RICE BLACK BUGS

Taxonomy, Ecology, and Management of Invasive Species

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2007

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Philippine Rice Research Institute
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Foreword

With increasing population pressure on land and diminishing per capita availability of arable land and irrigation water, the only pathway available to the Philippines and other developing countries in Asia to meet than growing food needs is improving productivity in perpetuity without ecological harm, a pathway which I have named "Ever-green Revolution". Pest management is vital for achieving an ever-green revolution. In 1982, when I was the Director General of the International Rice Research Institute at Los Baños, I watched with great concern the damage being done to the crop by rice black bug (RBB) *Scotinophara* species. RBB has become a highly invasive pest in several parts of the Philippines and particularly in the Palawan province. RBB outbreaks have also occurred in Visayas and Mindanao resulting in 15 to 23% yield loss.

Management of RBB becomes difficult because of the presence of several alternate hosts such as okra, corn and taro. The rice granary of the Philippines, Central Luzon is also threatened by this pest. Therefore the Philippines Rice Research Institute (PhilRice), in cooperation with IRRI, the University of the Philippines at Los Baños and the Department of Agriculture convened a workshop in February 2006 to identify effective control and management procedures for curbing the incidence and spread of this important pest. At this Workshop a strategy for the control of this pest was developed. The RBB management strategy recommended in this book is environment friendly as well as cost effective. We owe a deep sense of gratitude to Dr. Ravi Joshi and all his colleagues for bringing out this timely publication. I hope it will be widely used by scientists, policy makers, consumers and farmers for making the threat of RBB history.

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Foreword

From a little noticed minor pest, the rice black bug (RBB) *Scotinophara* spp., has become one of the most rice damaging insect pest. Its spread across nations and regions of the world has brought about complex and far-reaching challenges for its management.

RBB has proven to be a challenge to manage, its alternate hosts being grown together with, or after rice such as okra, corn, and taro. In the Philippines, RBB infestations or "bugburn" result in 15 to 23% yield loss. Frequent RBB occurrences lead to economic distress on account of the forgone income from production losses.

This is further aggravated by the misuse and abuse of broad-spectrum non-selective synthetic pesticides, which is commonly and inadvertently committed by farmers, as it is often their only known and affordable option of defense against the RBB menace. Hence, persistent RBB infestation triggers environmental degradation in the long run, aside from the immediate economic losses.

The solution for farmers is to learn more about ecological and sustainable management options for RBB, to prevent crop losses, as well as diminish environmental damage. Furthermore, awareness and knowledge about RBB and timely access to pest population dynamic information are critical elements for effective and ecologically sound management of other pest species in the rice system.

I am personally delighted with this publication as no other book thus far carries such an extensive literature on the taxonomy, ecology, and sustainable management of RBB. Its relevant scientific content makes it a very useful reference manual for entomologists, pest management practitioners and information officers in developing locally specific RBB management approaches. The availability of such management options will also help ensure the reduction of crop losses due to RBB infestation, and prevent environmental harm by suggesting biological control methods as alternative to synthetic pesticides.

The contributions of this publication's authors are highly appreciated. They have graciously shared their extensive knowledge and experience gained from working at international and national agricultural research centers. Many have dedicated their lives to making sure that invasive RBB species do not deprive farmers of their already precarious livelihood and income.

By publishing this important book, PhilRice helps the contributors with world-wide access to their knowledge and information in support of its strategy for exploring and deriving benefits from research activities for all concerned scientists, pest management specialists and rice farmers, and concentrating on areas of special interest to the Philippines.

With the editors' painstaking efforts, this book on RBB applied research and its derivatives such as RBB management methodologies shall benefit those researchers, students and rice farmers wanting to learn more about RBB and how to mitigate its devastating effects on the economy and environment.

I believe that this unique book will also fulfill its purpose for other RBB-invaded countries, as it has fulfilled PhilRice's quest for RBB knowledge useful to rice farmers in the Philippines.

HANS RUDOLF HERREN
President, Millennium Institute
Recipient, 1995 World Food Prize

Preface

After its first outbreak in the Philippines in 1982, rice black bug (RBB) *Scotinophara* spp. has remained as a highly invasive pest of rice in some regions of the country. In fact, the idea of establishing a national rice institute in the Philippines came-up when the Palawan province was being affected by RBB. This incidence amplified the need to have an organization fighting the country's local battles, despite the local presence of the International Rice Research Institute (IRRI) whose concerns are global.

Time and again, RBB outbreaks occurred in various rice-growing provinces in the Visayas and Mindanao resulting in 15 to 23% yield loss. Thriving primarily in rice, RBB is one of the most difficult pests to manage because its alternate hosts are crops grown together with or after rice such as okra, corn and taro.

Being able to fully identify its ecology and management would further help scientists and researchers to contain this pest in areas already affected, and prevent its spread in other rice-growing areas especially in Central Luzon, one of the Philippines' "rice bowls". Its reported occurrence in Sorsogon province in late 2005 raised alarm of the pest migrating and wreaking havoc in greater Luzon area, where rice and alternate host crops of RBB are planted in wider contiguous areas.

The Philippine Rice Research Institute (PhilRice), in cooperation with IRRI, the University of the Philippines Los Baños (UPLB) and the Department of Agriculture (DA) convened a workshop in February 2006 to determine currently available and effective tools and management alternatives to arrest the potential spread of the RBB in Central Luzon. Accordingly, the DA-Regional Field Unit 5 (RFU 5) reported RBB occurrence in three towns – Bulan, Gubat and Matnog of Sorsogon – between November and December 2005, attesting that RBB has become an ominous threat to rice cultivation in the Bicol region.

The Philippines' efforts to mitigate RBB infestation have been limited to its management. Less is known about its migration pattern, behavior, taxonomy, and ecology. Moreover, although a wealth of RBB information is internationally accessible through the World Wide Web, these are not thorough. Extensive literature searches have yielded that no single comprehensive book on the identification, ecology, and management of RBB has yet been published.

As one of its R&D strategies to explore and derive benefits from research activities around the world and concentrate on areas of special interest to the Philippines, PhilRice through this book presents the current knowledge of leading researchers from other countries where rice production has been antagonized by RBB. Consisting of four sections, each part addresses the following: Sec-

tion 1: clarifications on confusing taxonomy using traditional and modern taxonomic tools; Section 2: state-of-the-art technologies of the different approaches to the management of RBB pest species; Section 3: country reports and current available information; and Section 4: database of selected World bibliography on RBB and a stand-alone compact disc (DVD-ROM) containing PDF files of published scientific information on RBB.

Our book chapters reinterpret old problems and address new techniques for RBB management. The lessons, information and knowledge available in one country or region could be sources of helpful management approaches of RBB toward preventing its spread from one area to the next.

With the wealth of information compiled herein, this book will hopefully provide guidance and direction of RBB research on ecological management in the next few years. However, the taxonomy of African RBB species should be further reviewed and revised in the near future.

On a personal note, we, the editors find this book project challenging. Our subject matter may be minute to the naked eye, but its damaging effect on rice and alternate host crops results in economic loss mostly afflicting marginal rice farmers. And we never could have gone this far, if not for the hands that toiled; helpful individuals who made this book possible in the best way it can be. We especially thank Ms. Teresita De La Vega Rola and Mr. George Ramirez Reyes who patiently escorted us through the web of the editorial process and commercial production of this book. Mr. Henry F. Mamucod for the design of the attractive book cover.

We are most grateful to all contributors for sharing their personal knowledge and experiences without presenting the views of the institutions they may be affiliated to. We also commend them for their responsiveness to our invitation, perseverance in rectifying and shedding light to our reviews, while minding the production time table and tight schedule. Thank you for your help in making this work into a reality. At this juncture, any errors committed, may they be beyond our control, are our responsibility.

We are also indebted to the co-publishers of this book: the Department of Science and Technology (DOST), the Philippine Council for Agriculture, Forestry, and Natural Resources Research and Development (DOST-PCARRD), and the Bureau of Agricultural Research (DA-BAR). Thank you for helping PhilRice with the much needed resources for book printing.

Finally, we dedicate this book to the Filipino rice farmers. They may have been burned by the occurrence of RBB, but this disheartening experience has been the driving force in the establishment of PhilRice and now, our motivation in coming up with this book. The mounting problems on RBB among other local concerns have indeed prompted the Philippines' agriculture leaders and researchers almost 25 years ago to create a dedicated institution helping Filipino rice farmers produce enough rice for the Philippines.
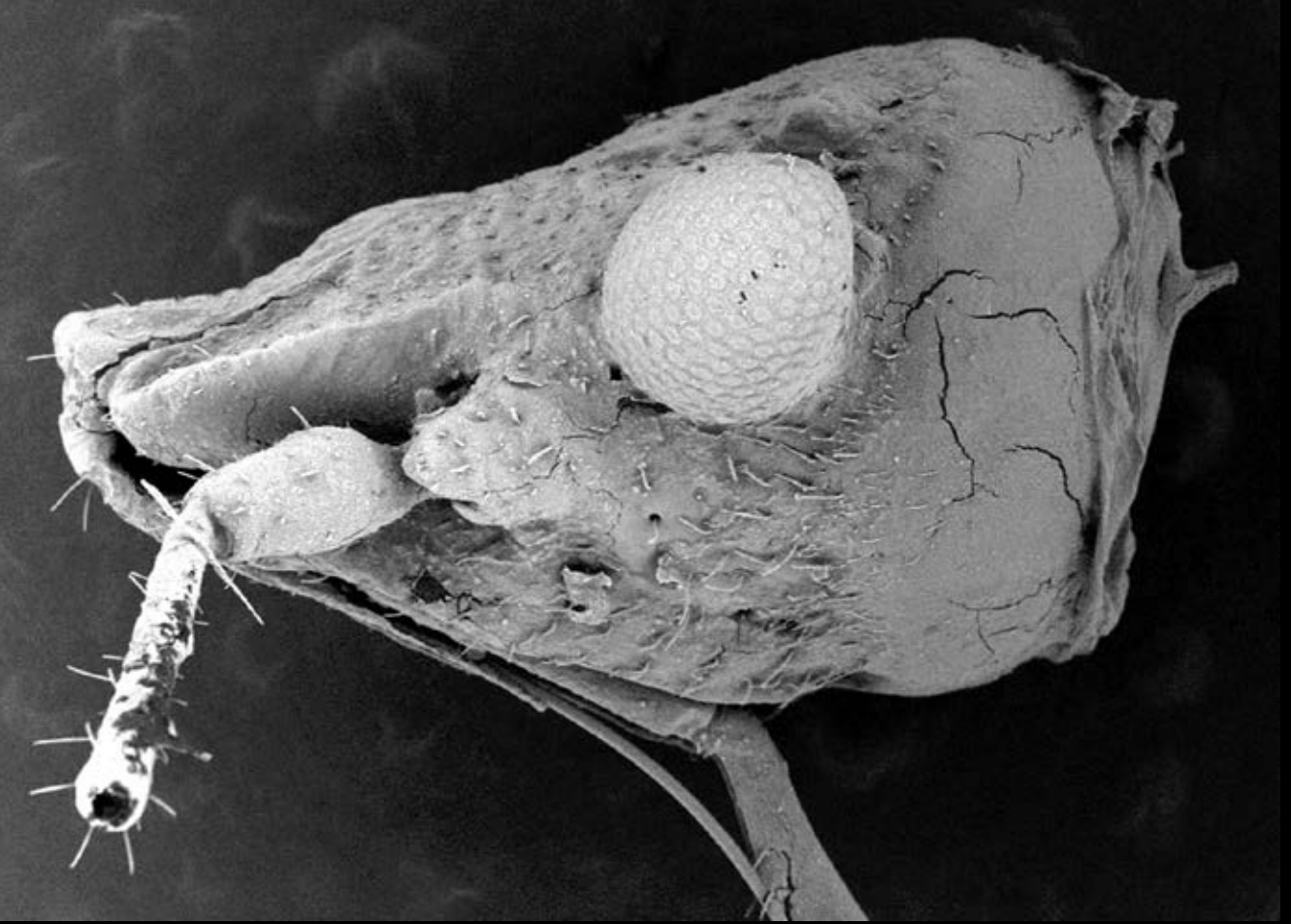
Systematics

Systematics of the Rice Black Bug, *Scotinophara* Stål (Hemiptera: Pentatomidae)

Alberto T. Barrion, Ravindra C. Joshi, A.L.A.B. Dupo, and Leocadio S. Sebastian

PHILIPPINES

Introduction

Rice (*Oryza sativa* L.) is a staple diet of almost two-thirds of the world's human population and food to 1,400 species of rice-feeding invertebrates (Walker 1962), of which 25 species are putative major and minor pests of rice in tropical Asia. Among the putative pests, the highly cryptic and invasive rice black bugs (RBB) of the genus *Scotinophara* Stål, 1867 (Pentatomidae: Podopinae) are emerging insect pests in irrigated and rainfed wetland rice fields in the Philippines. *Scotinophara serrata* (Vollenhoven 1863) is the first reported RBB from Palawan Island, Philippines (Distant 1902, Banks 1909), followed by the collection of *S. tarsalis* (Vollenhoven) in Los Baños, Laguna. Almost four decades past, six additional unidentified specimens belonging to three species [= to *S. serrata*, *S. latiuscula* Breddin, and *Scotinophara* nr. *cinerea* (Le Guillou) as recently determined by ATBarrion] were collected in the vicinity of Manila in 1948 by an agricultural entomologist of the Bureau of Plant Industry (BPI), Department of Agriculture. By 1983, a total of six species have been recorded in the Philippines (Miyamoto et al. 1983). All but *Scotinophara coarctata* (Fabricius) and *S. latiuscula* Breddin damaged the rice plant.

The RBB is a small (6.2-9 mm long), cryptic, and highly invasive pest species attacking all growth stages of the rice plant. Nymphs and adults are both sap-feeders, causing two kinds of damage, namely, "deadheart" damage during the vegetative stage and "whitehead" in the reproductive stage akin to the rice stem borer damage. Because of this similarity in damage, it is now surmised that previous data on damage and yield loss attributed to rice stem borers in countries where RBBs were poorly recognized (notably in Indonesia, Vietnam, Cambodia, Laos, and other countries) need a second look. RBB-infected plants are stunted, showing brown leaves with dark brown margins around the feeding holes resembling lesions caused by rice blast disease (Mueller 1980). Feaken (1976) reported that bug feeding may arrest grain development. Intensive bug feeding often causes "bugburn" and may result in total crop loss.

RBBs are highly active during migration periods and their biological clocks are highly precise, developing adults destined to fly coinciding with the occurrence of the full moon where thousands of adults dominated by males are attracted to lights.

In the Philippines, RBB *Scotinophara coarctata* outbreak was first recorded in Palawan Island in 1982 (Barrion et al. 1982), resulting in a massive use of chemical insecticides by the provincial government to control the pest to no avail. Miyamoto et al. (1983), however, reported that *S. coarctata* was first noticed infesting rice in Bonobono, Batarasa, in south Palawan. To date, the perception is the pest had invaded Mindanao and the Visayan Islands. About 4,500 ha of rice fields in the central and northern part of Palawan were devastated by RBB. By 1992, it had reached Mindanao, landing in Curuan, Zamboanga City, and damaging 2,070 ha of irrigated rice fields. Thereafter, RBB spread in the Autonomous Region of Muslim Mindanao (ARMM) and became a serious pest by March 1995. By June 1996, RBB population had settled and invaded irrigated rice fields in Cotabato, South Cotabato, Sultan Kudarat, and Sarangani provinces. Pest outbreaks occurred in these provinces in 1997. The spread continued eastward and RBB infestation was observed in Magsaysay rice fields in Davao del Sur. However, the Zamboanga population moved northward, invading the irrigated rice fields in Negros Island in 1998, eastward from Negros landing in Siquijor Island in January 1999 and Bohol Island in September 1999. It was surprising that RBB migrated southward in 2000, settling in the Caraga Region. The first infestation was observed in Alegria and Mainit, Surigao del Norte; Kitcharao, Agusan del Norte and Sta. Josefa, Agusan del Sur (PhilRice 2000). In May 2006, the Department of Agriculture in Region VI reported 1,411 ha of rice fields owned by 641 farmers infested by RBB, of which 75 ha were totally damaged (DA 2006).

Earlier, a workshop on RBB held at IRRI on 3 Feb 2006 reported that RBB had landed in Sorsogon, one of the Bicol provinces in the southern tip of Luzon. Henceforth, agriculturists, rice scientists, economists, and farmers were all alarmed by the potential catastrophic damage RBB can have on rice production. All agreed that *Scotinophara coarctata* (F.) will undoubtedly endanger the large tract of rice fields in the entire Luzon Island, producer and supplier of 60% of all rice consumed in the country.

The confused state of *Scotinophara* taxonomy in the Philippines is very frustrating. There had been many reports about RBB, including outstanding publications, but the RBB specimens are wanting. RBB collections are of paramount importance to (1) validate the many reported outbreaks and claims that the bugs came all the way from Palawan Island, (2) identify the RBB complex, and (3) develop strategies to manage the pest population below the damaging level and avert its spread in Luzon.

The primary objective of this paper is to resolve the confused state of RBB taxonomy, describe its diversity in Philippine farm setting, and develop a key to its identification.

Materials and methods

Field collection of specimens

Rice black bug specimens were collected from 104 sites representing 31 provinces (15 in Luzon, 5 in Visayas, and 11 in Mindanao) within an 11-mo period from 27 Feb 2006 to 29 Nov 2006 at irregular

intervals and on 10-11 Jan 2007 (Table 1, Fig. 1). Handpicking and light trapping were the two collection techniques used. Handpicking method sampled black bugs direct from mature rice plant ready to be harvested, stubbles, of newly harvested rice plants, and old stubbles, while light trapping used a 1000-watt super bulb to attract rice black bugs from unknown sources to light. Samples from both collection methods were kept in 150-ml polyethylene tubes provided with 80% ethenol and collection labels. A total of 2,015 specimens (nymphs and adults) had been collected and preserved in the laboratory for examination and identification. This excluded the 485 specimens of rice black bug col-

Table 1. Sampling sites and periods of collection of rice black bugs in the Philippines.

Island/province	Collection sites (no.)	Collection dates and holdings
LUZON (**15**)	(**53**)	
Sorsogon	16	27 Feb-29 Nov 2006
Albay	8	27 Feb-29 Nov 2006
Camarines Sur	4	UPLB MNH Coll.
Laguna	6	UPLB MNH, IRRI & PhilRice CES Coll.
Quezon	7	27 Feb-29 Nov 2006
Pangasinan	1	IRRI Coll.
Tarlac	1	IRRI Coll.
Ilocos Sur	1	IRRI Coll.
Nueva Ecija	1	IRRI Coll.
Nueva Vizcaya	1	IRRI Coll.
Kalinga	1	IRRI Coll.
Mt. Province	2	UPLB MNH & BPBM Coll.
Isabela	1	UPLB MNH Coll.
Palawan	2	UPLB MNH & IRRI Coll.
Manila	1	BPI-DA Coll.
VISAYAS (**5**)	(**16**)	
Leyte		
Leyte	1	UPLB MNH Coll.
Negros		
Kabankalan	1	PhilRice CES Coll.
Murcia	1	15-17 Aug 2006
Panay		
Iloilo	12	17-19 May 2006
Capiz	1	10 May 2006
MINDANAO (**11**)	(**35**)	
Agusan del Norte	4	24-29 Apr 2006
Agusan del Sur	2	24-29 Apr 2006
Maguindanao	2	24-29 Apr 2006
North Cotabato	7	24-29 Apr 2006
South Cotabato	8	24-29 Apr 2006
Sultan Kudarat	1	24-29 Apr 2006
Surigao del Norte	3	24-29 Apr 2006
Lanao del Norte	3	11 Jan 2007
Misamis Occidental	1	10 Jan 2007
Zamboanga del Sur	3	10 Jan 2007
Davao	1	OUMNH Coll.
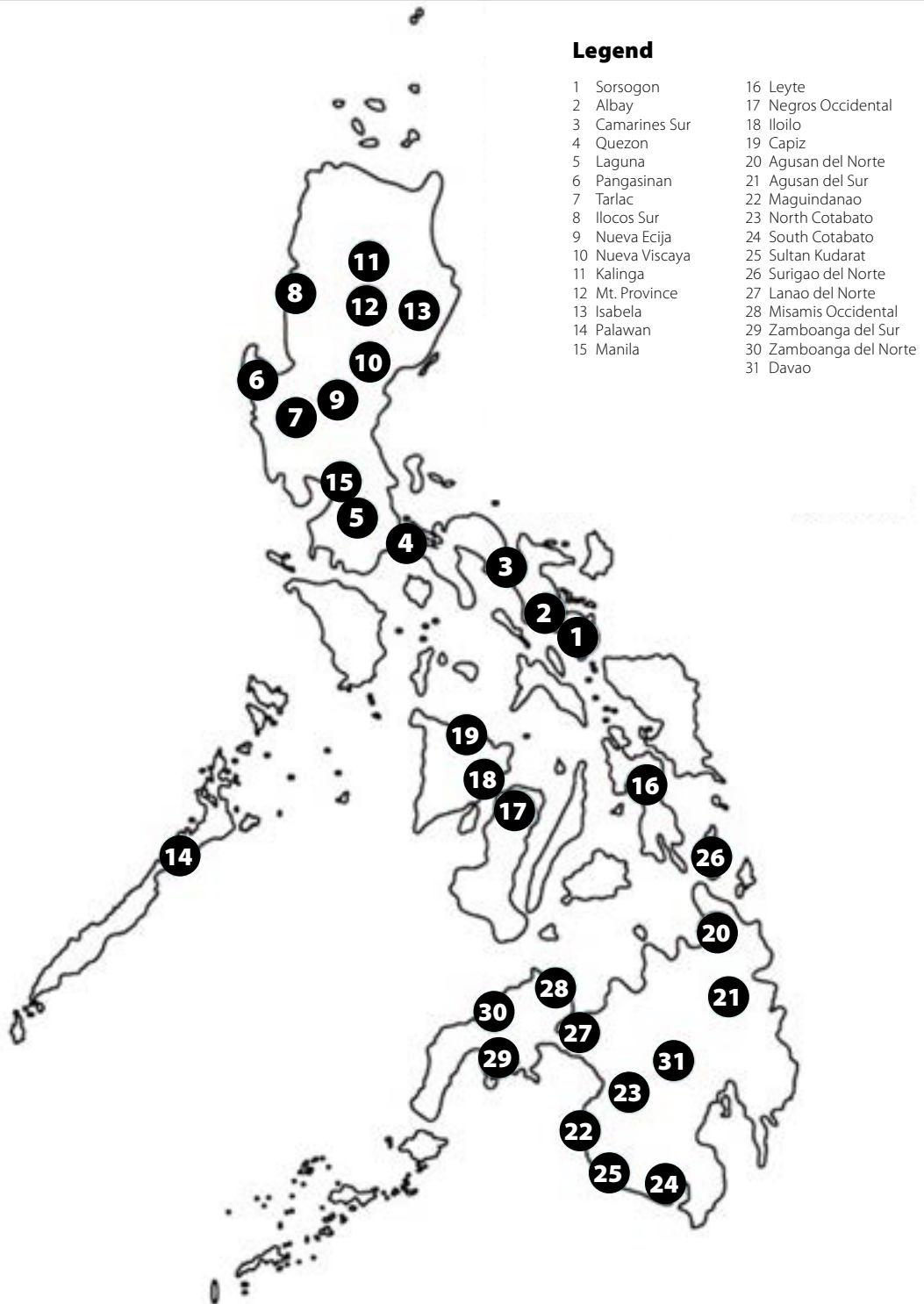
Fig. 1. Sampling sites of the Philippine *Scotinophara* including collection site data provided by museum-loaned specimen labels.

lections kept in the Taxonomy Laboratory, 60 specimens loaned from the UP Los Baños Museum of Natural History, and the six specimens in the Bureau of Plant Industry Insect Collection, Department of Agriculture, Manila, that were also examined. Philippine specimens of RBB from the Bernice P. Bishop Museum (Hawaii), SMNH (Sweden), OUMNH (UK) and NMNH-Smithsonian Institution (USA) were also loaned and examined.

Voucher collections of rice black bugs from the different sampling sites were pinned, labeled, and kept in insect boxes for deposition at a later date in the insect collections at PhilRice-Central Experiment Station (CES), Science City of Muñoz, Nueva Ecija; UP Los Baños Museum of Natural History (UPLBMNH), Los Baños, Laguna; and National Museum, Manila. Foreign museums will also be considered for deposition of specimens.

Photography and illustrations

The general habitus and the dissected body parts of the black bugs were photographed under a Nikon SMZ 2B stereomicroscope with the use of a Panasonic Lumix FX-7 digital camera. For adult bugs that have been preserved in alcohol, the use of rice straws as background produced good images under good lighting.

Line drawings were prepared based on loaned dried specimens as well as freshly collected materials. When facilities were available, camera lucida drawings were made at the Taxonomy Laboratory of the International Rice Research Institute. Separate line-drawn plates were also prepared for the labeled general morphology of the black bug (Fig. 2-4).

Scanning electron microscope (SEM) preparation

Representative samples of RBB from selected localities were separated (10 males and 10 females/site), soaked, and cleared in 10% KOH for 24 h. Each specimen was dissected by first separating the abdomen from the thorax, the head from the prothorax, forewings and hindwings from the thorax, and the scutellum and the mesonotum from the pronotum. The cleared parts were then washed with water several times. The wings (fore- and hind) were temporarily mounted on slides using a Hoyer's medium for a more effective pictorial viewing of the wings.

The cleared abdomen was cut laterally to free the tergite from the sternite and expose the genitalia capsule. The aedeagus was separated by opening the lateral sides of the capsule and pulling it out at the back of the proctiger. The claspers or parameres were taken out from the plate after removing the aedeagus. Tergite X was the last part removed from the capsule.

Fig. 2. Rice black bug (RBB) morphology- general habitus.

a   antennifer
b   antenna (1-5-antennal segments)
c   tylus
d   jugum
e   vertex
f   ocellus
g   anterior angle
h   anterolateral spine
i   cicatrice
j   tubercle
k   lateral margin
l   prehumeral spine
m   humeral angle
n   pronotum
o   posterolateral margin
p   posterolateral angle
q   femur
r   tibia
s   tarsus (1-3: tarsal segments)
t   scutellar pit
u   scutellum
v   clavus
w   claval suture
x   corium
y   membranal suture
z   membrane
a'   abdomen (2-6-sternites)
b'   genital segment
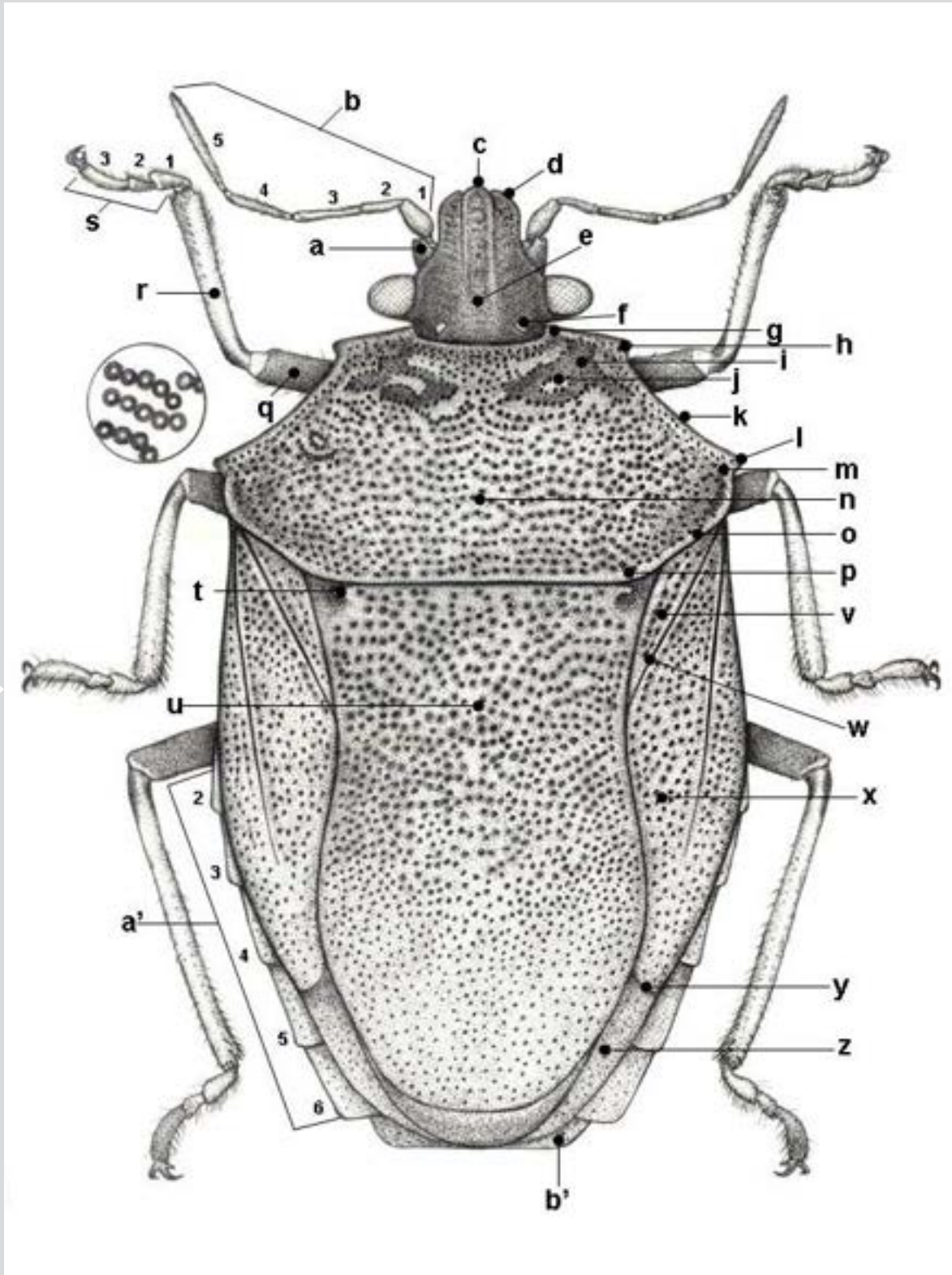
Fig. 3. Morphology of selected external and internal structures of the male black bug.

I   Lateral view of the head
- **a** antennifer
- **b** gena
- **c** buccula
- **d** rostrum or proboscis

II   Ventral view of abdominal tip
- **a** sternite VII

III Antennifer

IV Cross section of Gonophore
- **a** aedeagal cap
- **b** clasper
- **c** posterior lobe of gonophore

V   Right clasper
- **a** blade
- **b** median posterior surface
- **c** teeth
- **d** inner arm
- **e** stem

VI Aedeagus
- **a** anterior phallotheca
- **b** posterior phallotheca
- **c** pivot
- **d** lateral arm
- **e** basal plate
- **f** ejaculatory duct
- **g** penial plate
- **h** membranous conjunctiva

VII Tergite X
- **a** dorsolateral lobe
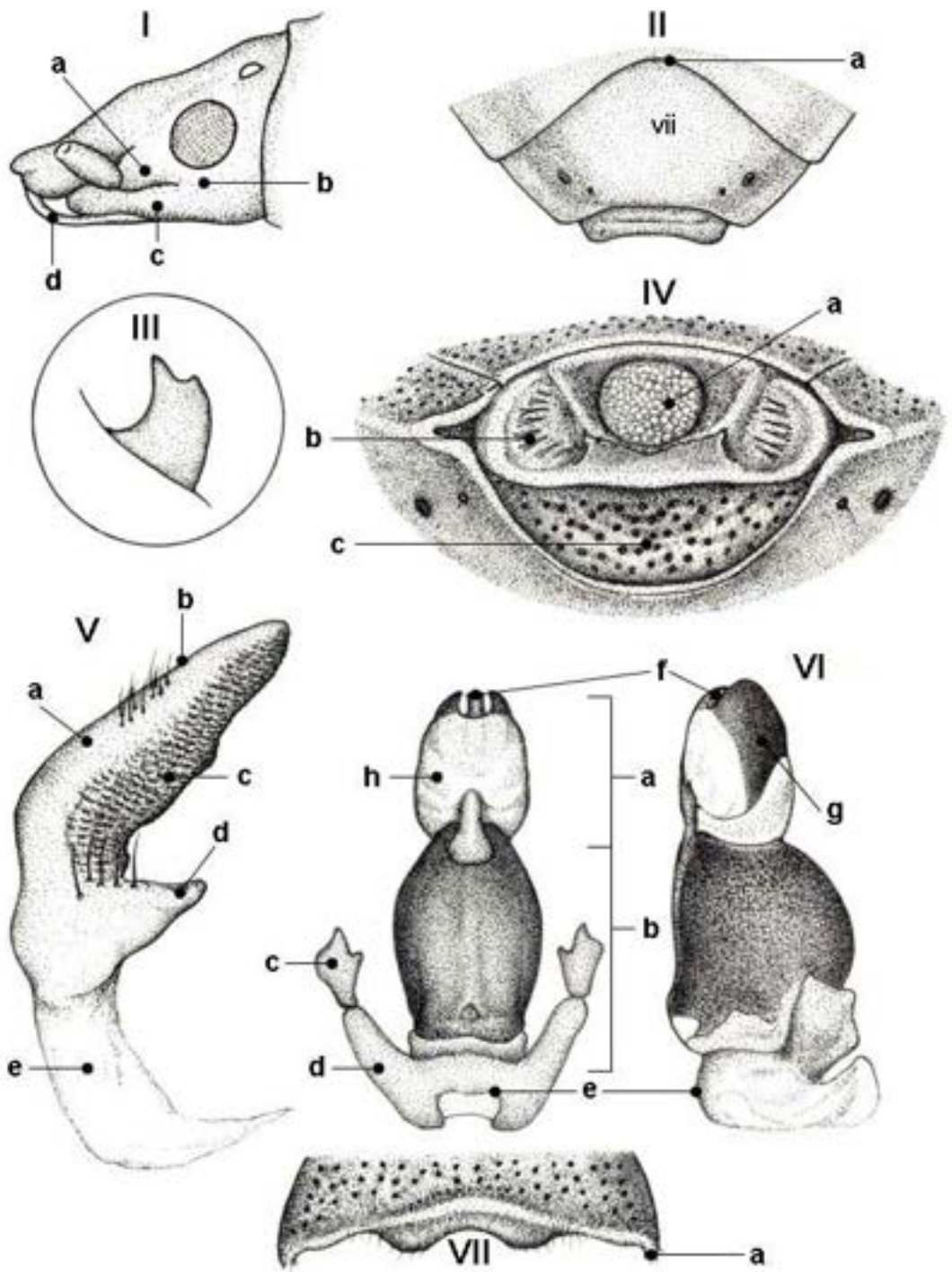
Fig. 4. Wing morphology and female reproductive structures of the rice black bug.

I Forewing
  a corium
  b vein R+M
  c closed marginal cells
  d membrane
  e longitudinal cells
  f clavus

II Hindwing
  a vein R+M
  b knob-like process
  c R+M junction
  d vein R
  e vein M
  f vein CuA
  g secondary veins
  h vein 1A
  i vein 2A
  j vein 3A
  k R+M-CuA triangle

III Spermatheca
  a proximal spermathecal duct
  b median dilation
  c spermathecal bulb
  d sclerotized median duct
  e pump
  f proximal flange

IV Female genital plate
  a proctiger
  b 9th paratergite
  c 8th paratergite
  d 2nd gonocoxae
  e 1st gonocoxae
  f arcus
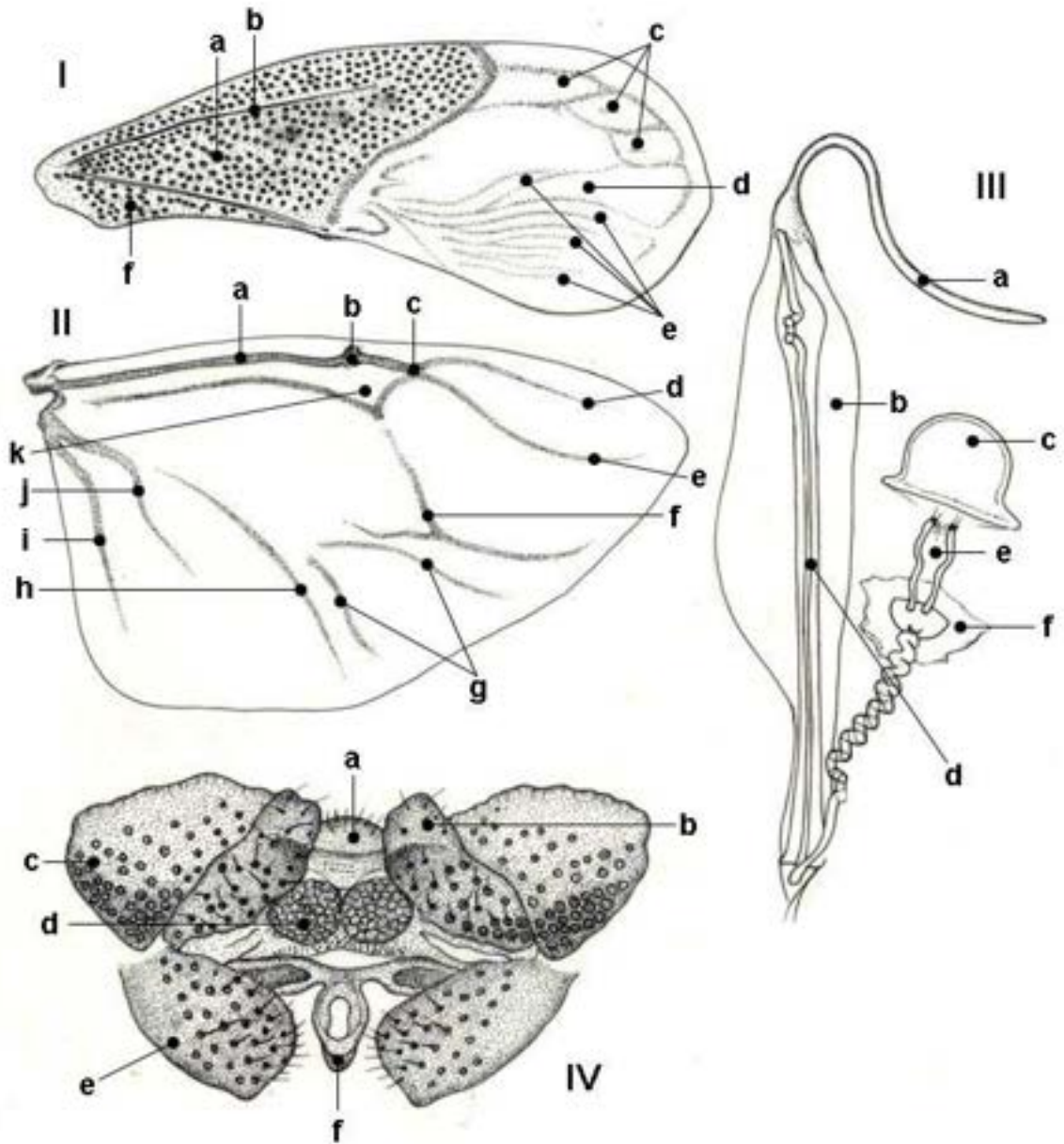
Separated parts were individually kept in small plastic tubes with 90% ethenol and labeled. These were brought to the National Biotechnology Institute (BIOTECH) Laboratory at UP Los Baños for fixation, mounting on aluminum rods, and gold coating prior to scanning.

The complete process, a must-see for all invertebrate enthusiasts aiming to have good photos, has been written by Dr. Lorele Trinidad of (BIOTECH), UP Los Baños, Philippines, as a section in this book.

Measurements

All measurements used for the description of field-collected and loaned specimens are in millimeters (mm), except for appendages measured under the scanning electron microscope. SEM measurements are in micrometers (μm).

Type depository

Type specimens described herewith will be deposited at the UPLB MNH (Los Baños) and PhilRice CES Insect Collection (Muñoz).

Key to the identification of Philippine species of *Scotinophara* Stål, 1867

1   Lateral margins of pronotum between anterior and prehumeral spines serrate or dentate; anterior part of pronotum with humps, transverse furrow behind it and cicatrices present 2

1'   Lateral margins of pronotum between anterior and prehumeral spines not serrate or dentate; anterior part of pronotum without humps, transverse furrow behind it and cicatrices not visible 4

2   Smaller species, body length less than 7 mm; midanterior pronotum elevated or swollen, lateral margins with 5-7 minute teeth; anterior lateral spine distinctly longer and more robust than the prehumeral spine; posterior end of male abdomen without horn-like spines; clasper with a slender tip; median dilation globoid; spermathecal bulb with three anchor-like processes ....***Scotinophara tarsalis*** (Vollenhoven) [Plate 1-1,7-1,11a-k]

2'   Larger species, body length more than 8.5 mm; midanterior pronotum not swollen, lateral margins distinctly serrated; anterior lateral spine small, shorter and less robust than the prehumeral spine; posterior end of male abdomen with horn-like spines; clasper blunt apically; median dilation slender; spermathecal bulb without processes 3

3   Lateral margins of pronotum each with 6-7 spines evenly spread throughout its length; leg II longer than I; forewings with 3 closed marginal cells and 3 longitudinal veins in the membrane; scutellum well constricted, ratio of WAB:WACP > 1.30; antenniferrous tubercle cleft apically; posterior phallotheca without scar midposterodorsally, not saddle-shaped viewed laterally..... ....***Scotinophara serrata*** (Vollenhoven) [Plate 1-2,7-2,12a-l]

3'   Lateral margins of pronotum each with 3-5 spines on anterior one-half of pronotum; legs I and II subequal; forewings with 2 closed marginal cells and 4 longitudinal veins in the membrane; scutellum not strongly constricted, ratio of WAB:WACP < 1.20; antenniferrous tubercle bluntly cut apically; dorsal posteromedian of saddle-shaped posterior phallotheca with a transverse scar .... ***Scotinophara pseudoserrata*** new species [Plate 1-3,7-3, 13a-i]

4   Post-ocular anterior margins of pronotum short and narrow varying from straight projected horizontally slightly sinuate with anterolateral spine upcurved or moderately oblique; clasper subtruncate apically without inner arm or tooth; distal spermathecal duct without loops; spermathecal bulb with processes.. 5

4'   Post-ocular anterior margins of pronotum relatively long and oblique directed posteriorly; clasper usually with slender blade and inner arm or tooth; distal spermathecal duct with loops; spermathecal bulb without processes..10

5   Post-ocular anterior margin sinuate to slightly oblique 6

5'   Post-ocular anterior margin straight 7

6   Proboscis reaching first abdominal segment; metapleuron with a densely punctated yellow plate and lightly punctated posterior area; mesepimeron with a thick ridge between microsculptured region; forewings with 2 closed marginal cells and 5 longitudinal veins; second longitudinal vein connected to first by an oblique crossvein subterminally or 2nd vein bifurcated at midlength

forming veins 2 and 3; tibia yellowish brown; median posterior surface of clasper bears 11 setae...***Scotinophara luzonica*** new species [Plate 1-4, 7-4, 14a-n]

6' Proboscis reaching coxa III; metapleuron with a sparsely punctated yellow plate and heavily punctated posterior area; mesepimeron with a shallow ridge between microsculptured region; forewings with 3 closed marginal cells and 6 longitudinal vein, second vein bifurcate towards the apex; tibia dark reddish brown; median posterior surface of clasper with 8 setae............... .... ***Scotinophara molavica*** new species [Plate 2-1, 7-5, 15a-h]

7 Membrane of forewing with a single closed marginal cell and 5 longitudinal veins without any crossvein; second segment of proboscis 1.65x longer than segment I; clasper bears 7 setae in the median posterior surface, blade rounded in the outer margin; ventral margin of bucculae black; mid anterior margin of sternite VII V-shaped in male.. ....***Scotinophara kalinga*** new species [Plate 2-2, 7-6,16a-k]

7' Membrane of forewing with 2-3 closed marginal cells 8

8 Antennal segments yellowish brown; ventrolateral margins of bucculae reddish brown; membrane of forewing with 2 closed marginal cells; blade of clasper angulate in the outer margin, median posterior surface with 11 setae in groups of 9 and 2.. ....***Scotinophara arkwata*** new species [Plate 2-3, 8-1,17a-l]

8' Antennal segments reddish brown; ventral margins of bucculae black; membrane of forewings with 3 closed marginal cells... 9

9 Claval suture short less than 1.5 mm; membrane of forewings with 4 complete longitudinal veins, first incomplete connected to 2nd with a crossvein forming two closed cells; paratergite IX with a diverging truncate triangular tip; 8th sharply pointed distally; first gonocoxae subovate; spermatheca without loops .... ***Scotinophara latiuscula*** (Breddin) [Plate 2-4, 8-2, 18a-m; Figs. 5-11]

9' Claval suture long, more than 1.5 mm; membrane of forewings with 3 closed cells without connections to the 6 longitudinal veins below; paratergite IX parallel-sides with rounded apices; 8th paratergite bluntly rounded; first gonocoxae rectangular; spermatheca with 11 loops or coils . ...***Scotinophara cinerea*** (Le Guillou) [Plate 3-1, 8-3, 19a-k]

10 Inner lateral midlength of tibia II with spines 11

10' Inner lateral midlength of tibia II without spines 16

11 Clasper upright with a broad blade 12

11' Clasper almost horizontal, blade narrows towards tip 13

12 Clasper bolo-like, constricted towards inner arm and broader towards tip; membrane of forewing with 3 closed marginal cells, 2nd cell small about one-third to one-half of first cell; distal spermathecal duct with 8 loops; 9th paratergite slightly exserted; inner margin of 8th paratergite acutely pointed; POL 1.8x eye length ....***Scotinophara sorsogonensis*** new species [Plate 3-2, 8-4, 20a-m; Figs. 12-23]

12' Clasper clamp-like, uniform in size from rounded tip to base of inner arm; membrane of forewing with 3-5 closed marginal cells, 2nd cell slightly smaller than first cell; distal spermathecal

duct with 9 loops; 9th paratergite not exserted; inner margin of 8th paratergite blunt to truncate; POL 1.9x eye length ....
....................................***Scotinophara pirurotonga*** new species [Plate 3-3, 21a-m; Figs. 24-35]

13   Spermatheca slender, widest medially; inner arm of clasper pointed 14

13'   Spermatheca large, uniformly wide, except narrow both ends or broadest distally...............15

14   Tibia II with 2-3 spines arranged longitudinally in the inner lateral side; membraneous conjunctiva U-lobed; penial plate apices touching each other dorsally and truncated laterally; midposterior base of phallotheca with a triangular to bullet-like marking; lateral arm of anterior phallotheca apically rounded; distal spermathecal duct with 6-7 loops; membrane of forewing with 3-4 closed marginal cells but without a triangular cell beneath the crossvein ....
............................***Scotinophara agusanortica*** new species [Plate 3-4, 8-5, 22a-k; Figs. 36-50]

14'   Tibia II with 1-2 spines in the inner lateral side; membraneous conjunctiva bow necktie-like; apices penial plate distinctly separated dorsally and rounded laterally; midposterior base of phallotheca without triangular-like scar; lateral arm of anterior phallotheca slightly acute at tip; distal spermathecal duct with 10 loops; membrane of forewing with 4 closed marginal cells and a triangular cell beneath the crossvein present ....
............................***Scotinophara tantanganica*** new species [Plate 4-1, 8-6, 23a-m; Figs. 51-65]

15   Distal median dilation of spermatheca enlarged, bag-like; distal spermathecal duct with 10 loops; proctiger quadrate; membrane of forewing with 3 closed marginal cells ....
............................***Scotinophara midsayapensis*** new species [Plate 4-2, 9-1, 24a-l; Figs. 66-78]

15'   Spermatheca uniformly wide except narrow ends; distal spermathecal ducts with 8 loops; proctiger rectangular; membrane of forewings with 5 closed marginal cells ....
...............................***Scotinophara putikanica*** new species [Plate 4-3, 9-2, 25a-m; Figs. 79-90]

16   Distance between ocelli (POL) more than 1.8x eye length...17

16'   Distance between ocelli (POL) less than 1.75x eye length 19

17   POL 1.8x eye length; spermatheca slender with 10 loops in the distal spermathecal duct; second gonocoxa with a spherical depression; arcus heavily sclerotized and distinctly T-like; forewing with 5 longitudinal veins, penultimate longitudinal vein shorter than 3rd and 5th, 3 closed marginal cells present; clasper with a small triangular scar, arm of basal plate diverging; tergite X narrowly concave (Palawan population ....
...................................***Scotinophara coarctata*** (Fabricius) [Plate 4-4, 9-3, 26a-m; Figs. 91-102]

17'   POL >1.84x eye length; spermatheca with a largely swollen median dilation and 9 loops in the distal spermathecal duct; second gonocoxa with a distinct quadrate depression to shallow and indistinctly divided; arcus lightly sclerotized; forewing with 5 closed marginal cells; blade of clasper slender; posteromedian area of phallotheca without scar and arm of basal plate not diverging; tergite X V-shaped to broadly concave 18

18   POL 2.3x eye length; second closed marginal cell of forewing divided to 2 cells; tergite X V-shaped; inner arm of clasper blunt; inner part of 8th paratergite subtruncate; antenniferous

tubercles cleft .... ***Scotinophara alegria*** new species [Plate 5-1, 27a-m; Figs. 103-113]

18' POL 1.84x eye length; third closed marginal cell of forewing divided to 2 cells; tergite X broadly concave; inner arm of clasper triangular and pointed; inner part of 8th paratergite rounded; antenniferous tubercles not cleft, outer area with a rounded tip...
.... ***Scotinophara kabangkalanensis*** new species [Plate 5-2, 9-4, 28a-l; Figs. 114-119]

19 POL 1.5x eye length; spermatheca with 10-11 loops in the distal spermathecal duct 20

19' POL more than 1.6x eye length..21

20 Anterolateral margin of pronotum obliquely straight; first longitudinal vein bifurcated towards the apex, spermatheca with 10 loops in the distal spermathecal duct; membraneous conjunctiva narrow not expanded; pivot long, extended to anterior margin of phallotheca and base of membraneous conjunctiva; antennal segment III shorter than IV..
.... ***Scotinophara zamboanga*** new species [Plate 5-3, 9-5, 29a-m; Figs. 120-127]

20' Anterolateral margin of pronotum slightly concave; first longitudinal vein bifurcate in the middle, spermathecae with 10-11 loops in the distal spermathecal duct; membraneous conjunctiva T-bone like expanded outside the penial plate; pivot short, below anterior margin of phallotheca; antennal segment III and IV subequal in length ....
...............................***Scotinophara trifurcata*** new species [Plate 5-4, 9-6, 30a-l; Figs. 128-140]

21 POL not more than 1.6x eye length; membrane of forewings with 2 large closed cells......... 22

21' POL more than 1.7x eye length; membrane of forewings with 3 large closed cells 23

22 Median posterior surface of clasper's slender blade concave before the tip, setae located close to the elevated area of the blade; inner arm with setae on the inclined area; penial plate subtruncate apically with tapered posterior end; mid anterior sternite VII widely V-shaped; antenniferous tubercles with a slight cleft; habitat—upland rice..
...........................***Scotinophara landangica*** new species [Plate 6-1, 10-1, 31a-m; Figs. 141-154]

22' Median posterior surface of clasper's moderately slender blade flat with setae in the middle; inner arm with setae on the flat surface; penial plate rounded on both ends; mid anterior sternite VII broadly convex; antenniferous tubercles without cleft; habitat—irrigated and rainfed lowland rice ....***Scotinophara maguindanaoana*** new species [Plate 6-2, 32a-l; Figs. 155-158]

23 First longitudinal vein branch in the middle; 2nd vein close to 3rd up to midlength only; clasper with slender blade, narrow apically, setae on inner arm evenly spread; midanterior of sternite VII broadly V-shaped to strongly convex; apices of 8th paratergite roughly blunt to slightly concave; distal end of 2nd gonocoxae widely concave; spermatheca slender with 6 loops in the distal spermathecal duct .... ***Scotinophara mlanga*** new species [Plate 6-3, 33a-l; Figs. 159-162]

23' First longitudinal vein normal or with a small pale branch distally; clasper with short blade and strongly triangular inner arm; surface of inner arm with subapical setae and 4 more basally; midanterior of sternite VII indented submedially forming a structure; apices of 8th paratergite truncate; spermatheca with 2 types—thin and slender form with 9 loops in the distal spermathecal duct and spherical spermathecal bulb and a large one with only 5 stretched loops and ovate spermathecal bulb ....***Scotinophara ilonga*** new species [Plate 6-4, 10-2, 34a-n; Figs. 163-182]

Scotinophara tarsalis (Vollenhoven 1863)

(Plate 1-1, 7-1, 11a-k)

Podops tarsalis Vollenhoven 1863. Faune ent. indo-neerl. I. 42, Pl. III.f.8.
P. tarsalis Breddin 1900. Stett. E. Z. LXI. 285.
Scotinophara tarsalis Stål 1871. O.V.A.F.XXVII. 623.

Length: Male: 6.5 mm. Width across prehumeral process 3.95 mm.
Female: 6.9 mm. Width across prehumeral process 3.90 mm.

Color: Brown with yellow mottles in the pronotum, scutellum, corium and clavus of forewings. Black head, post-ocular anterior process, lateral margins of pronotum, prehumeral spines, scutellar pit and midbasal half of scutellum, and body venter. Pronotum with a vertical yellow band between cicatrices. Compound eyes silvery red and simple eyes yellow. Antenna reddish brown. Proboscis yellow to yellowish brown. Legs with dark reddish brown femora, tibia I, basal one-third of tibia II and basal one-fifth of tibia III, rest of tibiae and tarsi yellowish brown. Laterals of abdomen and base of scutellum with yellow spots dorsal and ventral of spiracles and trichobothria.

Head distinctly pilose, 1.4x wider than long. Tylus shorter than the inwardly inclined jugum with a rounded apex. OOL subequal to eye length. POL 2.5x length of eye. Antennifers slightly curved inwards and pointed apically.

Antennal segment I longer than II, III=IV and III < IV in male and female, respectively. Proboscis segments III and IV subequal in both sexes, barely reaches coxae III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.35	0.28	0.58	0.58	0.90	2.69
♀	0.35	0.31	0.53	0.58	0.80	2.57

Length of proboscis (LOP) (mm).

Sex	1	2	3	4	Total
♂	0.58	0.88	0.59	0.58	2.60
♀	0.55	0.88	0.63	0.63	2.69

Pronotum roughly punctated, shortly pilose, 2x wider than long, anterior margin moderately concave, with a narrow collar. Anterior part of pronotum elevated. Anterior lateral margin slightly concave approaching the strongly triangular spine projected obliquely forward and passes the com-

pound eyes by 0.42 spine length. Lateral margin sinuate with a few small spines, widely rebordered. Prehumeral spine triangular, much smaller than the anterior lateral spine. Cicatrices with distinct elevated tubercles, and transverse furrows. Metathoracic scent gland globe-like, opening exposed without hood, posterodistal end bears a large oblong spot of black and yellow.

Legs spineless in the inner midlaterals of tibia II, femur III as long as tibia III in females. Leg length III>II>I.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.58	1.50	1.38	1.40	0.52	0.50	3.48	3.40
II	1.92	1.60	1.48	1.50	0.65	0.50	4.05	3.60
III	2.15	2.10	2.00	2.10	0.65	0.50	4.80	4.70

Forewings with a single rectangularly shaped marginal cell and six longitudinal veins. Longitudinal vein 2 bifurcate past midlength, veins 2 and 3 connected by a cross vein at midlength, vein 4 bifurcate shortly apically. Hindwing with well-sclerotized vein R & M extended only to the knob-like structure; R + M-CuA triangle small.

Scutellum elevated in the midbasal one-half forming a V-furrow towards the scutellar pit, rounded to slightly cleft tip almost at outer margin of abdomen. Ratio of WAB:WACP:L = 2.5: 2.3: 3.65.

Abdominal venter finely punctate, clothed with fine, short whitish yellow hairs, sternite VII inverted V-shape midanteriorly in male and broadly convex in female. Tergite X truncated to slightly cleft medially. Pygophore coarsely punctated and pilose, subglobe with elevated Y-mark medially, dorsomedian margin with a pair of protruding lobes opposite the visible broad sickle-shaped clasper. Blade of clasper oblongate, reduced apically to a slender and slightly curved tip, median posterior surface concave with about 10 setae. Inner arm reduced to a small swelling with 4 setae.

Male genitalia with an oblongate posterior phallotheca distinctly longer than its triangular anterior lateral arm and penial plates, laterally saddle-shaped. Apices of penial plates close to each other, laterally with rounded tips. Basal plate narrow basally, lateral arms short and diverging. Pivot oblongate, folds downward.

Female genital plates: 9th paratergite exserted slightly beyond tip of abdomen, 8th paratergite subtriangular with wavy posterior margins, 2nd gonocoxae with a bow-like band connected to the midposterior margins of the subquadrate first gonocoxae. Spermathecae globose, sclerotized median duct without loops inside the median dilation, distal spermathecal duct short without loops and almost as long as the pump; spermathecal bulb with 3 equally long processes.

Materials examined: **Philippines:** Mindanao Is., Agusan del Sur, San Francisco, 10 km SE, 1 female, 13 November 1959, L.W.Quarte (BPBM Coll.). Zamboanga del Norte, Dapitan, 1 male, Baker (USNMNH 2042719); same island, Surigao, 1 female (USNMNH 2042719); same island, Davao del Sur, Davao, 1 female, Baker (OUMNH, D. Leston Coll. 7075); Luzon Is., Laguna, Los Baños, 1 fe-

male, Baker (OUMNH, D. Leston Coll.); Camarines Sur, Pili, Mt. Isarog, 800 m asl, 2 males, 23-24 Apr 1965, H.M.Torrevillas (BPBM Coll.).

Remarks: Of all RBB from the Philippine Islands, this is so far the smallest.

Scotinophara serrata (Vollenhoven 1863)
(Plate 1-2, 7-2, 12a-l)

Podops serratus Vollenhoven, 1863. Faun. Ind. Neerl. 1:42
Scotinophara serrata Stål, 1870. Ofc.Vet. Akad. Forh. 27:623
P. serrata Distant, 1902. Faun. Brit. Ind. Rh. 1:75

Length: Male: 9.90-11.10 mm. Width across prehumeral process 5.80 mm.
Female: 9.70-10.60 mm. Width across prehumeral process 5.75 mm.

Color: Dark brown to light reddish brown with yellow mottles; black head, antenniferous tubercles and body venter. Reddish brown to yellow brown antennae. Base of scutellum with three yellow spots, median one forming a line. Proboscis light reddish brown. Apical one-half of femora black and basal half reddish brown; tibiae fully dull reddish brown, except in some individuals with yellow brown dorsal surface and dark brown ventrals. Tarsi yellowish brown with black to dark brown apical half of claws. Yellow spot at tip of vein R+M.

Head 1.2x wider than long, coarsely punctate, shortly pilose but thicker and longer around eye socket. Tylus shorter than jugum, narrow anteriorly and oblongately enlarge basally between eyes. Apices of jugum pointed. OOL as long as eye length. POL 2.4x eye length. Antennifers blunt to cleft medially at tip.

Antennal segments III and IV subequal in male and III slightly longer than IV in female. Proboscis reaching hind coxae, ventrolaterally hind with 2 longitudinal rows of short hairs.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.50	0.66	1.02	1.02	1.33	4.53
♀	0.54	0.52	1.10	1.02	1.28	4.46

Length of proboscis (LOP) (mm).

Sex	1	2	3	4	Total
♂	0.80	1.20	0.90	0.90	3.80
♀	0.90	1.40	1.25	1.00	4.55

Pronotum 2x wider than long. Anterior lateral spine prominent and moderately acute to triangular projected laterad. Lateral margin serrate with about 7 spines, 2nd spine usually the largest and strongly rebordered near lateral spine 2-5, connected to the distinct transverse furrow. Prehumeral spine subacutely large, 2-3x as wide as the anterior lateral spine. Cicatrices bear moderately elevated tubercle forming marginal grooves. Metathoracic scent gland with strong pebble-like swellings, on an elevated plate and scent gland opening short with 5 transverse ridges basad of the opening.

Leg length (mm) III > II > I; tibia II with 3 inner median lateral spine in a vertical row.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	2.50	2.80	2.50	2.60	1.00	1.10	6.00	6.50
II	3.00	3.30	2.75	2.80	1.10	1.20	6.85	7.30
III	3.60	3.90	3.70	3.80	1.35	1.40	8.65	9.10

Forewings with 3 closed marginal cells and 3 longitudinal veins, first longitudinal vein bifurcate apically forming third closed cell. Hindwing with a narrow R+M junction, moderately oblique knob-like process and R+M-CuA triangle with an acute bottom end.

Scutellum with three basal spots, tip far from posterior end of abdomen in line with midlength of terminal tergite. Ratio of WAB:WACP:L = 4.0:3.00:5.5.

Abdominal venter finely punctate, midanterior margin of sternite VII inverted V-shape in male and broadly convex in female. Tergite X widely truncate with a median cleft.

Pygophore subglobose, 1.2x wider than long, dorsolateral lobe with a spine projected posteriorly, lower half of pygophore with intertwined network of punctatures medially. Clasper with a short blade slightly curved at tip, median posterior surface bears 16-18 setae, inner margin with scale-like design, and inner arm with a rounded and blunt tip.

Male genitalia: posterior phallotheca slightly longer than the anterior part including penial plates, not saddle-shaped in lateral view, lateral apical arm of phallotheca bean-shaped with rounded tip, penial plate truncate apically seen laterally, ejaculatory duct slightly exserted; basal plate with a large subtriangular lateral arm and short pivot.

Female genital plate with bullet-like 9th paratergite. Second gonocoxae with a pair of subglobe openings. Spermathecae broadest at midlength, distal spermathecal duct without loops, spermathecal pump slender, spermathecal bulb ovoid with two processes.

Materials examined: **Philippines**: Leyte Is., Leyte, Balinsasayao, 50 m asl, 1 male and 2 female, April 1952, C.R.Baltazar (UPLBMNH Hem-Pen 023-025); Luzon Is., Camarines Sur, Mt. Iriga, 500-600 m asl, 1 male, 23 Apr 1962, H.M. Torrevillas (BPBM Coll.). Palawan Is., Aborlan, Tigman, Western Philippines University Experimental Field Station, 1 male, ex.grass clump of *Leersia hexandra* and *Digitaria* sp. along the irrigation canal, 23 May 2007, AT.Barrion and RC. Joshi; **Malaysia**: Borneo (Sarawak), Bau District, Pangkalan Tabang, 300-450m, 1 female, 5-8 Sep 1958, T.C. Maa (BPBM Coll. MB 305).

Other materials examined: **Borneo**, 1 male, Vollenhoven (Naturhistoriska Riksmuseum, Stockholm) and Philippine Is., 1 female, Semper (Naturhistoriska Riksmuseum, Stockholm).

Remarks: It is the largest of all Philippine RBB, easily recognized by the serrated lateral margins of the pronotum.

Scotinophara pseudoserrata new species
(Plate 1-3,7-3,13a-i)

Length: Male 8.55 mm. Width across prehumeral process 5.10 mm.
Female: 9.20 mm. Width across prehumeral process 5.30 mm.

Color: Brownish yellow to reddish brown with black head, antenniferous tubercles, lateral margins of pronotum and silvery eyes. Venter of abdomen reddish brown with yellow laterals. Legs and proboscis yellowish brown.

Head: 1.22-1.25x wider than long, punctated and rough. Tylus as long as to slightly shorter than jugum with subacute tip. Eyes about as long as anterior lateral margin of pronotum. OOL as long as eye diameter. POL 2.3x - 2.5x eye diameter. Antenniferous tubercle blunt to very slightly cleft at apex.

Length of antennal segments (mm). V>IV>III>II>I. Proboscis reaches coxae III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.45	0.55	0.85	0.90	1.30	4.05
♀	0.45	0.50	0.98	1.00	1.30	4.23

Length of proboscis (LOP) (mm), cut in female.

Sex	1	2	3	4	Total
♂	0.85	1.10	0.90	1.00	3.85
♀	-	-	-	-	-

Pronotum 2x wider than long, deep along collar and strongly punctated. Anterior lateral margin straight, spine small and directed laterally. Lateral margin of pronotum heavily rebordered, serrated with 3-5 small spines. Prehumeral spine more robust and longer than the anterior lateral spine. Cicatrices elevated by the groove in the collar, lateral margin and transverse furrow.

Legs without inner midlateral spine in tibia II, order of length III>II=I. Tibia II shorter than tibia I.

Leg measurements (mm)

Leg	Femur	Tibia	Tarsus	Total
No.	♂/♀	♂/♀	♂/♀	♂/♀
I	2.40	2.50	0.85	5.75
II	2.50	2.35	0.90	5.75
III	2.85	3.10	1.00	6.95

Forewings with 2 closed marginal cells in the membrane, 1st cell long and bullet-like and 2nd rectangular. Four longidutinal veins present, 1st bifurcate closed to base, bases of longitudinal vein sclerotized. Hindwing with a small knob-like processes, R+M-CuA triangle large and pointed with a strongly concave CuA and M heavily sclerotized. Scutellum not reaching tip of abdomen, broadly round distally, and in level to the subapex of penultimate laterotergite.

Abdominal sternites finely punctated, lined with around 15 transverse rows of small hairs in sternite VII. Midanterior of sternite VII smooth and strongly inverted V-shape, entire sternite 3.35x and 3x wider than sternite VI and V, respectively. Tergite X slightly cleft medially. Pygophore transverse with posteriorly projecting dorsolateral spine, 1.5x wider than long, posterior median surface with transverse striations and network of circular punctuations. Spines horn-like and converging distally, distance between spines 3x its length. Clasper similar to *S. serrata* but separated from the latter by the coarser and more elongate scale-like structures in the inner blade, 20 median posterior surface setae closer to the tip and a lone proximal seta below the angle of the blade, inner arm reduced to a rounded and blunt process lined with 7 setae.

Male genitalia: as in *S. serrata,* except for saddle-shaped posterior phallotheca, a long pivot, rounded ventral lateral arm of basal plate, concave dorsal margin and rounded tip of penial plate.

Female genitalia: 9th paratergite not exserted, proctiger longer than wide, distal margin of second gonocoxae truncate to slightly concave.

Materials examined: Philippines: Luzon Is., Mt. Province, Abatan, Buguias, 60 km.S of Bondoc, 1800-2000 m asl, holotype male, 06 May 1964, H.M. Torrevillas (BPBM Coll.); same island, Benguet Province, Baguio, paratypes 1 male and 1 female, 1524 m asl, 22-23 Jun 1951, C.R.Baltazar (UPLBMNH Hem-Pen 026-027).

Remarks: This species is distinguished from *S. serrata* on the basis of the following characters: (1) elongate membranous conjunctiva, (2) truncate apices of the lateral arm of the posterior phallotheca viewed laterally, (3) more saddle-shaped posterior phallotheca, and (4) shorter protrusion of the dorsolateral lobe.

Scotinophara luzonica new species

(Plate 1-4, 7-4, 14a-n)

Length: Male - 8.8 mm. Width across prehumeral process 4.85 mm.
Female 8.9 mm. Width across prehumeral process 4.90 mm.

Color: Brownish yellow, except black head, antenniferous tubercle, collar and lateral margins of pronotum, venter of body, femora I-III and apical one-half of claws; reddish brown inner bases of pro-meso-and metapleuron, coxae and trochanter, antennae, eyes with silvery luster, cicatrices, and venter of tibia I, yellow brown to brown proboscis, tibia I and II, and basal one-half of claws.

Head 1.3x wider than long, coarse with short pilosity. Tylus elevated, slightly longer to as long as jugum. Eyes about 0.9 length of anterior lateral margin. OOL 0.7x eye length. POL 1.70x eye length. Antennifers cleft, inner part slightly smaller and lower than the outer part.

Antennae incomplete, only 3 segments left, I=II= 0.44 mm and III= 0.82 mm. Proboscis long reaching first abdominal segment.

Pronotum 1.96x wider than long; anterior margin widely concave, with collar groove pilose; sinuate lateral margin rebordered, short anterior lateral margin sinuate to slightly oblique, with nipple-like spine at 45°; pronotal punctures well spaced and without brown shades; prehumeral spine subtriangular and as long as anterior spine. Cicatrices slightly elevated without tubercles. Transverse furrow traceable. Metathoracic scent gland with long opening. Metapleuron with an ovoid and densely punctated yellow plate and lightly punctated posterior area. Mesepimeron with a thick ridge between microsculptured region.

Legs incomplete with most tarsal segments missing. Midventer of tibia I with 2 spines-1 normal and 1 forked. Leg measurements (mm): femur I (2.10), II (2.45), III (3.20); tibia I (2.00), II (2.20), III (3.10) and tarsus I (0.40) and III (0.35).

Forewings with 2 closed marginal cells and 5 longitudinal veins, first vein connected to second by an oblique crossvein subterminally, or 2nd vein bifurcate at midlength forming veins 2 and 3. Corium with a narrow U-shaped line running from tip of vein R+M. hindwings with heavily sclerotized vein R+M, knob-like process, junction and outer part of R+M-CuA triangle. Arm of CuA below the triangle straight.

Scutellum broad and evenly punctated, except rough base, tip truncated. Ratio of WAB: WACP: L = 3.20: 2.8: 5.00.

Abdominal venter finely punctated medially, with fine short hairs, midanterior apex of sternite VII convex, VI-V-IV straight. Sternite VII 3.6x and 3.2x wider than VI and V, respectively. Tergite X cleft medially. Pygophore longer than wide to subglobose inner dorsolateral lobe hairy. Clasper visible in cross-sectional view, tip barely touching posterior margin of abdominal tergite; blade almost flat, median posterior surface bears 11 setae with a seta isolated from the group, tip bluntly rounded, basal posterior end constricted, and inner arm short and bears 12 setae.

Male genitalia with base of posterior phallotheca dorsally subrectangular and shorter than the anterior phallotheca excluding the long apical lateral arms, membraneous conjunctiva subtruncate apically to slightly cleft, penial plates with rounded tips in dorsal view to squarely cut in lateral view. Gonophore long and exserted.

Female genital plate with 9th paratergite slightly beyond abdominal tip, 8th paratergite acutely pointed inwards, 2nd gonocoxae with a pair of hairy cavities; genital plate puncture line with triangular or small warts in between punctures. Spermatheca elongately gourd-like, median dilation 3.4x longer than wide, distal sperm duct without loops, proximal flange convex, spermathecal pump slender about 4.3x longer than wide, spermathecal bulb with 2 processes.

Materials examined: **Philippines**: Luzon Island, Nueva Viscaya, Bagabag, holotype male, ex.light trap, 9 Apr 1972, A.D. Pawar (IRRI AR Coll.) and paratypes 1 female, Camarines Sur, Pili, ex.rice, 6 Jul 1973, A.D. Pawar (IRRI AR Coll.#00929).

Etymology: Named after the island's type-locality.

Scotinophara molavica new species
(Plate 2-1, 7-5, 15a-h)

Length: Male 9.50 mm. Width across prehumeral process 5.60 mm.

Color: Brownish yellow with black head, collar, cicatrices except disc, antennifers, lateral margins of pronotum and body venter. Antennae dark reddish brown including femora I-III, venter of tibiae, ventral posterior areas of tibia II and III, and apical half of claws. Tibia yellowish brown dorsally.

Head 1.4x wider than long, shortly pilose and coarsely punctated. Tylus as long as jugum. Eyes reach 0.81x length of anterior lateral angle. OOL 0.65x length of eye. POL 1.9x eye length. Antennifers with a lower subtruncate inner part and elevated pointed outer part.

Antenna incomplete, segments IV and V missing, length (mm) of I= 0.43, II= 0.45, and III= 0.79. Proboscis reaches coxae III.

Pronotum similar to *S. latiuscula*, except for broader collar, sinuate to concave anterior lateral margin, upcurved and more pointed anterior lateral spine, longer cicatrices inner arm and more pronounced prehumeral spine. Lateral margin of pronotum sinuate and concave. Cicatrices slightly elevated, without tubercles. Transverse furrow shallow but visible. Metathoracic scent gland opening long. Metapleural yellow plate slightly punctated with a double concave proximal margin, posterior area of metapleuron thickly punctated. Mesepimeron with a shallow ridge between microsculpture region.

Legs with spines in the midinner lateral sides of tibia II, claws sharp with short pseudoarolia. TCl= 0.20, TCh= 0.13, TCd= 0.11.

Leg measurements (mm)

Leg	Femur	Tibia	Tarsus	Total
No.	♂	♂	♂	♂
I	2.25	2.20	1.10	5.55
II	2.45	2.35	1.10	5.90
III	3.40	3.25	1.20	7.85

Forewings bear a yellow line parallel with the vein R+M, membrane with 3 closed marginal cells and 6 longitudinal veins. Second longitudinal veins bifurcate towards the apex. Hindwings with strongly concave junction of vein M and CuA, veins marginal cells R and M well separated distally and slightly sclerotized. Knob-like process small and junction subrectangular. Inner cavity of secondary veins broadly concave.

Scutellum with a dark longitudinal band medially, densely punctated and emarginate tip almost passed posterior end of abdomen. Ratio of WAB:WACP:L = 3.6: 3.1: 5.6.

Abdominal venter finely punctated with short fine hairs, midanterior margin of sternite VII broadly inverted V-shaped. Tergite X truncate to slightly emarginated. Pygophore transverse, 1.5x wider than high, ventral one-half transversely high medially and visibly punctated with short hairs. Clasper hidden by the wing membrane, blade broad with a pointed tip, strongly concave median posterior surface bears 8 setae, inner arm laterally blunt and concave cross-sectionally bearing 11 setae.

Male genitalia: posterior phallotheca shorter than anterior phallotheca including penial plate, basodorsal area with two transverse slits; anterior lateral arm of phallotheca slightly longer than heavily sclerotized posterior phallotheca. Penial plates well separated apicodorsally, cleft to concave laterally. Apices of lateral arms of phallotheca cleft in lateral view. Lateral arm of basal plate sinuate and as long as posterior phallotheca. Extended lobe of aedeagal cap with about 20 long bristles.

Materials examined: **Philippines:** Mindanao Is., Zamboanga del Sur, Molave, 50 km NWW, 500 m asl, holotype male and paratype male, 19-20 Oct 1959, C.M. Yoshimoto (BPBM Coll.).

Etymology: Named after the type-locality.

Scotinophara kalinga new species
(Plate 2-2, 7-6, 16a-k)

Length: Male 7.90-8.80 mm. Width across prehumeral process 4.85 mm.
Female 8.90 mm. Width across prehumeral process 5.10 mm.

Color: Brown with black head, antennifers, dark brown to reddish brown cicatrices, rebordered margin of pronotum, coxae and trochanter, pleural side of thorax adjacent to coxae, femora I-III, tibia I-II and apical one-half of tarsal claws, and yellow spots in the dorsal and ventral sides of spiracles

and posterolateral side of metapleuron. Antennae with reddish brown basal segment and yellowish brown to reddish brown segments II-III.

Head 1.3x - 1.4x wider than long, coarse, and shortly pilose. Tylus elevated and slightly longer than jugum. Eyes reached 0.85 length of anterolateral margin of pronotum. OOL about 0.83x as long as eye length. POL 2.0-2.2x eye length. Antenniferrous tubercles cleft, narrowly, inner arm lower than outer arm.

Antenna incomplete, three segments visible, segment I basally glabrous with slight submedian constriction, length of I=II (0.42mm) and III as long as combined length of I and II in male and I (0.46mm) slightly shorter than II (0.44mm) wioth combined length longer than III (0.80mm). Proboscis reaching coxae III.

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.62	1.02	1.0	0.88	4.52
♀	0.72	1.28	1.10	0.94	4.04

Pronotum regularly and evenly punctated, 1.74x-2x wider than long in male and 1.85x in the female. Anterior margin relatively shallow, anterior lateral margin straight to slightly sinuate, its spine small and acute, directed slightly forward at 45º angle. Lateral margin sinuate, distinctly rebordered from anterior lateral angle to the prehumeral spine. Anterior lateral spine smaller and more triangular than the subacute prehumeral spine. Cicatrice holster-like, disc with 3-4 transverse furrows of pilose punctures. Transverse furrow shallow but visible. Humeral cavity relatively deep. Posterior margin of pronotum slightly concave widely. Metathoracic scent gland with 2 distinct transverse ridges basad of the opening, entire anterior metapleuron higher than the lateral yellow plate. Anterolateral side of the mesopleuron bears a circular pit with 12-15 punctures.

Leg length III>II>I, tibia II with a subapical and median spine in the inner lateral side.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	2.00	2.10	1.80	2.00	0.92	0.92	4.72	5.02
II	2.10	2.30	1.80	2.10	0.92	0.95	4.82	5.35
III	2.50	2.90	2.35	2.80	0.92	1.06	5.77	6.76

Forewings with 3 closed marginal cells and 5 longidutinal veins in the membrane, vein R+M bears a U-shaped yellow band distally. Hindwings with a hammer-like knob process in vein R+M, junction long and rectangular, vein CuA lightly sclerotized proximally and below the R+M-CuA triangle.

Scutellum heavily punctated in basal one-half, punctures interconnected forming wavy transverse rows; ratio of WAB:WACP:L = 3.3:2.95:5.1.

Abdomen with the anterior margin of sternite VII widely V-shaped and convex in males and females, respectively. Sternite VI in male with a double convex anterior median border. Tergite X truncate posteriorly, median area not sclerotized. Pygophore subspherical cross-sectionally. Clasper sickle-shaped with acute tip, median posterior surface with 7 setae, inner margin with rough transverse row of scale-like teeth, inner arm not distinct lined with at least 9 setae.

Male genitalia bears a globose anterior and posterior phallotheca with a long lateral arm almost enclosing the dorsally elongate membraneous conjunctiva. Penial plate tips truncate in lateral view. Ejaculatory duct exserted. Aedeagal cap pilose with a median dorsal band forming two apically rounded plates.

Female genital plate with elongate, parallel-sided and apically rounded 9th parategite not beyond abdominal tip; base of 9th paratergite with a cavity touching the posterior lateral margin of the first gonocoxae; proctiger subquadrate; second gonocoxae with a truncate posterior margin, a pair of C-shaped depressions submedially bordered anteriorly with diverging striae.

Materials examined: **Philippines**: Luzon Is., Kalinga, Bagad, holotype male, ex. rice, 8 Apr 1972, A.D. Pawar (IRRI AR Coll.); paratypes: 1 female, Laguna Province, Pila, 10 Oct 1971, A.D. Pawar (IRRI AR Coll.#00927). 1 male, Ilocos Sur, Cabuyao, 28 May 1972, A.D. Pawar (IRRI AR Coll.).

Etymology: Named after type-locality.

Scotinophara arkwata new species
(Plate 2-3, 8-1, 17a-l)

Length: Male 8.40- 8.75 mm. Width across prehumeral process 4.70-4.90 mm.

Color: Dull brown to brownish yellow with black head, antenniferous tubercles and apical half of claws. Collar with a yellow margin and a yellow vertical T-band extended to a large yellow spot between cicatrices. Eyes silvery white to reddish brown. Antennae and proboscis reddish brown. Legs and body venter dark reddish brown, except yellowish brown tibiae and tarsi. Posteroventral 1/3 to ½ of tibiae dark brown. Tip of vein R+M of forewings with 2 yellow parallel lines.

Head coarsely punctated with short pilosity, 1.3x wider than long. Tylus slightly longer to as long as jugum. Eyes reached 0.86 length of anterior lateral margin of pronotum. OOL 0.7x eye length. POL 2.1x eye length. Bucculae lined with short hairs, anterior end with a pit, ventral margin reddish brown. Antenniferous tubercle with a thin and low inner and a high outer processes.

Antenna with incomplete segments, I (0.64 mm) basally swollen and as long as II. Proboscis reaches midlength of coxae III, length of segments (mm): I= 0.64, II=1.30, III=IV = 0.9

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.64	1.30	0.96	0.96	3.86
♀	–	–	–	–	–

Pronotum 2x wider than long across prehumeral process. Punctations separated from each other, not confined in furrows. Anterior margin widely concave as deep as 0.3x eye length, and collar distinctly punctated. Anterior lateral margin straight, rebordered, small, pointed spine directed obliquely forward at 45º angle. Lateral margin sinuately concave, rebordered progressively towards the bluntly rounded and more distinct prehumeral spine. Cicatrices pistol-like widely separated medially, without elevated tubercles, disc with 8-11 punctures. Transverse furrow shallow and traceable. Metathoracic scent gland elongate lobe-like with 6 transverse ridges basad of the opening. Humeral cavity shallow. Metapleuron plate relatively higher than the broad ventrolateral yellow spot lined with 4 rows of punctures.

Legs without dark markings on the posterodorsal areas of tibiae, inner laterals of tibia II without spines at midlength.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	2.05		2.10		?			
II	2.35		2.20		0.85			
III	2.60		2.80		?			

Forewings bear 2 closed marginal cells and 5 longitudinal veins, first longitudinal vein forms the second closed marginal cell. Apex of vein R+M with two parallel lines.

Scutellum with a truncated tip, ratio of WAB:WACP:L = 3.25: 2.8: 5.0.

Abdominal venter with a network of scale-like markings, interrupted transverse striae, and fine hairs. Sternite VII narrowly dome-shaped in the midanterior margin, 3x wider than sternite V and VI and 2.4x in sternite IV. Tergite X broadly truncated. Pygophore transverse, 1.4x wider than long, clasper shortly visible in cross-sectional view, basal ½ deeply punctated and rough and its median area moderately concave. Clasper with angulate blate and acute tip median posterior surface with 2 groups of 11 setae, 9 towards the tip and 2 median, blade bent before the slender stem and inner arm reduced to a small process with 9 setae. Ventral area of blade lined with fine scale-like markings.

Male genitalia bears a short posterior phallotheca, a distinctly long anterior lateral arm holding the elongate anterior cleft membraneous conjunctiva. Basal plate, lateral arm longer than the posterior phallotheca. Penial plate truncated apically in lateral view. Ejaculatory duct slightly exserted. Aedeagal cap with a pilose dorsal and indention midlaterally.

Materials examined: **Philippines:** Luzon Island, Laguna Province, Los Baños, holotype male, ex. rice, 10 May 1978, A.T. Barrion (IRRI AR Coll.# 00929) and paratype male, same province, Mabitac, 10 Oct 1971, A.D. Pawar.

Scotinophara latiuscula (Breddin)
(Plate 2-4, 8-2, 18a-m)

Podops latiuscula Breddin, 1900. Stett. E.Z. LIX. 284.

Length: Male 8.15 mm. Width across prehumeral spine 4.65 mm.
Female 7.8-8.6 mm. Width acroos prehumeral spine 4.2-4.85 mm.

Color: Brown with yellow markings in between punctures. Head black with reddish brown compound eyes, cicatrices, lateral margins of pronotum, antennae except segments II-IV with yellowish brown tinge and proboscis; collar yellow with dark brown femora I-III, venter of tibia I, dorsal and ventral posterior areas of tibiae. Dorsum of tibiae I-III and trochanter yellow including tarsal segments I and II, terminal tarsal segment brownish yellow. Bases of pleuron around coxae I-III with yellow spots. Lateral margins of abdomen with yellow mottles dorsad and ventrad of spiracles. Vein R+M of forewing marked with yellow line in its entire length and a relatively shorter but broader band parallel to it distally.

Head 1.3x wider than long, roughly punctated and shortly pilose, narrowed anteriorly and with elevated tylus slightly longer to as long as jugum. Eyes pass midlength of the anterior lateral margin of pronotum. OOL 0.6x eye length. POL almost 2x eye length. Antenniferous tubercles blunt with indistinct apical cleft, if distinct outer blunt part higher than the inner part.

Length of antennal segments V > III > IV > I > II, segment IV as long as combined length of I and II. Proboscis beyond coxae III, reaching first abdominal sternite.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.40	0.35	0.74	0.74	1.16	3.83
♀	0.38	0.30	0.77	0.68	1.05	3.18

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.65	1.28	0.96	0.88	3.77
♀	0.74	1.24	0.96	0.84	3.78

Pronotum shortly pilose, 1.92 wider than long across prehumeral spines, and punctures separated. Anterior margin widely concave with a broad collar. Anterior lateral margin of pronotum slightly oblique, anterior spine subacute projected laterad. Lateral margins of pronotum gradually concave and strongly rebordered before the prehumeral. Prehumeral spine more robust than the anterior spine. Cicatrices smooth without elevated tubercles, disk with 6-8 punctures inside the spot. Transverse furrow absent. Scent gland with 3-5 transverse ridges basad of the opening. Metapleuron oblongate and elevated from the yellow ventrolateral plate with more than 22 punctures.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.90	1.90	1.8	1.75	0.83	0.85	4.53	4.50
II	2.25	2.10	2.10	1.90	0.76	0.84	5.11	4.84
III	2.60	2.60	2.75	2.55	1.00	0.94	6.35	6.09

Forewings with 3 closed marginal cells and 5 longitudinal veins, first longitudinal vein incomplete producing open innermost cell. Claval suture short, less than 1.5 mm long. Hindwing with a deep concave secondary veins, small knob-like process, long vein R+M-CuA junction, and a relatively large R+M-CuA triangle.

Scutellum 2x wider than long, ratio of WAB: WACP:L = 3.0: 2.75: 4.6. tip of scutellum widely truncate almost at tip of abdomen.

Abdominal sternite VII of male with a widely V-shaped anterior margin and strongly convex in female. Male sternite VIII 3.5x wider than sternite VI, 3x in sternite V and IV; in female, sternite VIII 1.7x wider than each of sternite segments VI-V-IV. Pygophore transverse, 1.5x wider than long, basal lobe coarsely punctated, lined with short hairs and furrows. Clasper not visible in cross-sectional view, short sickle-like shape with large blade and median posterior surface, surface with 12 setae. Tip acute and slightly curved. Inner area widely concave above the blunt inner arm. Stem short and narrow basally.

Male genitalia with short and oblongate posterior phallotheca strongly sclerotized narrower than the V-shaped anterior phallotheca enclosing the membraneous conjunctiva. Subapical dorsal part of membraneous conjunctiva deep. Ejaculatory with 2 coils under the conjunctiva. Apex of lateral arm of phallotheca rounded to truncate. Ejaculatory duct long with exserted beyond penial plates. Apices of penial plate concave in side view. Basal plate subtriangular laterally with a long pivot. Aedeagal cap a pair of convex ridges at midlength V-shaped light band posteromedially.

Female genitalia with a pair cavities in the second gonocoxae, its anterior and posterior margins concave. 8th paratergite convergingly triangular. 9th paratergite with sparsely punctated basal one-half and pilose inner apical part. Spermatheca elongated, 4.5x longer than wide, median dilation relatively narrow; distal spermathecal duct with loops, and spermathecal bulb with equally long processes.

Materials examined: **Philippines**: Luzon Island, Laguna, Victoria, 1 male, ex. rice, 8 Nov 1981, A.T. Barrion (IRRI AR Coll.); same province, Sinoloan, 1 female, ex. rice, 8 Nov 1982, A.T.

Barrion (IRRI AR Coll.); Nueva Ecija, Muñoz, Maligaya, PhilRice CES, 8 males and 5 females (all dissected with wings, claspers, aedeagal cap and female genital plates on slides), ex. light trap, 1 Jul 2006, D.K.M. Donayre; same province, Los Baños, Mt. Makiling, 1 male, 2 Oct 1948. A. Diasanta (UPLBMNH Hem-Pen 001); College, 1 female, 5 Jun 1956, F.M. Llaneta (UPLBMNH Hem-Pen 002); 1 female, 27 Jun 1959 F.B. Calora (UPLBMNH Hem-Pen 006); 1 female, 1 Sep 1956, B.P. Gabriel (UPLBMNH Hem-Pen 007); 1 female, 10 Oct 1948, F. Magnaye (UPLBMNH Hem-Pen 011); 1 female, 4 Jul 1953, N. Lopez (UPLBMNH Hem-Pen 012); Calaun, 4 females, 4 Jul 1953, L. Rivera (UPLB-MNH Hem-Pen 005,003); Isabela, Roxas, 1 female, 2 May 1951, R. Santos (UPLBMNH Hem-PEN 004); Panay Is., Capiz, Balete, 1 female, 17 Jun 1951 (UPLBMNH Hem-Pen 013).

Scotinophara cinerea (Le Guillou)
(Plate 3-1, 8-3, 19a-k)

Podops cinereus Le Guillou, 1841. Rev. Zool. 262.
Podops cinereus Breddin, 1905. Beih. Jb. Hamb. Wiss. Anst. XXII (2): 113.
Podops vermiculatus Vollenhoven, 1863. Faune ent. Indo-neerl.1.41,Pl.III f. 7.
Podops vermiculatus Koningsberger,1903. Med. 's lands.Plant.LXIV.12,Pl.1.f. 17

Length: Male 8.10-8.40 mm. Width across prehumeral processes 4.65 mm.

Color: Brown with yellow mottles in the posterior pronotum, scutellum and forewing's corium and clavus. Black head, antenniferous tubercles, anterior pronotum including lateral margins and venter of body, except yellow brown ventrolaterals around the spiracles and part of metapleuron. Antennae reddish brown in segment I, slightly lighter in II but yellowish brown in III-IV. Proboscis glossy brownish red, darker in apical one-half of terminal segment. Femora I-III reddish brown, darker apically. Tibiae and tarsi yellowish brown with black patches in the dorsal and ventral posterior edges of tibiae.

    Head 1.4x wider than long, coarsely punctate and shortly pilose. Tylus as long as jugum. Eye length about 0.7x length of the oblique anterolateral margin of pronotum. OOL 0.6x length of eye. POL 1.5x length of eye. Antenniferous tubercles cleft, inner part elevated, acutely pointed and in-curved, the outerpart blunt. Ratio of antennal segments V > IV > III > II > I, segments I moderately incrassate. Proboscis reach anterior of coxae III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.34	0.38	0.58	0.60	1.00	2.90
♀	0.38	0.40	0.57	0.64	1.02	3.01

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.60	1.00	0.80	0.90	3.30
♀	0.65	1.10	0.85	0.85	3.45

Pronotum 2x wider than long. Punctated coarsely and heavily posteriorly with groups of punctures confined in furrows bordered by yellow flattened ridges. Anterolateral margin oblique, 1.6x longer than eye, its spine projected posterolaterally and smaller than prehumeral spine. Lateral margin moderately concave, depth slightly longer than height of prehumeral spine. Lateral margin moderately concave, depth slightly longer than height of prehumeral spine. Cicatrices smooth without elevated tubercles, disc with a convex yellow band and posterior margins lined with at least four transversely interrupted yellow line. Transverse furrow obscure. Evaporative area ovoid with a small seven punctated oblong and yellow spot laterally distal of the scent gland opening.

Legs bear no spines in the inner midlateral side of tibia II in males and one at midlength in females.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.84	1.85	1.62	1.75	0.70	0.80	4.16	4.40
II	2.24	2.25	1.80	2.00	0.70	0.85	4.74	5.10
III	2.55	2.70	2.40	2.70	0.90	0.90	5.85	6.30

Forewings coarsely punctated, with 3 closed marginal cells, 3rd one rectangular and 2.8x wider than long. Six longitudinal veins present, 2nd vein bifurcate and 4th short and connected by a small cross vein at midlength of 4th. Left forewing with 2 closed marginal cells and six longitudinal veins. Second and forth longitudinal veins forked. Hindwings with a short cross vein in the squarish junction connecting vein R+M, vein R with a rounded spot just after the junction, CuA arm emanating from the R+M-CuA triangle straightly oblique and basally concave.

Scutellum more coarsely punctated than the posterior pronotum, rounded tip reaches posterior end of abdomen. Ratio of WAB:WACP:L = 2.9: 2.2: 4.5.

Abdominal sternite VII strongly convex midanteriorly and twice broader than sternite VI. Tergite X widely concave. Pygophore transverse, 1.7x wider than long, ventral half roughly punctated with about six V-shaped grooves. Clasper long with slender blade and eight setae on the median posterior surface, tip of blade rounded. Inner arm subtriangular with slightly concave surface, base with two setae. Median posterior lobe with few hairs. Aedeagal cap deeply grooved medially and hairy in basal one half, lateral ridge distinctly developed.

Male genitalia: Posterior phallotheca ovoid, not saddle-shaped, slightly wider than midlength, its anterior lateral arm triangular viewed laterally with apex acutely pointed; membraneous conjunctiva expands a little beyond base of penial lobes and convoluted centrally. Penial lobes widely separated

apically, tips rounded in lateral view. Ejaculatory duct short. Basal plate with a short lateral arm and pivot.

Female genital plate with moderately punctated 8th paratergite, except its heavily punctated darkened base; inner apical lobe of 9th paratergite parallel sided, rounded apically and obliquely diverging basal two-thirds likewise parallel sided, with 3-4 vertical grooves; proctiger as long as wide and below apex of 9th paratergite; second gonocoxae with convex distal margin, medially with circularly punctated depressions and lateral expansion; first gonocoxae with truncate to rounded inner margins and obliquely groove and punctated central disc. Spermatheca oblongate, almost 3x longer than wide; sclerotized median duct with one and a half coil proximal of the median dilation; distal spermathecal duct short about 0.5x length of the 11 coiled loops; proximal flange thin and relatively wider than distal flange; pump constricted at midlength; subglobose spermathecal bulb with an oblique cut and without processes.

Materials examined: **Philippines**: Luzon Island, Manila, 3 males, 24 Aug 1948, F.O. Otanes (BPI Entomology Collection nos. 140-B, 140E, 140). **Indonesia**, Sumatra with number label 22, 1 male, (identified as *Podops vermiculata* Voll.), no collection date and collector labels (USNMNH Coll. 2042719); Peleralam, 5 males and 1 female, Java, Pekalongan, 3 males, no collection date, F. Muir (BPBM Coll.); Bogor, Tjimaggu along Tjiliwung River, 23 males and 2 females, ex. sweepnet, 4 Oct 1960 H.H.F. Habmann (BPBM Coll.); Botanical Garden, 1 female, 17 Nov 1960 (BPBM Coll.); same locality, 2 males and 1 female, 22 Augt 1964, M. Delfinado (BPBM Coll.); Jakarta, 5 males and 22 females, 10-22 Dec 1964, J. Winkler (BPBM Coll.); Bogor, Botanical Garden, 1 female, 17 Nov 1960, H. Hamann BPBM Coll.); LP3, 1 male and 1 female, 29 Nov 1978, Sr. Suharni Siwi; W. Java, Cirebon, 6 males and 3 females, 15 Nov 1977, J.T. Medler (BPBM Coll. Acc.# 1979-483); Cimanggis, 1 male and 3 females, 24 Feb 1977, ex. rice, Sri Suharni Siwi; Caleung, 4 females, 27 Jul 1978, Sri Suharni Siwi; C. Java, Kulonprogo, Wates, 6 males and 1 female, 29 Jun 1978, Denan and Agus; same province, Banyumas, Aji barang, 7 males and 3 females, 1 Jul 1978, Denan and Agus; Sukamandi, 6 males and 1 female, ex.light trap, 14 Apr 1980, A. Somad; 1 female, March 1980, Sri Suharni Siwi.

Remarks: Very often confused with *S. coarctata*.

Scotinophara sorsogonensis new species
(Plate 3-2, 8-4, 20a-m; Figs. 12-23)

Length: Male 7.7 mm. Width across prehumeral spine 4.3 mm.
             Female 7.9 mm. Width across prehumeral spine 4.3 mm.

Color: Brown except black head, antenniferous tubercles, cicatrices, venter of head, thorax and abdomen, coxae, trochanter and apical half of femora I-III; dark reddish brown basal half of femora I-III,

reddish eyes and ocelli and tip of tylus, yellowish brown antennal segments, yellow border spots of cicatrices and punctuations, yellow tibiae and tarsi with black dorsal and ventral posterior ends of tibiae I-III and apical ¾ of tarsal claw.

Head: coarsely punctated, wider (between eyes) than long (1.9x1.2 mm); tylus as long as to very slightly longer than juga and apically upturned; juga widest at midlength, narrowed towards the subtruncated apex; eyes slightly longer than wide, ovate and protrude laterally to 0.60 length of apical pronotal angle; OOL 1.25x ocelli diameter; POL 4x ocelli diameter; inner side of antenniferous tubercle slightly pointed and higher than the apically low and rounded outerside; antennae 5 segmented, basal segment stout along posterior one-half, longer than segment II, segment III shorter than IV; the longest segment V 1.6x longer than IV, length in decreasing order: V > IV > III > II > I; proboscis tip reaches coxae III to slightly beyond coxae III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.38	0.42	0.51	0.60	0.94	2.85
♀	0.40	0.37	0.58	0.62	0.96	2.93

Pronotum without distinct transverse shallow sulcus across pronotal disc behind cicatrices; anterior margin deeply concave medially, with a groove subanteriorly; rough anterior one-half with raised ridges around cicatrices; anterolateral margin straight to oblique as long as 2/3 of antennal segment V; small subapical spine directed posterolaterally; lateral margins between spines. Spineless and smoothly concave; mask-like cicatrice 2x longer than wide (1.6:0.6) smooth, except median elevated slightly yellow area and punctated margins; posterior pronotum across humeral area distinctly punctated.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.80	1.85	1.60	1.60	0.80	0.80	4.20	4.25
II	2.10	2.10	1.95	2.00	0.85	0.85	4.90	4.95
III	2.40	2.55	2.40	2.40	0.90	0.90	5.70	5.85

Pronotum 1.94-2x wider than long across prehumeral spines. Prehumeral spine more robust than the anterior lateral spine. Metathoracic scent gland ovoid with 6 transverse ridges basal of opening. Midventer of tibia I with 4 slightly curved spines, anterior end expanded frontolaterally to tubercle-like with 2-3 spines, posterolateral with 12-13 subapical spines, venter of basitarsus with a thick pad of fine white hairs unlike mid and apical tarsal segments; claws sharply pointed with a two hair-like arolium, 2 white flap-like and elongate pseudoarolia constricted at midlength. Tibia II with 1-2 inner lateral spines at about midlength.

Forewing 3.3x longer than wide, punctated and corium with spots link together, anterobasal without process, clavus basally smooth, punctures dense marginally; membrane with 2 elongate and one rounded marginal cells; 4 longitudinal veins present with 2 elongate and one rounded marginal cells; 4 longitudinal veins present with third vein branched apically. Hindwing 1.5x longer than wide, R+M+CuA triangle with large "node," merge point of R+M small, as long as wide but barely one-third height of triangle, separation of secondary veins as long as length of basal SV, 2A equally separated from 1A and 3A at the concave and convex areas of 2A, respectively.

Scutellum coarsely punctated similar to posterior pronotum; punctures regularly spaced, except confused state in median raised area, reaching posterior end of abdomen, tip evenly rounded, middle area slightly elevated with punctures joined together by black spots, scutellum ratio (WAB: WACP:L) 2.8:2.25:4.5. basolateral pit C-shaped, scutellar arm rounded apically, pointed laterally, 1.5x longer than wide.

Abdominal venter finely punctated medially moderately round and more pronounced marginally, spiracles slightly elevated with two thin hairs on a raised area posterior of each spiracle. Sternite VII with a convex anterior median margin. Tergite X widely V-shaped to strongly concave. Pygophore wider than long, clasper distinctly reaching posterior margin of terminal abdominal tergite, inner side of dorsolateral lobe thickly haired. Clasper with a semiporrect blade, blunt and rounded tip, median posterior surface with 7 spines. Inner arm slightly triangular, surface with 2-4 hairs in the inner most side, angle between arm and blade close to 90°. Stem elongated and parallel-sided.

Male genitalia: posterior phallotheca subglobose and slightly saddle-shaped, anterior median margin truncately indented. Lateral arm of basal plate at midlength of phallotheca, subtriangular laterally and slender pivot not reaching apex of phallotheca. Membraneous conjunctiva largely covering the widely separated apices of penial plates. Ejaculatory duct not visible dorsally. Laterally penial plates with rounded tips.

Female genitalia: second gonocoxae lip-like, anteriorly narrow and broad posteriorly. Ninth paratergite with a rounded tip hardly beyond tip of abdomen. Eighth paratergite with pointed laterals and inner interior ends. Spermatheca 3x longer than wide, broadest at midhalf, sclerotized median duct half-coiled proximally, distal spermathecal duct bears 7-8 coils, proximal flange slightly wider than globose spermathecal bulb.

Materials examined: Philippines: Luzon Island, Sorsogon Province, Bulan, Otavi, holotype male and 8 male and 5 female paratypes, ex. rice stubbles, 28 Feb 2007, A.T. Barrion.

Other materials examined: 4 males 7 females, ex. old rice stubbles, same province, Matnog, Gadgarin Vill., 28 Nov 2006, A.T. Barrion and E. Navarrete; 7 males and 5 females, Baco, Balogo Vill., 22 Jun 2006, A.T. Barrion, 2 males and 15 females, Gubat, Ariman Vill., 22 Jun 2006, A.T. Barrion; 30 males and 40 females, ex. old rice stubbles, Albay Province, Tiwi, 29 Jun 2006, A.T. Barrion; 2 males and 5 females, same province, Cabunturan, 29 Nov 2006, A.T. Barrion and E. Navarrete; 5 males and 10 females, Tabaco City, Balading, 29 Nov 2006, A.T. Barrion and E. Navarrete;

5 males and 16 females, ex. old rice stubbles, Camarines Sur, Sangay, Poblacion, 29 Nov 2006, A.T. Barrion and E. Navarrete.

Remarks: Very similar to *S. coarctata* but has a distinctly shaped aedeagus and clasper.

Scotinophara pirurotonga new species
(Plate 3-3,21a-m; Figs. 24-35)

Length: Male 8.10 mm. Width across prehumeral process 4.65 mm.
Female 9.20 mm. Width across prehumeral process 4.80 mm.

Color: Brownish yellow to blackish brown, except black head, antennifers, femora I-III, apical half of claws, dorsal and ventral posterior areas of tibiae I-III, and body venter. Eyes reddish brown with silvery luster. Antennae yellow brown with reddish brown segment I and V and apices of tibiae I-III yellow including tarsi and rest of claws. Proboscis brown with yellow.

Head: 1.34x-1.50x wider than long, shortly pilose and distinctly punctate, and venter including bucculae pilose. Tylus slightly shorter to as long as jugum. Apicolateral sides of jugum oblique. OOL 0.63x-0.73x eye length. POL 1.93x eye length. Antenniferous tubercles cleft, thin pointed inner side incurved, short rounded.

Antenna with a glabrous basal one half, segment III shorter than IV. Proboscis slightly touching abdominal sternite.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.40	0.43	0.58	0.68	1.05	3.14
♀	0.40	0.43	0.60	0.70	1.10	3.23

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.60	1.20	0.80	1.05	3.65
♀	0.80	1.30	1.10	1.00	4.20

Pronotum 1.90x-2x wider than long across prehumeral spine. Anterior margin and collar concave, not deeply punctated. Anterior lateral margin oblique, rebordered and spine directed posteriorly. Lateral margin concave, narrowly rebordered towards lateral spine. Prehumeral spine more robust than the lateral spine. Cicatrices smooth without tubercles, bordered with flatly raised spots. Posterior area visibly punctated, punctations enclosed by intricate networks of bands. Transverse furrow absent. Metathoracic scent gland ovoid with at least 8 transverse ridges basal of the opening.

Legs with a single midlateral inner spine in tibia II. Tarsal claws sharp with TCl=0.20, TCh = 0.20, TCd= 0.11.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.90	2.10	1.80	1.90	0.85	0.90	4.55	4.90
II	2.10	2.50	2.10	2.20	0.90	0.95	5.10	5.65
III	2.70	3.00	2.80	2.90	0.90	1.00	6.40	6.90

Forewings with 3-5 closed marginal cells, 4-6 longitudinal veins forming 1-2 median closed cells. Hindwing with a large knob-like process and R+M-CuA triangle, and a rectangular R+M junction.

Scutellum's basal one-half coarse, posterior end strongly rounded not beyond abdominal tip; ratio of WAB:WACP:L = 3.00:2.50:5.10 in males and 3.10:2.80:5.20 in females.

Abdominal sternite VI and VII with convex median anterior margins. Tergite X broadly concave. Pygophore transverse, ventral portion with U-shaped furrows, clasper visibly long almost reaching margin of terminal abdominal tergite. Blade of clasper machete-like with a nipple process apically, scale-like marking ventrally, 8-9 setae in median posterior surface, inner arm triangular with 5 setae on the surface. Inner dorsal lobe hairy.

Male genitalia: Posterior phallotheca wider anteriorly, basolaterally slightly expanded in dorsal view, saddle-shaped laterally; membraneous conjunctiva with concave anterior apices in dorsal view and with nipple-like protrusion in lateral view; ejaculatory duct short and penial plates apically separated. Laterally penial plates bear acute base and rounded tips. Basal plate broad dorsolaterally and subtriangular laterally. Pivot long, tip not beyond anterior margin of phallotheca.

Female genital plate: 8th paratergite broadly subtriangular, 9th with subacute to rounded apices; 2nd gonocoxae with a pair of circular deeply punctated cavities; 1st gonocoxae mildly punctated as in 8th and 9th paratergites. Spermatheca elongately slender, sclerotized median duct with a single coil proximally and 8-9 coils distally, distal lateral ends of sclerotized median duct strongly margined, distal flange with a rough edge, and spermathecal bulb circular.

Materials examined: **Philippines**: Mindanao Is., Agusan del Sur, Bayagan, Bucac Vill. paratype male and holotype 6 males and 7 females, ex. upland rice stubbles, 24 Apr 2006, A.T. Barrion.

Etymology: Named after the glutinous traditional rice variety *"Pirurotong-a."*

Scotinophara agusanortica new species
(Plate 3-4, 8-5, 22a-k; Figs. 36-50)

Length: Male 8.3-8.7 mm. Width across prehumeral spine 4.40 - 4.60 mm.
Female 8.75-9.90 mm. Width across prehumeral spine 4.5 - 4.9 mm.

Color: Blackish brown with black head, cicatrices, antenniferous tubercles, basal segment of proboscis, apical half of femora I-III and apical half of tarsal claws, body venter and dorsal and ventral posterior bases of tibiae I-III. Compound eyes reddish brown with silvery luster. Antennae with incrassate segment I reddish brown in basal one-half and black reddish brown apical half, segment II light reddish brownwith yellow band above midlength, III with yellow basal one-half and reddish brown along apical one-half; IV and V yellowish brown. Basal half of femora I-III including trochanter reddish brown. Tibiae I-III including claw's basal ½ yellow.

Head 1.3x wider than long and shortly pilose, venter tylus slightly longer than jugum, tip rounded and higher than jugum, rough with transverse ridges. Compound eyes beyond midlength of anterior lateral margin of pronotum. OOL two-thirds eye length. POL about 1.75x eye length. Antennifers with a thin and narrow inwardly curved inner process higher than the blunt outer margin.

Length of antennal segments in decreasing order: V > IV > III > II > I, combined length of I and II longer than III or IV. Antennal segment V with a moderately pointed tip. Proboscis reaching coxae III, anterior one-half of segment III flat.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.35	0.40	0.60	0.65	1.10	3.10
♀	0.40	0.45	0.60	0.70	1.05	3.20

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.75	1.10	0.90	0.95	3.70
♀	0.62	1.25	1.00	0.95	3.82

Pronotum 2x wider than long across the prehumeral spines, distinct punctuations close to each other slightly higher than the surrounding borders. Anterior pronotum not deeply concave, collar lightly margined. Anterior lateral margin oblique to slightly sinuate, strongly rebordered, spine short and blunt to indistinct directed posteriorly. Lateral margin of pronotum bordered only in the posterior one-half to the prehumeral spine. Prehumeral spine subacute, more distinct than the anterior lateral spine. Cicatrices without tubercles, disk smooth, posterior border lined with a pair each of yellow spots or bone-like markings. Transverse furrow absent. Humeral area developed. Metathoracic scent gland pear-shaped, 2x longer than wide, opening distinctly protruded with 5-6 transverse ridges basad of the opening.

Leg length (mm) in decreasing order III > II > I. Tibia II with 2-3 spines in the inner median side arranged in a longitudinal row.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.85	2.10	1.70	2.00	0.95	0.95	4.50	5.05
II	2.20	2.50	1.85	2.25	1.00	1.00	5.05	5.75
III	2.70	3.00	2.60	3.00	1.10	1.15	6.40	7.15

Forewings bear 6 longitudinal veins, 4 marginal and 1 large median cells in the membrane, first marginal cell 3.5x longer than wide, second cell pentagonal smaller than the first cell. First longitudinal vein branch towards apex, third branches subbasally and subapically.

Scutellum not reaching abdominal tip, lined with widely spaced punctures, median area at narrowest width concave, tip rounded. Ratio of WAB: WACP: L = 2.9: 2.35: 4.8 in male and 3.4: 2.9: 5.3 in female.

Abdominal sternite 7 smooth medially and shortly pilose sublaterally, convex apicomedian margin with sublateral indentions, posterior median margin with 4 long hairs in a transverse row. Tergite X broadly concave medially. Pygophore subglobose, long clasper visible and touching posterior margin of last abdominal tergite, ventral part of pygophore rough and punctuated, puncture diminishes in size in ventral most part. Clasper with a long, pointed and laterally projected blade, median plate of blade with 10 spines; inner arm triangular with at least 5 spines; stem broad basally.

Male genitalia with stout posterior phallotheca widest along midlength, more globose and saddle-shaped laterally; posterior phallotheca with a bullet-like anterior and posterior markings; dorsomedian conjunctival appendage U-shaped and sponge-like, lateral covers half of penial plate with its anterior end strongly rounded, ventrally with a protruding process. Penial plate touches each other anteriorly forming a wide opening for the short gonophore, laterally tip of penial plate subtruncate to bluntly rounded. Basal plate rectangular with a subtruncate median and arm extended to midlength of posterior phallotheca. Pivot long tip beyond anterior level of phallotheca.

Female genital plate with apically converging and parallel-sided 9th paratergite. Proctiger oblongate. 2nd gonocoxae truncate posteriorly, medially convex anteriorly, knob-like extension laterally and median area punctuated uniformly without divided depression. 8th paratergite subtriangular, anterior margin rough. Spermatheca with two typse of median dilation: 1. slender and narrow and 2. globose, both lined with 3-4 superfine longitudinal stripe. Sclerotized median duct swollen subproximally and slightly wide distally. Proximal spermathecal duct long. Distal spermathecal duct with 6-7 loops. Proximal flange circular. Spermathecal pump distinctly broader distally. Distal flange as wide as the proximal flange, holding the circular spermathecal bulb.

Materials examined: holotype male and paratypes: 3 males, 5 females and 4 nymphs, **Philippines**: Mindanao Is., Agusan del Norte, Talibong, Kitsarao, ex. rice stubbles, A.T. Barrion, 24 Apr 2006.

Etymology: Named after the Agusan marsh habitat where the bugs were collected.

Scotinophara tantanganica new species
(Plate 4-1, 8-6, 23a-m; Figs. 51-65)

Length: Male 7-8.2 mm. Width across prehumeral spine 3.9-4.2 mm.
Female 8.2-8.8 mm. Width across prehumeral processes 4.20-4.50 mm.

Color: Black to blackish brown. Head black including body venter, antennifers, femora I-III, dorsal and ventral bases of tibiae I-III, and scutellar pits. Antennae with dark reddish brown basal and apical segments, segments II-IV light reddish brown. Eyes silvery. Ocelli orange yellow. Proboscis reddish brown. Inner apical ends of femora II-III with a yellowish brown marks. Tibiae and tarsi yellow, except black apical half of claw. Membranes of forewings hyaline.

Head: 1.3-1.4x wider than long with short fine hairs. Tylus slightly to as long as jugum. Lateral midlength of jugum constricted. Anterior lateral margin oblique and sinuate and strongly small spine projected posteriorly. Lateral margin weakly concave, gradually rebordered towards the subtriangular humeral spine more robust than the anterior spine. OOL about 0.55x to 0.65x eye length. POL 1.75x eye length. Antennifers inwardly curved with elevated pointed tip and a lower outer part with a rounded tip.

Basal segment of antennae incrassate at basal one-half, segment III more than the combined length of segments I and II. Proboscis barely reaches the middle of coxa III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.35	0.38	0.55	0.53	0.95	2.76
♀	0.35	0.43	0.63	0.68	1.03	3.12

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.6	1.10	0.75	0.83	3.28
♀	0.65	1.10	0.88	1.00	3.63

Pronotum 2.1x wider than long across prehumeral process, heavily punctated; transverse sulcus indistinct. Cicatrices smooth including central disc, without tubercles. Post-ocular anterior margin bordered, slightly oblique sinuate with small process pointed posteriorly. Lateral margins concave, rebordered towards the subacute prehumeral spines and the post-ocular anterior margins. Humerals swollen. Inner tibia II with 1-2 spines at midlength.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.75	1.93	1.6	1.80	0.91	0.97	4.26	4.70
II	1.93	2.38	1.75	2.05	0.92	0.96	4.60	5.39
III	2.25	2.80	2.20	2.80	1.43	1.06	5.88	6.66

Forewings: Membrane with 4 long and 1 short longitudinal veins, 4 closed cells and a triangular one beneath the cross vein present. Hindwings: Vein R bifurcate at tip, R+M junction long; vein 2A prominently gray brown.

Scutellum rounded apically, not reaching tip of abdomen, WAB= 2.6 mm, WACP= 2.05 mm, L= 4.30 mm.

Abdominal venter with a broadly concave anterior margin of terminal sternite.

Pygophore subglobose, 1.24x wider than height; clasper long with blunt tip reaching margin of abdominal tergite VI. Blade with flat median surface, rough ventrals and slightly concave posterior end, median arm prominently acute and triangular.

Male genitalia: aedeagus with a moderately rounded posterior phallotheca slightly longer than anterior, not saddle-shaped, dorso-basal area without triangular impoint; membraneous cunjunctiva anteriorly concave medially; penial plates widely separated apically, tips bluntly rounded in lateral view; ejaculatory duct short.

Female genital plate with apices of paratergite IX not extended beyond paratergite VIII. 2nd gonocoxae simple. Spermathecae with slim median dilation; distal spermathecal duct has 10 loops; bulb rounded without processes.

Materials examined: **Philippines**, holotype male and 15 paratypes (8 males and 7 females), Mindanao Island, South Cotabato, Tantangan, New Iloilo, A.T. Barrion, 27 Apr 2006.

Scotinophara midsayapensis new species
(Plate 4-2, 9-1, 24a-l; Figs. 66-78)

Length: Male 7.9-8.20 mm. Width across prehumeral process 4.10-4.30 mm.
Female 8.5-9.0 mm. Width across prehumeral process 4.40 - 4.60 mm.

Color: Blackish brown to brownish yellow, except brownish antennal segments, yellowish brown tibiae and yellow tarsi; dark brown dorsal and ventral posterior ends of all tibiae; black apical three-fourths of claw; dark reddish brown compound eyes and red ocelli; base of scutellum bears 3 yellow spots. Hyaline membrane of forewings; and black abdominal venter with yellow pleuron marking.

Head: 1.3-1.4x wider than long, coarsely punctated, except ocellar area. Tylus longer than to as long as jugum with lateral side of jugum constricted at midlength and subapical end slightly rounded

to obliquely cut. Eyes barely passes midlength of anterior lateral margin of pronotum. OOL 0.6x length of eye. POL 1.84x length of eye. Anteniferrous tubercles cleft, thin inner part apically pointed, outer part bluntly rounded. Segment I of antenna basally stouter than anterior part, III shorter than IV and V the longest. Proboscis reaches anterior level of coxa III, length (mm) of segment I (1.15), II (1.10), III=IV (0.88).

Length of antennal segments (mm)

Sex	1	2	3	4	5	Total
♂	0.40	0.44	0.59	0.66	0.99	3.08
♀	0.40	0.46	0.62	0.63	1.02	3.13

Pronotum 2x longer than wide, posterior area more deeply and coarsely punctated than anterior area, punctations interconnected and separated by yellow ridges. Anterior margin not deeply concave, anterior lateral margin oblique and slightly sinuate, strongly rebordered and spine projected posteriorly. Lateral margin concave, rebordered narrowly posterior of anterior spine and heavily towards prehumeral spine. Cicatrices without elevated tubercles, posterior margin each with a t-bone-like marking. Transverse furrow absent. Metathoracic scent gland ovoid with 5 transverse furrows posterior of the opening.

Leg measurements (mm) in decreasing order III>II>I, mid-inner lateral side of tibia with 0 - 1 spine. Claws sharp and deeply curved, TCh= 0.19, TCl= TCc= 0.10.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.85	1.95	1.80	1.85	0.85	0.85	4.50	4.65
II	2.10	2.25	2.00	2.10	0.90	0.90	5.00	5.25
III	2.50	2.60	2.50	2.60	1.00	1.00	6.00	6.20

Wings with forewing nearly 3x longer than wide, corium and clavus punctations regularly spaced, membrane with 4 closed marginal cells (MC) with 2nd MC twice the size of the first and outermost cell the smallest. Five to six longitudinal veins present, first and second longitudinal veins both bifurcated, hindwing with basal two-thirds and arm of CuA below the R+M-CuA triangle lightly pigmented, knob-like process of R+M wide, junction of veins R and M longer than wide, vein 2A with a light brown band in the sinuate part of the vein.

Scutellum densely punctated in the elevated area, tip rounded not reaching posterior end of abdomen. Ratio of WAB:WACP:L - 2.8:2.35:4.6 in male and 3.25:2.75:5.3 in female.

Abdominal sternite 7 convex midanteriorly. Tergite X broadly concave medially. Pygophore 1.23x wider than long (height) moderately transverse. Clasper with a horizontally flat median posterior surface lined with 9-10 setae, moderately acute tip, blunt and rounded inner arm with 4-5 setae and long stem.

Male genitalia: posterior phallotheca subglobose, laterally saddle-shaped dorsally, base slightly swollen and midposterodorsal area with triangular marking. Membraneous conjunctiva within the long penial plate and pointed midanteriorly viewed dorsally. Penial plate apically rounded seen laterally with-dorsal and ventral margins straight, dorsally and ventrally penial plates widely separated with mid-inner region acutely pointed towards each other. Ejaculatory duct distinct, not beyon penial plate. Basal plate bears a median truncated indention, arm of basal plate subrectangular. Pivot passes midlength of basal phallotheca.

Female genitalia: paratergite VIII subtriangular, IX oblongate. Proctiger almost circular. Second gonocoxae without subcavities and with a truncated distal margin. First gonocoxae with a narrowed base and a broadly rounded distal margin. Spermatheca with a large median dilation, spermathecal duct with almost two loops subproximally, distal duct 10 - 12 coils, broad proximal flange, medially enlarged pump, and subglobose to button-like spermathecal bulb.

Materials examined: **Philippines**, Mindanao Island, North Cotabato, Midsayap, Palongalongin, holotype male and paratypes: 10 males and 16 females, ex. stubbles of harvested rice, 28 Apr 2006, A.T. Barrion; same province and town, Bual Norte, 1 male and 1 female, paratypes, 16 Nov 1997, A.B. Estoy (PhilRice CES-CPD Coll.).

Scotinophara putikanica new species
(Plate 4-3, 9-2, 25a-m; Figs.79-90)

Length: Male 7.00-7.80 mm. Width across prehumeral spine 4.00-4.20 mm.
Female 8.50-8.90 mm. Width across prehumeral spine 4.50-4.70 mm.

Color: Blackish brown to dark brown with yellow mottles, except black head, antennifers, femora I-III, venter of body, dorsal and ventral posterior ends of tibiae I-III and apical half of claws. Cicatrices surrounded by yellow spots. Eyes, proboscis and antennae reddish brown, except yellowish brown basal one-half of segment III, midlength of IV and base of segment V. Tarsi yellow with hyaline pseudoarolia and yellow brown apical segment of terminal claws.

 Head 1.3x wider than long, coarsely punctated and with short pilosity, transverse ridges lined with the central lobe (tylus) and lateral lobe (jugum) with oblique and inwardly converging striae. Tylus as long as jugum. Posterolateral margin of head with a longitudinal ridge at the back of eyes. OOL 0.6x eye length. POL 1.5x eye length. Antennifers with a thin and incurved inner part, outer part blunt and lower than the inner part. Antenna with a globose basal one-half of segment I, II-IV slender, segment III as long as IV in male and shorter in female. Proboscis length reaches abdominal segment in males but only in coxa III in females.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.38	0.36	0.60	0.60	0.98	2.92
♀	0.38	0.50	0.68	0.73	1.00	3.29

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.60	1.12	0.95	0.93	3.60
♀	0.70	1.20	1.00	0.95	3.85

Pronotum heavily punctated posteromedially, 2.1x wider than long across the prehumeral spines. Anterior margin medially convex in male and moderately concave in female. Anterior lateral margin broad and oblique, directed posteriorly and rebordered. Lateral margins slightly concave, only rebordered towards prehumeral spine. Anterior and posterior spines subequal in size. Cicatrices without elevated tubercles, surrounded by spots and separated medially by a relatively broad longitudinal band. Transverse furrow absent. Metathoracic scent gland with 8 longitudinal ridges running down from the opening.

Legs with a single spine in the midinner lateral side of tibia III. Tarsal claws sharp with a long pseudoarolia almost touching tip of claws. TCl = 0.18, TCh= 0.18, and TCd= 0.10, ratio of TCl:TCh= 1.8.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.50	1.85	1.60	1.80	0.80	0.85	3.90	4.50
II	1.80	2.25	1.80	2.10	0.90	0.90	4.50	5.25
III	2.25	2.70	2.30	2.55	0.90	0.90	5.45	6.15

Forewings with 3 closed marginal cells and 5 longitudinal veins in the membrane, 2nd marginal cell the largest though partially divided in some specimens. First longitudinal vein forked forming the 3rd closed marginal cell. Hindwing with a longitudinal grooved knob-like process in vein R+M, rectangular junction of vein R and M, CuA unsclerotized in basal region and heavily sclerotized just below the R+M-CuA triangle.

Scutellum with thicker punctations in basal half, tip rounded not reaching tip of abdomen, ratio of WAB:WACP:L = 2.9:2.45:4.73 in males and 3.03:2.50:4.85 in females.

Abdominal sternites VI and VII with medially convex anterior margins. Tergite X narrowly concave. Pygophore 1.26x wider than high, inner dorsolateral lobe densely pilose, clasper long and visible cross-sectionally. Blade of clasper almost at 45°, tip, blunt and median posterior surface bears 7-9 setae. Inner arm subquadrate with 6 setae on median surface. Stem long with a broad plate.

Male genitalia: posterior phallotheca globose with a subtriangular lobe posteromedially and basal plate with a long pivot. Membraneous conjunctiva not expanded apically forming a large opening

for the short ejaculatory duct. Slightly sclerotized lateral membraneous conjunctiva expanded laterally forming a subtriangular process. Penial plate wide apart apically, tip rounded and subtruncate laterally.

Female genital plate: 8th paratergite rectangular, 9th oblongate with a pointed base. Proctiger ovate, widely separating 9th parategite. Arcus with a pair of eye-like transparent bands. Second gonocoxae heavily punctated without distinct lobes inside, anterior margin widely concave. Spermatheca elongate, 2.4x longer than wide, sclerotized median duct bears a double bent proximally and 8 loops distally. Proximal flanges rounded similar to distal flange. Spermathecal bulb without process, strongly rounded.

Materials examined: **Philippines:** Mindanao Is., South Cotabato, Suraltah, Dahay Vill., holotype male and paratypes- 10 males and 10 females, ex. rice stubbles left after harvest, 27 Apr 2006, A.T. Barrion.

Etymology: Named after the muddy soil where the bugs are living (muddy soil = *putikan* in Tagalog)

Scotinophara coarctata (Fabricius)
(Plate 4-4, 9-3, 26a-m; Figs. 91-102; Palawan form)

Cimex coarctatus Fabricius 1798. Ent. Syst. Suppl. 530 (Tranuebar, India)
Podops spinosus Walker 1867. Cat. Het. Brit. Mus. 1:73 (Penang, Malaysia)
Podops nasalis Walker 1867. Cat. Het. Brit. Mus. 1:73 (Thailand)
Podops exactus Walker 1867. Cat. Het.Brit. Mus. 1: 74 (Unknown locality)
Scotinophara coarctata Stal 1868. Kongl. Svenska Vet. Akad. Handl. (4) 7(11):21
Scotinophara coarctata Atkinson 1887. Jour. Asiat. Soc. Beng. 56:195
Podops coarctata Distant 1902. Faun. Brit. Ind.Rh. 1:73

Length: Male 6.8 - 7.7 mm. Width across prehumeral spine 3.7 - 3.85.
Female 8.5 - 9.1 mm. Width across prehumeral spine 4.4 - 4.5 mm.

Color: Dark yellow brown with black head and anteniferrous tubercle, collar, anterior and lateral margins of pronotum including cicatrices, venter of head, thorax and abdomen, dorsal and ventral bases of tibiae I-III and apical one-half of claws; brownish antennal segments I and V and brownish yellow segments II-IV; reddish brown femora I-III and proboscis; labrum yellow to yellowish brown, yellow tibiae, tarsi and basal one-half of claws, and cicatrices central disc and posterior margins; silvery compound eyes; yellow mottles on the posterior pronotum, scutellum, abdominal edges dorsad of spiracles, and forewings corium and clavus; and white pseudoarolia.

Head: 1.42 wider than long, coarsely punctated and parallel-sided along basolaterals of the jugum. Tylus shorter to as long as jugum. Compound eye separation, as long as the combined length of antennal segments I-II-III, bears 12-13 rows of vertically arranged ommatida. OOL two-thirds eye length. POL 1.8x eye length. Antennifers cleft apically, elevated inner part curved and pointed, outer part slightly blunt to rounded. Length of antennal segments: V > IV > III > II > I, segments I basically globose. Proboscis reaches coxa III, length of segments in decreasing order: II > III > IV > I. Concave and collar distinctly grooved.

Length of antennal segments (mm)

Sex	1	2	3	4	5	Total
♂	0.38	0.28	0.53	0.60	1.00	2.79
♀	0.38	0.41	0.58	0.65	0.98	3.00

Pronotum 1.95x wider than long across prehumeral spines. Anterior margin, lateral margins between anterolateral and prehumeral spines slightly concave and rebordered, except margins opposite cicatrices. Inner arm separated by 1.2x eye length. Cavity posterior of prehumeral spine narrowly concave. Cicatrices slightly punctated to smooth, not elevated and without tubercles. Midposterior pronotum without clear transverse rows of punctures. Disc without transverse impression before the middle. Anterior angle oblique at around 12°, spine directed posterad. Anterior lateral and prehumeral spines both short and subacute.

Leg measurements (mm) and length in decreasing order: III > II > I. Tarsal claw sharply curved and pointed, TCl = 0.19, TCh = 0.13 and TCd = 0.13, TCl:TCh ratio = 1.5. Pseudoarolium obligate with a stalk-like base.

Leg measurements (mm).

Leg	Femur		Tibia		Tarsus		Total	
	♂	♀	♂	♀	♂	♀	♂	♀
I	1.65	1.80	1.30	1.50	0.80	0.84	3.75	4.14
II	1.90	2.18	1.50	2.02	0.88	0.90	4.28	5.10
III	2.22	2.50	2.0	2.50	0.98	1.00	5.20	6.00

Membrane of **forewing** with 3 closed marginal cells, 2nd cell often the largest and 4 longitudinal veins. Longitudinal veins 1 and 2 bifurcate. Secondary vein 2 of hindwing indulate to straight, base of secondary veins slightly rounded.

Scutellum not reaching abdominal tip with a basal width (BW) of 2.9 mm, width at constriction point (WACP) = 2.25 mm and length (L) = 4.2 mm in male and 3.2:2.7:5.2 in female. Tip rounded. Abdominal venter smooth medially and slightly rough laterally. Anterior margin of terminal sternite widely dome-shape. Tergite X broadly concave medially. Pygophore transverse, ratio of width (PW) and height (PH) = 1.78, ventral one-half lined with concave ridges.

Male genitalia: Basal lobe of phallotheca subglobose and weakly saddle-shaped, one-third longer than apical lobe. Membraneous conjunctiva slightly cleft apically. Penial plates wide apart, separated by two gonophore diameter, laterally apices truncated. Gonophore short. Lateral arm of basal plate at midlength of basal phallotheca. Clasper's blade at 45° angle, apically rounded, mid-dorsal with 8 - 11 bristles and ventrally line with scale-like teeth. Midclasper with a triangular inwardly projected arm, inner base with 5-8 bristles.

Female genitalia: 9th paratergite rounded apically, inner margins parallel-sided. 2nd gonocoxite anteriorly concave, bulged laterally and inner lobes indistinct. Spermatheca with slender and elongate median dilation, duct semi-coiled proximally, sclerotized median duct swollen proximally, distal spermathecal duct with 7 coils, pump narrow proximally, spermathecal bulb rounded without processes.

Materials examined: **Philippines**: Palawan Province, Bataraza, Bonobono, 16 males and 10 females (IRRI Coll.), ex. rice at booting stage, 12-18 Feb 1982, A.T. Barrion; 88 males and 172 females, same province, Brooke's Pt., Maasin, ex. Light trap, 7 Mar 1985, M. Parducho; same province, Aborlan, Philippine Western University Field Station, 8 males and 3 females, 23 May 2007, A.T. Barrion and RC Joshi; Roxas Minara, 3 males and 1 female, Jolo, 5 males and 2 females, 25 May 2007, A.T. Barrion and R.C. Joshi. **Malaysia**: Kedah, Alor Star, Stesen Penyelidikan, MARDI, 80 males and 86 females, including 2 nymphs 6 Jun 2006, and 20 males and 22 females, 26 Oct 2006, Nik Mohammad Noor Nik Salleh; 9 males and 11 females, **East Malaysia (Sabah):** Kota Kinabalu, Menggatal, Sepanggar, ex. Paddy field (Bundur Tahuri, Tamparuli) at 6"2' 60 N and 116"29' 60 E, 9 males and 11 females, 3 Mar 2007, H. Souki; **Thailand**: Songkhla, Hat Yai, 102 males and 131 females, 20 Oct 2006, J. Pecharat; Pathumthani, Nongsua, 2 males and 3 females, Feb 2007. W. Sriratanasak and A. Winotai; 4 males and 6 females, same locality, 2 Mar 2007, S.L. Ranamukhaarachchi; 48 males and 64 females, Bangkok, Jatujak, Jan 2007, A. Upanisakorn. Indonesia: Central Java, Kulanprogo, Wates, 6 males and 1 female, 29 Jun 1978, Denan and Agus; same province, Bayumas, Ajibarang, 7 males and 3 females, 1 Jul 1978, Denan and Agus; Sukamandi, 6 males and 1 female, 14 Apr 1980, A Somad. **Cambodia**: Prey Veng, Sen Pedou, 3 males and 9 females, 22 Aug 2006, Koun Hin and P. Visarto; Siem Reap, Angkor, 1 male and 1 female, J. Szent-Ivany, 6 Dec 1957 (BPBM). **Vietnam**: T-bihn, vie thuc, 6 males and 12 females, 16 Jun 2006, N.H. Huan; Vung Tau, Baria, Long Huong, 4 females, 16 Apr 1996, N.C. Duc and T.R. Hien. **Laos**: Vientiane, 1 female, 31 May- 3 Jun 1960, S. and L. Quate (BPBM Coll.); 2 males and 8 females, 28-30 May 1965, P.D. Ashlock (BPBM Coll.); 1 male and 1 female, 9 May 1965, J.A. Rondon (BPBM Coll.); Khamoune Prov., Phon Tiou, 2 males and 6 females, 9-10 Jun 1965, N. Wilson (BPBM Coll.).

Distribution: Cambodia, Indonesia, Laos, Malaysia, Philippines, Vietnam, Thailand, India, Pakistan, and Myanmar.

Remarks: Widely distributed in South and Southeast Asia, considered as the most phytophagous of all the podopines occurring on rice.

Scotinophara alegria new species
(Plate 5-1, 27a-m; Figs. 103-113)

Length: Male 8.1-8.5 mm. Width across prehumeral proceses 3.9-4.6 mm
Female 9.0-9.7 mm. Width across prehumeral process 3.85-4.80 mm.

Color: Blackish brown, except black head, antennifers, anterior pronotum including lateral margins and process, femora I-III and apical one-half of all claws and body venter; compund eyes silvery red; antennae light brownish red in segment I and yellowish brown in segments II and V and tip of tibia III; tibiae I-III, proboscis and basal one-half of claw yellow, except dorsal and ventral posterior ends of legs I-III reddish brown; scutellum brownish yellow; lateral sides of body with interrupted longitudinal yellow line running from anterior to posterior end of abdomen dorsal and ventral spiracles.

   Head 1.3x wider than long across eyes. Tylus slightly longer than jugum, visibly elevated at midlength. Jugum constricted at midlength and slightly broadened subapically. Eyes slightly wider than long OOL 0.8x eye length. POL 2.3x eye length. Antennifers widely cleft apically, inner part thinly acute and inclined inwards, outer part apically blunt, extending to one-third the length of preocular part of head. Antennae with incrassate basal one-half of segment I, segments II - IV wider towards the apex and V towards the middle; length in decreasing order V > IV = III > II > I. Segment II slightly longer than segment III. Proboscis barely reaches midlength of coxa III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.32	0.38	0.62	0.62	1.04	2.98
♀	0.40	0.40	0.65	0.75	1.15	3.35

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.88	1.08	0.96	1.06	3.98
♀	0.60	1.20	0.95	0.90	3.65

   Pronotum shallowly punctated, 2.2x wider than long across prehumeral spines. Cicatrices without tubercles, posterior margins lined with two yellow spots each. Transverse furrow absent. Post-ocular anterior margin of pronotum strongly rebordered and oblique , slightly sinuate, 2x longer than eye width, anterior spine small and projected posteriorly, lateral margins straight to slightly concave and rebordered along posterior one-half. Prehumeral spine small, bluntly rounded and height one-half of its basal width. Metathoracic scent gland globose to ovoid, than its length and opening slightly with 7 transverse ridges basad of the opening.
   Leg length III > II > I, femur III slightly longer than tibia III. Tibia II without spines in the mid-inner lateral side.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.86	2.10	1.75	1.90	0.85	0.90	4.46	4.90
II	2.20	2.4	2.10	2.20	0.94	0.95	5.24	5.55
III	2.70	2.75	2.65	3.0	0.98	1.10	6.33	6.85

Forewings with 4 equally spaced longitudinal veins anteriormost vein divided at tip; 4 closed cells present, middle cell divided in inner one-fifth. Hindwings with a sinuate CuA and tip of vein 1A, tip of R+M curved at junction broad.

Scutellum heavily punctated basally and medially, basal one-fifth with a pale yellow median longitudinal band and a median depression before the narrowest point, anterior end rounded not reaching tip of abdomen, ratio of WAB:WACP:L = 3.4:2.8:5.2.

Abdominal sternite VII (S7) with a medially convex anterior margin.

Tergite X widely cleft at the middle. Pygophore subglobose in cross-section with a long clasper. Inner margin of dorsolateral lobe with dense mat of hairs.

 Clasper almost 45° angle with a long blade and slender base, subacute apically, dorsal plate with 8 spines and slightly enlarged median area; inner tooth large, blunt apically and bears at least 3 spines.

Male genitalia: Aedeagus with oblongate posterior phallotheca and broad dorsomedian conjunctival appendage. Penial plate wide apart viewed dorsally, tip bluntly rounded. In lateral view and sharply pointed posteriorly. Basal plate rectangular dorsally with subtriangular arm viewed laterally. Pivot not extended beyond apex of posterior phallotheca. Gonophore short. Vesicle relatively broad.

Female genital plate with 9th paratergite basally narrow and broad at midlength, 2nd gonocoxae anteriorly concave medially, proctiger about 2x longer than wide and 8th paratergite sparsely punctated. Spermatheca with a large median dilation, 1.7x longer than wide; sclerotized median duct curved basally; distal spermathecal duct with 8 coils; proximal flange broad; spermathecal pump broader along apical half; spermathecal bulb rounded without processes.

Materials Examined: **Philippines:** Mindanao Is., Surigao del Norte, Alegria, Alipai, holotype male; paratypes 3 males and 6 females and 2 4th-instar nymphs, ex. ratooned rice, 25 Apr 2006, A.T. Barrion.

Scotinophara kabangkalanensis **new species**
(Plate 5-2, 9-4, 28a-l; Figs. 114-119)

Length: Male 8.8 mm. Width across prehumeral process 4.75 mm.
Female 8.5 mm. Width across prehumeral process 4.00 mm.

Color: yellowish brown to brownish black with black head, antenniferous tubercles, body venter and apical one-half of claws. Eyes, proboscis, antennal segment I and base of segment II and femora I-II, dorsal and ventral posterior ends of tibiae I-III reddish brown. Midposterior pronotum, tibiae, tarsi, and basal one-half of claws yellow. Pseudoarolia whitish yellow.

Head 1.65x wider than long, coarsely punctated with about 20 transverse ridges in the tylus, jugum shortly pilose and as long as tylus. Antennifers medially cleft, elevated and inclined inner side thinly pointed and lower outside apically blunt. OOL 0.5x eye length. POL 1.84x eye length. Antennal segment I incrassate basally, segment III 1.3x and 1.8x longer than segments II and I, respectively. Proboscis length II>IV>III>I, basal segment about half length of segment II, tip reaches coxa III.

Pronotum 2x wider than long across the prehumeral process, midanterior with a transverse cavity as long as distance of two ocelli, punctures on the central disc connected medially to a narrow vertical yellow line separating the cicatrices. Posterior disc of pronotum with about 5 wavy transverse rows of punctures on a yellow plate. Anterior angle of pronotum oblique 2x eye length and its small anterolateral directed posteriorly; lateral margin concave; anterolateral margin rebordered; posterolateral margin to prehumeral spine slightly rebordered. Prehumeral spine small, its height one-half the basal width. Transverse furrow absent.

Legs without mid-inner lateral spines in tibia II.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	2.00	2.10	1.75	1.80	0.80	0.90	4.55	4.80
II	2.30	2.50	2.00	2.15	0.90	0.95	5.20	5.60
III	2.70	3.00	2.60	2.80	0.98	1.00	6.28	6.80

Wings: Forewings with 9 (5 marginal and 4 median) closed cells in the membrane. Median cells elongate. Hindwings with a quadrate connection point of veins R+M. R+M - CuA triangle large.

Scutellum with a rounded tip, basally with 3 yellow spots-2 laterals and 1 median, WAB:WACP: L = 0.81: 0.69: 1.28, basally darker than apical parts. Scutellar pit slightly deep, projected laterad.

Abdominal sternite with a dome-shaped mid-anterior margin of terminal segment. TergiteX concave medially. Clasper distinctly long and slender with a long median posterior surface and 6 dorsal hairs; blade glabrous, median plate short with fewer bristles; stem broad.

Male genitalia: Aedeagus with a medially concave posterior phallotheca, 1.6x longer than the anterior phallotheca, posteromedian area unmarked; dorsally penial plates widely separated apically, laterally apical end bluntly rounded to pear-shaped; lateral arm or pivot basal plate short. Ejaculatory duct short.

Female genital plate with medially wide bean-shaped 9th paratergite, apex hardly beyond margin of 8th paratergite. Spermathecae with medially enlarged median dilation, ducts bear 9-10 loops, pump with a large apical part, proximal flange wide and thin, bulb semiglobular.

Materials examined: **Philippines**: Negros Occidental, Kabangkalan, holotype female and 2 paratypes: 1 male and 1 female (dissected) (PhilRice CES-CPD Coll.), ex. Rice, LB Flor et al., 27 Nov 1998 (PhilRice CES-CPD Coll.)

Scotinophara zamboanga new species
(Plate 5-3, 9-5, 29a-m; Figs.120-127)

Length: Male 7.5 mm. Width across prehumeral spine 4.25 mm.
       Female 8.8 mm. Width across prehumeral spine 4.80 mm.

Color: Blackish brown with black head, body venter, antennifers, basal antennal segment, collar, lateral margins including spines of pronotum and femora I - III including dorsal and ventral bases of tibiae I - III. Compound eyes silvery white. Simple eyes red. Antennal segment II brown with yellowish brown apical one-third, segment III brown apical one-half and yellow brown basal-half; segment IV yellowish brown with posterior and anterior ends, and segment V dark brown with yellow brown base. Proboscis reddish brown. Tibiae and tarsi including basal half of claws yellow.

Head: 1.3x wider (1.76 mm) than long (1.36 mm). Tylus slightly shorter to as long as jugum. Tylus lined with 10-12 transverse ridges in decreasing height posteriorly. Jugum wide subapically, constricted opposite base of antennae and blunt apically. Compound eye separation almost as long as combined length of antennal segments II and III. OOL 0.48x eye length. POL 1.5x eye length. Antenniferous tubercle cleft, inner side with pointed apex slightly higher than the blunt outer arm. Length of antennal segments V:IV:III:II:I, segment V as long as combined length of segments II and III, segment I incrassate susbasally. Proboscis reaches anterior to middle coxa III, second segment 1.4x longer than segment III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.34	0.45	0.53	0.63	0.98	2.93
♀	0.45	0.45	0.60	0.65	0.98	3.13

Pronotum 2.2x wider than long, coarsely punctated, with margined collar and lateral sides, except area opposite cicatrices. Post-ocular anterior margin oblique, process directed posterad. Lateral margin concave. Prehumeral spine subacute directed laterad, more developed than anterior process. Transverse sulcus and cavity posterior of prehumeral spine indistinct.

Leg length III>II>I, femur I slightly shorter than tibia I, femur III as long as tibia III. TCl= 0.17, TCh= 0.14, TCd 0.07, ratio of TCl:TCh = 1.2.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		TOTAL	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.90	1.90	1.65	1.70	0.90	0.80	4.45	4.40
II	2.20	2.30	2.00	2.10	0.85	0.85	5.05	5.25
III	2.50	2.60	2.40	2.60	0.95	0.90	5.85	6.10

Forewings with 4 closed marginal cells and 4 longitudinal veins, vein I merged to form closed cells 3 and 4. Hindwing with longer than wide junction of veins R+M.

Scutellum almost reaches tip of abdomen in males, not reaching tip in females; tip of scutellum rounded. Ratio of BW:WACP:L is 2.9: 2.3: 4.5 in male.

Abdominal venter smooth medially, very fine and sparsely punctated laterally. Mid-anterior margin of terminal abdominal sternite convex. Tergite X deeply concave medially. Pygophore moderately transverse, 1.5x wider than high, anterior lobe slightly higher than posterior lobe. Clasper similar to the *S. midsayapensis* in shape but *S. zamboanga* has fewer setae in the median posterior surface and has a triangular inner arm.

Male genitalia: Posterior phallotheca less globose, widest subapically and visibly saddle-shaped laterally. Membraneous conjunctiva not well-expanded laterally. Penial plate truncate apically. Ejaculatory duct short. Basal plate subtriangular laterally with a long T-bone-like pivot passing the anterior margin of phallotheca.

Female genitalia: Proctiger quadrate; distal margin of 2nd gonocoxae slightly convex and proximal margin strongly lip-like. Arcus with a pair of elliptical light band on each side of the opening. 9th paratergite with a subrounded inner margin. Permathecae oblongate, about 4x longer than wide. Distal spermathecal duct 10 loops, wide proximal flange and with a thin and concave distal flange. Pump with a slender basal half and subglobose distal half. Spermathecal bulb spherical.

Materials examined: **Philippines**: Mindanao Is., Zamboanga del Sur, Butong, holotype male and 88 males and 136 female paratypes, ex. grasses in the drying Agusan marshland, C.G. Demayo et.al., Nov-Dec 2006.

Etymology: Named after the type-locality.

Scotinophara trifurcata new species
(Plate 5-4, 9-6, 30a-l; Figs.128-140)

Length: Male 7.5-7.8 mm. Width across prehumeral spine 4.25-4.30 mm.
 Female 8.4-8.8 mm. Width across prehumeral process 4.40-4.70 mm.

Color: Blackish brown mottled yellow, except black head, antennifers, venter of body, femora I-III and apical half of tarsal claws. Central disk of cicatrice yellow. Compound eyes and ocelli reddish

brown with silvery luster. Antennae yellowish brown with dark reddish brown segments I and V. Proboscis reddish brown. Base of scutellum with 3 yellow spots. Tibiae and tarsi yellow, except dorsal and ventral posterior ends of tibiae I-III dark brown. Corium with a yellow margin and band on R+M forming a loop distally.

Head 1.3x wider than long, shortly pilose and punctate. Tylus shorter than to as long as jugum with transverse ridges anterior and posterior of the raised median area, elevated area either with transverse ridges or punctures. Jugum with oblique row of punctures, anterior lateral margin of jugum rebordered. Compound eyes pass midlength of anterior lateral margin of pronotum. OOL 0.5x length of eye. POL 1.5x eye length. Antennifers with thinly elevated inner process acute apically and at 90° angle from antennal base viewed ventrally, outer process bluntly rounded. Antennal segment I incrassate in basal one-half, segment III as long as IV or slightly shorter, tip of segment V acute. Proboscis reaches posterior margin of coxa III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.38	0.40	0.56	0.58	0.96	2.88
♀	0.38	0.36	0.63	0.63	1.00	3.00

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.60	1.06	0.72	0.80	3.18
♀	0.60	1.10	0.90	0.95	3.55

Pronotum 2x wider than long across the prehumeral spines, interconnected punctures bordered by elevated yellow ridges, ratio of width across anterior lateral spine (WALS): width at prehumeral spine (WPS): width at humerals (WAH) = 2.65: 3.65: 4.60 mm. Anterior lateral margin of pronotum mildly sinuate, oblique projected posteriorly, rebordered and bear a small blunt spine. Lateral margin not rebordered, except area near base of prehumeral spine. Bluntly rounded prehumeral spine more distinct than anterior spine. Cicatrices slightly elevated, smooth around the central disc with 14 punctures. Transverse furrow absent. Scent gland droplet-like with 5 transverse ridges basad of the opening and 6-7 interrupted longitudinal ridges distally.

Legs with 3-4 curved spines in the midventer of tibia I, no spines in the inner midlateral sides of tibia II.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.95	1.90	1.75	1.85	0.90	0.85	4.60	4.60
II	2.05	2.30	2.00	1.90	0.90	0.90	4.95	5.10
III	2.70	2.70	2.60	2.55	1.00	0.85	6.30	6.10

Forewing with heavily punctated basal area of corium and clavus. Membrane bears 5 longitudinal veins and 2-3 closed marginal cells, 2nd cell triangular and 3rd marginal cell pentagond; 2nd longitudinal veins emanate from the first forming a transversely elongated 5x wider than long (height). Hindwing with a light colored R+M but dark brown from the knob-like process, its junction, splitting veins R, M and CuA. R+M-CuA triangle with a short arm between the knob and junction, length less than the curved CuA connected to the junction.

Scutellum with light transverse interconnected impressions in the elevated basal median half, rest heavily punctated. Ratio of WAB:WACP:L 2.9:2.4:4.7 in male and 3.2:2.65:5 in female.

 Abdominal sternite 7 2x wider than sternite VI, anterior half smooth and posterior half with interrupted transversely striae. Tergite X broadly concave.

Pygophore transverse 1.5x wider than long (height); dorsolateral lobe slightly bulged and thickly pilose inside; ventroposterior margin broadly V-shaped; opening of aedeagal cap rectangular, 1.4x wider than high. Tip of clasper not reaching posterior margin of terminal tergite. Clasper bears 7-9 setae in the concave median posterior surface, apex bluntly rounded, blade bulbous posterior of setae. Inner arm acute and pointed with 4 setae; and stem broad basally.

Male genitalia with a globose posterior phallotheca, slightly saddle-shaped in lateral view, midposterior dorsal area with a subtriangular marking. Membraneous conjunctiva largely T-bone-like or wedge-shaped dorsally and protruding beyond penial plate in lateral view. Penial plate with a narrow anterior opening for the short ejaculatory duct, subtruncate to rounded apically viewed laterally. Basal plate with a short lateral arm and pivot not reaching apex of posterior phallotheca.

Female genital plate with a semi-triangular 8th paratergite, 9th paratergite not protruding beyond abdominal tip and with rough posterior apices. Proctiger slightly oblong. Second gonocoxae with a pair of circular and punctated depression. First gonocoxae truncated apically with an extended unsclerotized arm posteriorly. Arcus with a pair of transversely elongate transparent slits. Spermathecae slender, except widest midlength, sclerotized median duct with a half-coil proximally in the enlarged area, distal part with 10-11 coils, relatively broad and circular proximal flange, process of spermathecal bulb absent, and spermathecal bulb spherical.

Materials examined: Philippines, Mindanao Is., Agusan del Sur, ex. marshy swamp, holotype male, 2 males and 5 female paratypes, 6-10 Sep 2006, G. Estoy.

Etymology: Specific epithet derived from the three branches forming the second and third closed marginal cells in the membrane of the forewing.

Scotinophara landangica new species
(Plate 6-1, 10-1, 31a-m; Figs. 141-154)

Length: Male 7.55 mm. Width across prehumeral process 4.15 mm.
          Female 8.60 mm. Width across prehumeral process 4.50 mm.

Color: brown tinged with yellow, blackish brown punctations in between and below yellow ridges. Head black including collar, cicatrices, antenniferous tubercles, body venter, apical half of claws, and lateral margins of pronotum. Eyes, antennal segments and proboscis reddish brown, much darker in antennal segment I. Femora I-III black. Tibiae and tarsi yellow except dark reddish brown dorsal and ventral posterior ends of tibiae.

Head: 1.3 - 1.4x wider than long, transverse ridges in tylus and inwardly converging furrows in the jugum. Tylus as long as jugum obliquely cut. Antenniferous tubercle with a pointed inwardly curved inner process, lower outer part blunt. OOL 0.6x eye length. POL 1.6x eye length. Antennal segments I enlarged at basal one-half, apico-dorsal with a short spine on a small tubercle, segment IV on right side aberrant and enlarged at tip, segment III always shorter than IV. Proboscis reaches midlength of coxa III. Length of antennal segments (LAS): V>IV>III>II>I in both sexes.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.34	0.40	0.51	0.62	0.94	2.81
♀	0.36	0.37	0.59	0.62	0.96	2.90

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.56	0.90	0.88	0.84	3.18
♀	0.60	1.00	0.91	0.86	3.37

Pronotum 2.3x wider than long across prehumeral spine, punctations bordered by flat network of ridges, central area with a longitudinal line dividing cicatrices with a mask-like band. Anterior margin slightly elevated at midlength with shallow and lightly punctated collar. Anterior lateral margin strongly rebordered, oblique with subacute spine pointed posteriorly. Lateral margin mildly concave and rebordered. Prehumeral spine hardly larger than the anterior spine. Transverse furrow indistinct. Metathoracic scent gland opening visibly extended outside, with 4-5 transverse ridges above it.

Legs without spines in mid-inner lateral side of tibia II, claws sharp with TCl (0.14mm) > TCh (0.12mm) > TCd (0.11mm).

Leg measurements (mm).

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.80	1.75	1.60	1.70	0.80	0.80	4.20	4.25
II	2.00	2.10	1.80	1.95	0.90	0.85	4.70	4.90
III	2.30	2.40	2.45	2.55	0.95	0.90	5.70	5.85

Forewings with thick punctations in the corium and clavus, light towards coastal margin. Membrane venation shows three forms. Form I with 5 closed marginal cells and 5 longitudinal veins. Median closed cell 3.6x longer than wide. First longitudinal vein trifurcately branched and second

bifurcate. Form II bear 2 closed marginal cells and 5 longitudinal veins. Longidutinal veins 2-4 bisected close to midlength forming two small-elongated cells basally. Form III with 5 closed marginal cells, first two elongate and last three small. Five longitudinal veins present, vein 2 bifurcate subdistally. Hindwing with the knob-like process of vein R+M slightly branching in opposite direction, posterior end faintly branches toward vein CuA, junction of R+M quadrate and small. Secondary vein 2 and vein 1A closer to each other than secondary vein 1 and CuA.

Scutellum more rugose in the basal one-half, ratio of WAB:WACP:L is 2.8:2.2:4.4 in male and 3.00:2.6:5.1 in female.

Abdomen: Mid-anterior margin of abdominal sternite VII convex in both sexes; sternite VII 2.35x and 2.26x wider than sternites VI and V, respectively in male, and 1.58x and 1.73x, respectively in females. Tergite X widely concave medially.

Pygophore slightly wider than long cross-sectionally, clasper diverging and distinctly visible. Clasper with a slender median posterior blade lined with at least 8 setae dorsally and swollen behind the setae. Inner arm stout and slightly blunt with 5 setae on its surface. Stem relatively long.

Male genitalia: posterior phallotheca oblongate with slight laterobasal extension, 2x longer than the anterior part; basal plate strongly convex at midlength with a triangular arm as seen laterally; pivot short but at midlength of phallotheca; penial plate apart apically, ejaculatory duct visible; laterally tip of penial plate rounded. Membranous conjunctiva thinly spread.

Female genitalia: 9th paratergite with a well-rounded tip; 8th paratergite semitriangular, proctiger with a truncated proximal margin and 2nd gonocoxae medially hollow distally and proximally. Spermatheca extra large with subproximal sclerotized median duct with 3 coils, distally with 12-13 coils, slender spermathecal pump and circular spermathecal bulb.

Materials examined: **Philippines**: Mindanao Is.: Maguindanao, Datu Montawal, Landang, holotype male and paratypes-7males and 6 females, ex. from upland rice, 28 Apr 2006, A.T. Barrion.

Remarks: It is the only species of RBB associated with upland the rice ecosystem in the Philippines.

Scotinophara maguindanaoana new species
(Plate 6-2, 32a-l; Figs.155-158)

Length: Male: 8.10-8.33 mm. Width across prehumeral spine 4.05-4.30 mm.
Female: 8.20-9.10 mm. Width across prehumeral spine 4.00-4.70 mm.

Color: Dark brown to blackish brown with yellow mottles; black head, antennifers, femora I-III, body venter and apical one-half of claw. Antennae with dark reddish brown segment I, light reddish brown segments II-V, except yellowish basal one-half of segment III. Eyes reddish brown with silvery

luster. Proboscis reddish brown top blackish brown in segments III-IV. Scutellum bears yellow spots basally. Tibia and tarsi yellow, except black patches on dorsal and ventral areas of tibiae.

Head 1.3x wider than long. Tylus slightly longer than jugum, tylus with transverse ridges anteriorly and posteriorly and punctures medially. OOL 0.45x eye length. POL 1.6x eye length. Antennifers cleft, with incurved, thin inner part higher than the bluntly rounded outer part. Antennal segment I basally globose with a subapical ring of short hairs, II uniform in diameter, III and IV wider towards apices and V widest medially. In males, antennal segment III=IV and III < IV in females. Proboscis reaching midcoxa III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.36	0.38	0.58	0.58	0.94	2.84
♀	0.40	0.44	0.60	0.68	1.04	3.16

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.67	1.10	0.88	0.90	3.55
♀	0.72	1.18	0.92	0.90	3.72

Pronotum 1.8x-196x wider than long across prehumeral spines. Shallow cavity of the anterior margin slightly concave to straight. Anterolateral margin oblique to slightly sinuate, widely rebordered only with spine projected posteriorly. Lateral margin concave rebordered only towards the subacute prehumeral spine. Anterior spine smaller than the prehumeral spine. Punctations as in *S. mlanga*. cicatrice without elevated tubercles, borders with slightly raised humps. Transverse furrow absent. Metathoracic scent gland with a wide opening and 5-6 transverse ridges basad of the opening.

Legs with midtibial spur of 6-7 spines in leg I, tibia II without inner lateral spines.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.70	1.90	1.70	2.35	0.85	0.90	4.25	5.15
II	2.00	2.10	1.70	2.20	0.85	1.00	4.55	5.30
III	2.40	2.60	2.40	2.90	0.85	1.10	5.65	6.60

Forewings with 3-5 closed marginal cells and 4-5 longitudinal veins. Longitudinal vein I usually branched forming 2 closed marginal cells. Hindwings with a large knob-like process, quadrate junction of veins R and M, all veins well sclerotized, except inner CuA.

Scutellum with three basal spots, median spot most distinct. Ratio of WAB:WACP:L = 3.0:2.3:4.7 in male and 3.3:2.6:5.6 in female.

Abdominal sternite VII with convex mid-interior margins, 1.6x-2x wider than VI, V, and VI subequal in width. Tergite X deeply concave medially. Pygophore 1.4x wider than long, posterior part rough with two pits submedially, inner dorsolateral lobe pilose, clasper long and visible in cross-sectional view with tip touching posterior margin of terminal abdominal tergite. Clasper pointed apically, flat median posterior surface bears 9-11 setae and widely cut inside adjacent to the triangular inner arm with 5-6 setae.

Male genitalia: Anterior part of posterior phallotheca strongly globose and subtruncate basally, apices of penial plates rounded and membraneous conjunctiva V-shaped apically. Ejaculatory duct and pivot short. Lateral arm of basal plate barely reaches midlength of phallotheca.

Female genitalia: protiger slightly longer than wide, 8th paratergite subtriangular and lightly punctated, 9th paratergite basally pointed and apically rounded. 2nd gonocoxae indented medially on both distal and proximal margins with deep punctations. 1st gonocoxae distinctly lined with setae in the inner margins. Spermathecae large and oblongate, broadest at midlength, sclerotized median duct almost double-coiled proximally, distal spermathecal duct 10-11 coils and spermathecal bulb spherical without processes.

Materials examined: **Philippines**: Mindanao Is., Maguindanao Province, Datu Montawal, Buli Dist., holotype male and 5 male and 6 female paratypes, ex. rice stubbles, 28 Apr 2006, A.T. Barrion; 3 males and 3 females, Poblacion, Pagalongan Vill., ex. old decaying rice stubbles, 28 Apr 2006, A.T. Barrion.

Etymology: Named after the type-locality.

Scotinophara mlanga new species
(Plate 6-3, 33a-l; Figs.159-162)

Length: Male 7.7-7.9 mm. Width across prehumeral spines 4.1-4.25 mm.
              Female 8.2-8.9 mm. Width across prehumeral spines 4.40-4.65 mm.

Color: Blackish brown to dark brown with yellow mottles, except black head, antenniferous tubercles, femora I-III, body venter excluding yellow patches in the ventrolateral sides of pronotum, metathorax and abdomen. Antenna and proboscis reddish brown, except basal one-half of segment III yellow. Tibia and tarsi I-III yellow with black patches on the dorsal and ventral posterior ends. Claws black, except yellow basal one-half.

Head: 1.15x-1.25x wider than long, coarsely punctate and shortly pilose. Tylus as long as to slightly longer than jugum and smooth between ocelli. OOL 0.55x eye length. POL 1.75x eye length. Antennifers with the narrow and pointed inner part elevated and inwardly projected, lower outer part blunt. Antennal segment I globose, apices of segment wider than basal ends and segment V widest

at midlength. Segment III slightly shorter than IV and always less than the combined length of segments I and II. Proboscis reaches coxa III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.37	0.38	0.53	0.60	1.02	2.95
♀	0.38	0.40	0.58	0.64	0.96	2.96

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.62	1.08	0.76	0.80	3.26
♀	0.64	1.16	0.82	0.90	3.52

Pronotum 1.84x-1.97x wider than long, anterior margin moderately concave, anterior lateral margin rebordered oblique and slightly concave with spine projected posteriorly. Midpronotum bears a T-like band, top and bottom arms of band elevated around cicatrices. Margin of lateral pronotum concave, gradually rebordered up to prehumeral spine. Anterior spine less distinct than the prehumeral spine. Disc of pronotum distinctly punctated, punctures enclosed in shallow grooves bordered by interconnected ridges. Cicatrices without elevated tubercles, smooth and borders lined with fine punctures. Transverse furrow absent. Scent gland globose with 7-8 transverse ridges basad of the opening. Leg length (mm): III > II > I, tibia II without midlateral inner spines. Claws sharp and long, TCl= 0.18, TCh= 0.14 and TCd = 0.10. Ratio of TCl:TCh= 1.30.

Leg measurements (mm)

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.65	1.95	1.45	1.85	0.85	0.85	3.95	4.65
II	1.80	2.20	1.90	2.10	0.85	0.85	4.55	5.15
III	2.20	2.80	2.40	2.90	0.85	0.90	5.45	6.50

Forewings with 3-5 closed marginal cells and 4 longitudinal veins in the membrane, 3rd and 4th closed cell usually the largest. Hindwing with a rectangular junction of vein R+M, secondary veins merged basally, CuA with a long inner vein extension.

Scutellum coarsely punctated in basal one-half, midline with narrow yellow band, tip rounded and not reaching abdominal tip. Ratio of WAB:WACP:L is 2.8:2.2:4.3 in males and 3.3:2.6:5.1 in females.

Abdominal sternites VI and VII with mid-anterior margins slightly pointed in males and convex in females. Tergite X broadly concave. Pygophore transverse,1.62x wider than high, dorsolateral lobe densely pilose inside, aedeagal cap concave medially with thick hairs basally and rebordered lateral margins. Claspers long, visible in cross-sectional view, and apices touching margins of abdominal tergite.

Male genitalia: anterior part of posterior phallotheca globose, dorso-basally expanded viewed dorsally. Membraneous conjunctiva lobe-like in pairs, dorsal and subtriangular laterally. Penial plates widely separated apically, apices truncated view laterally. Ejaculatory duct very short not visible dorsally. Basal plate molar-like with short pivot.

Female genitalia plate: 9th paratergite not beyond abdominal tip with more basal punctations; 2nd gonocoxae moderately and widely concave posteriorly with rounded laterobasal swellings. Spermathecae slim with 4 long and slightly tinged bands, sclerotized median spermathecal duct half-coiled proximally and with 6 coils distally. Pump elongate and spermathecal bulb without process.

Materials examined: **Philippines**: Mindanao Is., North Cotabato Province, Mlang, Buayan Vill., holotype male, and paratypes: 13 males and 12 females including seven 4th-5th instar nymphs, ex. rice stubbles, 27 Apr 2006, A.T. Barrion.

Etymology: Named after the type-locality.

Scotinophara ilonga new species
(Plate 6-4, 10-2, 34a-n; Figs. 163-182)

Length: Male 7.2-7.5 mm. Width across prehumeral process 3.8 mm.
Female 7.6-8.8 mm. width across prehumeral process 4.5 mm.

Color: Blackish brown with interconnected yellow mottles on posterior pronotum, scutellum, and forewing's corium and clavus. Head black including antennifers, femora I-III, dorsal and ventral bases of tibiae I-III and body venter. Tibiae and tarsi yellow with apical one-fourth of tarsal segment III light brown. Antennae brownish red in segments I and V, brown in II, yellowish brown in III and IV with apical one-fourth of III and basal one-fourth of IV brown. Ocelli red orange. Compound eyes silvery with reddish marginal tinge. Proboscis dark reddish brown. Labrum black to yellow with dark brown median longitudinal band. Flap-like pseudoarolia white borne on black margins and base of claw.

Head 1.2x wider than long, shortly pilose, and coarsely punctated. Tylus longer than to as long as jugum in the females and slightly shorter than jugum in males, distinctly lines with transverse ridges. Anterior end of jugum laterally oblique with a narrow tip. Compound eye seperation as long as combined length of antennal segments I-II-III. OOL = 0.6 eye length. POL 1.7xeye length. Basal half of segment I incrassate. Antennifers inwardly curved tip elevated and thinly acute, outer blunt. Proboscis segment II 1.4x longer than segment III. Reaches midlength of coxa III.

Length of antennal segments (LAS) (mm).

Sex	1	2	3	4	5	Total
♂	0.31	0.38	0.53	0.58	0.95	2.75
♀	0.40	0.45	0.58	0.63	1.03	3.09

Length of proboscis (LOP) (mm)

Sex	1	2	3	4	Total
♂	0.53	1.12	0.8	0.75	3.20
♀	0.65	1.10	0.83	0.88	3.46

Pronotum 2x wider than long across prehumeral spines. Median disc with a transverse row of pits. Shallow collar, lateral margin rebordered, except anterior lateral margin of pronotum oblique, indistinct spine projected posteriorly. Lateral margin between spines concave. Prehumeral spine small but distinct. Cicatrice as in *S. coarctata* (F), without tubercles. Transverse furrow in the posterior pronotum absent.

Leg length III > II > I. Tibia II without spine in the inner lateral side.

Leg measurements (mm).

Leg	Femur		Tibia		Tarsus		Total	
No.	♂	♀	♂	♀	♂	♀	♂	♀
I	1.60	1.70	1.55	1.50	0.87	0.85	4.02	4.05
II	1.85	2.10	1.75	1.80	0.87	0.85	4.47	4.75
III	2.10	2.40	2.30	2.40	0.92	0.85	5.32	5.65

Tarsal claws sharply pointed. TCl=0.16, TCh=0.10, TCd= 0.08. Ratio of TCl:TCh =1.6

Forewings with 2-3 closed marginal cells and 4 longitudinal veins in the membrane. Punctures in corium and clavus relatively light and widely spaced, denser towards basal half in some specimens. Costal margin of membrane without band. Hindwings with a distinct knob-like process in vein R+M, junction narrow and quadrate, vein R elevated after the junction. R+M-CuA triangle small, part of vein M joining CuA in th triangle straight to convex. Vein 1A convexly curved.

Scutellum not reaching tip of abdomen, anterior end rounded. Ratio of BW:WACP:L 2.6:2.15:3.9.

Terminal segment of abdominal sternite with a smooth and broadly convex anterior margin. Tergite X concave medially. Pygophore 1.5x wider than high, median blade of clasper distinctly visible in cross-section, diverging and tip bluntly rounded. Clasper robust, shortly sickle-shaped, blade with a bluntly rounded tip, median posterior surface bears 5-7 short spines. Inner arm triangular with a subapical spine and 4 basal spines. Stem long and parallel-sided.

Male genitalia: posterior phallotheca oblong with laterobasal expansion, midbasal area without subtriangular marking. Membraneous cunjunctiva not bulbous and exposed sides of penial plates, apex V-shape. Penial plates widely separated apically, tip rounded laterally, and ventrolateral side subtruncate. Basal plate short and thin, lateral arm sub triangular and short. Pivot elongate dorsally and triangular laterally, reach slightly above midlength of phallotheca. Ejaculatory duct short.

Female genitalia: 9th parategite oblongate to subtriangular, apices not extended beyond tip of abdomen. Proctiger subquadrate, basally punctated. Second gonocoxae with two lobe-like punctated openings, anterior and posterior margins deep medially.

Materials examined: **Philippines:** Panay Is., Iloilo Province, Ajuy, Prospero Vill., holotype male and paratypes: 20 males and 120 females, ex. rice at flowering stage, 17-18 May 2006, A.T. Barrion and R.C. Joshi; same provinve, Dingle, Camambongan Vill., 6 males and 15 females, ex. rice at 35 DT, 17 May 2006, AT Barrion and RC Joshi; Dumangas, Dumangas Demo Farm, 4males and 8 females, ex. light trap, 19 May 2006, unknown farmer.

Etymology: Named after the native people in the area.

Color Plates

Philippine black bug specimens are photographed. Cross-sections of the male gonophore of representative species are also documented whenever possible. All figures are not life-size. However, scales are provided a page before each plate of photographs.

Scotinophara tarsalis

Scotinophara serrata

Scotinophara pseudoserrata

Scotinophara latiuscula

Plate 1

1 — *Scotinophara molavica*

2 — *Scotinophara kalinga*

3 — *Scotinophara arkwata*

4 — *Scotinophara latiuscula*

Plate 2

1 *Scotinophara cinerea*

2 *Scotinophara sorsogonensis*

3 *Scotinophara pirurotonga*

4 *Scotinophara agusanortica*

Plate 3

1 *Scotinophara tantanganica*

2 *Scotinophara midsayapensis*

3 *Scotinophara putikanica*

4 *Scotinophara coarctata*

Plate 4

Scotinophara alegria

Scotinophara kabangkalanensis

Scotinophara zamboanga

Scotinophara trifurcata

Plate 5

1 — *Scotinophara landangica*

2 — *Scotinophara maguindanaoana*

3 — *Scotinophara mlanga*

4 — *Scotinophara ilonga*

Plate 6

Scotinophara tarsalis

Scotinophara luzonica

Scotinophara serrata

Scotinophara molavica

Scotinophara pseudoserrata

Scotinophara kalinga

Plate 7

Scotinophara arkwata 1
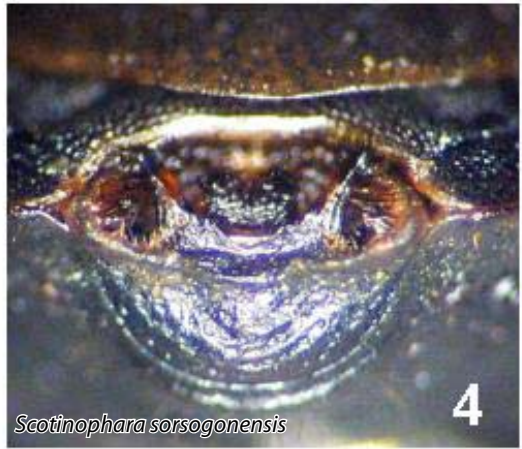
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Scotinophara latiuscula 2
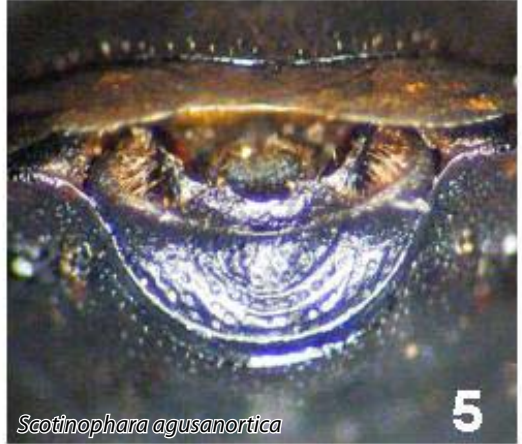
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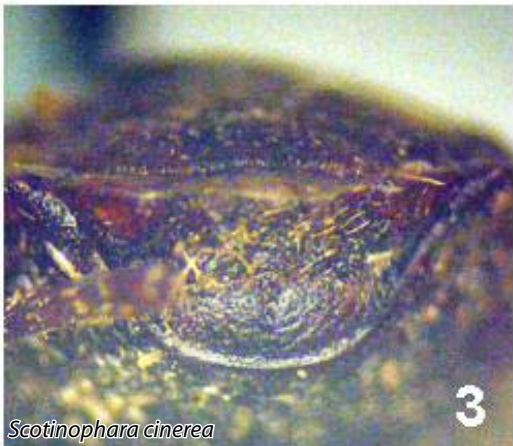
Scotinophara cinerea 3

Scotinophara tantanganica 6

Plate 8

Scotinophara midsayapensis **1**

Scotinophara kabangkalanensis **4**

Scotinophara putikanica **2**

Scotinophara zamboanga **5**

Scotinophara coarctata **3**

Scotinophara trifurcata **6**
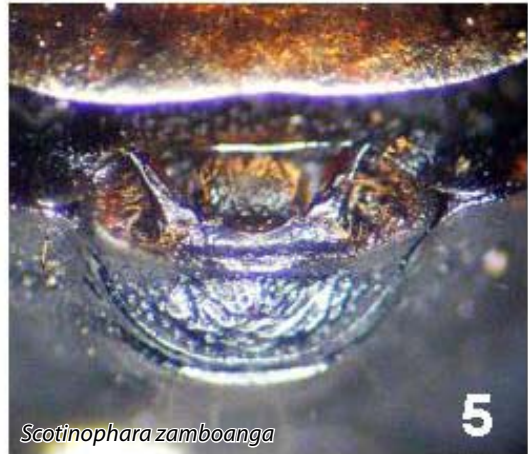
Plate 9

Scotinophara landangica — 1
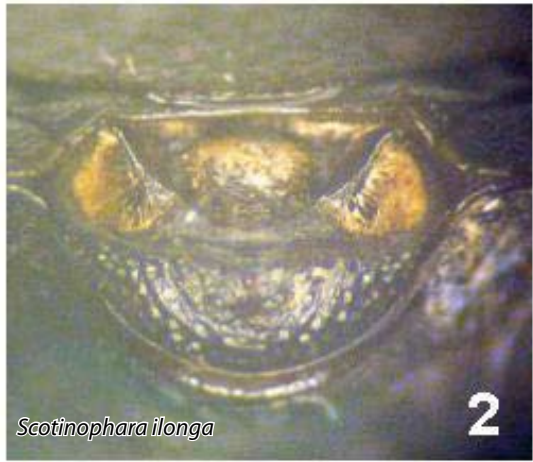
Scotinophara ilonga — 2

Plate 10

Line Drawings

The general habitus including pertinent morphological characters of Philippine black bug species are illustrated. Distribution maps are also supplied. In addition to this, separate comparative plates are prepared to aid in species delimitation.

a
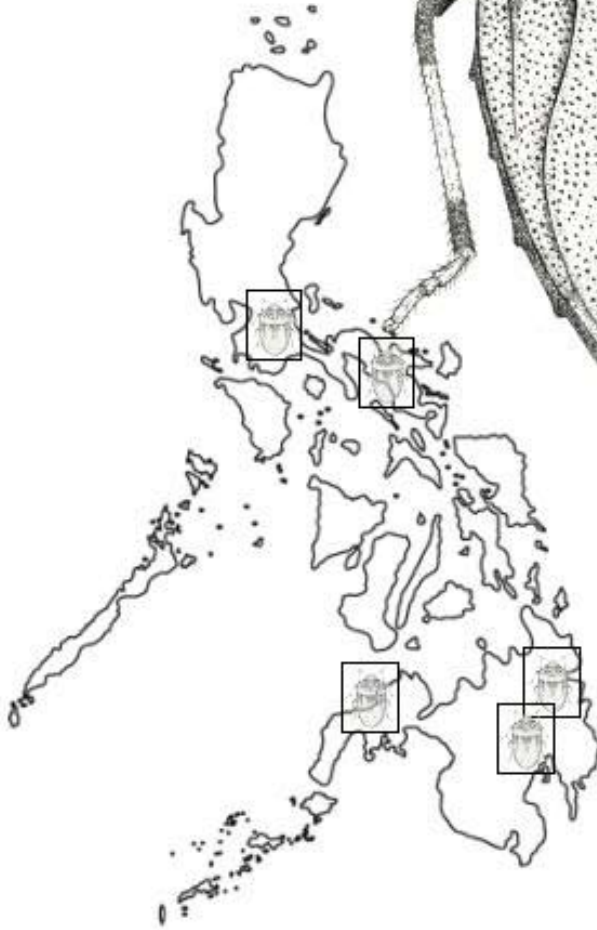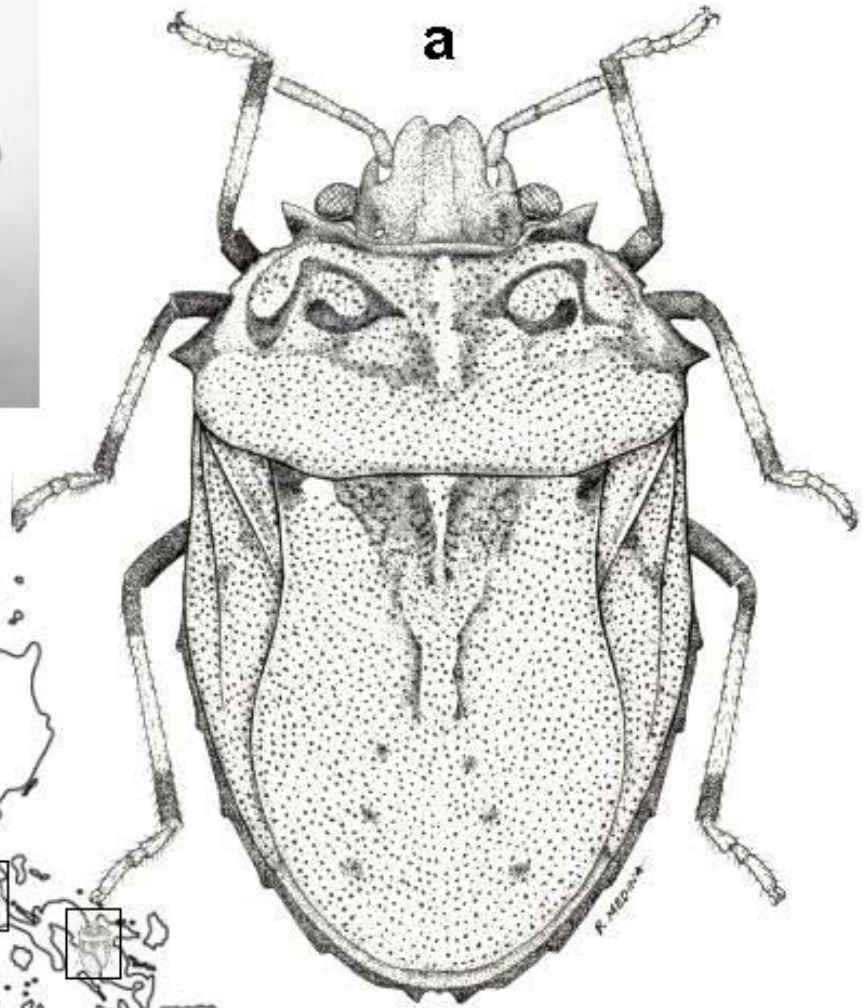
Plate 11
Scotinophara tarsalis

a. male habitus
b. lateral view of head
c. antennifer
d. ventral view of abdominal tip
e. cross-section of gonophore
f. left clasper
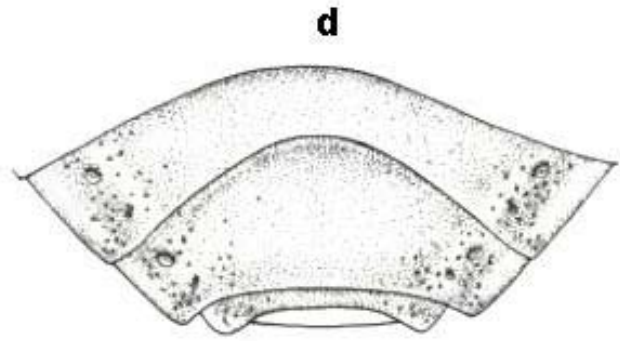g. dorsal view of aedeagus
h. lateral view of aedeagus
i. tergite X
j. spermatheca
k. female genitalia

Plate 11 b-i
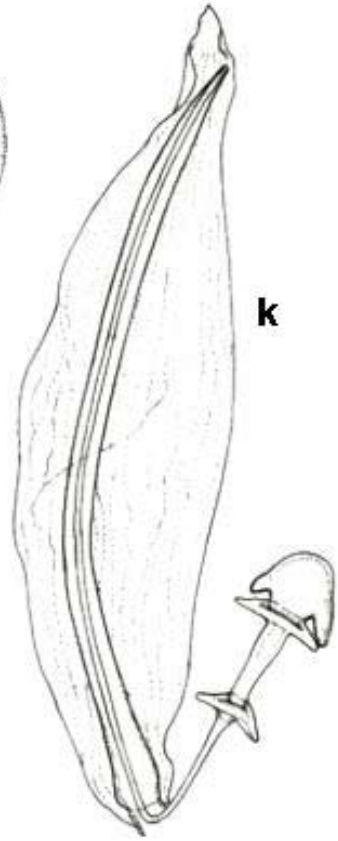*Scotinophara tarsalis*
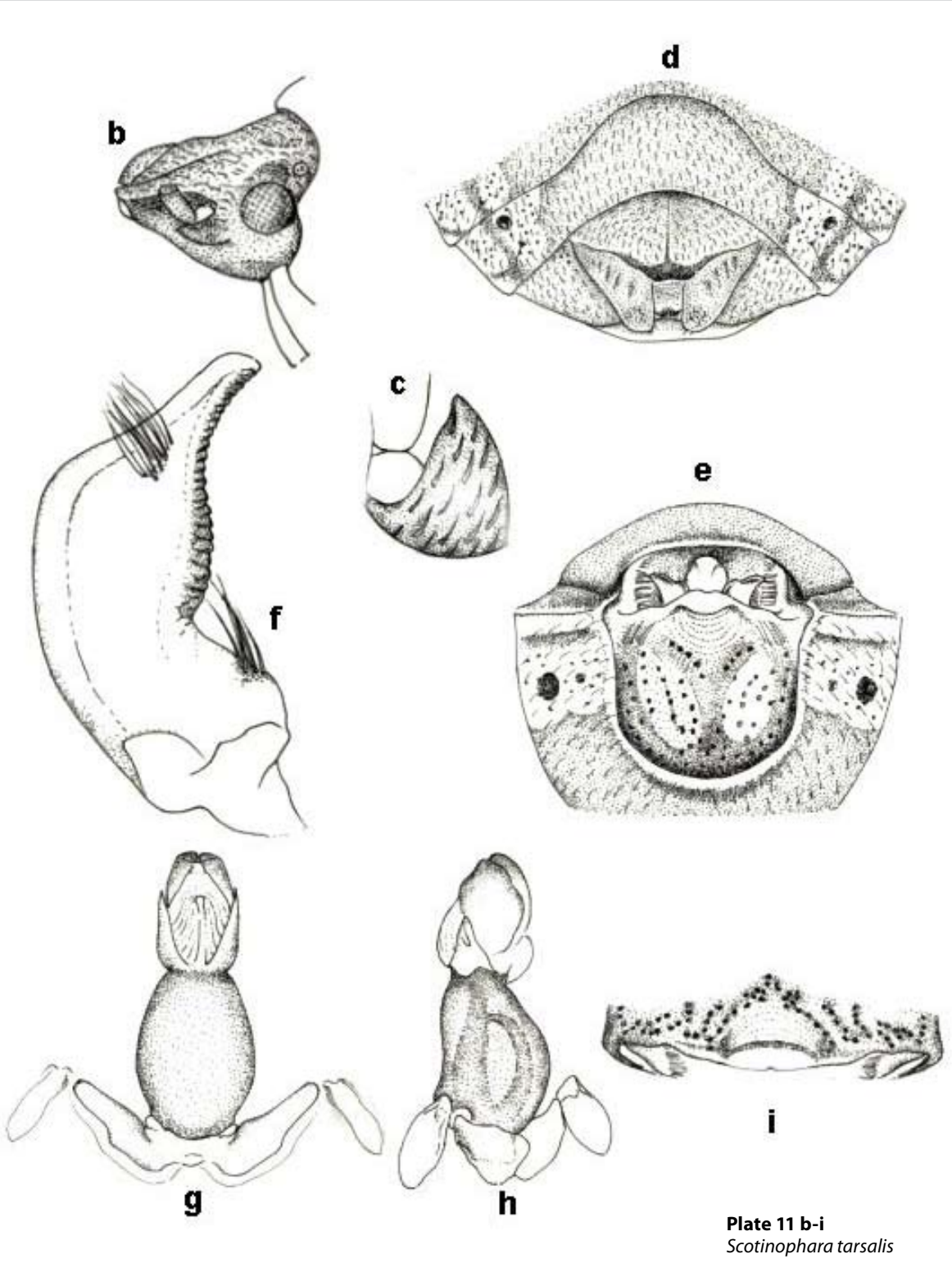
Plate 11 j-k
Scotinophara tarsalis
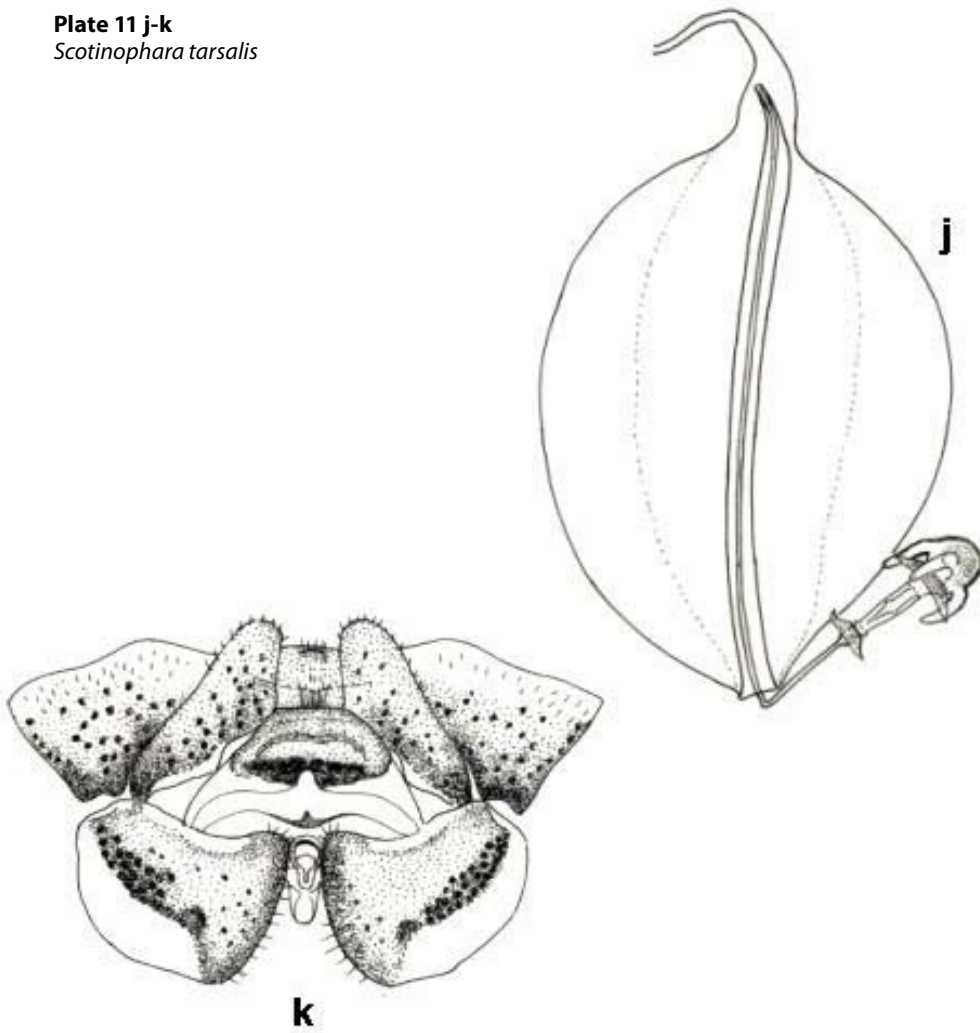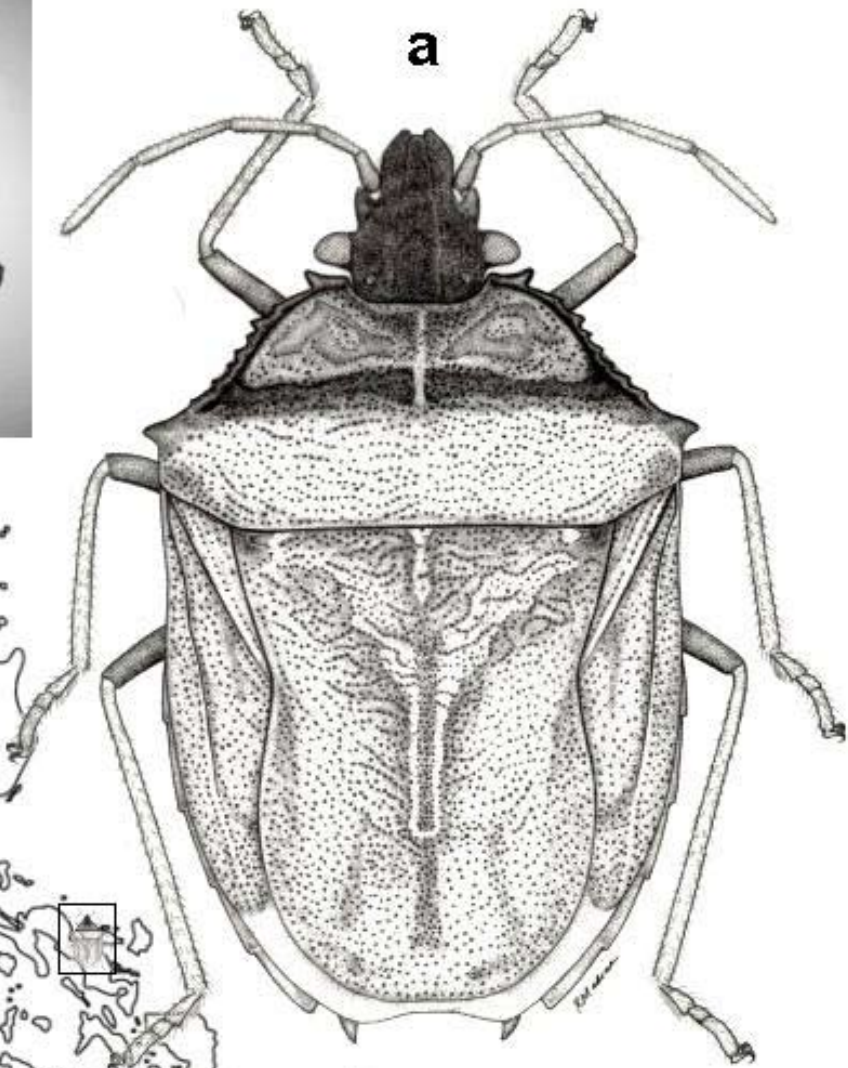
Plate 12
Scotinophara serrata

a. male habitus
b. lateral view of head
c. antennifer
d. ventral view of abdominal tip
e. cross-section of gonophore
f. left clasper
g. dorsal view of aedeagus
h. lateral view of aedeagus
i. forewing
j. hindwing
k. spermatheca
l. female genitalia
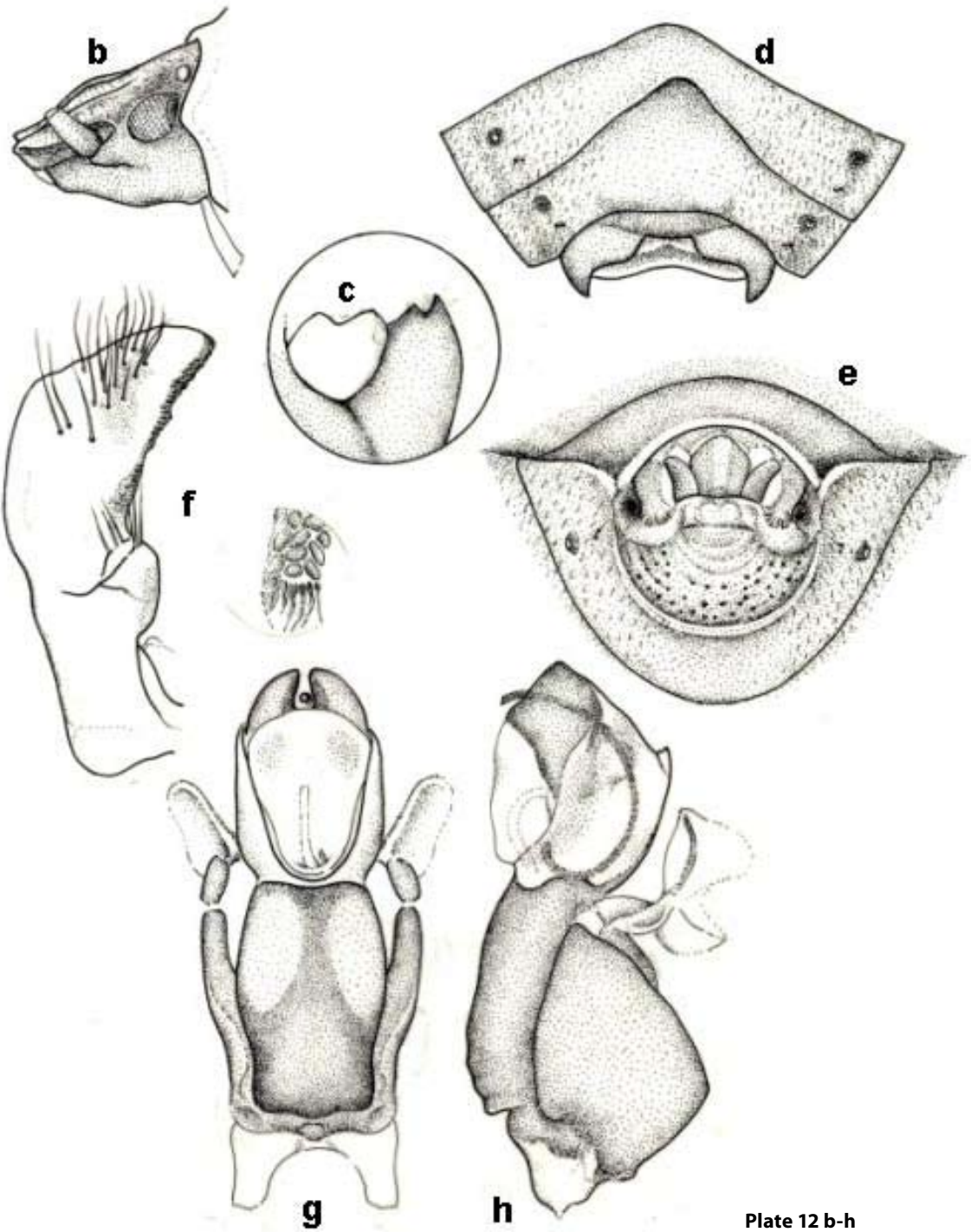
Plate 12 b-h
Scotinophara serrata
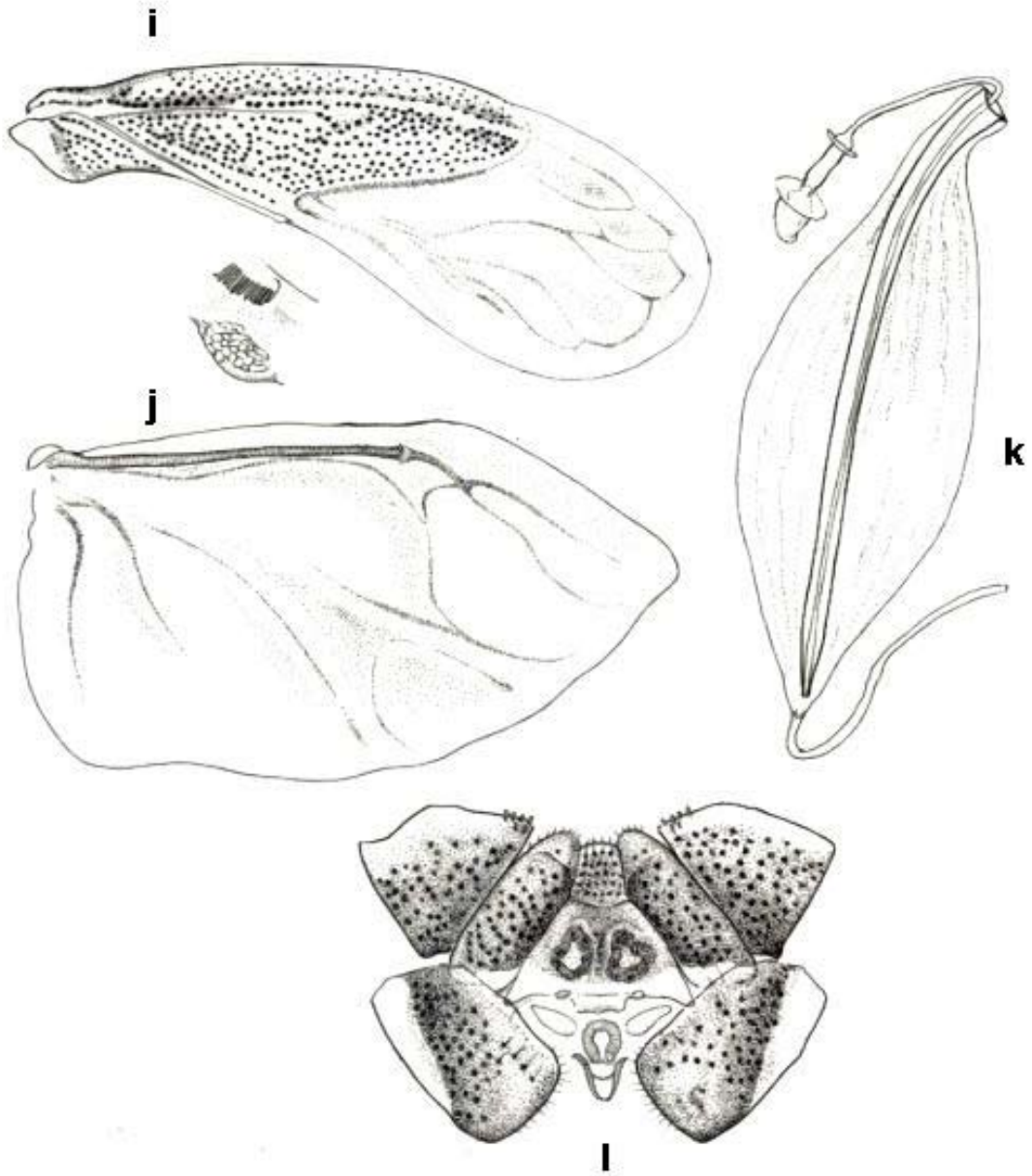
Plate 12 i-l
Scotinophara serrata
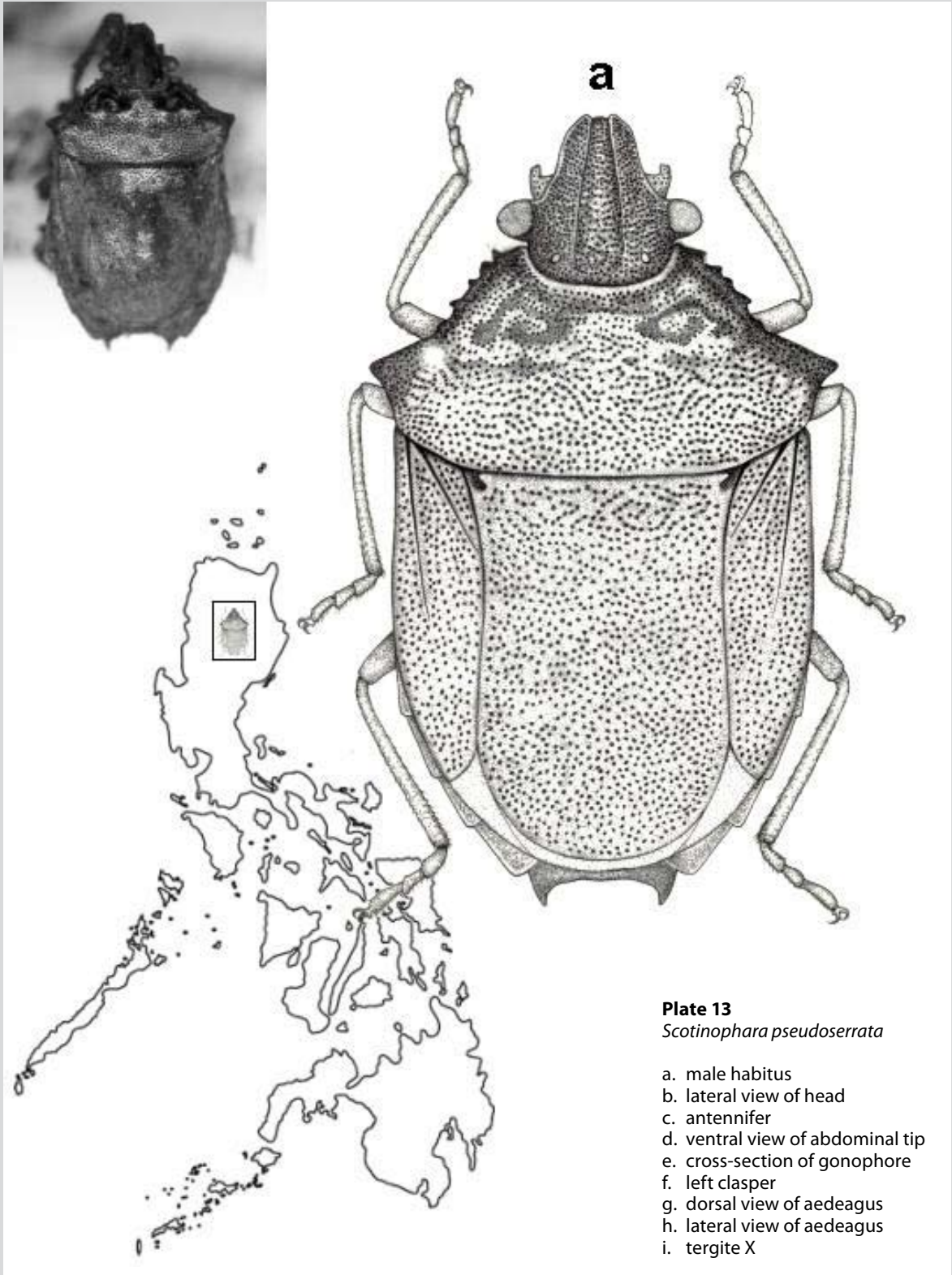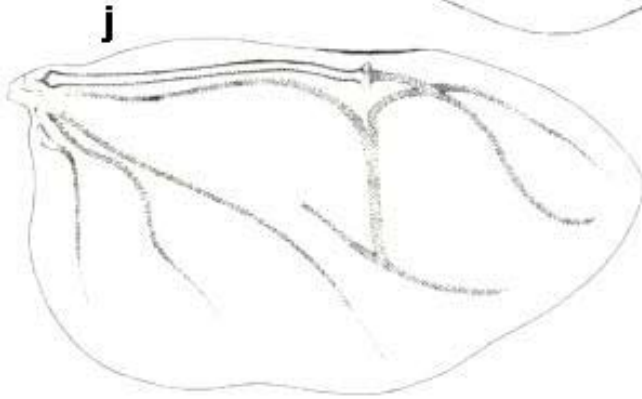
Plate 13
Scotinophara pseudoserrata

a. male habitus
b. lateral view of head
c. antennifer
d. ventral view of abdominal tip
e. cross-section of gonophore
f. left clasper
g. dorsal view of aedeagus
h. lateral view of aedeagus
i. tergite X
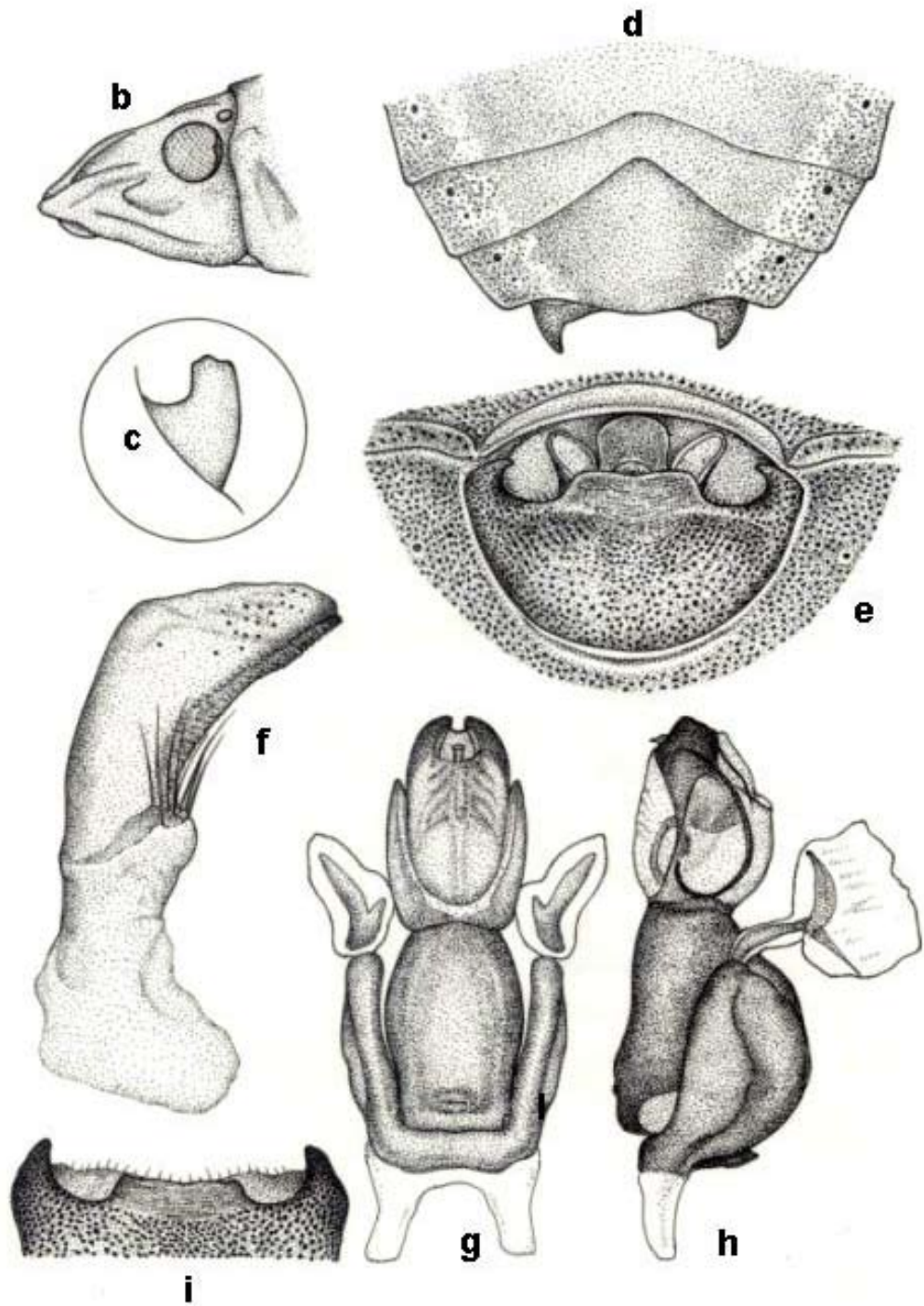
Plate 13 b-i
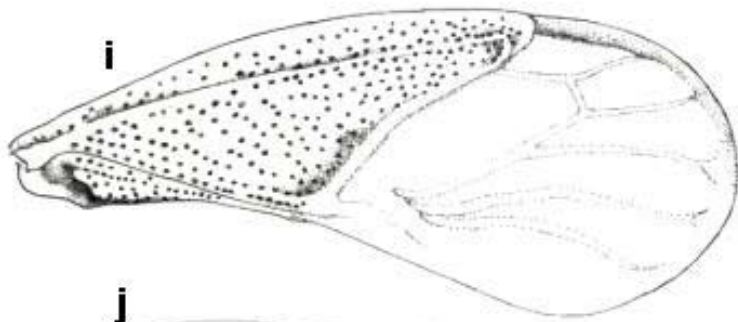*Scotinophara pseudoserrata*
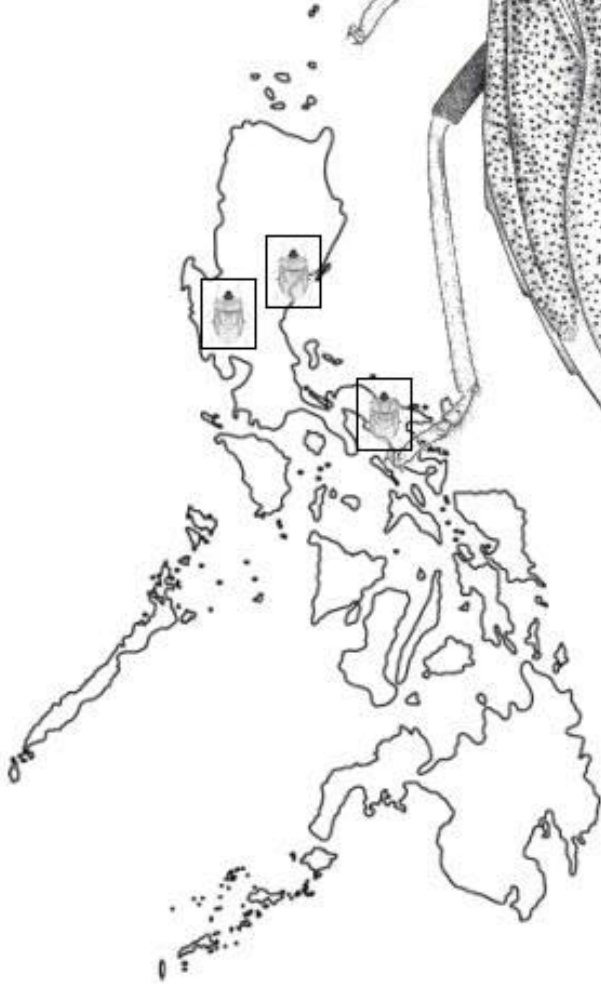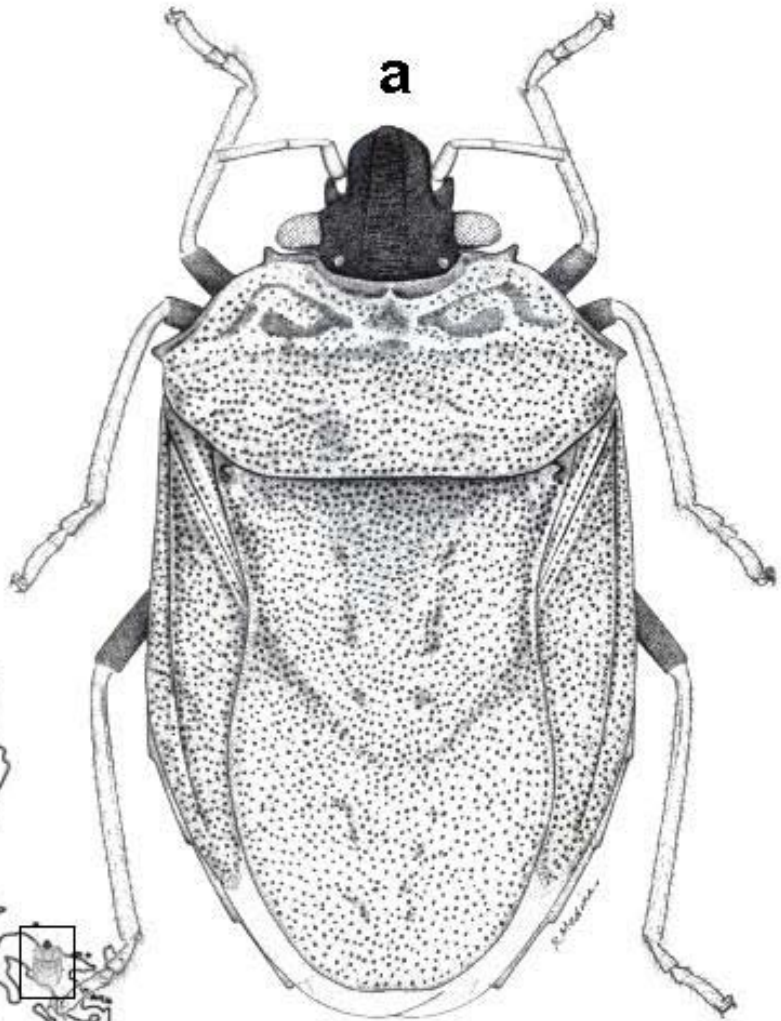
Plate 14
Scotinophara luzonica

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i forewing
j hindwing
k spermatheca
l female genitalia
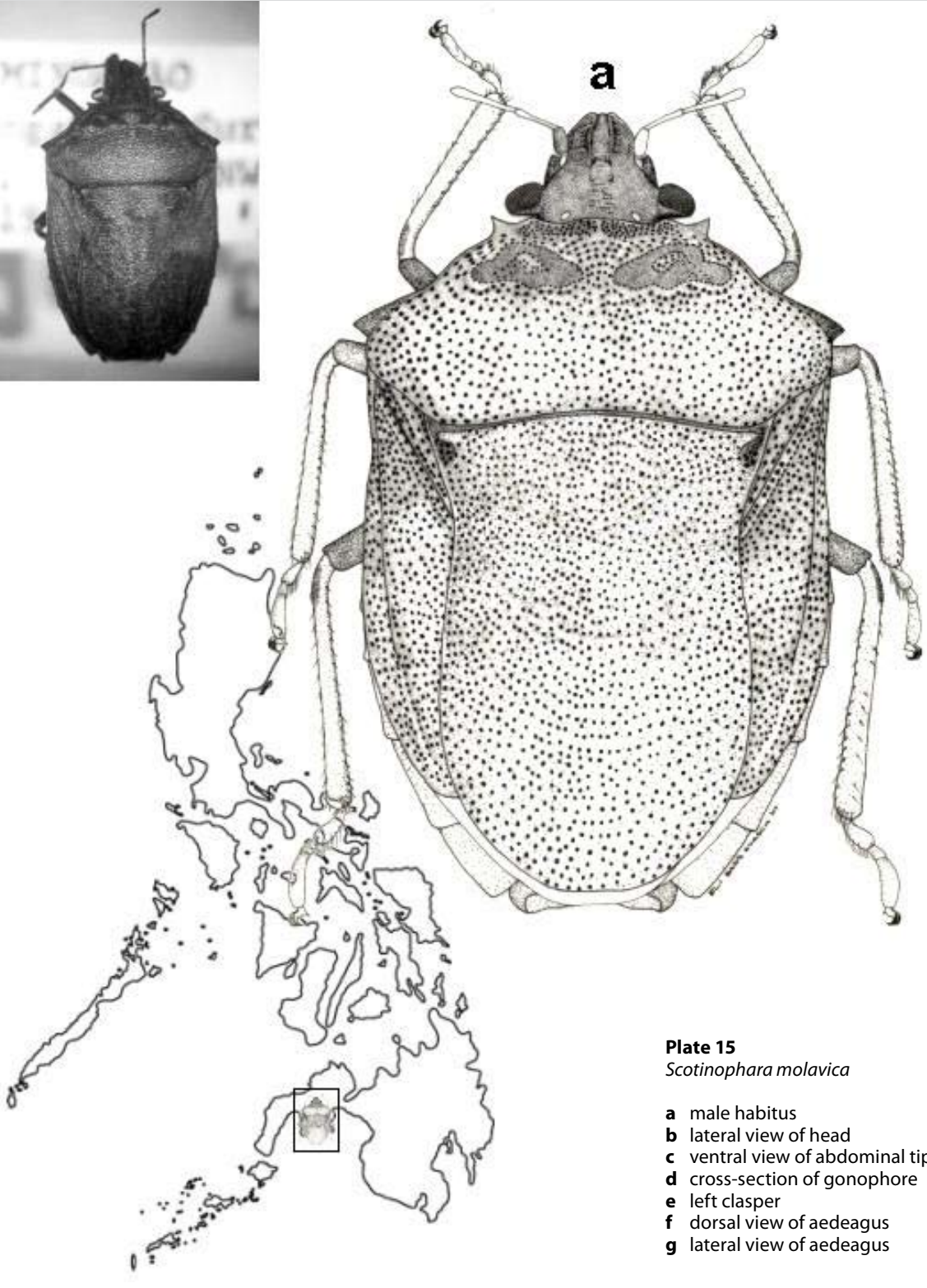**m** setae of female genitalia
n mesopleuron and metapleuron
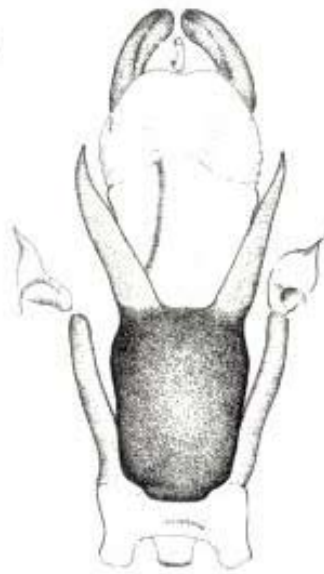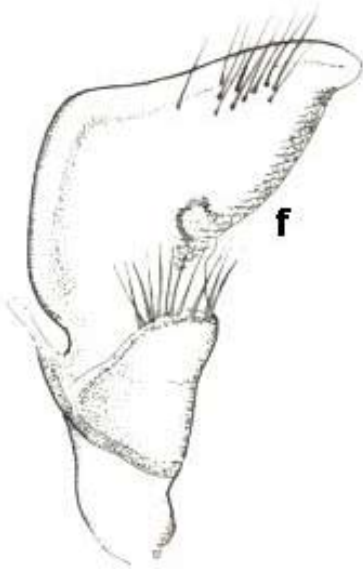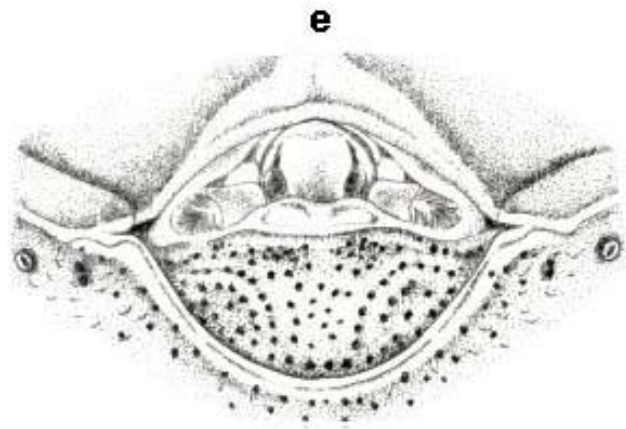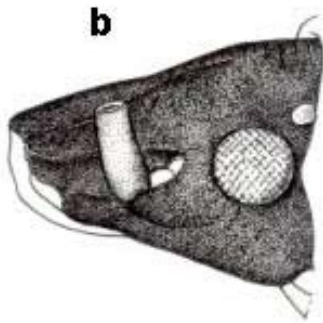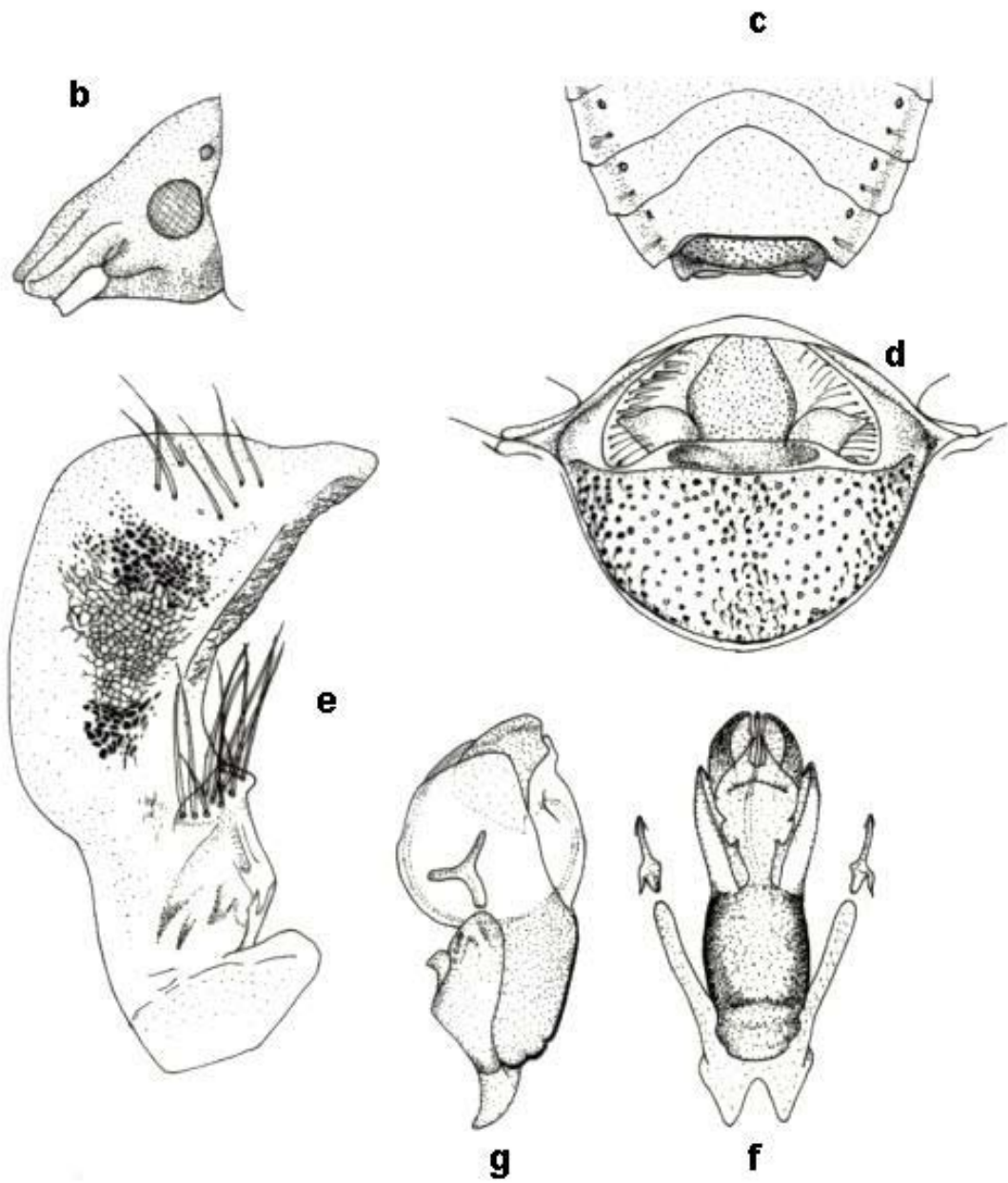
Plate 14 b-h
Scotinophara luzonica
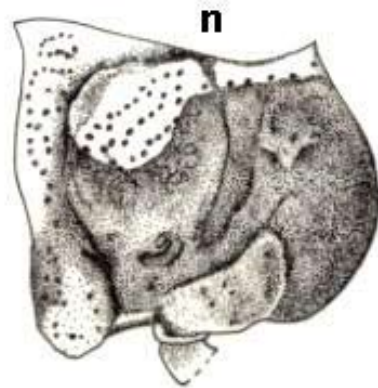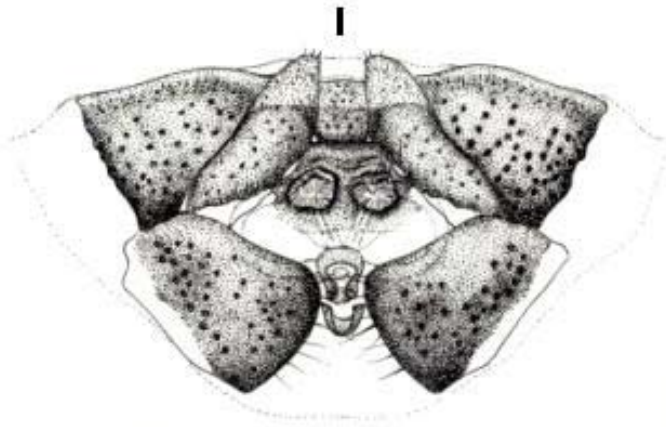
Plate 14 i-n
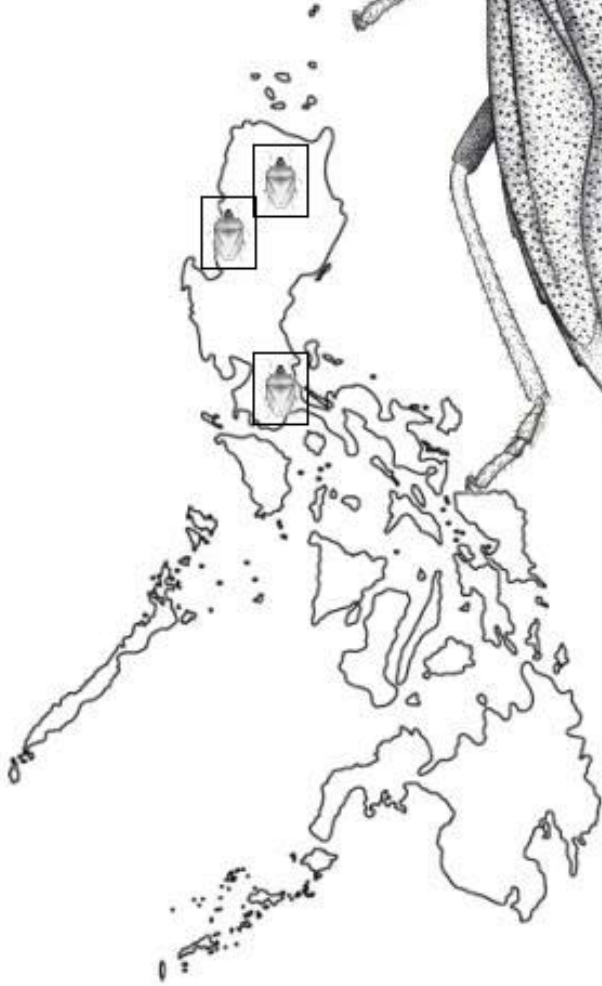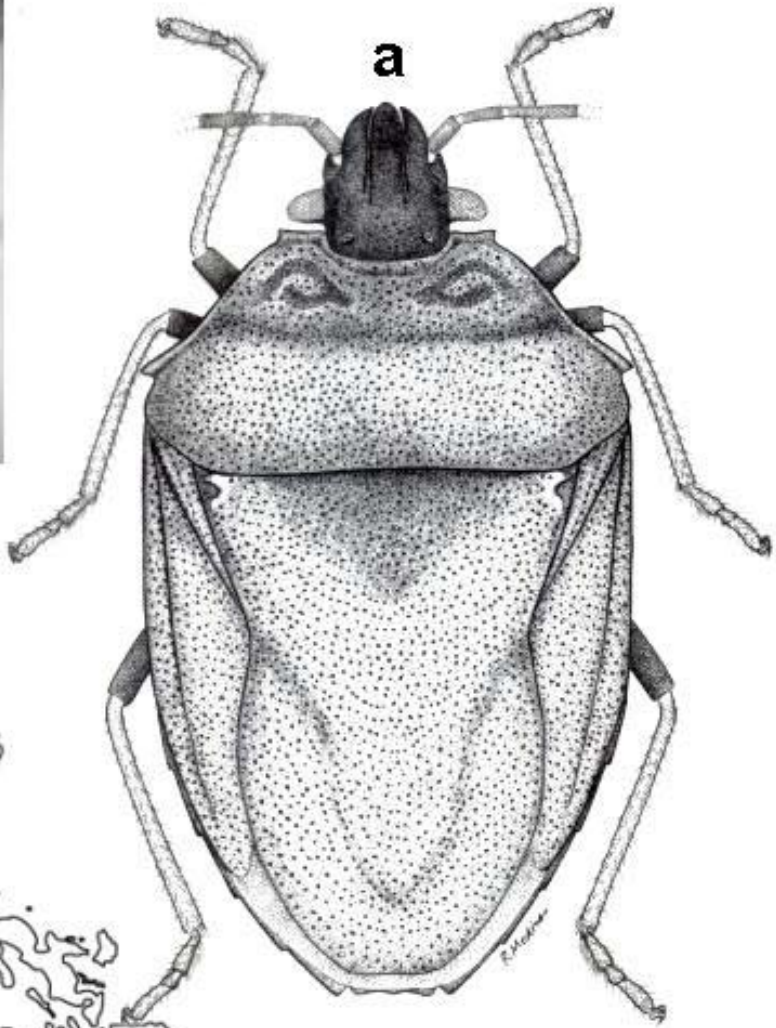*Scotinophara luzonica*

Plate 15
Scotinophara molavica

a male habitus
b lateral view of head
c ventral view of abdominal tip
d cross-section of gonophore
e left clasper
f dorsal view of aedeagus
g lateral view of aedeagus
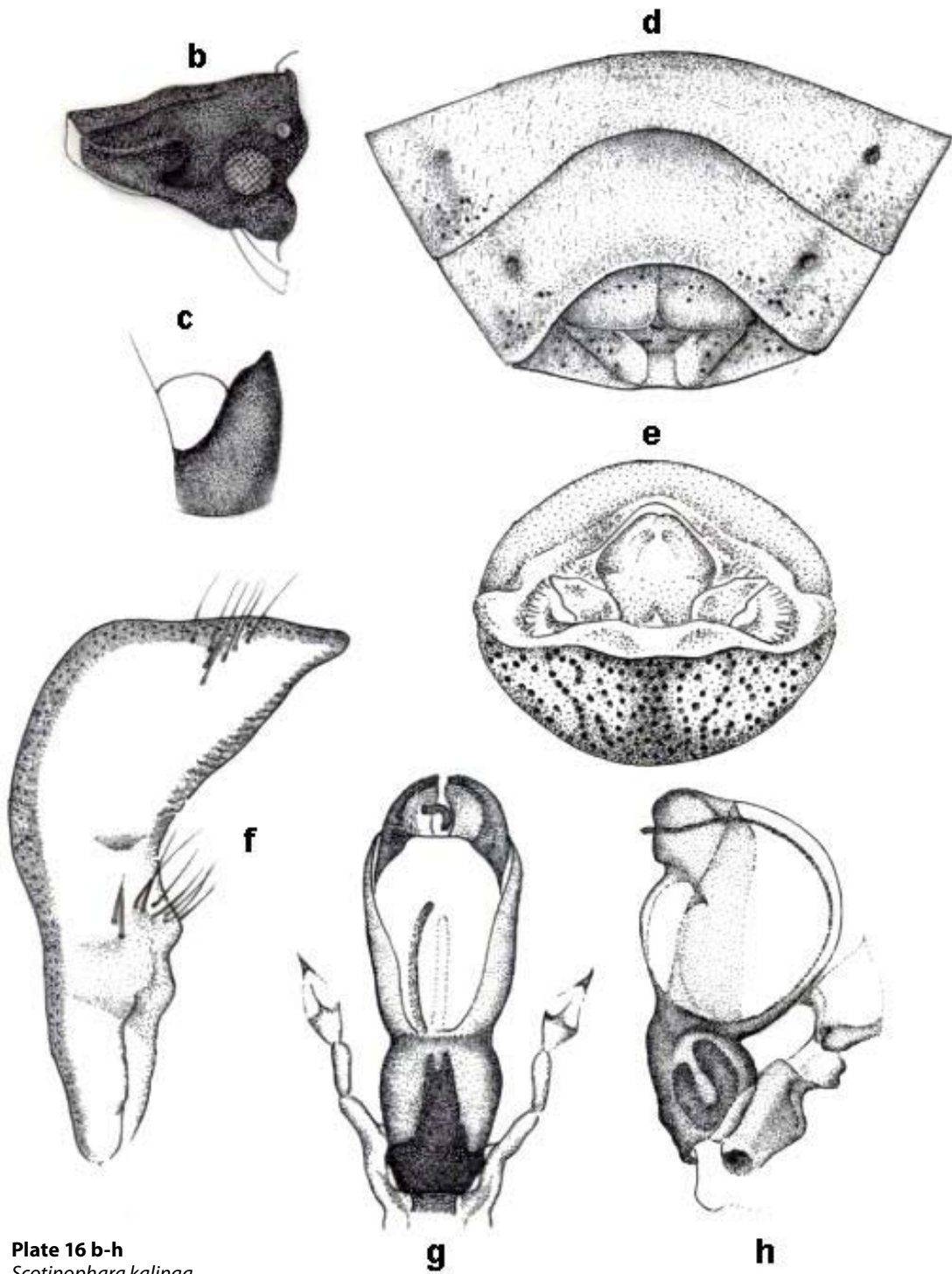
Plate 15 b-g
Scotinophara molavica

Plate 16
Scotinophara kalinga

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view oaf aedeagus
h lateral view of aedeagus
i tergite X
j forewing
k aedeagal cap

Plate 16 b-h
Scotinophara kalinga
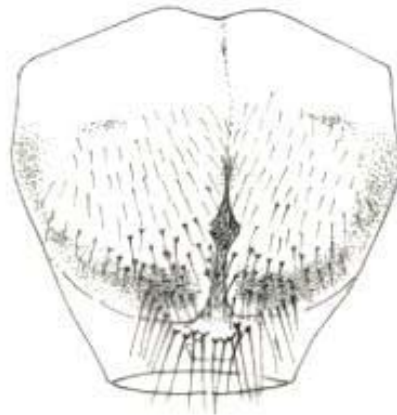
Plate 16 i-k
Scotinophara kalinga

a
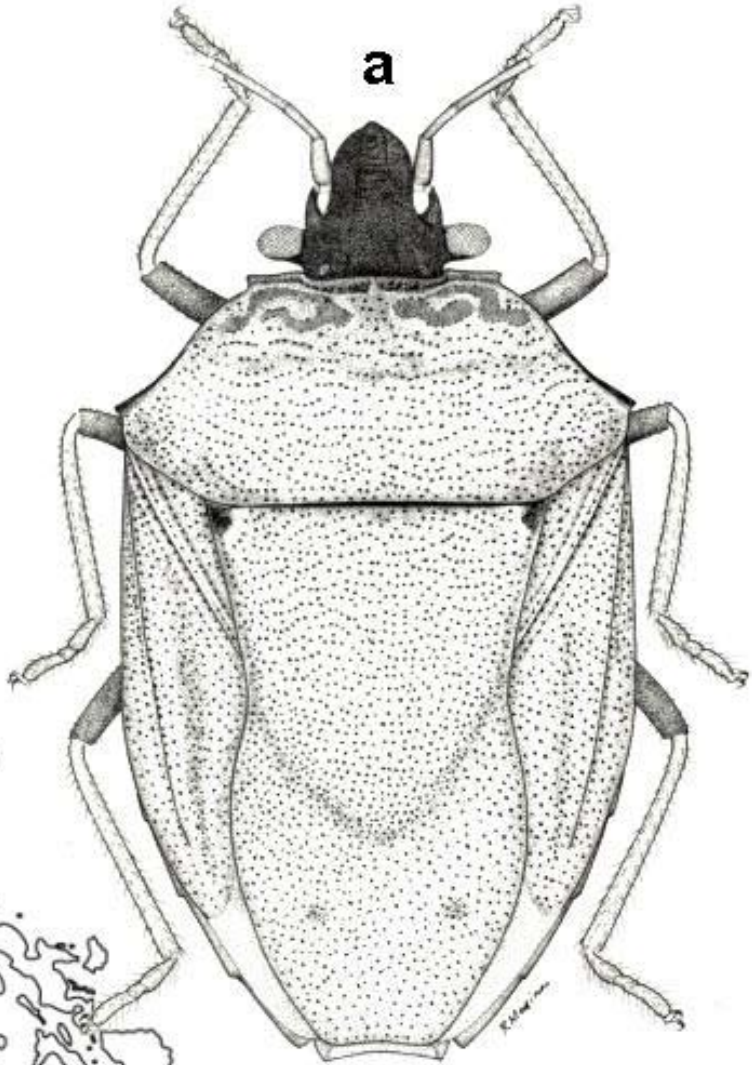
Plate 17
Scotinophara arkwata

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g clasper teeth
h dorsal view of aedeagus
i lateral view of aedeagus
j forewing
k mesopleuron and metapleuron
l aedeagal cap
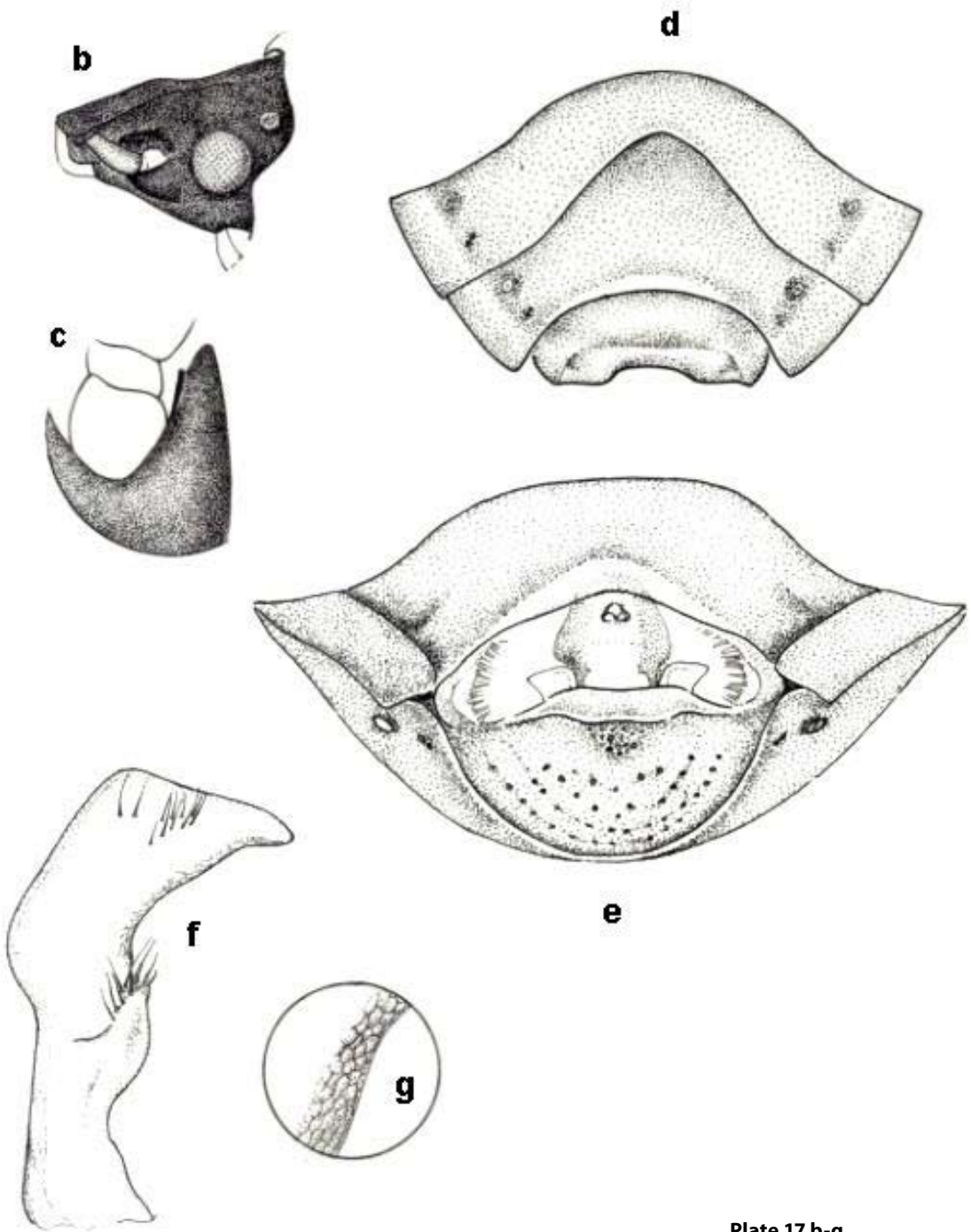
Plate 17 b-g
Scotinophara arkwata

Plate 17 h-j
Scotinophara arkwata

Plate 17 k-l
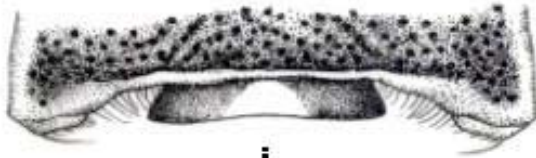*Scotinophara arkwata*

k

l

a
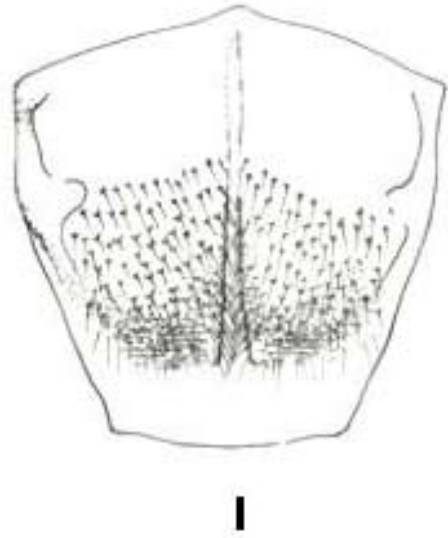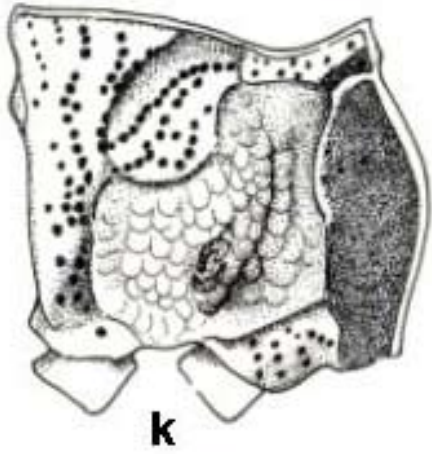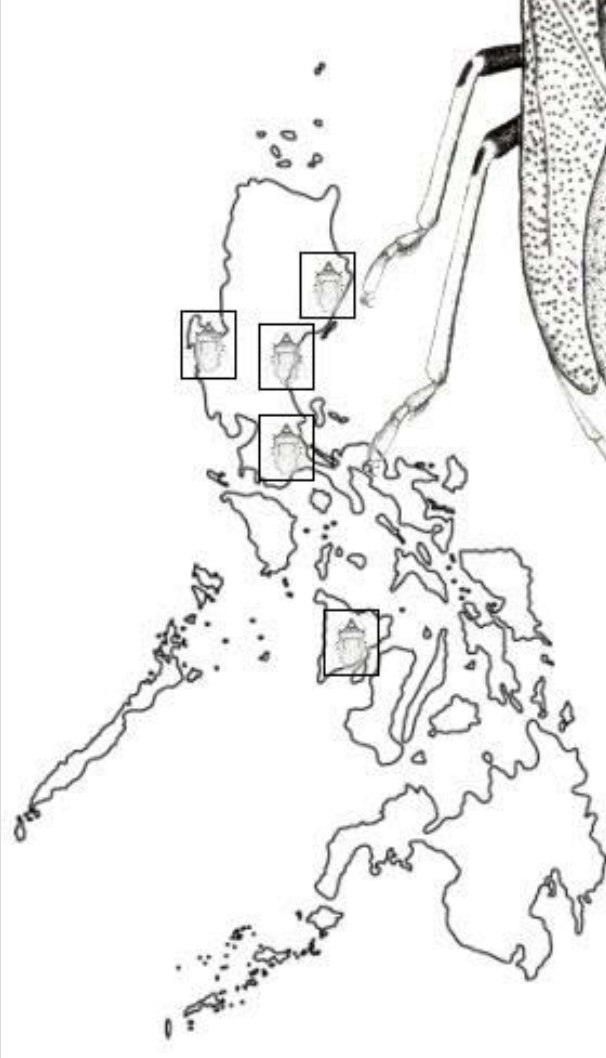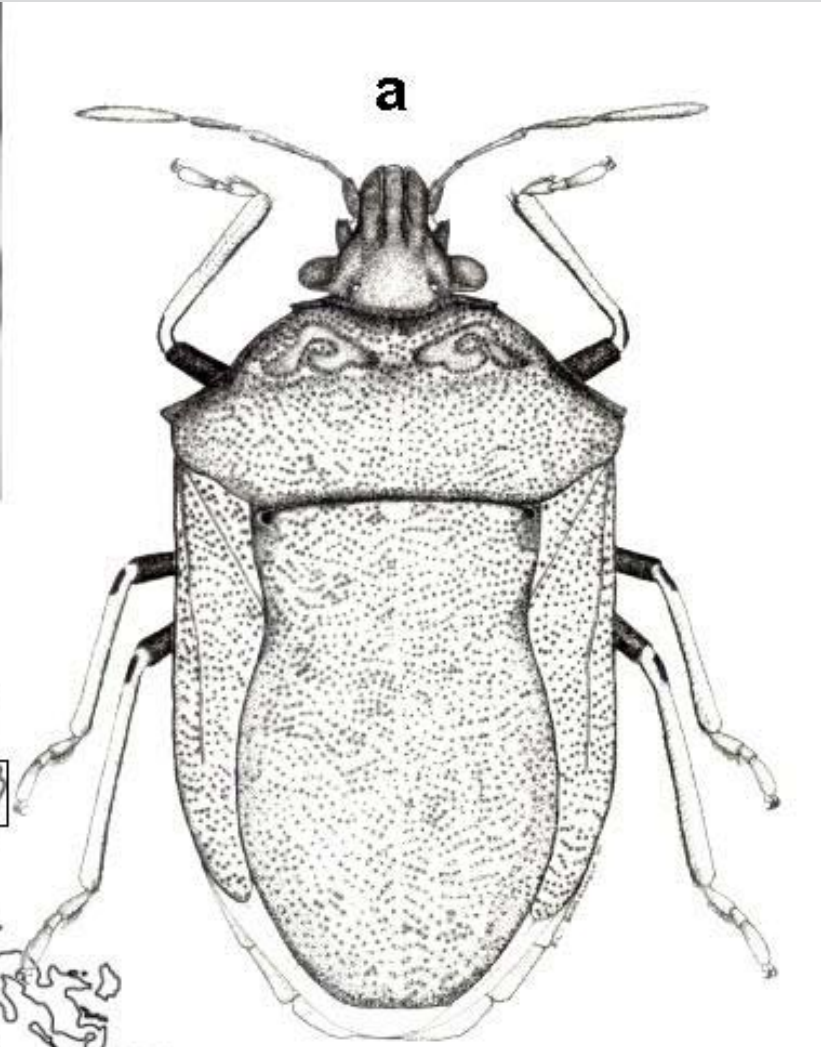
Plate 18
Scotinophara latiuscula

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
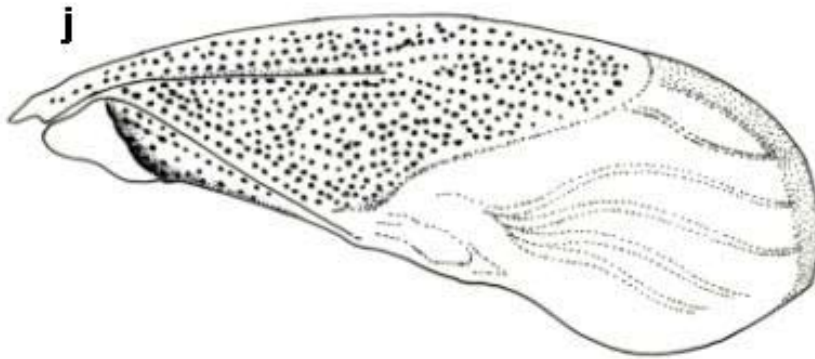**h** lateral view of aedeagus
i tergite X
j forewing
k hindwing
l spermatheca
m female genitalia
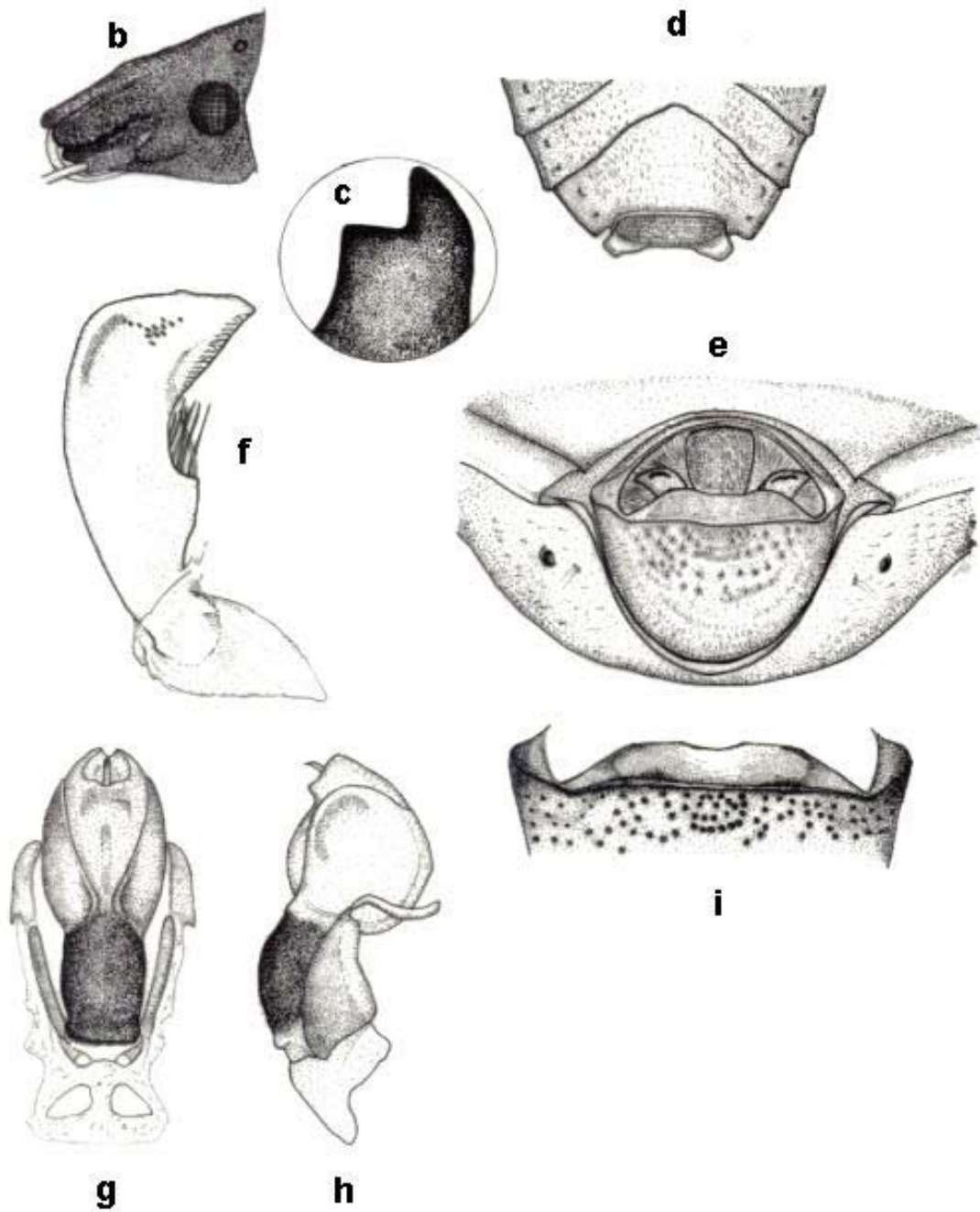
Plate 18 b-i
Scotinophara latiuscula

j

k

l

m
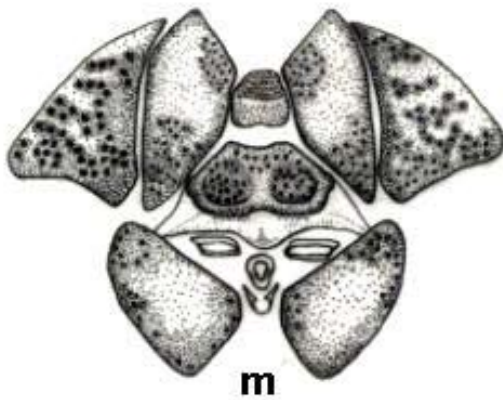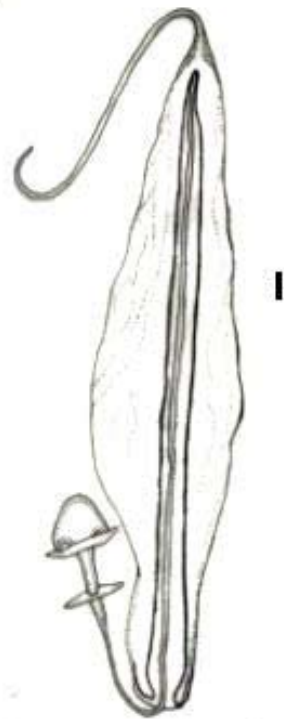
Plate 18 j-m
Scotinophara latiuscula

Plate 19
Scotinophara cinerea

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i tergite X
j spermatheca
k female genitalia
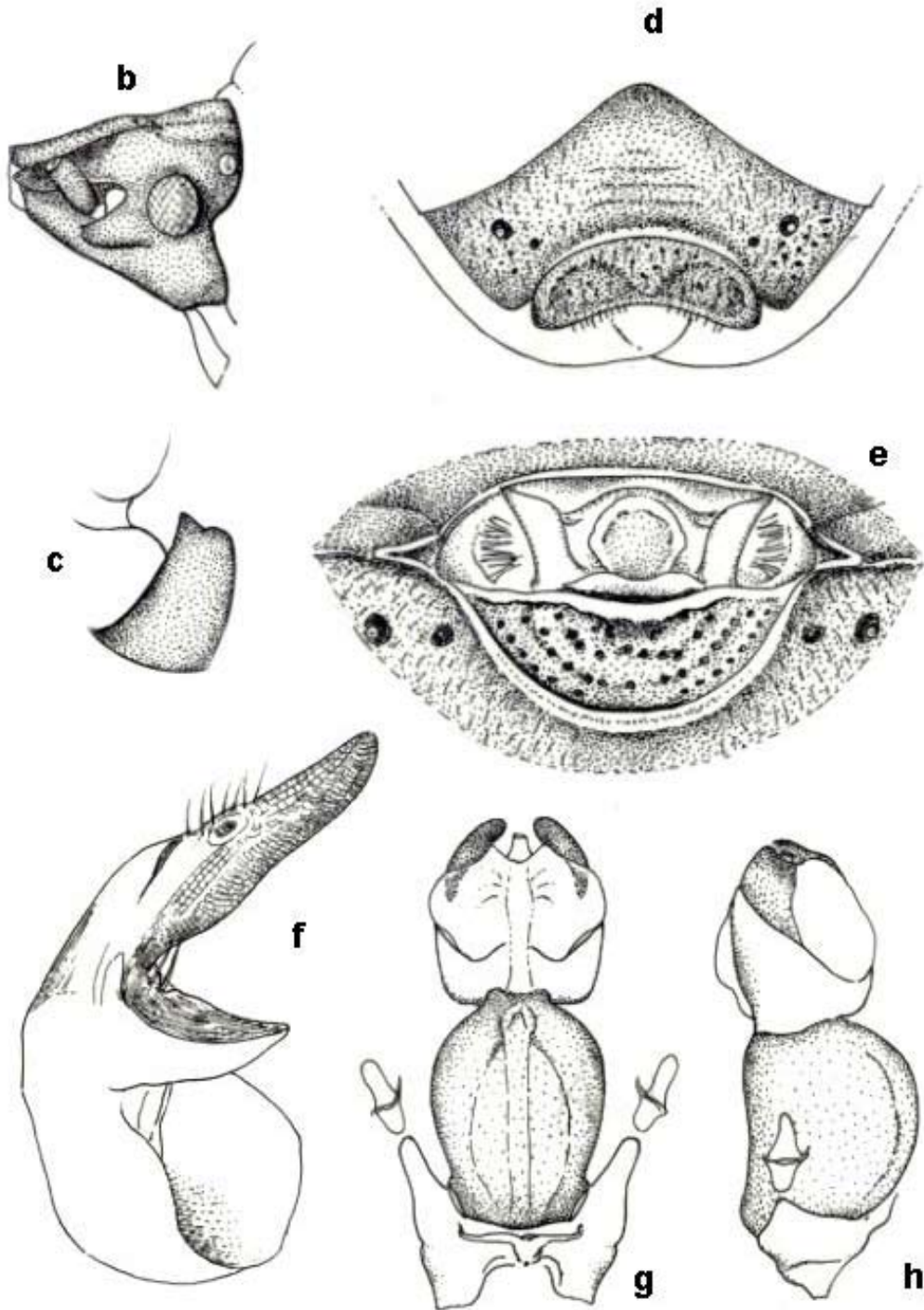
Plate 19 b-h
Scotinophara cinerea
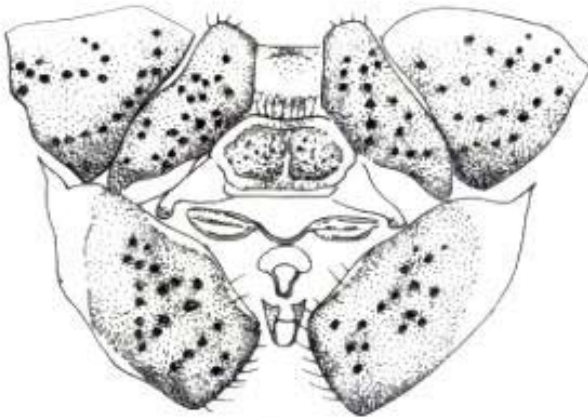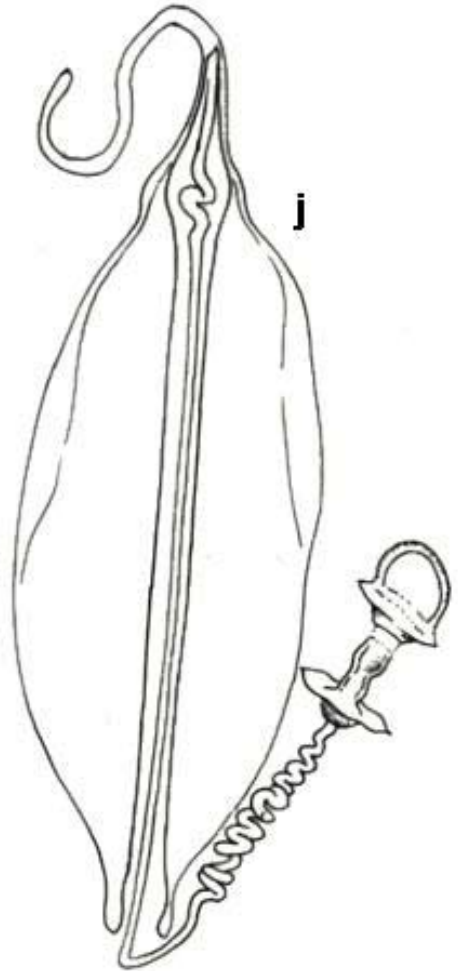
Plate 19 i-k
Scotinophara cinerea

a
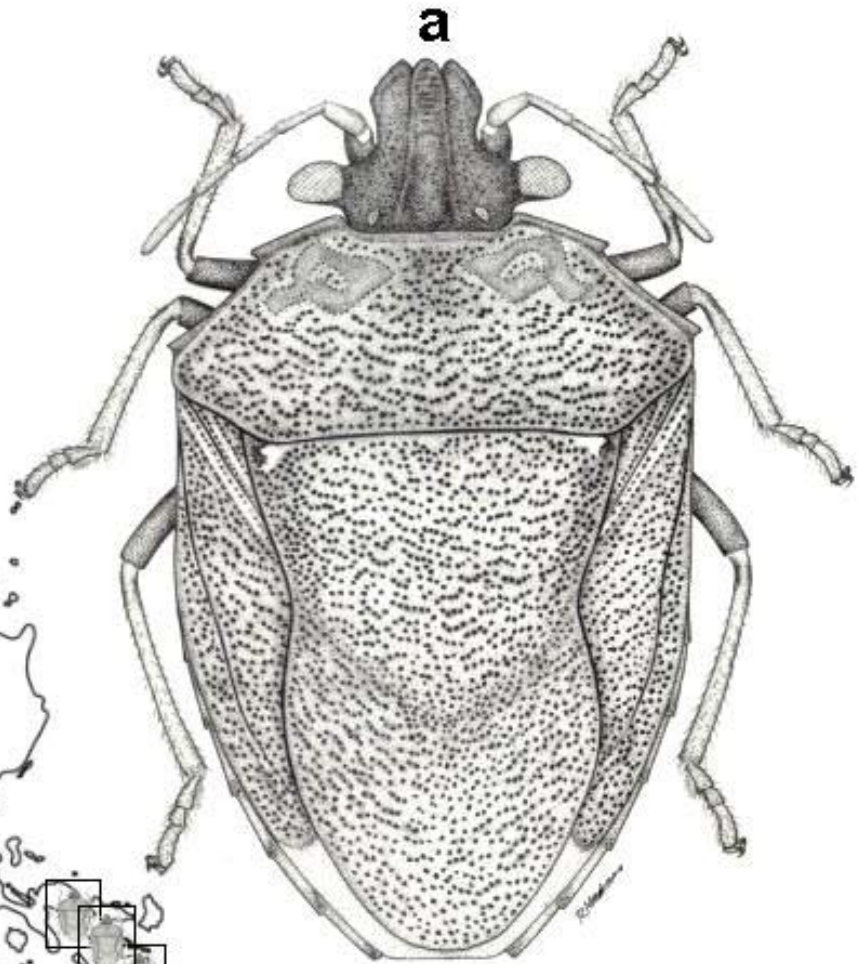
Plate 20
Scotinophara sorsogonensis

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e spiracle
f cross-section of gonophore
g left clasper
h dorsal view of aedeagus
i lateral view of aedeagus
j forewing
k hindwing
l spermatheca
m female genitalia
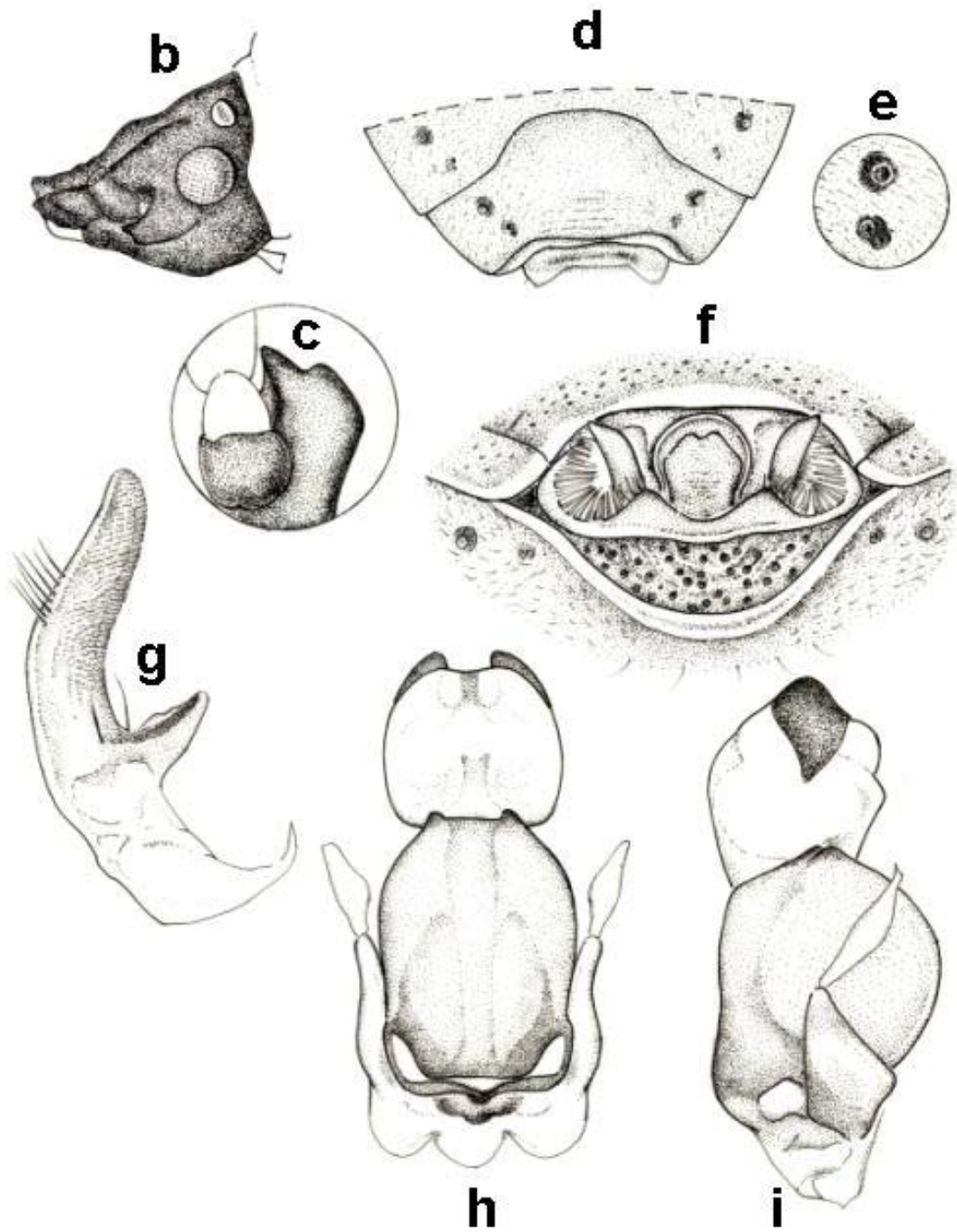
Plate 20 b-i
Scotinophara sorsogonensis
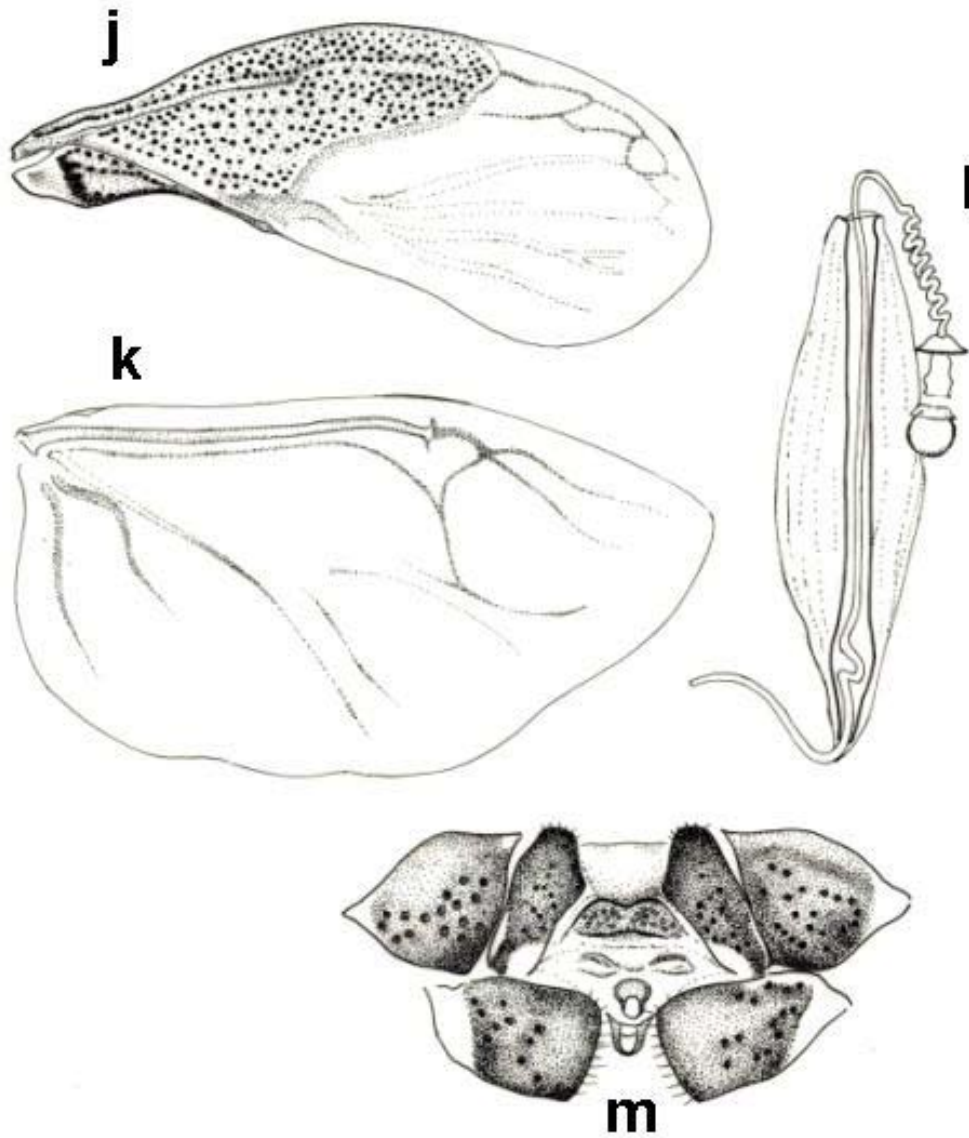
Plate 20 j-m
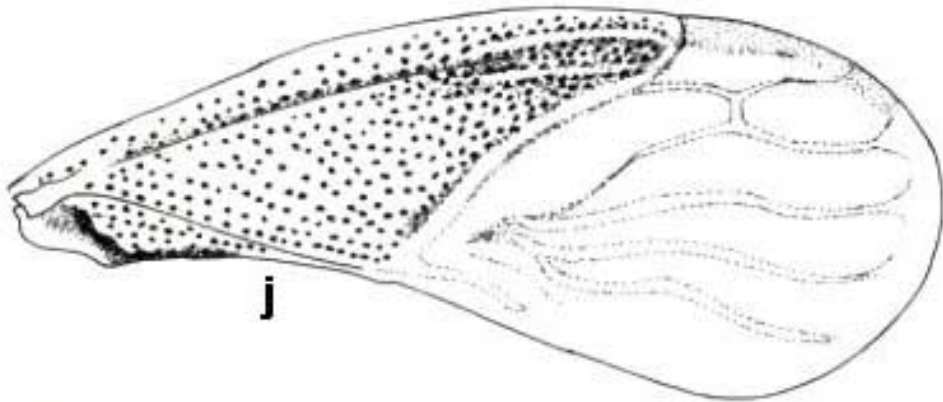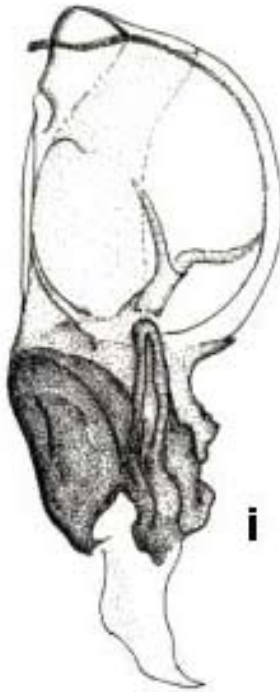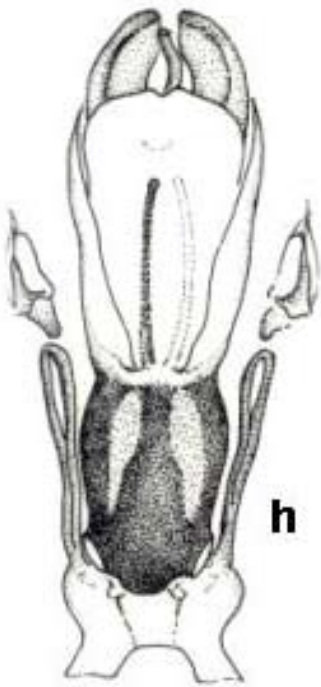*Scotinophara sorsogonensis*
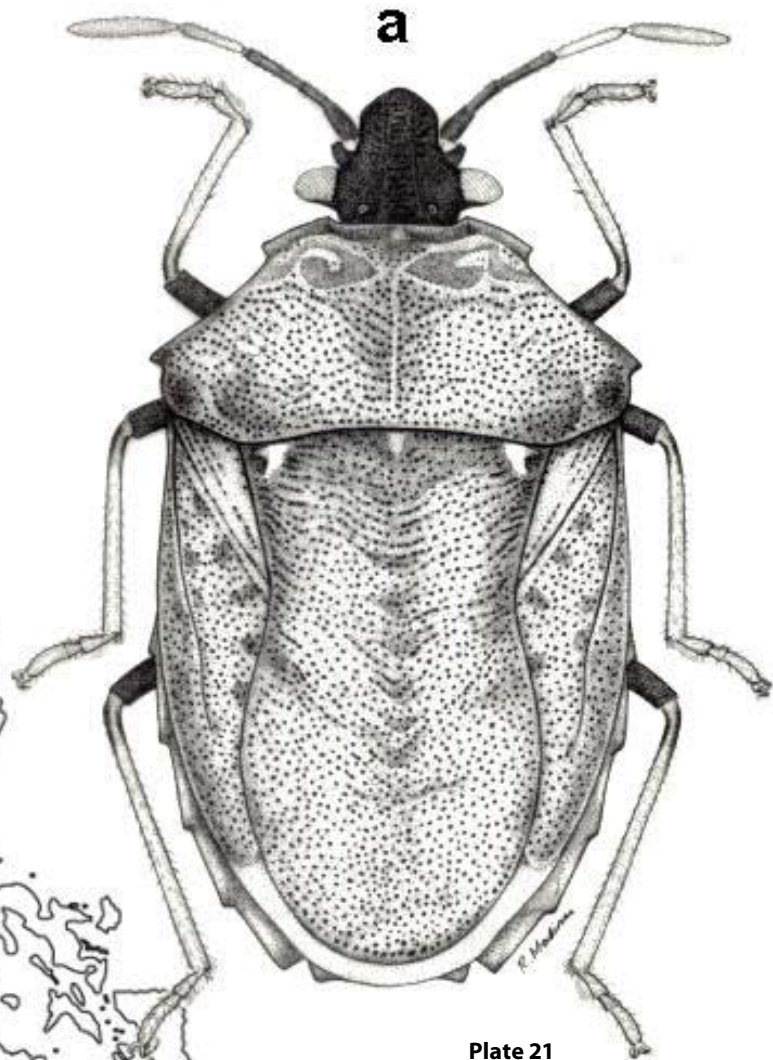
Plate 21
Scotinophara pirurotonga

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i tergite X
j forewing
k hindwing
l spermatheca
m female genitalia
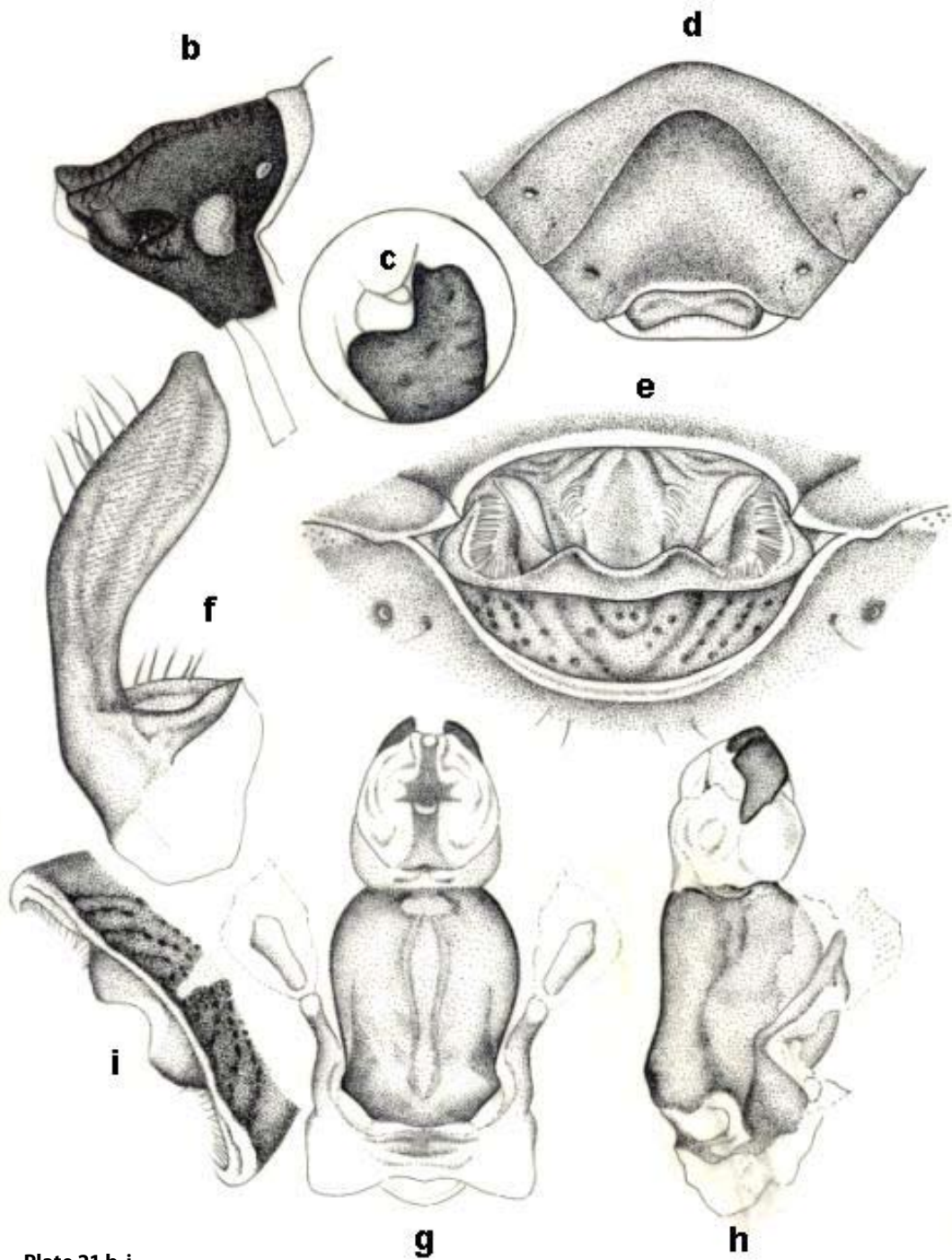
Plate 21 b-i
Scotinophara pirurotonga

Plate 21 j-m
Scotinophara pirurotonga
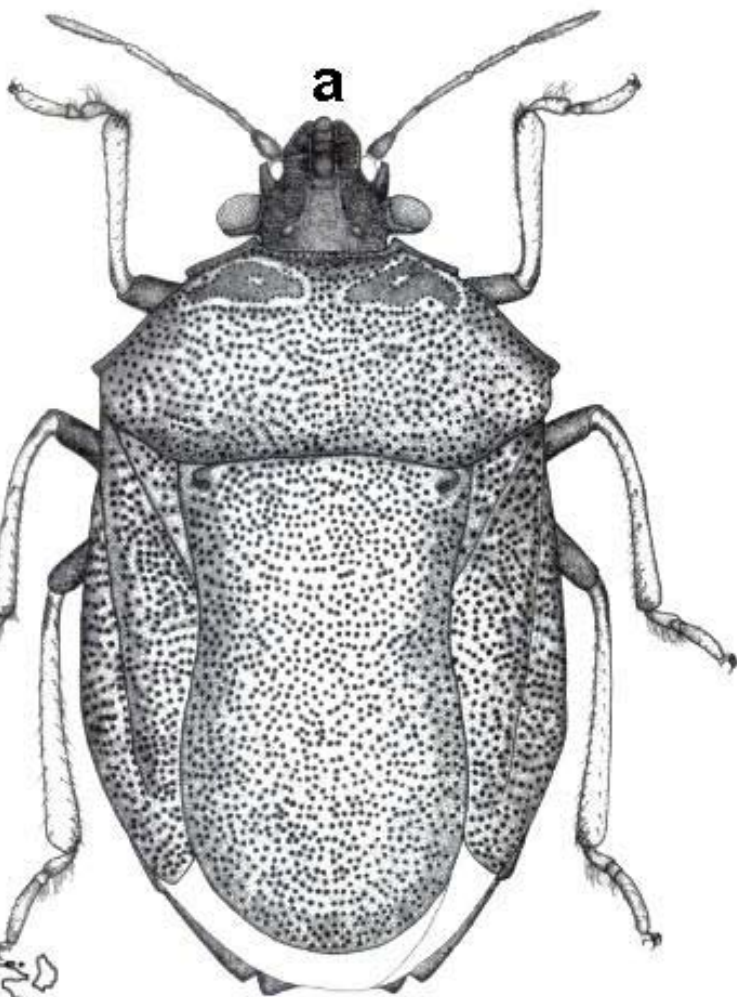
Plate 22
Scotinophara agusanortica

a male habitus
b lateral view of head
c ventral view of abdominal tip
d cross-section of gonophore
e left clasper
f dorsal view of aedeagus
g lateral view of aedeagus
h forewing
i hindwing
j spermatheca
k female genitalia
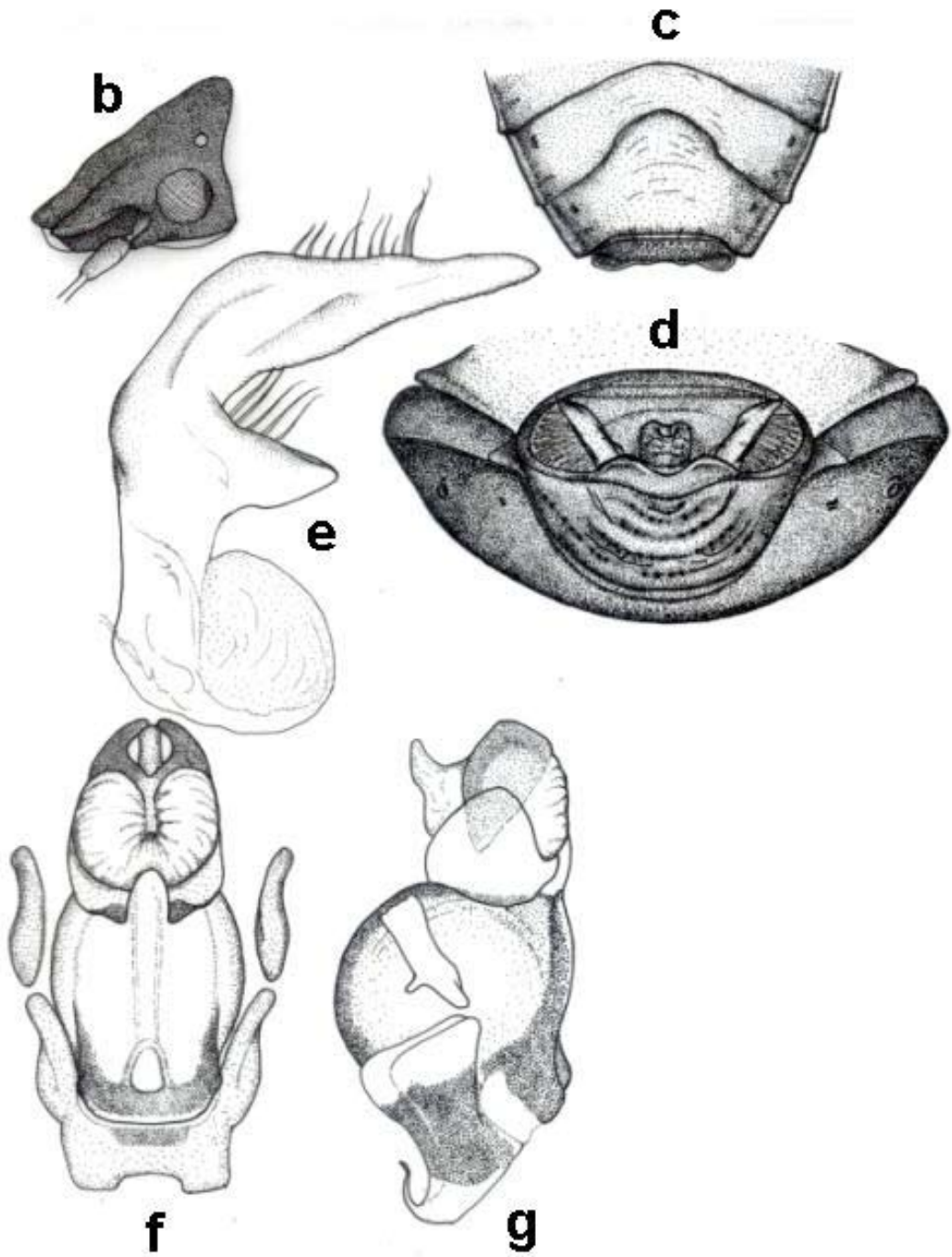
Plate 22 b-g
Scotinophara agusanortica
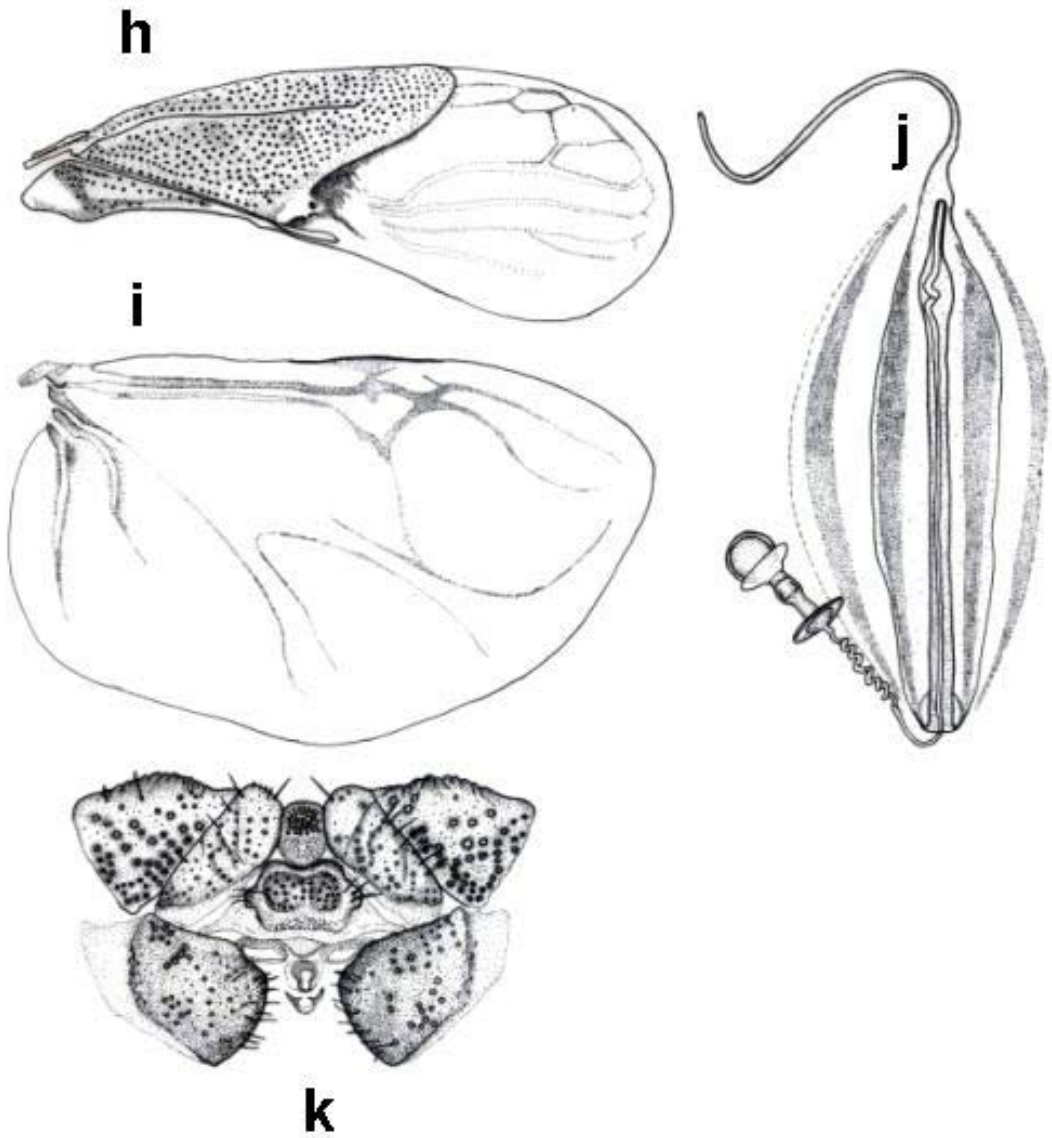
Plate 22 h-k
Scotinophara agusanortica
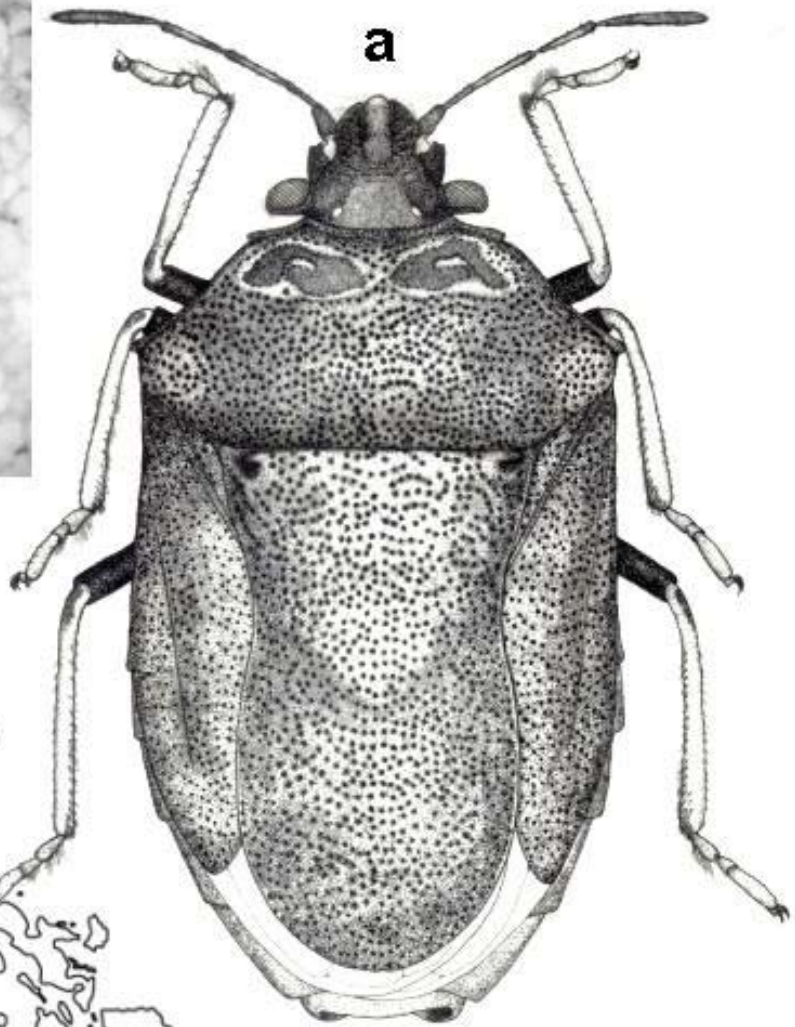
Plate 23
Scotinophara tantanganica

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e spiracle
f cross-section of gonophore
g left clasper
h dorsal view of aedeagus
i lateral view of aedeagus
j forewing
k hindwing
l spermatheca
m female genitalia
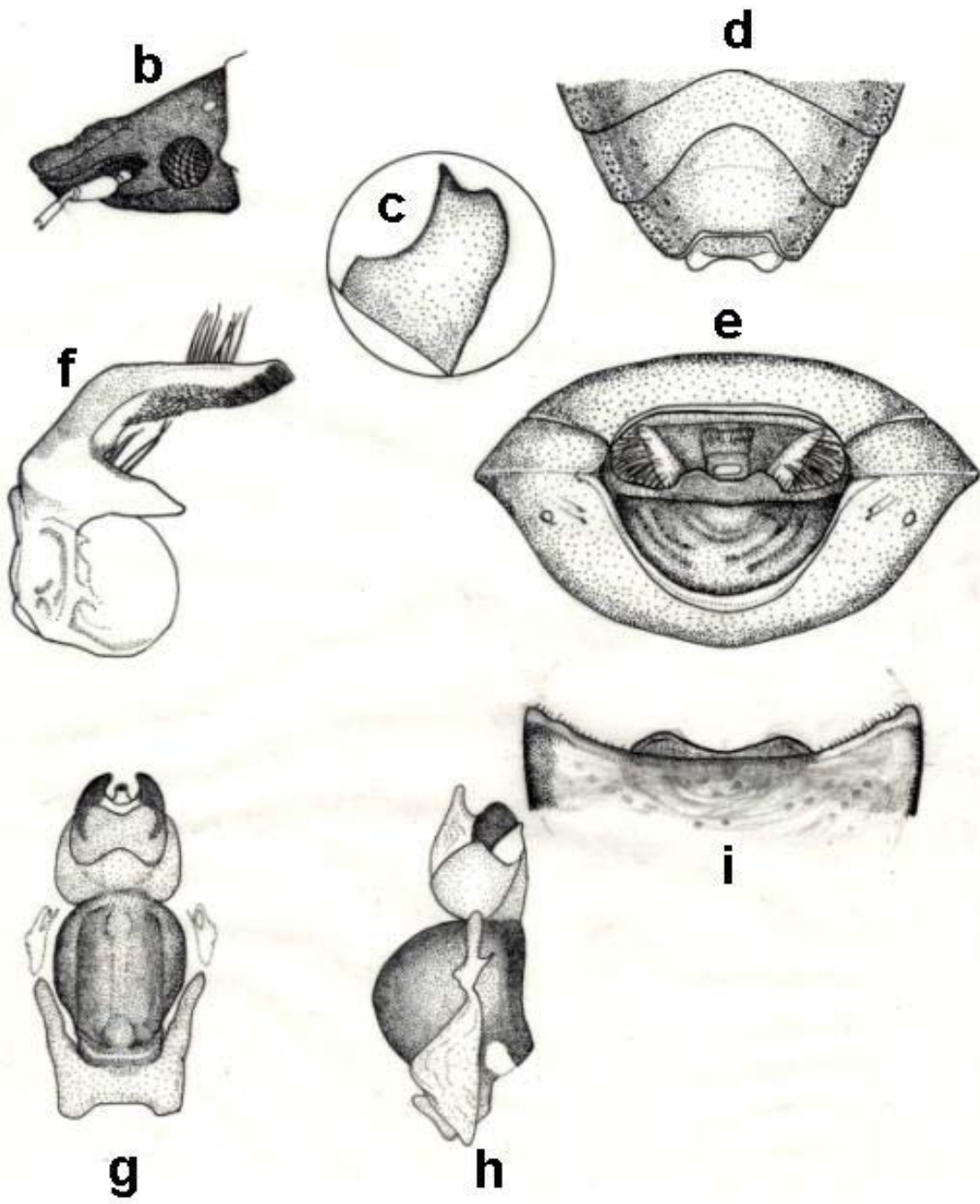
Plate 23 b-i
Scotinophara tantanganica
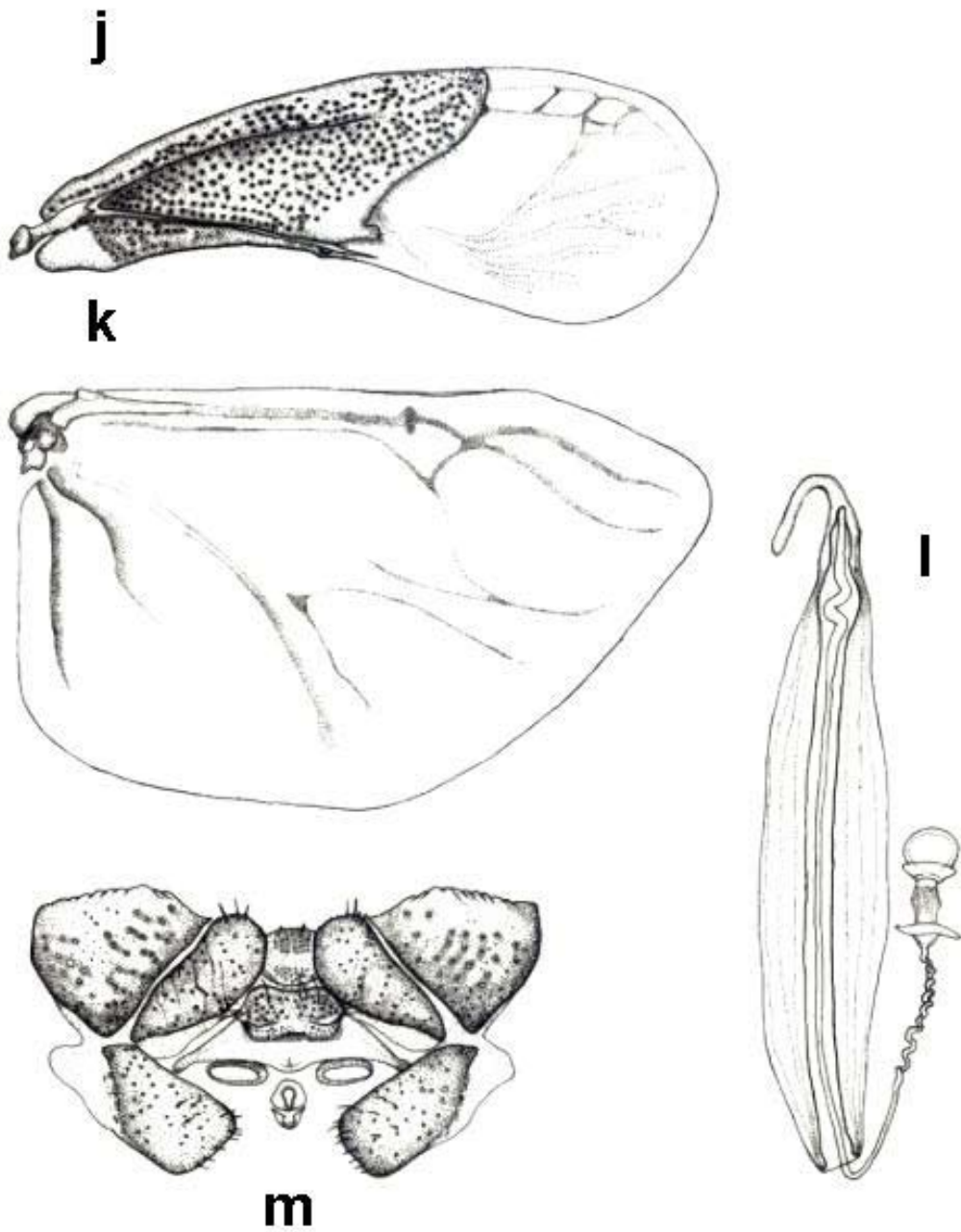
Plate 23 j-m
Scotinophara tantanganica
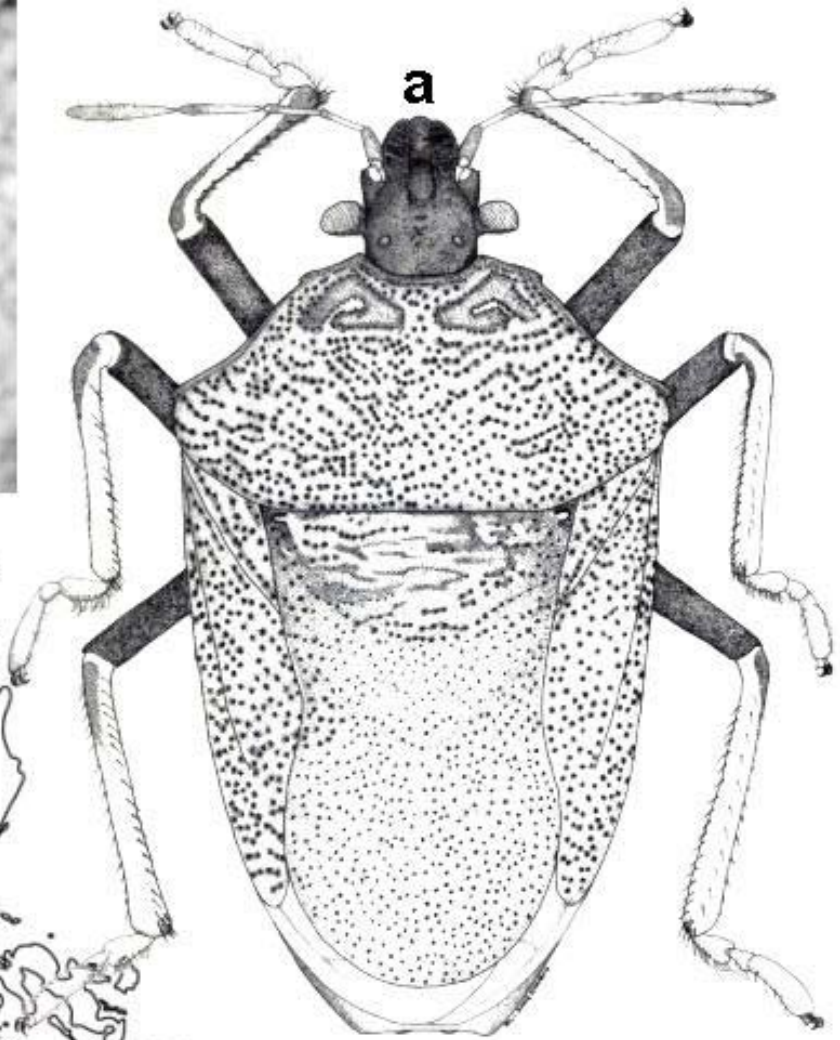
Plate 24
Scotinophara midsayapensis

a male habitus
b lateral view of head
c c. antenniferous tubercle
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i forewingj
j hindwing
k spermatheca
l female genitalia
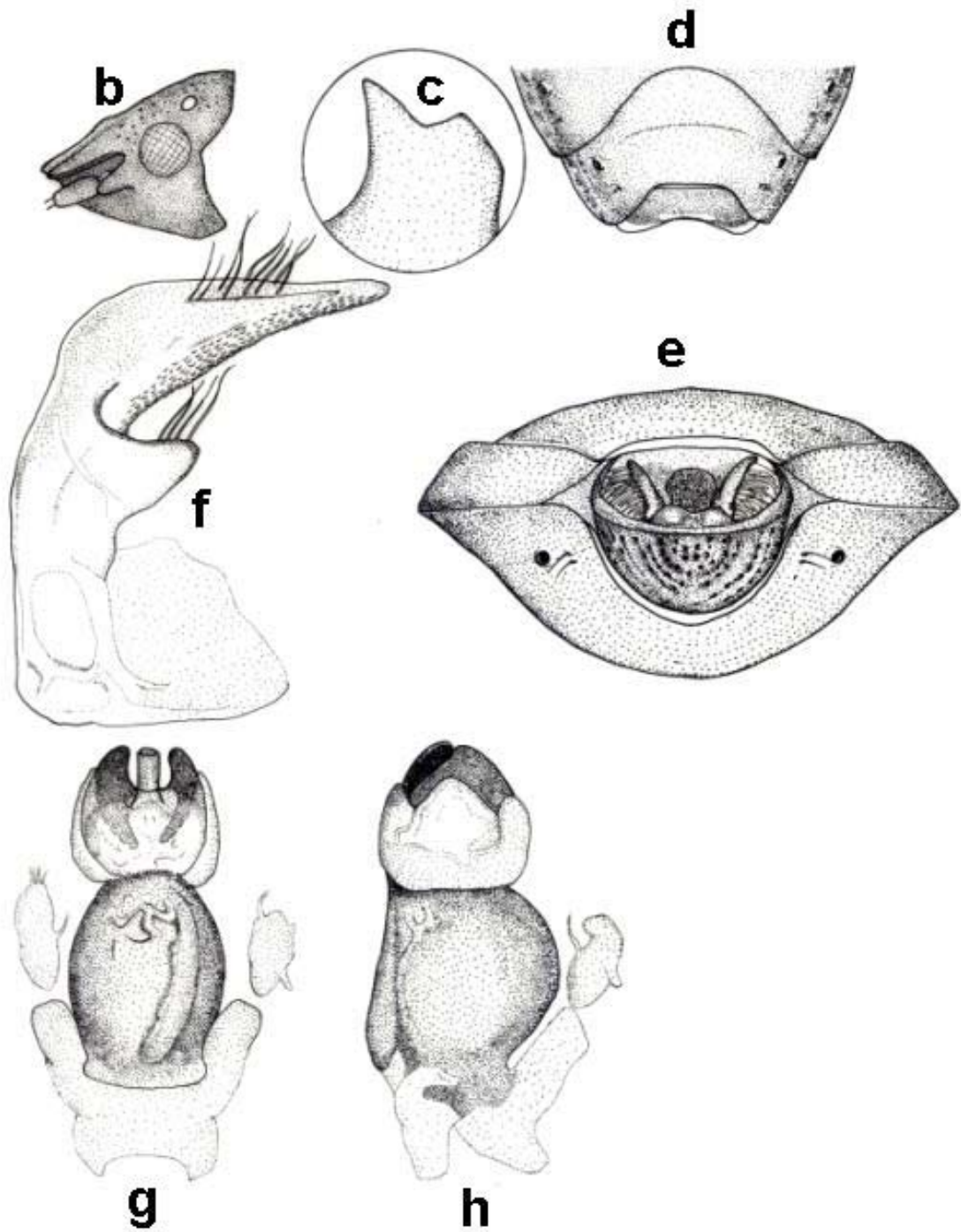
Plate 24 b-h
Scotinophara midsayapensis
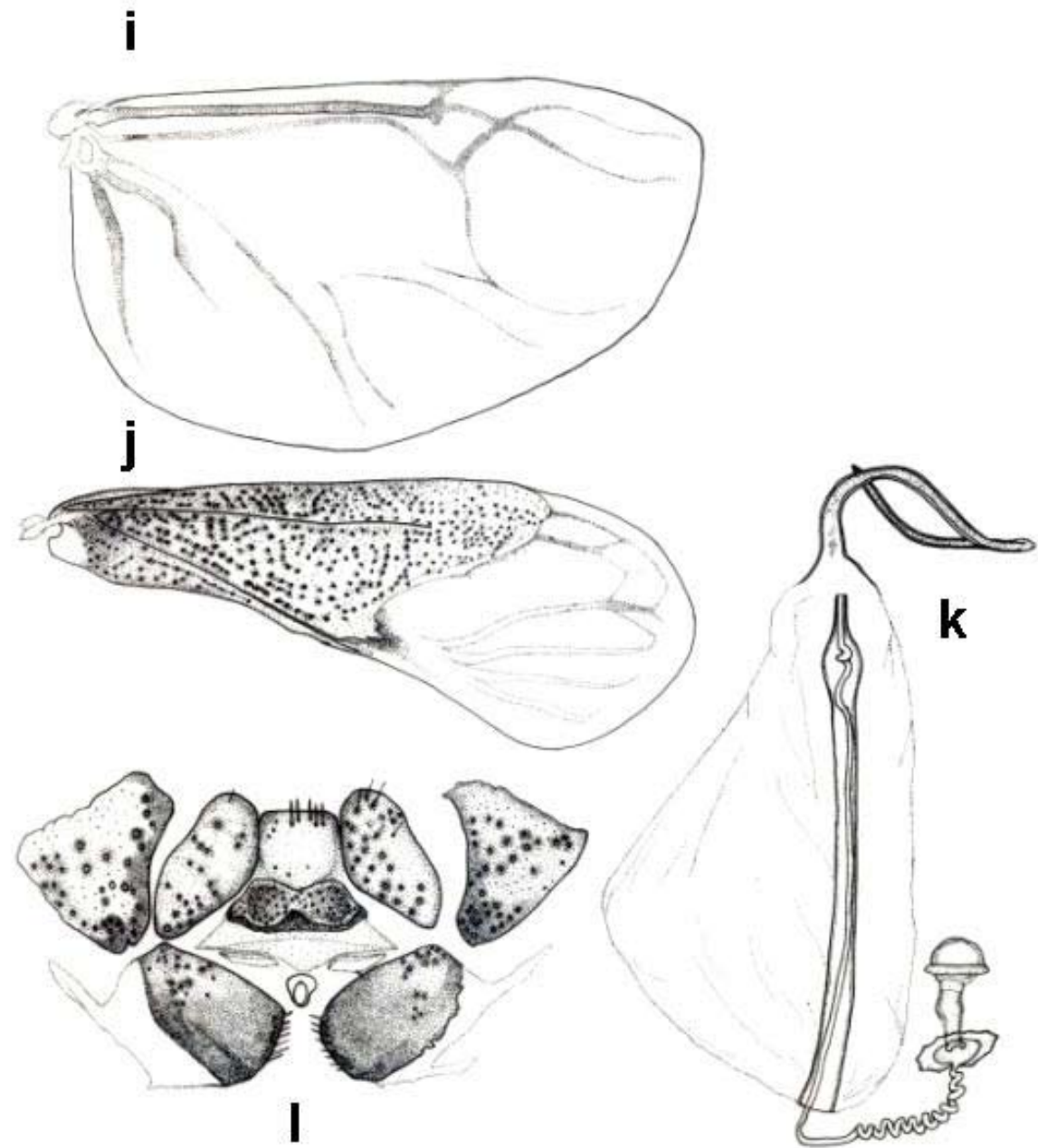
Plate 24 i-l
Scotinophara midsayapensis
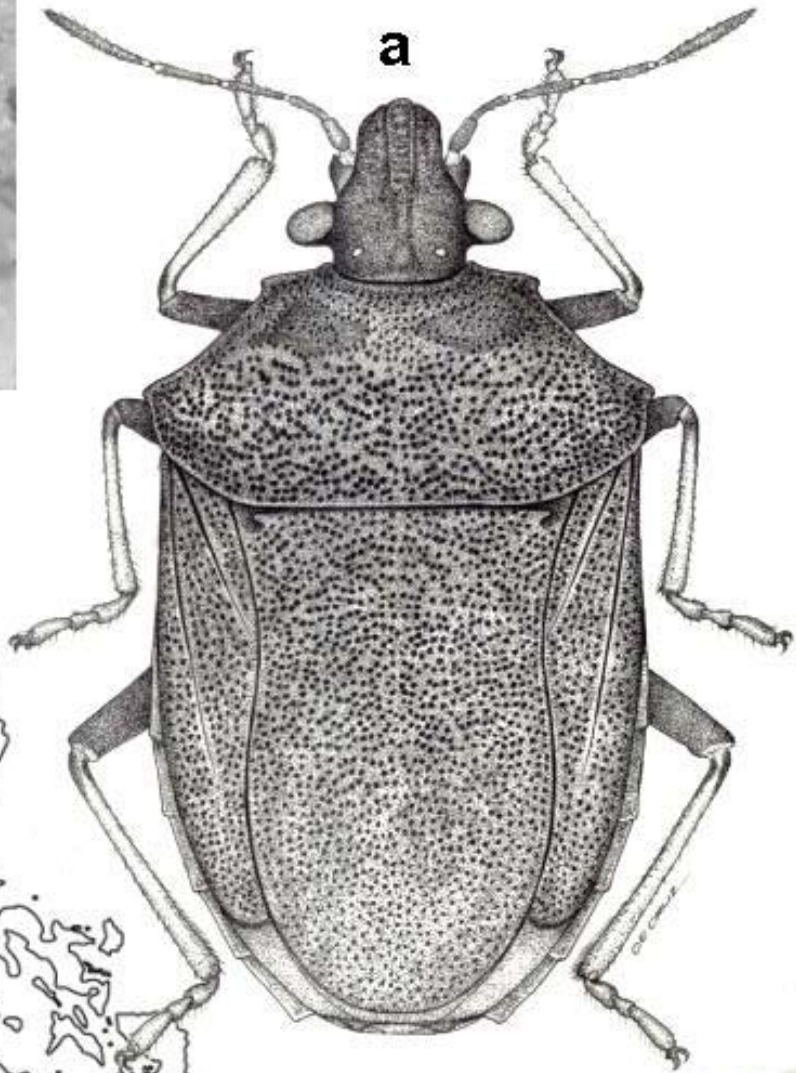
Plate 25
Scotinophara putikanica

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i tergite X
j forewing
k hindwing
l spermatheca
m female genitalia
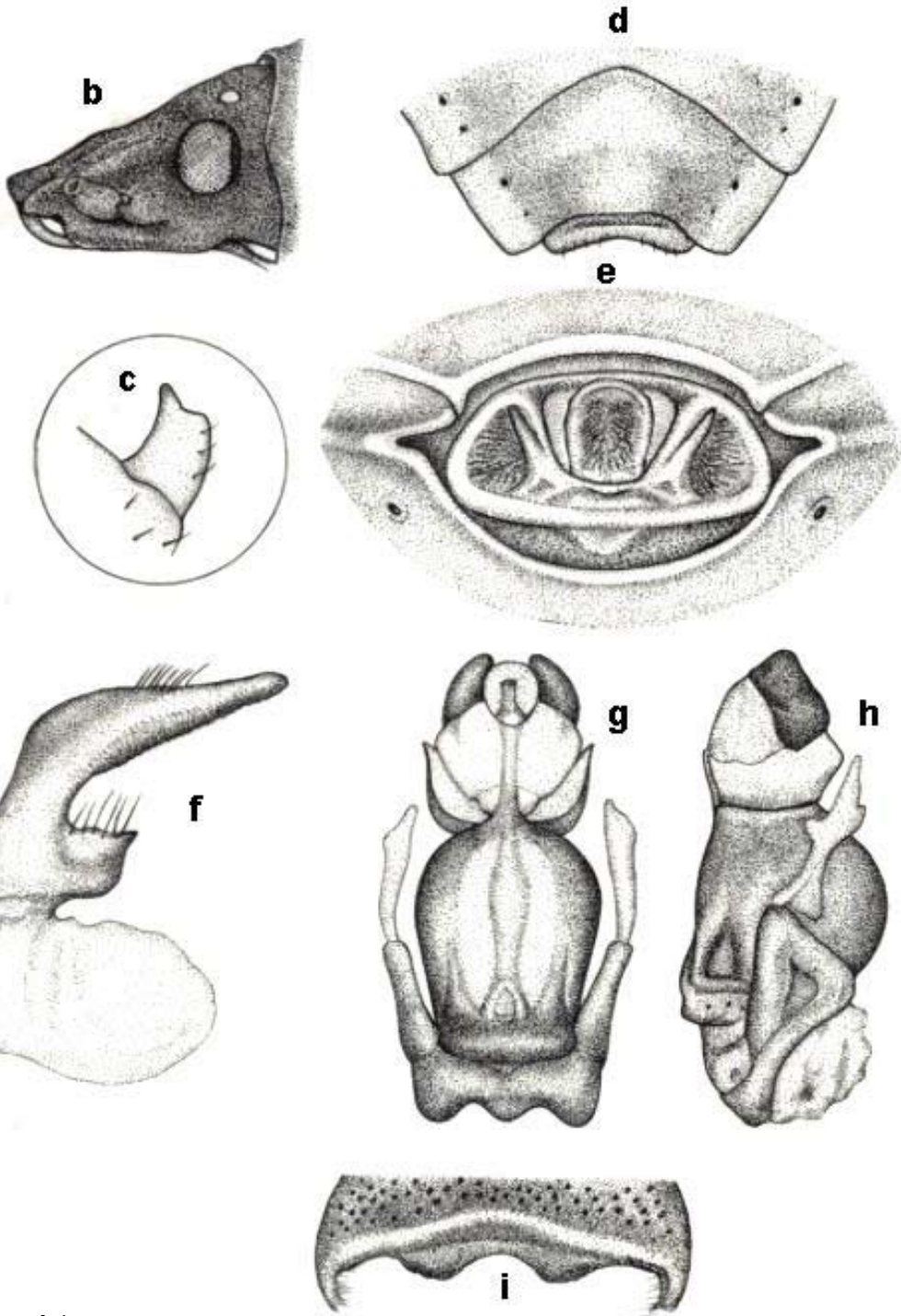
Plate 25 b-i
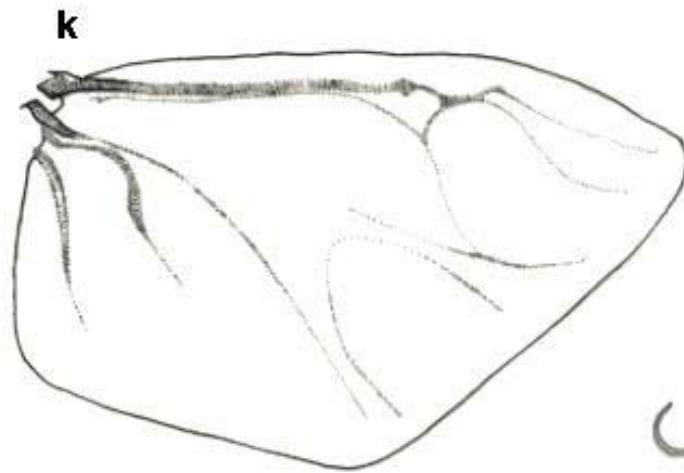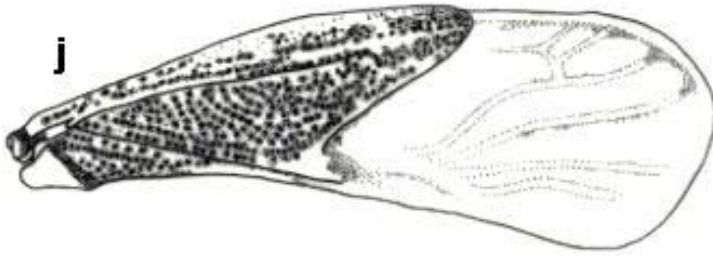*Scotinophara putikanica*
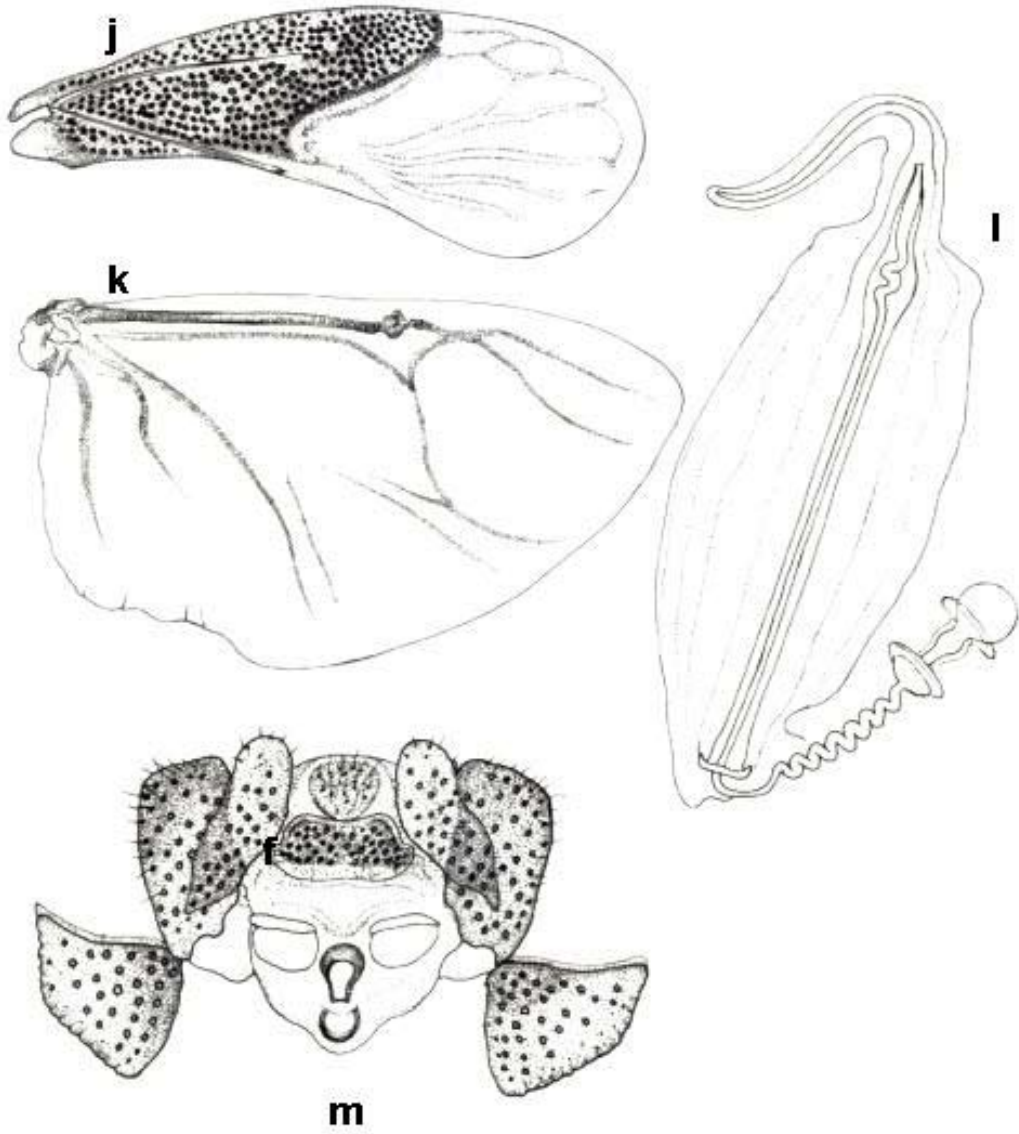
Plate 25 j-m
Scotinophara putikanica
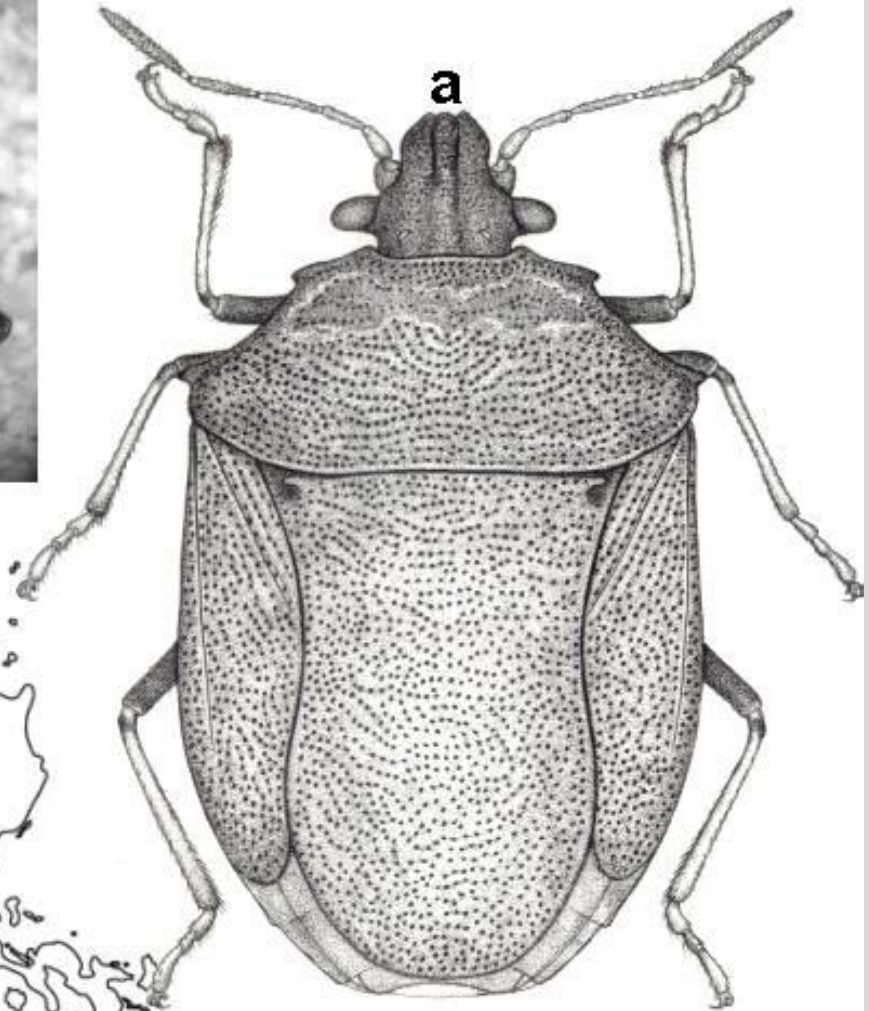
Plate 26
Scotinophara coarctata

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i tergite X
j forewing
k hindwing
l spermatheca
m female genitalia
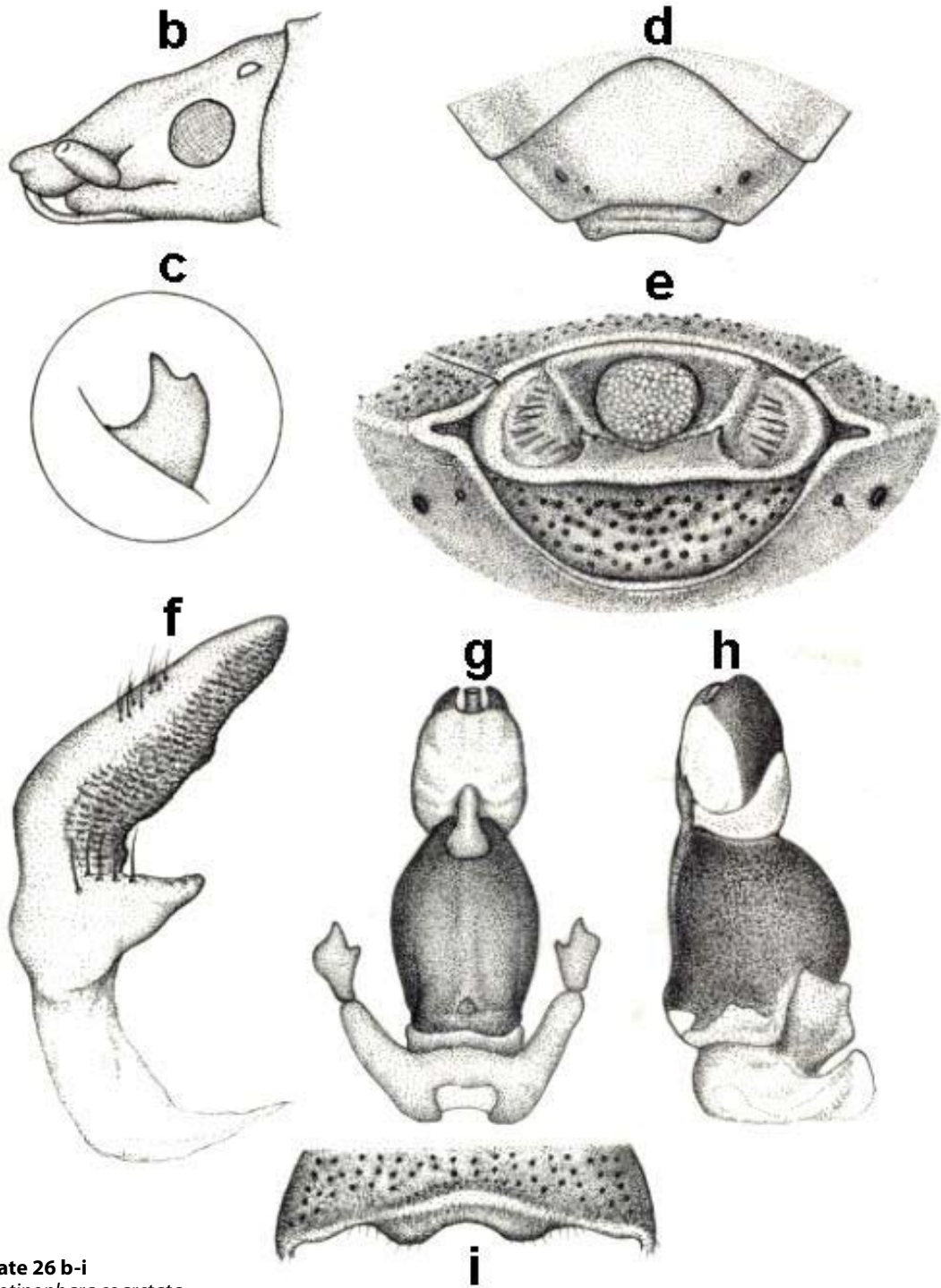
Plate 26 b-i
Scotinophara coarctata
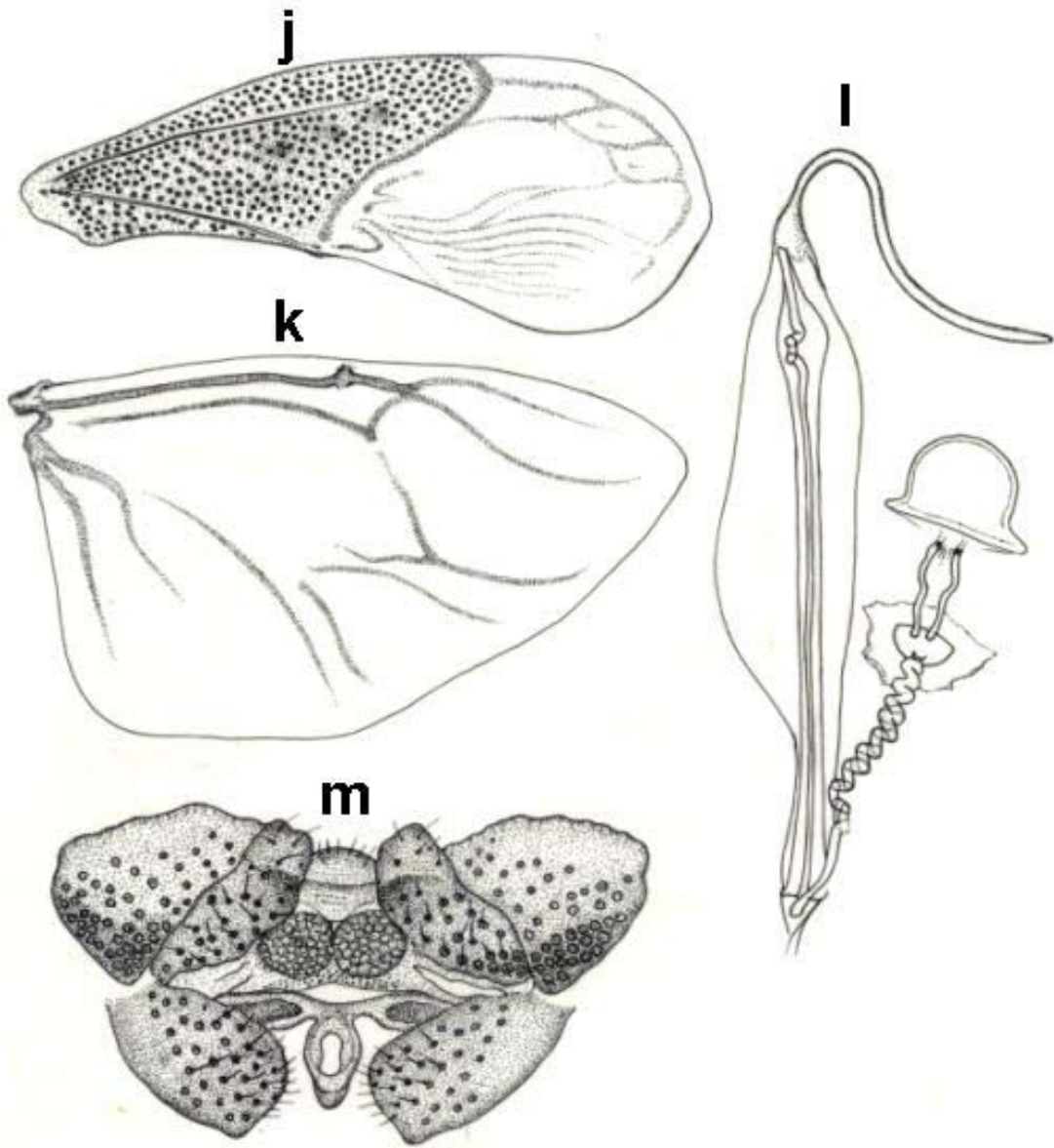
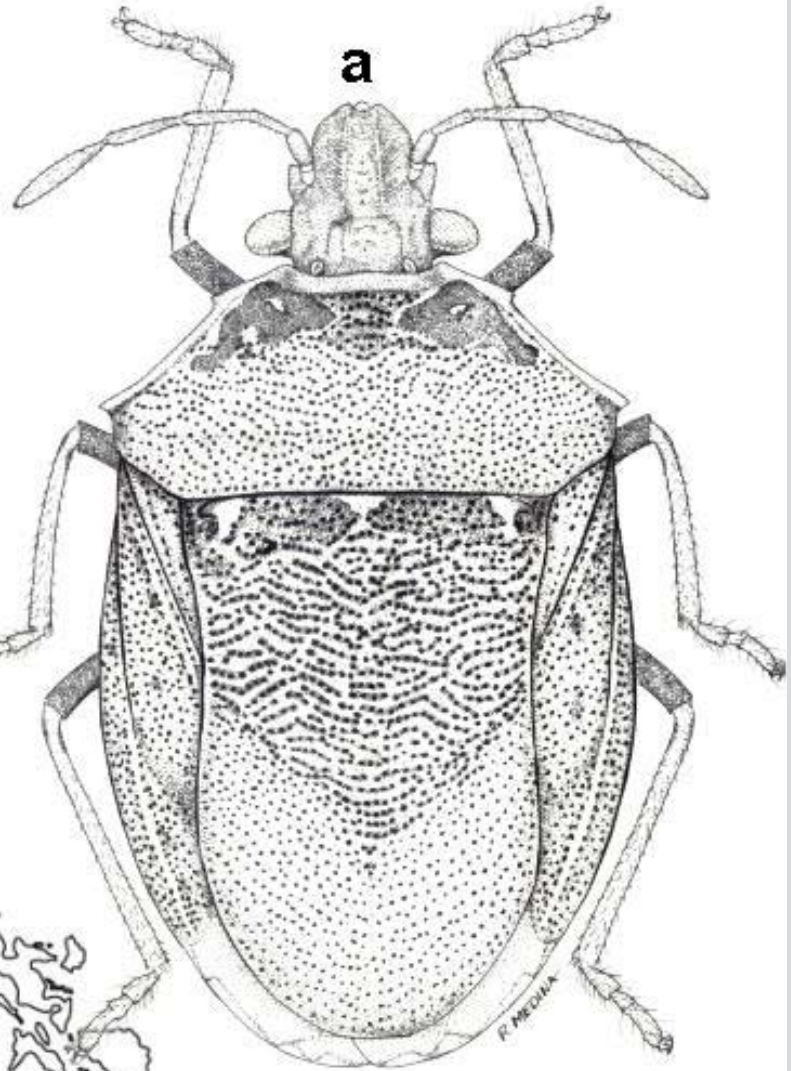**Plate 26 j-m**
Scotinophara coarctata
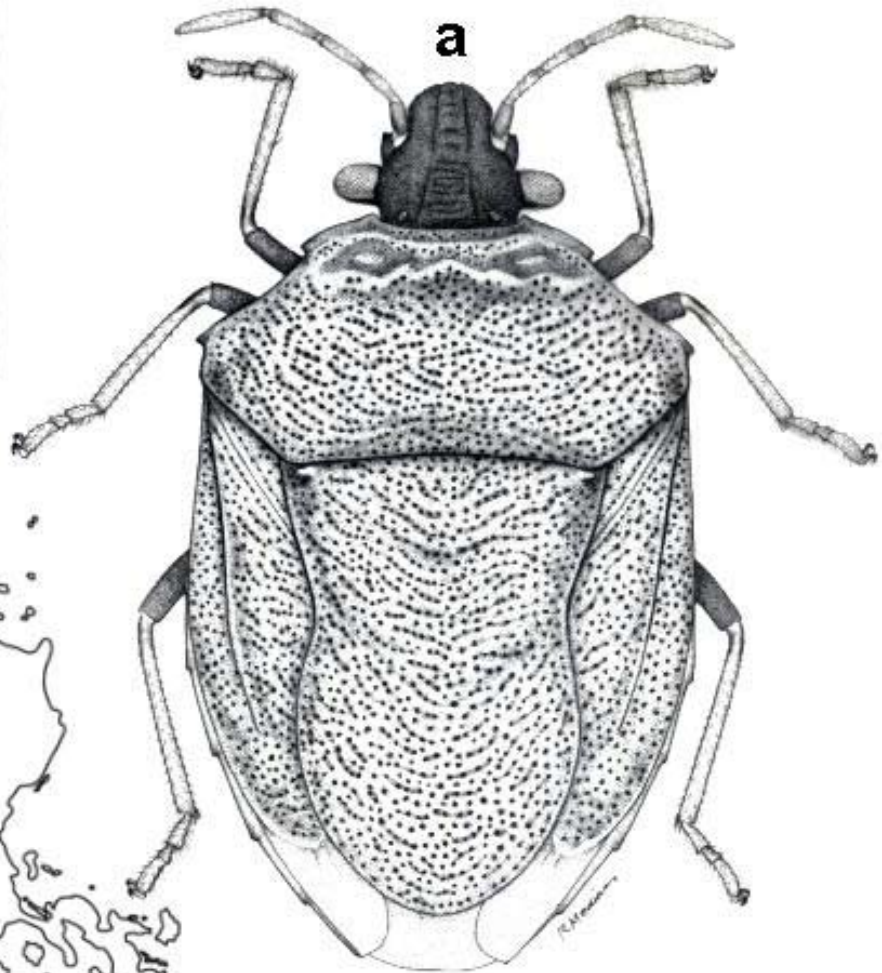
Plate 27
Scotinophara alegria

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i tergite X
j forewing
k hindwing
l spermatheca
m female genitalia
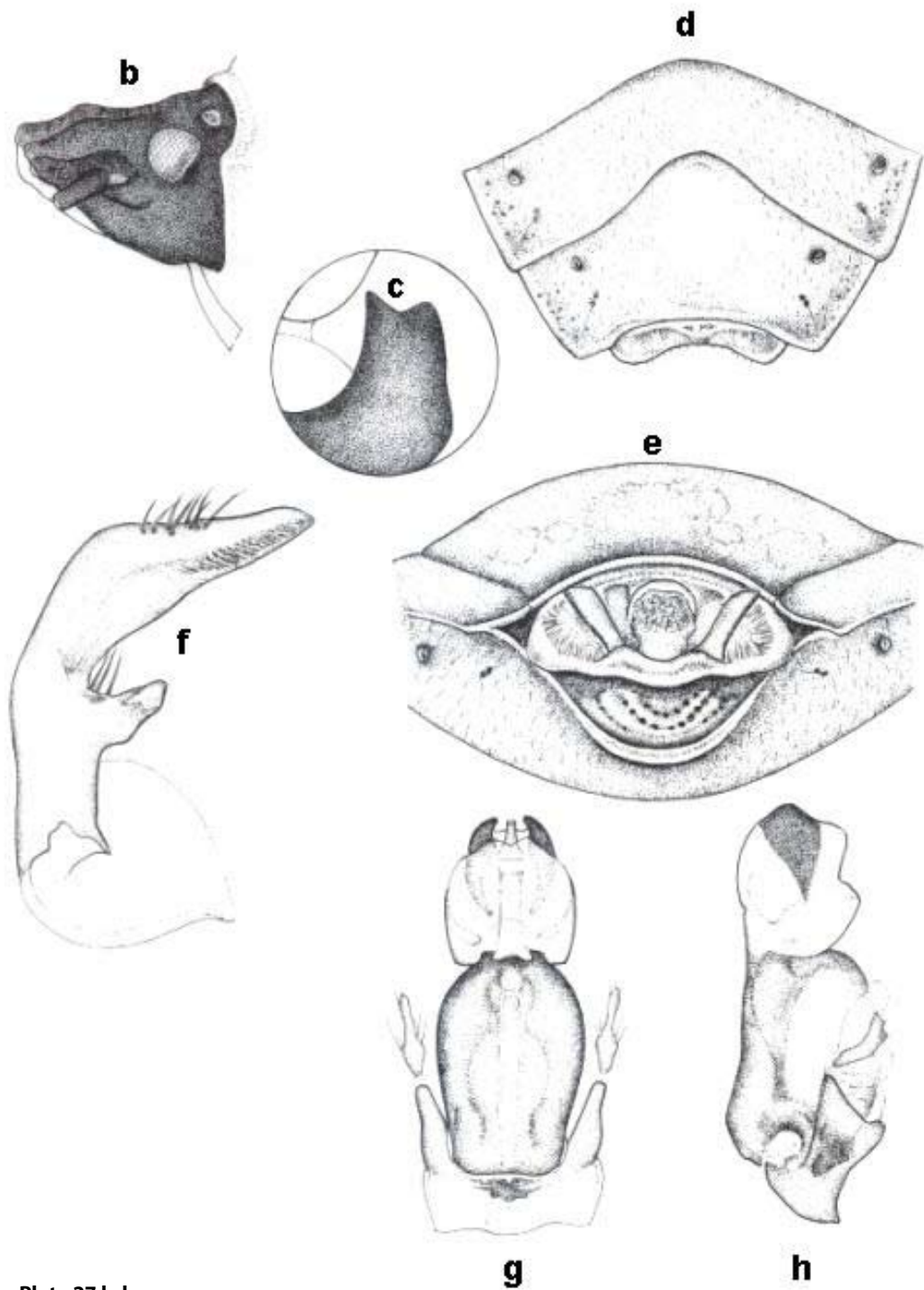
Plate 27 b-h
Scotinophara alegria
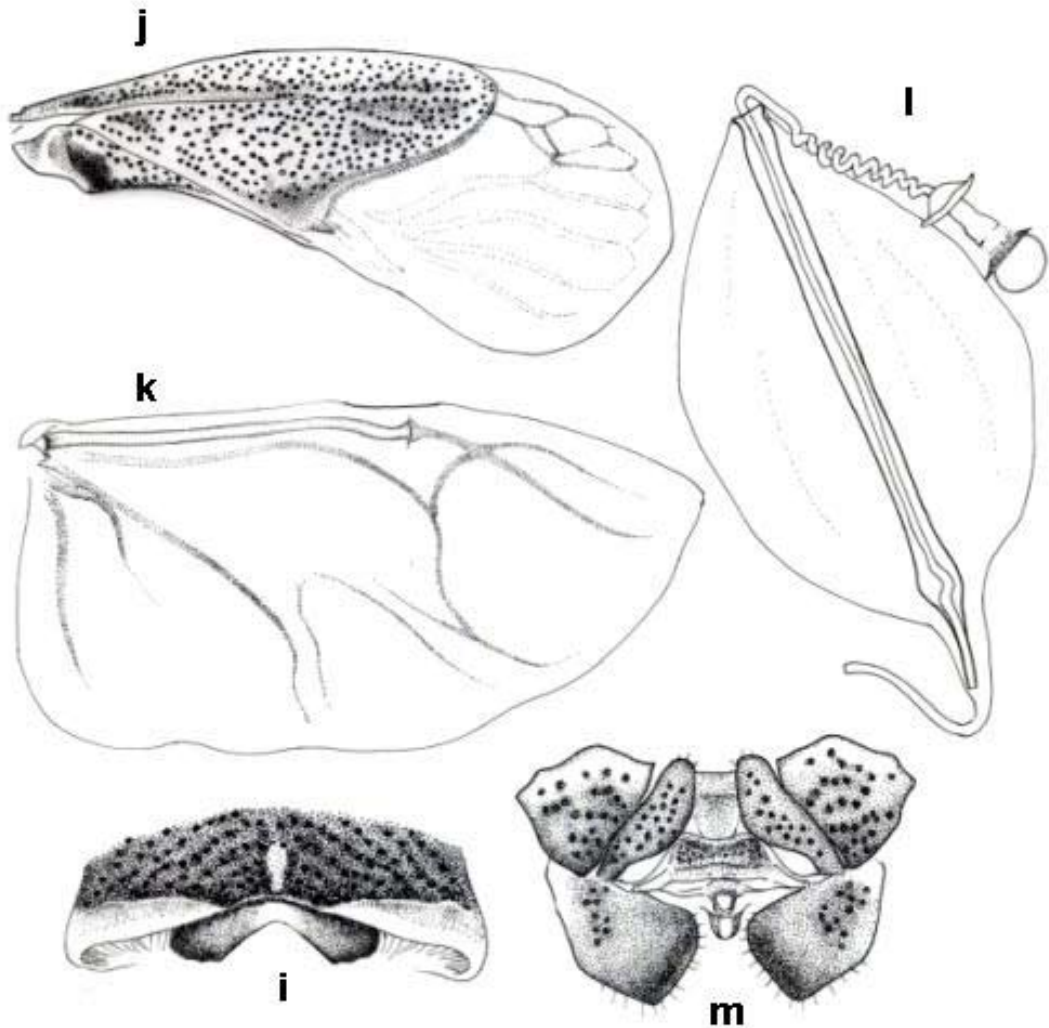
Plate 27 i-m
Scotinophara alegria

a
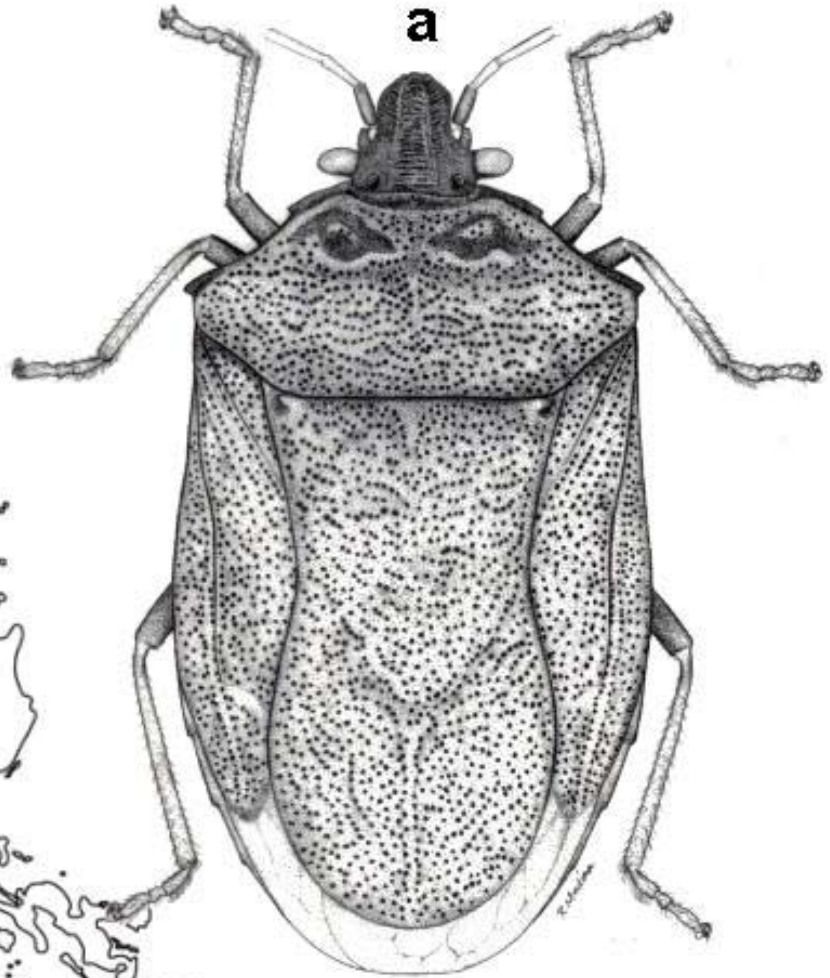
Plate 28
Scotinophara kabangkalanensis

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e left clasper
f dorsal view of aedeagus
g lateral view of aedeagus
h tergite X
i forewing
j hindwing
k spermatheca
l female genitalia
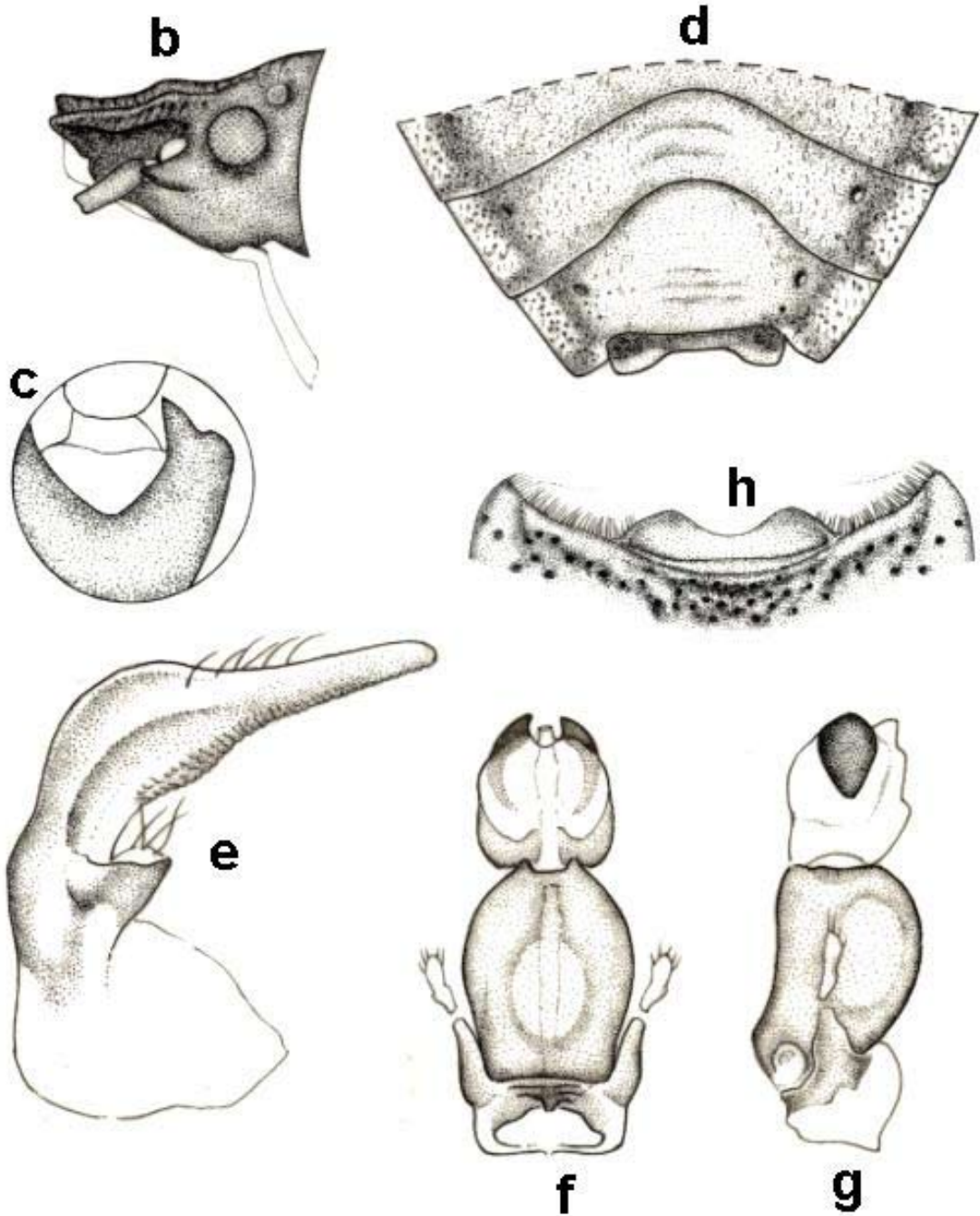
Plate 28 b-h
Scotinophara kabangkalanensis
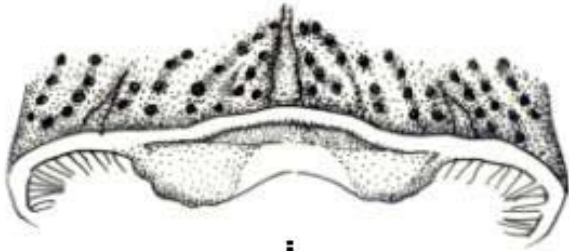
i

j

k

l
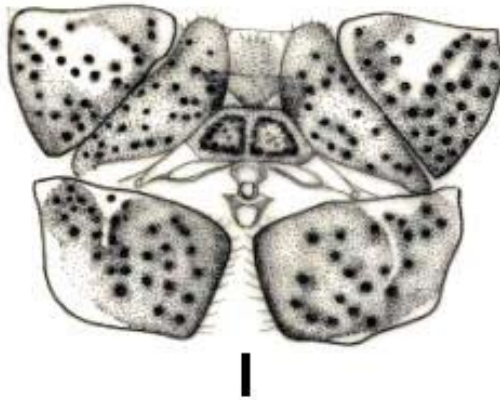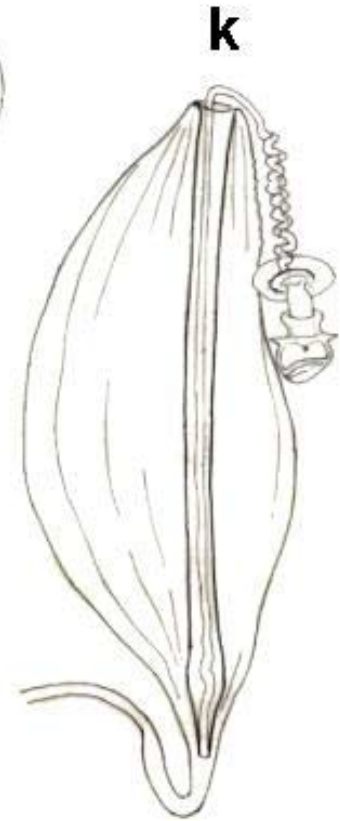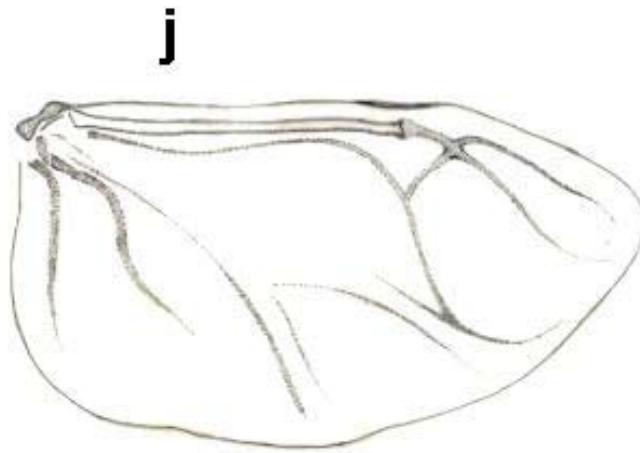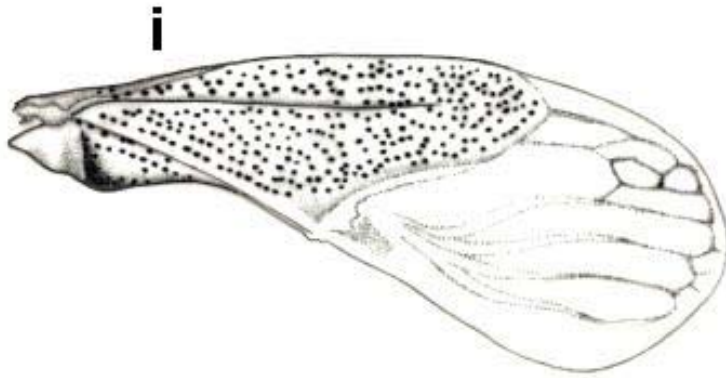
Plate 28 i-l
Scotinophara kabangkalanensis
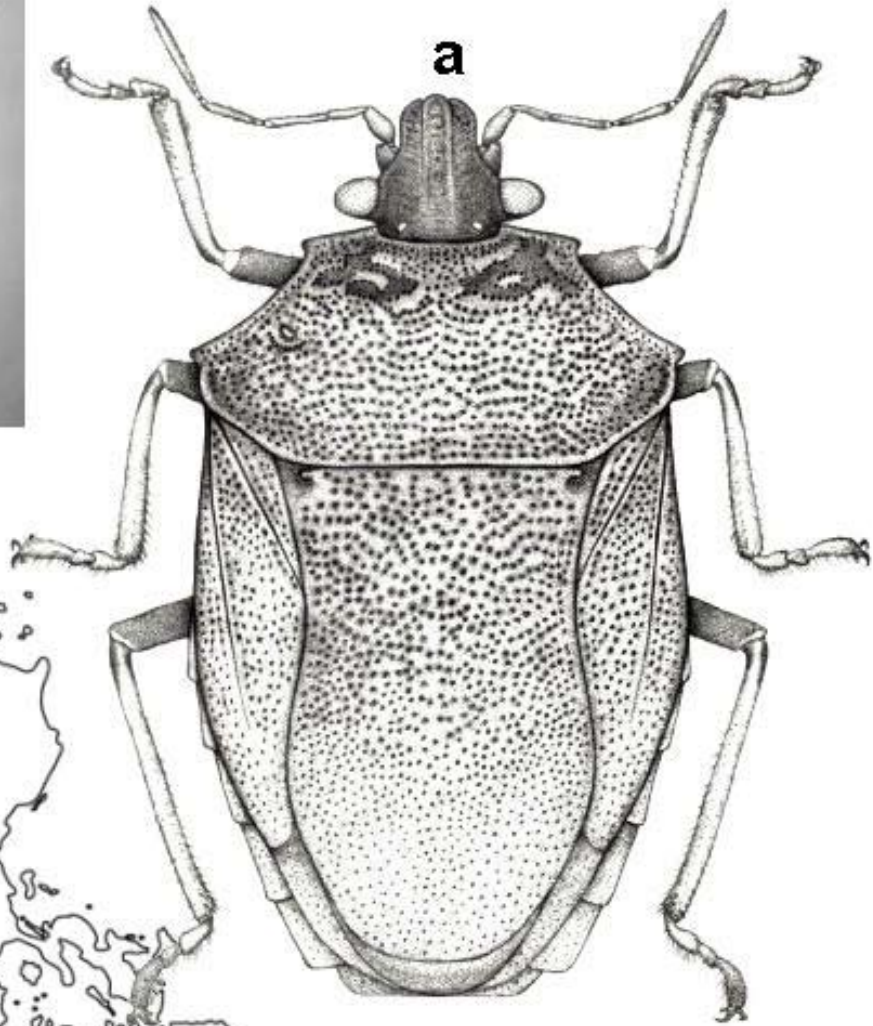
Plate 29
Scotinophara zamboanga

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i tergite X
j forewing
k hindwing
l spermatheca
m female genitalia
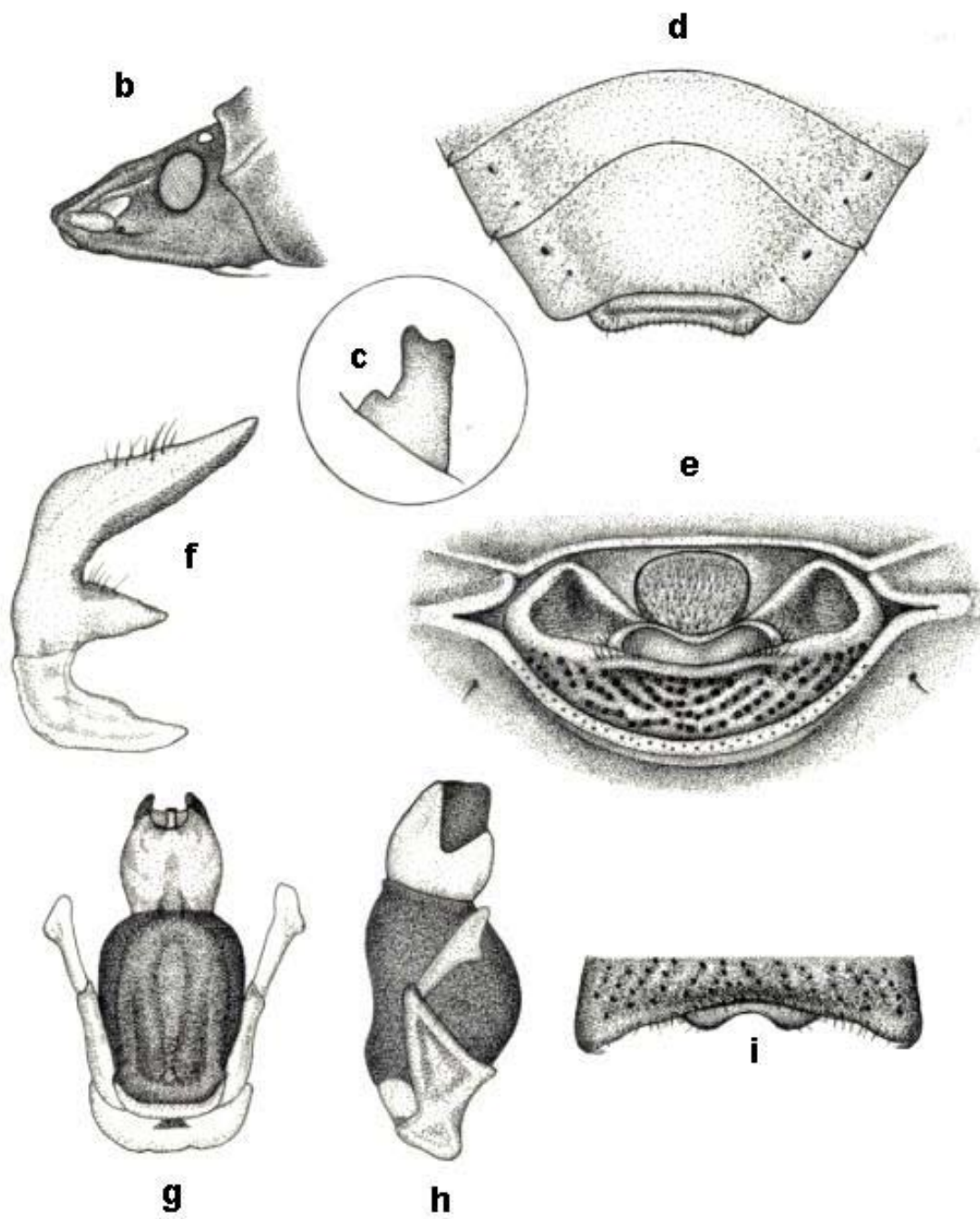
Plate 29 b-i
Scotinophara zamboanga
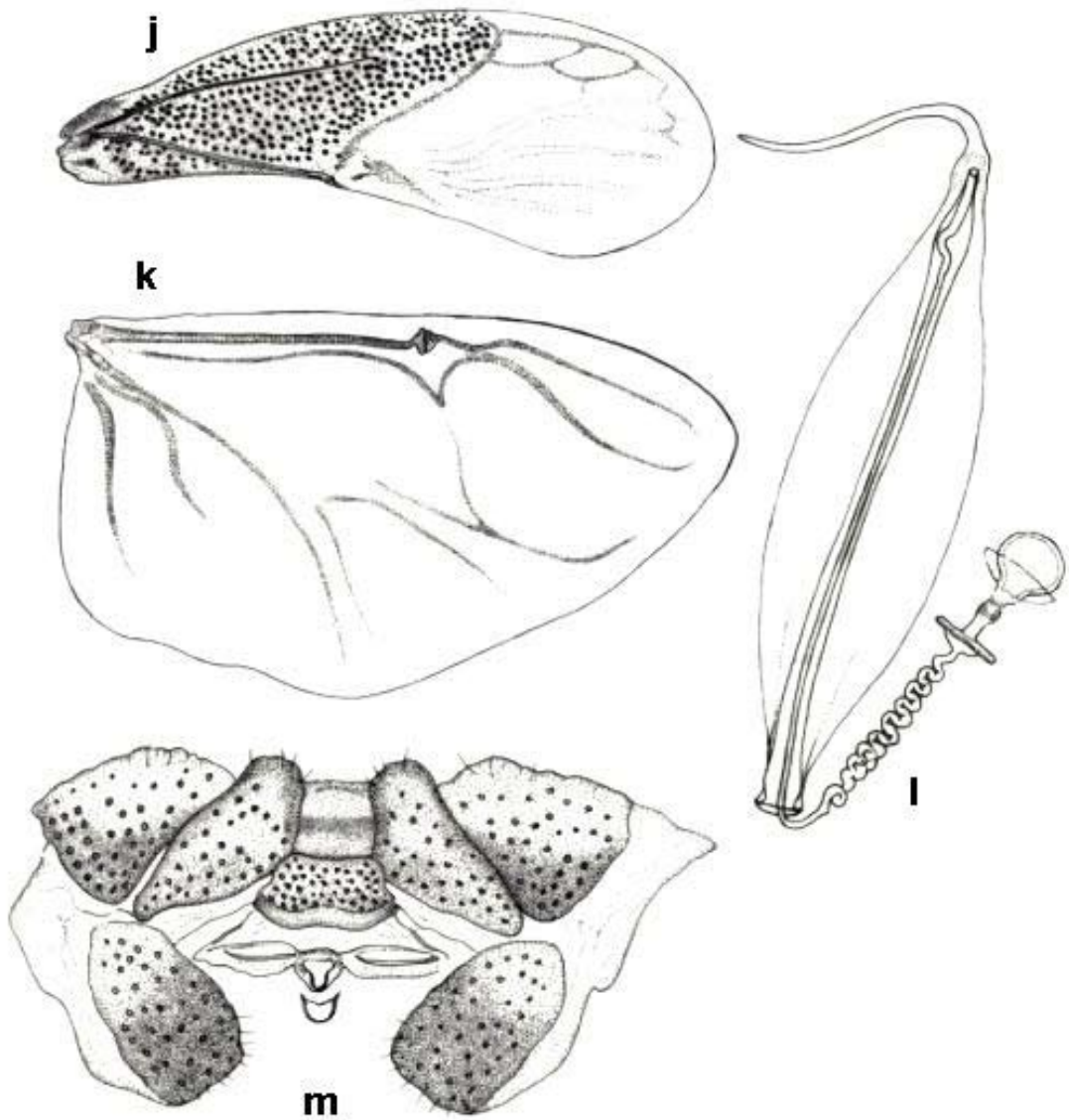
Plate 29 j-m
Scotinophara zamboanga
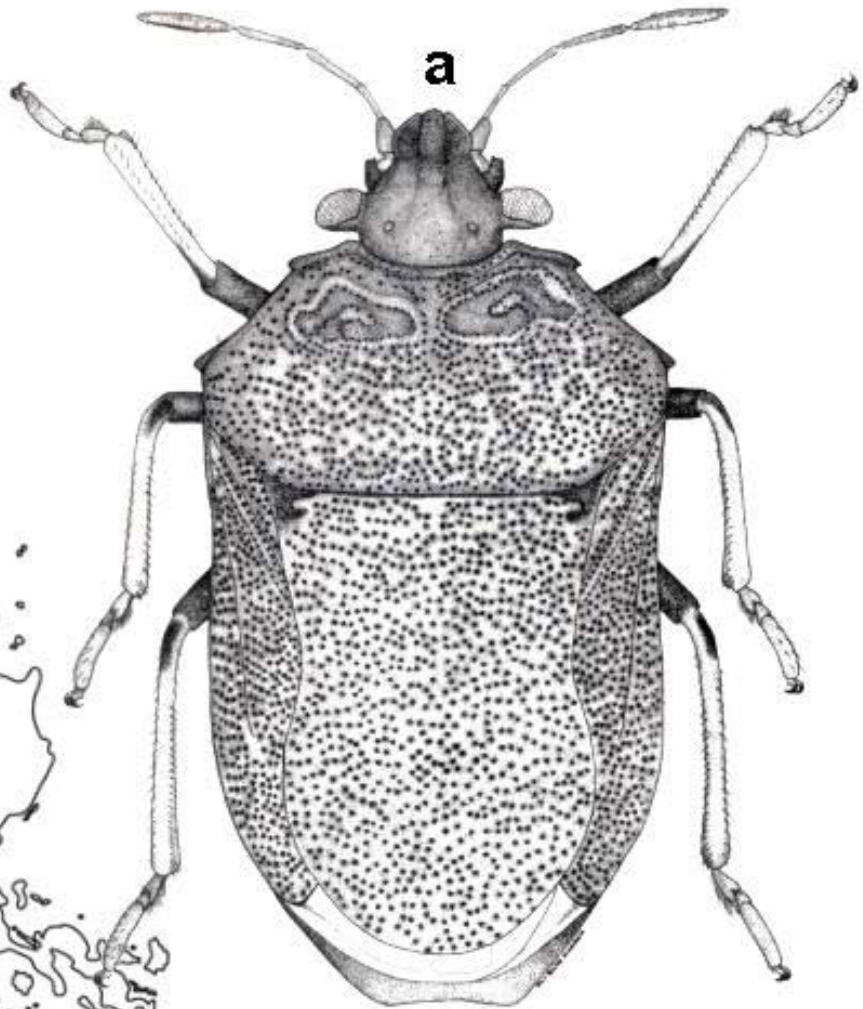
Plate 30
Scotinophara trifurcata

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i forewing
j hindwing
k spermatheca
l female genitalia
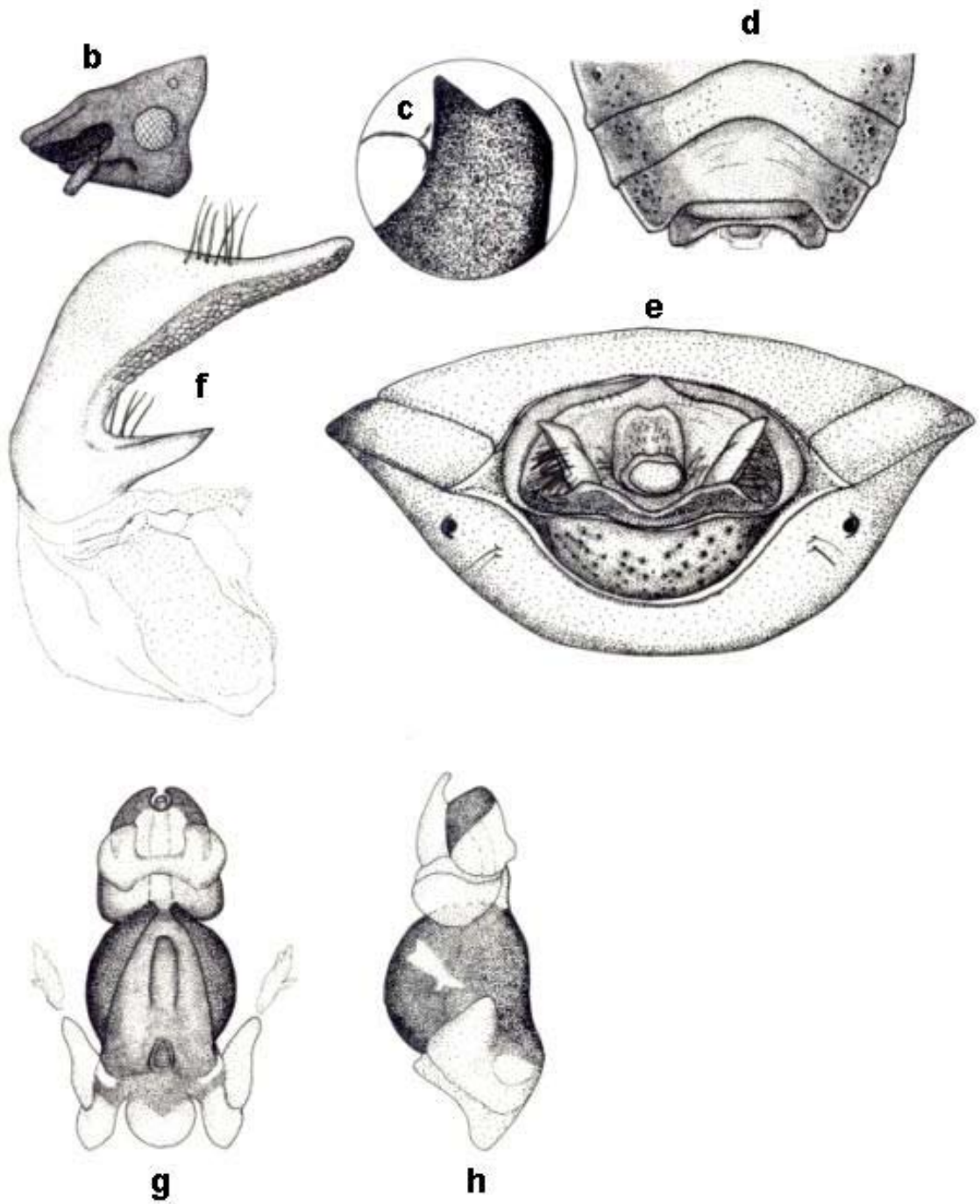
Plate 30 b-h
Scotinophara trifurcata
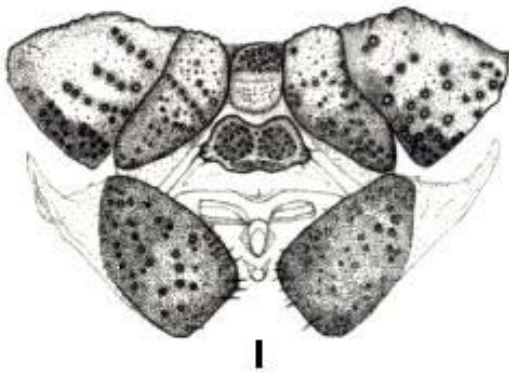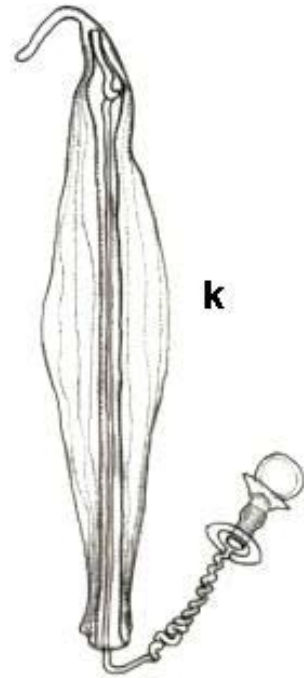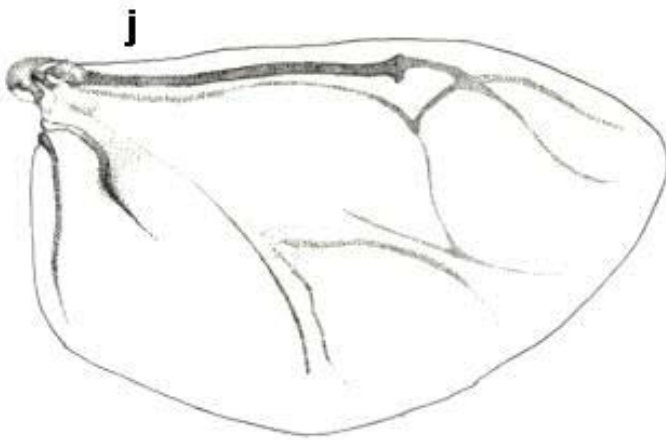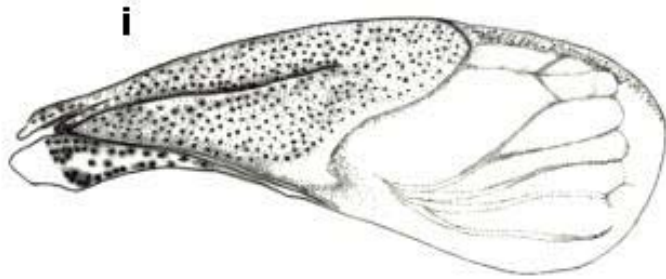
Plate 30 i-l
Scotinophara trifurcata
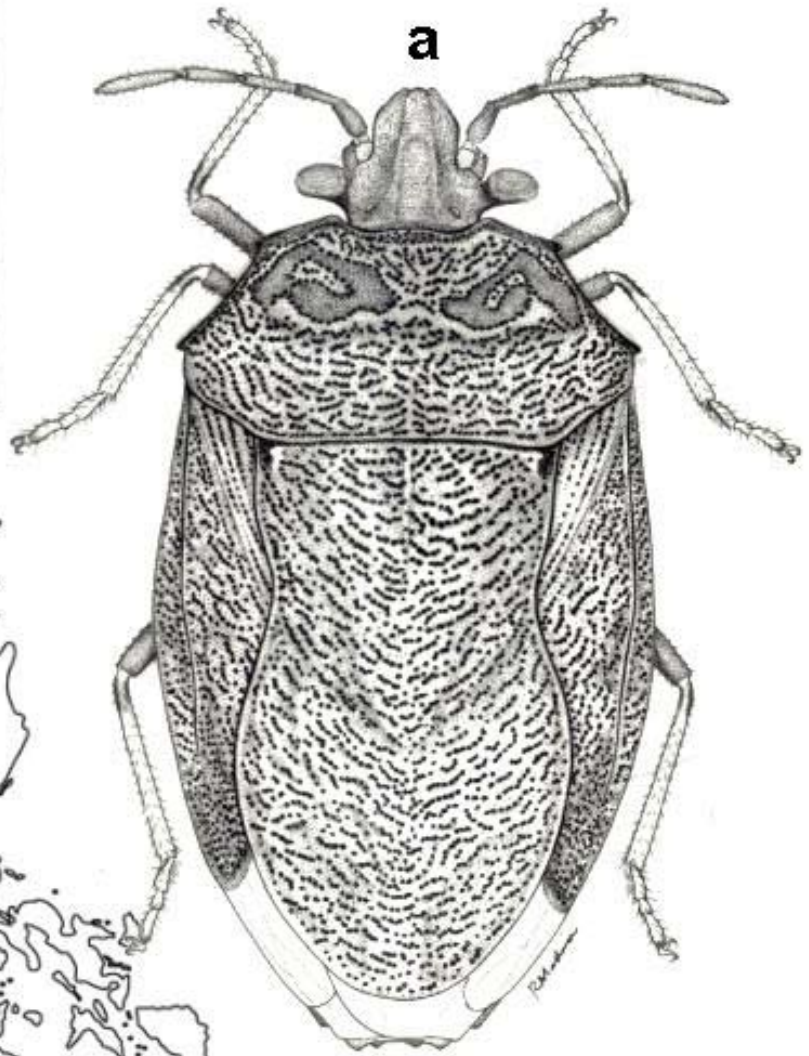
Plate 31
Scotinophara landangica

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i tergite X
j forewing
k hindwing
l spermatheca
m female genitalia
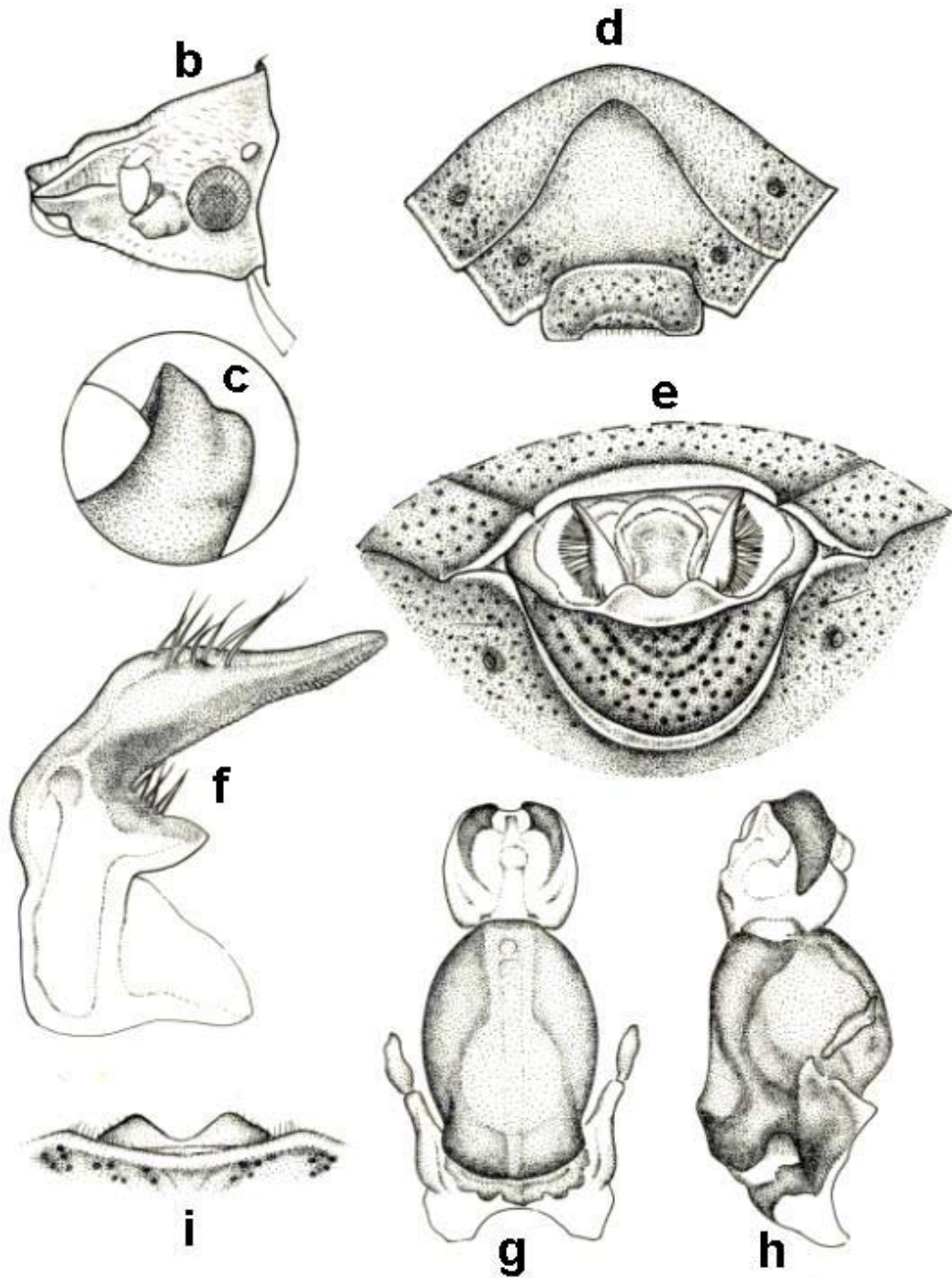
Plate 31 b-i
Scotinophara landangica
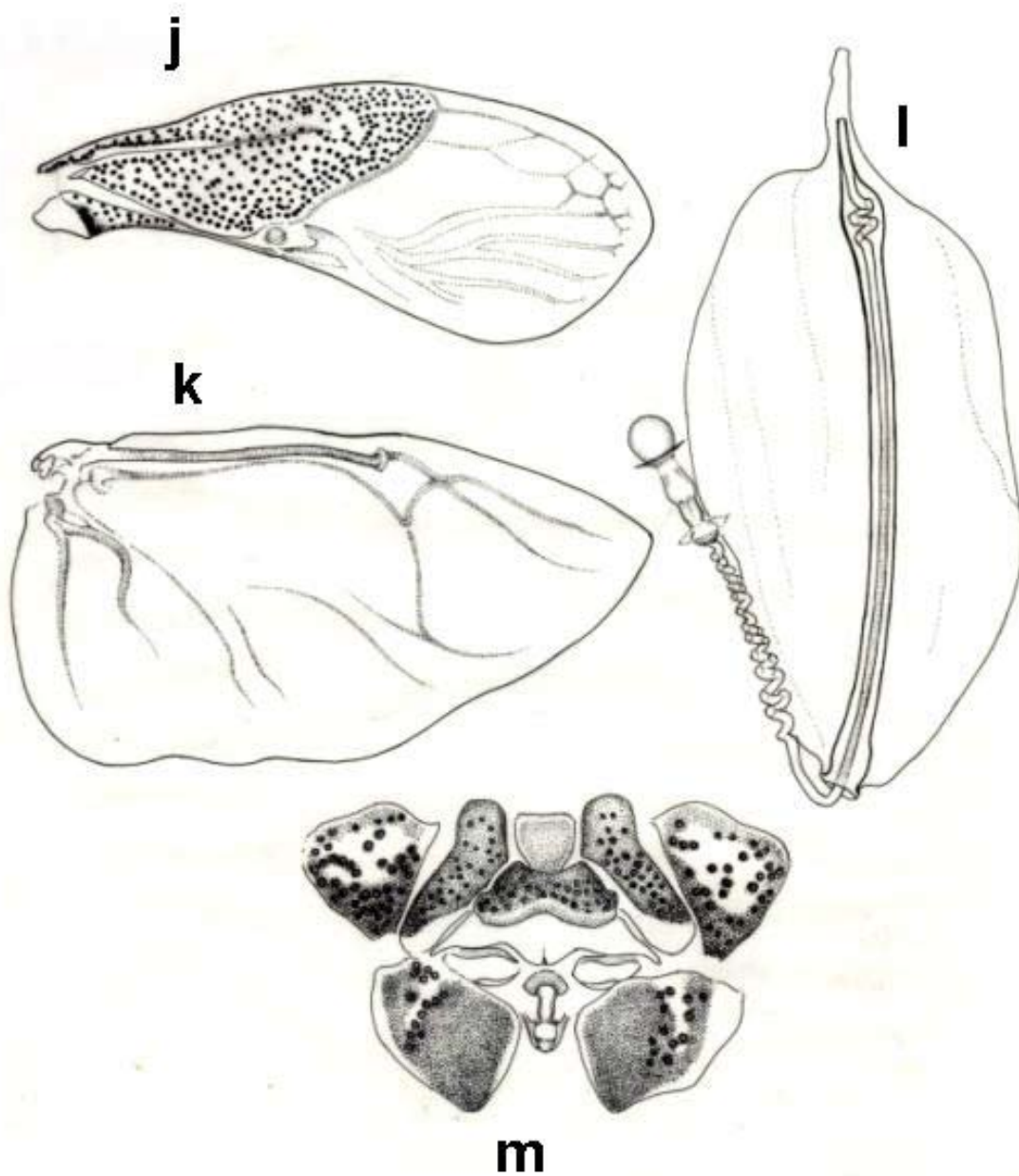
Plate 31 j-m
Scotinophara landangica
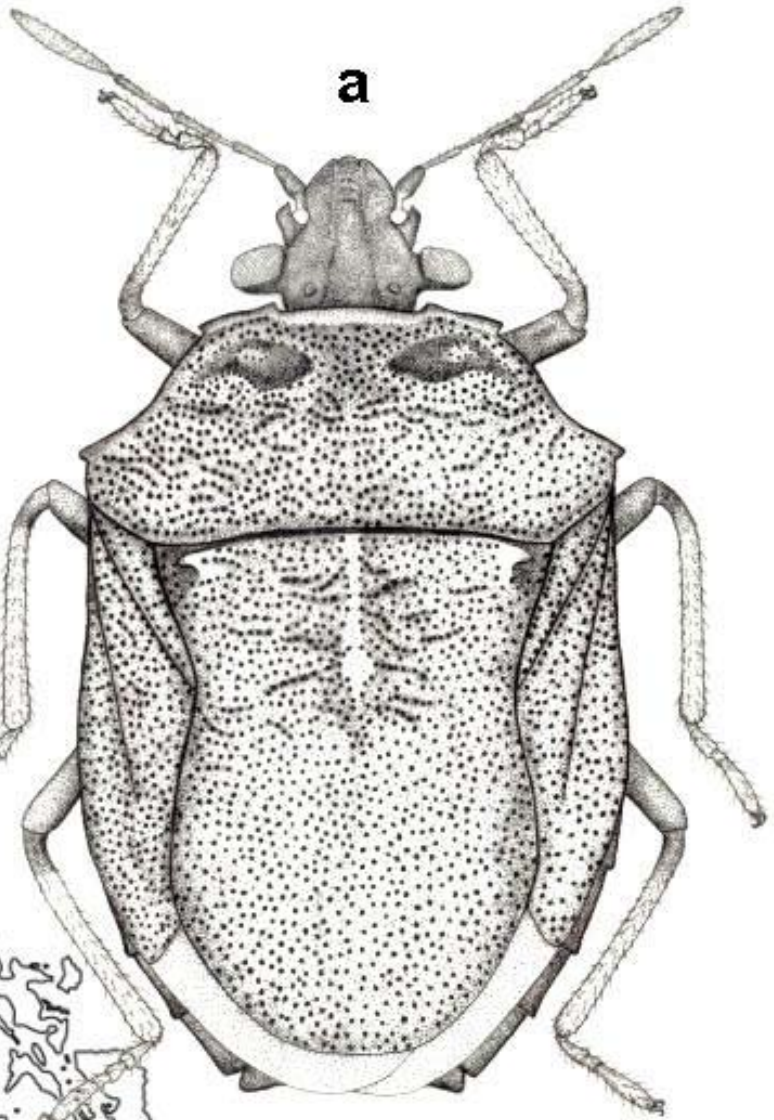
Plate 32
Scotinophara maguindanaoana

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i forewing
**j** hindwing
k spermatheca
l female genitalia
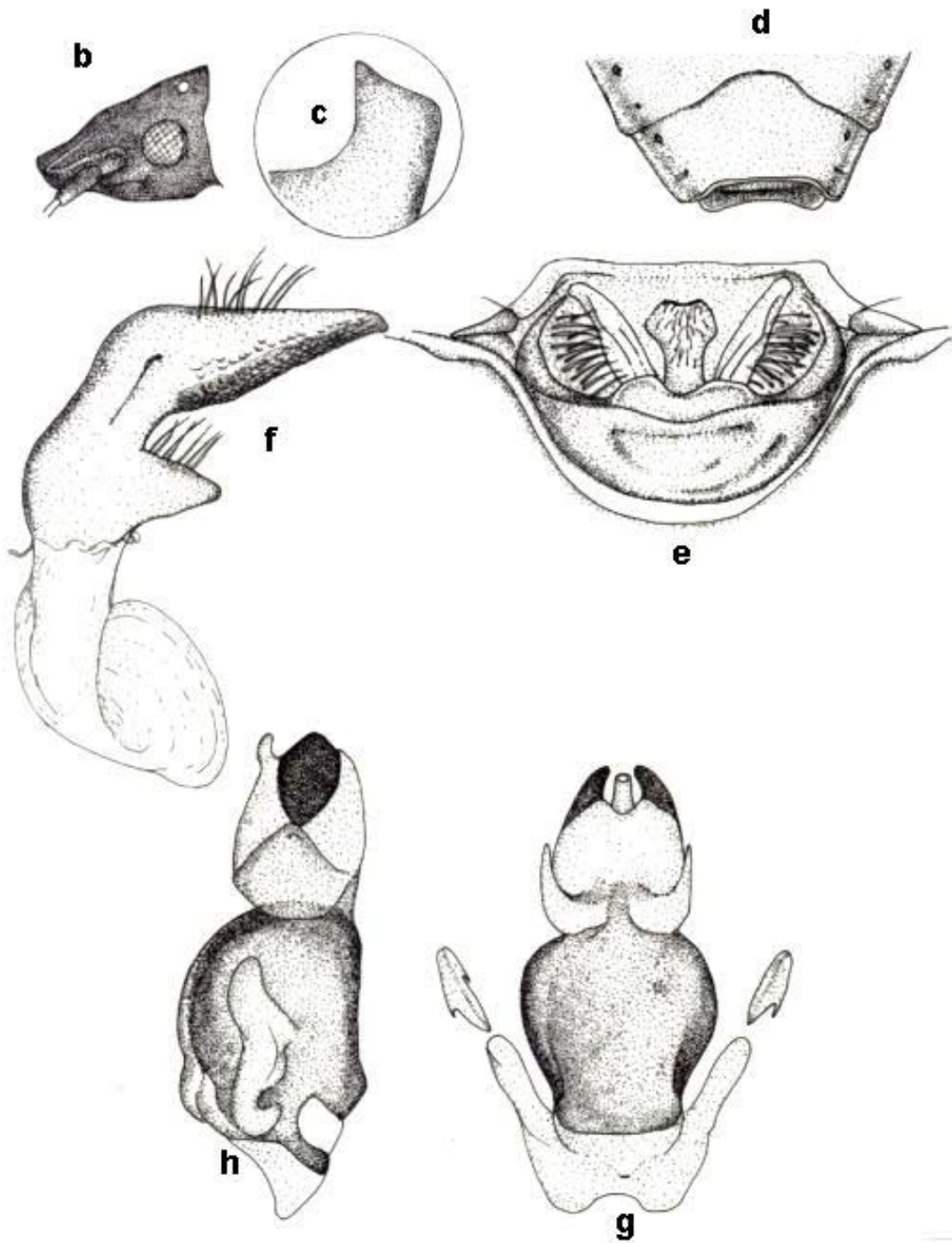
Plate 32 b-h
Scotinophara maguindanaoana
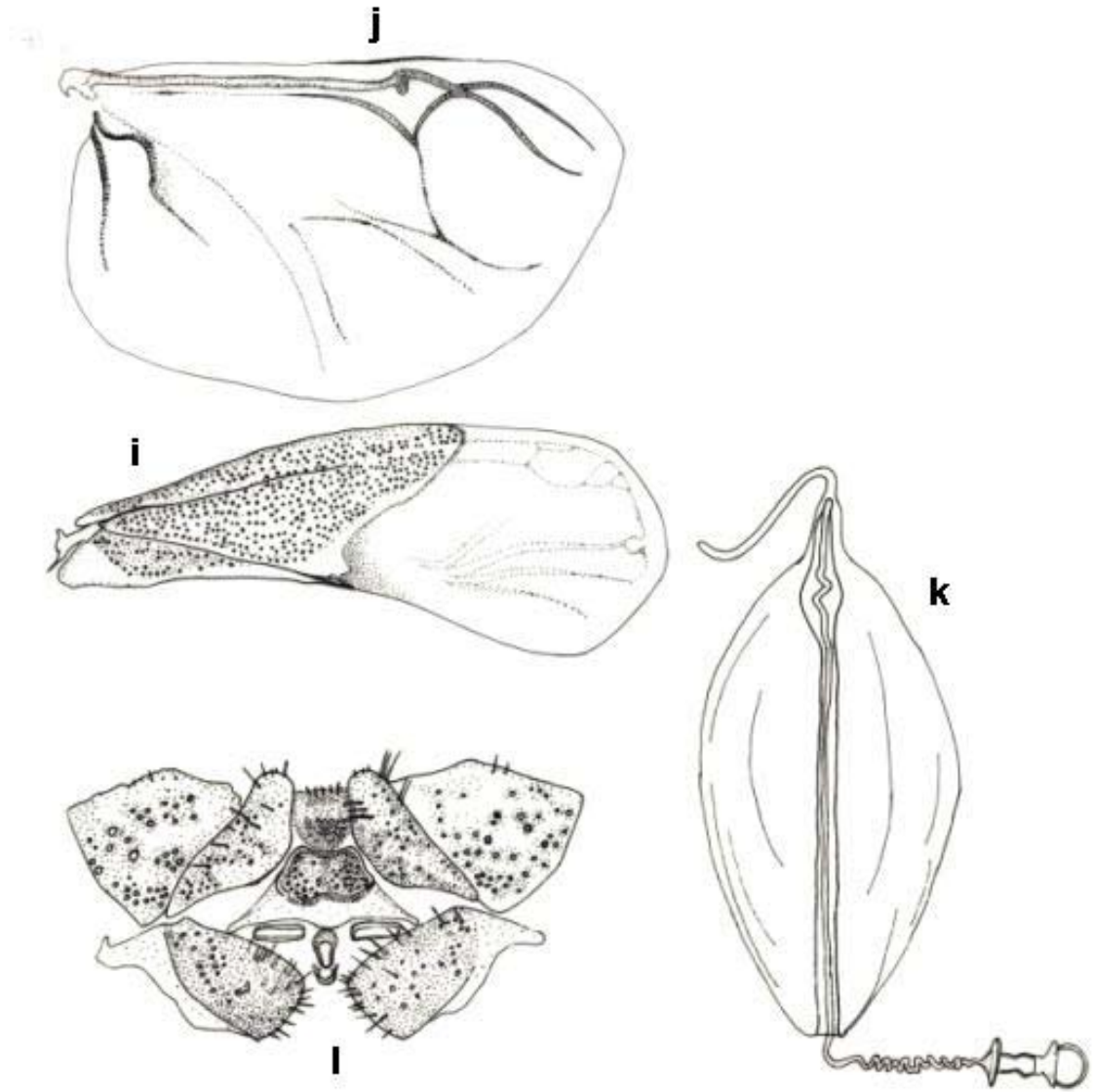
Plate 32 i-l
Scotinophara maguindanaoana
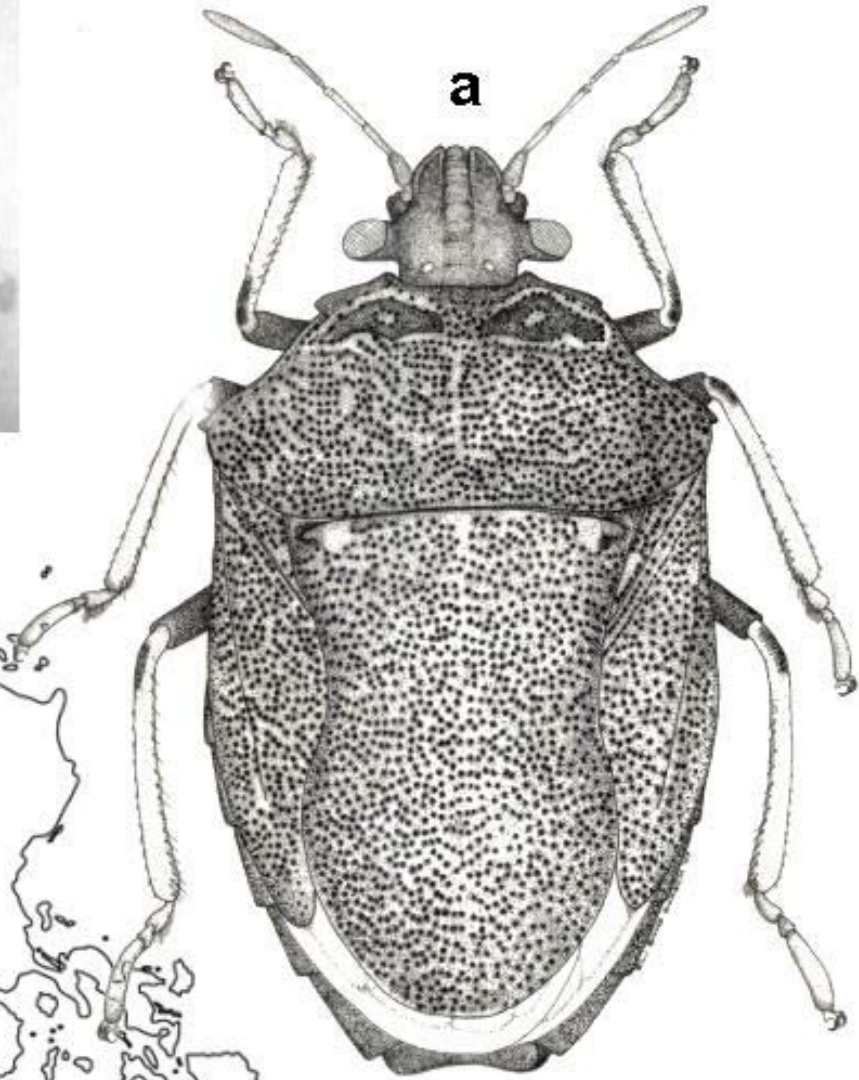
Plate 33
Scotinophara mlanga

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i forewing
j hindwing
k spermatheca
l female genitalia
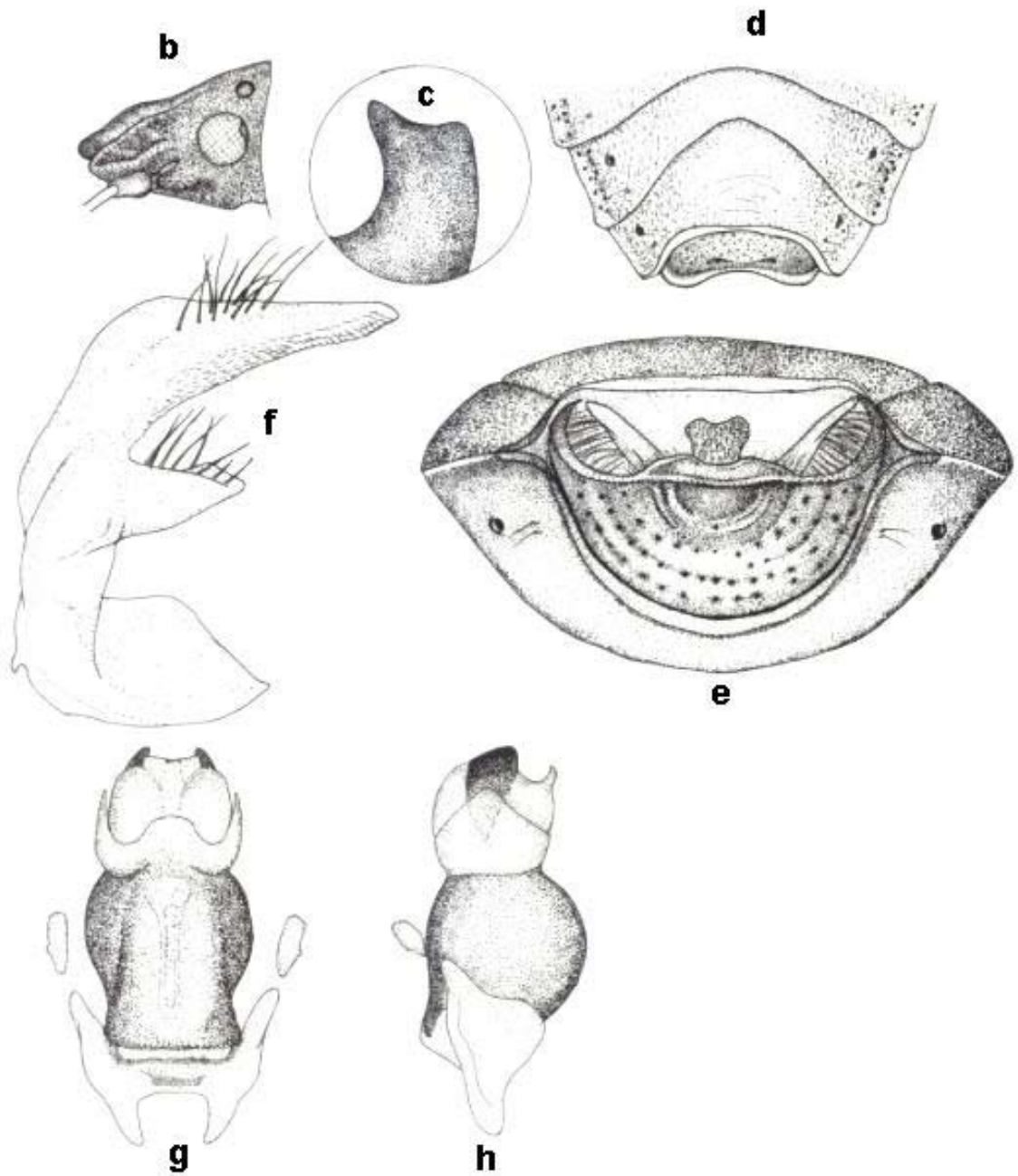
Plate 33 b-h
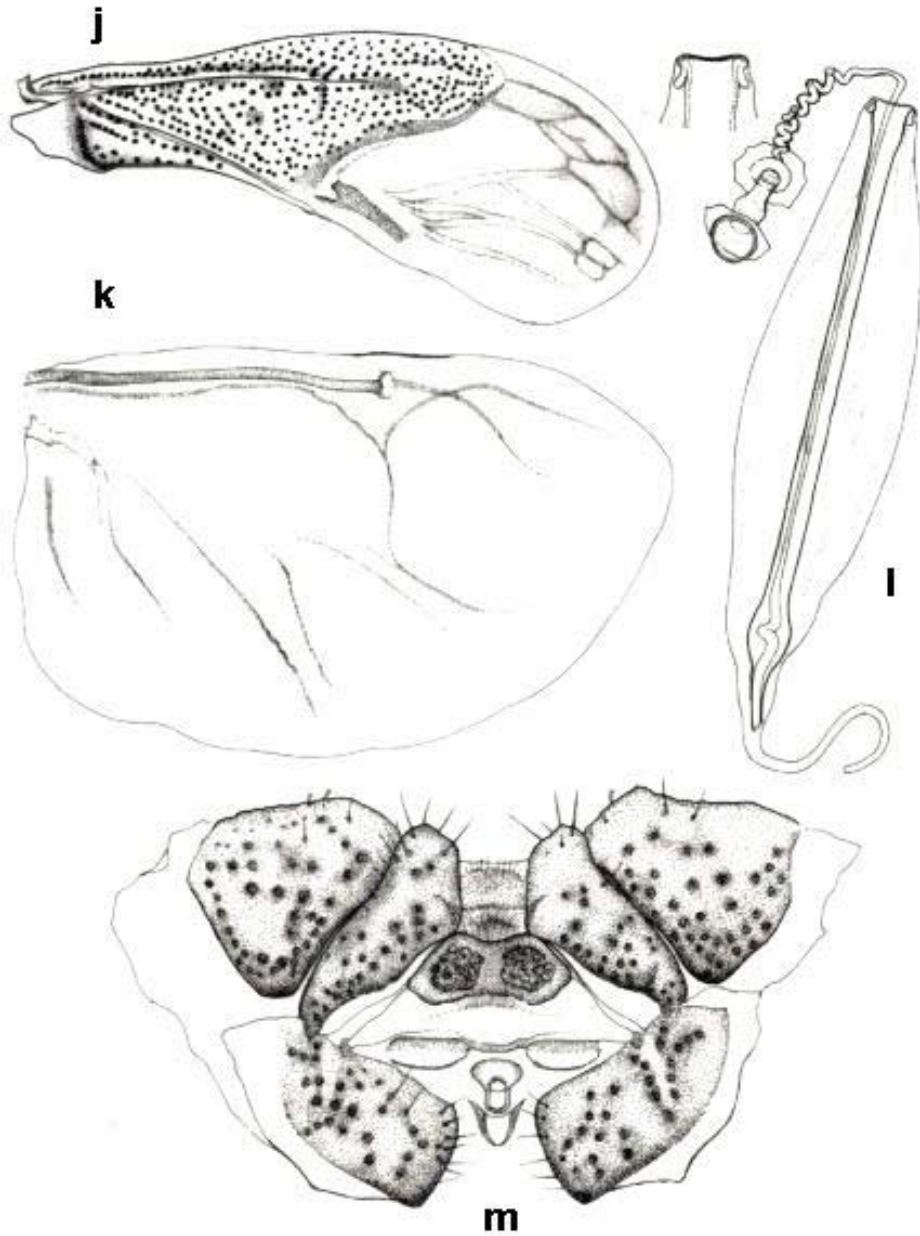*Scotinophara mlanga*
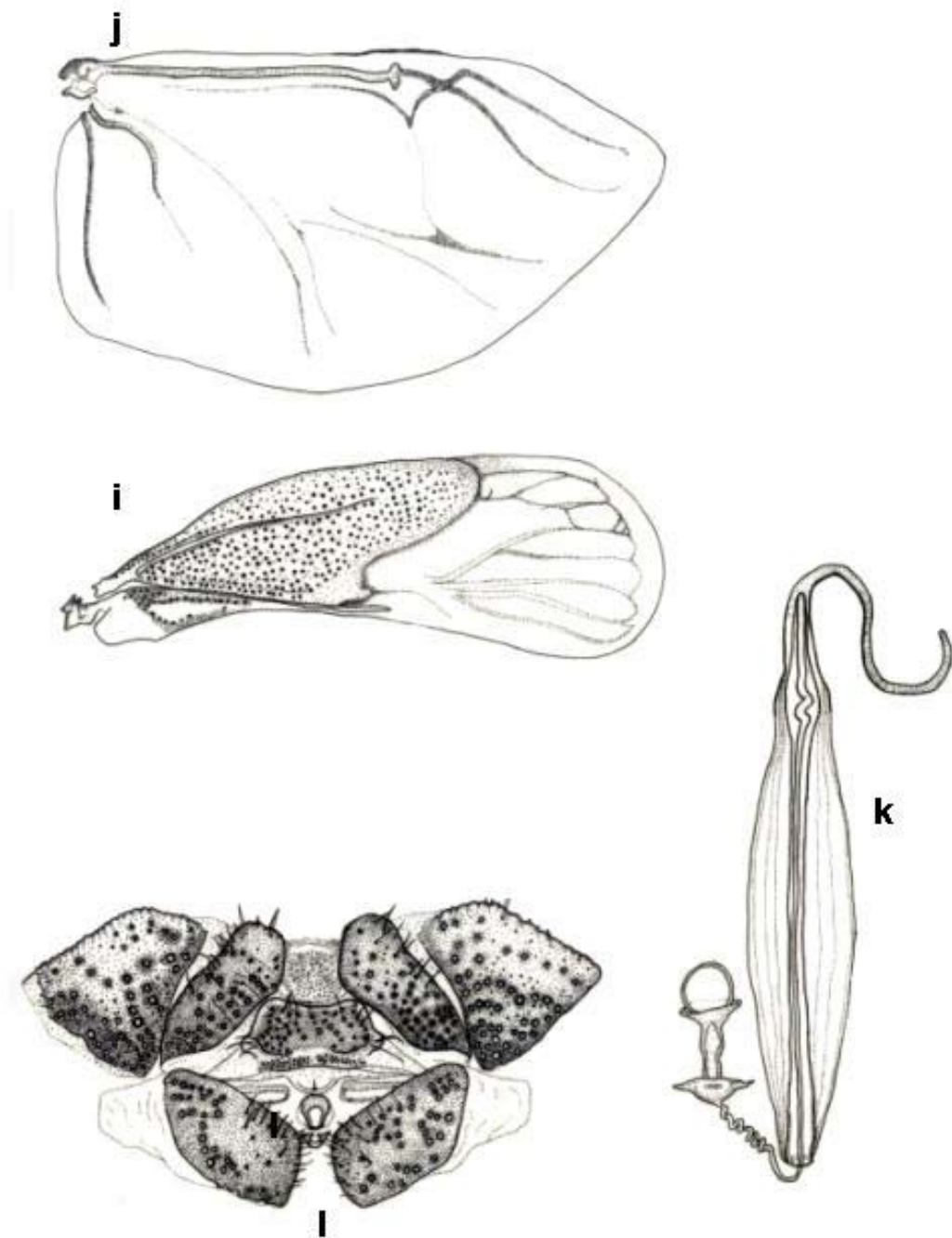
Plate 33 i-l
Scotinophara mlanga

a
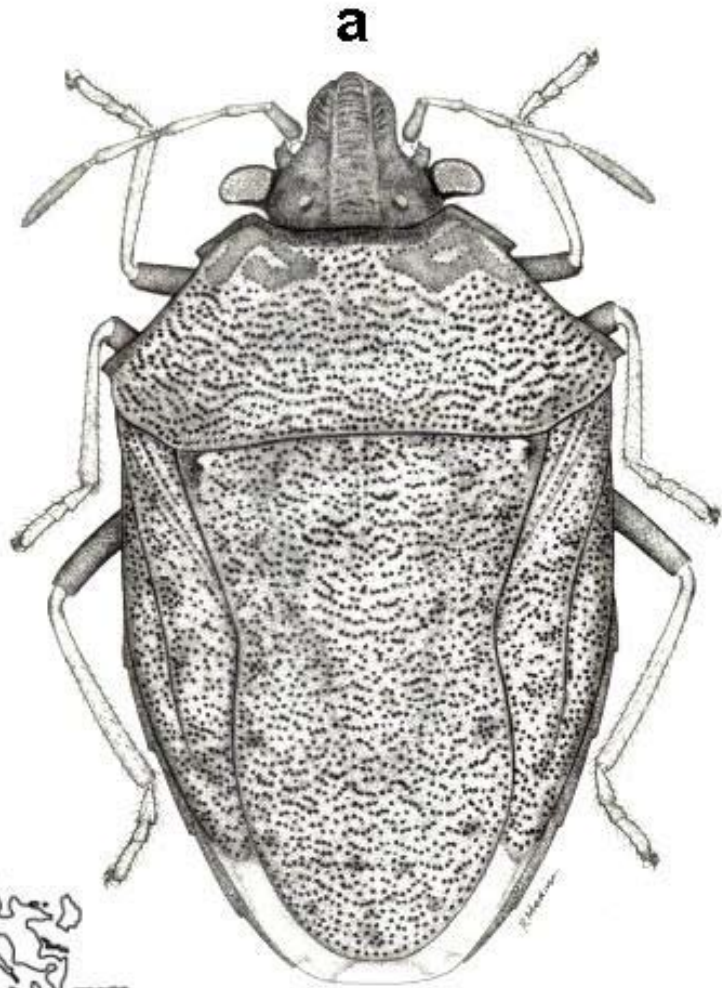
Plate 34
Scotinophara ilonga

a male habitus
b lateral view of head
c antennifer
d ventral view of abdominal tip
e cross-section of gonophore
f left clasper
g dorsal view of aedeagus
h lateral view of aedeagus
i forewing
j hindwing
k spermatheca
l female genitalia
m setae of female genitalia
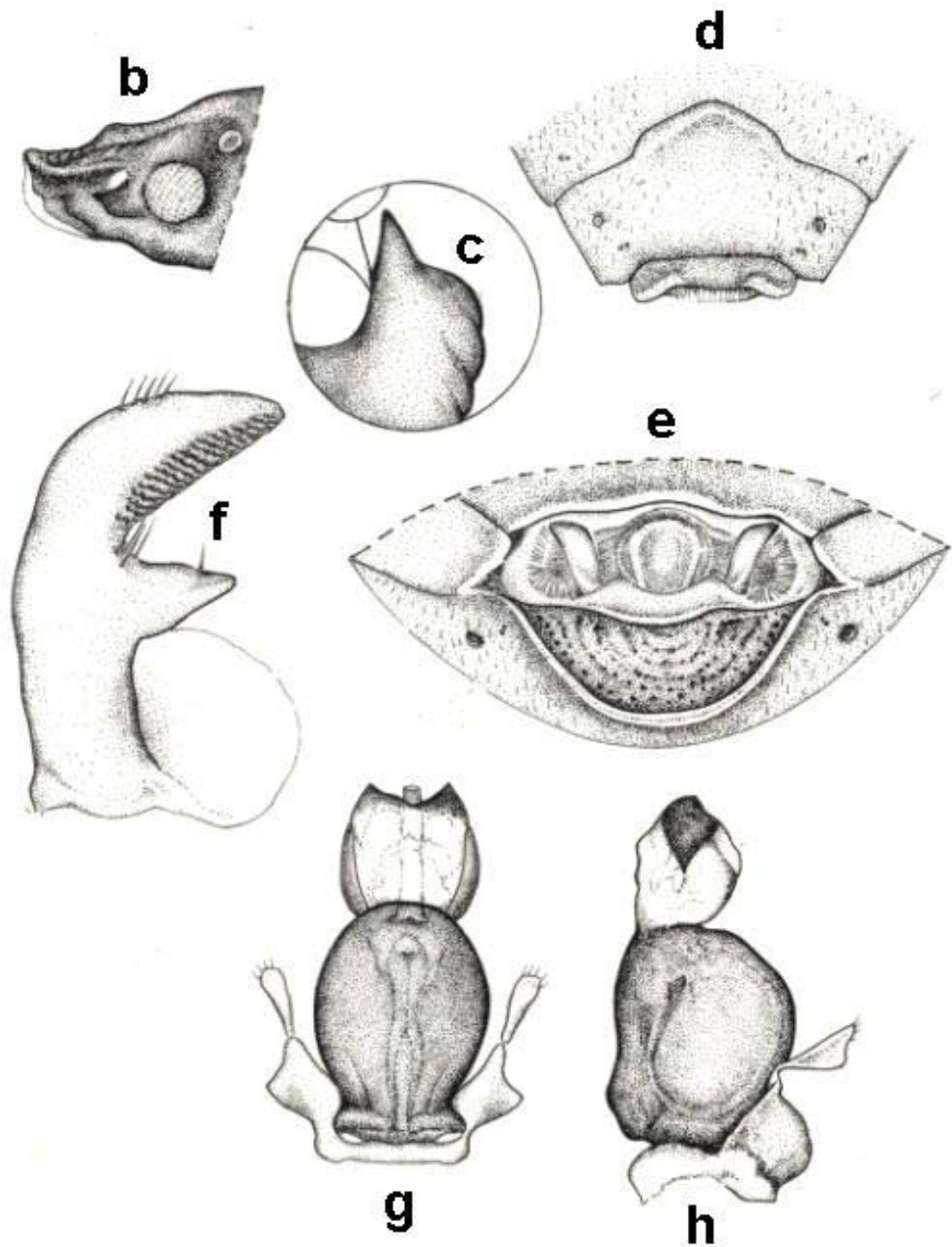
Plate 34 b-h
Scotinophara ilonga
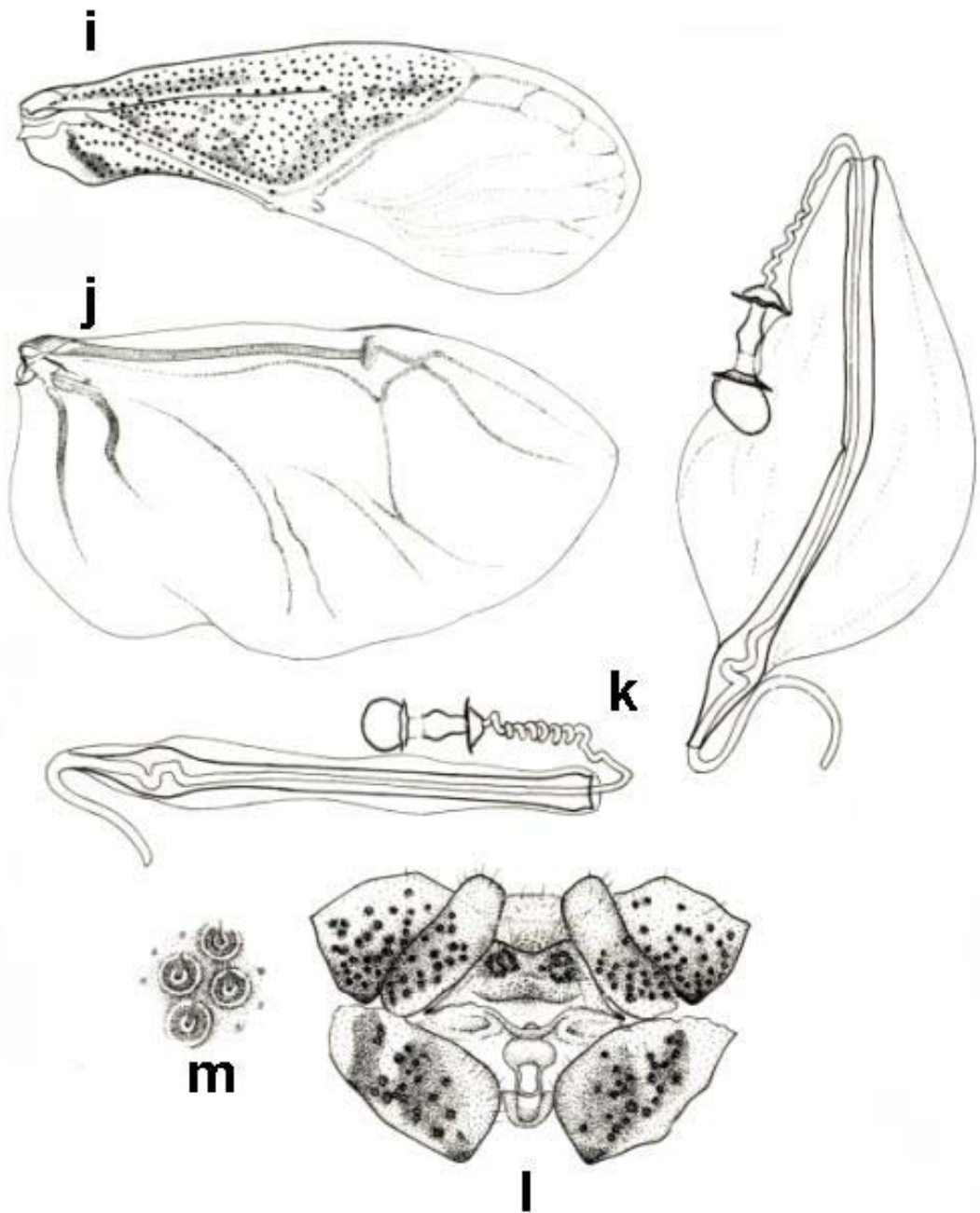
Plate 34 i-m
Scotinophara ilonga

Figures of Genitalia and Other Structures

Genitalia and other structures, whenever possible, were documented by means of a digital camera or by scanning electron microscope.

Scotinophara latiuscula

5 head, dorsal view

6 head, ventral view

7 tarsal hairs

8 tarsal claw

9 pronotum

10 aedeagus tip, dorsal view

11 tergite X

Scotinophara sorsogonensis

12 general habitus, venter

13 proboscis

14 pronotum

15 scutellar pit

16 pronotal spine

Scotinophara sorsogonensis

abdominal venter

forewing

hindwing

aedeagus tip, dorsal view

aedeagus, lateral view

aedeagus, ventral view

clasper

Scotinophara pirurotonga

24
general habitus, venter

25
proboscis

26
pronotum

27
pronotal spine

28
head, dorsal view

29
pronotum, anterior angle

Scotinophara pirurotonga

tarsal hairs

tarsal claw

tergite X

aedeagus, lateral view

clasper

aedeagus, dorsal view

Scotinophara agusanortica

general habitus, venter

pronotal spine

proboscis

scutellar pit

pronotum

hindwing

Scotinophara agusanortica

head, lateral view

42

pronotum, anterior angle

43

tarsal hairs

44

tergite X

46

tarsal claw

45

47

aedeagus, ventral view

48

aedeagus, dorsal view

aedeagus, lateral view

49

clasper

50

Scotinophara tantanganica

51

general habitus, ventral view

52

proboscis

53

pronotum

54

pronotal spine

55

scutellar pit

56 abdomen, ventral view

57 forewing

58 hindwing

59 head, lateral view

60 pronotum, anterior angle

61 tarsal claw

62 clasper

63 aedeagus, lateral view

64 aedeagus, dorsal view

65 aedeagus, ventral view

Scotinophara midsayapensis

66 general habitus, ventral view

67 proboscis

68 pronotum

69 abdomen, ventral view

70 pronotal spine

71 scutellar pit

72 forewing

Scotinophara midsayapensis

head, lateral view

pronotum, anterior angle

tarsal claw

aedeagus, dorsal view
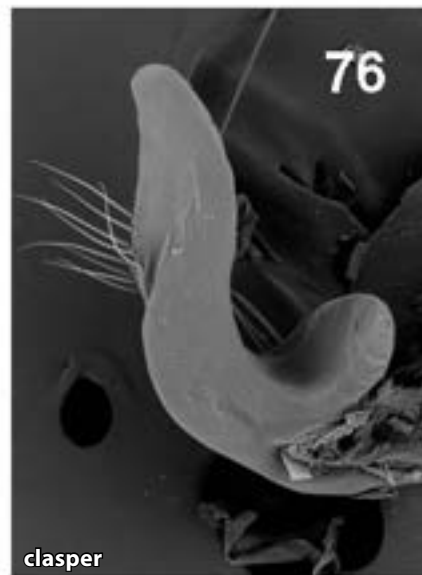
clasper

aedeagus, lateral view

Scotinophara putikanica

general habitus, ventral view

79

80

proboscis

81

pronotum

82

pronotal spine

83

head, dorsal view

84

pronotum, anterior angle

Scotinophara putikanica

tarsal claw

male gonophore

setae on female genitalia

hindwing

proboscis, magnified

tarsal hairs

Scotinophara coarctata

general habitus, ventral view

proboscis

pronotum

pronotal spine

scutellar pit

Scotinophara coarctata

forewing

96
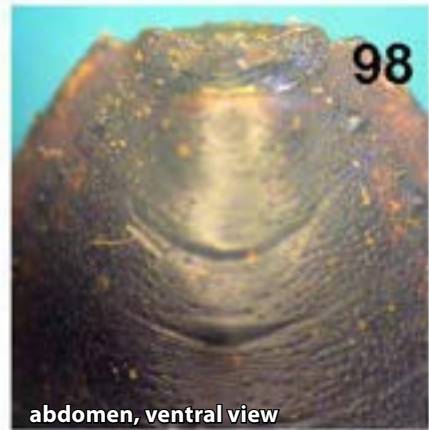
abdomen, ventral view

98

hindwing

97

99

aedeagus, dorsal view
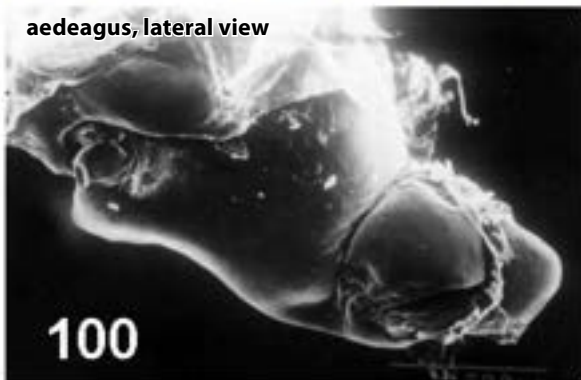
aedeagus, lateral view

100

102
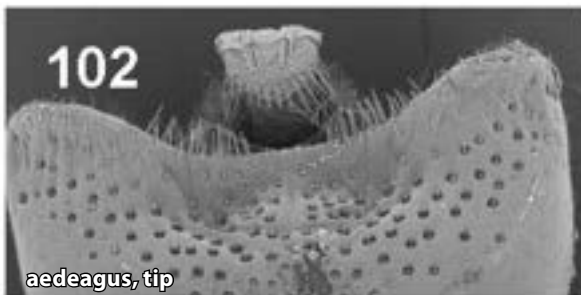
aedeagus, tip
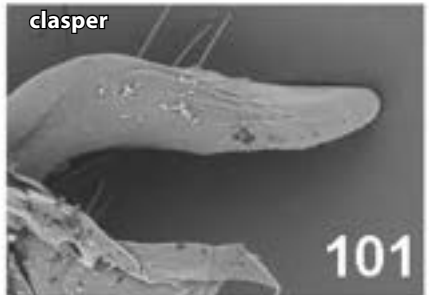
clasper

101

Scotinophara alegria

general habitus, ventral view

pronotal spine

proboscis

head, ventral view

pronotum, anterior angle

pronotum

Scotinophara alegria

111 aedeagus, dorsal view

109 tarsal hairs

113 clasper

110 tarsal claw

112 aedeagus, lateral view

Scotinophara kabangkalanensis

general habitus, ventral view
114

117
pronotal spine

115
proboscis

118
abdomen, ventral view

116
pronotum

119
forewing

Scotinophara zamboanga

tarsal claw

tarsal claw, lateral view

aedeagus, lateral view

clasper

head, ventral view

pronotum, anterior angle

tergite X

tarsal hairs

128 general habitus, ventral view

129 proboscis

130 pronotum

131 scutellar pit

132 scutellar pit

133 head, dorsal view

Scotinophara trifurcata

head, ventral vie

134

tarsal hairs

135

137

tergite X

clasper

140

136

tarsal claw

138

aedeagus, ventral

aedeagus, lateral

139

general habitus, ventral view

141

pronotal spine

144

proboscis

142

scutellar pit

145

143

pronotum

abdomen, ventral view

146

Scotinophara landangica

forewing

147

149

pronotum, anterior angle

head, lateral view

148

150

tarsal claw

153

aedeagus, lateral view

151

aedeagus, ventral view

152

aedeagus, dorsal view

154

clasper

Scotinophara maguidanaoana
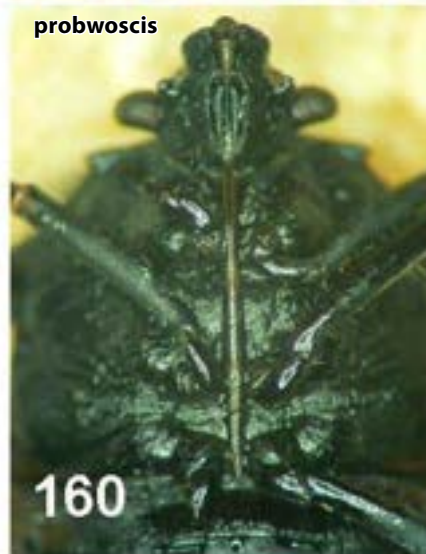
general habitus, ventral view
155

proboscis
156

pronotal spine
158

157
pronotum

Scotinophara mlanga

159

general habitus, ventral view

probwoscis

160

162

pronotal spine

pronotum

161

Scotinophara ilonga

general habitus, ventral view

proboscis

pronotum

hindwing

pronotal spine

scutellar pit

abdomen, ventral view

Scotinophara ilonga

170
head, ventral view

171
pronotum, anterior angle

172
forewing, close-up

173
tarsal segments

174
tarsal claw

tergite X
175

176 abdominal punctations

177 male gonophore

178 female genitalia

181 aedeagus, lateral view

179 aedeagus, ventral view

180 aedeagus, dorsal view

182 clasper
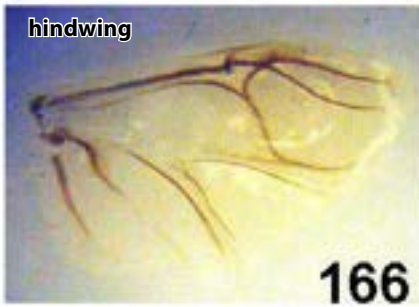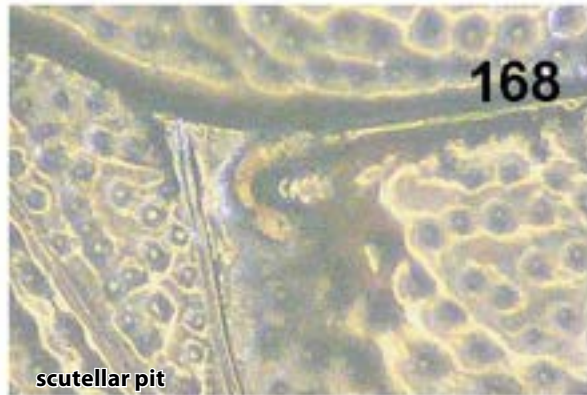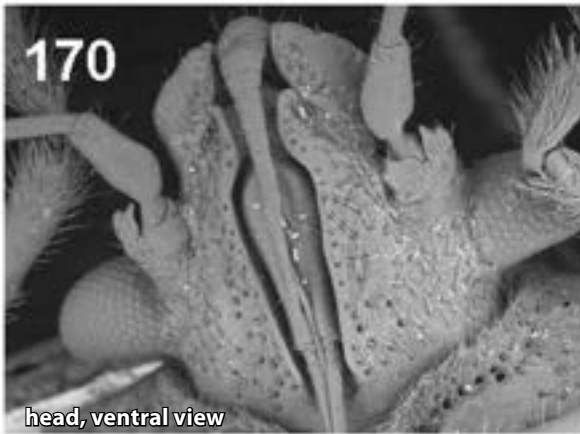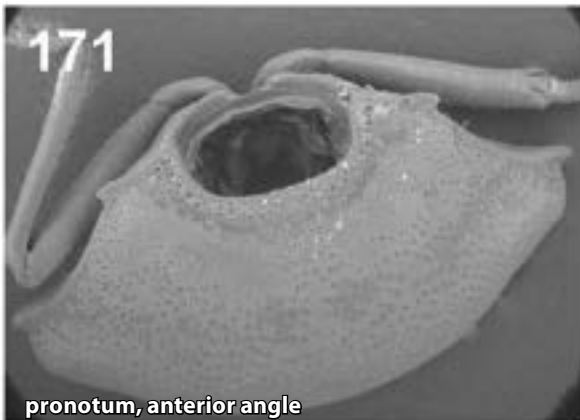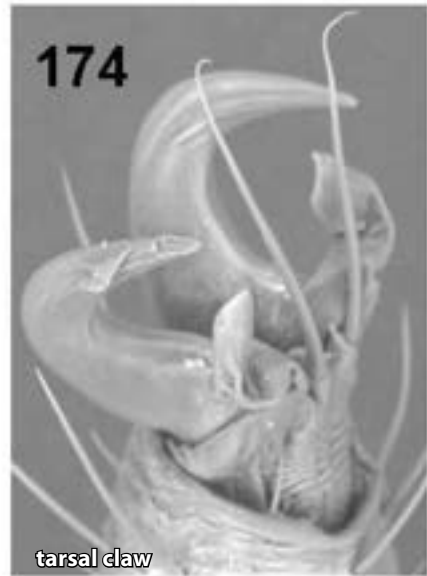
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Notes

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DNA Barcoding: A New, Universal Tool for Invasive and Pest Species Identification

Shelley L. Ball and Karen F. Armstrong

Abstract

The past decade has seen a significant increase in global trade and travel and with it, a concomitant increase in the spread of species around the world. The potential economic and environmental impacts of the movement of exotic species, which can become invasive or establish as pests, is enormous. Preventing the establishment of invasive or pest species requires rapid species identification. However, for many insect species, this is not a straightforward task. Many invasive and pest species are inadvertently transported as eggs or larvae, which are often impossible to identify morphologically. DNA barcoding, using a short segment of the COI mitochondrial genome as a 'species identification tag,' offers a universal and standardized approach to species identification. Here, we give examples of the application of DNA barcoding to invasive and pest species identification and discuss the role of international barcoding organizations and initiatives such as the Consortium for the Barcode of Life (CBOL), the Barcoding of Life Database (BOLD), and the Barcoding of Life Initiative (BOLI) in promoting and developing DNA barcoding on a global scale.

Key words: DNA barcoding, COI, mtDNA, species identification, invasive and pest species, insect, biosecurity, CBOL, BOLD, INBIPS

Introduction—the problem of species identification

Over the past decade, there has been a significant increase in the movement of goods around the world due to increased global trade and travel. This had led to a concomitant increase in the movement of species around the world, particularly insects which are small and easily transported inadvertently as eggs and larvae on produce, in packaging materials, or on other inanimate objects. It is estimated that 1% of these will become invasive and have serious economic impacts (Williamson 1996) and, although this number may seem small, the economic and environmental impact of just one or two spe-

cies becoming invasive can be staggering. For example, in the United States, the cumulative economic impacts of establishment of two invasive moth species, Asian gypsy moth (*Lymantria dispar*) and the Nun moth (*Lymantria monacha*), is estimated to be Euro 28-46 billion. Given the potentially large economic and environmental costs of invasive species, it is critical to minimize their establishment and spread. A key aspect of this is the ability to detect the arrival of new exotic species as quickly as possible; however, this is often a difficult task.

Species identification typically relies on morphology, but for several reasons, this approach can be extremely problematic. First, phenotypic variation for taxonomically important traits can make accurate species identification difficult if not impossible. Second, where reliable taxonomic traits exist, dichotomous keys can be difficult for non-experts to use effectively and for some life stages (eggs, larvae, pupae), taxonomic keys simply do not exist. This is particularly relevant for insects since it is often the immature life stages that are inadvertently spread through human travel and movement of trade goods. Third, morphologically cryptic species, by definition, cannot be identified using morphological characters. Hence, we are reliant on other biological traits. Finally, traditional taxonomic expertise may not be readily available for many taxa. Given that it is important to identify exotic species as quickly as possible, this may pose a major impediment to rapid identification.

Each species, however, has an array of unique 'genetic signatures' at the molecular level. DNA sequences can provide this 'signature' and be used as a species identifier that, unlike morphology, is not subject to environmental influences and is constant across all life stages. DNA sequencing technology can be readily taught and utilized, therefore overcoming the impediments of complex keys and the dearth of taxonomists. There is also the additional benefit of being able to identify partial specimens that have been damaged or fragments of specimens (e.g., legs, faeces, etc.).

Several molecular genetic tools have been developed for the purpose of species identification: polymerase chain reaction (PCR) restriction fragment length polymorphism (PCR-RFLP; Armstrong et al. 1997a, b; Brunner et al. 2002), species-specific PCR (Kohlmayer et al 2002, Lu et al. 2002, Liu 2004), multiplex PCR (Kumar et al. 1999, Kengne et al. 2001), and oligonucleotide array analyses (Naeole and Haymer 2003). In many cases, development of these tools has been ad hoc and often done on a reactive basis to meet local needs, with different approaches tailored for different taxa or different genomes (e.g., mitochondrial vs nuclear) and gene regions. Consequently, there has been no standardization of the technology across laboratories, making it inefficient and expensive to use. This impedes the critical technical transfer to international biosecurity authorities and, ultimately, prohibits its application. Very recently, however, the basic issue of standardization and universality has been addressed by DNA barcoding—a new tool developed for large-scale species identification that has enormous potential as a generic approach to invasive and pest species identification.

DNA barcodes as species identifiers

DNA barcodes are short nucleotide sequences from a standardized region of the genome that provide a species-specific 'genetic identification tag.' For animals, DNA barcodes consist of a ~ 650 base pair fragment of the mitochondrial gene, cytochrome c oxidase I (COI). This 5' end of COI has three

main advantages as a marker for species identification. First, there are robust universal PCR primers that are extremely successful for amplifying it in most animal phyla (Folmer et al 1994, Zhang and Hewitt 1997). Second, because COI is a protein-coding gene, sequence insertions and deletions are rare and therefore sequence alignment is straightforward. Third, the relatively high rate of 3rd codon position nucleotide substitutions means that this gene contains considerable phylogenetic signal useful for discrimination at the species level. Finally, in animals, the mitochondrial genome is generally maternally inherited and thus, does not recombine. Consequently, gene sequences become relatively fixed in species, resulting in diagnostic arrays of species' DNA sequences.

Species exhibit characteristic arrays of COI sequences, reflecting the haplotype diversity of the species. Central to the concept of barcoding is that the distribution of these intraspecific genetic distances shows little or no overlap with the distribution of interspecific genetic distances (Fig. 1a, b). Consequently, mean genetic divergence among individuals of different species is far greater (typically an order of magnitude) than genetic divergence among individuals of the same species. In reality, most taxonomic groups are likely to show some overlap between intra- and interspecific distance distributions due to the existence of young species pairs or recent hybridization events. However, barcoding studies to date on a variety of animal taxa have shown that the degree of overlap between the distributions is indeed small (Hebert et al. 2003, 2004a; Ball et al. 2005; Clare et al. 2006; Nelson et al. 2007) and that significant overlap, which would completely blur species boundaries (Fig. 1c), is exceedingly rare.

The ability of DNA barcodes to perform species identification and discrimination has been assessed in numerous studies of biodiversity such as general invertebrates (Hebert et al. 2003), collembolans (Hogg and Hebert 2004), spiders (Barrett and Hebert 2005), mayflies (Ball et al. 2006), tussock moths (Ball and Armstrong 2006), bats (Clare et al. 2006), mosquitoes (Cywinska et al.
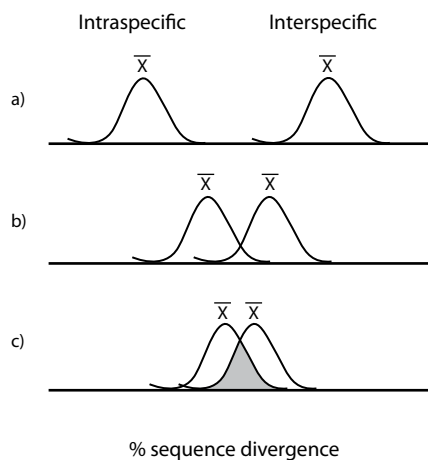
Fig. 1. Distribution of interspecific and intraspecific distances.

2006), tropical Lepidoptera (Hajibabaei et al. 2006), ciliates (Lynn and Struder-Kypke 2006), scarab beetles (Ahrens et al. 2007), birds (Kerr et al. 2007), chitons (Kelly et al. 2007), and chironomid flies (Pfenninger et al. 2007). DNA barcoding also has been applied to the identification of morphologically cryptic species, subspecies, or biotypes (Ball and Armstrong 2006, Clare et al. 2006, Hajibabaei et al. 2006, Smith et al. 2006, Kerr et al. 2007, Smith et al. 2007). Furthermore, DNA barcoding has contributed to species discovery. Hebert et al. (2004b) used DNA barcodes, in combination with extensive natural history observations and larval morphology, to assess species diversity in the neo-tropical skipper butterfly, *Astraptes fulgerator*. At least 10 sympatric species, which differed in larval morphology, food plant use, and ecosystem preference, were shown to be present; retrospectively, this had not been apparent from the adults, which showed very subtle morphological variation and no genitalic differences. Such studies demonstrate the value of DNA barcoding when combined with other biological data. It should be emphasized, however, that DNA barcodes alone are insufficient for naming new species and that assessment of other biological characters such as ecology, phenology, and behavior is essential.

Invasive and pest species can be identified using DNA barcodes

DNA barcoding shows enormous potential as a powerful tool for invasive and pest species identification. Particularly beneficial, after a species has been characterized with a barcode, is the ability to identify any life stage. Often, it is the immature life stages of invasive and pest species that are spread through global trade and travel. Their rapid identification is a desirable, if not essential, component of the incursion response procedure. However, new invaders may not be readily recognized by local experts. The process is usually hampered by the dearth of keys available for their diagnosis and dwindling access to taxonomic expertise worldwide; identifications might take several weeks and severely impede the ability to deal with new invaders before they become established. However, DNA barcodes generated previously from morphologically validated adult specimens as a species reference overcome this impediment. Moreover, using DNA technology to alleviate our reliance on taxonomists for providing routine species identification services should allow them to focus more on hypothesis-driven research (Lipscomb et al. 2003, Wheeler 2005). The technology used for DNA barcoding makes rapid species identification possible. Using efficient DNA extraction and PCR methods and an in-house auto-sequencer, we are able to identify unknown insects in less than 24 h. As DNA-technologies evolve, processing time (and cost) will continue to decrease.

Perhaps one of the most important benefits of DNA barcoding is the identification of morphologically cryptic species, subspecies, and biotypes. These can be very different biologically from their close yet morphologically indistinguishable relatives, often possessing distinct life history, reproductive, and behavioral traits. Such traits may make them far more likely to be an invasive or pest species and thus pose significant economic and environmental risks. In these cases, genetic methods such as DNA barcoding may provide the only means of rapidly distinguishing high-risk taxa from their morphologically cryptic yet more benign relatives.

Examples of invasive and pest species identification

Although COI data have been used to investigate genetic diversity in a number of pest insects (Gullan et al. 2003, Brunner et al. 2004, Frey et al. 2004, Hille et al. 2005, Scheffer and Lewis 2005, Kaila and Stahls 2006, Li et al. 2006, Mcleish et al. 2006, Memon et al. 2006, Saw et al. 2006, Coeur d'acier et al. 2007, Nagoshi at al. 2007), only a few studies have specifically used DNA barcodes to identify invasive and pest species (Armstrong and Ball 2005, Ball and Armstrong 2006, Scheffer et al. 2006, Schmidt et al., submitted manuscript). We tested the ability of DNA barcodes to identify 20 species of lymantriid, including the gypsy moth *Lymantria dispar*, and other species considered 'high-risk' species to New Zealand (Ball and Armstrong 2006). Using a reference barcode data set of these lymantriid as well as 93 additional species in the super family Noctuoidea, barcodes were 100% successful at correctly identifying all 20 lymantriid species. They were also effective at the subspecies level, distinguishing the established Asian and European gypsy moth morphotypes as well as a new gypsy moth subspecies (*L. dispar hokkaidoensis*).

We recently tested the effectiveness of DNA barcoding on tephritid fruit fly identification, which included several known pest species. Tephritids present a particular challenge since there are several known species complexes. This includes the large *Bactrocera dorsalis* complex (oriental fruit fly), which contains both pest and nonpest species and for which diagnostic morphological characters are complicated (Drew and Hancock 1994, Iwaizumi 2004). DNA barcoding worked extremely well for identification of species outside the complexes but was of limited value for species within complexes (Ball and Armstrong, manuscript in preparation). This problem is a likely consequence of very recent evolutionary radiations. Clear discrimination of species within tephritid complexes using molecular tools is recognized as problematic elsewhere (Morrow et al. 2000, Clarke et al. 2005).

The performance of DNA barcodes relative to other DNA-based approaches for identifying unknown specimens has also been tested (Armstrong and Ball 2005). We re-analyzed tephritid and lymantriid immature life stages that had been intercepted at the New Zealand border and previously identified using PCR-RFLP or species-specific primers (SSP). For fruit flies, 97.5% of identifications using barcodes agreed with the previous results. The discrepancies included two of 79 fruit fly specimens that were previously unidentifiable based on RFLP or SSP analysis but were unambiguously identified to species using DNA barcodes (Armstrong and Ball 2005). In the same study, the DNA barcode and RFLP results for 86% of the lymantriid specimens agreed. However, of an additional eight specimens that had not been identifiable by RFLP, five were confidently matched to species in the Barcoding of Life Database (BoLD) (Ratnasingham and Hebert 2007). Since our study in 2005, all but one species have now been identified with DNA barcodes (unpubl. data). This has been made possible by the significant growth in the BoLD database with a current (July 2007) taxonomic coverage of >29,000 species, 8,550 of which are Lepidoptera.

Another important function of DNA barcodes is the discovery of morphologically cryptic species and the discrimination of genetically distinct biotypes or subspecies. For example, DNA barcoding has shown that *Lymantria mathura*, the pink gypsy moth, consists of two genetically distinct entities. DNA barcodes showed that individuals from three populations in Japan (Henton,
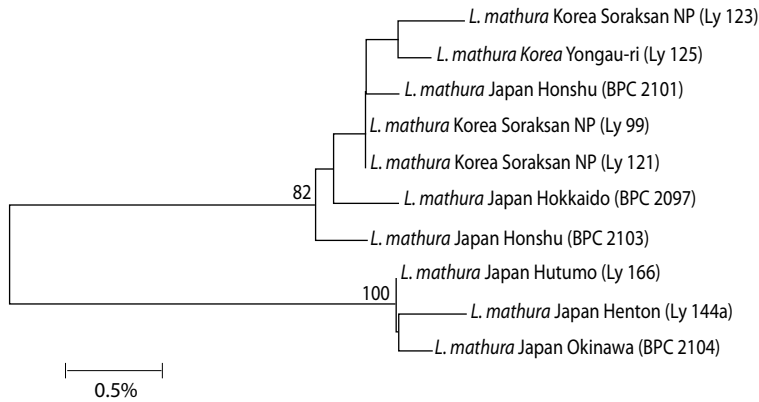
Fig. 2. ???

Hutoma, and Okinawa) showed large sequence divergence (4.2%) from individuals from Korea and two populations in Japan (Honshu and Hokkaido; Fig. 2). The percent sequence divergence between these two groups was comparable with those seen between different moth species reported in Hebert et al. (2003). The genetic difference between these two groups was also supported by other biological observations. Attraction to a synthetic pheromone lure was effective for individuals in one group of populations but not the other (Paul Schaefer, USDA, pers. commun.). Initially, this lack of uniform response to the synthetic lure across the different populations was enigmatic. However, the genetic difference between the two groups suggests that *L. mathura* may consist of two cryptic species and thus, may explain their differential response to the synthetic lure. Clearly, more work needs to be done to quantify these pheromone response differences as well as determine what other biological differences may exist between these two putative species, before any taxonomic revision can be done. However, this example clearly shows the role of DNA barcoding in flagging potentially cryptic species, subspecies, or biotypes.

International scope of DNA barcoding

The success with which DNA barcoding can identify species is dependent on the accumulation of taxonomically diverse reference sequence data sets. In the context of invasive and pest species, the most useful approach is to obtain DNA barcodes from an entire taxon. An example might be to obtain DNA barcodes for every species of lymantriid moth to ensure that pest and high-risk species could be distinguished from each other as well as from related low-risk species. Clearly, this objective cannot be attained by a single laboratory or research group. Instead, such large-scale barcoding initiatives will rely on international collaboration and the taxonomic research community at large.

The opportunity to achieve this now exists through two main global initiatives. The Consortium for the Barcoding of Life (CBOL), established in 2004, is an international initiative devoted to promoting the development and use of DNA barcoding as a global standard for species identification

(www.barcoding.si.edu). CBOL encourages and campaigns for the rapid compilation of high-quality DNA barcode records in a public library of DNA barcode sequences; the development of new instruments and processes to make barcoding cheaper, faster, and more portable; the participation of taxonomists and taxonomic research organizations in all regions and countries; and the use of DNA barcoding for the benefit of science and society. Members of the consortium include researchers from universities, museums and herbaria, government agencies, biodiversity research institutes, conservation organizations, and private companies from across the world. Currently, the consortium has more than 150 member organizations spanning 45 countries. CBOL's central role has been to connect individual barcoding initiatives from around the world, some of which are promoted as case studies on the CBOL website, as well as to facilitate major international initiatives. Two large-scale campaigns have been launched to accumulate barcodes for well-defined taxonomic groups—The All Birds Barcoding Initiative (ABBI) and FishBoL, barcoding the fishes of the world. Two more recent campaigns, started in 2006, are designed to demonstrate the practical value of DNA barcoding and create global operational systems for species identification. One is to barcode roughly half of the 4,500 known species of tephritid fruit fly, prioritizing agricultural pests or beneficial species used for biological control, as well as other relevant and closely related species. The other initiative is to barcode 80% of the 3,200 known mosquito species, prioritizing the disease-bearing species and their relatives. Each initiative consists of a collaboration of international barcoding scientists and expert taxonomists. In addition to large campaigns, there are several opportunities to become involved in CBOL, from submitting individual case studies, to assisting working groups in the development of processes and procedures for databasing, DNA analysis, data analysis, and barcodes for non-animal taxa.

Within CBOL, the International Network for Barcoding Invasive and Pest Species (INBIPS; www.barcoding.si.edu/INBIPS.htm) operates to promote the development and use of DNA barcoding for the identification of invasive and pest species. INBIPS promotes this with the goal of accumulating a global-scale collection of DNA barcodes for the world's terrestrial, freshwater, and marine invasive and pest species. Such a barcode collection will be invaluable in the rapid detection and monitoring of species as they continue to disperse across the globe.

The second crucial initiative is The Barcoding of Life Data Systems (BOLD; http://www.barcodinglife.com/views/login.php) at the University of Guelph, Canada. Central to DNA barcoding's role as a universal tool for species identification is the need for global-scale and open-access databases of species barcodes. Without doubt, the success of DNA barcoding to identify species depends critically on the taxonomic and geographic breadth of accumulated barcode sequences. Increasing the collection of species' barcodes on a global scale depends on the cooperative efforts of researchers around the world and on their willingness to deposit their data into open-access databases. BOLD is a freely accessible web-based DNA barcode repository designed specifically for this purpose. It also contains analytical tools that allow users to identify unknowns by entering a query COI barcode sequence to be compared against barcode sequences in the database (Ratnasingham and Hebert 2007). The analytical tools provide estimates of the degree of matching between the query sequence and the

best matches in the database. In this sense, the database functions much like Genbank, except that the barcode sequences consist of a single, homologous region of the COI gene as opposed to the large diversity of genes and gene regions held in Genbank. BOLD is a repository for worldwide activity, although it arose through, and is hosted by, the largest national initiative, the Canadian Barcode of Life Network (BOLNET) (http://www.bolnet.ca/) that itself focuses on Canadian biota.

In addition to these two initiatives that have overseen the global development of DNA barcoding is the Barcode of Life Initiative, BOLI (http://www.dnabarcodes.org/). This is a "bottom-up" initiative of like-minded researchers and organizations and draws together CBOL- and BOLD-related activities with other barcoding projects launched by taxonomists working on separate initiatives, such as the Census of Marine Life, or by individual research teams or taxonomists.

Future directions

The success of DNA barcoding for invasive and pest species detection will depend on accumulating DNA barcode sequences for a large diversity of taxa across their geographic ranges. Developing pest lists, defining the taxa around these, and engaging taxonomists from around the world is fundamental to this activity. The support of CBOL and BOLD to enable accumulation of barcode sequences for the benefit of developing countries is also a key objective. Advances in the development of new technological platforms that can deliver DNA barcoding in the field will directly benefit their application for the identification of pest and invasive species. For example, systems that can rapidly extract, amplify, and sequence DNA on site, at a country's port of entry, can play a vital role in detecting invasive and pest species and in preventing their establishment and spread. New technology, such as miniaturized DNA sequencers (see http://phe.rockefeller.edu/barcode/blog/) and entirely new technology platforms, such as nanotechnology, will also likely progress DNA barcoding activity in the future.

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Notes

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Comparative Karyology of Philippine Black Bugs (Hemiptera: Pentatomidae) Sampled from the Bicol Region and Laguna

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Abstract

Lacto-aceto-orcein macerations of Carnoy-fixed testes of male black bugs *Scotinophara latiuscula* (Breddin) and *Scotinophara coarctata* (Fabricius) revealed variations in the karyological features of their spermatogenetic cells. One hundred males of each species showed mean frequency occurrences of meiocytes and interphase to be higher (399 and 102, respectively) in *S. coarctata* than in *S. latiuscula* (177 and 62, respectively), resulting in higher mean meiotic index in the former (79.64%) than in the latter (74.05%). The chromosome number of male *S. latiuscula* is 2n=13 (6IIA + XO), while that of *S. coarctata* is 2n=16 (7IIA +XY). Mean relative lengths of pachytene autosomes of *S. latiuscula* ranged from 0.04 to 0.10, NOR-autosome measured 0.08, sex chromosomes measured 0.03(X) and 0.02(Y), while the autosomes of male *S. coarctata* ranged from 0.09 to 0.21, NOR-autosome measured 0.17, and the X chromosome measured 0.09. Spermatocytes of both *Scotinophara* species exhibited normal meiosis, first (reductional) followed by second (equatorial) divisions. Most frequently encountered were substages of Prophase I, followed by Metaphase I, and then by Prophase II.

Key words: chromosomes, karyotype, pachytene, diakinesis, rice black bug

Introduction

Approximately 2.3 million ha or 25% of total arable land in the Philippines is devoted to rice cultivation. Such importance is given to the production of this crop because rice serves as the most important carbohydrate-rich food crop in the country as well as in other Asian nations (Heinrichs 1994). Unfortunately, a percentage of the annual rice production is lost to insect damage. So far, around 100 species of insects have been identified as rice pests. Twenty of these were classified as major pests (e.g., rice leafhoppers and planthoppers), while additional threats to yield loss are reported by Pathak and Khan (1994) to be caused by what is termed as minor pests (e.g., whorl maggots and rice bugs).

The rice black bugs (Hemiptera: Pentatomidae) in many rice-growing regions in the Philippines manifested significant geometric increases in number and therefore alarmed rice growers. These black bugs attracted much interest since the detection in February 1982 of the Malayan black bug, *Scotinophara coarctata* (Fabricius) in southern Palawan (Barrion et al. 1982). Then, on 8 June 1982, a report of the Malayan black bug from the Bureau of Plant Industry at Los Baños led Barrion and Litsinger (1987) to sample the black bugs from Siniloan, Laguna, near Laguna de Bay and study their bionomics, karyology, and chemical control. The species was identified as the node-feeding black bug, *Scotinophara latiuscula* (Breddin).

Recently, in 2006, black bug outbreaks occurred in more than 1,338 ha in 29 municipalities of four provinces in the Bicol region—Albay, Camarines Sur, Catanduanes, and Sorsogon. Populations of saprophytic black bugs were sampled by PhilRice consultant, Dr. A.T. Barrion, from rice stubbles in San Roque, Sangay, Camarines Sur; Tulangan, Matnog, Sorsogon; Bagacay, Gubat, Sorsogon; Gadgaran, Matnog, Sorsogon; Balading, Tabaco, Albay; and Nagas, Tiwi, Albay. From the field collections of black bugs, the adult males were used for karyological investigation. Karyology refers to a cytological study focusing on the nuclear features (e.g,. chromosomes) of the eukaryotic cells of the species. The nuclear chromosomes are the carriers of genetic materials of the species and, although mutable, they are basically stable intraspecifically. In modern systematics, karyological characters are considered useful in describing and differentiating species. In this study, the karyology of the two black bug species, *S. coarctata* and S. *latiuscula*, were determined and compared. These include meiotic index, chromosome number, relative length of pachytene chromosomes, and behavior of meiotic chromosomes.

Materials and methods

Collection, identification, and fixation of black bugs

Adult black bugs were randomly sampled from rice fields of Siniloan, Laguna (Fig. 1) and six areas of the Bicol region (Fig. 2)—San Roque, Sangay, Camarines Sur; Tulangan, Matnog, Sorsogon; Bagacay, Gubat, Sorsogon; Gadgaran, Matnog, Sorsogon; Balading, Tabaco, Albay; and Nagas, Tiwi, Albay.

Based on the morphological characters of black bugs, those from Siniloan, Laguna, were identified by Dr. Barrion as *Scotinophara latiuscula* (Breddin), while those from the Bicol region were *Scotinophara coarctata* (Fabricius).

From the collections, 100 adult males of the two species were sorted and fixed in Carnoy's fluid (3:1; 95% ethanol: glacial acetic acid). After 24 h of fixation, the insects were transferred to 70% ethanol for preservation inside a refrigerator.

Slide preparation of testicular cells of black bugs

One fixed black bug was placed on a clean glass slide. Using a bent needle and forceps, the abdomen was separated from the thorax and head. The abdomen was dissected and the testes were extracted and gently macerated with a drop of lacto-aceto-orcein. Debris was removed. A clean cover slip was placed on top of the macerated tissues. Excess stain was removed using a coarse filter paper. The
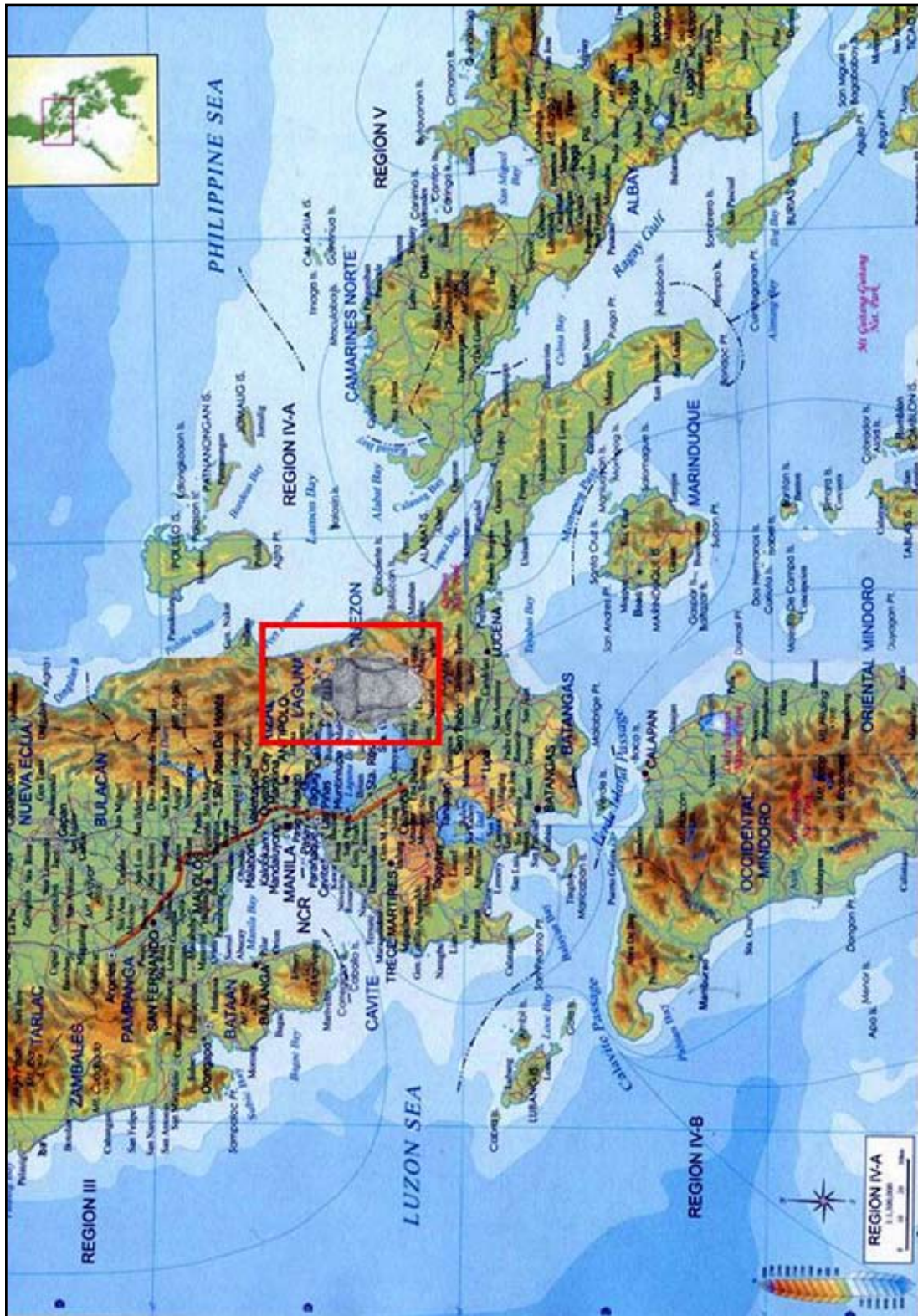
Fig. 1. Map of Southern Tagalog region showing the sampling site for *Scotinophara latiuscula* (Breddin) (NBS 2006).

Fig. 2. Map of the Bicol region showing sampling sites for *Scotinophara coarctata* (Fabricius) (NBS 2006).

bubbles that formed were removed by gently pressing the cover slip with an eraser-end of a pencil. The process also evenly spread the cells on the slide. The glass slide was slightly warmed over a spirit of alcohol flame to enhance staining and let the cells stick to the slide.

Destaining was done by adding a drop of 45% acetic acid on one side of the cover slip and the excess fluid was then withdrawn from the other side with a small piece of filter paper. The slide was again passed over the flame to clear the cytoplasm.

Temporary mounting was done by sealing the edges of the cover slip with melted paraffin using a heated bent needle.

Documentation of testicular cells and nuclear details of the black bugs

Photomicrographs of testicular cells and chromosomes of the black bugs were taken using the S_3 Capture Software at the Genetics and Molecular Biology Division.

Interpretative drawings of the pachytene and diakinesis chromosomes were done on the basis of their photomicrographs. An ideogram of pachytene chromosomes and a karyogram of diakinesis chromosomes were constructed.

Microscopic observation and analysis of testicular cells of black bugs

The slides were observed under a phase contrast microscope. Cells were scanned through a scanner objective coordinated with a coarse adjustment knob. Cellular details were observed using the oil immersion objective.

Qualitative observation of cells and chromosomes of black bugs included the shapes and behavior during the different stages of meiosis.

Quantitative analyses of the testicular cells and chromosomes included the determination of the meiotic index (MI):

$$\text{MI (\%)} = \frac{\text{Number of dividing cells (meiocytes)}}{\text{Total number of dividing + non-dividing (interphase) cells}} \times 100$$

Chromosome counts of haploid (n) number were determined during diakinesis. The actual and relative lengths of diakinesis chromosomes were also measured, presented, and compared between *S. latiuscula* and *S. coarctata*.

The actual length of each of the pachytene chromosomes was measured and their relative lengths (rl) determined using the formula:

$$\text{rl} = \frac{\text{Actual length of each chromosome}}{\text{Total length of all chromosomes}}$$

Results and discussion

The lacto-aceto-orcein squashes of Carnoy-fixed testes of the black bugs revealed the karyological features of the non-dividing (interphase) and dividing (meiocytes) spermatogenetic cells. In this study, the karyological features refer to the mean frequency of occurrence of interphase and meiocytes, mean MI, haploid chromosome numbers, sex-determining mechanisms, karyotype formulae (diploid chromosome number), and mean rl of pachytene chromosomes. Such aforementioned feats are utilized in comparing the two species of black bugs, the node-feeding black bug [*S. latiuscula* Breddin)] and the Malayan black bug [*S. coarctata* (Fabricius)]. The former species was sampled from the irrigated wetland of Siniloan, Laguna near Laguna de Bay, while the latter was collected from different provinces of the Bicol region.

Table 1 and Figures 3 and 4 show the interspecific karyological variations between *S. latiuscula* and *S. coarctata*. Figures 5 and 6 present the stages of the first (reductional) and second (equational) meiotic divisions common in both *Scotinophara* species.

Frequency of occurrence of spermatogenetic testicular cells of *S. latiuscula* and *S. coarctata*

Based on 100 males of each black bug species, the mean frequencies of occurrence of the meiocytes or dividing cells were 177 and 399, while those of non-dividing cells (interphase) were 62 and 102, respectively, for *S. latiuscula* and *S. coarctata* (Table 1).

Meiotic index of *Scotinophara* species

These numerical values resulted in mean MIs of 74.05% for *S. latiuscula* and 79.64% for *S. coarctata* (Table 1). The MI is directly correlated with the spermatogenetic potential of the male black bugs. The higher the index, the more spermatozoa are formed. In bisexual species such as black bugs, more sperms can fertilize the eggs and, therefore, more progenies are expected from *S. coarctata* than from *S. latiuscula*.

Haploid (n) chromosome numbers of *S. latiuscula* and *S. coarctata*

Figure 3 shows the reductionally divided meiocytes at diakinesis whereby the homologues formed distinct bivalents of both autosomes and sex chromosomes. Diakinesis, therefore, is the ideal Prophase I substage that presents the haploid (n) chromosome numbers of the *Scotinophara* species. The haploid (n) chromosome number of *S. latiuscula* was 8 and that of *S. coarctata* was either 6 or 7 (Table 1).

Sex-determining mechanism

A close scrutiny of diakinesis cells as well as other substages of Prophase I reductional division revealed the sex-determining mechanisms of the males of *S. latiuscula* and *S. coarctata*. The former possessed two heterochromatic but variously sized X (bigger) and Y (smaller) univalents, while the latter could possess a heterochromatic X univalent or not. The male *S. latiuscula* has, therefore. XY

Table 1. Comparison of karyological characteristics of black bug (*Scotinophara* species) populations.

Karyological feature[a]	Black bug populations	
	Scotinophara latiuscula (Breddin)	*Scotinophara coarctata* (Fabricius)
Mean frequency of occurrence		
Dividing cells (Meiocytes)	177	399
Non-dividing cells (Interphase)	62	102
Meiotic index (%)	74.05	79.64
Chromosome number		
Diakinesis (Haploid)	n=8 (7IA + X) n=8 (7IA + Y)	n=7 (6IA + X) n=7 (6IA)
Leptonema (Diploid)	2n=16 (7IIA + XY)	2n=13 (6IIA + XO)
Sex-determining mechanism	XX(F) : XY (m)	XX (F) : XO (m)

[a]Based on 100 males of each species.

sex chromosomes, while the male *S. coarctata* has an XO sex-determining mechanism. Ovarian macerations of the female counterparts showed the XX sex-determining mechanism (Table 1).

Karyotype formulae (diploid chromosome number)
of the male *S. latiuscula* and *S. coarctata*

During diakinesis, the autosomal bivalent (II) counts in male *S. latiuscula* were seven bivalent autosomes (A) plus XY sex chromosomes. The diploid chromosome number (2n) of *S. latiuscula* was 16. On the other hand, the male *S. coarctata* had 2n=13 consisting of 6IIA + XO (Table 1).

The two *Scotinophara* species were both heterogametic or capable of producing two types of sperm cells. *S. latiuscula* produced the (7IA + X) and (7IA + Y) sperms, while *S. coarctata* produced (6IA+X) and (6IA) sperms.

Mean relative lengths of pachytene chromosomes
of *S. latiuscula* and *S. coarctata*

During Pachynema, the homologues of *Scotinophara* species exhibited an elongated or still uncondensed state and were therefore desirable for length measurement. From the actual length meas-
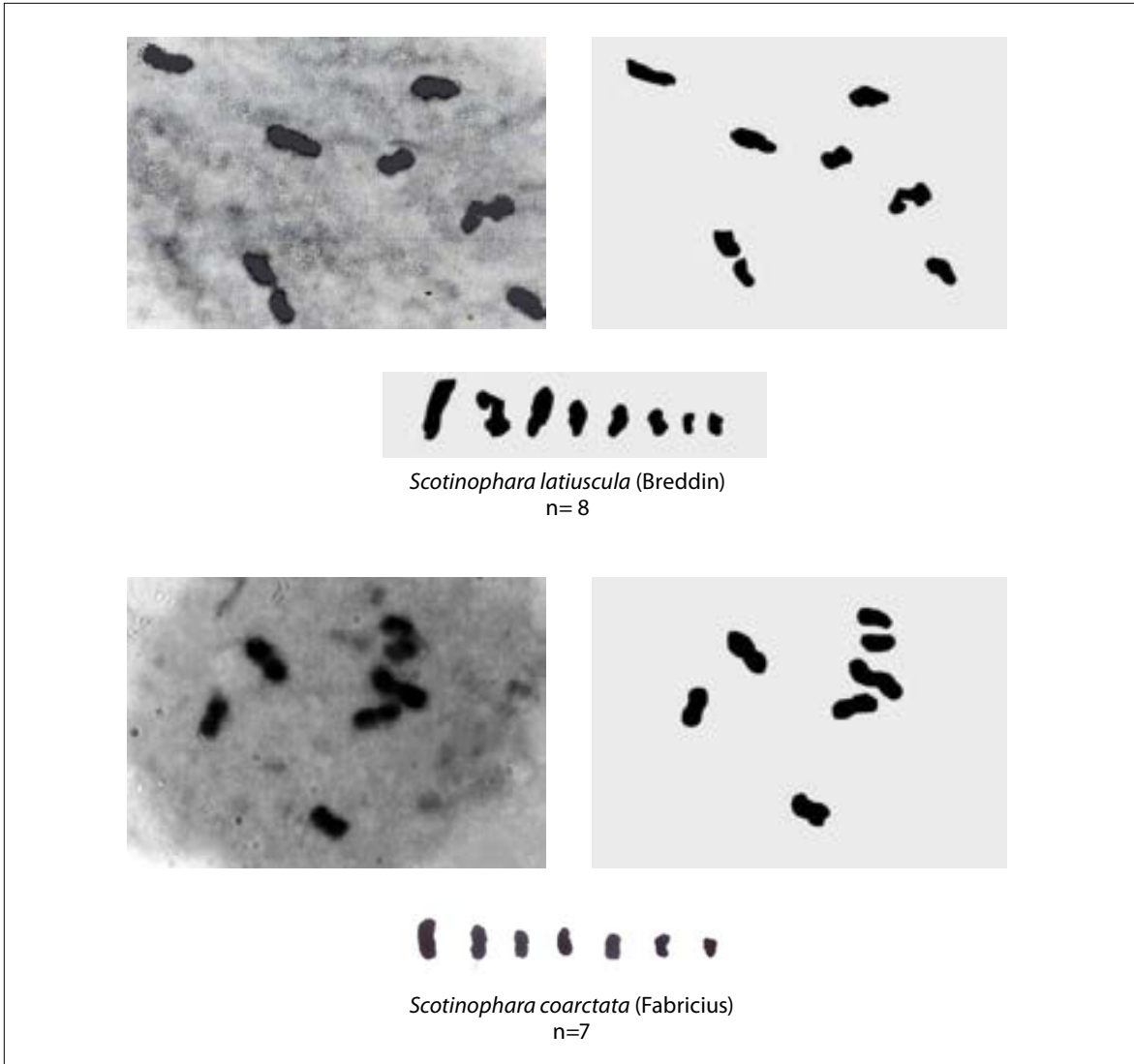
Fig. 3. Diakinesis chromosomes of two black bug species, *Scotinophara latiuscula* (Breddin) and *Scotinophara coarctata* (Fabricius) showing their haploid (n) chromosome numbers.

urements, the relative lengths were determined and arranged for the ideogram presentations (Fig. 4). The mean relative chromosome lengths, the autosomes including that with the nucleolus organizer (NOR), as well as the sex chromosomes of male *S. latiuscula* were shorter (ranging from 0.02 to 0.10) than those of male *S. coarctata* (ranging from 0.09 to 0.21). The autosomes of *S. latiuscula* ranged from 0.04 to 0.10, the autosome with NOR measured 0.08, and sex chromosomes X measured 0.03 and Y measured 0.02. On the other hand, the autosomes of *S. coarctata* measured 0.09−0.21, the autosome with NOR was 0.17, and the X chromosome measured 0.09.
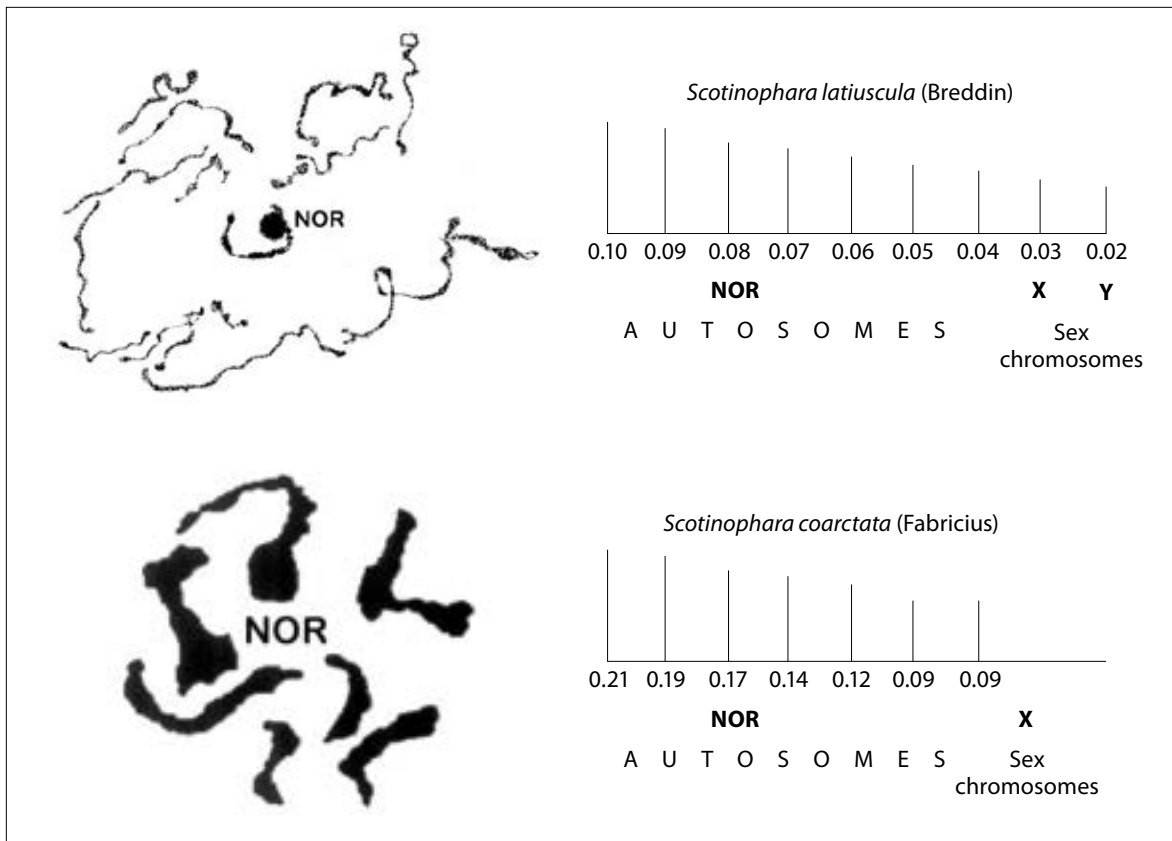
Fig. 4. Pachytene chromosomes of black bug species *Scotinophara latiuscula* (Breddin) and *Scotinophara coarctata* (Fabricius) and corresponding mean relative lengths of their autosomes and sex chromosomes.

First (reductional) and second (equational) meiotic stages in *S. latiuscula* and *S. coarctata*

The two *Scotinophara* species exhibited normal meiosis consisting of the first (reductional) and second (equational) stages (Figs. 5 and 6). The most frequently encountered karyological events in both *Scotinophara* species were Prophase I, followed by Metaphase II, then by Prophase II.

Thus, the overall meiotic divisions in spermatocytes of *S. latiuscula* and *S. coarctata* were similar, but their karyological features or the nuclear properties of their testicular cells were different.

Conclusion

Since the chromosomes are the carriers of genetic materials, they determine as well as control the characteristics of the species. It is therefore responsible for species distinctiveness. Information on the chromosomes of the species are essential for diversity study, hybridization experiments, genetic
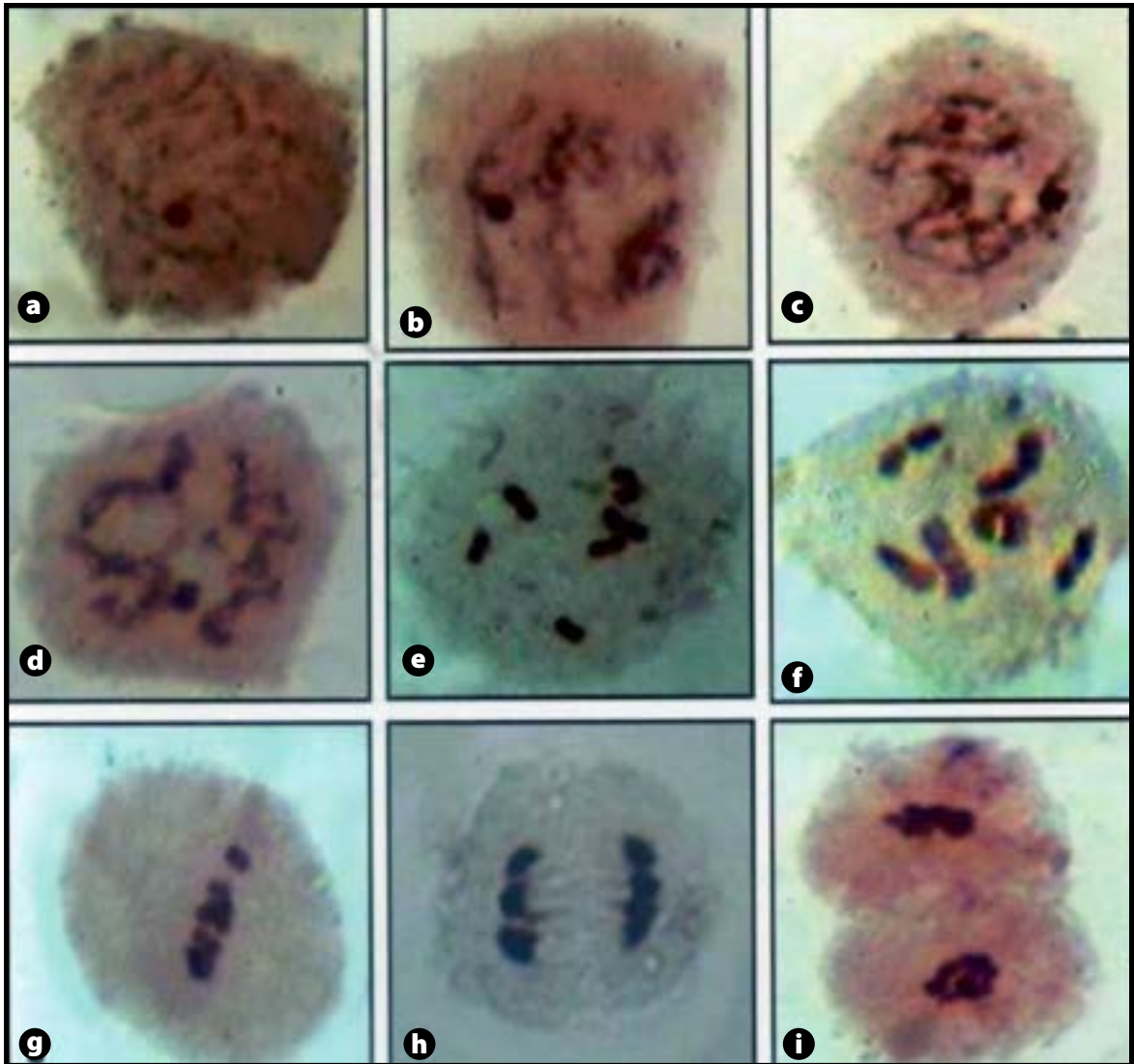
Fig. 5. First meiotic (reductional) division substages and stages in black bugs [*Scotinophara latiuscula* (Breddin) and *Scotinophara coarctata* (Fabricius)]. Substages of Prophase I: a. Leptonema; b. Zygonema; c and d. Pachynema; e and f. Diakinesis; g. Metaphase I; h. Anaphase I, and i. Telophase I.

and evolutionary research as well as those dealing with regulation and management of the pest species populations.

This study on the karyological features of the spermatogenetic cells of two *Scotinophara* species presented the MI, chromosome number, and mean relative lengths of both the autosomes and sex chromosomes.

Results of the comparative karyological investigation between *S. latiuscula* and *S. coarctata*, though preliminary, help contribute to a more detailed systematic study of these little-known insects.
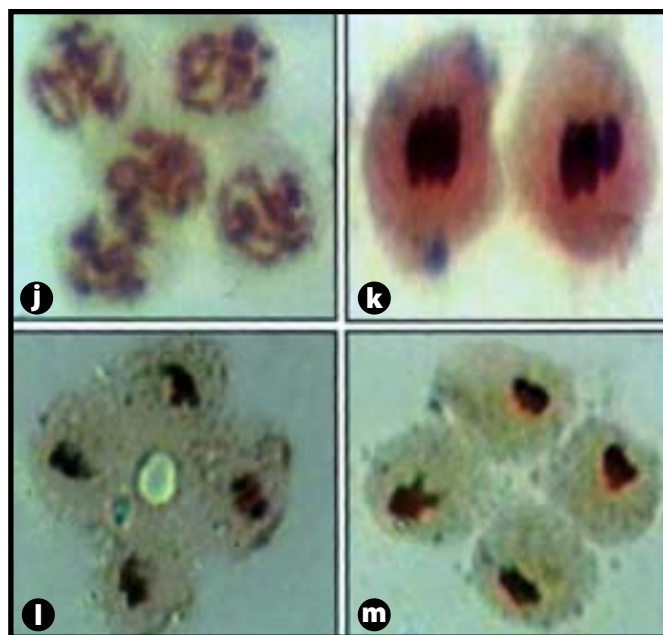
Fig. 6. Second meiotic (equational) division stages in black bugs [*Scotinophara latiuscula* (Breddin) and *Scotinophara coarctata* (Fabricius)]. j. Prophase II; k. Metaphase II; l. Anaphase II; and m.Telophase II.

In terms of the implications of this study in the field of pest management, this technique may potentially serve as one of the tools in characterizing and identifying what would otherwise be considered as morphologically indistinguishable or cryptic rice black bug species. Moreover, such pioneering contribution to the study of Philippine rice black bugs may very well be applied in the decisionmaking process of selecting and efficiently implementing the most appropriate control measures against future threats of rice black bug infestations.

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AUTHOR: PhilRice 2003—where was this cited? Please cite at the appropriate paragraph or delete from the list.

Notes

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Isozyme Polymorphism in Rice Black Bug *Scotinophara* sp. (*coarctata* Group) (Hemiptera: Pentatomidae) Sampled from Rice Fields in the Bicol Region

Frances Gerard dM. Genil, R.N. Tandang, Adelina A. Barrion, Alaberto T. Barrion, Ravindra C. Joshi, and Leocadio S. Sebastian

Abstract

Hemolymphs from 100 male rice black bugs (RBB) *Scotinophara* sp. (*coarctata* Group) (20 bugs from each of five localities in the Bicol region: San Roque, Sangay, Camarines Sur; Tulangan, Matnog, Sorsogon; Bagacay, Gubat, Sorsogon; Balading, Tabaco, Albay; and Nagas, Tiwi, Albay) were subjected to starch gel electrophoresis. The three enzyme systems considered were acid phosphatase (ACPH), alkaline phosphatase (ALPH), and esterase (EST). On the bais of Rf values, eight zones of activity or isoloci were identified: *ACPH-1*, *ACPH-2*, *ALPH-1*, *ALPH-2*, *ALPH-3*, *EST-1*, *EST-2*, and *EST-3*. Monomorphism of locus in all localities was exhibited by the *ALPH-3* isolocus, while polymorphic isoloci in all localities were observed in *ACPH-1*. The highest computed genetic identity (I) and lowest genetic distance (D) values were shown by male RBBs from Tulangan and Bagacay, both within Sorsogon. These populations also manifested the highest proportion of polymorphic loci (0.38), followed by those from localities Balading and Nagas (0.25). These values connote that Sorsogon RBBs possess higher genetic variations, probably more proteins that would help them survive and reproduce in their respective environment.

Key words: isozyme polymorphism, rice black bug, *Scotinophara* sp. (*coarctata* Group), rice

Introduction

Rice (*Oryza sativa* L.) is the staple food among Filipinos as well as in many other Asian nations. It provides about 80% of the calories of most Asians and one-third of the calorie intake of about a billion people in Africa and Latin America (Heinrichs 1994). A major factor that significantly limits rice production is infestation by more than 100 insect pests, 20 of them are major pests. Later, minor pests such as rice bugs, rice leaffolders, and whorl maggots became more important (Pathak and Khan 1994).

It was in February 1982 when the Malayan black bug, *Scotinophara coarctata* (Fabricius), was initially detected in the rice fields of southern Palawan. The bug was not included in the faunal list of arthropods injurious to Philippine crop plants (Woodworth 1921, 1922 a&b; Capco 1957; Cendana and Calora 1967; Baltazar 1968; Gabriel 1975). Then, on 8 June 1982, a report from the Bureau of Plant Industry at Los Baños led the researchers A.T. Barrion and J.A. Litsinger of the International Rice Research Institute (IRRI) to an irrigated wetland site in Siniloan, Laguna, near Laguna de Bay where another species of rice black bug, *Scotinophara latiuscula* (Breddin), was observed to be causing deadheart damage to rice. Their intensive research on the species from June 1982 to February 1984 enabled them to document the bionomics, karyology, and chemical control of the node-feeding bug *S. latiuscula* (Hemiptera: Pentatomidae) in the Philippines (Barrion and Litsinger 1987).

Six *Scotinophara* species have been recorded in the Philippines: *S. cinerea* Le Guillou (Hasegawa 1971); *S. ochracea* (Distant) and *S. lurida* (Burmeister) (Wongsiri 1975); and *S. latiuscula* (Breddin), *S. serrata* (Vollenhoven), and *S. tarsalis* (Vollenhoven) (Miyamoto et al 1983). None of these species have ever been reported as rice pest.

The outbreaks of black bugs occurred in provinces such as Zamboanga and Sorsogon in 1992 and Negros Occidental in 1998. Recently, in 2006, outbreaks were recorded in Capiz, Iloilo, and Bicol. RBB infestations were noted in four provinces in Bicol, namely: Sorsogon, Albay, Catanduanes, and Camarines Sur where more than 1,338 ha in 29 municipalities were reported (UMAsenso 2006).

The alarming outbreaks of RBBs in many rice-growing sites in the Philippines prompted many researchers to conduct scientific investigations regarding the insect species. Since no molecular information has yet been reported on RBBs sampled from the Bicol Region, this study was conducted. The foundation knowledge would serve as basis for future studies about the pest. The study aimed to investigate the isozyme polymorphism of the RBBs from five different localities in Bicol: San Roque, Sangay, Camarines Sur; Tulangan, Matnog, Sorsogon; Bagacay, Gubat, Sorsogon; Balading, Tabaco, Albay; and Nagas, Tiwi, Albay (Fig. 1). The specific objectives are to identify the isoloci of three enzymes—acid phosphatase (ACPH), alkaline phosphatase (ALPH), and esterase (EST)—and estimate gene and genotypic frequencies; to determine genetic variability by calculating the degree of polymorphism, average number of alleles per locus, and average heterozygosity within the population. The genetic similarities and distance of the populations of *Scotinophara* sp. from the different localities of the Bicol Region were determined.

Materials and methods

Storage of RBBs

Twenty adult male RBBs from each of the five different localities of the Bicol Region namely: San Roque, Sangay, Camarines Sur (locality 1); Tulangan, Matnog, Sorsogon (locality 2); Bagacay, Gubat, Sorsogon (locality 3); Balading, Tabaco, Albay (locality 4); and Nagas, Tiwi, Albay (locality 5) were placed in five separate plastic tubes labeled correspondingly and were placed in a freezer prior to homogenization.
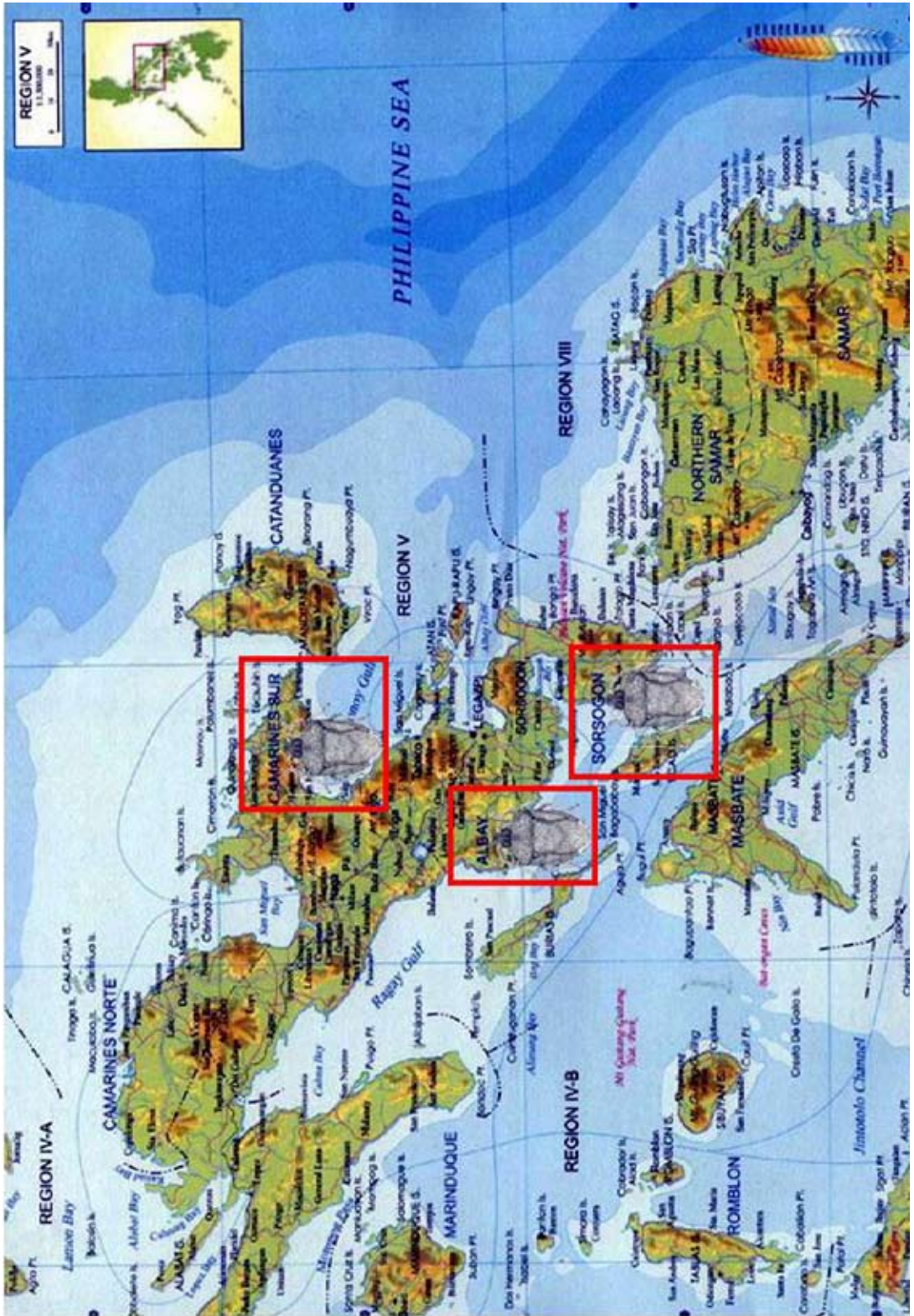
Fig. 1. Map of Bicol Region showing the sampling sites.

Preparation of crude extracts of hemolymphs

One adult male RBB with 200 μL of homogenizing buffer was placed in a ceramic mortar and squashed using a stirring rod. The exoskeleton of the insect was removed from the crude extract of hemolymph containing the hemocytes using forceps. The crude extract was placed in an Eppendorf tube. The tube was then placed immediately in a freezer until electrophoresis was conducted.

Preparation of starch gel

The hydrolyzed potato starch (20.4 g) was measured and poured in a 300-ml slide flask. The diluted Tris-His buffer (170 ml) was added to dissolve the starch. The mixture was partially mixed until it was almost homogeneous. The solution was heated in a microwave oven and swirled occasionally to prevent the formation of lumps. Heating was stopped when the mixture became transparent. Excess bubbles were removed using a deaerator. The side of the comb and the molder were wiped with glycerine to prevent the solidified gel from sticking to the apparatus. The gel was poured into the molder and the combs were inserted. These combs created wells where the samples would be loaded. The gel was cooled down and stored in a refrigerator overnight prior to use in electrophoresis.

Loading of samples

The inserted combs in the gel were removed. Excess moisture was removed from the wells using pieces of tissue or filter papers to prevent dilution of the crude extracts of RBB hemolymph. A micropipettor was used to transfer an ample amount of sample from the Eppendorf tube to the wells. The first 10 wells were loaded with the crude extracts, while the eleventh and twelfth wells were loaded with the pooled crude extracts and tracking dye, respectively.

Electrophoretic run

The Mupid Gel Electrophoresis Apparatus was set prior to the electrophoresis proper. The gels were placed in the apparatus filled with running buffer. An initial voltage of 50 volts was set and later adjusted to 100 volts after an hour. The apparatus was placed inside the refrigerator over a tray filled with ice to prevent overheating that may cause denaturation of the samples. Tracking was monitored until the run was finished.

Staining and fixation

After electrophoresis, each gel was sliced horizontally in a gel slicer using a fine copper wire. The edge of the gel nearest the tracking dye was cut diagonally to mark the location of the tracking dye with reference to the samples. The sliced gels were then placed in previously labeled plastic containers with the specific staining solution for the enzyme being analyzed. The gels were then incubated in the dark for an hour or until bands appeared. The stains were then discarded after use. The gels were immersed in a destaining solution composed of acetic acid, methanol, and distilled water (1:5:5 ratio). After destaining, the gels were washed with distilled water and dried by blotting of tissue or

filter paper. The gels were wrapped in a transparent plastic film, labeled, and stored in the refrigerator for future reference.

Analysis of data

Each gel after the runs was photographed. The distance traveled by the tracking dye was measured for each gel. Also, the distance traveled by the bands for each particular enzyme was measured. Each band was characterized by a particular electrophoretic mobility value (Rf), which was computed using the following formula:

$$Rf = \frac{\text{Distance traveled by the band (mm)}}{\text{Distance traveled by the tracking dye (mm)}}$$

The genotype and gene frequencies were then estimated after obtaining the Rf values. By convention, the slowest moving band, which has the lowest Rf value, was designated as number 1, the second as number 2, and so on, depending on the number of bands obtained. Each zone of activity corresponds to the number of isoloci.

Genetic identity (I) was computed to determine the degree of similarity between the different populations of RBBs using the following equation:

$$I_{xy} = \frac{\sum X_i * \sum Y_i}{\sqrt{\sum X_i^2 * Y_i^2}}$$

Genetic distance (D) was computed to determine the degree by which the RBB populations differ using the following equation:

$$D = -\ln I$$

The extent of genetic variation in the population of RBB was determined by computing for the proportion of polymorphic loci (P), the average number of alleles per locus (A), and the mean heterozygosity (H_e) using the following formulae:

$$P = \frac{\text{Number of polymorphic loci}}{\text{Total number of loci}}$$

$$A = \frac{\text{Number of alleles in all loci}}{\text{Total number of loci}}$$

$$H_l = 1 - \sum x_i^2$$

where x_i is the frequency of the ith allele at the locus

$$H_e = \sum H_l / R$$

where R is the total number of loci observed.

Results and discussion

Isozymes of adult male *Scotinophara* sp. (*coarctata* Group)

Based on the Rf values of the bands produced by the three hemolymph enzyme systems (ACPH, ALPH, and EST) in the adult male RBBs, there were eight zones of activity of presumptive isoloci—*ACPH-1, ACPH-2, ALPH-1, ALPH-2, ALPH-3, EST-1, EST-2, and EST-3* (Table 1).

Table 1. Relative mobility (Rf) values of the protein bands at eight presumptive loci observed in the male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region.

Locus[a]	Locality 1[b]		Locality 2[c]		Locality 3[d]		Locality 4[e]		Locality 5[f]	
	S[g]	F[h]	S	F	S	F	S	F	S	F
ACPH-1	0.0769–0.1346	0.1538–0.1923	0.3850–0.1154	0.1538–0.2308	0.0385–0.1346	0.1538–0.2308	0.0385–0.1346	0.3462–0.3846	0.0769–0.1346	---
ACPH-2	---	---	---	---	---	---	0.2885–0.3462	0.3477–0.3846	0.2885–0.3269	0.3477–0.4038
ALPH-1	---	---	0.0385–0.0769	---	0.0385–0.0769	---	---	---	---	---
ALPH-2	0.1154–0.1731	---	0.1153–0.1731	0.2116–0.2692	0.1153–0.1731	0.1923–0.2500	0.1154–0.1737		---	0.1695–0.2542
ALPH-3	0.2692–0.3462	---	---	---	---	---	0.2692–0.3462	---	0.3051–0.3500	---
EST-1	0.0600–0.1200	---	0.0577–0.1154	---	0.7471–0.1111	---	0.0577–0.1154	---	---	---
EST-2	0.1538–0.2037	---	0.1535–0.2115	0.2131–0.2692	0.1481–0.1852	0.2037–0.2593	---	0.2115–0.2692	0.1731–0.2115	0.2308–0.2692
EST-3	---	---	---	---	---	---	0.3077–0.3462	---	0.2885–0.3462	---

[a]ACPH–acid phosphatase, ALPH–alkaline phosphatase, EST–esterase. [b]San Roque, Sangay, Camarines Sur. [c]Tulangan, Matnog, Sorsogon. [d]Bagacay, Gubat, Sorsogon. [e] Balading, Tabaco, Albay. [f]Nagas, Tiwi, Albay. [g]S–slow region. [h]F–fast region.

Three hemolymph enzymes of the male RBBs sampled from the Bicol Region

Acid phosphatase (ACPH)

The Rf values of the ACPH bands revealed two zones of activity (isoloci), *ACPH-1* and *ACPH-2*. The former has lower Rf value and slower migration than the latter (Fig. 2).

The number of alleles present in each isolocus was deduced from the Rf values. For each of the *ACPH* isoloci, two alleles were observed and designated as either slow (S) or fast (F).

An isolocus is polymorphic when the frequency of its most frequent allele is between 0.05 and 0.095; otherwise, the isolocus is monomorphic. For *ACPH-1*, both S and F alleles were present in four localities. The F allele was absent in locality 5. It is therefore polymorphic in all localities. The S allele was most frequent in locality 2 (0.75) and least frequent in localities 4 and 5 (0.25). On the other hand, the *ACPH-2* locus with S and F alleles was found only in localities 4 and 5 and therefore polymorphic in these localities (Table 2). The S and F alleles were present only in localities 4 and 5 with the frequency of 0.25 for both.

Figures 2a and 2b contain representative photograph and a summary zymogram of the banding pattern of *ACPH*. The zymogram presents the possible band patterns (genotypes) in the samples from all the localities. The slowest migrating bands on the S zone of the *ACPH-1* locus had Rf values ranging from 0.0385 to 0.1346, whereas the bands on the F zone had Rf values within the 0.1538 to 0.2308 range. The other locus, with S and F alleles, had Rf values of migrating bands ranging from 0.2885 to 0.3462 and 0.3477 to 0.4038, respectively. The samples in the photograph were designated as S/F genotype or heterozygote for both isoloci because both autosomal codominant alleles were present.


```
                                           --- ACPH 2 F (0.3477–0.4038)
                                           --- ACPH 2 S (0.2885–0.3269)

                                           --- ACPH 1 F (0.1538–0.2308)
                                           --- ACPH 1 S (0.0385–0.1346)

  1    2    3    4    5    6    7    8    9   10   control
 SF   SF   SF   SF   SF   SF   SF   SF   SF   SF     SF
 SF   SF   SF   SF   SF   SF   SF   SF   SF   SF     SF
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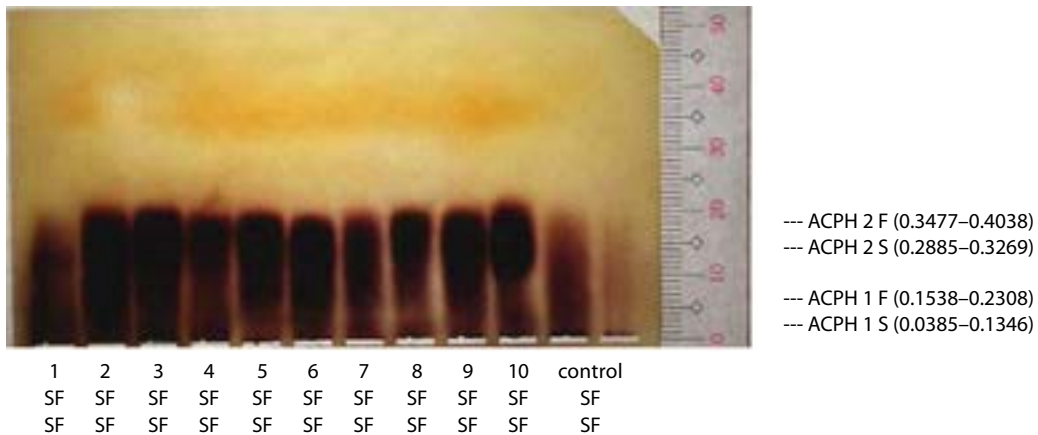
Fig. 2a. Representative photograph of the banding pattern on acid phosphatase (ACPH) in male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region.

Rf values
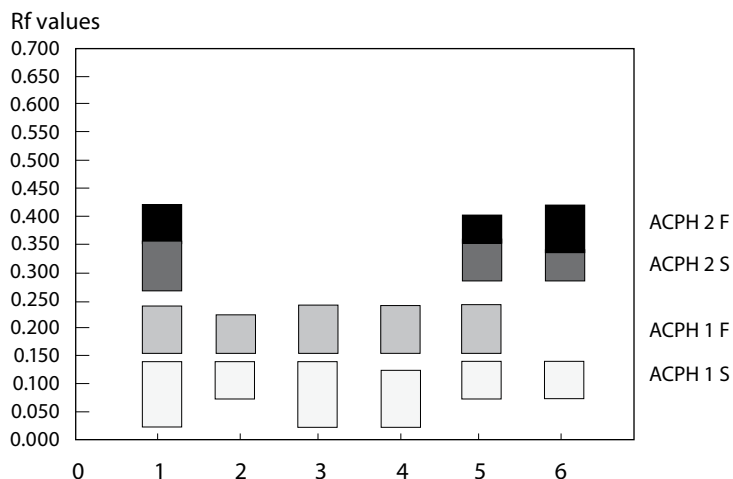
Fig. 2b. Summary zymogram of the banding pattern on acid phosphatase (ACPH) in male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region. Lane 1 = bands that appeared in ACPH; lanes 2–6 = banding patterns in localities 1–5 accordingly; S = slow region; F = fast region.

Table 2. Summary of electrophoretic analysis of the three protein systems at eight presumptive loci in the male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region.[a]

Locus[a]	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
ACPH 1	Polymorphic	Polymorphic	Polymorphic	Polymorphic	Polymorphic
ACPH 2	---	---	---	Polymorphic	Polymorphic
ALPH 1	---	Monomorphic	Monomorphic	---	---
ALPH 2	Monomorphic	Polymorphic	Polymorphic	Monomorphic	Monomorphic
ALPH 3	Monomorphic	Monomorphic	Monomorphic	Monomorphic	Monomorphic
EST 1	Monomorphic	Monomorphic	Monomorphic	---	---
EST 2	Monomorphic	Polymorphic	Polymorphic	Monomorphic	Monomorphic
EST 3	---[b]	---	---	Monomorphic	Monomorphic

[a]See Table 1 for locus and locality designations. [b]---isolocus not observed in the particular locality.

In terms of genotype frequencies, *ACPH-1* had S/S genotype exhibited by RBBs from localities 1 and 2. The F/F genotype was exhibited by RBBs from all localities. S/F genotype was observed in RBBs of four localities, except those in locality 3. For *ACPH-2,* only S/F genotype was exhibited by RBBs from localities 4 and 5, both with a frequency of 0.50 (Tables 3 and 4).

Alkaline phosphatase (ALPH)
Three zones of activity (isoloci) were deduced for the ALPH from the five different localities. The higher the Rf value of the enzyme band, the faster is its migration; so the slowest locus (lowest Rf

Locus[a]	Locality 1				Locality 2				Locality 3				Locality 4				Locality 5			
	SS	SF	FF	Total	SS	SF	FF	Total	SS	SF	FF	Total	SS	SF	FF	Total	SS	SF	FF	Total
ACPH 1	9	10	0	19	10	10	0	20	0	20	0	20	0	10	0	10	0	10	0	10
ACPH 2	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	0	10	0	10
ALPH 1	0			0	10			10	7			7	0			0	0			0
ALPH 2	19			19	2	6	1	9	10	9		19	20			20	0		20	20
ALPH 3	9	0	0		6	0	0	6	9	0	0	9	20	0	0	20	10	0	0	10
EST 1	20			20	20			20	20			20	19			19	19			19
EST 2	19	0	0	19	0	18	0	18	0	18	0	18	0	0	19	19	0	0	19	19
EST 3	0			0	0			0	0			0	10			10	10			10

[a]See Table 1 for locus and locality designations**.**

Locus[a]	Allele	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
ACPH-1	S/S	0.450	0.500	---	---	---
	S/F	0.500	0.500	1.000	0.500	0.500
	F/F	---	---	---	---	---
ACPH-2	S/S	---	---	---	---	---
	S/F	---	---	---	0.500	0.500
	F/F	---	---	---	---	---
ALPH-1	S/S	---	0.500	0.350	---	---
ALPH-2	S/S	0.950	0.100	0.500	1.000	---
	S/F	---	0.300	---	---	---
	F/F	---	0.050	---	---	1.000
ALPH-3	S/S	0.450	0.300	0.450	1.000	0.500
EST-1	S/S	1.000	1.000	1.000	0.950	0.950
EST-2	S/S	0.950	---	---	---	---
	S/F	---	0.900	0.900	---	---
	F/F	---	---	---	0.950	0.950
EST-3	S/S	---	---	---	0.500	0.500

[a]See Table 1 for locus and locality designations.

values) was designated as ALPH-1, followed by ALPH-2, and lastly ALPH-3. In ALPH, the S and F alleles were only observed to be present in the ALPH-2 isolocus of the male RBB in the five localities.

Since only a single allele was available in ALPH-1 and ALPH-3, the isoloci were designated as monomorphic (Table 2). Based on the aforementioned frequency range, ALPH-2 was found to be polymorphic in localities 2 and 3 and monomorphic in localities 1, 4, and 5.

A representative photograph and a summary zymogram of the banding pattern of RBB ALPH are shown in Figures 3a and 3b, respectively. However, the photograph only showed the bands on

--- ALPH 2 S (0.1153 – 0.1731)
--- ALPH 1 (0.0385 – (0.0769)

1	2	3	4	5	6	7	8	9	10	control
SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
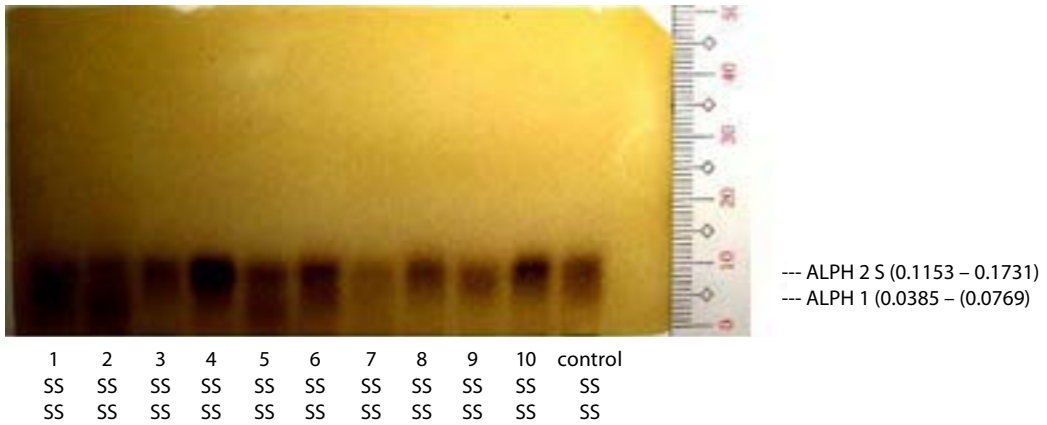
Fig. 3a. Representative photograph of the banding pattern on alkaline phosphatase (ALPH) in male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region.
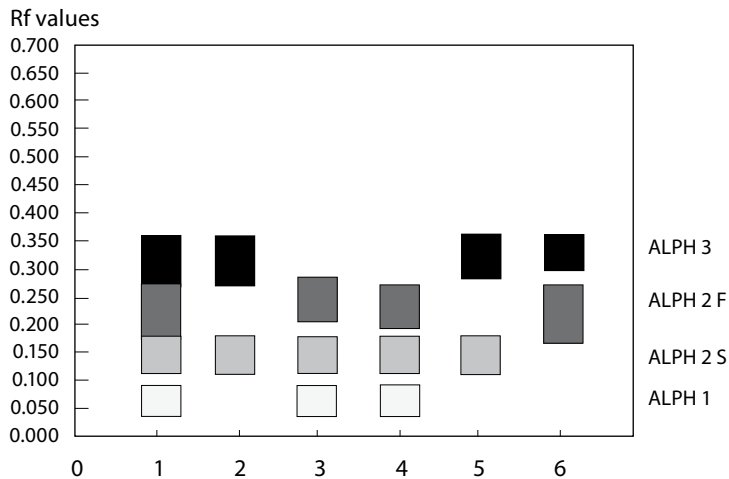
Fig. 3b. Summary zymogram of the banding pattern on alkaline phosphatase (ALPH) in male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region. Lane 1 = bands that appeared in ALPH; lanes 2–6 = banding patterns in localities 1–5 accordingly; S = slow region; F = fast region.

ALPH-1 and the ALPH-2 S zone. The slowest migrating bands had a mean range of 0.0385−0.0769, falling under the ALPH-1 locus, while the bands on the S allele of the ALPH-2 locus had a mean range of 0.1153−0.1731.

In terms of genotype frequency (Tables 3 and 4), the S allele, which was the only allele present in ALPH-1, was observed in localities 2 and 3 with a frequency of 0.500 and 0.350, respectively. Both S and F alleles were present in ALPH-2. The S allele was found in all the localities, except in

locality 5. The highest frequency observed was in locality 4 (1.000) and the lowest was in locality 2 (0.250). The F allele was found in localities 2, 3, and 5. The highest frequency was found in locality 5 (1.000), while the lowest was in locality 2 (0.200). The only allele present in ALPH-3 was the S allele and this was observed in all localities. The S allele for the mentioned loci was found to be most frequent in locality 4 (1.000) and least frequent in locality 2 (0.300).

Esterase (EST)

Three zones of activity or three isoloci were identified in esterase: EST-1, EST-2, and EST-3; with EST-2 having the S and F alleles (Table 1). The EST-1 and EST-3 loci were identified to be monomorphic since only a single allele was available for both mentioned loci. Based on the frequency range of polymorphism mentioned earlier, the EST-2 locus was found to be polymorphic in localities 2 and 3 (Table 2). The locus was found to be monomorphic in localities 1, 4, and 5. A single allele was only observed: S in locality 1 and F in localities 4 and 5.

A representative photograph and a summary zymogram of the banding pattern of EST are shown in Figures 4a and 4b, respectively. The summary zymogram showed that there were also four possible bands for EST like ACPH. In the representative photograph, all the samples showed various bands, except in the 9th well, which did not show any bands. The slowest migrating bands on the EST-1 locus have an Rf value range of 0.0577−0.1200 and were designated as S/S. All samples, except in the 10th and 11th well (control), showed bands in this locus. The next migrating bands on the EST-2 locus had an Rf value range of 0.1481−0.1852 on the S zone and 0.2037−0.2692 on the F zone. The samples shown in the photograph were designated as S/F genotype (heterozygote) for both isoloci. Like the previous locus, all the samples, except in the 10th and 11th well (control), showed bands in the S and

--- EST 3 (0.2885-0.3462)
--- EST 2 F (0.2037-0.2692)
--- EST 2 S (0.1481-0.2115)
--- EST 1 (0.0577-0.1200)

1	2	3	4	5	6	7	8	9	10	control
---	---	---	SS	SS	SS	SS	SS	---	SS	SS
SF	SF	SF	SF	SF	SF	SF	SF	---	---	---
SS	SS	SS	SS	SS	SS	SS	SS	---	---	---
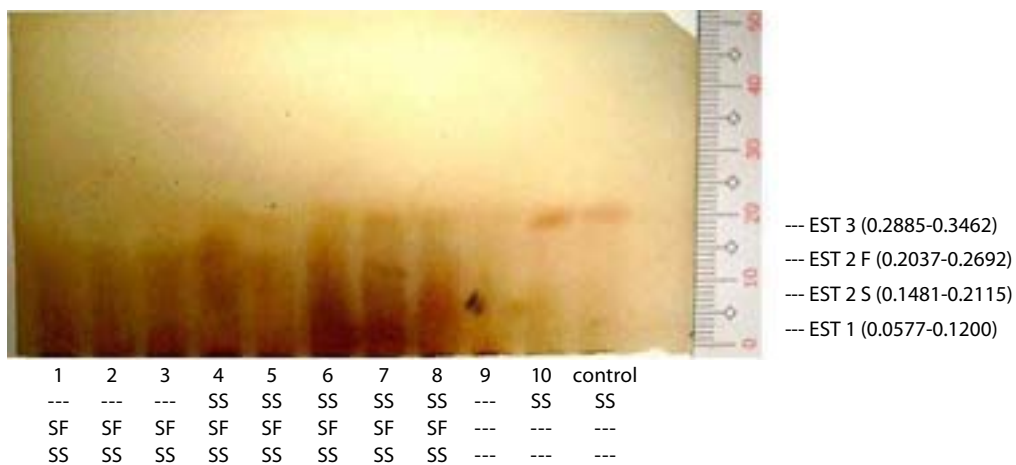
Fig. 4a. Representative photograph of the banding pattern on esterase (EST) in male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region.
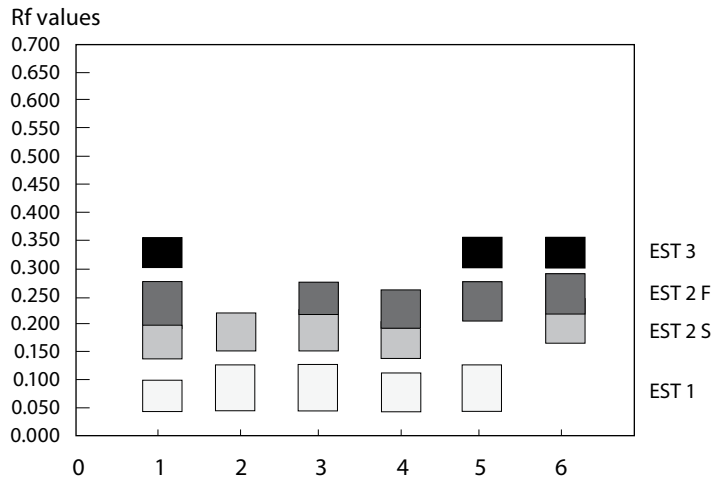
Fig. 4b. Summary zymogram of the banding pattern on esterase (EST) in male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region. Lane 1 = bands that appeared in ALPH; Lanes 2 –6 = banding patterns in Localities 1 to 5 accordingly; S = slow region; F = fast region.

F alleles of the EST-2 locus. The fastest migrating bands were observed on the EST-3 locus with an Rf value range of 0.2885−0.3462 and were designated as S/S. All the samples, except in the 1st to 3rd wells, showed bands in this locus.

In EST-1 and EST-3, the only present allele was the S allele. A very high frequency (1.000) was observed in localities 1, 2, and 3 in the S allele of the EST-1 locus. A frequency of 0.500 was observed in both localities 4 and 5 in the same allele of the EST-3 locus. On the other hand, both the S and F alleles were present in EST-2. The S allele was observed in localities 1, 2, and 3 in which the highest frequency was noted in locality 1 (0.950). The F allele was present, except for locality 1. The highest frequency (0.950) was observed in localities 4 and 5.

Genetic identity and distance among RBB populations
Genetic identity (I) serves as a basis for determining the degree of similarity between RBB populations, whereas genetic distance (D) is used to determine the degree by which the RBB populations differ. The computed I and D values in the different RBB populations from the five localities in the Bicol Region are shown in Tables 6a and 6b, respectively.

The computed I values ranged from 0.397 to 0.927. The obtained D values ranged from 0.073 to 0.603. The highest I value and lowest D value were observed in RBBs from localities 2 and 3, suggesting that the RBB populations have a high degree of genetic similarity. This is plausible since localities 2 and 3 are both within the province of Sorsogon. However, this observation was not noted in RBBs in localities 4 and 5, which are both in Albay.

Table 6a. Genetic identity (I) values obtained from comparing the populations of male rice black bug _Scotinophara_ sp. (_coarctata_ Group) sampled from rice fields in five different localities[a] in the Bicol Region.

	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
Locality 1	*	0.805	0.884	0.636	0.397
Locality 2	*	*	0.927	0.667	0.667
Locality 3	*	*	*	0.806	0.658
Locality 4	*	*	*	*	0.717
Locality 5	*	*	*	*	*

[a]1–San Roque, Sangay, Camarines Sur; 2–Tulangan, Matnog, Sorsogon; 3–Bagacay, Gubat, Sorsogon; 4–Balading, Tabaco, Albay; 5– Nagas, Tiwi, Albay.

Table 6b. Genetic distance (D) values obtained from comparing the populations of male rice black bug _Scotinophara_ sp. (_coarctata_ Group) sampled from rice fields in five different localities[a] in the Bicol Region.

	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
Locality 1	*	0.195	0.116	0.364	0.603
Locality 2	*	*	0.073	0.333	0.333
Locality 3	*	*	*	0.194	0.342
Locality 4	*	*	*	*	0.283
Locality 5	*	*	*	*	*

[a]See Table 6a for designation of localities.

Genetic variation in RBBs sampled from the Bicol Region

Table 7 shows the proportion of polymorphic loci (P), average number of alleles per locus (A), and mean heterozygosity (H_e) in all the populations (localities) of the male RBBs from the Bicol Region.

Considering the proportion of polymorphic loci, localities 2 and 3, followed by 4 and 5, had computed values of 0.38 (highest value) and 0.25, respectively, among the RBB populations. This implies that the RBBs in these localities have more polymorphic loci or genetic variation than the rest of the localities and possibly with more forms of protein that would help them survive and adapt to their respective environment.

In terms of the number of alleles in each locus, all of the localities had a value of 0.750, except for locality 1 (0.625).

The heterozygosity value obtained was highest in locality 3 (0.675). A high mean value of heterozygosity implies high genetic diversity because it estimates the probability that two alleles taken at random from the population are different (Alpuerto 2005). It also implies the mean proportion of heterozygote at a single locus. A low mean value of mean heterozygosity implies a high number of homozygotes in the population and this would cause loss in genetic diversity for the succeeding generations.

Table 7. Measures of genetic variation in the populations of male rice black bug *Scotinophara* sp. (*coarctata* Group) sampled from rice fields in five different localities in the Bicol Region.

Parameter[a]	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5
P	0.125	0.375	0.375	0.250	0.250
A	0.625	0.750	0.750	0.750	0.750
H_e	0.581	0.601	0.675	0.544	0.637

[a]P – proportion of polymorphic loci. A – average number of alleles per locus. H_e – mean heterozygosity.

Summary and conclusion

An electrophoretic study involving 100 male RBBs (20 each from five localities in Bicol Region) was conducted to determine the genetic variations of the populations. The populations of *Scotinophara* sp. were designated as locality 1: San Roque, Sangay, Camarines Sur; locality 2: Tulangan, Matnog, Sorsogon; locality 3: Bagacay, Gubat, Sorsogon; locality 4: Balading, Tabaco, Albay; and locality 5: Nagas, Tiwi, Albay. The three enzyme systems considered were acid phosphatase (ACPH), alkaline phosphatase (ALPH), and esterase (EST).

A total of eight isoloci (ACPH-1, ACPH-2, ALPH-1, ALPH-2, EST-1, EST-2, and EST-3) were identified, but not all were present in each locality. Only five (ACPH-1, ALPH-2, ALPH-3, EST-1, and EST-2) isoloci were observed in locality 1, and six isoloci in localities 2 and 3 (ACPH-1, ALPH-1, ALPH-2, ALPH-3 EST-1 and EST-2), 4, and 5 (ACPH-1, ACPH-2, ALPH-2, ALPH-3, EST-2 and EST-3). Monomorphic isoloci present in all localities were only observed in the ALPH-3 isolocus, while polymorphic isoloci present in all localities were observed in ACPH-1.

There were also differences in genotype and gene frequencies. The alleles observed were S and F, but not all isolocis have both alleles. The mentioned alleles were only present in ALPH-2, ACPH-1, ACPH-2, and EST-2 isoloci. The rest of the isoloci (ALPH-1, ALPH-3, EST-1, and EST-3) only have the S allele. Not all the genotypes were present in each isolocus. For example, the S/F genotype of the ALPH-2 isolocus was only present in locality 2.

The genetic identity (I) and genetic distance (D) were also computed. The highest genetic identity and lowest genetic distance values occurred in localities 2 and 3. This is plausible because the populations compared are located in the same area (province).

The proportion of polymorphic loci was found to be the same in localities 2 and 3, and in 4 and 5. The average number of allele per locus was the same for all localities (0.750), except in locality 1 (0.500). In terms of mean heterozygosity, the highest value was obtained in locality 3 (0.675). This implies that there are more heterozygotes among the RBBs in the locality than the rest. Therefore, the RBBs from Sorsogon are more genetically diverse and have a higher capacity to contribute more chances of variation to the next generation of RBBs.

This finding has implications in the management of RBBs in the Bicol Region, specifically in Sorsogon. The decreasing marshy and wetland habitats for RBBs in the province need to be regulated to confine the RBBs in their preferred habitats and mitigate the spread and further incursion into the rice fields. Because these bugs show high reproductive potential and can develop huge swarms to house and streetlights during full moon, it is necessary to adopt the abovementioned suggestions. Noncompliance to this recommendation may likely build up the farmers' addiction to use chemical pyrethroids that ultimately kill the beneficial insects and spiders that abound in the rice ecosystems.

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Notes

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Importance of Scanning Electron Microscopy Images to Identify Cryptic Invasive Alien Rice Insect Pests: Case Study on the Philippine Rice Black Bugs (*Scotinophara* spp.)

Lorele C. Trinidad

Abstract

The scanning electron microscope (SEM) is generally used to observe the ultrastructures on the surface of biological specimens. Dry, hard material samples do not need any elaborate treatments, whereas soft and wet biological samples need to be carefully processed to avoid damage to the fragile surface ultrastructure. Sample preparation for biological specimens would include several steps: i) fixation, ii) buffer wash, iii) dehydration, iv) critical point drying (CPD), v) mounting on stubs, and vi) ion coating prior to SEM observation. Depending on the nature and size of the specimen, these can take 2-4 d. Samples can be up to 2 cm^3 in size for efficient fixation and drying. Fixatives normally used are glutaraldehyde and osmium tetroxide. Dehydration series may be done using ethanol or acetone. Pretreatment with isoamyl acetate is done prior to CPD using liquid CO_2. The dried samples are then mounted on stubs, then subjected to ion coating using gold or gold-palladium in an ion sputter. The sturdiness of the RBB specimens has led to a much shorter version of the sample preparation procedure, facilitating the examination of more specimens in a given time without compromising the quality of the micrographs obtained. For taxonomic work on RBB, this finding is valuable and makes possible the handling of large sample populations. One virtue of the SEM is its applicability to the examination of large specimens. Intact organisms or a portion of the organism can be examined without resorting to the tiny ultra-thin section required for the TEM. This is important especially if one is dealing with preserved museum specimens collected from different countries over a period of time.

Introduction

Electron microscopy can be defined as the science of imaging specimens by using an electron beam as the information carrier. As we shall see, the advantage of using electrons over light is the greater resolving power or the ability to distinguish fine details.

The electron microscope has a resolution about 100 times better than that of a light microscope and has proven to be a powerful and a useful tool for biological research.

In 1986, the Nobel Prize in Physics was awarded jointly to Ernst Ruska of the Fritz Haber Institute in West Berlin for his work on the original design of the transmission electron microscope and to Gerd Binnig and Heinrich Rohrer of IBM Zurich Research Laboratory for their design of the scanning tunneling microscope. In doing so, the Nobel Prize committee called the transmission electron microscope and electron microscopes, in general, "one of the most important inventions of this century."

Since Ruska's time, several kinds of microscopes have been designed using the electron beam as the source of image formation. The two basic column designs are the transmission electron microscope and the scanning electron microscope (Fig. 1).
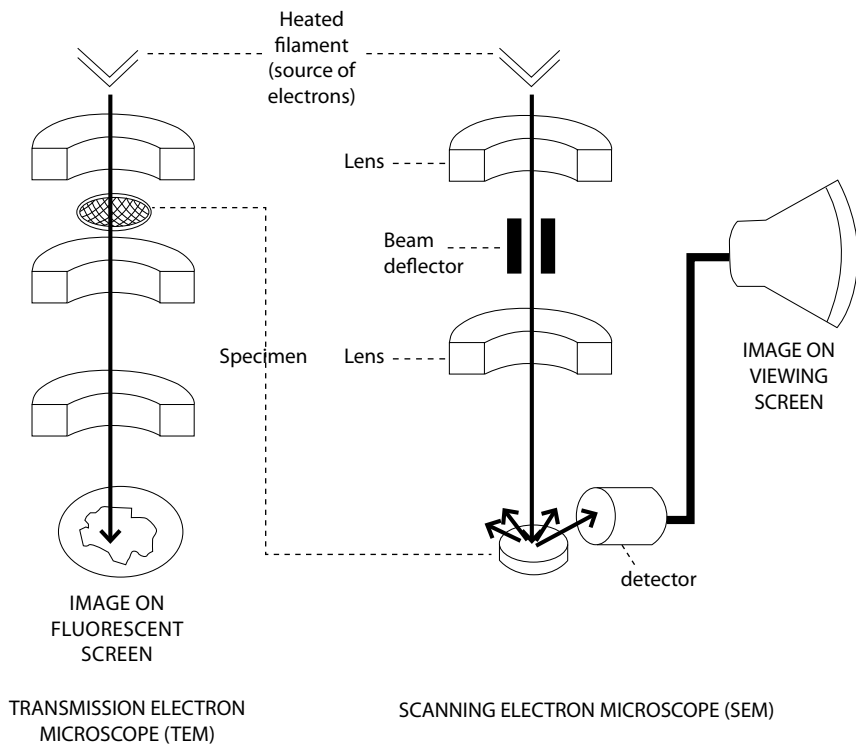
Fig. 1. Principal features of transmission and scanning electron microscopes.
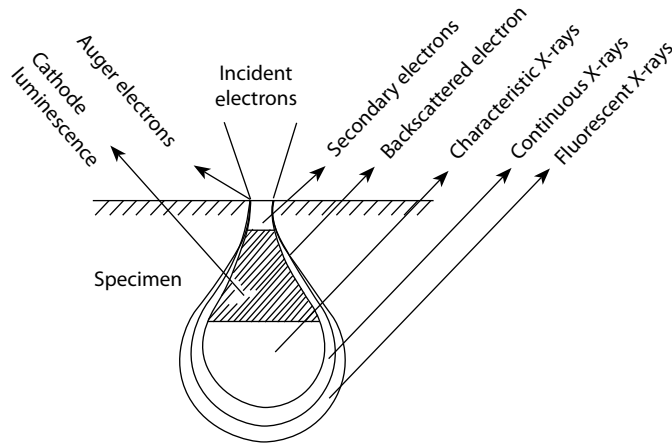
Fig. 2. Interaction between incident electrons and specimen.

The scanning electron microscope

In the scanning electron microscope (SEM), the electron beam rapidly scans the surface of the specimen to induce radiations (low-energy secondary electrons or backscattered primary electrons) (Fig. 2). Both secondary and backscattered electrons contribute to the image in SEM. These form an image on a cathode ray tube (CRT) by synchronizing the movement of the electron beam in the microscope (and the information being collected) with the information displayed (as a raster) on the tube; the process is similar to the formation of a television picture. Thus, with the column subjected under high vacuum, the biological specimen must first be chemically fixed, dried (best by critical point drying [CPD] or freeze drying to avoid distortion), and given a thin metal coating to make it conductive (sputtered *in vacuo* with gold, palladium, platinum, or gold-palladium combination).

Advantages of the SEM

There are various reasons for the popularity and usefulness of the SEM among biologists. Perhaps, the greatest is the large depth of field, which can be up to 400 times greater than that which can be obtained with a light microscope. Much of the analysis of biological samples is done within the magnification range of the light microscope. However, the total information content of the SEM image can be immensely greater. As an illustration, compare Figures 3a and 3b, and Figures 4a–4e.

The large depth of field of the SEM makes it appear as if a different sample is being viewed. The SEM also has a higher resolution than a light microscope but it is not as high as that of a TEM. Light microscopes are limited by the wavelength of light to a resolution of about 200 nm. Electron microscopes are limited by the design of the electromagnetic lenses to a resolution of about 0.2 nm.

The SEM produces an image, which has a high dimensionality—i.e., the photos obtained have much eye appeal and can be easily appreciated. The instrument has an extremely wide range of magnification, usually between about 10x and 100,000x. Since bulk samples as opposed to sections
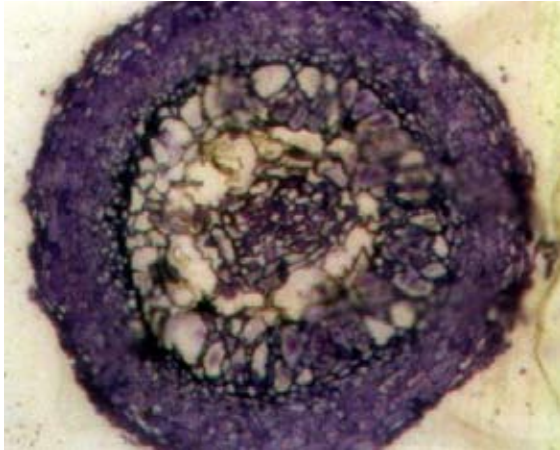
Fig. 3a. Root cross-section taken at 200X using a light microscope.

Fig. 3b. Root cross-section taken at 200X using a scanning electron microscope.

are examined, preparation of samples for the SEM is considerably easier and requires a shorter time than that for the TEM. The SEM also allows the user to scan large areas of the specimen. Intact organisms or a portion of the organism can be examined even without dissection. This is important if one is dealing with rare and/or preserved museum specimens. All of the above reasons have made the SEM the instrument of choice for much of the microscopic photography now being done.

Sample preparation for SEM

The surface of an object, which is to be investigated by SEM, must have the following characteristics (Reimer and Pfefferkorn 1977):

- It must be free from foreign particles (dust, exudates, etc.),
- It must be vacuum stable,
- It must remain stable after exposure to the electron beam,
- It must emit a sufficient number of secondary electrons and should develop as few surface charges as possible.

Some biological structures fulfill automatically these prerequisites, e.g., the hard exoskeleton of insects or crustaceans, various mineralized structures (teeth, bone, diatom), as well as many structures of plant origin (pollen, wood, etc.). In the majority of cases, however, biological objects have to be treated so that the above requirements are met. The preparation will depend on the nature of the specimen being examined and the type of analysis required (Robinson et al 1987).

Conventional methods of preparation

The general scheme for SEM sample preparation is shown in Figure 5 (Hayat 1970).

The preparation of biological specimens for SEM usually involves the following steps:

a) Selection, removal, and cleaning up of the desired tissue or portion of the specimen;

Fig. 4a. Stereomicroscope image of RBB.
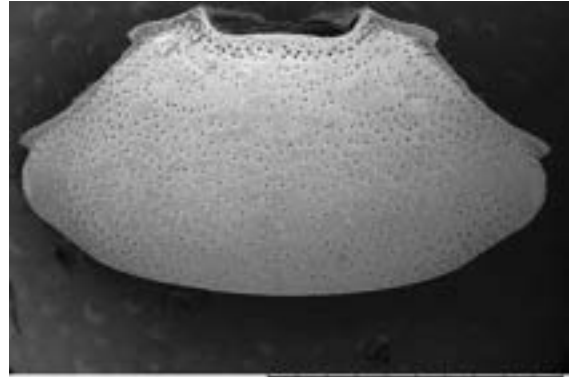
Fig. 4b. SEM image of head taken at 80X.

Fig. 4c. SEM image of pronotum taken at 50X.
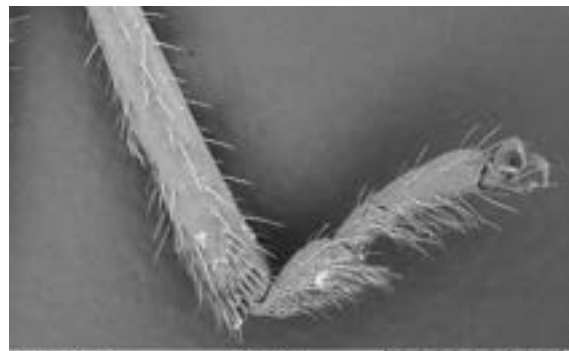
Fig. 4d. SEM image of tibia, tarsus, and claw taken at 120X.
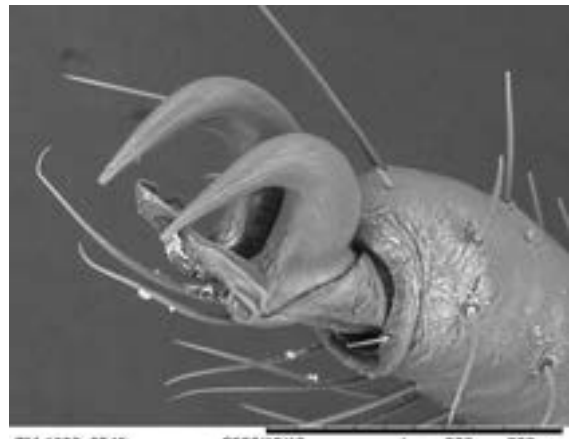
Fig. 4e. SEM image of claws taken at 500X.

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                    ┌─────────────────────────┐
                    │    ALDEHYDE FIXATION     │
                    └─────────────────────────┘
                                 ↓
                    ┌─────────────────────────┐
                    │       BUFFER WASH        │
                    └─────────────────────────┘
                                 ↓
                    ┌─────────────────────────┐
                    │      POST-FIXATION       │
                    │          (O S O )        │
                    └─────────────────────────┘
                                 ↓
                    ┌─────────────────────────┐
                    │       BUFFER WASH        │
                    └─────────────────────────┘
                                 ↓
                    ┌─────────────────────────┐
                    │       DEHYDRATION        │
                    │      Ethanol series      │
                    └─────────────────────────┘
```
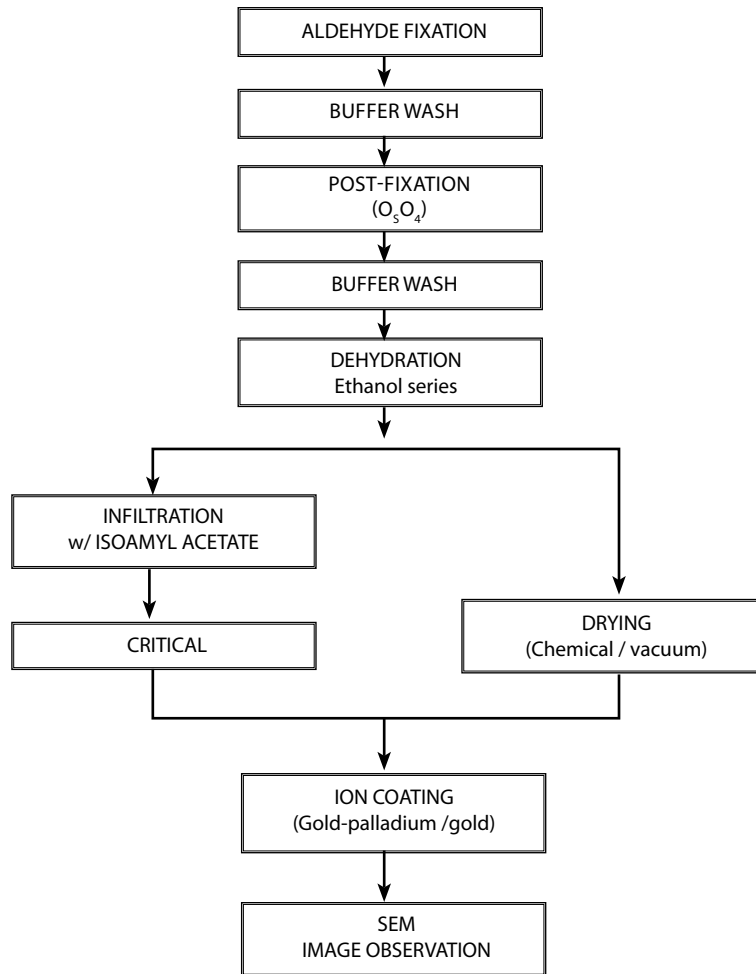
Fig. 5. General scheme for SEM biological sample preparation.

b) Stabilization of the object by fixation usually by immersion to preserve the natural form of the specimen;

c) Buffer washing, usually three times, to remove excess fixative and to clean up specimen;

d) Dehydration by ethanol or acetone (use concentration series 50%, 60%, 70%, 80%, 90%, 95%, and 100%) to avoid sudden shrinkage of cells;

e) Drying the specimen, usually with the aid of a CPD or freeze dryer;
(Use a pretreatment fluid [isoamyl acetate] when liquid CO_2 is used in the CPD.
If it is not possible to dry the sample using CPD, alternative drying methods such as vacuum oven-drying and freeze-drying can be tried.)

f) Mounting the specimen on stubs, most of which are made of aluminum; and

g) Creating or increasing surface conductivity by the use of a sputtering device.

Specimens prepared in this way can normally be inserted into the SEM ready for viewing. If stored, they must be maintained in a dry, dust-free environment such as a desiccator. In general, the cleanliness of the glassware and solutions is a must to avoid artifacts that can deposit on the surface of the specimen. Liquid solutions are passed through filtration setups to eliminate impurities. Microscopy depends as much on the techniques for preparing the specimen as on the performance of the microscope itself.

Fixation

The importance of good fixation in electron microscopic (EM) studies cannot be overemphasized. The preparation of fixation is to preserve biological ultrastructure with minimal alteration during dehydration and subsequent drying and viewing in the SEM. Since important chemical bonds in living tissue depend on the presence of water for their stability, a fixative should provide the stable bonds necessary to hold the molecules together during dehydration. Fixatives form cross-links not only between their reactive groups and the reactive groups of the tissue but also between the different reactive groups within the tissue (Hayat 1989). The most common and best method of fixation for EM involves the use of glutaraldehyde followed by osmium tetroxide.

Dehydration and drying

Chemically fixed objects must be dehydrated before drying. This cannot be achieved by simply allowing to dry in the air because of the considerable surface tension effects involved. Figures 6a and 6b reveal the comparison between air-drying and CPD. Air-drying causes considerable specimen deformation as in Figure 6a, whereas CPD causes almost no deformation of specimens, with original shape retained as in Figure 6b (JEOL 2000).

For effective dehydration, either the object is subjected to freeze drying or it is dehydrated through substitution. Freeze drying or lyophilization is a dehydration process in which the water in the sample is first converted to ice, which is then sublimed away at low temperatures and high vacuum. The rate of drying is a function of the temperature and the vapor pressure of ice. Freeze drying requires the use of a special machine called a freeze dryer.

In dehydration by chemical substitution, the specimen is immersed in 50% (v/v) ethanol or acetone after fixing and washing. The specimen is then transferred through increasing concentrations of solvent solutions until it is brought to absolute ethanol or acetone. The speed with which this is done and the number of steps involved depend on the nature and size of the specimen, but it usually takes 10–60 min per step change. During the dehydration steps, the specimen must not be allowed to dry out. In general, acetone tends to induce greater swelling/shrinkage effects than ethanol.

After water has been removed from the specimen, the dehydrating medium (organic solvent) also has to be removed. This constitutes "drying" and has to be done very carefully to prevent defor-
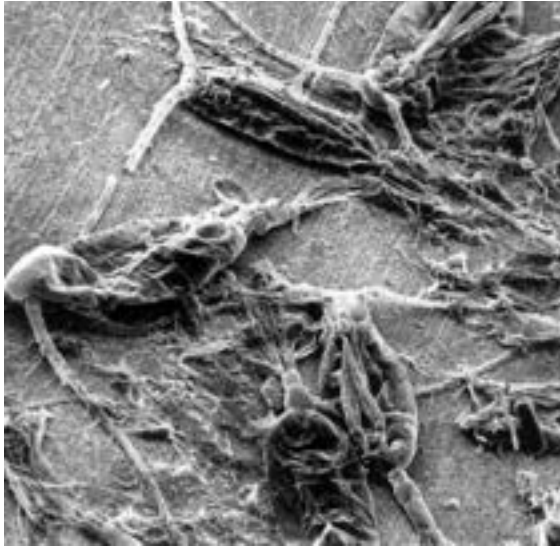
Fig. 6a. Specimen subjected to air-drying.

Fig. 6b. Specimen subjected to critical point drying.

mation at the surface during the phase change from liquid to gas. Such artifacts can be successfully avoided by the critical point method and by freeze-drying. The first method is quicker and more preferable in most cases.

Critical point drying has been developed to avoid surface tension. The dehydrated sample is dried in a CPD and relies on the critical point of carbon dioxide (CO_2). The dryer essentially consists of a pressure chamber, which can be thermally heated to increase the pressure of the gas inside the chamber, while the pressure and temperature can be easily regulated. The liquid CO_2 cylinder is usually attached to the dryer, which is fitted with pressure gauge, thermometer, and regulator valves.

Normally, a specimen subjected to dehydration with alcohol or acetone is substituted with isoamyl acetate (pretreatment fluid) having a low volatility, and then dried with CO_2. The sample is placed in the cylinder in liquid CO_2 and heated to raise the temperature and pressure to the critical point of CO_2 (1073 psi, 31.1 ºC). At this point, CO_2 exists neither in the form of a liquid nor a gas, therefore by venting the chamber, drying is effected in the absence of any surface tension.

Only seldom is it possible to air-dry specimens successfully; in comparison with CPD, it is always inferior. RBB samples, on the other hand, were found to be so sturdy that, when subjected to immersion in 70% ethanol, even without prior fixation, and when followed by overnight drying in an oven or desiccator, no shrinkage or distortion was observed. This was noted especially in samples obtained from Mindanao. This observation led to a much shorter version of the sample preparation procedure, bypassing the fixation, post-fixation, dehydration series, and CPD steps. This would allow the examination of more specimens in a given time without compromising the quality of the micrographs obtained. For taxonomic work on RBB, this finding makes possible the handling of large populations for SEM examination in a reasonable period of time. However, we found it neces-

sary to do the ion-coating step to increase conductivity and minimize the charge-up often observed in biological specimens.

Increasing conductivity

When a nonconductive specimen is directly illuminated with an electron beam, its electrons with a negative charge collect locally (specimen charge-up), thus preventing normal emission of secondary electrons. This charge-up causes some unusual phenomena such as abnormal contrast (bright streaks) (Figs.7a and 7b), loss of sharpness, and image deformation and shift (Figs. 8-11). In general, biological objects are poor electrical conductors or they do not conduct at all. Conductivity can be imparted during the fixation step (with osmium tetroxide) or by coating the surface of the object with a metal conductor. Both of these measures cause an increase in the number of secondary electrons emitted and lead to a considerable improvement in the video signal. Moreover, the heating effects of the electron beam will be considerably reduced as a result of the coating.

However, some methods are employed to observe specimens without coating in order to know their true surface state. Generally, the following methods are used to reduce specimen charge-up:

- Reducing the probe current
- Lowering the accelerating voltage
- Tilting the specimen to find the balance point between the amount of incident electrons and the amount of electrons that go out of the specimen.

Rough-surfaced specimens must be evenly coated from every direction. Two coating methods exist: sputtering and vacuum evaporation. In both cases, heavy metals are involved, especially gold and gold-palladium. A major problem is the heating of the specimen that results during coating. One should coat in small steps, allowing the specimen to cool down between each step. Sputtering is quicker to perform than a conventional vacuum evaporation and produces a more even coating.

Fig. 7a. RBB aedeagus taken at 150X 25 KV (SEM S-510).

Fig. 7b. RBB aedeagus taken at 150X, 15 KV (SEM S-510).
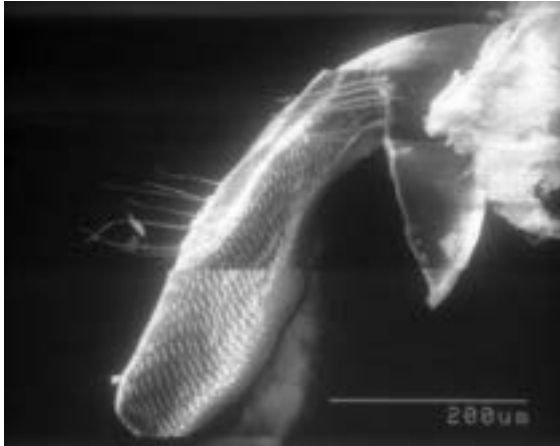
Fig 8. RBB clasper taken at 200X, 25 KV (SEM S-510).
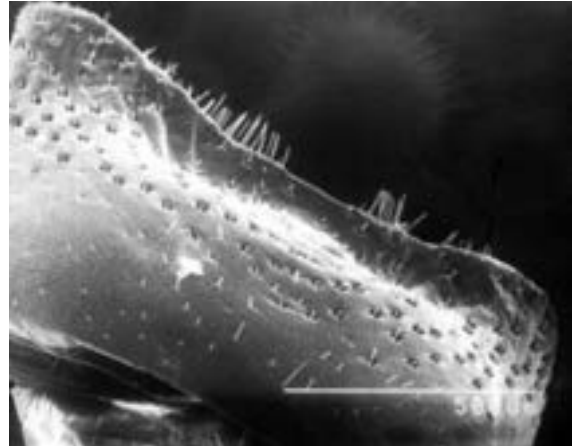
Fig 9. RBB tergite taken at 100X, 15 KV (SEM S-510).
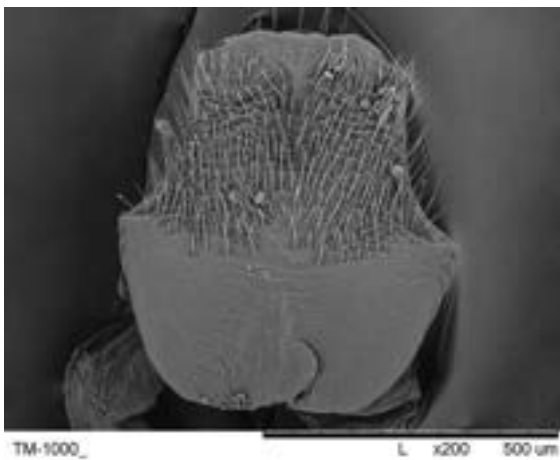
Fig 10. Aedeagal cap taken at 200X.
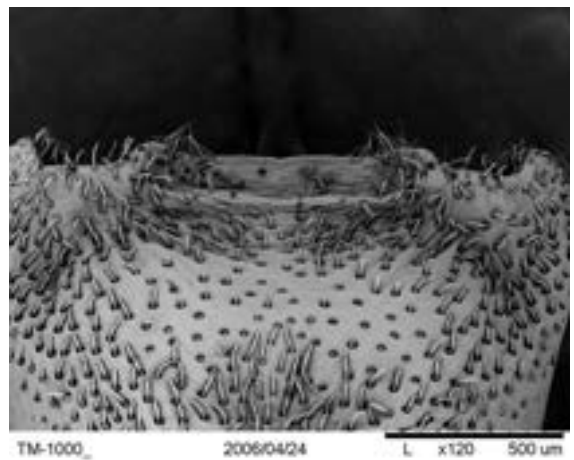
Fig. 11. Tergite with thick coating taken at 120X.

In addition, because of their higher energy, heavy metal particles produced by sputtering adhere better to surfaces than do conventionally deposited metal layers. One final, but important point: the thickness of the coating should not exceed the resolving power of the SEM. In general, the thinner the coating, the better is the detail that can be obtained.

Field sampling and sample preparation

In practice, when one goes to the field for sampling of RBB, one tries to get as much specimens from different regional areas as possible and tries to bring them across ports as quickly and as inconspicuously as possible. This constraint then would only allow minimum containers and minimum reagents as well. One method that was tried is the use of 70% ethanol immersion directly without prior fixa-

tion. The specimens upon reaching the laboratory were blot-dried on filter paper, then allowed to completely dry overnight in a desiccator or a vacuum oven. The specimens were mounted on stubs with carbon tapes and subjected to ion coating (gold-palladium) prior to SEM observation. The micrographs taken reveal no distortions or shrinkage and compared well with those of specimens that had undergone complete sample preparation.

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Notes

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Geometric Morphometric Analysis of Variability in Rice Black Bugs

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Abstract

The rice black bug (RBB) collected from the Philippines is believed to be composed of a complex of morphologically distinguishable sibling species based on SEM studies of male and female genital plates. The practical importance of determining the true nature of RBB and delineating species boundaries lies in the fact that inadequate taxonomic knowledge of target pests in agricultural systems is one of the reasons management and control programs fail. In the last few decades, the use of geometric morphometric (GM) techniques has greatly advanced the ability to discriminate taxa based on two-dimensional modeling of the organism's morphology. Technological advances and progress in image analysis allows one to sample the organismal phenotypes more widely or in more detail than ever before by permitting separate analyses for the size and shape components of the biological form. Practical advantages of using GM include objective interpretations of minor morphological variation, which have been helpful in studies of species with fuzzy borders. Outline and landmark-based GM techniques were applied in this study to explore and model variability in the shapes of the head, genital plates, pronotum, and external wings of RBB from diverse geographic origins in the Philippines and in one site in Omar, Malaysia, and to clarify relationships among the RBB populations examined. Our results showed that, in many cases, the landmark and outline configurations separated the Philippine and the Malaysian RBB. Also, considerable differences between populations were also found locally within Luzon, Iloilo, Palawan, and Mindanao. All of these are suggestive of the presence of 'species groups.' However, the biological relevance of the morphological distinctness of the RBB from the different sites has yet to be further studied and the application of different techniques appears necessary to better understand the taxonomy and biosystematics in the group and how microevolutionary processes operating on these species groups may determine the efficacy of present pest management systems.

Key words: rice black bugs, geometric morphometrics, elliptic Fourier analysis, landmark-based analysis

Introduction

Rice is the primary staple of more than two billion people in Asia and hundreds of millions of people in Africa and Latin America. The increasing demand for this crop requires that this should be properly managed to be able to sustain the increasing need of the growing human populations. However, in rice production, low yields due to insect attacks are a big problem. Several control measures, whether chemical, biological, cultural, or by host plant resistance, usually encounter failures because of the pest's ability to develop counter resistance. This ability to develop counter resistance by pest populations suggests adaptation, genetic polymorphism, or evolution of new species of pests. Understanding the variability in insect populations and their interactions with selection factors like the release of different rice varieties with different genes for resistance is important in breeding for resistant varieties. It has implications not only on how new varieties should be tested but also on how they can be best deployed so as to retard the process of evolution of counter resistance. A good example of this group of insect pests is the RBB, also known as Malayan black bug *Scotinophara coarctata* (Fabricius).

The Malayan RBB is geographically distributed in the Philippines and abundant in some areas of the archipelago. The pest has been known as a serious pest of rice in Malaysia as early as the 1920s and was only known in the Philippines during its infestation in Bataraza, Palawan, in 1979. Many unpublished and a few newspaper and radio reports showed RBB outbreaks in the country. The islands of Palawan; Mindanao farms including Zamboanga City, Cotabato, and Sultan Kudarat; the Visayas provinces of Bohol, Siquijor, Iloilo, Capiz, Negros Occidental; and Luzon, specifically the four towns in Sorsogon (Gubat, Prieto Diaz, Bulan, and Matnog), were found adversely hit by the bug. Control of black bugs includes the burning of rice stubbles, light trapping followed by burning, use of resistant varieties, and chemical control.

There have been many studies conducted to determine inter- and intraspecific categories of several taxa employing the use of traditional morphometrics. They ranged from descriptive accounts through univariate methods of analysis to applications of multivariate analyses of morphometric characters (Bookstein 2001b; Tilde et al. 2000; Koeniger and Koeniger 2000; Maddison and McMahon 2000; Hepburn et al. 2001a,b; Ken et al. 2003; Henderson 2002). The greatest obstacle, however, is the inability of traditional morphometrics to do separate analyses for the size and shape components of biological forms. The importance of having to do separate analyses for these components stems from the fact that size and shape are fundamental features of form and function that can affect how the organism interacts with its environment. Recently, however, a more powerful statistical framework for analyzing and describing size and shape differences has been provided through the development of geometric morphometrics (Kendall 1984, 1989; Bookstein 1991, 1996a,b; Dryden and Mardia 1998; Rohlf 1996, 2000; Rohlf and Marcus 1993; Rohlf et al. 1996; Small 1996 as cited by Dos Reis et al. 2002; Monteiro et al. 2000).

In this paper, we present the results of our geometric morphometric assessment of variations in selected populations of RBB collected from different geographical locations of the Philippines as well as the population from Oman, Malaysia. Geometric morphometrics is a relevant tool for characterizing

insect phylogenetic relationships (Pretorius and Scholtz 2001), intraspecific morphological variation (Querino et al. 2002), sibling species and sexual dimorphism (Adams and Funk 1997), morphological adaptations (Moran 1986, Medeiros and Moreira 2002), and instar identification (Daly 1985). The introduction of multivariate techniques for studying the morphological changes of animals and plants using multivariate statistical analyses, now known as multivariate morphometry or geometric morphometry, emerged (Reyment 1995a). Bookstein (1989, 1991) was the first to enhance the theory and practice of analyzing variation in shape by geometric methods.

Geometric morphometry in biology was pioneered by Thompson (1917) who expressed changes in shape in organisms by transforming the data into coordinates observed at diagnostic sites on the organism. These sites of reference are known as landmarks, a term borrowed from craniometry and previously from topographic surveying. Data in the form of coordinates are more comprehensive than those expressed as lengths, heights, and breadths and "distances between" because they encompass not only all information on the relative positions of the points observed but also the distances between these points (Reyment 1995). This particular development in the field of morphometrics is valuable, especially in investigating the RBB, which were becoming widespread in its distribution not only here in the Philippines but also in Southeast Asia. This study was therefore conducted to understand variability in the Philippine RBB using the different tools of geometric morphometrics—outline and landmark-based analysis. These two methods were used as these are more powerful in defining species boundaries where subtle differences in shapes can be detected. In taxonomy and systematics, species boundaries are often defined using a suite of characters reflecting a subset of all possible characters. Variations in the shapes of these biological structures could be continuous but are often fragmented. Such patterns of shape variation could be detected only using the geometric morphometrics approach.

This study was conducted at the Evolutionary Biology Laboratory, Department of Biological Sciences, College of Science and Mathematics, Mindanao State University-Iligan Institute of Technology, Iligan City, from February to May 2007.

Materials and methods

From the RBB samples taken from 18 sites in four islands of the Philippines, namely Mindanao, Luzon, Panay (Iloilo), and Palawan, as well as those from Oman, Malaysia (Fig. 1), a total of 553 bugs (286 females and 267 males) (Table 1) were used in this study. Sexual size and shape dimorphism in the RBB were determined using discriminant function analyses (DFA) from the principal component scores.

Sampled RBBs were prepared for the two-dimensional geometric morphometric analysis (Hammer et al. 2001), which consisted of these steps: 1) image acquisition, 2) recording of landmark and outline coordinates, 3) derivation of shape descriptors using Procrustes-fitting and elliptic Fourier analysis, 4) derivation of size component of the form using a centroid size estimate, and 5) statistical analysis of the shape and size descriptors.
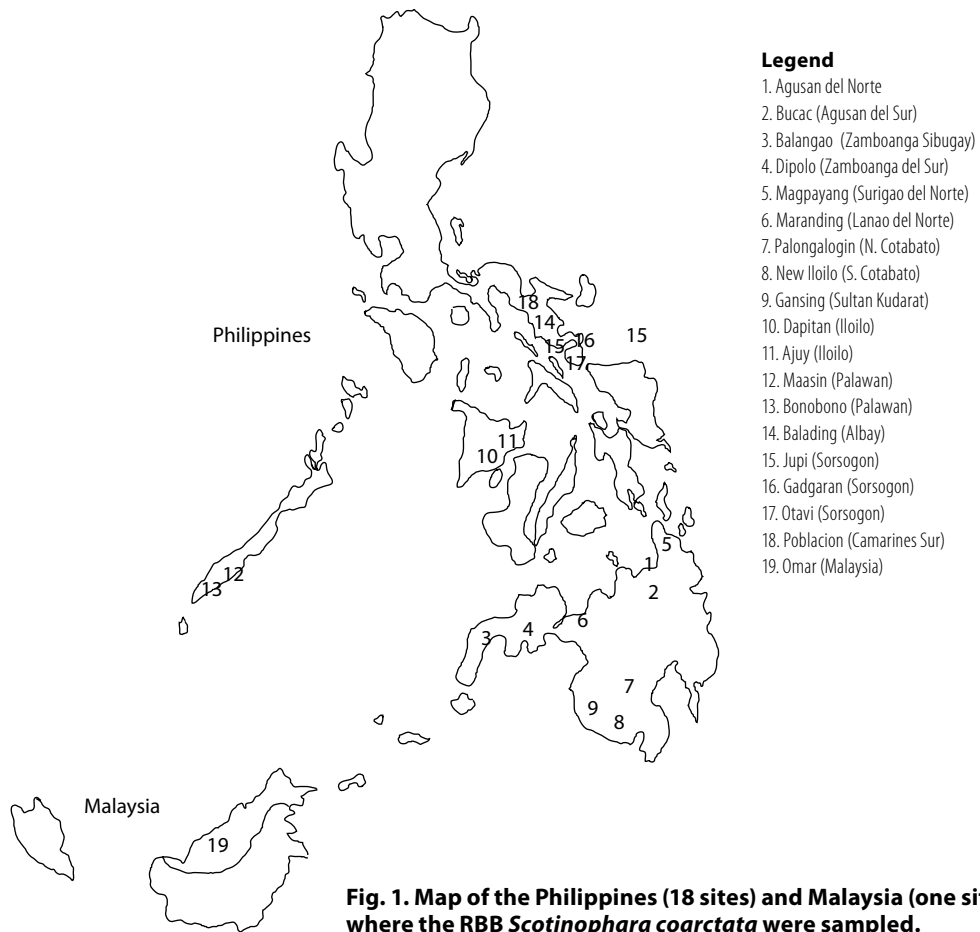
Fig. 1. Map of the Philippines (18 sites) and Malaysia (one site) where the RBB *Scotinophara coarctata* were sampled.

The wings were detached from the bodies and mounted on clean glass slides. The positions of the head, pronotum, scutellum, and female genital plates were firmly arranged in a microscope stage for image capture using the macroncam provided for by Dr. Nitzie Bebing of the Genetics and Molecular Biology Laboratory of the University of the Philippines Los Baños, College, Laguna. Some individuals have damaged parts and were thus excluded from the analyses.

The images were then digitized using the ScionImage program to facilitate the acquisition of the "x" and "y" coordinates of each of the landmark and outline coordinates. Several landmark and outline coordinates were identified on each character, the image data of which were converted into simple mathematical coordinate data of 24 to 360 coordinates (Table 2). To summarize the shape and size information from these data, a number of geometric morphometric tools and multivariate methods of analysis were used (Table 2).

To determine the variation in shapes and the effects of size, the rotation and position of each image were first removed by subjecting the landmark and outline data to a generalized Procrustes superimposition and elliptic Fourier analysis, respectively.

Table 1. Frequency distribution of male and female RBB *Scotinophara coarctata* groups sampled from 18 sites in the Philippines and Oman, Malaysia showing varying outlines and landmarks of five and two characters, respectively.

Region	Site	Outline Scutellum M	Scutellum F	Left wing M	Left wing F	Right Wing M	Right Wing F	Genitalia F	Pronotum M	Pronotum F	Landmark Pronotum M	Pronotum F	Head M	Head F
Mindanao	Agusan del Norte	47	45	50	50	49	48	50	50	50	50	50	50	29
	Burac (Agusan del Sur)	8	10	6	8	6	9	10	7	10	7	10	10	10
	Balangao (Zamboanga Sibugay)	32	26	50	50	50	50	50	35	35	35	39	50	50
	Dipolo (Zamboanga del Sur)	3	3		8	3	7	8	3	6	3	6	3	6
	Magpayang (Surigao del Norte)	6	2	6	2	4	2	4	6	2	6	2	6	2
	Kapatagan (Lanao del Norte)	31	31	35	26	34	23	30	31	8	31	9	30	29
	Palongalogin (N. Cotabato)	4	3	7		7		9	12	10	12	10	12	10
	New Iloilo (S. Cotabato)	8	11	7	9	8	8	11	10	9	10	7	9	9
	Gansing (Sultang Kudara)	7	10		11		12	9	6	9	6	10	9	9
	Total	146	141	161	164	161	159	181	160	139	160	143	179	154
Luzon	Balading (Albay)	5	5	4	5	0	5	3	5	5	5	5	5	5
	Gadgaran (Sorsogon)	7	17	7	15	3	15	15	8	21	8	22	9	20
	Jupi (Sorsogon)		8			6	5	7		6		7		5
	Otavi (Sorsogon)	3	16	4	5			12	3	14	3	14	4	17
	Poblacion (Camarines Sur)	9	13	7	5	3	10	13	12	14	12	12	13	11
	Total	24	59	22	30	12	35	50	28	60	28	60	31	58
Iloilo	Ajury	16	24	22	16		14	28	18	29	18	29	19	29
	Dapitan	17	12	17	11		12	11	16	12	16	12	17	12
	Total	33	36	39	27	0	26	39	34	41	34	41	36	41
Palawan	Maasin	8	8	8	4	8	7	7	6	8	6	8	7	8
	Bonobono	9	7	8	7	6	7	8	10	8	10	8	9	7
	Total	17	15	16	11	14	14	15	16	16	16	16	16	15
Malaysia	Omar	9	2	11		11		1	4	2	4	2	5	2

Table 2. Number of landmark and outline points of morphological characters of RBB *Scotinophara coarctata* group used for image digitization.

Character	Type of analysis	No. of points	No. of coordinates
Pronotum	Landmark	24	48
	Outline	70	140
Head	Landmark	12	24
Wing	Outline	180	360
Scutellum	Outline	70	140
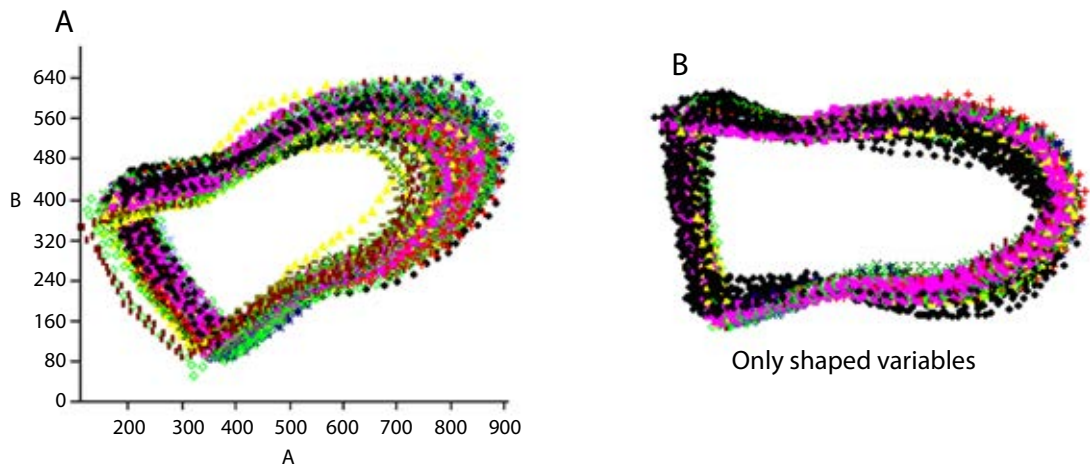
Fig. 2. Plots of the coordinate pairs of characters of RBB *Scotinophara coarctata* group before (a) and after (b) removal of residual variation not related to shape.

Procrustes superimposition was done first by calculating the centroid of each shape or the point having "x" and "y" coordinates equal to the mean of the "x" and "y" coordinates of all the landmarks. Then, each of the landmarks was connected to the centroid and rescaling of the coordinates was done, so that the sum of the squares of the distances was scaled to unity. Then, all the shapes were superimposed on each other, on the centroid of each shape where each shape is rotated to minimize the sum of squared distances between matched landmarks. The entire process removed the variation related to size and position when the image was acquired. Figure 2 illustrates of the effect of removing residual variation not related to shape.

For the landmark data, a generalized Procrustes superimposition method was used to separate the size and shape components of the RBB forms. For the outline analysis of the shape of the left and right forewings, the pronotum, scutellum, and external female genital plates of the RBB, elliptic Fourier analysis (EFA) was applied. EFA reduces the character outline to a sum of harmonics (geometrically characterized by an ellipse) weighted by four coefficients. These coefficients were used to reconstruct the outline, which was useful in determining the number of harmonics required

to describe the shape of the pronotum, scutellum, forewings, and external genital plates. The lower ranked harmonics described major details of shape, whereas the higher ranked harmonics described smaller and finer details of shape (Renaud and Michaux 2004). If the harmonic coefficients were calculated invariant to size, position, rotation and starting point, they corresponded only to shape differences and could be used as shape descriptors in statistical analysis. In this particular approach, more points were taken into account that could best present the contour of the whole shape of the object under study. This particular methodology was important, considering that the shapes could be best illustrated by curves or surfaces. Outlines of structures can be captured and analyzed using shape variables such as those generated by EFA. The approach involved the digitization of points along an outline, fitting the points with a mathematical function (usually some form of Fourier analysis), and then comparing curves by using the coefficients of the functions as shape variables in multivariate analyses. Points in this multivariate parameter space (e.g., Fourier coefficient space) could be transformed back to the physical space of the RBB and visualized as outlines. This method proceeded by interpolating the outline of any structure to get a large number of equally spaced points. Then, the x and y increments from one point to another were considered (Fig. 3) (Hammer et al. 2001). These increments define two periodic functions that are independently subjected to Fourier analysis. The idea is that the original, high-dimensional shape space as define by the digitized points was reduced to a lower dimensional space, which retained the most important shape information.

The shape variables obtained from Procrustes superimposition and EFA of the coordinate data were then used to reconstruct the shapes of the structures of the RBB. The shape variation was summarized using principal component analysis (PCA) (Fig. 4, 5). This procedure found hypothetical variables (components) that accounted for as much of the variance in the multidimensional shape data as possible (Davis 1986, Harper 1999). These new variables were linear combinations of the original variables. Only the first six principal components were shown in this study as these explained most of the variance contained in the data. Also, PCA allows one to visualize differences in the shapes
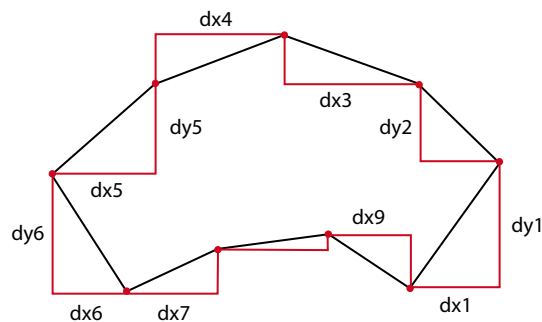
Fig. 3. Elliptic Fourier analysis of a closed contour. The outline has been interpolated so that the nine points are placed at regular distances. The counterclockwise increments in the x and y directions define two periodic functions which can be subjected to elliptic Fourier analysis (Hammer et al. 2001).
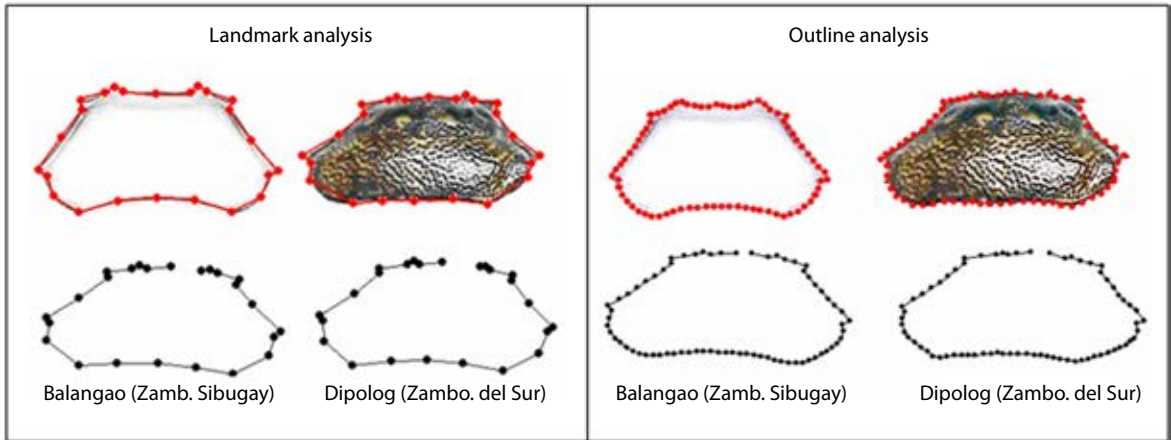
Fig. 4. Sample reconstructions of the pronotum of RBB *Scotinophara coarctata* group derived from landmark and outline coordinates.
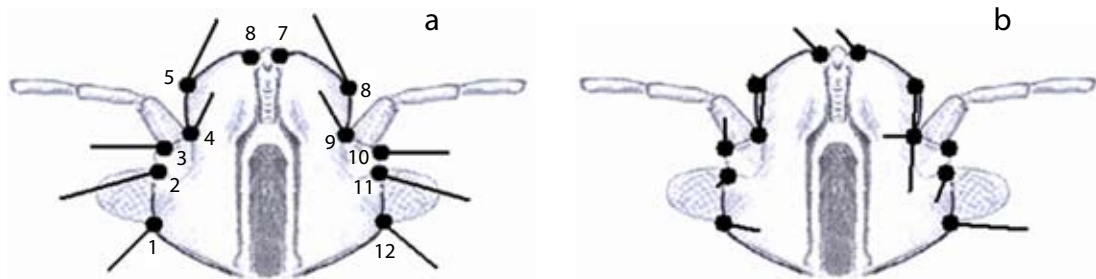
Fig. 5. Sample plots of influential landmarks in the head of RBB *Scotinophara coarctata* group showing regions of greatest morphological variation. Maps such as in (a) represent symmetrical variation and indicate that most of the variation is associated with changes in the shape of the posterior and anterior regions. On the other hand, the plot in (b) represents residual variation due to trait asymmetries.

of various characters. The PAST software (Hammer et al. 2001) provided a platform for determining landmarks that represented regions of greatest morphological variability across populations and contributed disproportionately to trends in shape changes within and among populations. This was shown as plots/maps of the most influential landmarks for principal components 1-6 (Fig. 5). The length of the vectors or lines indicates the relative contribution of each landmark to shape variability, whereas its direction indicates the direction of shape changes. After PCA, the eigenvalues and the principal component scores for each individual were obtained. The eigenvalues indicated the amount of variation explained by each principal component.

The principal component scores were then subjected to discriminant function analysis to test whether geographic populations can be segregated on the basis of the shapes of the various characters included in this study. Group centroids for each function were derived and used in determining the phenetic relationships of the populations using Ward's method (Hammer et al. 2001).

Geometric size

Separate analyses were conducted on the geometric size component of the RBB forms. The geometric size of each specimen was estimated by the centroid size, defined as the square root of the sum of squared distances from all landmarks to the centroid of the configuration (Bookstein 1991). This was often used as an estimate of overall size. The landmark coordinates for each specimen were aligned and superimposed by the Procrustes generalized orthogonal least square method (Rohlf and Slice 1990). In this procedure, the configurations were scaled to unit centroid size and then centered and rotated to minimize the sum of squared distances between the landmark of each individual configuration to the corresponding landmarks of a reference or "consensus" configuration, computed as the mean landmark configuration of all specimens. Computation of the centroid of all landmarks is as follows:

1. Determination of centroid by point with x and y coordinates equal to the mean of x and y of all landmarks.
2. Summation of squared distances from centroids to all landmarks and square root taken.

A mathematical algorithm calculated the size of centroid and the baseline size of the shapes. The centroid size of the shape $S(X)$ is the squared root of the sum of squared Euclidean distances from each landmark to the centroid. The formula for calculating the centroid size $S(X)$ is

$$S(X) = \sqrt{\sum_{j=1}^{k} \| (X)_j - \bar{X} \|^2},$$

where X_j is the j th row of $X(j = 1,...,k)$ and $\xi = (\xi_p... \xi_m)$ is the centroid.

Differences in sizes of the various characters were visualized using box-and-whisker plots and tested using Kruskal-Wallis, a nonparametric form of the analysis of variance.

Results and discussion

Sexual size and shape dimorphism

The DFA on the principal component scores representing independent shape characteristics of the structures of male and female RBB showed that the two sexes were significantly different and members of each sex were classified correctly 61.7−100% of the time. The sexes were distinctly separated based on the shape of the pronotum when outline analysis was performed (Table 3).

For this reason, separate analyses were conducted between sexes before any geographic morphometric portrait can be determined to gain insight into the organization and structure of variation within and among populations. Also, separate analyses were performed on each structure as characters usually do vary independently between and among populations. The discrepancies in the results of the DFA when landmark and outline coordinates were used on the pronotum is a normal phenomenon when using different numbers of landmarks and semilandmarks, where the results depend on the relative density of landmark and semilandmark spacing.

Table 3. Results of the test for sex differences in the shapes of structures examined. This was carried out using discriminant function analyses of the principal component scores representing independent shape characteristics of the structures examined.

	Female	Male	% Correct	Wilk's λ	Sig.
Pronotum (landmark)					
Female	262	0	100	0.001	<0.000
Male	0	245	100		
Pronotum (outline)					
Female	187	72	72.2	0.79	<0.000
Male	70	172	71.1		
Head					
Female	173	92	65.3	0.90	<0.000
Male	112	155	58.1		
Wing					
Female	399	67	85.6	0.53	<0.000
Male	70	400	85.1		
Scutellum					
Female	196	57	77.5	0.79	<0.000
Male	83	146	63.8		

Female genital plates

The first five principal components showed that a considerable amount of variation was attributed to asymmetries in the shapes of the left and right sides of the individual genital plates among female RB's with a cumulative variance of 92.55% (Fig. 6).

The principal component scores were used for discriminant analysis to see whether the individuals can be discriminated into geographic groups (Table 4). Results showed that the geographic RBB populations can be differentiated using the principal component scores for each individual, with predictive accuracies of 81.5–100%. The single specimen from Omar, Malaysia, can be discriminated from other individuals from the Philippines, which means that its genital plate is of a different shape. Similar results were obtained when separate analyses were conducted on different regions per island, which is indicative of divergence in the shape of the female genital plates of RBBs.

Figure 7 shows the phenogram constructed from a cluster analysis of the squared Euclidean distances between centroids of the factor scores for the samples grouped by major sampling location per (a) island and in a microscale among localities within (b) Luzon and (c) Mindanao. Two main branches were formed in Figure 7A, which supported the distinctiveness of the Philippine populations, separate and different from that of the Malaysian sample. Figure 7B showed two major branches separating the Gadgaran (Sorsogon) population from the rest of the other Sorsogon populations.

Figure 7C, on the other hand, revealed three main groups for the Mindanao populations, one that combined the Agusan del Norte black bugs with those of Balangao in Zamboanga Sibugay.

Significant differences in sizes were observed among the populations (KW: 98.68; P<0.0001). Considerable variation in sizes was observed when the RBBs from the Philippines were compared with the single population from Omar, Malaysia, being small in size (Fig. 8). Post-hoc tests using Dunn's multiple comparison tests were carried out and the results of the analyses are summarized in
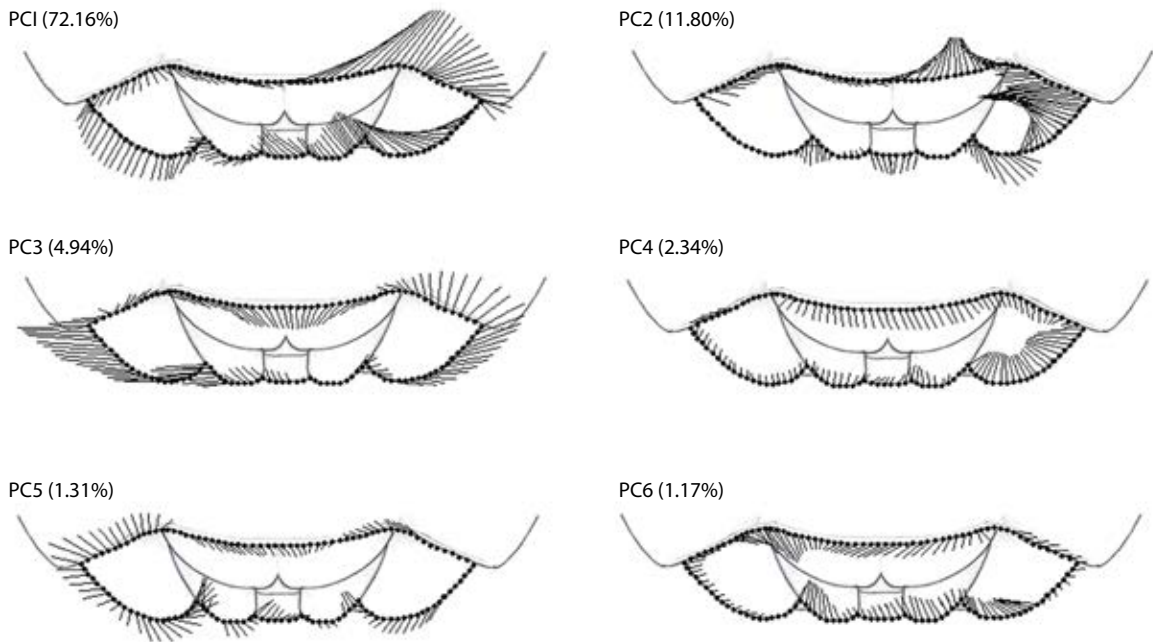
Fig. 6. Maps of influential landmarks for principal components 1–6. These maps were generated through PCA of outline coordinates of all female genital plates. Influential landmarks represent regions of greatest morphological variability and contribute disproportionately to trends in shape changes within and among populations of female RBB.

Table 5. The Ajuy population was shown to be significantly different from the populations in Agusan del Norte, Bonobono (Palawan), Dapitan (Iloilo), Dipolog (Zamboanga del Sur), Gadgaran and Jupi (Sorsogon), Maranding (Kapatagan, Lanao del Norte), and Balangao (Zamboanga del Norte). The sizes of the female genital plates from New Iloilo (South Cotabato), Otavi (Sorsogon), and Poblacion (Camarines Sur) were found to show differences in some of the other populations (Table 5).

Wing geometry

Results of the analysis showed that the left and right wings can be differentiated with a predictive accuracy of only 69.7% (Wilks $\lambda = 0.808$, $\chi^2 = 196.74$, df = 19, P < 0.0001). Because of this, separate analyses were conducted on the left and right wings. Results of the PCA of the shape coordinates showed the relative variations in the position of each outline point among the different samples (Fig. 9, 10). More than 80% of the total variance in the shapes of both wings for the two sexes is related to curving of the upper median half of the wing and expansion of the wing apices as described by the first principal components.

The principal component scores, which were also subjected to DFA, showed that wing shape had differentiated across all populations and that significant differences existed among populations (Table 6, a–d). Using the PC scores of the left wing, for example, all females could be differentiated

Table 4. Results of discriminant analyses (DA) with the principal component scores, derived from analysis of the shapes of the female genital plates, as the grouping variables among RBB *Scotinophara coarctata* group.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
Major islands											0.179	<0.000
Mindanao	165	5	3	8	0					91.2		
Panay (Iloilo)	12	24	1	2	0					61.5		
Palawan	1	3	9	2	0					60		
Luzon	13	2	1	34	0					68		
Malaysia	0	0	0	0	1					100		
Total	191	34	14	46	1					**81.5***		
Luzon											0.071	<0.000
Balading (Albay)	1	1	0	0	1					33.3		
Gadgaran (Sorsogon)	0	15	0	0	0					100		
Jupi (Sorsogon)	0	0	7	0	0					100		
Otavi (Sorsogon)	0	0	0	10	2					83.3		
Poblacion (Camarines Sur)	1	0	0	1	11					84.6		
Total	2	16	7	11	14					**88***		
Mindanao											0.008	<0.000
Agusan del Norte	42	0	7	0	0	0	1	0	0	84		
Bucac (Agusan Sur)	0	9	0	0	0	0	0	1	0	90		
Balangao, (Zamboanga Sibugay)	7	0	42	0	0	1	0	0	0	84		
Dipolog (Zamboanga del Sur)	0	0	0	8	0	0	0	0	0	100		
Magpayang (Surigao del Norte)	0	0	0	0	3	1	0	0	0	75		
Maranding (Lanao del Norte)	1	0	0	0	0	28	0	0	1	93		
Palongalogin (North Cotabato)	0	0	0	0	0	0	9	0	0	100		
New Iloilo (South Cotabato)	0	0	0	0	0	0	2	9	0	82		
Gansing (Sultan Kudarat)	0	0	0	2	0	1	0	1	5	56		
Total	50	9	49	10	3	31	12	11	6	**85.6***		
Iloilo											0.095	<0.000
Ajuy	28	0								100		
Dapitan	0	11								100		
Total	28	11								**100***		
Palawan											0.029	<0.000
Maasin	7	0								100		
Bonobono	0	8								100		
Total	7	8								**100***		

*Percentage of original grouped cases correctly classified.

using the first three discriminant functions accounting for 55.5, 35.3, and 9.2% of the total among-group variance, respectively, for a total of 100%. These three functions were used in the analysis and were shown to discriminate island female populations with a high predictive accuracy of 81.9%. On the other hand, populations within Luzon, Mindanao, Iloilo, and Palawan were shown to be differentiated with correct classification rates of 63.3, 79.9, 96.3, and 90.9%, respectively.

Different rates of classification can be observed if the shape coordinates of the right wing were used to discriminate female populations of *S. coarctata* (Table 6b). The island populations were correctly classified 72.6% of the time. On the other hand, the Luzon, Mindanao, Iloilo, and Palawan
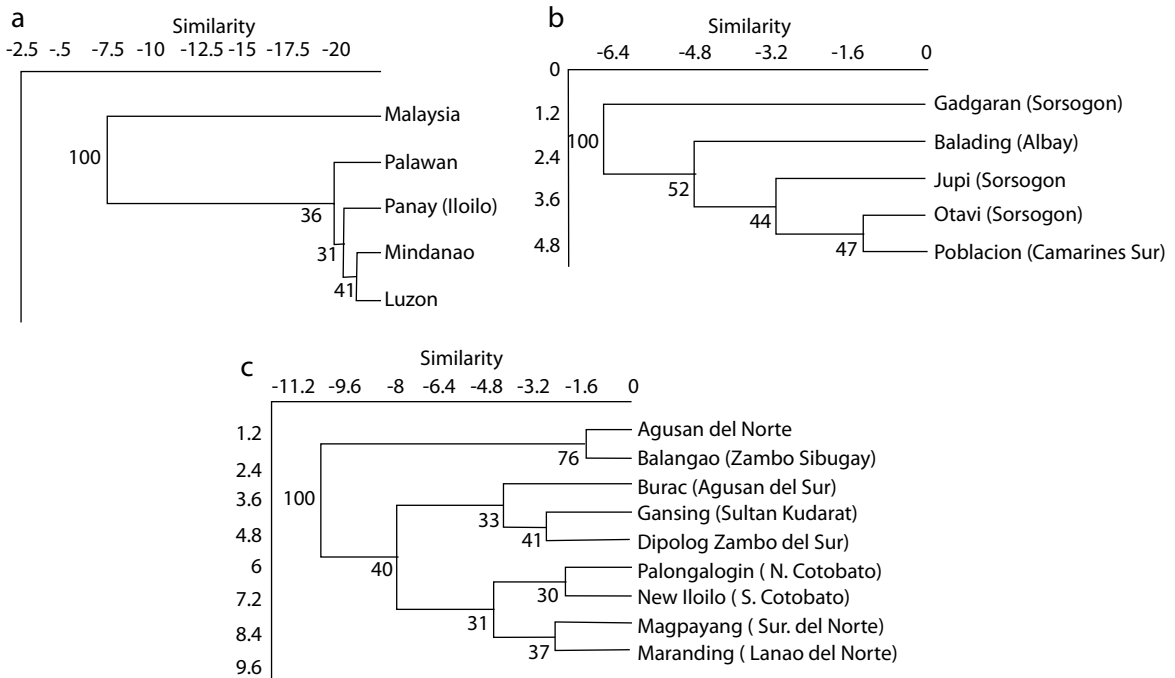
Fig. 7. Phenetic relationships among the (a) major islands, (b) Luzon, and (c) Mindanao RBB populations. Similarities were based on squared distances between centroids from principal component analysis of the EFA coordinates of the female genitalia; this tree was constructed using Ward's clustering algorithm.
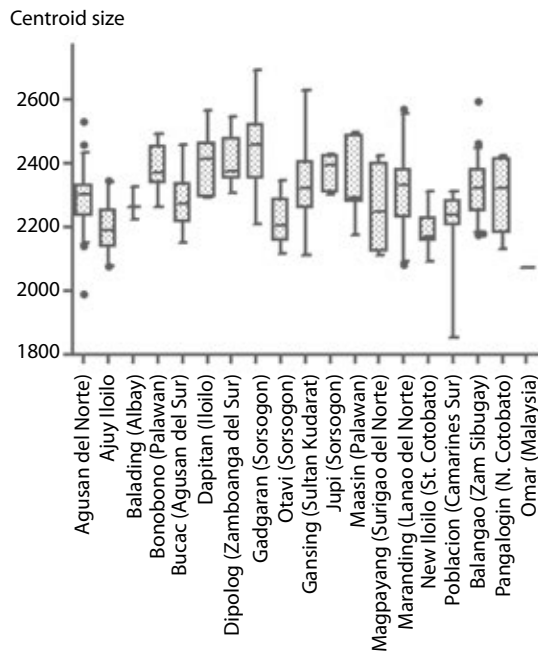
Fig. 8. Plot of centroid size in *Scotinophara coarctata* group showing interpopulation differences in the size of the female genital plates.

Table 5. Results of the test for significant differences in the size of the female genital plates across all *Scotinophara coarctata* group (KW: 98.68; P<0.0001).

	POST hoc test	Difference	Summary
Ajuy (Iloilo)	Agusan del Norte	73.25	*
	Bonobono (Palawan)	-145.7	**
	Dapitan (Iloilo)	-151.8	***
	Dipolo (Zamboanga del Sur)	-160.6	***
	Gadgaran (Sorsogon)	-161.1	***
	Jupi (Sorsogon)	-144.1	**
	Maranding (Lanao del Norte)	-87.58	**
	Balangao (Zamboanga Sibugay)	-93.36	***
New Iloilo (South Cotabato)	Bonobono (Palawan)	156.1	**
	Balangao (Zamboanga Sibugay)	-103.8	*
	Jupi (Sorsogon)	154.5	*
	Dapitan (Iloilo)	162.2	***
	Dipolog (Zamboanga del Sur)	171	**
	Gadgaran (Sorsogon)	171.6	***
Otavi (Sorsogon)	Dapitan (Iloilo)	132.9	*
	Gadgaran (Sorsogon)	142.3	**
	Dipolog (Zamboanga. del Sur)	141.7	*
Poblacion (Camarines Sur)	Dapitan (Iloilo)	129.5	*
	Dipolog (Zamboanga del Sur)	138.3	*
	Gadgaran (Sorsogon)	138.9	**

*Significant at P≤0.05. **Significant at P≤0.01. ***Significant at P≤0.001.

populations had classification rates between 65 and 100%. The results also showed significant differences among populations as shown by the results of the multivariate analysis of variance (MANOVA) of the shape variables derived from the right wing coordinates.

Similar results were obtained when the principal component scores derived from shape variables of the left and right wings of all male individuals were used in the DFA (Table 6, c and d). Significant differences were also observed among populations of RBB.

Relationships of *S. coarctata* from the island populations and within each of the islands were determined using cluster analysis of the group centroids derived from DFA of the principal component scores. The resulting dendrograms showed inconsistent groupings of the different island populations and those within each of the islands (Fig. 11, 12). These results show no clear-cut geographic pattern despite the significant differences observed.

Differences in the sizes of the wings were also scored and visualized as box-and-whisker plots in Figure 13. Populations of both sexes from Agusan del Norte and Balangao, Zamboanga Sibugay showed consistently bigger wings, whereas female populations from Ajuy, Iloilo, had smaller wings when compared with the other populations. Further tests showed that these variations were significant (Table 7).

Left wing

PCI (80.30%)

PC2 (6.72%)

PC4 (3.06%)

PC3 (3.56%)

PC5 (1.92%)
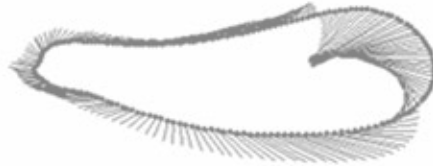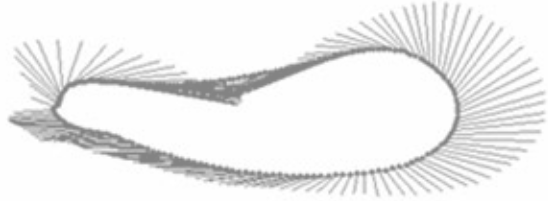
PC6 (1.14%)

Right wing

PC1 (82.98%)

PC2 (6.20%)
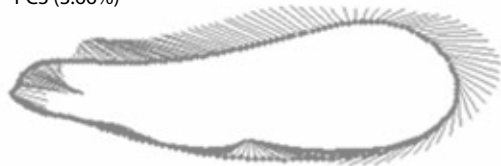
PC3 (3.66%)

PC4 (2.09%)

PC5 (1.55%)

PC6 (0.75%)

Fig. 9. Maps of influential landmarks for principal components 1–6 generated through PCA of outline coordinates of the left and right wings of all female samples of RBB.

Left wing

PCI (81.49%)

PC2 (6.40%)

PC3 (3.66%)

PC4 (2.81%)

PC5 (1.77%)

PC6 (1.71%)

Right wing

PC1 (84.00%)

PC2 (6.28%)

PC3 (2.73%)

PC4 (2.15%)

PC5 (1.40%)

PC6 (0.66%)

Fig. 10. Maps of influential landmarks for principal components 1–6 generated through PCA of outline coordinates of the left and right wings of all female samples of RBB.

Table 6a. Classification results for female *Scotinophara coarctata* group from a discriminant function analysis of the shape coordinates of the left wing.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.363	<0.000
Mindanao	153	2	1	8						93		
Panay (Iloilo)	7	18	1	1						67		
Palawan	6	0	5	0						46		
Luzon	12	1	3	14						47		
Total	178	21	10	23						**81.9***		
(B) Luzon											0.219	<0.000
Balading (Albay)	1	4	0	0						20		
Gadgaran (Sorsogon)	1	12	2	0						80		
Jupi (Sorsogon)	1	2	2	0						40		
Poblacion (Camarines Sur)	0	1	0	4						80		
Total	3	19	4	4						**63.3***		
(C) Mindanao											0.055	<0.000
Agusan del Norte	39	0	11	0	0	0	0	0		78		
Bucac (Agusan Sur)	1	6	0	0	0	0	0	1		75		
Balangao, (Zamboanga Sibugay)	5	0	44	0	0	0	0	1		88		
Dipolog (Zamboanga del Sur)	1	0	0	6	0	0	1	0		75		
Magpayang (Surigao del Norte)	0	0	0	0	2	0	0	0		100		
Maranding (Lanao del Norte)	2	1	1	0	0	20	0	2		77		
Palongalogin (North Cotabato)	0	0	0	1	0	0	7	1		78		
New Iloilo (South Cotabato)	1	0	0	0	0	0	3	7		64		
Total	49	7	56	7	2	20	11	12		**79.9***		
(D) Iloilo											0.281	<0.000
Ajuy	15	1								94		
Dapitan	0	11								100		
Total	15	12								**96.3***		
(E) Palawan											0.208	0.002
Maasin	4	0								100		
Bonobono	1	6								86		
Total	5	6								**90.9***		

*Percentage of original cases correctly classified.

Geometry and size of the head

The lengths of the vectors or lines attached to each of the landmark and semilandmarks of the head of the RBB indicated the amount of morphological variability at each point (Fig. 14, 15). Most of the variations observed included differences in shapes of the base of the head, accounting for more than 40 and 36% of the variance in females and males, respectively, as described by the first principal component. The remaining principal components described subtle asymmetries in the shapes of the left and right sides of the head.

The results of the discriminant function analysis showed differentiation among the populations with regard to the shapes of the head as shown by the result of the MANOVA on the head shape variables (Tables 8 and 9). Island populations were correctly classified 66.8 and 70% for females and males, respectively. Populations within each of the islands were also shown to be differentiated, but populations in Mindanao had low correct classification rates (55.8–60.9%).

Table 6b. Classification results for female *Scotinophara coarctata* group from a discriminant function analysis of the shape coordinates of the right wing.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.354	<0.000
Mindanao	116	13	13	17						73		
Panay (Iloilo)	3	17	3	3						65		
Palawan	2	0	12	0						86		
Luzon	8	1	1	25						71		
Total	129	31	29	45						**72.6***		
(B) Luzon											0.586	0.011
Balading (Albay)	4	1	0	0						80		
Gadgaran (Sorsogon)	0	15	0	0						100		
Jupi (Sorsogon)	0	4	1	0						20		
Poblacion (Camarines Sur)	1	6	0	3						30		
Total	5	26	1	3						**65.7***		
(C) Mindanao											0.065	<0.000
Agusan del Norte	31	0	15	0	0	1	0	1		65		
Bucac (Agusan Sur)	0	6	2	0	0	1	0	0		67		
Balangao, (Zamboanga Sibugay)	11	0	37	0	0	2	0	0		74		
Dipolo g(Zamboanga del Sur)	0	0	0	6	0	0	0	1		86		
Magpayang (Surigao del Norte)	0	0	0	0	1	1	0	0		50		
Maranding (Lanao del Norte)	4	4	0	0	0	15	0	0		65		
Palongalogin (North Cotabato)	0	1	0	0	0	0	4	3		50		
New Iloilo (South Cotabato)	0	1	0	0	0	1	2	8		67		
Total	46	12	54	6	1	21	6	13		**67.9***		
(D) Iloilo											0.112	<0.000
Ajuy	14	0								100		
Dapitan	0	12								100		
Total	14	12								**100***		
(E) Palawan											0.665	0.03
Maasin	5	2								71.4		
Bonobono	1	6								85.7		
Total	6	8								**78.6***		

*Percentage of original grouped cases correctly classified.

The results of the cluster analyses on the group centroids after DFA of the principal component scores showed two main branches that separated Omar, Malaysia samples from the Philippine populations (Fig. 16). The separation was supported by bootstrap values of 100 (1,000 replicates). For the Luzon populations, the RBB from Otavi, Sorsogon, was found to be different (bootstrap value: 100; 1,000 replicates).

Centroid size estimates of the head of all the samples showed that females from Agusan del Norte, Ajuy (Iloilo), Gansing (Sultan Kudarat), New Iloilo (South Cotabato), and Omar (Malaysia) have smaller head sizes (Fig. 17). A different pattern can be observed for their male counterparts where males from Dapitan (Iloilo) also had smaller heads as well as with individuals from New Iloilo (South Cotabato) and Omar (Malaysia).

The results of the Kruskal-Wallis test for significant differences in head sizes between pairs of populations are shown in Table 10. Males from Maranding (Lanao del Norte) and Palongalogin

Table 6c. Classification results for male *Scotinophara coarctata* group from a discriminant function analysis of the shape coordinates of the left wing.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.264	<0.000
Mindanao	144	10	2	5	0					89.4		
Panay (Iloilo)	12	26	1	0	0					66.7		
Palawan	5	0	10	1	0					62.5		
Luzon	5	2	1	13	1					59.1		
Malaysia	5	1	0	0	5					45.5		
Total	171	39	14	19	6					**79.5***		
(B) Luzon											0.079	<0.000
Balading (Albay)	3	0	0	1						75		
Gadgaran (Sorsogon)	0	7	0	0						100		
Otavi (Sorsogon)	0	1	3	0						75		
Poblacion (Camarines Sur)	0	0	0	7						100		
Total	3	8	3	8						**90.9***		
(C) Mindanao											0.049	<0.000
Agusan del Norte	36	0	13	0	0	1	0			72		
Bucac (Agusan Sur)	0	5	0	0	0	1	0			83.3		
Balangao, (Zamboanga Sibugay)	12	0	36	0	2	0	0			72		
Dipolog (Zamboanga del Sur)	0	0	0	6	0	0	0			100		
Magpayang (Surigao del Norte)	2	0	2	0	30	1	0			85.7		
Maranding (Lanao del Norte)	0	0	0	0	1	6	0			85.7		
Palongalogin (North Cotabato)	0	0	1	0	0	1	5			71.4		
Total	50	5	52	6	33	10	5			**77***		
(D) Iloilo											0.249	<0.000
Ajuy	21	1								95.5		
Dapitan	0	17								100		
Total	21	18								**97.4***		
(E) Palawan											0.006	<0.000
Maasin	8	0								100		
Bonobono	0	8								100		
Total	8	8								**100***		

*Percentage of original grouped cases correctly classified.

(North Cotabato) have significantly bigger heads when compared with some of the populations. On the other hand, females from Agusan del Norte, Ajuy (Iloilo), and Maasin (Palawan) have significantly smaller head sizes.

Scutellum

Differences in the shape of the scutellum among populations of *S. coarctata* group were also observed, assessed using the same protocol. Sex-related differences in shape variability as evidenced by the discrepancies in the direction of the vectors attached to the outline points in PC1 are shown in Figures 18 and 19. The first principal components describe the extent of asymmetry in the shapes of the left and right sides of the scutellum. Results of the DFA performed on the principal component scores showed significant differences among the island populations and populations within Luzon, Mindanao, and Iloilo but not for Palawan (Tables 11 and 12). The island populations were classified

Table 6d. Classification results for male *Scotinophara coarctata* group from a discriminant function analysis of the shape coordinates of the right wing.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.328	<0.000
Mindanao	151	3	1	1	5					93.8		
Panay (Iloilo)	4	6	1	5	0					37.5		
Palawan	9	0	4	1	0					28.6		
Luzon	7	3	1	8	0					42.1		
Malaysia	4	0	0	0	7					63.6		
Total	175	12	7	15	12					**79.6***		
(B) Luzon											0.151	<0.000
Balading (Albay)	1	0	0	2						33.3		
Gadgaran (Sorsogon)	0	5	0	1						83.3		
Otavi (Sorsogon)	0	0	2	1						66.7		
Poblacion (Camarines Sur)	0	1	0	6						85.7		
Total	0									**79.5***		
(C) Mindanao											0.033	<0.000
Agusan del Norte	36	0	12	0	0	1	0	0		73.5		
Bucac (Agusan Sur)	0	4	0	0	0	1	0	1		66.7		
Balangao, (Zamboanga Sibugay)	11	0	38	0	0	1	0	0		76		
Dipolog (Zamboanga del Sur)	0	0	0	2	0	0	1	0		66.7		
Magpayang (Surigao del Norte)	0	0	0	0	4	0	0	0		100		
Maranding (Lanao del Norte)	1	1	0	0	0	31	1	0		91.2		
Palongalogin (North Cotabato)	0	0	0	0	0	1	5	1		71.4		
New Iloilo (South Cotabato)	0	0	0	0	0	0	0	8		100		
Total										**73.7***		
(D) Palawan											0.024	<0.000
Maasin	8	0								100		
Bonobono	0	6								100		
Total										**100***		

*Percentage of original grouped cases correctly classified.

correctly more than 60% of the time. The two Iloilo populations were differentiated with higher correct classification rates (>90%).

Hierarchical cluster analysis of the group centroids derived from the DFA showed discrepancies in the groupings when analyses were done separately for the two sexes (Fig. 20). The scutellum of the male RBB from Omar, Malaysia, has a different shape from that of the Philippine samples (Fig. 20d). However, female RBB from Malaysia were similar to samples from Palawan and Mindanao. The same observations can be made on the Mindanao and Luzon populations where different groupings were seen.

Figure 21 shows the differences in the size of the scutellum. Males from Maranding, Lanao del Norte have bigger scutellum than other populations. On the other hand, all samples from Ajuy, Iloilo, have significantly smaller scutellum when compared with other populations. Tests for significant differences in scutellar size were conducted and results showed that the Maranding male samples have significantly larger scutellum than samples from the seven other populations.
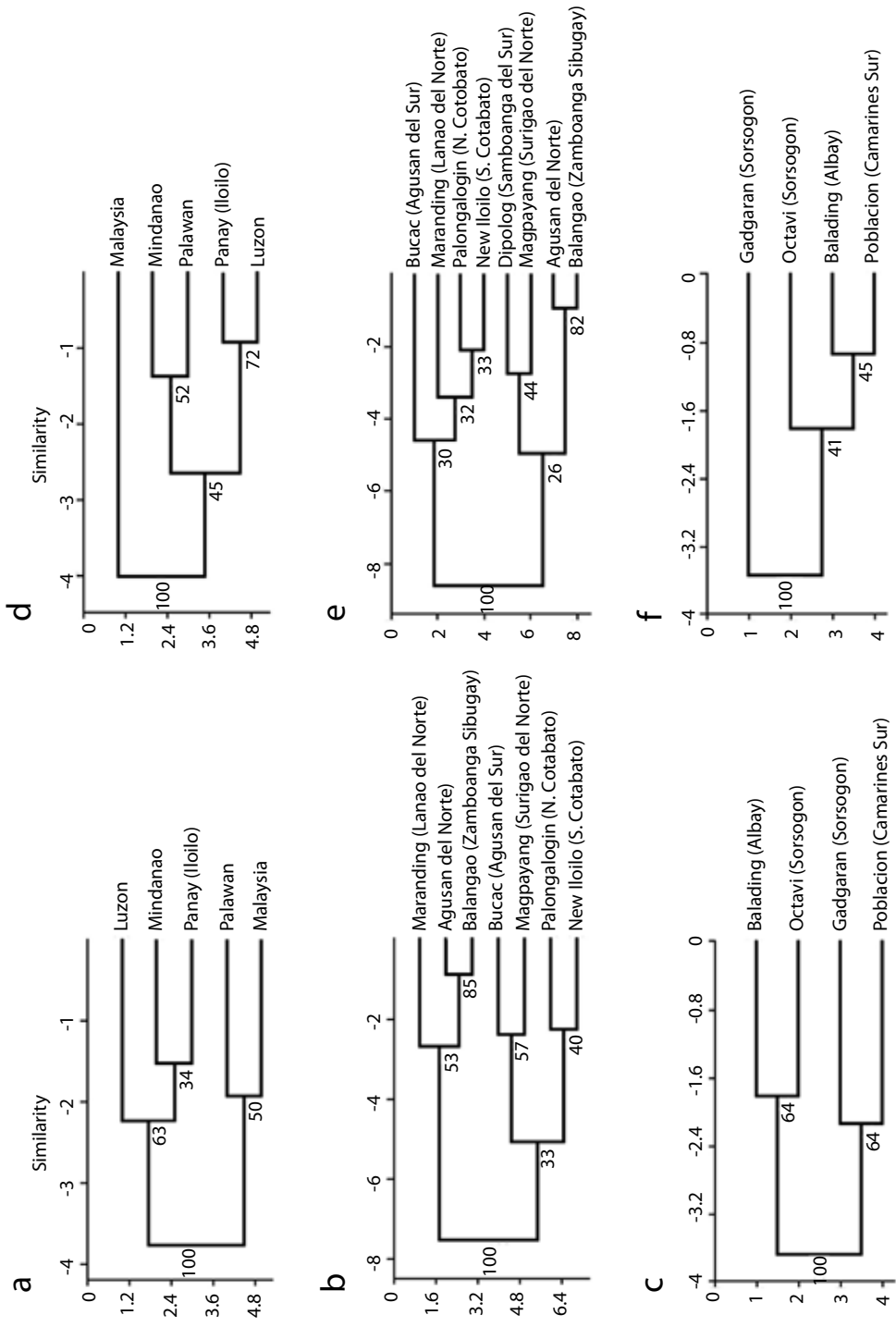
Fig. 11. Results of cluster analyses performed on the group centroids derived from discriminant function analysis of the principal component scores for the (a–c) left and (d–f) right wings of all male RBB.
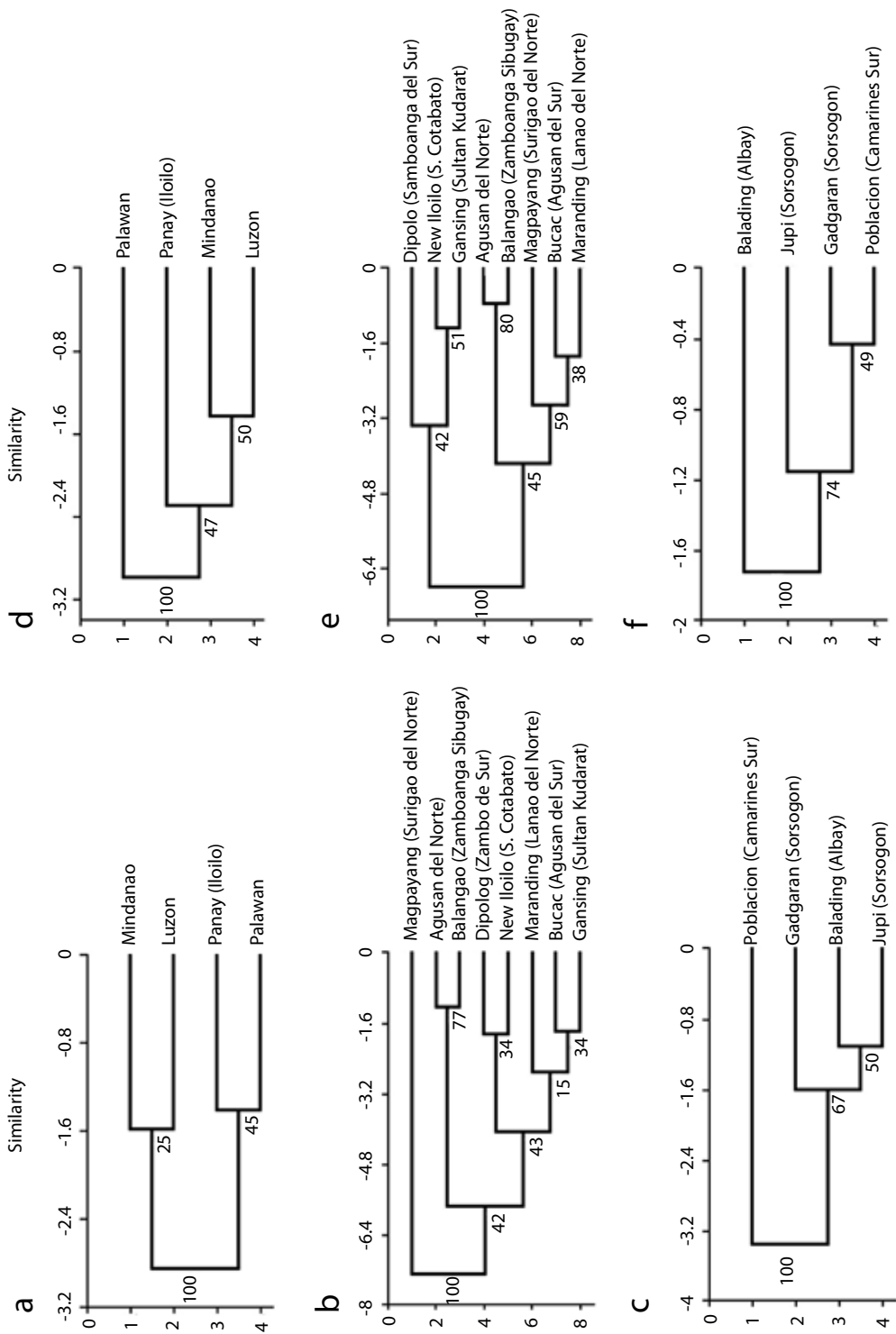
Fig. 12. Results of cluster analyses performed on the group centroids derived from discriminant function analysis of the principal component scores for the (a–c) left and (d–f) right wings of all male RBb.
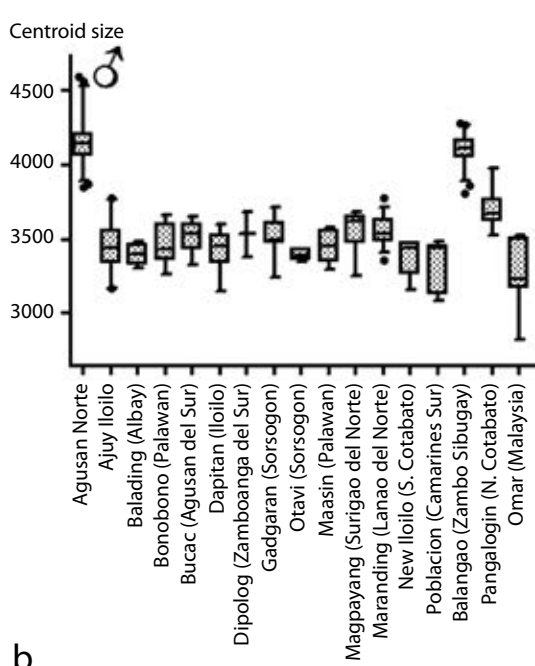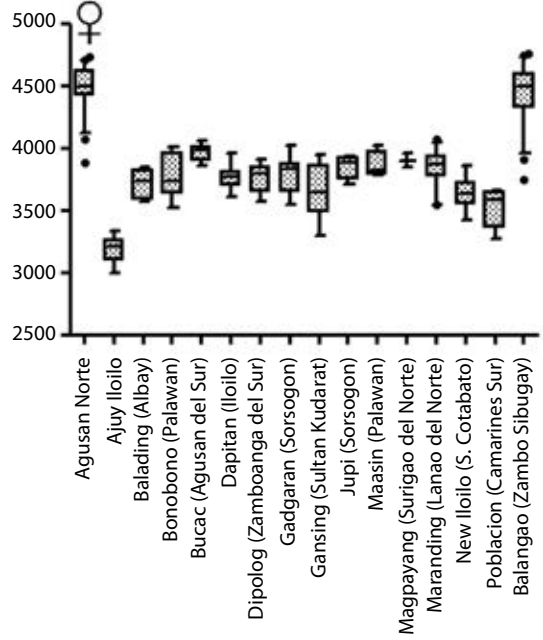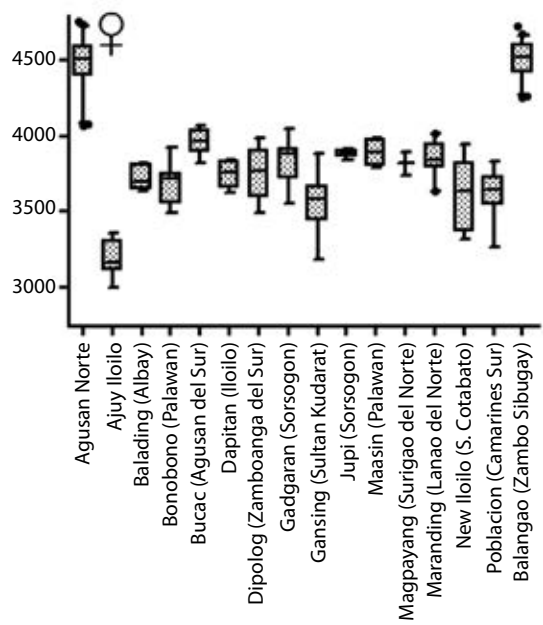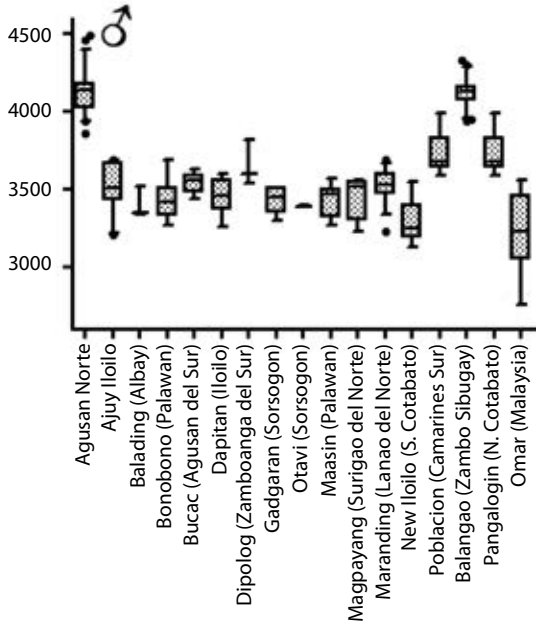
Fig. 13. Plot of centroid size in *Scotinophara coarctata* group showing interpopulation differences in the size of the (a) left and (b) right wings.

Table 7. Results of the test for significant differences in wing sizes across all populations of RBB.

Character/sex	Post hoc test		Difference	Summary
(A) Left wing/males (KW: 198.9; P<0.0001)	Agusan del Norte	Ajuy (Iloilo)	135.7	***
		Balading (Albay)	159.6	**
		Bonobono (Palawan)	137.7	***
		Bucac (Agusan del Sur)	115.9	*
		Dapitan (Iloilo)	141.9	***
		Gadgaran (Sorsogon)	116.9	**
		Otavi (Sorsogon)	164.8	**
		Maasin (Palawan)	138.8	***
		Maranding (Lanao del Norte)	105.8	***
		New Iloilo (South Cotabato)	162.9	***
		Poblacion (Camarines Sur)	163.5	***
		Omar (Malaysia)	172.2	***
	Balangao (Zamboanga Sibugay)	Ajuy (Iloilo)	-126.5	***
		Balading (Albay)	-150.3	**
		Bonobono (Palawan)	-128.4	***
		Dapitan (Iloilo)	-132.6	***
		Gadgaran (Sorsogon)	-107.6	*
		Otavi (Sorsogon)	-155.5	**
		Maasin (Palawan)	-129.5	***
		Maranding (Lanao del Norte)	-96.53	***
		New Iloilo (South Cotabato)	-153.6	***
		Poblacion (Camarines Sur)	-154.2	***
		Omar (Malaysia)	163	***
(B) Right wing/males (KW: 198.5; P<0.0001)	Agusan del Norte	Ajuy (Iloilo)	114.3	***
		Balading (Albay)	151.1	*
		Bonobono (Palawan)	139.7	***
		Dapitan (Iloilo)	133.3	***
		Gadgaran (Sorsogon)	142.4	***
		Otavi (Sorsogon)	161.4	*
		Maasin (Palawan)	138.9	***
		Maranding (Lanao del Norte)	109.2	***
		New Iloilo (South Cotabato)	168.3	***
		Omar (Malaysia)	165	***
	Balangao (Zamboanga Sibugay)	Ajuy (Iloilo)	-114	***
		Balading (Albay)	-150.7	*
		Bonobono (Palawan)	-139.3	***
		Dapitan (Iloilo)	-133	***
		Gadgaran (Sorsogon)	-142.1	***
		Otavi (Sorsogon)	-161.1	*
		Maasin (Palawan)	-138.6	***
		Maranding (Lanao del Norte)	-108.9	***
		New Iloilo (South Cotabato)	-168	***
		Omar (Malaysia)	164.6	***
(C) Left wing /females (KW: 188.3; P<0.0001)	Agusan del Norte	Ajuy (Iloilo)	175.5	***
		Balading (Albay)	126.6	**
		Bonobono (Palawan)	114.5	**
		Dapitan (Iloilo)	113.7	***
		Dipolog (Zamboanga del Sur)	116	***
		Gadgaran (Sorsogon)	105.6	***

continued on next page...

Table 7 continued.

Character/sex	Post hoc test		Difference	Summary
		Gansing (Sorsogon)	130.8	***
		Maranding (Lanao del Norte)	93.9	***
		New Iloilo (South Cotabato)	139.7	***
		Poblacion (Camarines Sur)	153	***
		Bucac (Agusan del Sur)	-110.8	*
		Maranding (Lanao del Norte)	-81.59	*
	Balangao (Zamboanga Sibugay)	Ajuy (Iloilo)	-168.9	***
		Balading (Albay)	-119.9	*
		Bonobono (Palawan)	-107.9	**
		Dapitan (Iloilo)	-107.1	***
		Dipolog (Zamboanga del Sur)	-109.4	**
		Gadgaran (Sorsogon)	-98.94	***
		Gansing (Sorsogon)	-124.2	***
		Maranding (Lanao del Norte)	-87.28	***
		New Iloilo (South Cotabato)	-133.1	***
		Poblacion (Camarines Sur)	-146.3	***
(D) Right wing/females (KW: 197.5; P<0.0001)	Agusan del Norte	Ajuy (Iloilo)	175.6	***
		Balading (Albay)	126.3	**
		Bonobono (Palawan)	128.7	***
		Dapitan (Iloilo)	118	***
		Dipolog (Zamboanga. Del Sur)	115	**
		Gadgaran (Sorsogon)	94.46	***
		Gansing (Sorsogon)	146.2	***
		Maranding (Lanao del Norte)	93.2	***
		New Iloilo (South Cotabato)	131.5	***
		Poblacion (Camarines Sur)	140.1	***
	Ajuy (Iloilo)	Bucac (Agusan del Sur)	-110.5	*
		Maranding (Lanao del Norte)	-82.4	*
		Balangao (Zamboanga Sibugay)	-177.6	***
	Balangao (Zamboanga. Sibugay)	Balading (Albay)	-128.3	**
		Bonobono (Palawan)	-130.8	***
		Dapitan (Iloilo)	-120.1	***
		Dipolog (Zamboanga del Sur)	-117.1	**
		Gadgaran (Sorsogon)	-96.5	***
		Gansing (Sorsogon)	-148.3	***
		Maranding (Lanao del Norte)	-95.24	***
		New Iloilo (South Cotabato)	-133.5	***
		Poblacion (Camarines Sur)	-142.1	***

*Significant at P≤ 0.05. **Significant at P≤ 0.01. ***Significant at P≤ 0.001.
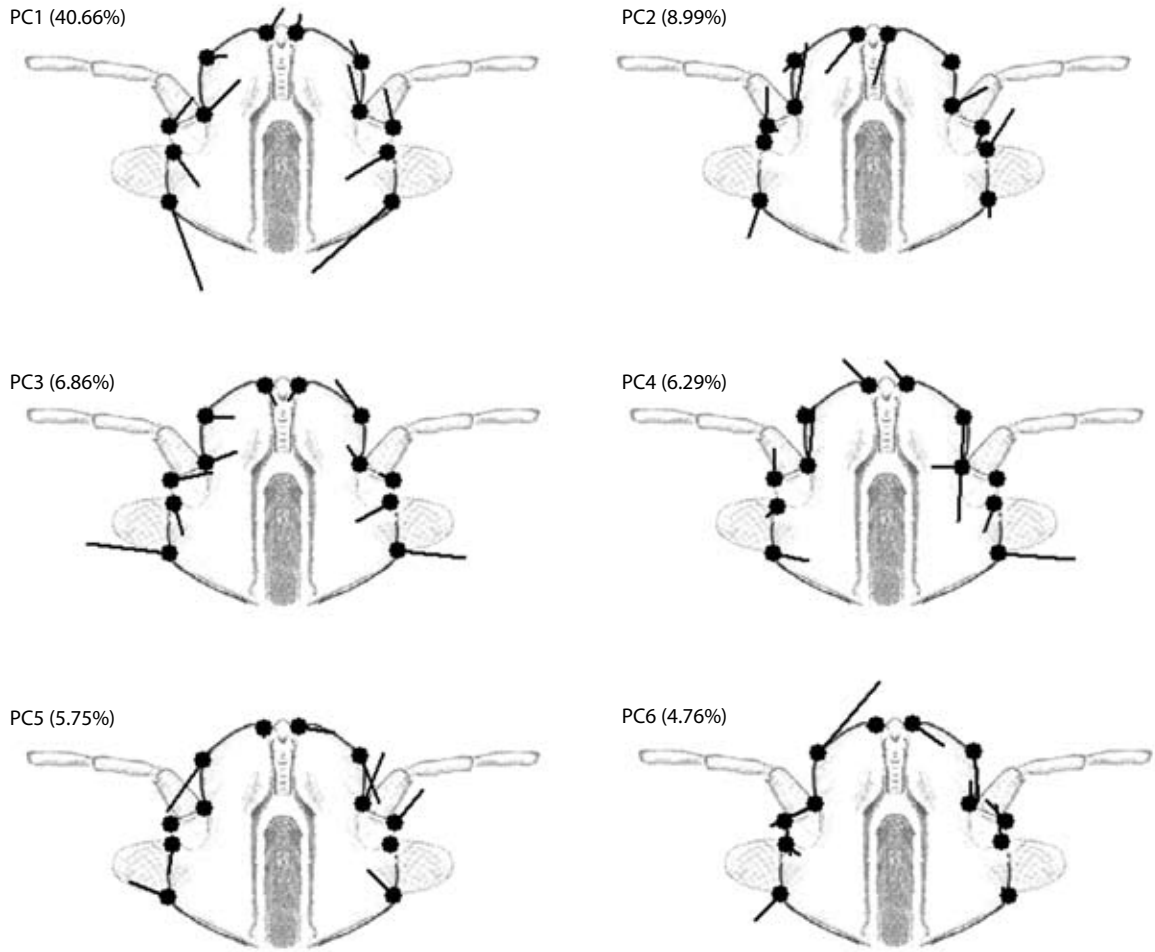
Fig. 14. Maps of influential landmarks for principal components 1–6 generated through PCA of Procrustes-fitted coordinates of the head of all female samples. Influential landmarks represented regions of greatest morphological variability and contributed disproportionately to trends in shape changes within and among populations of female RBB.

Pronotum

Both landmark and outline analyses showed differences in the patterns of shape variation in the pronotum captured using the two methods of geometric morphometric analyses (Figs. 22–25). However, outline analysis was able to capture much better differences in the shapes of the pronotum with the first principal components able to contain 53–72% of the variance when compared with 24–26% variance captured using landmark analysis. Sex-related differences in the trends of shape variation can be observed. Results of the DFA showed high correct classification rates, implying geographic

Fig. 15. Maps of influential landmarks for principal components 1–6 generated through PCA of Procrustes-fitted coordinates of the head of all male samples. Influential landmarks represented regions of greatest morphological variability and contributed disproportionately to trends in shape changes within and among populations of male RBB.

differentiation in the shapes of the pronotum (Tables 13–16). This was also supported by the results of the MANOVA of the shape variables showing that the differences were statistically significant.

Hierarchical cluster analysis of the group centroids after DFA of the shape variables showed differences in the clusters formed when landmark and outline analyses were performed (Fig. 26). However, when the result of the outline analysis was used in constructing the phenogram, all Philippine

Table 8. Classification results for female *Scotinophara coarctata* group from a discriminant function analysis of the shape coordinates of the head.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.518	<0.000
Mindanao	138	5	0	11	0					90		
Panay (Iloilo)	19	18	1	3	0					44		
Palawan	9	1	4	1	0					27		
Luzon	30	4	3	16	0					30		
Malaysia	1	0	0	0	1					50		
Total	197	28	8	31	1					**66.8***		
(B) Luzon											0.223	<0.000
Balading (Albay)	2	3	0	0						40		
Gadgaran (Sorsogon)	0	18	0	2						90		
Otavi (Sorsogon)	0	1	16	0						94		
Poblacion (Camarines Sur)	0	5	0	6						55		
Total	2	27	16	8						**79.2***		
(C) Mindanao											0.063	<0.000
Agusan del Norte	21	0	1	1	2	0	0	3	1	72		
Bucac (Agusan Sur)	0	3	3	0	0	2	0	2	0	30		
Balangao, (Zamboanga Sibugay)	7	5	20	3	5	6	0	1	3	40		
Dipolog (Zamboanga del Sur)	0	0	0	5	0	0	1	0	0	83		
Magpayang (Surigao del Norte)	0	0	0	0	2	0	0	0	0	100		
Maranding (Lanao del Norte)	2	4	7	0	2	12	0	1	1	41		
Palongalogin (North Cotabato)	0	0	0	1	0	0	9	0	0	90		
New Iloilo (South Cotabato)	0	1	0	0	0	2	0	6	0	67		
Gansing (Sultan Kudarat)	0	0	0	0	0	0	0	1	8	89		
Total	30	13	31	10	11	22	10	14	13	**55.8***		
(D) Iloilo											0.315	<0.000
Ajuy	27	2								93.1		
Dapitan	0	12								100		
Total	27	14								**95.1***		
(E) Palawan											0.017	<0.000
Maasin	8	0								100		
Bonobono	0	7								100		
Total	8	7								**100***		

*Percentage of original grouped cases correctly classified.

Table 9. Classification results for male *Scotinophara coarctata* group from a discriminant function analysis of the shape coordinates of the head.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.638	<0.000
Mindanao	167	6	1	5	0					93		
Panay (Iloilo)	26	9	0	1	0					25		
Palawan	15	0	1	0	0					6		
Luzon	22	1	0	8	0					26		
Malaysia	2	1	0	0	2					40		
Total	232	17	2	14	2					**70***		
(B) Luzon											0.203	<0.000
Balading (Albay)	1	4	0	0						20		
Gadgaran (Sorsogon)	0	7	1	1						78		
Otavi (Sorsogon)	0	0	4	0						100		
Poblacion (Camarines Sur)	0	2	0	11						85		
Total	1	13	5	12						**74.2***		
(C) Mindanao											0.168	<0.000
Agusan del Norte	41	0	3	1	0	1	3	1	0	82		
Bucac (Agusan Sur)	0	1	5	0	0	2	0	2	0	10		
Balangao, (Zamboanga Sibugay)	0	1	41	0	0	7	0	1	0	82		
Dipolog (Zamboanga del Sur)	2	0	0	1	0	0	0	0	0	33		
Magpayang (Surigao del Norte)	0	0	3	0	0	3	0	0	0	0		
Maranding (Lanao del Norte)	2	0	14	0	0	14	0	0	0	47		
Palongalogin (North Cotabato)	3	0	1	0	0	0	8	0	0	67		
New Iloilo (South Cotabato)	0	0	3	0	0	3	0	3	0	33		
Gansing (Sultan Kudarat)	1	0	7	0	0	1	0	0	0	0		
Total	49	2	77	2	0	31	11	7	0	**60.9***		
(D) Iloilo											0.474	<0.000
Ajuy	16	3								84.2		
Dapitan	2	15								88.2		
Total	18	18								**86.1***		
(E) Palawan											0.09	<0.000
Maasin	7	0								100		
Bonobono	0	9								100		
Total	7	9								**100***		

*Percentage of original grouped cases correctly classified.
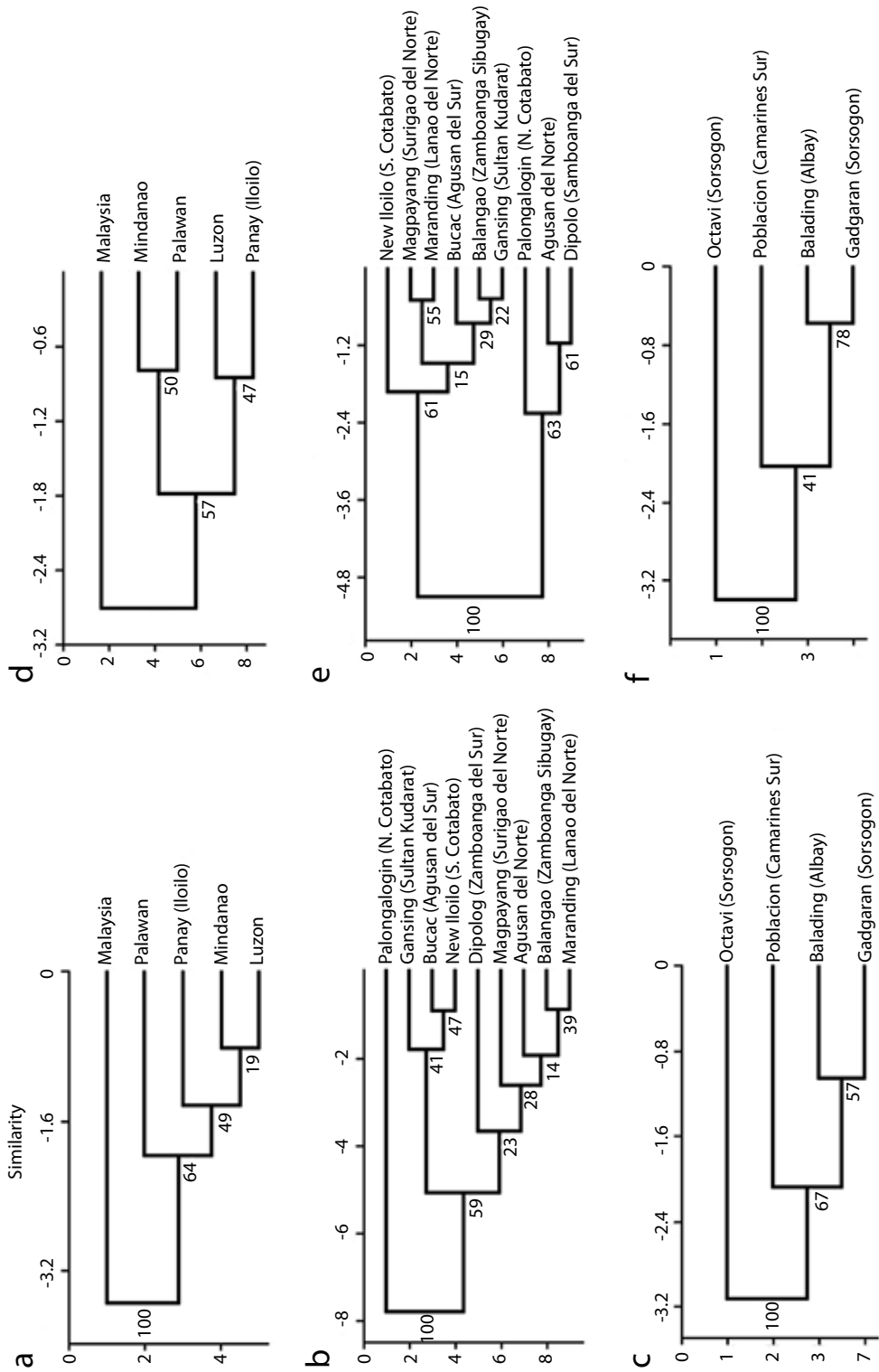
Fig. 16. Results of cluster analyses performed on the group centroids derived from discriminant function analysis of the principal component scores for the head of all (a-c) female and (d-f) male samples.
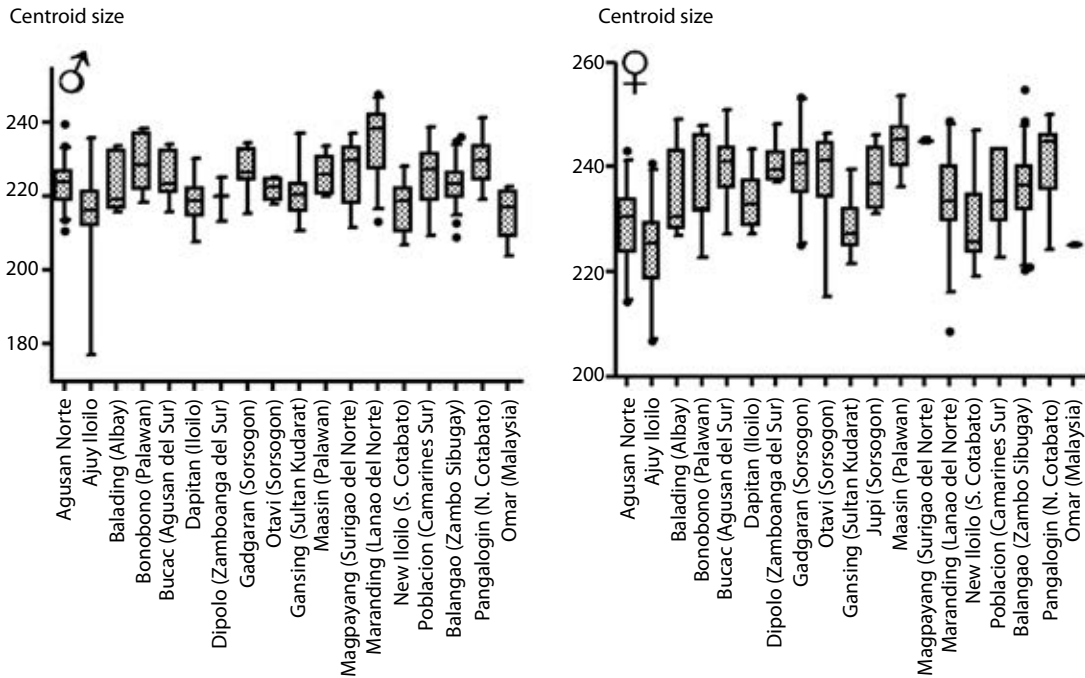
Fig. 17. Plot of centroid size in *Scotinophara coarctata* group showing interpopulation differences in the size of the head.

samples were separated from the Omar, Malaysia samples (Fig. 27). No clear-cut geographic pattern can be observed when cluster analysis was performed on the Luzon and Mindanao populations.

Figure 28 and Table 17 show that samples from Maranding, Kapatagan, Lanao del Norte had significantly bigger pronotum when compared with some of the populations. The opposite was true for samples from Ajuy, Iloilo, which had significantly smaller pronotum sizes.

The results of the current study strongly suggest the existence of morphological differentiation in the black bugs. The existence of morphological differentiation within, among, and between populations of this insect pest indicates possible genetic differentiation. As to the argument whether population differences in this group of insect pests indicate speciation remains to be further investigated. Are the variations observed an indication of the existence of intraspecific categories in the black bugs? Are the insect populations mere geographical races? More data on important variables such as environmental heterogeneity and sample position within the population's distribution should be further explored.

Are the variations in sizes and shapes of the various morphological structures an indication of phenotypic plasticity in the species? Are the variations observed due to the ability of an organism with a given genotype to change its phenotype in response to changes in the environment? Many

Table 10. Results of test for significant differences in the centroid sizes of the head across all populations of the RBB.

Character/sex	Post hoc test		Difference	Summary
Males (KW: 86.55; P<0.0001)	Maranding (Lanao del Norte)	Agusan del Norte	-92.89	***
		Ajuy (Iloilo)	-147.6	***
		Dapitan (Iloilo)	-142.6	***
		Gansing (Sultan Kudarat)	-125.2	**
		New Iloilo (South Cotabato)	149.6	***
		Balangao (Zamboanga Sibugay)	92.15	***
		Omar (Malaysia)	163.5	**
	Palongalogin (North Cotabato)	Ajuy (Iloilo)	-115	**
		Dapitan (Iloilo)	-109.9	*
Females (KW: 97.18; P<0.0001)	Agusan del Norte	Gadgaran (Sorsogon)	-94.96	**
		Otavi (Sorsogon)	-90.03	*
		Maasin (Palawan)	-139.3	**
		Palongalogin (North Cotabato)	-117.5	**
	Ajuy (Iloilo)	Bucac (Agusan del Sur)	-128.2	**
		Dipolog (Zamboanga del Sur)	-138.6	*
		Gadgaran (Sorsogon)	-127.4	***
		Otavi (Sorsogon)	-122.4	***
		Maasin (Palawan)	-171.7	***
		Maranding (Lanao del Norte)	-83.21	**
		Balangao (Zamboanga Sibugay)	-90.36	***
		Palongalogin (North Cotabato)	-149.9	***
	Maasin (Palawan)	Gansing (Sultan Kudarat)	-148.6	*
		New Iloilo (South Cotabato)	143.7	*

cases of such plasticity express several highly morphologically distinct results. Organisms of fixed genotype may differ in the amount of phenotypic plasticity they display when exposed to the same environmental change. Hence, phenotypic plasticity can evolve and be adaptive if fitness is increased by changing the phenotype. It is also possible that genetic variations within local populations of RBB (individuals or genotypes) in their utilization of different rice varieties and distribution of genetic variants across different rice varieties in the field exist and these are reflected in their phenotypes. Many studies seem to confirm the ideas to be operating especially in agricultural pests (Gould 1979, Wasserman and Futuyma 1981, Tabashnik et al. 1981). While geographical variations were observed among RBB populations in terms of size and shapes of selected characters, there are more distinct characters such as genitalia that are robust. There is really a need for more studies that will involve the determination of the genetic basis of variations observed among the local populations of the insect pest. There are questions also as to how these variations can be maintained. Are the variations due to multiple niche polymorphism or mutation, which is considered to be sufficient to maintain observed levels of genetic variance in polygenic characters? Or do the populations have reduced recombination where there seems to be a high level of distinctness of the various populations based on the results of

PC1 (58.53%)

PC2 (142.371%)
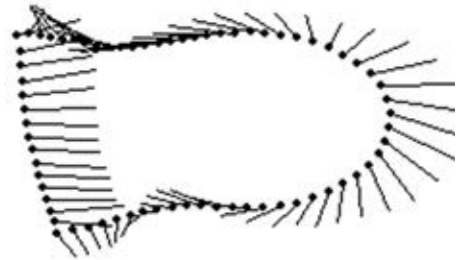
PC3 (6.78%)

PC4 (4.54%)

PC5 (2.45%)
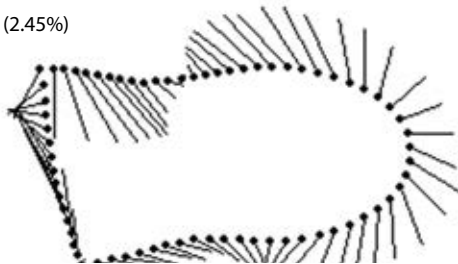
PC6 (1.99%)

Fig. 18. Maps of influential landmarks for principal components 1–6 generated through PCA of outline coordinates of the left and right wings of all female RBB.

PC1 (58.95%)
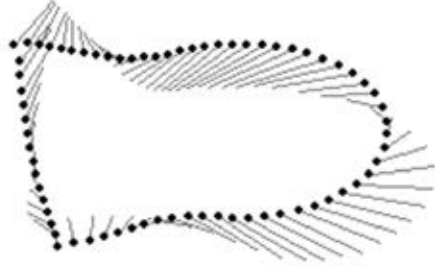
PC2 (13.05%)

PC3 (6.23%)

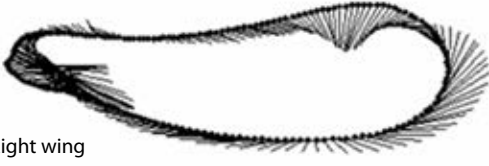PC4 (4.29%)

PC5 (2.67%)
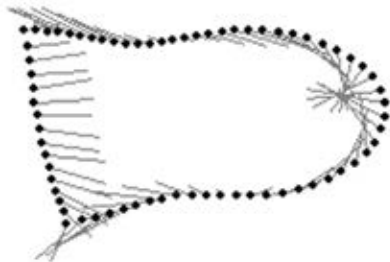
PC6 (2.34%)

Fig. 19. Maps of influential landmarks for principal components 1–6 generated through PCA of outline coordinates of the left and right wings of all male RBB.

Table 11. Classification results for female *Scotinophara coarctata* group from a discriminant function analysis of the shape coordinates of the scutellum.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.459	<0.000
Mindanao	130	3	0	8	0					92.2		
Panay (Iloilo)	15	17	0	4	0					47.2		
Palawan	5	1	6	3	0					40		
Luzon	22	4	0	33	0					55.9		
Malaysia	2	0	0	0	0					0		
Total	174	25	6	48	0					**73.5***		
(B) Luzon											0.201	<0.000
Balading (Albay)	2	2	0	0	1					40		
Gadgaran (Sorsogon)	0	10	0	6	1					58.8		
Otavi (Sorsogon)	0	0	6	0	2					75		
Poblacion (Camarines Sur)	0	6	1	8	1					50		
Balading (Albay)	0	3	1	1	8					61.5		
Total	2	21	8	15	13					**57.6***		
(C) Mindanao											0.148	<0.000
Agusan del Norte	31	0	4	0	0	6	1	2	1	68.9		
Bucac (Agusan Sur)	0	8	1	0	0	0	0	1	0	80		
Balangao, (Zamboanga Sibugay)	7	1	14	0	0	0	0	2	2	53.8		
Dipolog (Zamboanga del Sur)	1	0	1	1	0	0	0	0	0	33.3		
Magpayang (Surigao del Norte)	0	0	0	0	2	0	0	0	0	100		
Maranding (Lanao del Norte)	11	0	0	0	0	19	0	1	0	61.3		
Palongalogin (North Cotabato)	1	0	0	0	0	0	2	0	0	66.7		
New Iloilo (South Cotabato)	1	0	1	0	0	1	0	7	1	63.6		
Gansing (Sultan Kudarat)	4	0	0	0	0	1	0	1	4	40		
Total	56	9	21	1	2	27	3	14	8	**62.4***		
(D) Iloilo											0.295	<0.000
Ajuy	23	1								95.8		
Dapitan	1	11								91.7		
Total	24	12								**94.4***		
(E) Palawan											0.586	0.1
1. Maasin	7	1								87.5		
2. Bonobono	1	6								85.7		
Total	8	7								**86.7***		

*Percentage of original grouped cases correctly classified.

Table 12. Classification results for male *Scotinophara coarctata* group from a discriminant function analysis of the shape coordinates of the scutellum.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.346	<0.000
Mindanao	82	14	20	22	8					56.2		
Panay (Iloilo)	3	24	5	1	0					72.7		
Palawan	1	0	15	1	0					88.2		
Luzon	1	2	4	17	0					70.8		
Malaysia	2	0	0	0	7					77.8		
Total	89	40	44	41	15					**63.3***		
(B) Luzon											0.267	0.002
Balading (Albay)	4	0	0	1						80		
Gadgaran (Sorsogon)	0	6	0	1						85.7		
Otavi (Sorsogon)	0	0	3	0						100		
Poblacion (Camarines Sur)	3	1	1	4						44.4		
Total	7	7	4	6						**70.8***		
(C) Mindanao											0.091	<0.000
Agusan del Norte	34	0	3	0	0	4	0	4	2	72.3		
Bucac (Agusan Sur)	0	6	0	0	0	0	1	1	0	75		
Balangao, (Zamboanga Sibugay)	3	0	15	3	2	1	1	1	6	46.9		
Dipolog (Zamboanga del Sur)	1	0	0	2	0	0	0	0	0	66.7		
Magpayang (Surigao del Norte)	0	0	0	0	3	0	1	0	2	50		
Maranding (Lanao del Norte)	1	0	1	0	0	27	1	1	0	87.1		
Palongalogin (North Cotabato)	0	0	0	0	0	1	3	0	0	75		
New Iloilo (South Cotabato)	2	1	0	0	0	0	0	4	1	50		
Gansing (Sultan Kudarat)	0	1	1	0	1	0	0	1	3	42.9		
Total	41	8	20	5	6	33	7	12	14	**66.4***		
(D) Iloilo											0.39	<0.000
Ajuy	15	1								93.8		
Dapitan	2	15								88.2		
Total	17	16								**90.9***		
(E) Palawan											0.785	0.061
Maasin	5	3								62.5		
Bonobono	3	6								66.7		
Total	8	9								**64.7***		

*Percentage of the original grouped cases correctly classified.
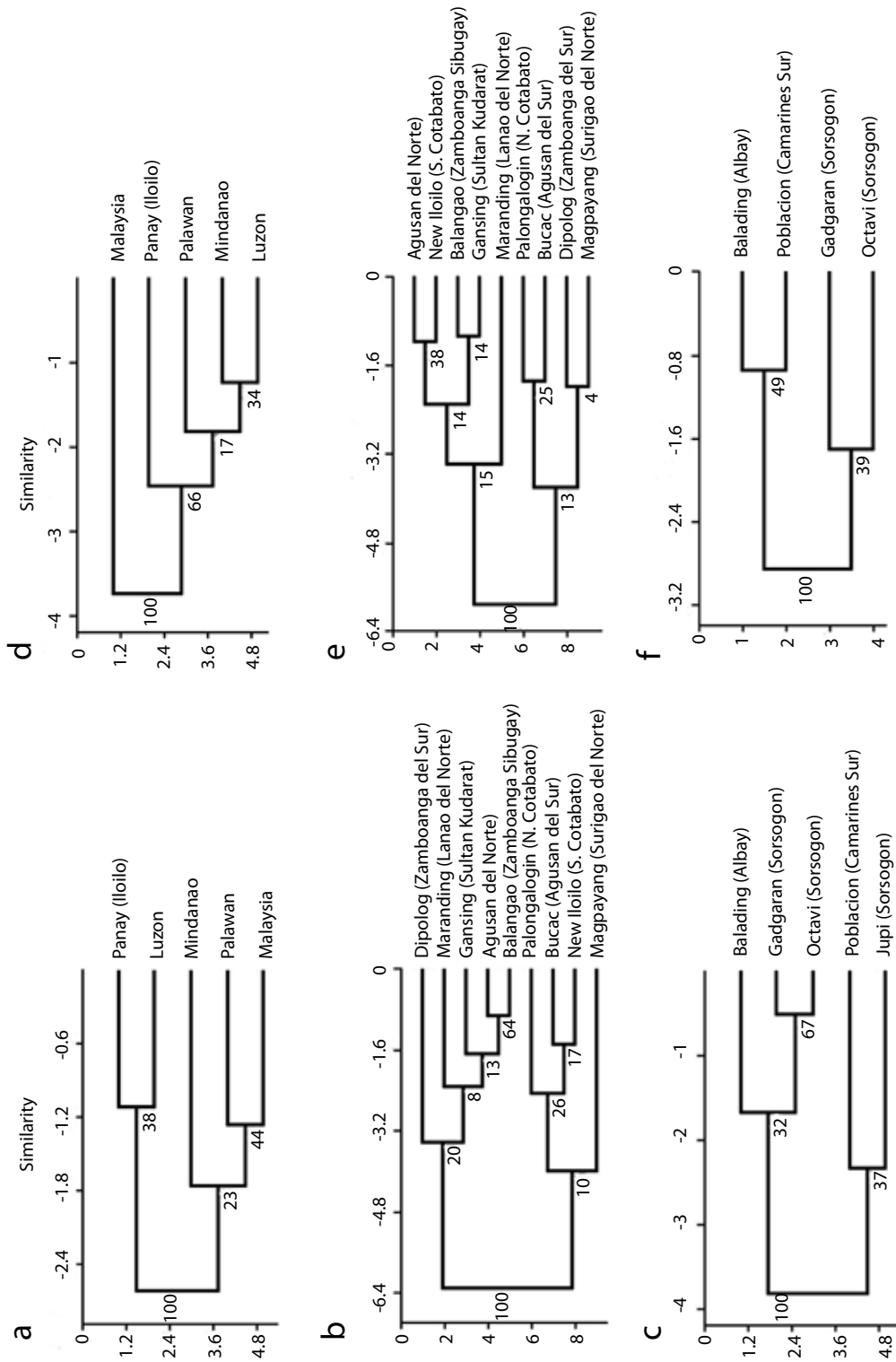
Fig. 20. Results of cluster analyses performed on the group centroids derived from discriminant function analysis of the principal component scores for the scutellum of all (a-c) female and (d-f) male RBB.

Centroid size (♂)

Centroid size (♀)

Agusan Norte
Ajuy Iloilo
Balading (Albay)
Bonobono (Palawan)
Bucac (Agusan del Sur)
Dapitan (Iloilo)
Dipolog (Zamboanga del Sur)
Gadgaran (Sorsogon)
Otavi (Sorsogon)
Gansing (Sultan Kudarat)
Maasin (Palawan)
Magpayang (Surigao del Norte)
Maranding (Lanao del Norte)
New Iloilo (S. Cotabato)
Poblacion (Camarines Sur)
Balangao (Zambo Sibugay)
Pangalogin (N. Cotabato)
Omar (Malaysia)

Fig. 21. Plot of centroid size in *Scotinophara coarctata* group showing interpopulation differences in the size of the scutellum.

Table 13. Results of test for significant differences in scutellum centroid sizes across all populations of the RBB.

Sex	Post hoc test		Difference	Summary
Females (KW: 115.3; P<0.0001)	Ajuy (Iloilo)	Bucac (Agusan del Sur)	-179.2	***
		Gadgaran (Sorsogon)	-98.23	**
		Otavi (Sorsogon)	-137.2	***
		Jupi (Sorsogon)	-160.2	***
		Maasin (Palawan)	-135.9	***
		Maranding (Lanao del Norte)	-126.5	***
		Balangao (Zamboanga Sibugay)	-91.67	**
		Agusan del Norte	106.8	***
	Bucac (Agusan del Sur)	Bonobono (Palawan)	-134.7	*
		Gansing (Sultan Kudarat)	130.5	*
		New Iloilo (South Cotabato)	141.7	**
		Poblacion (Camarines Sur)	174.4	***
	Poblacion (Camarines Sur)	Otavi (Sorsogon)	132.4	***
		Jupi (Sorsogon)	155.4	***
		Poblacion (Camarines Sur)	131.1	*
		Maranding (Lanao del Norte)	121.7	***
		Agusan del Norte	102	**
Males (KW: 112.2; P<0.0001)	Ajuy (Iloilo)	Agusan del Norte	70.54	*
		Bucac (Agusan del Sur)	-153.8	***
		Magpayang (Surigao del Norte)	-130.2	**
		Maranding (Lanao del Norte)	-172.9	***
		Balangao (Zamboanga Sibugay)	-90.09	**
	Maranding (Lanao del Norte)	Dapitan (Iloilo)	-125.4	***
		Gansing (Sultan Kudarat)	-132.8	***
		New Iloilo (South Cotabato)	132.7	***
		Poblacion (Camarines Sur)	125.6	***
		Balangao (Zamboanga Sibugay)	82.79	***
		Omar (Malaysia)	100.4	**
		Agusan del Norte	-102.3	***
	Bucac (Agusan del Sur)	Dapitan (Iloilo)	106.4	*

PC1 (53.59%)

PC2 (20.40%)

PC3 (8.12%)

PC4 (4.28%)

PC5 (2.03%)

PC6 (1.79%)
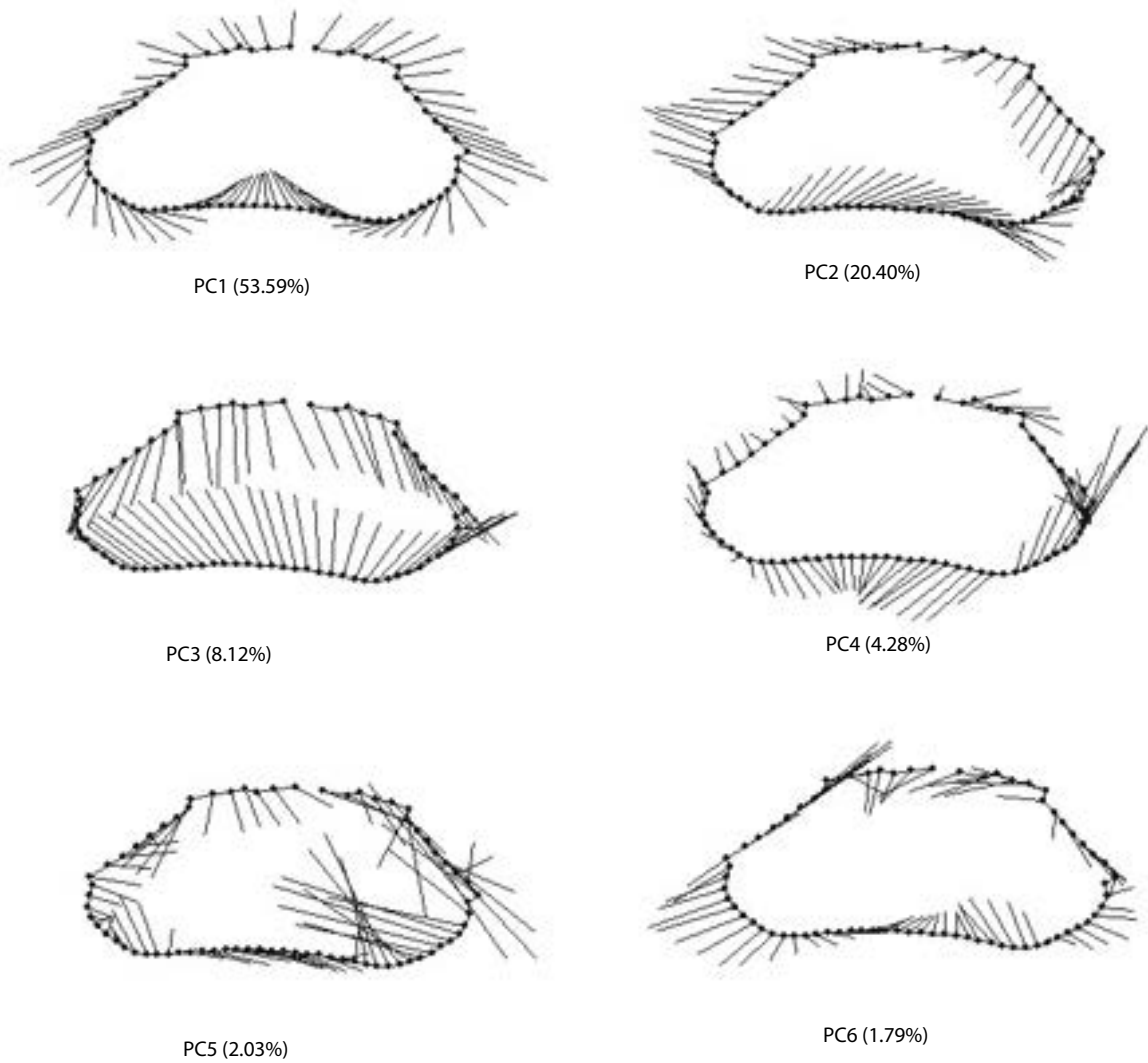
Fig. 22. Maps of influential landmarks for principal components 1–6 generated through PCA of elliptic Fourier coordinates of the pronotum of all female samples. Influential landmarks represented regions of greatest morphological variability and contributed disproportionately to trends in shape changes within and among populations of female RBB.
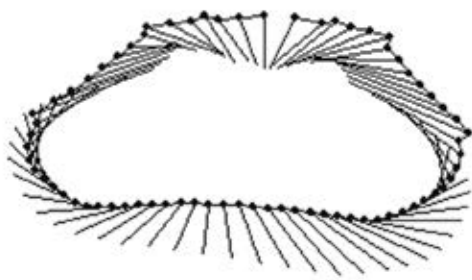
PC1 (72.39%)

PC2 (14.25%)
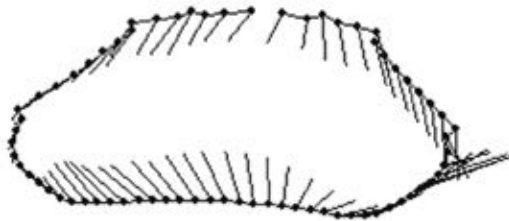
PC3 (3.95%)
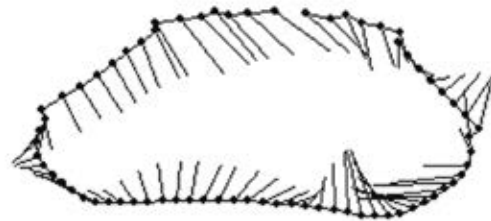
PC4 (1.88%)

PC5 (1.00%)

PC6 (0.73%)

Fig. 23. Maps of influential landmarks for principal components 1–6 generated through PCA of elliptic Fourier coordinates of the pronotum of all male samples. Influential landmarks represented regions of greatest morphological variability and contributed disproportionately to trends in shape changes within and among populations of male RBB.

Table 14. Classification results for female *Scotinophara coarctata* group from a discriminant function analysis of the elliptic Fourier shape coordinates of the pronotum.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.367	<0.000
Mindanao	122	4	1	12	0					87.8		
Panay (Iloilo)	15	22	0	4	0					53.7		
Palawan	9	1	5	1	0					31.3		
Luzon	25	3	0	33	0					54.1		
Malaysia	0	0	0	0	2					100		
Total	171	30	6	50	2					**71***		
(B) Luzon											0.204	<0.000
Balading (Albay)	1	0	0	3	1					20		
Gadgaran (Sorsogon)	0	18	0	2	1					85.7		
Jupi (Sorsogon)	0	0	3	2	1					50		
Otavi (Sorsogon)	0	2	1	9	2					64.3		
Poblacion (Camarines Sur)	0	3	0	1	10					71.4		
Total	1	23	4	17	15					**68.3***		
(C) Mindanao											0.057	<0.000
Agusan del Norte	44	0	3	0	0	1	1	0	1	88		
Bucac (Agusan Sur)	0	7	1	0	0	0	0	0	2	70		
Balangao, (Zamboanga Sibugay)	6	1	25	0	0	0	0	2	1	71.4		
Dipolog (Zamboanga del Sur)	1	0	2	3	0	0	0	0	0	50		
Magpayang (Surigao del Norte)	0	0	0	0	2	0	0	0	0	100		
Maranding (Lanao del Norte)	2	0	1	0	0	5	0	0	0	62.5		
Palongalogin (North Cotabato)	2	0	0	0	0	0	7	0	1	70		
New Iloilo (South Cotabato)	0	1	0	0	0	0	0	8	0	88.9		
Gansing (Sultan Kudarat)	0	1	0	0	0	1	0	2	5	55.6		
Total	55	10	32	3	2	7	8	12	10	**76.3***		
(D) Iloilo											0.14	<0.000
Ajuy	29	0								100		
Dapitan	0	12								100		
Total	29	12								**100***		
(E) Palawan											<0.000	<0.000
Maasin	8	0								100		
Bonobono	0	8								100		
Total	8	8								**100***		

*Percentage of original grouped cases correctly classified.

Table 15. Classification results for male *Scotinophara coarctata* group from a discriminant function analysis of the elliptic Fourier shape coordinates of the pronotum.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.104	<0.000
Mindanao	152	2	1	5	0					95		
Panay (Iloilo)	6	28	0	0	0					82.4		
Palawan	2	0	13	1	0					81.3		
Luzon	3	1	1	23	0					82.1		
Malaysia	0	1	0	0	3					75		
Total										**90.5***		
(B) Luzon											0.095	<0.000
Balading (Albay)	4	0	1	0						80		
Gadgaran (Sorsogon)	2	4	2	0						50		
Otavi (Sorsogon)	0	0	3	0						100		
Poblacion (Camarines Sur)	0	0	0	12						100		
Total										**82.1***		
(C) Mindanao											0.044	<0.000
Agusan del Norte	43	0	5	1	0	0	1	0	0	86		
Bucac (Agusan Sur)	0	5	1	0	0	1	0	0	0	71.4		
Balangao, (Zamboanga Sibugay)	5	1	27	0	0	0	2	0	0	77.1		
Dipolog (Zamboanga del Sur)	0	0	1	2	0	0	0	0	0	66.7		
Magpayang (Surigao del Norte)	1	0	1	0	3	0	1	0	0	50		
Maranding (Lanao del Norte)	0	0	1	0	0	30	0	0	0	96.8		
Palongalogin (North Cotabato)	0	1	2	0	0	0	9	0	0	75		
New Iloilo (South Cotabato)	1	0	1	0	0	0	0	8	0	80		
Gansing (Sultan Kudarat)	0	0	1	0	0	1	1	0	3	50		
Total										**81.3***		
(D) Iloilo											0.062	<0.000
Ajuy	18	0							100	100		
Dapitan	0	16							100	100		
Total										**100***		
(E) Palawan											<0.000	<0.000
Maasin	6	0								100		
Bonobono	0	10								100		
Total										**100***		

*Percentage of original grouped cases correctly classified.
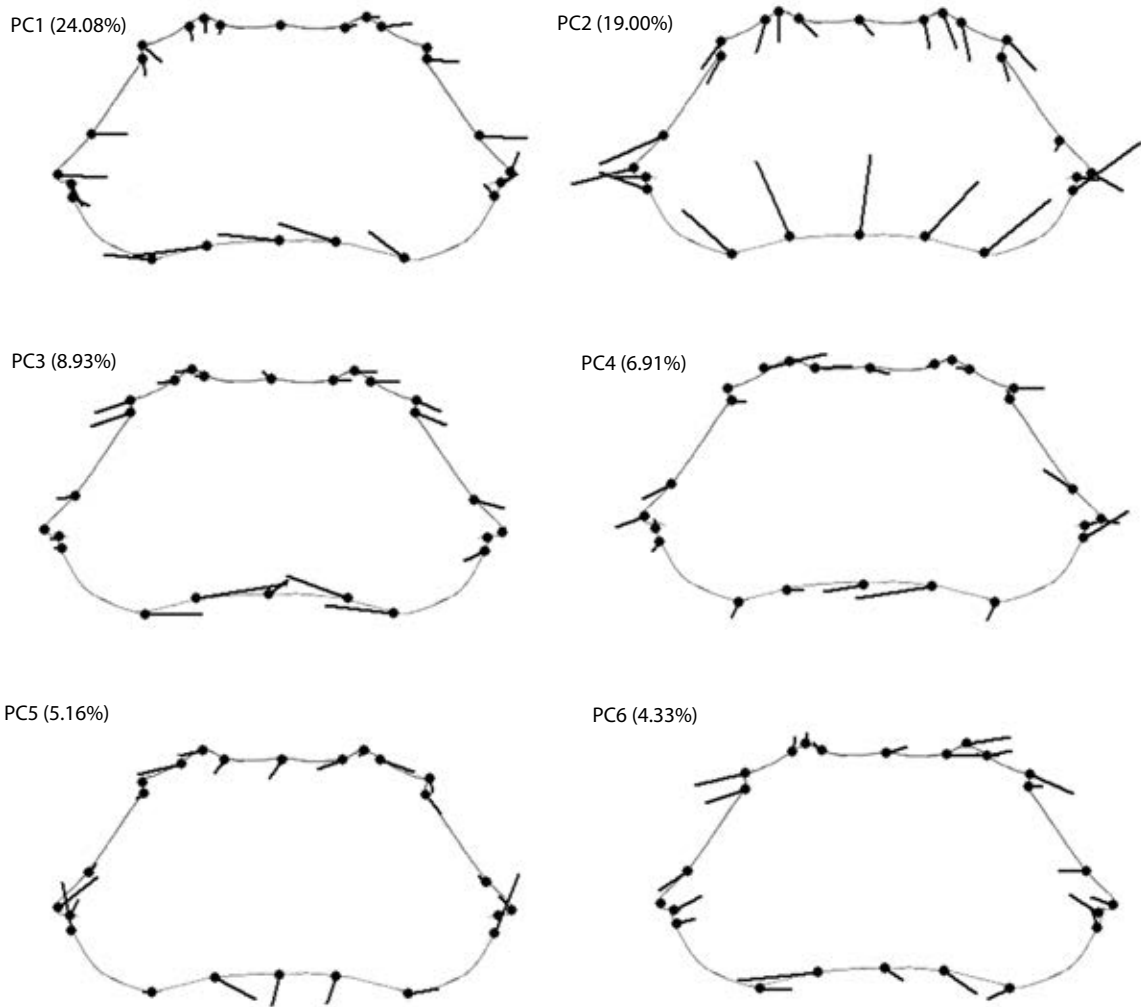
Fig. 24. Maps of influential landmarks for principal components 1–6 generated through PCA of Procrustes-fitted landmark coordinates of the pronotum of all female RBB. Influential landmarks represented regions of greatest morphological variability and contributed disproportionately to trends in shape changes within and among populations of female black bugs.
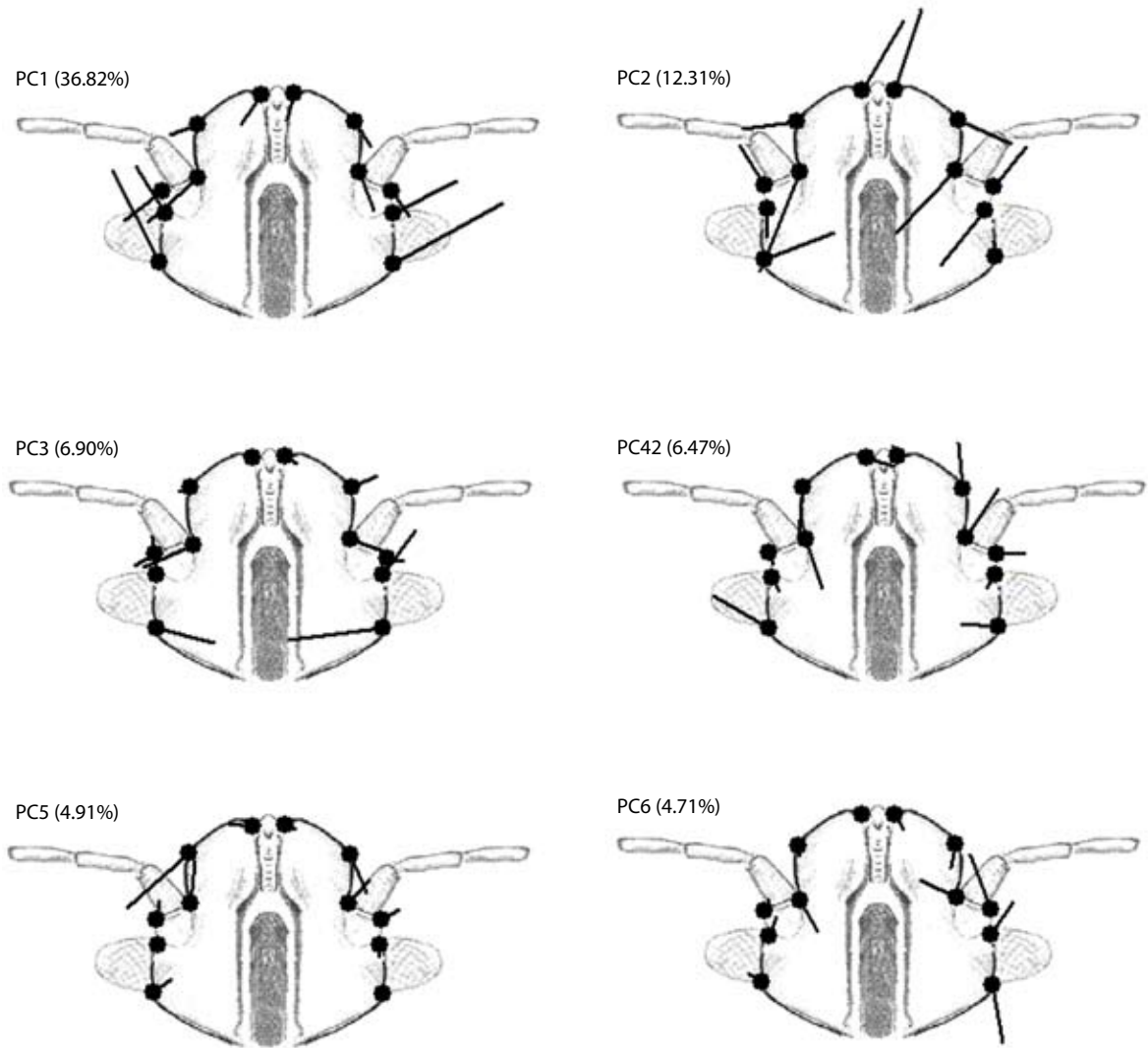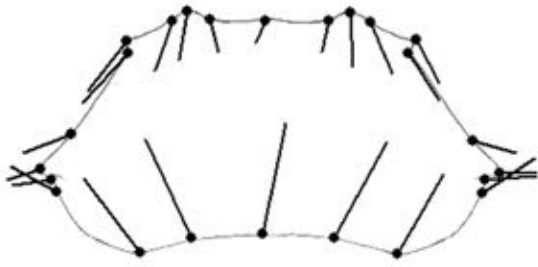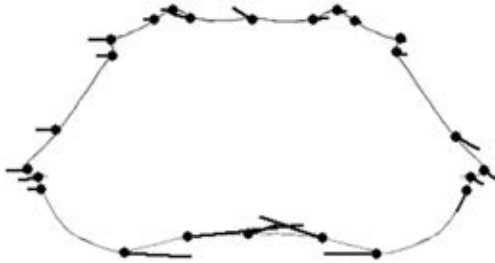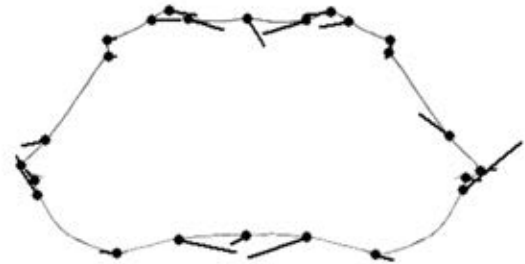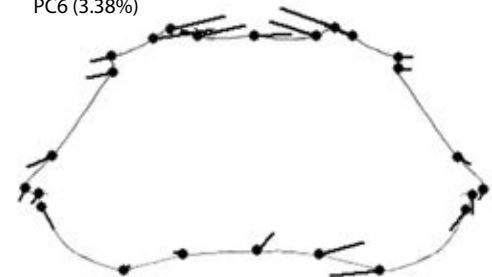
Fig. 25. Maps of influential landmarks for principal components 1–6 generated through PCA of Procrustes-fitted landmark coordinates of the pronotum of all male rice black bugs. Influential landmarks represented regions of greatest morphological variability and contributed dispropor-tionately to trends in shape changes within and among populations of male black bugs.

Table 16. Classification results for female *Scotinophara coarctata* group from a discriminant function analysis of the landmark shape coordinates of the pronotum.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.37	<0.000
Mindanao	90	17	12	24	0					62.9		
Panay (Iloilo)	5	30	2	4	0					73		
Palawan	2	0	12	2	0					75		
Luzon	12	10	7	31	0					52		
Malaysia	0	0	0	0	2					100		
Total	109	57	33	61	2					**63***		
(B) Luzon											0.264	<0.000
Balading (Albay)	1	2	0	2	0					20		
Gadgaran (Sorsogon)	0	19	0	2	1					86		
Jupi (Sorsogon)	0	1	1	5	0					14		
Otavi (Sorsogon)	0	0	2	11	1					79		
Poblacion (Camarines Sur)	0	2	0	0	10					83		
Total	1	24	3	20	12					**70***		
(C) Mindanao											0.007	<0.000
Agusan del Norte	49	0	0	0	1	0	0	0	0	98		
Bucac (Agusan Sur)	0	6	2	0	0	0	0	2	0	60		
Balangao, (Zamboanga Sibugay)	0	0	35	0	1	0	1	1	1	90		
Dipolog (Zamboanga del Sur)	1	0	0	5	0	0	0	0	0	83		
Magpayang (Surigao del Norte)	0	0	0	0	2	0	0	0	0	100		
Maranding (Lanao del Norte)	0	0	0	0	0	9	0	0	0	100		
Palongalogin (North Cotabato)	0	0	0	0	0	0	9	0	1	90		
New Iloilo (South Cotabato)	0	1	0	0	0	0	0	6	0	86		
Gansing (Sultan Kudarat)	0	0	0	0	0	0	0	1	9	90		
Total	50	7	37	5	4	9	10	10	11	**90.9***		
(D) Iloilo											0.222	<0.000
Ajuy	28	1								96.6		
Dapitan	0	12								100		
Total	28	13								**97.6***		
(E) Palawan											0.105	<0.000
Maasin	8	0								100		
Bonobono	0	8								100		
Total	8	8								**100***		

*Percentage of original grouped cases correctly classified.

Table 17. Classification results for male *Scotinophara coarctata* group from a discriminant function analysis of the landmark shape coordinates of the pronotum.

	1	2	3	4	5	6	7	8	9	% Correct	Wilk's λ	Sig.
(A) Major islands											0.321	<0.000
Mindanao	152	2	1	5	0					95		
Panay (Iloilo)	6	28	0	0	0					82		
Palawan	2	0	13	1	0					81		
Luzon	3	1	1	23	0					82		
Malaysia	0	1	0	0	3					75		
Total	163	32	15	29	3					**90.5***		
(B) Luzon											0.009	<0.000
Balading (Albay)	4	0	1	0						80		
Gadgaran (Sorsogon)	2	4	2	0						50		
Otavi (Sorsogon)	0	0	3	0						100		
Poblacion (Camarines Sur)	0	0	0	12						100		
Total	6	4	6	12						**82.1***		
(C) Mindanao											0.005	<0.000
Agusan del Norte	43	0	5	1	0	0	1	0	0	86		
Bucac (Agusan Sur)	0	5	1	0	0	1	0	0	0	71		
Balangao, (Zamboanga Sibugay)	5	1	27	0	0	0	2	0	0	77		
Dipolog (Zamboanga del Sur)	0	0	1	2	0	0	0	0	0	67		
Magpayang (Surigao del Norte)	1	0	1	0	3	0	1	0	0	50		
Maranding (Lanao del Norte)	0	0	1	0	0	30	0	0	0	97		
Palongalogin (North Cotabato)	0	1	2	0	0	0	9	0	0	75		
New Iloilo (South Cotabato)	1	0	1	0	0	0	0	8	0	80		
Gansing (Sultan Kudarat)	0	0	1	0	0	1	1	0	3	50		
Total	50	7	40	3	3	32	14	8	3	**81.3***		
(D) Iloilo											0.17	<0.000
Ajuy	18	0								100		
Dapitan	0	16								100		
Total	18	16								**100***		
(E) Palawan											0.001	<0.000
Maasin	6	0								100		
Bonobono	0	10								100		
Total	6	10								**100***		

*Percentage of original grouped cases correctly classified.
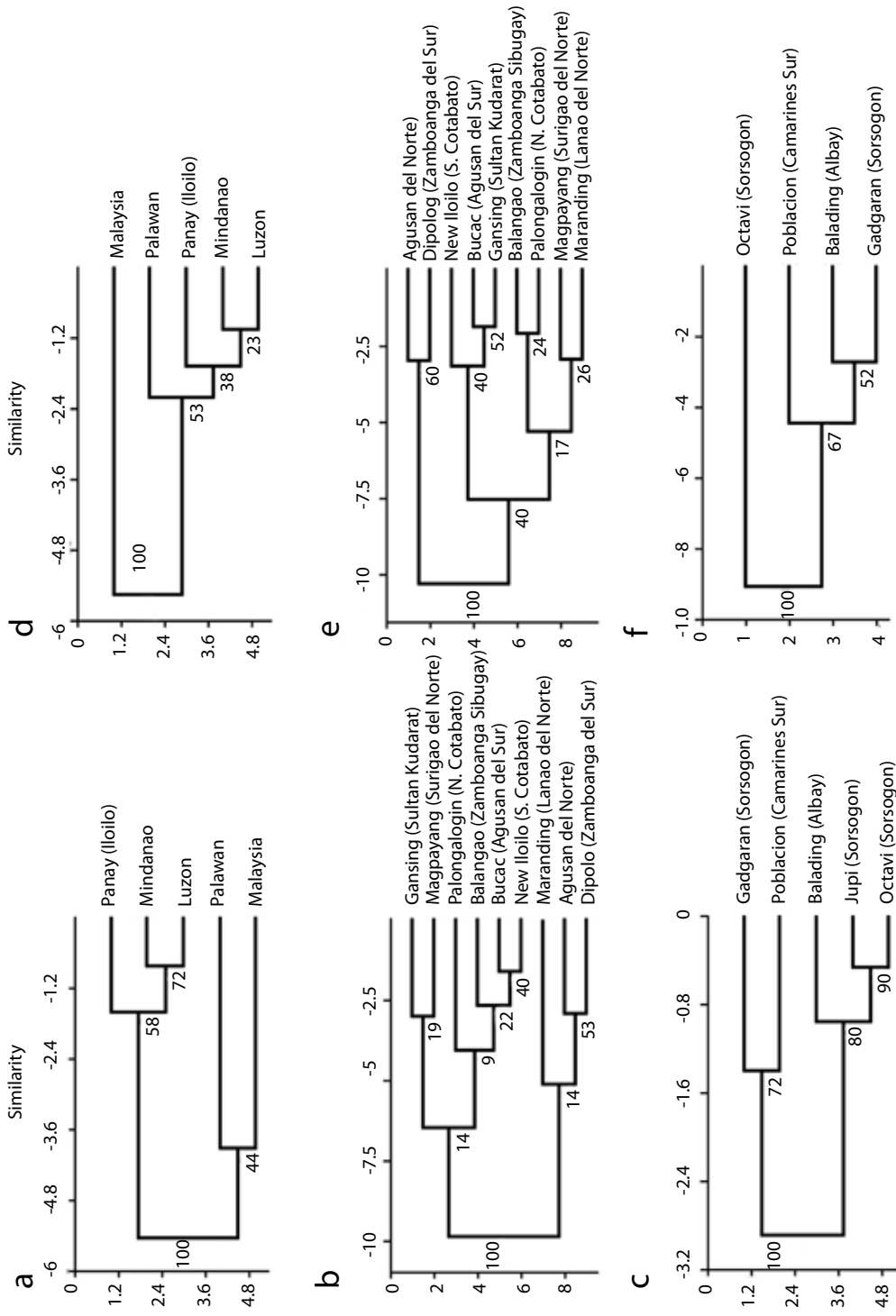
Fig. 26. Results of cluster analyses performed on the group centroids derived from discriminant function analysis of the principal component scores after landmark analysis of the pronotum of all (a-c) female and (d-f) male RBB.
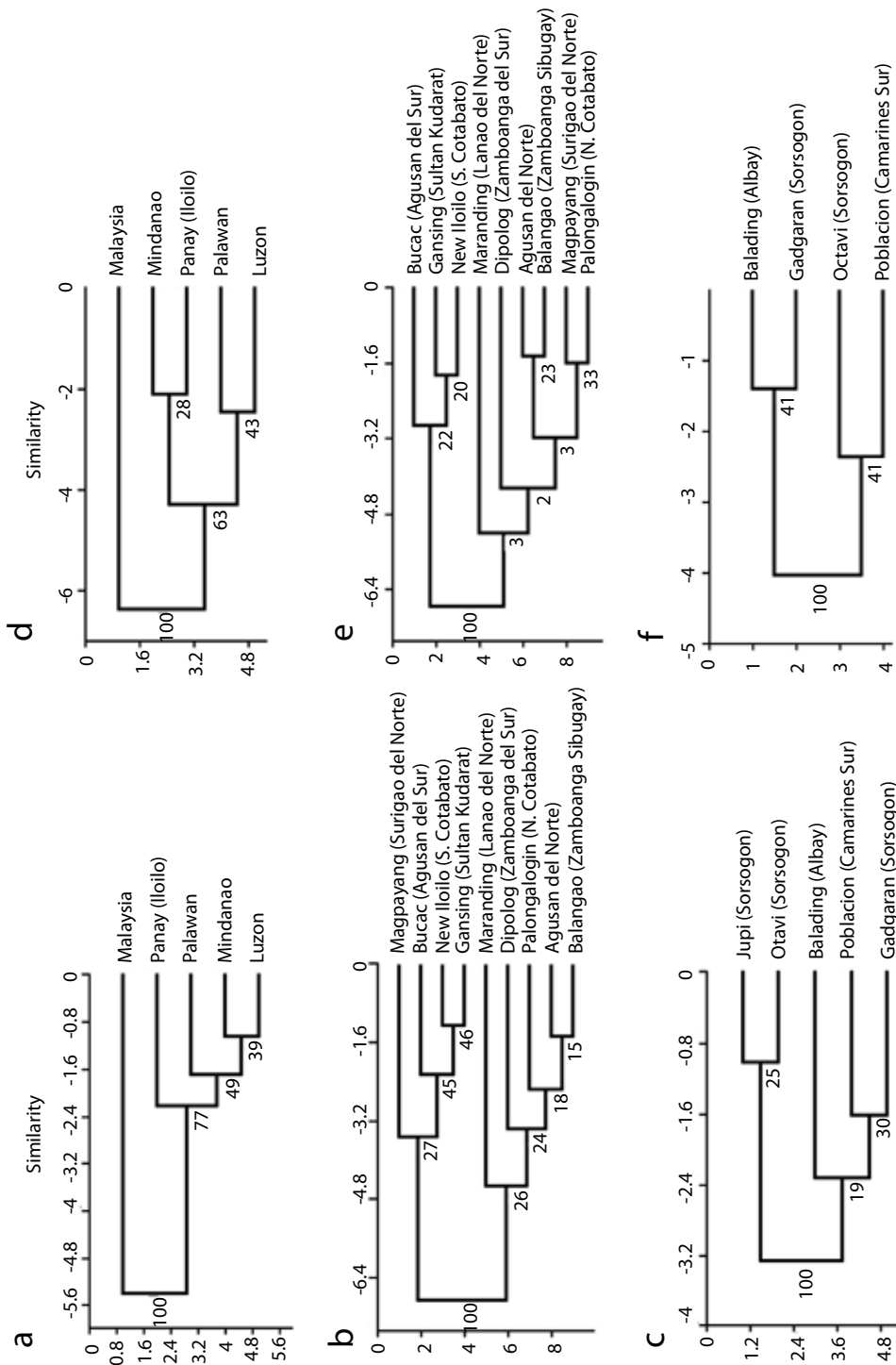
Fig. 27. Results of cluster analyses performed on the group centroids derived from discriminant function analysis of the principal component scores after elliptic Fourier analysis of the pronotum of all (a-c) female and (d-f) male RBB.
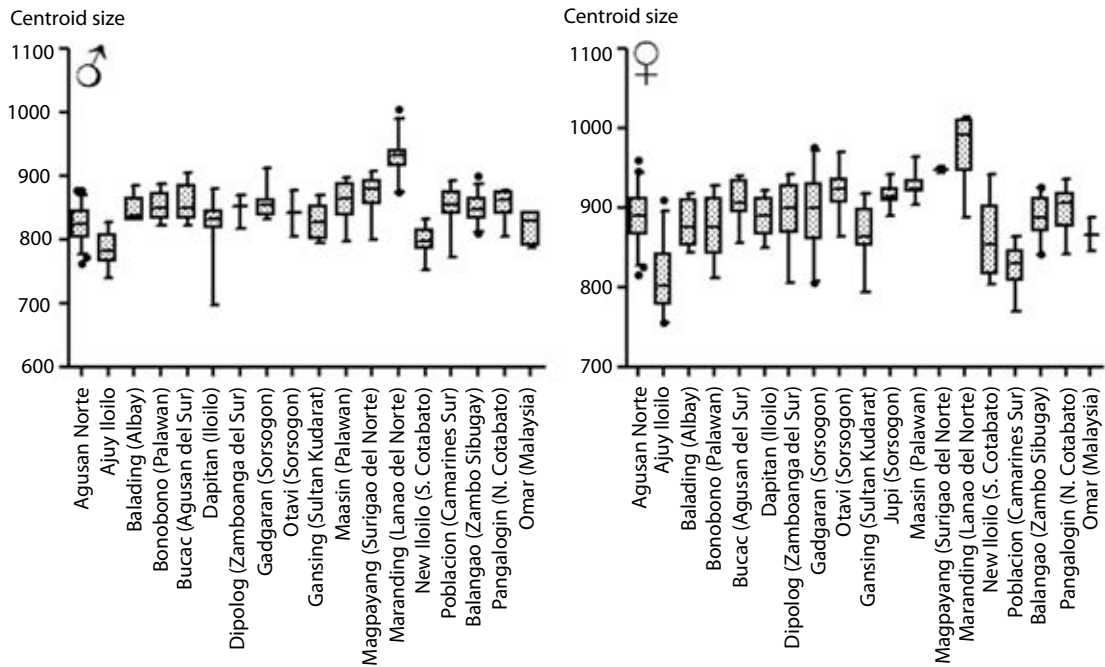
Fig. 28. Plot of centroid sizes of the pronotum in *Scotinophara coarctata* group showing interpopulation differences.

multiple discriminant function analysis of the shape data? In an accompanying paper (Barrion et al., this volume), the results of the aedeagus morphology show the distinctness of selected populations and these are elevated to species status. While the character being considered is genetically determined, factors that would themselves be sufficient to determine the integrity of these new identified species of RBB should be further investigated. In this size and shape variation study on RBB, the reasons for variations and the degree of representation are still unknown. Genetically based geographic differences in morphometric characters, including the relative contribution of environmental and genetic components to geographic variations in such morphometric characters, are also not yet known.

It is recommended that more genetic and behavioral evidences be accumulated to support the species-level status of the morphometric groups, and more can be done to investigate the evolutionary barriers among these putative species. Careful scrutiny of morphological and genetic divergence in these groups should be done and continuous genetic sampling and analysis should be pursued. This is because the patterns of covariation between morphology and molecules are not often uniform. In some groups, it seems that high levels of genetic divergence do not necessarily predict clear-cut morphological divergence, just as clear-cut levels of morphological divergence do not necessarily

Table 18. Test for significant differences in centroid sizes of rice black bugs.

Sex	Post hoc test		Difference	Summary
Males (KW: 141.9; P<0.0001)	Ajuy (Iloilo)	Bonobono (Palawan)	-126.6	***
		Bucac (Agusan del Sur)	-136.2	**
		Gadgaran (Sorsogon)	-132.8	**
		Maasin (Palawan)	-133.5	**
		Magpayang (Surigao del Norte)	-152.5	***
		Balangao (Zamboanga Sibugay)	-103.7	***
		Palongalogin (North Cotabato)	-117.7	**
		Maranding (Lanao del Norte)	-199.2	***
	Maranding (Lanao del Norte)	New Iloilo (S. Cotabato)	166.7	***
		Poblacion (Camarines Sur)	128	***
		Balangao (Zamboanga Sibugay)	95.53	***
		Omar (Malaysia)	151.5	**
		Agusan del Norte	-140.7	***
		Dapitan (Iloilo)	-121.7	***
		Gansing (Sultan Kudarat)	-120.3	*
Pronotum/females (KW: 119.4; P<0.0001)	Ajuy (Iloilo)	Agusan del Norte	83.94	***
		Bucac (Agusan del Sur)	-142.8	***
		Dapitan (Iloilo)	-118.5	***
		Gadgaran (Sorsogon)	-117	***
		Otavi (Sorsogon)	-175.4	***
		Jupi (Sorsogon)	-165.4	***
		Maasin (Palawan)	-167.8	***
		Magpayang (Surigao del Norte)	-212.4	*
		Maranding (Lanao del Norte)	-207.3	***
		Balangao (Zamboanga Sibugay)	-110.6	***
		Palongalogin (North Cotabato)	-146.4	***
	Maranding (Lanao del Norte)	Agusan del Norte	-123.3	**
		Gansing (Sultan Kudarat)	-146	*
		New Iloilo (South Cotabato)	133.1	*
		Poblacion (Camarines Sur)	154.6	***
	Otavi (Sorsogon)	Agusan del Norte	-91.44	**
		Poblacion (Camarines Sur)	122.7	**

indicate high levels of genetic distance. It will also be very important to sample more individuals from the putative species across their geographic ranges to more fully address their hypothesized species status and to have a better understanding of patterns of intra- and interspecific variation. Although the advent of geometric morphometrics continues to advance our knowledge of the extent of diversity in this group of pentatomids, molecular methods should also be used to uncover cryptic genetic lineages.

There is also a need to assess how control programs such as insecticide applications, biocontrol agents, and other practices would affect the genetic structure of the RBB populations. Comparison of manipulated populations with natural ones would help in determining how number reduction,

or suppression, influences variability. Ideally, populations should be surveyed before, during, and after control practices have been applied. Understanding the genetic rules in the modification of populations of the black bugs under changing environmental conditions that elicit changes in size or changes in the direction or intensity of selection can help in the proper management of RBB. It is also recommended that genetic control techniques (such as male sterile techniques) be explored. Many pest managers too long solely occupied with insect numbers must consider the roles of population quality and changes in quality in population dynamics. Strategies in controlling this insect pest must be reevaluated from this context.

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Notes

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Ecology and Management

Farmers' Knowledge, Perceptions, and Management Practices on Rice Black Bug

G.O. Redondo, C.B. Casiwan, and R.G. Manalili

Abstract

The rice black bug (RBB), *Scotinophara coarctata,* is one of the serious insect pests that attack all stages of the rice plant, causing severe crop yield loss of up to 80% or complete yield loss during heavy infestations. This study sought to determine and document current farmers' knowledge, perception, and management practices to control RBB. The results of the study will be useful to farmers in deciding appropriate measures to manage the pest and to local government units and agencies that work collaboratively to control and prevent the spread of RBB. Thirty farmers in Palawan and 45 farmers from Zamboanga del Sur were interviewed using a pretested survey questionnaire in 2002-03. The total area planted was 1.72 ha for the dry season and 1.85 ha during the wet season. Farmers knew and perceived RBB as a serious oval-shaped pest, brownish-black in color, has offensive odor (stinky), and which multiplies rapidly. The presence of RBB was observed in 1970; the outbreak occurred in 1980 and this lasted up to 2002. Farmers observed RBB in all stages of the plant, from seedbed to harvesting, particularly from maximum tillering to flowering. Damage done by the nymphs and adults were rotting at the base of the plant, discoloration of the leaves, death of upper leaves, desiccation of the plant, and death of the plant. The RBB insert themselves in the stems, sucking and draining the sap until the plants weaken, wither, and die. A higher population of RBB was observed during the dry season than in the wet season due to lack of water in the field. Direct seeding was only popular in Palawan. Majority used the 111-125-d modern varieties. Farmers control RBB by practicing water management/flooding and spraying pesticides. They do not have enough knowledge on other practices such as synchronous planting, herding of ducks, light trapping, plowing-under heavily infested areas, plowing the field immediately after harvest, and use of beneficial organisms such as *Metarhizium anisopliae* and *Telenomus triptus*.

Key words: rice black bug, perception, synchronous planting, *Metarhizium anisopliae*

Introduction

The rice black bug (RBB), *Scotinophara coarctata,* is one of the serious insect pests that attack during all growth stages of the rice plant, causing severe crop yield loss of up to 80% or complete yield loss during heavy infestations. The first incidence of RBB reported was in Palawan; the pest spread to Zamboanga, ARMM, Cotabato, Sultan Kudarat, South Cotabato, Saranggani, Davao del Sur, Negros Occidental, Siquijor, Leyte, Bohol, Caraga Region, and to Sorsogon, Albay, Camarines Sur, and Catanduanes (DA-PhilRice 2000, UMAsenso 2006). Despite heavy application of pesticides, farmers experienced difficulties in controlling the spread and infestation of this insect pest.

This study sought to determine and document current farmers' knowledge, perception, and management practices against RBB. It also sought to identify adoption constraints to the use of *Metarhizium anisopliae* technology against RBB. The results of the study will be useful to farmers in deciding appropriate measures to control RBB and to local government units and agencies that collaborate to control and prevent the spread of RBB.

Methodology

A survey was conducted in 2002-03 in Palawan and Zamboanga del Sur, the first two provinces where the RBB outbreak occurred. Thirty farmers from three municipalities in Palawan and 45 farmers from three municipalities in Zamboanga del Sur were interviewed regarding their knowledge, perceptions, and farmers' management practices to control RBB using a pretested structured survey questionnaire. Farmers who experienced RBB attack in their farms were purposively sampled from municipalities where the RBB outbreak occurred; they were identified by the Office of the Provincial Agriculturist and agricultural technicians (Table 1, Figs. 1 and 2). Descriptive analytical tools such as means and frequencies were used.

Table 1. Number of samples from each study site.

Province	Municipality	Barangay	Sample farmers	
			No.	%
Palawan	Bataraza	Bono bono	2	2.67
		Bulalacao	6	8.00
		Malihud	2	2.67
	Brooke's Point	Mambalot	5	6.67
		Pangubilyan	3	4.00
		Tubtob	2	2.67
	Narra	Malinao	2	2.67
		Tagisan	1	1.33
		Tartin	2	2.67
		Urduja	5	6.67
Zamboanga del Sur	Labangan	Lantian	15	20.00
	Molave	Rizal	15	20.00
	Tukuran	Baclay	15	20.00
Total			75	100.00

Fig. 1. Map of Palawan province showing where RBB outbreaks were observed.

Fig. 2. Map of Zamboanga del Sur showing where RBB outbreaks were observed.

Table 2. Selected characteristics of rice farmer respondents.

Parameter	Palawan		Zamboanga		Total	
	Mean	% of farmers reporting	Mean	% of farmers reporting	Mean	% of farmers reporting
Age of farmer (yr)	44		49		47	
Number of years in the barangay	28		34		32	
Number of years in farming	22		22		22	
Household size (no.)	5		6		6	
5-6		40		36		37
3-4		30		29		29
Number of years in school	9		8		8	
High school graduate		20		31		27
Elementary graduate		20		20		20
College graduate		20		7		12
Major source of income						
Farming		100		100		100
Land owned (ha)	2.54		0.53		1.33	
Land rented (ha)	0.73		0.55		0.62	
Land cultivated (ha)	3.22		0.93		1.85	
Number of parcels	2		1		1	
Rice area (ha)						
Wet season	3.22		0.93		1.85	
Dry season	3.08		0.81		1.72	

Results and discussion

Socioeconomic characteristics of farmer respondents

Results showed that, on the average, the farmer respondents were of middle age (47 years old), had resided in the barangay for 32 years, had 22 years of farming experience, were heads of six-member households, and had reached second year high school. Farming was their major source of income, owning 1.33 ha of land and renting 0.62 ha of land. They cultivated an average of 1.85 ha with only one parcel. During the 2002 dry season, the total area planted to rice was 1.72 ha; it was 1.85 ha during the wet season (Table 2).

Parcel characteristics

As to land parcel characteristics, farmers cultivated at most four parcels in Palawan and two parcels in Zamboanga del Sur. The average parcel size was 1.86 ha. Most of the farmer respondents owned the land they till, had irrigated farms, and followed rice-rice and rice-fallow cropping patterns. For the irrigated area, the source of irrigation was the National Irrigation Administration (NIA); others obtained water from river, springs, falls, or swamps. They described their drainage condition as well-drained and good, although some of them said that their field was hard to drain and it has no drainage canal (Table 3).

Table 3. Characteristics of land parcels cultivated by respondents.

Parameter	Palawan	Zamboanga	Total
	% of farmers reporting		
Area (mean, ha)	3.26	0.93	1.86
Tenure status			
Owner	74.50	42.60	59.20
Leaseholder	5.90	27.70	16.30
Tenant	9.80	29.80	19.40
Mortgagor	9.80		5.10
Farm type			
Irrigated	96.10	74.50	85.70
Rainfed	2.00	25.50	13.30
Upland	2.00		1.00
Cropping pattern			
Rice-fallow	3.90	19.10	11.20
Rice-rice-rice	3.90		2.00
Rice-rice	88.20	80.90	84.70
Vegetable	3.90		2.00
Source of irrigation			
NIA	28.00	74.50	50.50
Pump/shallow tubewell	4.00		2.10
SFR/deep well/dam	8.00		4.10
Rivers/springs/falls/swamps	60.00		30.90
Rainfed		25.50	12.40
Drainage condition			
Good	40.00		25.00
No drainage canal			
Hard to drain	4.40	19.10	15.30
Not well-drained	4.40		2.80
Well-drained	51.10	80.90	84.70

Farmers' knowledge and perception of rice black bug

On knowledge and perceptions, the results of the survey showed that most farmers were aware of the characteristics and behavior of RBB in their fields. Farmers described RBBs as brownish-black in color (79%), as having offensive/stinky odor (68%), as multiplying rapidly (56%), as a serious pest (44%), and as having an oval shape like that of a turtle or cockroach (15%). Other aspects of RBB behavior mentioned were eggs being attached to the leaves, bugs staying on the leaves when there is enough water during full moon, bugs flying when it is time to lay eggs, bugs staying at the base of the plant when there is no water, in groups or in mass, occurrences during full moon, staying in areas with light, and attacking when there is no water (Table 4). These descriptions of adult RBB by farmers coincide with those contained in materials published by PhilRice (DA-PhilRice 2000).

In Palawan, while some farmers have observed the presence of RBB in 1970 and 1978, many of the respondents said the first RBB outbreak in their area occurred in 1980 and the incidence was observed until 2002. When asked about when the latest RBB outbreak happened, majority of the farmers in Palawan mentioned between 2000 and 2001. Ramos (1983) reported isolated cases of rice infestations as early as 1979 by unknown species of insects feeding on grasses and young banana

Table 4. An adult rice black bug as described by respondents.

Item	No. (N=75)	%
Brownish-black in color	59	78.67
Offensive odor/stinky	51	68.00
Multiply rapidly	42	56.00
Pest	33	44.00
Oval-shaped (like turtle or cockroach)	11	14.67
Small	7	9.33
Stay at the base of the plant when there is no water	6	8.00
Occur during full moon	5	6.67
Hot	5	6.67
Nymphs are more dangerous	5	6.67
Hard-covered wings and body	4	5.33
Wide-back	4	5.33
Eggs are attached to the leaves	2	2.67
Bigger than ordinary beetle	2	2.67
Acidic	1	1.33
Stay on the leaves when there is enough water	1	1.33
Can see them flying when it's time to lay eggs	1	1.33
In groups or in mass	1	1.33
With feet	1	1.33
Difficult to kill	1	1.33
Stay on the lighted area	1	1.33
Attack when there is no water	1	1.33
Adult black bug have white spots during full moon	1	1.33

leaves. Later on, it was found on a rice field in Bonobono, Bataraza. These pests multiplied rapidly and were scattered in the southern part of Palawan.

In the case of Zamboanga, the respondents were unanimous in saying that the presence of RBB was first observed in 1997 and that the outbreak occurred around 1998-99. There seemed to be no outbreak in 2000−01 (Table 5).

Majority of the farmers reported that RBB came from nearby towns (26%), from neighboring rice fields (24%), from neighboring barangays (23%), and from sea vessels from other countries (Japan, Malaysia, Taiwan, and Indonesia) (14%). Some 7% said that they just arrived and they did not know where they came from (Table 6).

In Palawan, farmers thought that RBB originated from Japan and Malaysia and were transported through trading vessels. Others said they just came from nearby towns and just arrived owing to changes in the environment. In Zamboanga, most of the farmers said that they came from either neighboring fields or barangays and some farmers perceived them as being transported through vessels from other countries such as Taiwan and Indonesia.

Farmers observed the presence of RBB, especially the adult ones, in all stages of the rice plant, in particular from early tillering to flowering. The RBB nymphs caused the most damage from the seedbed to booting stage, particularly during maximum tillering extending through booting stage.

Table 5. Observations on the presence and outbreak of RBB in rice fields.

Year	Year presence of RBB was first observed		Year RBB outbreak was first experienced		Latest RBB outbreak	
	Palawan	Zamboanga	Palawan	Zamboanga	Palawan	Zamboanga
	% of farmers reporting					
1970	10		10			
1978	6.7				3.3	
1979			3.3			
1980	26.7		23.3			
1981	3.3		3.3			
1982	3.3		3.3		3.3	
1983			3.3			
1984	3.3		3.3			
1985	6.7					
1986	6.7		3.3			
1987	6.7		3.3			
1988	3.3					
1989	3.3		3.3			
1990	10		13.3		3.3	
1991						
1992					3.3	
1993						
1994						
1995	3.3		6.7		3.3	
1996			3.3		3.3	
1997	6.7	100				
1998			6.7	31.1	6.7	31.1
1999				68.9	10	66.7
2000					30	
2001					30	
2002						2.2
No response			10		3.3	

Table 6. Origin of RBB according to respondents.

Item	Palawan	Zamboanga	Total
Neighboring rice fields	11.4	27.2	24.0
Rice fields from neighboring barangays	2.9	28.7	23.4
Rice fields from nearby town (Bataraza)	25.7	26.5	26.3
Grass		0.7	0.6
From other countries (Japan, Malaysia, Taiwan, Indonesia)	31.4	8.8	13.5
From other provinces (Mindanao, Palawan)	5.7	2.2	2.9
From cracked land	2.9		0.6
Just arrived, don't know where they came from/from the environment	20.0	3.7	7.0
From the forest		1.5	1.2
Came from palay seed sacks		0.7	0.6

Table 7. Growth stages of the rice plant where RBB was observed.

Stage	Presence of RBB	Most RBB adults	RBB nymphs caused most damage	RBB adults caused most damage	RBB a serious problem
	% of farmers reporting				
Seedbed	3				1
Early tillering	15	5	11	4	8
Maximum tillering	25	24	52	16	24
Panicle initiation	14	8	8	7	13
Booting stage	19	41	15	41	23
Flowering	9	13	5	19	18
Milking stage	6	5	5	10	9
Hard dough	5	3	1	1	2
Harvest period	4	1	3		1
All stages	1			4	

The RBB adults were most damaging from early tillering to milking stage, especially during booting and flowering. Most of the farmers considered RBB a serious problem during maximum tillering up to flowering (Table 7).

As perceived by farmers, damages usually caused by RBB nymphs were rotting at the base of the plant, death of the plant, discoloration of leaves, death of upper leaves, and desiccation of the plant. Damage done by RBB adults included rotting at the base of the plant, death of plants, empty grains/whitehead, and death of upper leaves. Adults or nymphs insert themselves at the base of the stems, and then suck the stems and leaves, thus resulting in yellowing, drying of young leaves, and stunted growth. When the sap of the plants is drained, the plants weaken, the stalks wither and die. These conditions exist especially when water is inadequate. Farmers reported further that adult nymphs also suck the panicles, resulting in failure of booting and unfilled grains. Majority of them also mentioned that RBBs discharge a liquid that is warm and acidic, thus causing burn-like damage to the rice leaves or stem. Deadhearts occur when RBBs attack during the vegetative stage, damaging the shoot or the younger leaf of the plant. Whiteheads result from damage done during the reproductive stage; and bugburn is observed when RBBs attack during milking stage, eating the panicles and damaging the rice grains. The most destructive RBB is like the size of a black bean as it sips the juice from the midrib of the leaves and panicles at the milking stage; at night they feed mostly on the basal part of the tillers (Bordado 2005) (Table 8).

More than two-thirds of the farmers (68%) observed higher RBB populations in the dry season than in the wet season due to a limited supply or lack of water in the field, which favors the rapid multiplication of RBB.

Only one-third (29%) of the farmers interviewed reported that RBBs feed on other plants or alternate hosts such as weeds and grasses; they eat these plants, causing rotting of the base of the plant and wilting until the plants die. Host plants serve as the source of food when rice panicles are

Table 8. Damage observed in the field caused by nymph and adult rice black bugs.

Item	Nymphs		Adults	
	No. (N=75)	%	No. (N=75)	%
Rotting at the base of the plant	41	57	34	45
Death of the plant (bugburn)	38	53	38	51
Discoloration of the leaves	19	26	3	4
Death of upper leaves	13	18	21	28
Desiccation of the plant	10	14		
Empty grains/whitehead	3	4	25	33
Discoloration (blackening/yellowing) of grains	2	3	10	13
Suck plant sap through nodes	1	1	5	7
Suck tillers causing drying of the plant	1	1		
Burning of the leaf	1	1		
Plants unable to bear flowers	1	1		

Table 9. Farmers' sources of information on rice black bug and its management.

Item	No. (N=75)	%
LGU technician	34	46
Co-farmers	32	43
DA	11	15
Insecticide label	11	15
Chemical companies	8	11
Experience	3	4
Farmers' field school	2	3
Insecticide brochures	2	3
Training	1	2

not yet available. These host plants serve as their breeding places and should be eliminated to break the life cycle of RBB.

Farmers get their information about RBB and its management from the local government unit (LGU) (46%), co-farmers (43%), Department of Agriculture (DA) staff (15%), insecticide label (15%), and chemical companies (11%). Other sources mentioned were farmers' field school, insecticide brochures, experience, and training (Table 9).

Regarding attendance in training on RBB control, more than half (53%) of the respondents enrolled in farmers' field school and attended training courses on RBB management, pest management, rice production, in addition to seminars conducted by chemical companies. Most of the training was undertaken in 1999–2000 in their respective barangay hall; these activities were sponsored by the DA-LGU and chemical companies (Table 10).

Table 10. Trainings attended by farmer respondents regarding rice black bug Management.

Item	No. (N=40)	%
Farmers' field school	8	20
Chemicals to control RBB	1	3
Pest management seminar/IPM	5	12
Postharvest training	1	2.5
Rice production training	3	7.5
Chemical company seminar	2	5
Rice black bug management	23	58

Table 11. Method of crop establishment practiced by farmer respondents.

Method	Palawan		Zamboanga		TOTAL	
	WS	DS	WS	DS	WS	DS
	% of farmers reporting					
Direct seeding	77	77			30	31
Transplanting	23	20	100	82	69	57
Did not plant during DS		3		18		12

Farmers' management and cultural practices to control rice black bug

Method of crop establishment

Three-fourths of the farmers interviewed in Palawan practiced direct seeding during wet and dry seasons, whereas those in Zamboanga practiced transplanting (100% of farmers in the wet season and 82% in the dry season) (Table 11). Direct seeding is an option to manage RBB because plants have few tillers and sunlight can pass through the lower part of the plant. Transplanting is not a good control measure for RBB because the result is more tillers that favor RBB reproduction.

Variety planted

Majority of the respondents planted varieties that have 111–125 d of maturity, medium-maturing ones such as PSBRc 18 and IR74. Also, a late-maturing variety was used by many farmers in Zamboanga, while PSBRc 14, an early-maturing variety, was grown by many farmers in both provinces. If farmers will plant varieties synchronously, they will prevent the spread of RBB in the area (DA-PhilRicce 2000; UMAsenso, 2005; IRRI 2007) (Table 12). The variety to be planted should be tolerant of RBB such as IR1314 and IR44526 cultivated in Mindanao. Early-maturing varieties are recommended for their shorter crop stand in the field, which means less food available to RBB.

Table 12. Varieties planted by farmers based on maturity.

Variety	Palawan		Zamboanga		Total	
	WS	DS	WS	DS	WS	DS
			% of farmers reporting			
<110 d maturity	20.97	12.9	11.1	29.73	24	23.46
IR36	1.61	2.27			0.93	1.23
IR60	1.61		2.22	2.70	1.87	1.23
IR66		2.27		2.70		2.47
PSBRc 4	1.61	2.27			0.93	1.23
PSBRc 14	6.45	9.09			3.74	4.94
PSBRc 82	4.84			10.81	2.80	4.94
7-tonner	1.61	2.27			0.93	1.23
Arimunding	1.61				0.93	
Sampaguita	1.61				0.93	
Taiwan			6.67	8.11	2.80	3.70
V10			2.22	5.41	0.93	2.47
111-125 d maturity	72.60	72.73	57.80	48.65	96.00	61.73
PSBRc 2	1.61				0.93	
PSBRc 20		2.27				1.23
PSBRc 18	24.19	27.27	28.89	24.32	26.17	25.93
PSBRc 28	6.45	13.64			3.74	7.41
PSBRc 54	3.23	2.27	4.44	2.70	3.74	2.47
PSBRc 64	3.23	4.55			2.80	2.47
PSBRc 66			4.44		1.87	
PSBRc 68	1.61	2.27			0.93	1.23
PSBRc 72h		2.27				1.23
PSBRc 74	3.23	9.09	4.44	2.70	3.74	6.17
PSBRc 78	3.23				1.87	
PSBRc 80	3.23				1.87	
PSBRc 84			2.22	5.41	0.93	2.47
PSBRc 98	1.61				0.93	
PSBRc1 02	1.61				0.93	
Biniding	1.61				0.93	
Burdagol	3.23		6.67		4.67	
California	1.61	2.27			0.93	1.23
Kinadoy	6.45	4.55			3.74	2.47
Magnolia	1.61				0.93	
Malagkit	3.23	2.27			1.87	1.23
Masipag			6.67	13.51	2.80	6.17
<126 d maturity	6.45	9.09	31.10	21.62	22.67	14.81
IR74	1.61	2.27	15.56	2.70	7.48	2.47
PSBRc 44	1.61	4.55			0.93	2.47
PSBRc 92	1.61				0.93	
PSBRc 94			2.22	2.70	0.93	1.23
BPI 3-2	1.61	2.27			0.93	1.23
Texas			13.33	16.22	5.61	7.41

Table 13. Types of rice varieties planted.

Type	Wet season		Dry season	
	N	%	N	%
Modern	85	79	62	77
Traditional	22	21	19	23

Majority of the farmers interviewed used modern varieties such as the BPI, IR, and PSB varieties (79% and 77% for wet and dry season, respectively). Only one-fifth used traditional varieties such as Kinadoy, Biniding, California, Magnolia, Arimunding, Sampaguita, Masipag, Taiwan, Texas, and V 10. Their main source of seeds were co-farmers; others got their seeds from DA, own produce, seed growers, and NFA (Table 13).

Farmers' management practices and control measures
The most common measures that the farmer respondents implemented were water management, spraying of pesticides, plowing the field immediately after harvest, synchronous planting, plowing under heavily infested areas during outbreaks, use of other organisms that feed on RBB, herding of ducks, use of light traps, use of plants effective against RBB, and use of beneficial organisms.

Water management
Water management or flooding, spraying pesticides, and water management and spraying after flooding were the most common measures done during planting and harvesting times, during a standing crop, and during outbreaks. These were widely known control measures practiced by farmers to prevent RBB. They irrigated the fields to force the RBB to float or move to the upper part of the rice plant, after which they spray chemicals. Other practices included alternate irrigating and draining of the field, spraying 3 d before the full moon, crushing RBB eggs, and collecting the RBB and then burning or spraying chemicals on them (Table 14, 15). Intermittent flooding and draining of the field effectively destroyed the eggs of the bugs, which were usually found at the base of the plant nearest the water surface. Parducho et al. (1988) found that all of the RBB eggs did not hatch when submerged in water for 24 h.

Spraying of pesticides
All the farmers interviewed sprayed pesticides to control RBB (Table 16). Majority of the farmers (68%) sprayed cypermethrin in their field, followed by lambdacyhalothrin and deltamethrin. The reasons given for choosing these pesticides were their effectiveness in controlling RBB and the low price. The other reasons were that these were the only chemical known, they were newly released insecticide, they knew from experience, they were systemic pesticides, highly concentrated, available,

Table 14. Farmers' management, knowledge, and practices against rice black bug.

Practice	Palawan Yes	Palawan No	Zamboanga Yes	Zamboanga No	Total Yes	Total No
	% of farmers reporting					
Spraying pesticides	100		100		100	
Plowing the field immediately after harvest	37	63	56	44	48	52
Synchronous planting	48	52	33	67	39	61
Plowing under heavily infested areas during outbreaks	33	67	4	96	16	84
Use of other organisms that feed on RBB	33	67		100	13	87
Use of duck herds	23	77	4	96	12	88
Use of light traps	27	73		100	11	89
Use of plants effective against RBB	17	83		100	7	93
Use of beneficial organisms	3	97		100	1	99

Table 15. Management practices during planting and harvesting, standing crop, and outbreaks.

Practice	Palawan	Zamboanga	Total
	% of farmers reporting		
During planting and harvesting			
Water management	20	100	74
Water management and spraying	50		16
Crushing RBB eggs	5		2
Spraying insecticides	25		8
In standing crop			
Spraying insecticides	47	49	49
Water management	47	49	49
Water management and spraying		1	0.8
Light trapping	3		0.8
Collecting and burning	3		0.8
During outbreaks			
Spraying insecticides	61	50	52
Water management	39	50	48

less risky, and also kill other pests. The use of chemical insecticides has persistent residual toxicity on treated grains, which is unsafe for human consumption, dangerous to pesticide applicators, and affects the environment (Burdeous 1995). Spraying of pesticides should be minimized because it also kills the natural enemies.

The respondents sprayed because the chemicals were effective in killing and controlling RBB, they did not know any other way to control RBB, they do asynchronous planting, they want to have yield, the RBB fell into the water when sprayed, and they believe the promotional material on chemi-

Table 16. Chemicals sprayed by farmers to control RBB.

Chemical	No.	%
Carbofuran	2	1.8
Chlorpyrifos+BPMC	3	2.6
Creolina	1	0.9
Cypermethrin	77	67.54
Cypermethrin+chlorpyrifos	1	0.9
Deltamethrin	9	7.9
Diazinon	2	1.8
Ethofenprox	1	0.9
Fipronil	1	0.9
Lambdacyhalothrin	13	11.4
Methamidophos	1	0.9
Monocrotophos	3	2.6

cals. The problems encountered in spraying pesticides were that the RBB were not totally killed: they only flew to other unsprayed fields; it constitutes an additional/high expense; poses health risks; creates labor problems; and necessitates big capital. The other factors have something to do with unavailability of water, no effect seen on RBB, and adverse weather condition.

Synchronous planting
Thirty-nine percent of the farmers interviewed practiced synchronous planting to control RBB. Planting rice synchronously over a wide area will destroy the life cycle of the RBB (Guzman 2002). For those practicing asynchronous planting, their reasons were financial problems, dependence on farmers' decision on when to plant, and farmers having their own planting schedule.

Cropping calendar
Farmers had varying planting calendar. Planting for the wet season was from March to August. The most common schedule was June to September, August to November, or August to December. For the dry season, the prevalent planting calendar covered November to February, January to April, January to March, and October to January. Two farmers in Palawan planted after harvesting the second crop and considered as third crop the February to June and March to June croppings. Looking at this diverse planting schedule, the farmer respondents did not follow synchronous planting during the period covered in the survey (Table 17).

Use of light traps
Eleven percent of the farmers interviewed used light traps to control RBB. This was done by putting a stand with a light above (usually petromax or any bright light) and with a basin below with chemicals or used oil to capture the RBB. This was done 3 d before and 3 d after the full moon, when there is a high population of RBB. It is very effective to mass-trap adults. The problems encountered by farmers

Table 17. Cropping calendars followed by farmer respondents.

Cropping period	Palawan			Zamboanga		Total		
	1st crop	2nd crop	3rd crop	1st crop	2nd crop	1st crop	2nd crop	3rd crop
				% of farmers reporting				
Jan to Mar					18.92		10.61	
Jan to Apr		3.45			29.73		18.18	
Jan to May					2.70		1.52	
Feb to May					2.70		1.52	
Feb to Jun			50.00					50.00
Mar to Jun		3.45	50.00				1.52	50.00
Apr to Jul	6.70	3.45				2.70	1.52	
May to Aug	13.30			4.40		8.00		
May to Sept	10.00			2.20		5.30		
Jun to Aug				4.40		2.70		
Jun to Sept	40.00			28.90		33.30		
Jun to Oct	6.70			17.80		13.30		
Jul to Oct	6.70			11.10		9.30		
Aug to Nov	3.30			20.00		13.30		
Aug to Dec	10.00			11.10		10.70		
Sept to Dec		3.45					1.52	
Sept to Jan		3.45					1.52	
Oct to Jan		13.79			8.11		10.61	
Oct to Feb		6.90			2.70		4.54	
Nov to Jan		6.90					3.03	
Nov to Feb		31.03			21.62		25.76	
Nov to Mar		10.34			5.40		7.58	
Dec to Mar		10.34			8.11		9.09	
No response	3.30	3.45				1.30	1.52	

in using this method are that they are labor-consuming (as RBBs are collected in the morning and burned or sprayed); the light and basin are stolen; and it is difficult to watch at night.

The reasons given for not using a light trap are that spraying is more effective if light trapping was done asynchronously, unavailability of materials, and not being knowledgeable or aware of the technology (Table 18).

Awareness of beneficial organisms to control RBB
Only one farmer was aware of the beneficial organisms that can control RBB such as *Telenomus triptus* and *Metarhizium anisopliae*. This he learned through the farmers' field school, but he is not using these organisms because they are unavailable in the area. A testimony from farmer Daniel Guico indicates a saving of at least P3,000 ha^{-1} by using *Metarhizium* rather than chemicals, which are harmful to human (Galeon 2002). *Metarhizium* is a fungus that kills nymph and adult RBB (Estoy 1999). *Telenomus* was effective because they eat the eggs of RBB.

Table 18. Reasons for not using a light trap.

Item	N	%
No materials to use/unavailability of materials such as extension wire	16	23.2
Don't know how to use/don't know the technology/not aware	6	8.7
Only a few RBB in our place	2	2.9
Nobody used it in the place	3	4.3
No effect if you're alone, RBB will go to your field	2	2.9
Not yet tried	3	4.3
Don't mind light trap	4	5.8
Spraying is more effective if light trapping is done asynchronously	23	33.3
No electric power in the field	3	4.3
Laborious in using petromax	1	1.4
Expensive	2	2.9
Will just invite RBB from other farms to come to my field	3	4.3
Financial problem	1	1.4

Knowledge of other organisms that feed on RBB
Thirteen percent of the farmers interviewed knew other organisms that feed on RBB. The so-called predators are frogs, spiders, carabao egret, fish, ants, and lady beetles. These predators eat the eggs, nymphs, and even adult RBBs.

Knowledge of plants effective against RBB
Only seven percent of the farmers interviewed were aware of plants that can control RBB such as tubli, taro, pepper, and grasses. These plants are attractive to RBB and it is easy to kill these pests when they are attached to these plants.

Herding of ducks
Twelve percent of the farmers interviewed practiced herding of ducks in their field to control RBB. According to the respondents, ducks eat RBB, but they also eat the rice plants. Thus, ducks cannot be used when the rice plant is already 1 mo old. Also, they think that the use of ducks can trigger tungro infestation, and that eating too much RBB causes blindness in ducks.

Plowing under heavily infested areas during RBB outbreaks
Sixteen percent of the farmers plowed-under their heavily infested fields. This was done to prevent the spread of RBB because the eggs, nymphs, and even adults are killed or buried in the soil. The problem with this measure is that RBBs leave the field temporarily and then go back during planting time. Farmers should spray the field immediately to avoid RBB damage and bugburn.

Table 19. Fallow period practiced in both sites.

Month (no.)	Palawan	Zamboanga	Total
		% of farmers reporting	
0	10.00		4.00
0.5		6.70	4.00
1	26.70	20.00	22.70
1.5		17.80	10.70
2	16.70	20.00	18.70
2.5		11.10	6.70
3	10.00	4.40	6.70
4	10.00	2.20	5.30
7		4.40	2.70
8		13.30	8.00
No response	26.70		10.70

Plowing the field immediately after harvest
Almost half of the farmers interviewed (48%) plowed the field immediately after harvest. This was done to submerge all the stubbles under water until they decompose and to bury the nymphs under the mud to completely eradicate the food source. After harvest, black bugs at all growth stages remain on the stubbles; incorporation of stubbles into the soil destroys their breeding and hiding habitat.

Many farmers waited for the water to become available, rested the field for at least 1 mo, and waited for 10 or 45 d after harvest, herding the ducks first until the water arrived. Problems encountered were unavailability of water after harvest and lack of capital.

Use of fallow period
Farmers had short fallow period after harvest. They left the farm vacant or let the farm rest for only 1–2 mo before they plant again (Table 19). This happened because there were areas with sufficient supply or continuous flow of water; the farmers were forced to plant. The problem with this is that RBBs were still there or in nearby fields and there was a continuous supply of food for them. This is why their spread is very hard to prevent. A fallow period is very important because it breaks the life cycle of the insects, reducing the population for the next cropping season.

Production, yield loss, and cost of production
More than one-half (56%) of the farmers interviewed reported experiencing more than 30% yield loss. Many farmers said that yield loss was 38.42% during wet season and 32.71% during dry season. Farmers had, on average, a normal yield of 3.77 t ha^{-1} during wet season and 3.65 t ha^{-1} during dry season. When infested with RBB, yield declined to 2.3 t ha^{-1} during the wet and dry seasons, losing 1.47 t ha^{-1} during wet season (38.42%) and 1.35 t ha^{-1} during dry season (32.71%). There was no significant difference between the dry-season and wet-season yields, even if RBB attacks were more frequent in the dry season than in the wet season.

Table 20. Yield, yield loss, and cost of production.

Parameter	Palawan		Zamboanga		Total	
	WS	DS	WS	DS	WS	DS
Yield loss caused by RBB based on experience						
>30%	20.8		76.2		56.1	
21-30%	29.2		7.1		15.2	
10-20%	33.3		14.3		21.2	
<10%			2.4		1.5	
>50%	12.5		4.5			
60-80%	4.2		1.5			
Average normal yield (t ha^{-1})	3.57	3.53	3.88	3.74	3.77	3.65
Average yield when infested with RBB (t ha^{-1})	2.42	2.54	2.22	2.12	2.30	2.30
Yield loss reported by farmers (t ha^{-1})	1.15	1.00	1.67	1.62	1.47	1.35
Yield loss reported by farmers (%)	30.94	19.69	43.08	42.55	38.42	32.71
Average production cost ha^{-1} (pesos)	8179	8468	6516	7000	7153	7592
Additional cost due to RBB control (pesos)	1745	1479	557	606	1003	892
Total production cost including RBB control (pesos)	9697	9701	7073	7606	8034	8291
Increase in production cost due to RBB control (%)	17.72	15.33	8.64	9.13	11.96	11.16

Average production cost per hectare was P7,153 and P7,592 during wet and dry season, respectively. Additional cost due to RBB control was P1,000 during wet season and P892 during dry season. Total production cost including RBB control totaled P8,034 for wet season with an increase of 11.96% and P82,291 during dry season with 11.16% increase in production cost (Table 20).

Conclusions and recommendations

Farmers know what a black bug is and they can describe it well. They also know that it is a pest, but they have difficulties describing its behavior. More than one-half of the respondents had training on RBB management.

Water management/flooding and spraying are the most commonly known measures practiced by farmers to control RBB. However, they need more information on the importance and benefits of synchronous planting, plowing-under heavily infested areas, plowing the field after harvest, use of other organisms that feed on RBB, light trapping, and use of beneficial organisms. Based on the problems identified and the reasons given for not using the control measures mentioned by farmers in this study, information dissemination and training programs on RBB management can still be improved. Given that the farmers are already aware of the problems associated with spraying, it is important that the mechanism of how other measures cut the life cycle of RBB, kill RBB, or cut their food supply be explained clearly to farmers.

Furthermore, the constraints to adopting synchronous planting and water management strategies can only be addressed in proper coordination with NIA or the irrigation associations. Com-

munity-based efforts to control RBB are important, especially in areas where RBB outbreaks have not occurred yet. This approach will address the concerns of farmers in using some of the control measures, as well as ensure the long-term eradication of RBB.

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The Role of Alternate Plant Hosts in Rice Black Bug Ecology

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Abstract

Plant hosts such as weeds play a role in the ecology of black bugs by offering food, an oviposition substrate, and shelter when rice is not in the field. There are records of alternate hosts for four species of black bugs. *Scotinophara lurida* has 10 recorded ovipositional hosts and 14 developmental hosts, mostly grasses. *S. coarctata* has nine developmental hosts, while *S. latiuscula* has eight, mostly grasses. *S. cinerea* has two developmental hosts aside from rice.

Key words: alternate plant host, weed host, developmental host, ovipositional host, insect ecology

Introduction

Scotinophara black bugs occur in a wide range of rice field habitats—from wetland marshy areas to dryland hill-agriculture. Corbett and Yusope (1924) concluded that *S. coarctata* (Fabricius) thrived best when there is stagnant water and least when conditions are dry. Van Vreden and Ahmad Zabidi (1986) show a photo of a totally desiccated ('bug burned') dryland hill-rice field due to the feeding damage of *S. coarctata*. Black bugs have the potential to reach very high population densities and to cause complete loss of a crop in a range of rice cultures.

The great expansion of rice culture due to breeding of modern rices in the mid-1960s spawned an era of irrigation system expansion. The new rices were photoperiod-insensitive in contrast with traditional rices and could be sown more than once a year. The greater apparency of rice in local environments in time and space has been thought to favor monophagous rice pests such as the brown planthopper *Nilaparvata lugens* (Stål), green leafhopper *Nephotettix virescens* (Distant), and *Scirpophaga* spp. stem borers. These species multiplied in an exponential fashion with the greater

length of time rice was cultivated each year, which reduced the period of the rice-free fallow (the tropical 'winter') as well as to asynchrony in planting dates, which multiple rice cropping encourages (Loevinsohn et al. 1993). Multiple cropping of rice also expanded the growing seasons of weeds and other aquatic plants that grow in association with rice, including black bugs (Hirao and Ho 1987).

The wide habitat range of *Scotinophara* species places them in contact with a wide array of plants besides rice *Oryza sativa* L. Black bugs are least active during bright sunny days and become active at night or when the weather is overcast. In addition, black bugs are known to thrive under conditions when fields are weedy, which increases the relative humidity at the base of rice plants necessary for egg survivorship (Fernando 1960). Black bugs are known to shun sunlight that weeds obscure, thus increasing habitat suitability. Weeds and other plants in and around rice fields perform other key functions in the life cycle of black bugs. Hirao (1998), however, believed that *S. lurida* is monophagous, which begs the question of what is the role of weeds on black bug ecology. Do they play an additional role as a food source? The answer may be different for each black bug species.

Attributes of a plant host

The beginning of rice cultivation dates back some 10,000 years in Asia, which suggests that most of the arthropod species inhabiting rice agroecosystems coevolved with rice cultivation (Kiritani 1979). Weeds associated with rice have also evolved together with the herbivores that feed on them. Ecological evidence has shown that the role of a plant host can fulfill many useful functions for an insect to improve fitness (Bernays and Graham 1988). Not only does a plant host supply sustenance for development, it also provides a depository for eggs, a rendezvous site for locating a mate, shelter from the elements, and enemy-free space to escape predation or parasitism. Some insects extract secondary plant chemicals to use in their own defense against natural enemies.

Heinrichs and Medrano (1984), upon reviewing the literature, noted that the host range of the brown planthopper was inconclusive because of discrepancies in the definition of what constitutes a host. Most references named a plant a host when the insect was seen on the plant rather than after rearing the insect to determine a proof of utility or fitness (survival and reproductive potential). The same comment can be made from a review of the *Scotinophara* literature. During dispersal, adult *Scotinophara* may be blown off course by storms onto locations near rice fields or into nonrice crop fields where they seek shelter from the storm. While there, adults may probe plants testing for acceptance and host recognition and may reject them in a few moments but remain on the host (Sogawa 1976). Thus, just the act of resting or feeding does not constitute designating a plant as a host.

A host range list is not fixed or absolute and there are some hosts where only a small percentage of an insect species' population can subsist. For example, *Nephotettix malayanus* Ishihara et Kawase can survive on only some rice cultivars (Kim et al. 1986). Litsinger et al. (1993), studying the host range of rice caseworm *Nymphula depunctalis* (Guenée), noted that published host lists differed by location and concluded that plant host range can vary geographically in response to adaptive selection. Heinrichs and Medrano (1984) noted that TN1, considered the most susceptible rice cultivar to insect pests in IRRI greenhouse tests, was resistant in Australia to brown planthopper populations.

The same phenomenon was found true for insect biotypes. In Sri Lanka, brown planthopper populations separated by <100 km showed virulence patterns and adaptation to specific rice cultivars on which they were collected. In addition, Claridge and den Hollander (1980) were able to 'change' a brown planthopper biotype population killed off and nonadapted to a rice cultivar possessing one resistance gene to a biotype population whose descendants survived on the same cultivar in only 10 generations.

Insects must also adjust to the various ecotypes of weeds just like rice cultivars. Weed ecotypes differ in morphology and sensitivity to herbicides as well as other features based on local conditions (Moody 1990). Thus, the plant host ranges for insect pests are highly site-specific and labile both ecologically and evolutionarily (Bernays and Graham 1988). For example, a polyphagous species may be locally highly restricted in diet, whereas other species with limited host ranges may make adaptations to unrelated plant hosts. Host plant shifts are not rare in nature. The classic host plant shift noted in rice has been with the brown planthopper to a sympatric population feeding only on *Leersia hexandra* Sw., living side by side with brown planthoppers on rice plants (Heinrichs and Medrano 1986). The shift was so great that the two populations did not successfully interbreed.

Greenhouse studies show that using habituation can increase the speed of host plant shifts. Habituation refers to gradually increasing the proportion of one plant species or cultivar in a mixture to another species from generation to generation (Bernays and Graham 1988). Most herbivores are relatively host-specific, feeding on only one or a few genera or on a single plant family. Where faunas have been comprehensively studied, <10% of all phytophagous insects develop on plants of more than three different plant families (Bernays and Graham 1988). If the plant is plentiful in nature, local insects will adapt to it. Perhaps no plant defense is insurmountable as insects as a group have been very adaptable to all kinds of defenses. Alternate hosts, which are more prevalent or apparent in a habitat, would increase the chances of being found by a herbivore and over time it can develop on it. Also, as the popularity of a crop increases, planting material is carried into new locations and habitats. Insect species that fed on other plants soon shift to the new crop and disperse within the crop's expanded range. This is why there is a positive correlation between a crop's cultivated area and the number of recorded pests (Strong et al. 1977).

According to Chapman (1971), the definition of a monophagous species is an insect that survives well on plants within one genus, an oligophagous species is one that survives well on plants within one family or subfamily, while a polyphagous species can survive well on plants in more than one family. We use *N. virescens* and *N. nigropictus* (Stål) as examples. The host plant ranges for both species were based on greenhouse rearings at the International Rice Research Institute in Los Baños, Philippines (Tables 1 and 2). *N. virescens* is classified as monophagous as survival was highest on rice. Two other *Echinochloa* species supported development but with <22% survival. *N. nigropictus,* on the other hand, showed survival rates >80% on three species in three genera within the family Poaceae and thus is classified as oligophagous.

Another dynamic feature of black bugs is that they often reach epidemic proportions. Under such conditions of high densities, many new genetic recombinations form in the population, giving

Table 1. Plant host range of the rice green leafhopper *N. virescens*, a monophagous species, IRRI greenhouse.[a]

Plant family	Plant species	Eggs laid (no. female[-1])	Egg survivorship (%)	Nymphal survivorship (%)	Nymphal developmental period (d)	Fecundity of surviving females (no. eggs female[-1])
Poaceae	*Oryza sativa* (TN1 cultivar)	86.0 ± 11.6 a	62.0 ± 8.9 a	84.9 ± 2.4 a	16.2 ± 0.3 a	29.2 ± 3.8 a
	Echinochloa glabrescens	53.5 ± 8.5 b	20.4 ± 1.3 b	21.7 ± 1.9 b	16.0 ± 0.1 b	12.4 ± 1.8 b
	Echinochloa colona	34.0 ± 4.4 cd	9.0 ± 1.1 c	12.6 ± 1.2 c	15.3 ± 1.9 c	9.3 ± 2.6 c
	Cynodon dactylon	87.6 ± 31.7 a				
	Echinochloa crus-galli	60.6 ± 30.4 b				
	Eleusine indica	53.0 ± 32.2 b				
	Panicum repens	47.9 ± 22.8 bc				
	Leersia hexandra	34.0 ± 3.2 cd				
	Paspalidium flavidum	31.0 ± 7.4 cde				
	Paspalum paspalodes	28.0 ± 8.3 def				
	Leptochloa chinensis	25.1 ± 12.9 d-g				
	Brachiaria distacnya	12.3 ± 7.8 e-h				
	Zea mays	10.9 ± 7.6 f-h				
	Digitaria setigera	7.9 ± 10.0 gh				
	Chrysopogon aciculatus	6.6 ± 5.0 gh				
	Paspalum scrobiculatum	5.6 ± 6.2 gh				
	Chloris barbata	5.5 ± 6.7 gh				
	Panicum maximum	3.3 ± 5.3 h				
	Dacytloctenium aegyptium	2.4 ± 5.4 h				
Cyperaceae	*Fimbristylis miliacea*	3.5 ± 6.4 h				
	Cyperus iria	0.7 ± 1.1 h				
Rubiaceae	*Hedyotis biflora*	2.1 ± 3.5 h				
Scrophulariaceae	*Lindernia anagallis*	6.5 ± 10.8 gh				

[a]In a column, means followed by a common letter are not significantly different (P < 0.05) by LSD test. Green leafhoppers were field collected and reared in the greenhouse on 4-5-wk-old TN1 rice. Plant hosts were uprooted from the field and held for 3 weeks. No-choice tests of 10 replications for each plant species, 1 mated pair 2-d old in a mylar plastic cage 10 x 72 cm with side and top vents, set around a vegetative stage plant hosts rooted in a clay pot, a pinch of inorganic NPK fertilizer was added to the pot (data adapted from Catindig 1993).

more individuals the capacity to feed and develop on more species of plant hosts than would occur under normal low-density situations. In addition, populations that are expanding their geographic distribution, such as what black bugs have done in the Philippines, will be in flux as they adapt to a new mix of plant species. A number of years will need to pass before populations stabilize in their new surroundings in terms of host plant preferences.

Oviposition hosts

The requirements as an oviposition host are not as great as a development host. We saw from Tables 1 and 2 that green leafhopper females oviposited on five-seven times more plants than were found to be development hosts. *Scotinophara* eggs are laid on the surface of plants, glued with a secretion from the female's accessory glands so the eggs do not come into contact with plant tissues, while eggs of rice leafhoppers and planthoppers are injected into rice tissue by females with spearlike ovipositors.

Table 2. Plant host range of the rice green leafhopper *N. nigropictus*, an oligophagous species, IRRI greenhouse.

Plant family	Plant species	Eggs laid (no. female⁻¹)	Egg survivorship (%)	Nymphal survivorship (%)	Nymphal developmental period (d)	Fecundity of surviving females (no. eggs female⁻¹)
Poaceae	Oryza sativa	89.5 ± 5.8 a	77.1 ± 10.2 a	83.9 ± 7.0 a	16.4 ± 0.9 a	87.3 ± 7.2 a
	Leersia hexandra	83.1 ± 7.8 b	76.9 ± 9.3 a	83.2 ± 10.8 ab	16.8 ± 1.2 a	75.0 ± 8.5 b
	Echinochloa colona	69.5 ± 8.1 c	76.8 ± 8.2 a	81.0 ± 10.3 b	17.1 ± 1.2 ab	61.8 ± 5.9 c
	Brachiaria mutica	54.4 ± 6.1 d	58.9 ± 9.3 b	63.7 ± 12.6 c	18.8 ± 1.1 b	11.7 ± 2.0 d
	Echinochloa glabrescens	48.9 ± 5.9 e				
	Eleusine indica	32.7 ± 5.5 f				
	Echinochloa crus-galli	28.9 ± 6.3 g				
	Panicum repens	28.2 ± 2.4 g				
	Cynodon dactylon	26.8 ± 5.9 g				
	Paspalidium flavidum	23.3 ± 2.6 h				
	Panicum distichum	19.6 ± 3.7 i				
	Leptochloa chinensis	18.0 ± 2.0 ij				
	Zea mays	17.4 ± 8.2 j				
	Chloris barbata	14.0 ± 4.0 k				
	Paspalum conjugatum	13.6 ± 3.9 k				
	Digitaria setigera	13.4 ± 5.0 kl				
	Dactyloctenium aegyptium	12.3 ± 4.0 kl				
	Panicum maximum	11.3 ± 4.2 lm				
	Brachiaria distachya	9.6 ± 1.5 mn				
	Eriochloa procera	8.7 ± 1.8 no				
	Chrysopogon aciculatus	7.7 ± 2.1 op				
	Digitaria ciliaris	6.6 ± 1.1 pq				
	Imperata cylindrica	5.5 ± 3.3 q				

See footnotes in Table 1. (Data adapted from Catindig 1993)

Placing eggs within plant tissue reduces predation and provides a more moist environment. To guard against such intrusions, *Scotinophara* females protect the egg mass by sitting over it until hatch.

Fernando (1960) named many weeds, mostly grasses, as oviposition hosts (Table 3). He noted most of them occurred within fields but some also occurred along field borders. He noted *Isachne globosa* and *Echinochloa crus-galli* were preferred but eggs were also found on a number of plants, sedges primarily, but other families as well. Under very windy conditions when the crop was in the seedling stage, egg laying was mainly on the shorter, better protected grasses growing around the rice seedlings rather than on the rice seedlings themselves. Oviposition, he noted, also occurred on plant debris.

From Table 3, we note that many plant species, even in different families are recorded from the literature as hosts during the egg stage. If the plant turns out not to be a development host, then the neonate nymph has to find a more suitable plant and if unsuccessful will die. This is perhaps what prompted Bernays and Graham (1988) to conclude that locating food may be more important than nutritional benefit.

Table 3. *Scotinophara lurida* black bug oviposition plant hosts based on the literature aside from rice.

Plant family	Species	Reference
Poaceae	*Isachne globosa* (Thunb.) O.K.	Fernando (1960)
Poaceae	*Echinochloa crus-galli* (L.) P. Beauv. (= *Panicum crusgali*)	Liu (1933), Fernando (1960)
Cyperaceae	*Cyperus difformis* L.	Fernando (1960)
Cyperaceae	*Cyperus flavidus* Retz.	Fernando (1960)
Cyperaceae	*Cyperus iria* L.	Fernando (1960)
Cyperaceae	*Cyperus rotundus* L.	Fernando (1960)
Cyperaceae	*Fimbristylis miliacea* (L.) Vahl	Fernando (1960)
Cyperaceae	*Fimbristylis dichotoma* (L.) Vahl	Fernando (1960)
Marsileaceae	*Marsilea quadrifolia* L.	Liu (1933), Fernando (1960)
Pontederiaceae	*Monochoria vaginalis* (Burm. f.) Presl	Fernando (1960)

Development hosts

A development host is a plant that can sustain the growth of the insect from eclosion to adulthood and can provide adequate nutrition for reproduction. In insects that undergo complete metamorphosis such as Lepidoptera, the larval stage may have different food needs than the adult. Thus, a stem borer larva feeds on rice while the adult may not feed at all or take nourishment from nectar. More mobile insects can partake of different plant species individually. A more complete diet may be obtained from feeding on different plant hosts and, in studies using artificial diets, it has been found that individuals of some species of grasshoppers and butterflies select food from different diet mixtures that ensure the greatest nutritional fitness (Bernays and Graham 1988). Most studies to determine plant host fitness are performed under no-choice conditions where the insect is forced to feed on only one host. *Scotinophara* black bugs being more mobile may prefer a mixed diet of rice and rice field grasses rather than one plant species but this has not been determined.

Only one study was found where the fitness of plant hosts was determined by greenhouse-rearing trials and that was on a lesser known black bug *S. latiuscula* (Breddin) (Barrion and Litsinger 1987). The node-feeding black bug as it is called was found in the Philippines as a pest of rice in swampy habitats with peat soils. It prefers to feed at the nodes of rice tillers over other locations on the plant.

Various parameters inferring ecological fitness of plant hosts were evaluated, including nymphal survival rate, weight gain, number of eggs laid (fecundity), egg viability, and longevity (Table 4). In this study, 9 of 19 plant hosts sustained development with rice as the most fit. In statistical comparisons, rice topped all other rice field plants in the fitness categories tested. There were three alternate plant hosts in Poaceae and three in Cyperaceae. Ten plants however resulted in total death of nymphs and are thus nonhosts (Table 5).

Records of plant hosts were found for three other black bug species. The Malayan black bug *S. coarctata* has five recorded hosts in Poaceae, the same family as rice as well as four sedges (Cyperaceae) (Table 6). Corbett and Yusope (1924) noted that *S. coarctata* feeds on a wide host range

Table 4. Plant host range of *Scotinophara latiuscula*, IRRI greenhouse, Los Baños, Philippines, 1983-84.[a]

Plant species	Survivorship (%)[b,c]	Body weight (mg)[b]		Eggs laid (no. female[-1])[b]	Eggs hatched (%)[b]	Longevity (days)[b]
		Female	Male			
Cyperaceae						
Cyperus difformis L.	68 b	21 ab	24 ab	62 a	81 b	84 b
C. iria L.	25 de	20 ab	22 bc	37 b	78 b	58 cd
Fimbristylis miliacea (L.) Vahl	14 e	14 d	17 d	20 c	15 e	38 e
Poaceae						
Echinochloa colona (L.) Link	48 c	17 cd	22 bc	46 b	72 b	62 c
Echinochloa crus-galli (L.) Beauv. subsp. *hispidula* (Retz.) Honda	73 b	19 bc	24 ab	64 a	81 b	89 b
E. glabrescens Munro ex. Hook f.	32 d	18 bc	20 cd	47 b	68 bc	86 b
Leptochloa chinensis (L.) Nees	21 dc	14 d	17 d	25 c	32 d	53 cde
Oryza sativa L.	82 a	23 a	27 a	72 a	93 a	117 a
Commelinaceae						
Commelina benghalensis L.	11 e	14 d	16 d	14 d	14 e	46 de

[a]In a column, means followed by a common letter are not significantly different (P < 0.05), by DMRT. [b]Average of four replications of 10 mated pairs per replication. [c]Completed development from egg to adult.

Table 5. Plants that did not support *S. latiuscula* development.

Family	Species	Reference
Poaceae	*Digitaris cilaris* (Retz.) Koel	Barrion and Litsinger (1987)
Poaceae	*Eleusine indicata* (L.) Gaertn.	Barrion and Litsinger (1987)
Poaceae	*Imperata cylindrica* (L.) Beauv.	Barrion and Litsinger (1987)
Poaceae	*Ischaemum rugosum* Salisb.	Barrion and Litsinger (1987)
Poaceae	*Leersia hexandra* Sw.	Barrion and Litsinger (1987)
Poaceae	*Rottboelia exaltata* L.f.	Barrion and Litsinger (1987)
Poaceae	*Saccharum spontaneum* L.	Barrion and Litsinger (1987)
Poaceae	*Sorghum halpense* (L.) Pers.	Barrion and Litsinger (1987)
Pontederiaceae	*Monochoria vaginalis* (Burm. f.) Presl	Barrion and Litsinger (1987)
Sphenocleaceae	*Sphenochlea zeylanica* Gaertn.	Barrion and Litsinger (1987)

[a]Nondevelopmental hosts' means that no survival occurred in no-choice rearing.

of plants, particularly grasses. Between rice crops, it feeds on volunteer rice, ratoons, and grasses. Thus, host range was determined by records of feeding.

The Japanese black bug *S. lurida,* which has been studied more thoroughly, has the largest number of recorded plant hosts (Table 7). Nine of the 13 alternate hosts belong to Poaceae, while only one each come from four other families, including dicotyledons. Outbreaks of *S. lurida* have been attributed to population buildup in weedy areas (Rodrigo 1942).

S. cinerea black bug of Indonesia is found mainly on grasses but the species were not delineated by Kalshoven (1981). The only hosts named were from two agricultural crops, oats and maize

Table 6. *S. coarctata* plant hosts from the literature aside from rice.

Family	Species	Reference
Poaceae	*Hymenachne acutigluma* (Steud.) Gilliland (= *Panicum amplexicaule* and *Hymenachne pseudointerrupta*)	Van Vreden and Latif (1986), Grist and Lever (1969), Yunus (1965, 1967), Corbett and Yusope (1924)
Poaceae	*Zea* sp.	Van Vreden and Latif (1986)
Poaceae	*Panicum auritum* Presl ex Nees	Corbett (1923)
Poaceae	*Sacciolepis myurus* (Lam.) A. Chase(= *Panicum myurus*)	Corbett and Yusope (1924)
Poaceae	*Sacciolepis indica* (L.) A. Chase (= *Panicum indicum*)	
Cyperaceae	*Scirpus grossus* L.f.	Van Vreden and Latif (1986), Grist and Lever (1969), Yunus (1965,1967), Lever (1955), Corbett and Yusope (1924)
Cyperaceae	*Scleria sumatrensis* Retz.	Van Vreden and Latif (1986), Grist and Lever (1969), Yunus (1965, 1967), Lever (1955), Corbett and Yusope (1924)
Cyperaceae	*Carex* sp.	Corbett (1923)
Cyperaceae	*Scirpus mucronatus* L.	

Table 7. *S. lurida* plant hosts from the literature aside from rice.

Family	Species	Reference
Poaceae	*Zizania aquatica* L.	Kuwana (1930)
Poaceae	*Zizania latifolia* (Griseb.) Turcz. Ex Stapf	
Poaceae	*Triticum aestivum* L. (= *vulgare*)	Kuwana (1930), Grist and Lever (1969)
Poaceae	*Oryza minuta* J.S. Presl. Ex C.B. Presl.	Grist and Lever (1969)
Poaceae	*Setaria italica* (L.) P. Beauv.	Grist and Lever (1969)
Poaceae	*Hordeum vulgare* L.	Grist and Lever (1969)
Poaceae	*Saccharum officinarum* L.	Grist and Lever (1969), 877
Poaceae	*Zea mays* L. sp.	Grist and Lever (1969)
Poaceae	*Echinochloa crus-galli* (L.) P. Beauv. (= *Panicum crusgali*)	Kuwana (1930), Grist and Lever (1969), Liu
Cyperaceae	*Carex lurceolata*	Kuwana (1930)
Marsileaceae	*Marsilea quadrifolia* L.	Liu (1933)
Leguminoseae	Bean	Kuwana (1930)
Solanaceae	*Solanum hitsosum*	Kuwana (1930)
?	*Croix agrentis*	Kuwana (1930)

Table 8. *S. cinerea* plant hosts from the literature aside from rice.

Family	Species	Reference
Poaceae	*Avena sativa* L.	Kalshoven (1981)
Poaceae	*Zea mays* L.	Kalshoven (1981)

(Table 8). Greatest damage occurs in Sumatra and Kalimantan in swampy areas and perhaps many of the host records were based on bug burn symptom along with wilted rice during such outbreaks. It is assumed that alternate hosts also exhibit the same injury manifestations as rice.

Conclusion

Rice black bugs appear to be closely associated with grasses, which can act as alternate food hosts, oviposition substrates, and shelter that improve the microclimate. Published records of alternate plant hosts of four black bug species were found. *S. lurida* has both ovipositional host (10 species) and development host (14 species) records; the latter were mainly Poaceae but included two dicots. However, evidence for the term developmental host is lacking as no data were found indicating that *S. lurida* can develop on the plants mentioned.

The plant host records for *S. coarctata* included nine developmental host species divided among Poaceae and Cyperaceae, but, as with *S. lurida,* no data are presented from rearings. Designation of developmental host may be from observation of feeding in the field or of feeding damage. As stated, this is not conclusive enough evidence.

S. latiuscula has eight developmental host records confirmed from rearings from mostly Poaceae and Cyperaceae. This would indicate that *S. latiuscula* is classified as polyphagous as records included more than one family based on the definition of Chapman (1971). The less studied *S. cinerea* has only two developmental hosts aside from rice in its list, and both are Poaceae. These records, however, need to be confirmed.

Hirao's 1978 claim that some species may be monophagous and only benefit from weeds as an improvement of their local environmental conditions awaits confirmation. In irrigated double cropping systems, black bugs have less of a need for alternative plant hosts as they can endure the rice-free fallows through dormancy. However, as was emphasized in this chapter, insects can adapt to the local flora as a source of food when rice is not around. Whether some black bug species coevolved with rice or only shifted to rice when it became more prevalent awaits determination and clues would emerge based on the ranking of *O. sativa*'s plant host fitness compared with other rice field plant species. In the case of S. *latiuscula*, rice was the most fit host.

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Biological Control of the Rice Black Bug

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Abstract

The rice black bug (RBB), *Scotinophara coarctata* (F.), is believed to arrive from neighboring countries. A survey of this bug in the Philippines suggests that natural biological control is limited. As such, a classical biological control program should be initiated. From literature and field surveys in the Philippines, the natural enemies include general predators, scelionid egg parasitoids, and *Beauveria bassiana*, *M. anisopliae*, and *Paecilomyces lilacinus*. Apparently effective natural enemies exist in neighboring countries and also from a closely related *S. lurida*. To dispel the mystery surrounding this pest, farmer education focusing on a better understanding of this insect is required. This will prepare the farmers to work with researchers in understanding the ecology of RBB as well as involve farmers right from the beginning in any classical biological control work.

Introduction

There is a large and diverse community of plant-feeding arthropods and natural enemies that live in rice paddies (Shepard et al. 1995, 1988; Settle et al. 1996). A study in Indonesia reported in Pontius et al (2002) suggested that about 21% of the arthropod species in rice fields are herbivores and predators are the most diverse, contributing to 37% of the species recorded. Many natural enemies attack eggs, nymphs, or adults of the rice black bug (RBB) *Scotinophara coarctata* (Fabricius) (Hemiptera: Pentatomidae) (PhilRice 2006, 2002, 1995). This chapter reviews our understanding of the biological control of a new pest of rice in the Philippines.

Status of RBB

The biology of this insect has been described in Ooi 1988 and van Vreden and Abdul Latif (1986) in Malaysia where the insect is believed to be endemic. Outbreaks of this insect had been reported

intermittently since 1919. Following its discovery on the island of Palawan in 1982, a survey of natural enemies was carried out there (Perez et al. 1989). Considered an exotic pest, a search for natural enemies of this insect was initiated by the senior author that resulted in the importation of the egg parasitoid, *Telenomus triptus*. However, an understanding of the biological control of RBB continues to elude researchers and farmers alike in the Philippines.

The role of predators in biocontrol of RBB

As early as 1924, predatory arthropods were reported to impact RBB (Corbett and Yusope 1924). Beetles in the family Carabidae feed on eggs and nymphs. Also, included in the arthropod predator complex are several species of generalist predators such as ground and coccinellid beetles, spiders, crickets, and ants (Shepard et al. 1988, Perez et al. 1989, Corbett and Yusope 1924). Besides invertebrate predators, chickens, ducks, and frogs also eat the RBB nymphs and adults (Corbett and Yusope 1924, Ooi, 1988); however, quantitative assessment of the action of most predators is lacking.

The role of parasitoids in biocontrol of RBB

Parasitoids have been reported as major mortality factors against RBB for many years. In 1918, RBB was first reported as a serious pest of rice in Malaysia (Corbett and Yusope 1924). At that time, these authors reported that 55% of RBB eggs surveyed were parasitized. The most successful egg parasitoid out of five species tested in the Philippines was *Telenomus triptus,* which parasitized about 90% of the eggs in an experiment that utilized small Mylar® cages (Fig. 1) (Arida et al. 1988). The four other parasitoid species (*T. cyrus, Trissolcus basalis, Psix lacunatus*, and *T. chloropus*) each parasitized fewer than 10% of RBB eggs. Clearly, *T. triptus* could be a major part of any biological control program against RBB (see photo a). van Vreden and Abdul Latif (1986) reported that *T. triptus* parasitized up to 60% of RBB eggs in Malaysia. Fernando (1960) reported that *T. triptus* parasitized 30–36% of *S. lurida* eggs in the rice fields in Ceylon (Sri Lanka). It could be worthwhile exploring whether or not natural enemies of *S. lurida* would be effective against RBB.

The role of insect pathogens in biocontrol of RBB

RBB usually occurs in a moist environment in rainfed or irrigated rice and spends time on the lower part of the plant just above the water. This environment is ideal for entomopathogenic fungi. A closely related species of black bug (*S. lurida*) was found in Japan to be infested with *Metarhizium anisopliae* that was causing significant mortality (see photo b). Several fungi, particularly those in the Deuteromycotina, infect RBB (van Vreden and Abdul Latif, 1986, Rombach et al. 1986, Perez et al. 1989, PhilRice 2002). These included *Beauveria bassiana*, *M. anisopliae,* and *Paecilomyces lilacinus*. Rombach et al. (1986) introduced these fungi into field cages with 180 RBB per cage using suspensions of conidia and mass-produced dry mycelia. All fungal species and isolates reduced populations of RBB, but it was clear that more research was needed to refine the system of fungal production and application. Anandhi and Pillai (2006) reported that, when *M. anisopliae* and *B. bassiana* were

Egg parasitization (%)
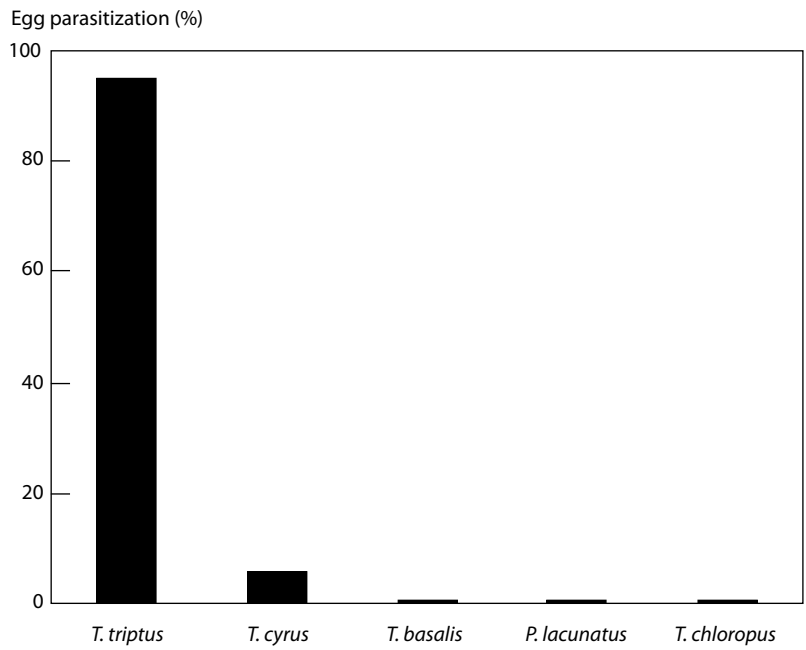
Fig. 1. Parasitization of various parasitoid species on RBB eggs.
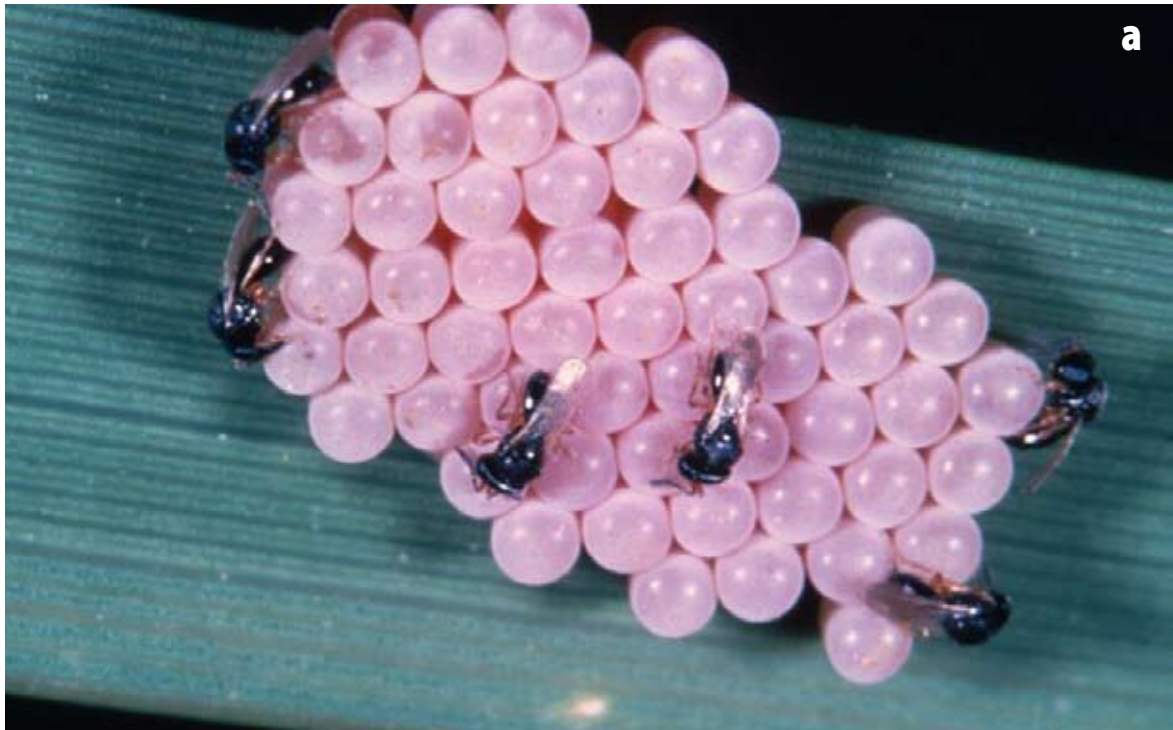
Telenomus triptus **adults on RBB egg mass ready for parasitization.**

RBB adult infected with *Metarhizium anisophiae.*

applied to rice plants in the field and screen house, highest mortality of RBB was observed after 7 d. More than 90% mortality was obtained when adults of *S. lurida*, the major black bug pest in Taiwan, Japan, China, and Sri Lanka, were dipped in spore suspensions of *Cephalosporium* sp.. However, this fungus has not been reported in RBB. A mermithid nematode of *S. lurida* was reported to cause 39% mortality in Japan (see photo c).

Possibility of effective biological control of RBB in the Philippines

Any strategy for managing RBB should first encourage naturally occurring biological control agents in order to take full advantage of their benefits while preventing RBB resurgence that often occurs when these are eliminated by chemical insecticides. The most disruptive action of all regarding conserving natural enemies is the use of chemical insecticides, thus alternatives to chemical control should always be a priority when developing a RBB management strategy. Although reports of the action of natural enemies of RBB are limited, there are several reports of their action against a closely related species, *Scotinophara lurida* (Burmeister), which is a major pest of rice in Japan, Taiwan, China, and Sri Lanka. *Scotinophara lurida* shares a number of natural enemies with *S. coarctata*. Nevertheless, any attempt at classical biological control should take note of the lessons learned in the past. Ooi and

Mermithid nematode of *S. lurida* adult.

Shepard (1994), in a review of biological control in rice pest, noted that casual introduction of exotic parasitoids had not been successful.

RBB behavior affects the ability of certain natural enemies to reach their full potential. For example, after laying her eggs, female RBB often sits on the egg mass to guard it against both predators and parasitoids. In the field, we have observed that, often times, only the periphery of an egg mass was parasitized because of the "egg-guarding" behavior that prevents the parasitoids from coming in contact with eggs in the middle of the egg mass. While sitting on the eggs, RBB uses its legs and antennae to fend off parasitoids and probably small predators, although more tenacious ones, such as ants (*Solenopsis geminata*) (see photo d) are able to displace adults from guarding the egg mass.

Augmentative releases of egg parasitoids (probably *T. triptus*) early in the season would likely provide significant suppression of RBB. In past attempts at augmentative releases of egg parasitoids for rice stem borers, this approach was not successful (Ooi and Shepard, 1994). Although the approach may not be practical, however, considering the time and costs associated with this activity, this might be carried out as a "cottage industry" by individuals trained in parasitoid-rearing techniques. A constraint to production of large numbers of parasitoids is the availability of RBB eggs. It would be worth determining if RBB egg masses could be collected from the field during outbreak situations then stored in a freezer for use for parasitoid rearing at a later time. Powell and Shepard (1982) found that eggs of another pentatomid, *Nezara viridula*, could be frozen for up to a year and were still viable for rearing the parasitoid, *Trissolcus basalis*.

An attempt at augmentation of *Telenomus triptus* was carried by one of the authors (G.S.A., unpubl. data) in Gubat, Sorsogon. A pamphlet was developed to assist the local government unit with mass rearing the parasitoid. It was noted earlier that parasitoid numbers were low at the begin-

d

Ants (Solenopsis geminata) are able to displace adults from guarding the egg mass.

ning of the season and gradually built up as the growing season progressed. The approach involved augmentative releases of the parasitoid early in the season when RBB was just beginning to colonize the crop. Egg masses were collected to assess the incidence of parasitism before augmentative releases were made. Unfortunately, a typhoon damaged the study site and results were inconclusive, but activities will continue during 2007 under the auspices of G.S. Arida. This approach should be tailored in such a way that farmers are involved in the actual parasitoid rearing, releasing, and subsequent followup with egg mass collections that are held in appropriate containers to assess the incidence of egg parasitism. Using simple rearing techniques that were developed (G.S.A., unpubl. data, PhilRice 2006), this approach certainly has merit and will be used in future field studies and farmer field school exercises.

To find the most efficacious fungal species and strains, it would be appropriate to collect as many isolates as possible and carry out laboratory screenings against RBB. Selecting the most efficacious

isolate is critical. The pathogenicity of *B. bassiana* to the brown-winged green bug, *Plautia stali* (Hemiptera: Pentatomidae), varied considerably (Tsuda et al. 1997). Developing the right formulation is critical when entomogenous fungi are used. Proper formulations of *M. anisopliae* var. *acridum* contributed greatly to the success in locust and grasshopper control programs in Africa (Lomer et al. 2001). The oil-based formulation extended the life of the fungus in the field. Thus development of a sustainable biological control-based program for RBB should involve finding an efficacious fungal isolate and development of an effective formulation. Moreover, the resulting mixture could be applied using equipment that is used to apply chemical insecticides. This approach, coupled with parasitoid releases and water level manipulation, should be tested with farmers in several areas infested by RBB.

One approach would be to develop farmer-level techniques for culturing the fungi and establishing a central repository where farmers could come and obtain fungal isolates. Alternatively, techniques could be developed and training conducted so that culturing the fungi could be carried out as a cottage industry with farmers purchasing the fungus on an "as needed" basis. In West Sumatra, farmers obtain inoculum from "Bioagent Posts," then they grow entomopathogenic fungi on rice inside plastic bags. When the fungi are ready, these are used against pest insects (BMS, personal observations). The most successful of these efforts involves a nucleopolyhedrovirus against the beet armyworm, *Spodoptera exigua*. Unfortunately, no viruses have been found in RBB.

Methods for assessing the action of RBB predators and parasitoids

One of the most important aspects of biological control is developing and evaluating methods for assessing the impact of indigenous or introduced biological control agents. With microbial agents, such as fungi and viruses, this is more straightforward because these materials can be applied with conventional spray equipment, such as a backpack sprayer, and evaluation is similar to that of evaluating a chemical insecticide. Assessing the impact of predators and parasitoids, however, presents special challenges and requires specifically designed methods. An overview of various approaches was published by Luck et al. (1988) and Luck et al. (1999). The "classical" biological control approach involves the introduction of an exotic natural enemy usually found by surveying the original "home" of the pest, culturing the biocontrol agent, introducing it into the field where the pest is present, and see if it becomes established and brings the population of the pest under control. Most evaluation methods can be grouped into six general experimental approaches. These are 1) introduction and augmentation, 2) use of cages and barriers, 3) removal of natural enemies, 4) prey enrichment, 5. direct observation, and 6) chemical evidence of natural enemy feeding. These are not listed in order of preference and the ones selected for participatory field trials with farmers will probably be confined to the first four methods.

Other field studies have been carried out that show that insecticide use actually increases the incidence of RBB (G.S.A., unpubl. data). This was undoubtedly due to the negative effects of these chemicals on natural enemies, particularly parasitoids. Chemical sprays reduced parasitism by nearly 60% compared with the unsprayed area (G.S.A., unpubl. data). Elimination of natural enemies with

chemical insecticides is one of the methods used for assessing the benefits of arthropod predators and parasitoids.

The use of cages and barriers should prove to be another important method to assess natural enemy effectiveness against rice insect pests (Shepard and Ooi 1991) and very likely for RBB. This approach was originally reported by Smith and Debach (1942) and has been used in many natural enemy assessment programs. This approach should work particularly well as a farmer field school exercise. Egg masses of RBB could be located in the field and small screened cages, fashioned from styrofoam cups, could be placed over each egg mass to exclude natural enemies. Natural enemy action on egg masses in a companion set of cups (without the screen on the ends to allow entry by natural enemies) would allow direct comparison of predator and parasitoid action. Marking the exact location of each exclusion and nonexclusion cup, using field flags, would facilitate finding the egg masses. The egg masses could then be collected (if they have not been consumed by predators), brought to a laboratory or a similar cool area, and held and observed for parasitoid emergence. At the same time, egg masses that were fed upon by predators could be noted.

Clearly, an integrated approach, involving farmers as well as extensionists and researchers would be the most likely to succeed. The integrated pest management (IPM) approach, however, must have biological control as its core and the use of chemical insecticides should not be a part of the IPM tactics used as these will seriously disrupt the action of natural and introduced biological control agents.

Cultural techniques with biological control

Experiments were carried out in the Philippines to determine if raising the water level for different periods of time would drive adult RBB from egg masses and leave them exposed to the action of parasitoids and other natural enemies (Parducho et al. 1988, Shepard et al. 1988). These experiments, using potted rice plants, showed that percent parasitism rose from 17% in plots that were not flooded to 54% in pots flooded for 24 h (Fig. 2). Raising the water level caused RBB to leave the egg masses, thus making them vulnerable to attack by parasitoids. The action of natural enemies would be increased if it is practical to raise the water level by 4–6 inches and leave it at this level for about a day, then lowered. Although no studies were carried out on the role of predators in this situation, clearly their action would be enhanced if the egg mass was left unguarded. In addition, flooding itself caused significant egg mortality if egg masses remain under water for 24 h. In addition, about 50% of the submerged but parasitized eggs yielded parasitoids even after being submerged (Fig. 3) (Parducho et al. 1988).

Involving rice farmers in biocontrol of RBB

Any efforts at biological control of insect pests in general and RBB in particular should involve the rice farmer at the inception (Ooi 1996). This will ensure that the tactics that are used will fit into a practical system that can be used by farmers. Experiences over the last decade suggest that a farmer
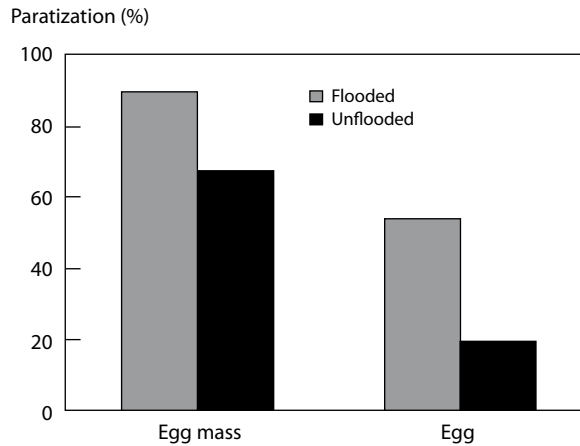
Fig. 2. Effect of flooding on percent parasitism.
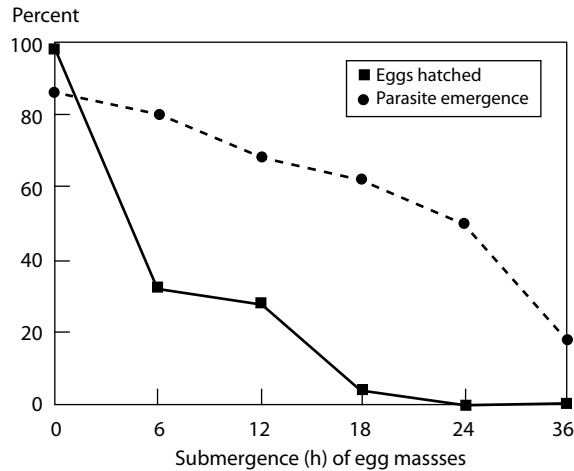
Fig. 3. Effect of submergence on egg mortality
and parasite emergence.

field school (FFS) approach is the first step toward farmer education. This approach is well described by Pontius et al. (2002). After farmers have obtained skills in experimentation at the FFS, they could become effective research partners to researchers (Ooi 1998). Some guidelines to discover biological control is provided by Ooi et al. (1991) and these exercises can be adapted to discover biocontrol of RBB.

Of particular interest to both farmers and researchers is the level of egg parasitism following augmentative or introductory releases of an egg parasitoid, e.g., *T. triptus.* Farmers can be grouped

together to work with researchers to collect egg masses from the field and keep them separately in clear plastic/glass vials. The number of eggs per batch, number parasitized, number healthy. and number unemerged can be recorded by farmers with support from researchers. Using this method, a more definitive set of data will be collected and the involvement of farmers will greatly facilitate buy-ins from farmers in the successful implementation of biological control.

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Biological Control of the Rice Black Bug, *Scotinophara coarctata* (Fabricius) (Hemiptera: Pentatomidae)

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Abstract

Periodic monitoring of the rice black bug (RBB) *Scotinophara coarctata* (Fabricius) and its natural enemies in North Cotabato was done to determine the occurrence of the major biological control agents associated with RBB in the field. A scelionid wasp, *Telenomus triptus,* and a green muscardine fungus, *Metarhizium anisopliae,* were observed in RBB-infested areas. These organisms varied in temporal and spatial occurrence in North Cotabato. Based on percentage parasitized eggs, *T. triptus* parasitization was higher (55%) during the early stages of crop growth than during the reproductive stages (24%). In contrast, percentage infection of RBB nymphs and adults by *M. anisopliae* was generally observed to be very low during the vegetative stage; however, at reproductive stage, incidence of infection gradually increased beginning at 1 wk (2%) until 4 wk after flowering (as high as 18% per 25 hills). The RBB population was generally higher on transplanted rice (TPR) than on direct-seeded rice (DSR) fields based on the number of egg masses (46 and 20) and the number of nymphs and adults m^{-2} (470 and 206). However, percentage of parasitized egg masses and incidence of *Metarhizium*-infected RBB seemed to be very low (8%) for both DSR and TPR fields. Field release of *T. triptus* at the rate of 2,800 parasitoids 16 m^{-2} resulted in 96% increase in percentage parasitism at 6 d after release, while a slight increase (12%) in egg mass parasitism was observed in untreated plots. The rate of release of the egg parasitoid significantly affected the degree of egg parasitism. Egg parasitism increased as the rate of release of the egg parasitoid was increased. Parasitism was significantly higher (72%) when 24,000 egg parasitoids were released 1,250 m^{-2} or at the rate of 168,000 parasitoids ha^{-1}. Likewise, field evaluation of the efficacy of *M. anisopliae* applied through irrigation water at the rate of 1 x 10^{13} conidia ha^{-1} reduced 30% of the RBB population in the field in 7 d. Results of this investigation imply that biological control agents such as *T. triptus* and *M. anisopliae* can be mass-produced and applied in the field to augment the existing natural enemy population, and can thus be used in RBB management.

Key words: rice insect pest, rice black bug, biological control, *Telenomus triptus*, *Metarhizium anisopliae*

Introduction

The rice black bug (RBB), *Scotinophara coarctata* (Fabricius), is a serious insect pest of rice in various areas of the Philippines. Unlike other pests, RBB attacks the rice plant at all stages of growth from seedling to ripening by sucking the sap of the plant. Damage caused by this pest could result in 60-80% yield reduction; however, in severe cases, complete crop loss could occur due to bug burn when infestation is extremely high. *S. coarctata* is known to occur in the South and Southeast Asian countries of Bangladesh, India, Indonesia, Malaysia, Myanmar, Pakistan, Sri Lanka, Thailand, Vietnam (COPR 1976, Grist and Lever 1969), Cambodia (Reissig et al. 1985), and the Philippines (Mochida et al. 1982). The first reported incidence of RBB in the Philippines was in Bonobono, Bataraza, south Palawan, in September 1979. A major outbreak of this pest occurred in June 1982 where about 4,057 ha of rice fields were severely infested (Mochida et al. 1982). Ten years later, RBB infested rice crops in Mindanao, particularly in Curuan, Zamboanga City, in June 1992 and damaged about 2,070 ha of rice fields. Since then, RBB infestation has gradually spread over vast rice areas in Mindanao. In 1998, RBB traveled far and settled in the Visayas region, particularly in Sta. Catalina, Negros Oriental, in January and in Kabankalan, Negros Occidental, in September. In 1999, RBB infestation was observed in Bohol. RBB infestation spread all over Mindanao and some parts of the Visayas. In late 2005, RBB infestation was reported in the Bicol region in Luzon. The movement and dispersal of RBB in other rice-growing areas in the country and the tremendous damage they inflict on rice plants can hinder the country's goals of self-sufficiency in rice and sustainable food security.

The use of chemical insecticides was the main approach implemented in managing RBB during outbreaks. However, the characteristic behavior of the insect renders chemical control ineffective for RBB management. For this reason, other alternative management strategies were developed.

Under natural field conditions, RBB is found associated with natural enemies. These are living organisms that attack RBB and, in so doing, reduce the RBB population in the field. Among these natural enemies or beneficial organisms, *Telenomus triptus*, an egg parasitoid, and *Metarhizium anisopliae*, a fungus that infects the nymphs and adults of RBB, are found in RBB-infested fields. However, information on the ability of these naturally occurring biological control agents in reducing RBB population is scanty. Thus, this paper aimed a) to know the effect of different crop establishments on the occurrence of primary biological control agents, b) to determine the occurrence of *Telenomus* and *Metarhizium* in the field, and c) to determine the efficiency of the egg parasitoid *T. triptus* and green muscardine fungus *M. anisopliae* in reducing RBB population.

Materials and methods

Determination of occurrence of primary biological control agents of RBB

Crop establishment

Rice variety IR56 was planted using the two methods of crop establishment: direct-seeded rice (DSR) and transplanted rice (TPR). Plants were seeded at the same time, except that for the TPR crop, plants

were seeded in a seedbed and transplanted 25 d after sowing at the rate of one seedling per hill. Rice plants were planted at 20- × 20-cm planting distance in a 6- × 4-m plots.

Monitoring of RBB population
Weekly monitoring of the RBB population and its natural enemies through actual counts was made. The following data were taken: a) number of egg masses m^{-2}, total number of egg masses, number of egg masses parasitized, and percentage parasitism; b) egg count: number of eggs per egg mass, number of parasitized eggs, and percentage parasitism; c) number of nymphs m^{-2}, number of nymphs infected with *Metarhizium,* and percentage infection; and d) number of adults m^{-2}, number of adults infected with *Metarhizium,* and percentage infection.

Evaluation of effect of crop growth stage on occurrence of natural enemies of RBB

Different rice varieties, which include PSBRc 4, -6, -8, -10, and -18; IR56, IR60, and IR64; C4-137, C4-63G, BPI Ri 10, and rice line T16256, were monitored for the presence of RBB at the vegetative and reproductive stages of crop growth. The egg masses were collected, counted, and the number of parasitized egg masses and parasitized eggs were taken to determine parasitization. These egg masses were individually placed in test tubes for parasitoid emergence. The number of eggs that turned black were considered parasitized, while those eggs that were not parasitized turned pinkish when about to hatch. When the RBB has already emerged, eggs exhibited whitish coloration.

Evaluation of efficiency of *Telenomus triptus* as an egg parasitoid of RBB

Planting of Taro as host plant for RBB
Taro, *Colocasia esculenta* Schott. suckers were collected and planted in an area near the banana plantation inside the PhilRice-Midsayap experiment station. The usual care and management practices in growing taro were followed. These taro plants were used as host plants for the RBB.

Mass rearing of egg parasitoid T. triptus
Two strategies in rearing RBB were followed: one was the use of rice plants in clay pots, which were confined in nylon netting, and the other was the use of rice plants in petri dishes provided with cut pieces of taro stalk. RBB adults were collected from the field or from the cultures of RBB in caged potted plants and were brought to the laboratory for sorting. The insects were placed in petri dishes at the rate of seven individuals per petri dish at 4:3 male to female ratio. Daily collections of egg masses were made. These egg masses were placed in sterilized petri dishes and were used as host for the egg parasitoid, *T. triptus.*

    T. triptus were mass produced in the laboratory using newly laid egg masses of RBB. Egg masses were collected daily and mounted on a paper strip at the rate of 7-10 egg masses per paper strip. Egg masses on paper strips were introduced to the stock cultures of *T. triptus,* which were confined in

oviposition tubes (100 × 15 mm). These egg masses were exposed to the parasitoids for 24-48 h. After oviposition, parasitized egg masses were incubated for 1 wk under laboratory conditions. Parasitized egg masses on paper strips were used in the field releases.

Field evaluation of T. triptus

Two trials were conducted to determine the efficiency of the egg parasitoid, *T. triptus,* against the RBB. During the first trial, 2,800 parasitoids 16 m^{-2} were released. In the second trial, the rate of release was reduced to 784 parasitoids 16 m^{-2}. Each trial was replicated three times. Egg parasitism was evaluated 6 d after release (DAR).

In the 2002 wet season, the efficiency of *T. triptus* against RBB was evaluated using the following rates of release as treatments: T1=control (no parasitoids released), T2=7,000 parasitoids, T3=14,000 parasitoids, and T4=21,000 parasitoids. Treatments were replicated three times and were arranged in randomized complete block design (RCBD). Efficiency of the egg parasitoid was determined based on egg parasitism at 4 DAR.

Evaluation of efficacy of *M. anisopliae* in managing RBB population

Mass production of M. anisopliae

Metarhizium anisopliae was mass produced in the laboratory using palay substrate. Two hundred grams of palay were placed in polypropylene plastic bag (9 × 16 in) and 200 ml water was added to the substrate. Palay and water were mixed thoroughly. A PVC ring was placed at the open end of the plastic bag and was secured with a rubber band. The plastic bag was finally sealed with cotton plug. The substrate was sterilized in a pressure cooker at 15 psi for 1 h. The sterilized palay substrates were allowed to cool before inoculation. The palay substrates were inoculated with 2-5 ml conidial suspension of *M. anisopliae*. Inoculated substrates were incubated at 25 °C for 2 wk.

Field application of M. anisopliae

Comparative efficiency of different application methods of **M. anisopliae**

The field efficacy of *M. anisopliae* against RBB was evaluated in Midsayap, North Cotabato using PSBRc 18. Seedlings were transplanted at two-three seedlings per hill at a distance of 20 × 20 cm. The experiment was laid out in RCBD with the following treatments: a) sprayed, b) irrigated, c) broadcast, and d) untreated control. Treatments were replicated four times. The plants were maintained following the procedures in growing rice without insecticide application (Estoy 1999).

Application of **M. anisopliae** *through irrigation water*

Two-week-old cultures of *M. anisopliae* were added with equal volume of Tween solution (02% v/v) as wetting agent. Palay substrates with *Metarhizium* were applied in the field through the irrigation water. During the day of application, the field was drained in the morning to allow the bugs to move down the basal part of the plant near the soil surface.

Then, late in the afternoon, the moistened palay substrates with the fungal materials were placed on the water inlets before water was conveyed onto the rice field. *M. anisopliae* was applied at 36 d after transplanting (DAT) at the rate of 1 x 10^{14} conidia ha^{-1} or 50 bags (200 g bag^{-1}) per hectare. RBB counts were made before application and at 7 and 14 d after application (DAA).

Results and discussion

Occurrence of primary biological control agents of RBB

Weekly monitoring of the RBB population and the occurrence of its primary biological control agents on both DSR and TPR from 44 to 93 d after seeding (DAS) revealed an increasing trend of RBB population on both DSR and TPR fields. On the basis of number of egg masses observed, (Fig. 1a) and on the number of RBB nymphs and adults m^{-2} (Fig. 1b), RBB population was generally higher on TPR than on DSR. However, percentage parasitism of RBB egg masses did not vary much in both crop establishment methods, with 36% and 35% parasitized egg masses on DSR and TPR, respectively. The number of egg masses was generally lower during the early stages of crop growth (44-51 DAS). The highest number of egg masses (69 and 39 egg masses m^{-2}) were observed at the reproductive stage (79 DAS) on TPR and DSR, respectively. However, at ripening stage (86-93 DAS), the number of egg masses gradually declined (Fig. 1). A greater percentage of RBB egg masses were parasitized

No. of RBB egg masses 25 hills^{-1}
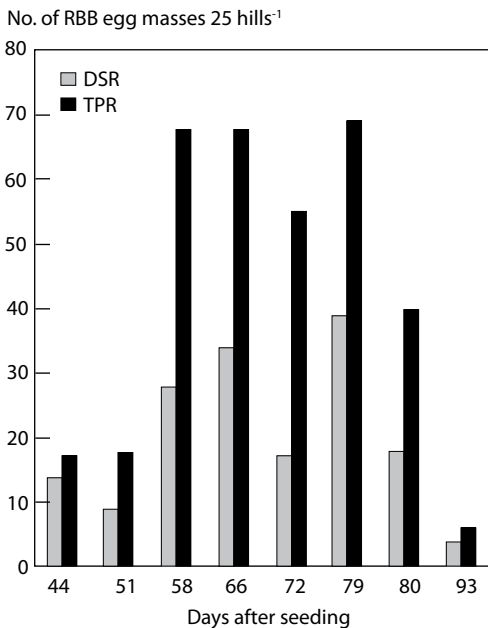
Fig. 1a. Egg mass counts on direct-seeded rice (DSR) and transplanted rice (TPR).

No. of RBB nymphs/adults 25 hills^{-1}
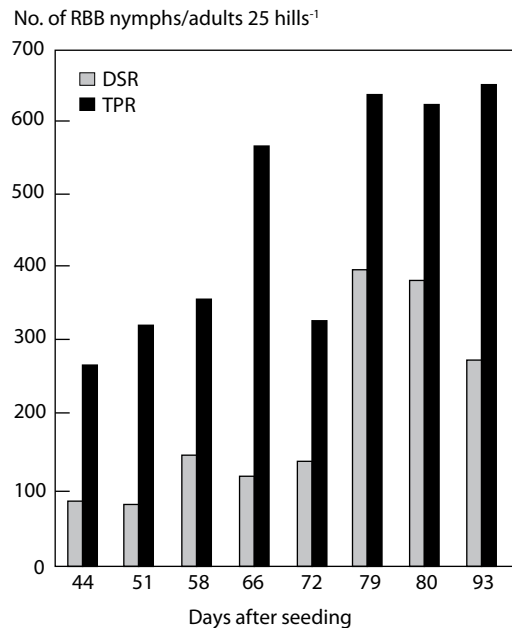
Fig. 1b. Rice black bug (RBB) *Scotinophara coarctata* population on direct-seeded rice (DSR) and transplanted rice (TPR).

Table 1. Parasitism of the rice black bug, *Scotinophara coarctata* (Fabricius) eggs caused by the egg parasitoid, *Telenomus triptus* on different rice varieties at vegetative and reproductive stages of crop growth.

Variety	Vegetative stage			Reproductive stage		
	Egg mass 25 hills^{-1}	Parasitized egg mass	% egg parasitism	Egg mass 25 hills^{-1}	Parasitized egg mass	% egg parasitism
PSBRc 4	2	2	86.30	9	5	9.24
PSBRc 6	2	2	95.31	11	9	30.05
PSBRc 8	5	5	87.68	12	8	10.41
PSBRc 10	8	7	48.62	3	2	33.83
PSBRc 18	2	2	44.70	12	8	11.24
IR50	1	1	23.08	9	8	29.24
IR60	1	1	41.02	10	6	26.65
IR64	1	1	17.65	3	3	22.86
C463G	7	7	52.24	12	12	31.55
C4137	3	3	69.64	11	10	22.59
BPIRi 10	3	3	63.83	10	10	35.00
T16256	2	2	28.17	19	17	27.83
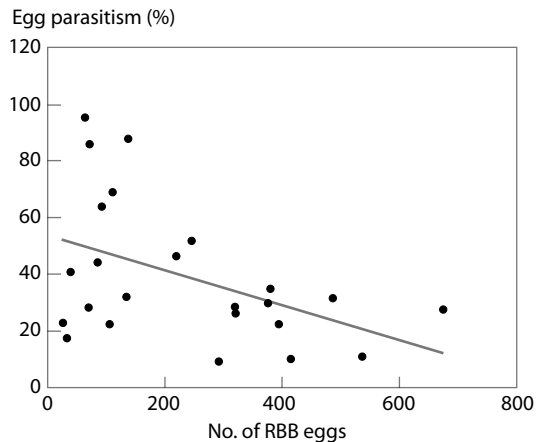
Fig. 2. Relationship between number of eggs and egg parasitism (%) of the rice black bug *Scotinophara coarctata* (Fabricius) in the field.

by *T. triptus* at early stages of crop growth, when the number of egg masses (1-8) laid was low, but as the number of egg masses during the reproductive stage (3-19) increased, percentage of parasitized eggs was reduced (Table 1). A negative correlation (r= -0.45*) between number of egg masses in the field and percentage of parasitized eggs was obtained (Fig. 2). Based on recent findings, *T. triptus* caused a greater percentage of parasitism under field conditions. Perez et al. (1989) reported that the most abundant natural enemy species against RBB in Palawan was the egg parasitoid *T. triptus*. However, the level of egg parasitism due to this egg parasitoid was low. In our investigation, percent egg parasitism ranged from 18 to 95% at vegetative stage and 9 to 35% at reproductive stage. Most of the eggs in an egg mass were parasitized at random (45%) with a few egg masses parasitized at the
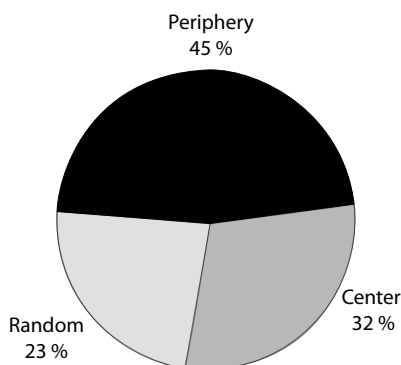
Fig. 3. Distribution of egg parasitization patterns of the egg parasitoid, *Telenomus triptus* at Bual Norte, Midsayap, North Cotabato (1997).

center (23%) (Fig. 3). This could probably be explained by the egg-guarding behavior of the female RBB (Corbett and Yusope 1924). However, IRRI (1987) reported that parasitoids could scout for RBB egg masses more easily when the female is guarding the egg mass. It was suspected that the female may emit an olfactory cue, which could guide female parasitoids in locating the host eggs.

Incidence of *Metarhizium*-infected RBB in the field

The incidence of *Metarhizium*-infected RBB was generally higher during the later stages of the rice plant. The mean percentage infection observed was 8% on both the DSR and TPR fields, with 17% as the highest percentage infection observed on DSR at 65 DAS. Among the reported entomogenous fungi affecting the RBB, such as *Paecilomyces lilacinus*, *Beauveria bassiana,* and *M. anisopliae*, only *M. anisopliae* was found to infect RBB in Midsayap, North Cotabato. However, in Palawan, two fungal species were found affecting RBB population, *M. anisopliae* and *P. lilacinus*, but incidence of these two entomopathogens was very low (Rombach et al. 1987). However, since the infected insects often drop into the paddy water and could not be determined, mortality due to fungal infection could probably be underestimated (Rombach 1986).

Field evaluation of the efficiency of *T. triptus*

Field trials on the efficiency of laboratory-reared *T. triptus* released at the rate of 2,800 parasitoids 16 m^{-2} against RBB showed an increase in percentage parasitized egg masses by 96% at 6 DAR compared with an increase of 12% parasitized egg masses on untreated plots, indicating a significant increase in the level of parasitism resulting from the artificial field release of the parasitoids (Table 3). However, during the second trial, when the number of parasitoids was reduced to 800 parasitoids 16 m^{-2}, no significant increase on egg parasitism was observed. In the 2002 wet season, the effects of the different rates of release of *T. triptus* on the efficiency of the egg parasitoid were evaluated. The initial egg parasitism ranged from 20 to 40%. At 4 DAR, egg parasitism (72%) was significantly

Table 3. Field efficiency of *Telenomus triptus* as egg parasitoid of the rice black bug *Scotinophara coarctata* (Fabricius).[a]

Treatment	Percentage parasitism		
	Initial	6 DAR	% increase in parasitism
		1st trial[b]	
Treated	20.97	41.30	96.95 a
Untreated	36.33	40.67	11.95 b
		2nd trial[c]	
Treated	36.31	54.04	49.00 a
Untreated	41.58	61.11	47.00 a

[a]In a column, means having a common letter are not significantly different from each other at the 5% level by DMRT. [b]A total of 2,800 parasitoids 16 m^{-2} were released. Av of three replicates. [c]A total of 784 parasitoids 16 m^{-2} were released. Av of three replicates.

Table 4. Effect of the different rates of release on the efficiency of the egg parasitoid *Telenomus triptus* against the rice black bug *S. coarctata* in the field.

Rate of release 1250 m^{-2}	Computed rate of release ha^{-1}	% egg parasitism[a]	
		Initial mean ± SE	4 DAR mean ± SE
0	0	28.97 ± 5.10	21.12 ± 3.85a
7,000	56,000	20.34 ± 6.56	26.99 ± 5.88ab
14,000	112,000	39.97 ± 7.23	54.11 ± 4.24b
21,000	168,000	39.57 ± 6.02	71.67 ± 4.16c

[a]In a column, means having a common letter are not significantly different from each other at the 5% level by DMRT.

higher when 21,000 egg parasitoids were released in a 1,250-m^2 field as compared with egg parasitism when 7,000 and 14,000 parasitoids were used with 27% and 54% egg parasitism, respectively. Results showed that egg parasitism increased as the rate of release was increased (Table 4).

Field evaluation of efficacy of *M. anisopliae* against RBB

Field application of *M. anisopliae* using different application methods revealed that RBB (nymph and adult) populations were reduced in all *M. anisopliae*-treated plots, regardless of application method used. At 7 DAA, the greatest population reduction was noticed in plots applied with *Metarhizium* through irrigation water (30%). However, at 14 DAA, RBB populations tended to increase in all the treatments, with the least population increase observed in the irrigated (11%) treatment, while the population in the untreated plots increased by 54% (Fig. 4). These findings show that *M. anisopliae*

Population increase/decrease
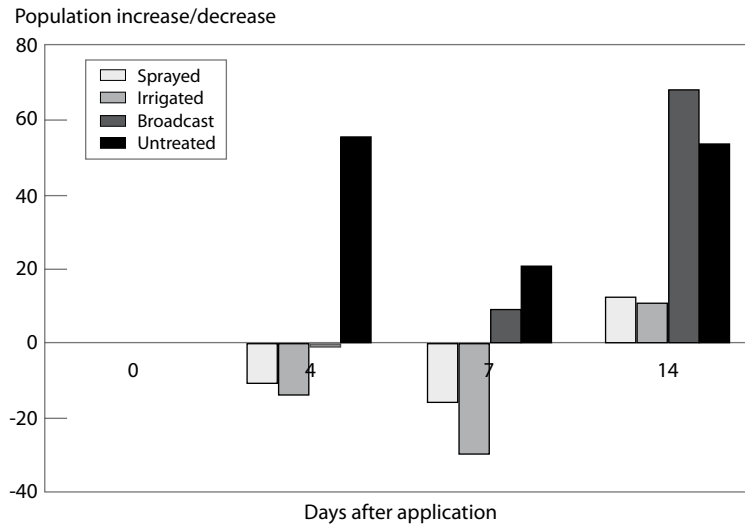
Fig. 4. Field efficacy of *Metarhizium anisopliae* against the rice black bug *Scotinophara coarctata* (Fabricius) using different application methods.

can reduce 30% of the RBB population in the field in 7 d (Estoy et al. 1998a,b). Likewise, Rombach et al. (1986) reported that RBB populations were significantly reduced by fungal application compared with the control over a period of 9 wk. In Japan, the use of conidia of *M. anisopliae* was found most effective against the RBB, which caused about 40-100% mortality of the insects for 2 mo (Morimoto 1957). Our recent findings showed that *Metarhizium* reduced RBB population at 7 DAA when applied through irrigation water at the rate of 10^{14} conidia ha^{-1}. Rates of conidia within the range of 10^{12}–10^{13} conidia ha^{-1} have been widely applied in tests with entomogenous fungi—to mention some, the use of *Beauveria bassiana* against *L. decemlineata* (Fargues et al. 1980) and the use of *M. anisopliae* for the biological control of spittle bugs on sugarcane in Brazil (Ferron 1981).

Conclusions and recommendations

The egg parasitoid *T. triptus* and green muscardine fungus *M. anisopliae* were found in the field from vegetative to reproductive stages of crop growth. However, the occurrence of these beneficial agents is not usually in proportion to the RBB population, hence they cannot cope with the increasing RBB population, particularly at the later stages of crop growth. Field releases of these beneficial agents increased the percentage parasitism of RBB eggs and reduced the number of RBB population in the field. Likewise, *M. anisopliae* infect RBB and reduce RBB population in the field. Thus, *T. triptus* and *M. anisopliae* can be mass-produced for artificial field releases in order to augment the natural enemy population in the field. These natural enemies can be used in RBB management.

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Bioecological Studies on Rice Black Bug *Scotinophara coarctata* (Fabricius) in Cotabato, Mindanao, Philippines

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Abstract

Rice black bug (RBB), *Scotinophara coarctata* (Fabricius), is a migratory pest of rice in rainfed and irrigated environments in Mindanao. Development from egg to adult ranged from 57 to 70 d (63.7 ± 0.84 d). Eggs hatched in 3–4 d and nymphs passed five instars in 54–66 d. Adult longevity averaged 105.4 d. Fecundity ranged from 37 to 63 eggs per female with 20–59 eggs per mass and 3–7 egg rows per egg mass. A scelionid wasp, *Telenomus triptus,* was found to parasitize RBB eggs. Red ants, *Solenopsis geminata* (Fab.); coccinellid beetle, *Micraspis crocea* (Mulsant); and black and brown crickets, *Metioche vittaticollis* (Stål.) and *Anaxipha longipennis* (Serville) attacked RBB eggs. A fungal pathogen, *Metarhizium anisopliae* (Sorokin) Metschnikoff, and toads attacked both nymphs and adults of RBB. Prey consumption rate of toads ranged from 32 to 46 RBB per day in both field and screenhouse conditions, while infection rate of *M. anisopliae* under natural field occurrence ranged from 0.038% to 10.22%. Four-year data (1996-99) on the light trap catches in Cotabato showed unusually high RBB population in the first 2 yr of infestation. RBB population was higher during the dry season (January to June) than during the wet season (July to December). Peak catches in light traps were recorded during the full moon period. Light-attracted adults survived in 22–66 d when they were given food, but they lasted for only 4 d without food and water. Adults collected had a 1:1 male to female ratio. Females caught in the light trap were still capable of laying eggs. Among the 155 females collected from the light trap, 59 (37%), 33 (21%), and 7 (5%) laid eggs once, twice, and thrice, respectively, while in captivity. However, the viability of the eggs laid decreased from 94% during the first egg laying to 34% in the third oviposition.

Key words: rice black bug, life history, natural enemies, population fluctuation, survival, sex ratio, reproductive status

Introduction

The rice black bug (RBB), *Scotinophara coarctata* (Fabricius), is a serious pest of rice in some parts of the Philippines. It has been reported as a pest of rice in Malaysia (Corbett and Yusope 1972), Myanmar, India, Indonesia, Sri Lanka, Thailand, and Vietnam (Miyamoto et al. 1983). It was also reported in Bangladesh, Pakistan, and south China (Hill 1983).

The first incidence of RBB in the Philippines was reported in Bonobono, Bataraza, south Palawan, in 1979. It reached outbreak proportion in March-June 1982; it later spread toward central and northern Palawan (Barrion et al. 1982). In late June 1992, RBB infestation was reported in Curuan, Zamboanga City, damaging around 2,000 ha of rice fields toward the end of the year (Simbajon 1992). In March 1995, RBB become a serious pest in the Autonomous Region of Muslim Mindanao. From there, RBB infestation dramatically spread to other rice-growing areas in Mindanao. In 1996, RBB was observed in North Cotabato, Sultan Kudarat, and South Cotabato.

Both RBB nymphs and adults attacked the rice plant at all growth stages. They feed at the base of the rice plant, sucking the plant sap from the stem and nodes. During the tillering stage, their feeding results in damage to the central shoots, causing "deadheart." Affected plants are stunted and tiller number is reduced (Reissig et al. 1985), Feeding during the reproductive stage affects panicle development and exsertion and panicles have empty grains known as "whiteheads." Heavy infestation may result in stunting and total drying of the rice plants, a condition known as "bug burn."

Adults and nymphs aggregate at the base of the rice plants just above the water level and move up the plant at night or during when weather is overcast. They are weak fliers but can be transported over long distances by wind, ships, and other means of transportation (Chang et al. 1991). Adults are attracted to light and more light trap catches were recorded during the full moon and least around the new moon period (Ito et al 1993).

This paper presents bioecological studies on RBB during the 4-yr infestation period (1996-99) in North Cotabato and discusses practical implications on pest management. These studies were conducted to determine the biology and ecology of the pest, determine the population fluctuations of RBB, know the effect of rainfall on the population fluctuations of RBB, and know the survival and reproductive status of RBB collected from light traps.

Materials and methods

Study site

The experiment was conducted at PhilRice Midsayap from 1996 to 1999. This site is located in Barangay Bual Norte, municipality of Midsayap, province of North Cotabato. Crops grown include rice in the lowland areas and mango, coconut, and assorted dryland crops such as corn, sugarcane, upland rice, and vegetables in the highland areas. It has a climate with no pronounced dry and wet season, with a 2–3 dry-month period. The source of irrigation was the Libungan River Irrigation System, which allows farmers to plant two to three croppings per year.

Life history of RBB

The life history studies were undertaken at PhilRice Midsayap using 10 pairs of RBB adults collected in a heavily infested field. Each pair was placed in individual petri plates lined with moistened tissue paper and sliced stem of gabi (*Colocasia esculenta* L.) as food and oviposition substrate. The use of gabi stem (instead of the rice plant) was less laborious.

Host plants were changed every 3−6 d due to rapid deterioration. The egg masses were collected daily and transferred to individual petri plates for hatching. Fifty-five newly emerged nymphs were selected and placed in individual petri plates with sliced gabi stem as their food. Daily observations were done to determine the number and duration of nymphal stages. Longevity and fecundity were determined from newly emerged adult bugs. In the fecundity study, dead insects were replaced to maintain a 1:1 male and female ratio in individual petri plates.

Natural enemies of RBB

RBB egg masses were collected from different cultivars at different growth stages at the PhilRice Midsayap crop protection research area. The collected egg masses were placed in individual petri plates and incubated for 1 wk at room temperature to study parasite emergence and parasitism. The data gathered included a) number of egg masses collected 25 hills[-1], b) number of egg masses parasitized, c) total egg count, d) number of eggs parasitized, and e) percent parasitism.

Predation and fungal infection by the entomopathogen were observed in the heavily infested farmers' fields during monitoring. Predators that were observed to feed on RBB were collected and recorded, then brought to the laboratory for further confirmation of their predatory behavior. Likewise, natural occurrence of fungal infection by *Metarhizium anisopliae* was assessed at different growth stages of the rice plant.

Seasonal abundance

Installation of light trap

A light trap with a 20-watt fluorescent tube was installed near the experimental field of PhilRice Midsayap in July 1996. The trap was provided with a hood and mylar plastic to protect the trap. The light trap was operated at 6 p.m. and switched off at 6 a.m. the following day. The trap was provided with a container with soap solution.

Monitoring of RBB

Weekly monitoring of RBB population using a fluorescent light trap was made. Light trapping was done every Monday of the week and collection of the light trap catches was made the following day. Light trap catches were brought to the laboratory where they were sorted and counted.

In a separate observation, light trap catches in mercury and fluorescent light traps were taken 5 d before and 5 d after the full moon period. Adults caught weekly were brought to the laboratory for sorting, counting, and recording.

Determination of relationship between RBB population and rainfall

Rainfall data were obtained from the Engineering Section of PhilRice Midsayap, Bual Norte, Midsayap, Cotabato. Occurrence of RBB was correlated with rainfall using the Microsoft excel program.

Determination of sex ratio of RBB

Samples of RBB population in the field and those collected from the light traps were taken. The sample population was sorted and the number of males and females recorded; male to female ratio was determined.

Determination of RBB survival

Live RBB adults were collected early in the morning from the fluorescent light trap funnel to which they had been attracted the previous night. Five pairs of RBB adults were placed in petri plates with different host plants. One group of RBB adults was kept in petri plates with food and another group was kept without food and water. Survival period was determined from the different treatments in five replications.

Determination of reproductive status of RBB caught from light traps

One hundred and fifty RBB females caught from light traps were individually placed in petri plates as oviposition cage. The oviposition cage was provided with cut pieces of gabi stem as food substrate for RBB. RBB female adults were allowed to lay eggs in captivity. Data on the number of females that laid eggs, number of eggs laid, and percentage viability of the eggs laid were taken.

Statistical analysis

Data were statistically analyzed using IRRISTAT and subjected to ANOVA. Differences among means were tested for significance using the least significant difference test.

Results and discussion

Life history and behavior

RBB adult females laid their eggs in masses of 20-59 eggs per mass, arranged longitudinally in 3−7 rows (Table 1). The egg is cylindrical, shiny with pale greenish color when laid, turning pinkish as it matures. The female RBB adult guards her eggs by staying on top of the mass. Eggs hatched in 3−4 d (3.1 ± 1.10 d). Hatched eggs were 80−100%. During hatching, the operculum is thrust off by each emerging nymph with its egg buster. Eggs within a mass hatched on the same day but not at the same time. Newly hatched nymphs remain aggregated on the dorsal surface of the empty egg chorion after which they scattered themselves and feed on the gabi stem.

Before the molting of nymphs, they remained motionless for 2-7 min. The nymph is brown in color with yellowish green abdomen. Newly emerged nymphs undergo five instars under room temperature. The total nymphal period ranged from 54 to 66 d (60.1 ± 0.45 d). The total developmental

Table 1. Life history parameters of *Scotinophara coarctata* (Fabricius) reared in sliced gabi stem at PhilRice Midsayap.

Parameter	Range	Mean[a]
Oviposition period (d)	2-10	6.7 ± 0.89
Egg incubation period (d)	3-4	3.1 ± 1.10
Nymphal development (d)		
First instar	3-4	3.0 ± 0.71
Second instar	20-24	20.7 ± 0.89
Third instar	7-16	9.5 ± 1.52
Fourth instar	8-14	10.1 ± 1.79
Fifth instar	13-20	15.8 ± 1.34
Total nymphal period (d)	54-66	60.1 ± 0.45
Total developmental period (d)	57-70	63.7 ± 0.84
Eggs laid female^{-1} (no.)	37-63	49.7 ± 0.55
Eggs egg mass^{-1} (no.)	20-59	38.3 ± 1.14
Egg row egg mass^{-1} (no.)	3-7	5.7 ± 0.55
Adult longevity (d)	30-180	105.4 ± 0.55

[a]Mean ± SD. n = 55.

period from egg laying to adult emergence ranged from 57 to 70 d (63-7 ± 0.84 d). Adult longevity ranged from 30 to 180 d (105.4 ± 0.55 d) (Table 1). An adult RBB measures 7−9 mm long, has black head, yellowish brown antennae, dark brown thorax, pale to dark brown abdomen, and brown legs with reddish brown tibiae and tarsi. Adults give off an offensive odor when touched or disturbed.

Mating took place any time of the day and lasted 3-10 h, especially if it is not disturbed. During copulation, both sexes faced opposite directions. Oviposition began 2-10 d after copulation, usually any time of the day. The female glued the eggs singly, forming the first row before starting a second row. Usually, the hind legs guided egg deposition. Mating was seen to recur several hours after egg laying.

Natural enemies

A scelionid wasp, *Telenomus triptus,* parasitized RBB eggs (Table 2). Parasitism was higher during the vegetative stage than during the reproductive stage of the rice plant. Results imply a greater ability of the parasitoid to search for their host at the vegetative than at the reproductive stage. This was attributed to the dense canopy of the rice plant at the reproductive stage, where the adult parasite found it difficult to locate its host. Parasitized egg masses were 97.30% (Fig. 1). However, only 58.63% of the eggs per egg mass were parasitized. At the reproductive stage, 80.99% of the egg masses were parasitized, whereas only 23.80% of the eggs were parasitized by *Telenomus* sp.
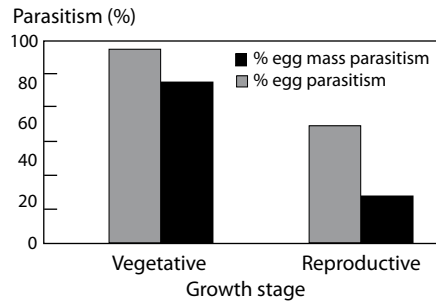
Fig. 1. Parasitism of RBB eggs by *Telenomus triptus* at vegetative and reproductive stages of the rice plant in Midsayap, Cotobato.
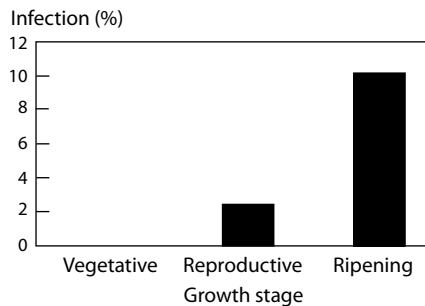
Fig. 2. Natural occurrence of RBB infected with *Metarhizium anisopliae* in Midsayap, Cotobato, Oct. 1996 to Feb. 1997.

A fungal pathogen, *Metarhizium anisopliae,* attacked both the nymphs and adults of RBB. Under natural field occurrence, RBB infected with the pathogen was 0.04% at the vegetative stage, 2.52% at the reproductive, and 10.22% at the ripening stage (Fig. 2). The results imply that RBB mortality increased with time.

Toads attacked both nymphs and adults of RBB. The prey consumption rate of toads under field and screenhouse conditions is presented in Table 3. The number of RBB nymphs and adults recovered 24 h after release did not differ significantly between young and adult toads under both field and screenhouse conditions. The prey consumption rate of a toad per day ranged from 34 to 46 RBB nymphs and adults under field condition and from 32 to 46 under screenhouse condition, respectively, suggesting that toads can be potential biocontrol agents of RBB.

The red ants, *Solenopsis geminata* (Fab.); coccinellid beetle, *Micraspis crocea* (Mulsant); and black and brown crickets, *Metioche vittaticollis* (Stål.) and *Anaxipha longipennis* (Serville) attacked RBB eggs. Spiders preyed on RBB eggs, nymphs, and adults (Table 2).

Table 2. Natural enemies of RBB in Midsayap, Cotabato.

Natural enemy	Egg	Nymph	Adult
Parasitoid			
Hymenoptera			
Scelionidae			
Telenomus sp.	*		
Pathogen			
Metarhizium anisopliae (Sorokin**)**		*	*
Predators			
Coleoptera			
Coccinellidae			
Micraspis crocea (Mulsant)	*		
Orthoptera			
Gryllidae			
Metioche vittaticollis (Stal.)	*		
Anaxipha longipennis (Serville)	*		
Hymenoptera			
Formicidae			
Solenopsis geminata (Fabr.)	*		
Spider	*	*	*
Toad		*	*

Table 3. Prey consumption rate of toad under field and screenhouse conditions at PhilRice Midsayap.

Toad size	Field[a]	Screenhouse[a]
	RBB nymphs and adults recovered (no.)	RBB nymphs and adults recovered (no.)
Young	34.00 ± 0.70	32.00 ± 0.71
Adults	46.00 ± 0.71	46.00 ± 0.71
Difference	-12.00 ns	-14.00 ns
LSD (5%)	15.87	20.54

[a]Av of eight replications. ns = not significant.

Population fluctuations of RBB

Four-year (1996-99) population data of RBB in North Cotabato showed a decreasing trend since the outbreak was observed in 1996 (Fig. 3). The population peak was observed 6 mo after the outbreak. Occurrence of RBB in the area posed serious rice production problems for 3 consecutive years, after which the population was maintained at low levels. The same trend in RBB population was observed
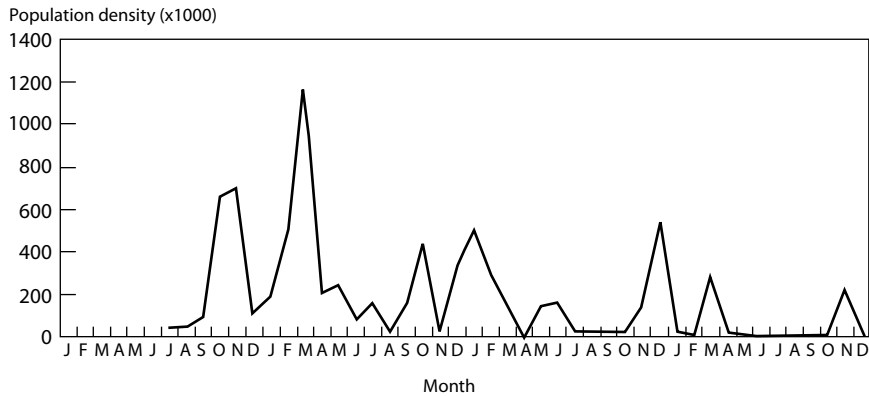
Fig. 3. Population fluctuations of rice black bug in Mid sayap, Cotobato (1996-99).
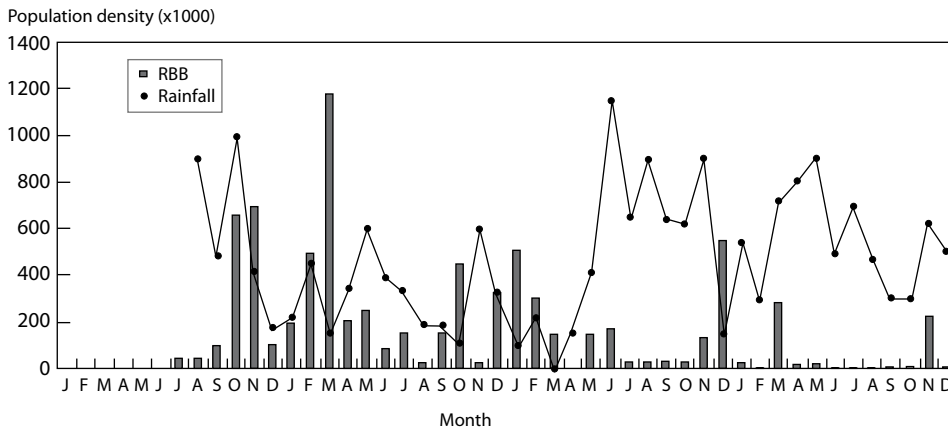
Fig. 4. Relationship between RBB population and rainfall in Midsayap, Cotobato (1996-99).

in Malaysia in 1980−82 and in Palawan in 1984−86 (de Sagun 1991). A negative correlation (r= -0.22) between light trap catches and rainfall was observed (Fig. 4). High RBB population was generally observed during the dry season and during the full moon (Fig. 5). The results conform with previous findings of Ito et al. (1993), that RBB adults are attracted to light and that more light trap catches were collected during full moon and least when there was a new moon. More RBB adults were attracted to the mercury light trap than to the fluorescent light trap.

Survival of RBB adults collected in light traps

The survival of RBB adults caught in the light traps was studied; the insects were provided sliced gabi stem, banana petiole, and cotton wad with water. A group of bugs was deprived of food and water. The results are presented in Table 4.

RBB adults caught (no.)
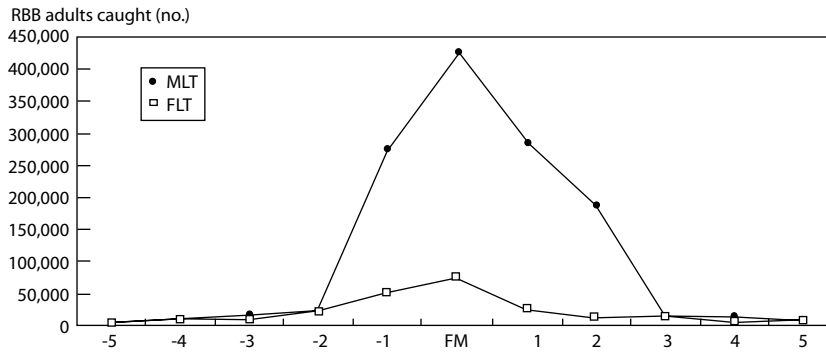
Fig. 5. Mean number of RBB adults caught from fluorescent light trap (FLT) and mercury light trap (MLT) 5 d before and 5 d after the full moon period. PhilRice Midsayap, Jan-Dec 1997.

Table 4. Survival of RBB adults collected from light traps reared in different host plants[a] at PhilRice Midsayap, 1997 wet season.

Treatment	Survival (d)[b]
No food and water	4.00 ± 0.82 a
Cotton wad with water	22.75 ± 0.50 ab
Banana petiole	23.00 ± 0.82 ab
Gabi stalk/stem	66.00 ± 0.80 b

[a]Av of four replications. 10 RBB adults per replication. [b]Mean ± SD. In a column, means followed by the same letter are not significantly different at the 5% level by LSD.

Considerable variations in survival period of light-attracted adults were noted on the different treatments. RBB adults reared on gabi stem significantly survived longer (66 d) than those reared on banana petiole (23 d) and cotton wad with water (22.75 d), respectively. RBB adults collected from light traps without food and water died within 4 d (Table 4).

Sex ratio of RBB caught in light traps
Samples of RBB population caught in the super light and fluorescent light traps yielded 45% and 55% males and females, respectively (Table 5). A similar trend was observed in Palawan where field collections showed 44% males and 56% females, whereas samples from light trap-collected population had 49% and 51% males and females, respectively. The sex ratio of the light trap catches was 1:1 male to female, while RBB population in the field showed a 1:2 male to female ratio (Table 6). This result could be due to the egg-guarding behavior of the females; the females that already laid eggs will not leave their eggs, hence, they are not caught in the light trap.

Table 5. Sex ratio of RBB caught in light traps.

Light trap	Male	Female	Total	Male-female ratio
Super light (2000 watts)	2,135	2,865	5,000	1:1.2
Fluorescent (20 watts)	720	780	1,500	1:1.1

Table 6. Sex ratio of RBB collected in the field.

Place collected	Male	Female	Total	Male-female ratio
San Pedro, Midsayap	31	72	103	1:2.3
Central Glad, Midsayap	152	350	502	1:2.3
Upper Glad, Midsayap	88	122	210	1:1.4
Palongoguen, Midsayap	40	85	125	1:2.1
Agriculture, Midsayap	37	73	110	1:2.0
Salunayan, Midsayap	103	122	225	1:1.2
Bual Sur, Midsayap	41	89	130	1:2.2
Central Bulanan, Midsayap	51	71	122	1:1.4
Bual Norte, Midsayap	250	449	699	1:1.8
Bubunao, Midsayap	75	121	196	1.1.6

Table 7. Reproductive status of RBB adults caught in light traps at PhilRice Midsayap.

Oviposition	Females that oviposited (no.)	Duration (d)	Eggs laid (no.)	Eggs laid female^{-1} (no.)	Viability (%)
1st oviposition	58 (37%)	2-28	1,385	24	93.79%
2nd oviposition	33 (21%)	9-21	800	24	82.38
3rd oviposition	7 (5%)	15	137	20	33.58

Reproductive status of RBB females collected in light traps

Of the 155 female RBBs collected from light traps, 56.77% (88) died after 2 d in captivity. However, 37% (58), 21% (33), and 5% (7) laid eggs once, twice, and thrice, respectively. Viability of the eggs laid was 94, 82, and 34% during the first, second, and third oviposition, respectively (Table 7). The ability of RBB females to lay eggs while in captivity implies that RBB has the capacity to store and utilize sperm once the female egg is ready for fertilization. This result further implies that some of the RBBs collected in the light trap have the ability to multiply and produce offspring as manifested by their high fecundity and fertility. Hence, light trap catches should be destroyed to avoid further increases in RBB population. The result agrees with previous findings of Apao et al. (1997) that about 68% of RBB females caught in light traps were still reproductively active and capable of producing 69–255 eggs before they died.

Summary and conclusion

The development of RBB from egg laying to adult stage averaged 63.7 d. Eggs hatched in 3–4 d and nymphs passed five instars in 54–66 d. Adult longevity averaged 105.4 d, while fecundity ranged from 37 to 63 eggs per female with 20–59 eggs per mass and 3–7 egg rows. Under natural field occurrence, egg parasitism was higher in the vegetative than in the reproductive stage of the crop, while fungal infection by *M. anisopliae* was highest at ripening. Peak catches in light traps were observed during the full moon.

The increase in RBB population can be alarming for a period of 2 yr, starting from the onset of RBB infestation. After such a period, RBB population will decline below damaging level. It is thus recommended that effective management strategies for RBB be instituted immediately once the bugs are observed in the field to prevent further increases in population. Light trap catches should be destroyed to reduce the RBB population and to minimize the movement of RBB to other areas.

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Taxonomy of the Egg parasitoids of Rice Black Bug, *Scotinophara* spp.

Andrew Polaszek and Rajmohana Kumar

Abstract

Current knowledge of the egg-parasitoids of *Scotinophara* species is presented. A key to all known species is provided, with detailed accounts of species actually encountered in the field. The following data are provided: original description reference, synonyms, *Scotinophara* hosts and alternative hosts, and geographical distribution by country.

Key words: ooparasitoids, biological control, integrated pest management, Hymenoptera, Scelionidae

Introduction

Throughout the range of *Scotinophara* rice black bug species in East, South, and Southeast Asia, only six species of egg parasitoids, all belonging to the family Scelionidae, are of economic importance as either actual or potential natural control agents of these pests. By far the most important and common of these is the scelionid *Telenomus triptus* Nixon, the range of which extends from India to Borneo, where it attacks several *Scotinophara* species. Recent studies (Barrion andJoshi, *in litt.*) suggest that *T. triptus* may consist of a complex of cryptic species, possibly including two undescribed species, although detailed investigations on antennal and genitalia morphology (Polaszek, unpubl. data) do not support this. The eulophid *Trichospilus pupivora* has been associated with *Scotinophara* in error (Debjani Dey et al. 1999) following an erroneous interpretation of a published report (Hutson 1937).

Egg parasitoid species recorded from *Scotinophara* species

Family Scelionidae

***Psix lacunatus* Johnson & Masner**   ex *S. coarctata* (Philippines: Barrion and Litsinger 1987, Arida et al. 1988–greenhouse / laboratory host <1% parasitization)

***Telenomus chloropus* Thomson**   ex *S. coarctata* (Philippines: Arida et al. 1988–laboratory host <1% parasitization); ex *S. lurida* (unpubl. record).

***Telenomus cyrus* Nixon**   ex *S. coarctata* (Philippines: Arida et al. 1988–laboratory host <5% parasitization); ex *S. latiuscula* Barrion and Litsinger 1987–probable misidentification of *T. triptus. T. cyrus* is a common parasitoid of *Nezara viridula* (L.) and is therefore included in this review as host-switching between *N. viridula* and *Scotinophara* species is likely.

***Telenomus gifuensis* Ashmead**   ex *S. lurida* (Katsumata 1930, Hidaka 1958)
ex *S. scotti* Horvath (Ryu and Hirashima 1985)

***Telenomus triptus* Nixon**   ex *S. coarctata* (Philippines: Perez and Shepard 1992, Parducho et al. 1988, Shepard et al. 1988). ex *S. lurida* (Sri Lanka: unpubl. record).

***Trissolcus basalis* (Wollaston)**   ex *S. coarctata* (Philippines: Arida et al. 1988–laboratory host <1% parasitization).

Key to genera and species

Although the probability is that only *Telenomus gifuensis* (in Japan) and *T. triptus* (in South and Southeast Asia) are the only genuine, naturally occurring egg parasitoids of *Scotinophara* species, we provide here a key to separate the genera and species of Scelionidae that have been previously recorded from *Scotinophara*.

1.   Head with longitudinal striations or ridges laterally (arrowed, Fig. 1)................*Psix lacunatus*
Head without longitudinal striations or ridges laterally (Figs. 2, 3 2

2.   Front of head between antennal insertions and anterior ocellus predominantly sculptured (arrowed, Fig. 2); female antennal clava with six segments.................................*Trissoclus basalis*

Front of head between antennal insertions and anterior ocellus predominantly smooth (arrowed, Fig. 3); female antennal clava with five segments... 3

3. F1 of female antenna clearly less than twice as long as wide (arrowed, Fig. 4), and shorter than pedicel ....*Telenomus triptus*
   F1 of female antenna clearly more than twice as long as wide (arrowed, Figs. 5, 6), and longer than pedicel 4

4. Female antenna as in Fig. 5; F2 only slightly shorter than F1, and approximately 1.5 x as long as F3 ....*Telenomus gifuensis*
   Female antenna as in Fig. 6; F2 clearly much shorter than F1, and only slightly longer than F3... 5
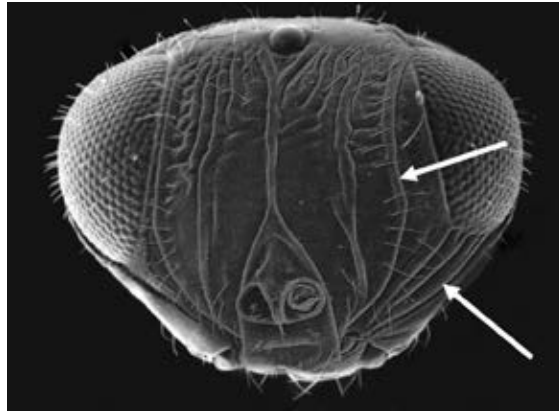
Fig. 1. *Psix* species with facial striations shown by arrows.
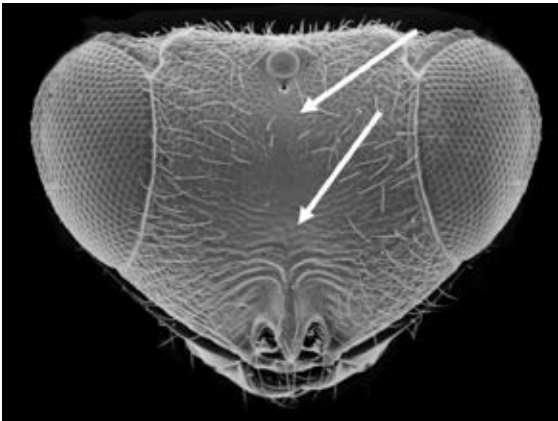
Fig. 2. *Trissolcus* species, with frontal sculpture shown by arrows.

Fig. 3. *Telenomus chloropus*, with lack of frontal sculpture indicated by arrows.

Fig. 4. *Telenomus triptus* **female antenna.**

Fig. 5. *Telenomus gifuensis* **female antenna.**

Fig. 6. *Telenomus chloropus* **female antenna.**

Fig. 7. *Telenomus chloropus* **male antenna.**

5. Head with junction of vertex and occiput strongly angular, without extensive reticulate sculpture. Legs entirely dark brown to black...*Telenomus chloropus*
    Head with junction of vertex and occiput rounded, with extensive reticulate sculpture. Legs entirely pale brown to yellow.. *Telenomus cyrus*

Since, to the authors' knowledge, *Psix lacunatus* and *Trissoclus basalis* have been recorded only once from *Scotinophara* eggs and, based on the same report (Arida et al. 1988), we do not deal with them in any detail here.
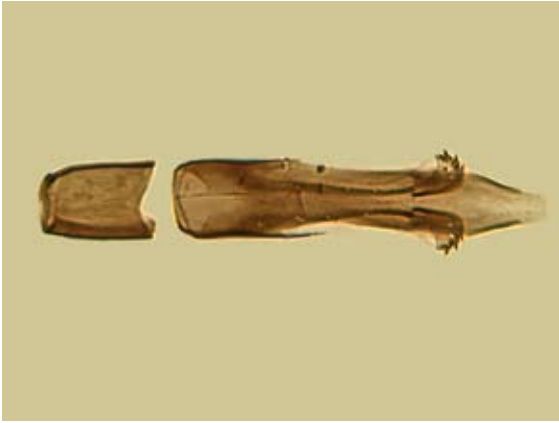
Fig. 8. *Telenomus chloropus* **male genitalia.**
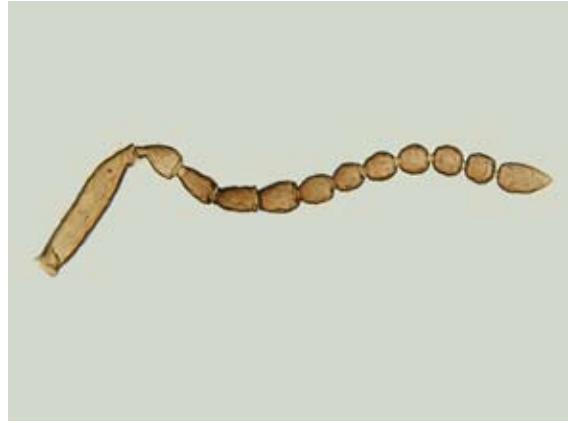
Fig. 9. *Telenomus triptus* **male antenna.**

Species accounts

Telenomus chloropus (Thomson)
(Figs. 3, 6, 7, 8)

Phanurus chloropus Thomson, 1861: 173
Synonyms: *T. sokolowi* Mayr, *T. tischleri* Nixon
Scotinophara hosts: *S. coarctata*; ? *S. lurida*

Alternative hosts: Pentatomidae: *Aelia furcula* Fieber, *A. rostrata* (Boheman), *Carpocoris fuscispinus* (Boheman), *Dolycoris baccarum* (L.), *Eysarcoris ventralis* (Westwood), *Graphosoma lineatum* (L.), *Nezara viridula* (L.), *Palomena prasina* (L.), *P. viridissima* (Poda), *Perillus bioculatus* (F.), *Piezodorus rubrofasciatus* (F.). Scutelleridae: *Eurygaster austriaca* Schranck, *E. integriceps* Puton, *E. maura* (L.).

Distribution: Entire Palaearctic from Western Europe to Japan. Present in the Philippines as a laboratory host only. Unsuccessfully introduced into southern USA in the late 1980s (W.A. Jones, *in litt*.).

Remarks: The association with *S. lurida* may stem from the period when *T. gifuensis* (see below) was regarded as a synonym of *T. chloropus*. *T. gifuensis* was removed from that synonymy by Johnson (1984).

The female antenna of *T. chloropus* is illustrated in Figure 7, the male antenna and genitalia in Figures 7 and 8, respectively.
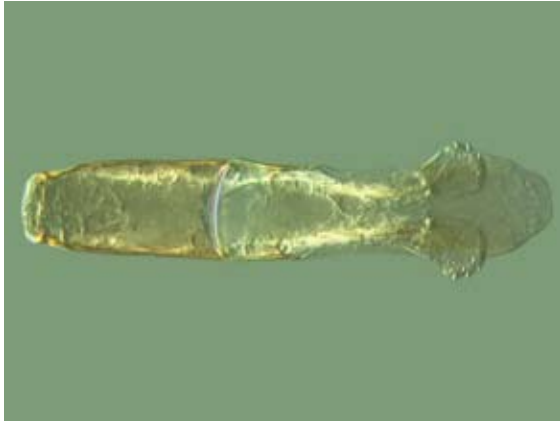
Fig. 10. *Telenomus triptus* male genitalia.

Fig. 11. *Telenomus cyrus* female antenna.

Telenomus cyrus Nixon
(Fig. 11)

Telenomus cyrus Nixon, 1937: 448-450
Synonyms: None
Scotinophara hosts: *S. coarctata*; *S. latiuscula*
Alternative hosts: Pentatomidae: *Nezara viridula* (L.)

Distribution: India, Java, Philippines

Remarks: As stated earlier, at least one record of *T. cyrus* appears to be based on a misidentification, so observations that *T. cyrus* really attacks *Scotinophara* sp. eggs await confirmation.

The female antenna of *T. cyrus* is almost identical to that of *T. chloropus* (Fig. 7); the male genitalia closely resemble those of *T. triptus* (Fig. 8), although this observation is not based on type material, as Nixon described the species from females only.

Telenomus gifuensis Ashmead
(Fig. 5)

Telenomus gifuensis Ashmead, 1904: 72-73.
Synonyms: None
Scotinophara hosts: *S. lurida*, *S. scotti* Horvath
Alternative hosts: Coreidae: *Acanthocoris concoloratus* Uhler; *Riptortus clavatus* Thunberg. Pentatomidae: *Dolycoris baccarum* (L.); *Eysarcoris guttiger* Westwood; *E. parvus* Uhler; *E. ventralis* Thunberg; *Nezara antennata* Scott; *Piezodorus hybneri* (Gmelin), *P. rubrofasciatus* (F.).

Distribution: Japan

Remarks: An extensive account of the biology of *T. gifuensis* was published by Hidaka (1958) following an earlier study by Katsumata (1930). Hidaka's study provides descriptions of the immature stages, the seasonal life cycle, and fecundity. He found that, on average, each female produced about 95 eggs, with a recorded minimum and maximum of 38 and 143, respectively. However, the proportion of progeny that developed successfully was much lower than the actual number of eggs laid, with an average of about 70. Sex ratios were in the region of one male to 3.5 females. Successful development can take place only on eggs 5 d old or less, with the percentage of emergence decreasing rapidly with each day. For example, eggs that were 1 d old produced 98% emergence while 5-d-old eggs produced 25% emergence. An interesting observation regarding longevity is that adult wasps fed on aphid honeydew live twice as long as those fed on honey or sugar solution.

Telenomus triptus Nixon
(Figs. 4, 9, 10)

Telenomus triptus Nixon, 1937: 447, 452
Synonyms: None
Scotinophara hosts: *S. coarctata; S. lurida*
Alternative hosts: *Eysarcoris guttiger* (Thunberg), *Piezodorus hybneri* (Gmelin)

Distribution: Japan, Malaysia (Peninsula and Sarawak); Philippines, Sri Lanka.

Remarks: A mass-rearing technique for *T. triptus* is provided by Perez and Shepard (1992). The effect of flooding rice plants on percentage parasitism by *T. triptus* was studied by Parducho et al. (1988) and Shepard et al (1988). As well as attacking *Scotinophara* spp. in rice, *T. triptus* is reported to be an important natural enemy of *Eysarcoris guttiger* and *Piezodorus hybneri* in soya bean. Higuchi (1993) rates *T. triptus* as the predominant parasitoid of *P. hybneri* and strongly supports its use as a biocontrol agent. His studies on the seasonal prevalence of adult *T. triptus* in relation to its pentatomid hosts yield significant data on the migratory behavior of these parasitoids in synchrony with that of their hosts. Icuma and Hirose (1996) have studied the effect of temperature on the development and survival of *T. triptus* on eggs of *P. hybneri* and *E. guttiger* in the laboratory, predicting its reproductive success through estimating the number of parasitoid generations per year on both hosts.

According to Barrion and Joshi (*in litt.*), there may be two additional species closely related to *T. triptus* attacking *S. coarctata* in the Philippines. Further taxonomic investigations, perhaps including DNA sequencing studies, are necessary to confirm this.

The female antenna of *T. triptus* is illustrated in Figure 4, and the male antenna and genitalia are shown in Figures 9 and 10, respectively. The genitalia figure is based on Nixon's (1937) specimen (i.e., a paratype) on which the original figure was based.

Discussion

All the species treated above are solitary, primary endoparasitoids, although facultative hyperparasitism by *T. chloropus* of *Trissolcus semistriatus* has been reported. Females generally oviposit into the base or the side of the host egg, only rarely through the operculum, presumably due to its greater thickness. Females almost certainly mark the host egg after oviposition, as with most *Telenomus* species. Fecundity is extremely variable under different conditions and between individuals. There are three larval instars. The developmental period from egg stage to adult emergence is almost certainly variable and dependent on temperature and other factors but has been recorded to be 18−24 d in *T. chloropus* and 10−19 d in *T. gifuensis* (Hidaka 1958).

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The Food Web of the Invasive Rice Black Bugs of the World, *Scotinophara* spp., and its Application to Biological Control

E.DT. Navarrete and A.T. Barrion

Abstract

Field observations and laboratory evaluation of potential natural enemies of rice black bugs (RBB), coupled with literature and internet searches, were conducted to gather information on the different *Scotinophara* spp., their distribution and, most importantly, their natural enemies and secondary players. The details gathered were compiled and documented in order to produce the food web of one of the most destructive pests of the rice plant, "the invasive RBB of the world," the genus *Scotinophara*. The collected information served as the foundation for the development of the RBb food web. Experts had been consulted, earlier works had been put together, and the RBB food web has been developed. Based on the gathered information, the food web of the *Scotinophara* spp. comprises 70 species: 39 predators, 17 parasitoids/parasites including 4 entomopathogens, 32 hyperpredators, and 7 hyperparasitoids. The dominant predators are Coleoptera (11), Araneae (7), Aves (5), Orthoptera (4), Dermaptera (3), Salientia (3), Hymenoptera (3), Hemiptera (2), and Lepidoptera (1). The dominant parasites/ parasitoids/ entomopathogens are Hymenoptera (8), Entomophthorales (4), Nematoda (3), and Acarina (2). There are 39 species of secondary natural enemies, which include hyperpredators such as Araneae (15), Coleoptera (11), Aves (5), Hymenoptera (3), Salientia (3), Dermaptera (3), and hyperparasitoids such as Hymenoptera (4), Acarina (1), Diptera (1), and Neuroptera (1). There are 512 linkages that comprise the RBB food web: 56 linkages on predation and parasitism on RBB, 7 linkages on hyperparasitism, and 449 linkages on hyperpredation. Data regarding action and identification of natural enemies, host ranges, and bioecology were compiled to give emphasis on and to device a biological control method against RBB.

Key words: food web, *Scotinophara* spp., rice black bug, natural enemies, hyperparasitoids, hyperpredators

Introduction

The rice black bug (RBB), *Scotinophara* spp. (Hemiptera: Pentatomidae), is regarded as a newly emerging pest associated with rice in South and Southeast Asia. This insect is known to survive well on rice and, in evolutionary terms, has coevolved with the rice plant. From an economically unimportant pentatomid, it has become one of the major pests of rice.

The *Scotinophara* spp. has been recognized in Asia as early as the 1920s—Malaysia (Yusope 1921, Corbett et al. 1924, South 1926, Corbett 1927, Miller and Pagden 1930, Yunus et al. 1975, Miyamoto et al. 1983); Laos (FAO 1975); Indonesia (Konningsberger 1903, Van Stetten 1922); Sri Lanka (De Alwis 1941); India (Maxwell Lefroy 1909, Krishna Ayyar 1929, Rao 1977); Senegal (Trinh 1980), Taiwan (Chen et al. 1982); China (Fernando 1960, Grist and Lever 1969); Japan (Hasegawa 1971); and the Philippines (Barrion et al. 1982).

Populations of RBB are usually kept low by the action of a wide range of natural enemies. Outbreaks reported in the tropics were usually associated with regular use of broad-spectrum chemical insecticides. The stronger the insecticide, the faster is the recovery of the pest populations due to the destruction of their natural enemies (Kenmore et al. 1994, Rombach et al. 1994). In unsprayed fields, the population of RBB does not increase to any significant level, suggesting the importance of biological control agents. Farmers gain knowledge about beneficial insects by carrying out experiments. When they discover the function of these natural enemies, they are less likely to use insecticides.

The objective of this study is to compile all information gathered from different documented works and field observations on the natural enemies of the RBB to develop a food web of the RBB and its natural enemies. In the study of the different species of RBB from different areas in the world, RBB natural enemies, host ranges, and bioecology were compiled to device a biological control method against this invasive insect.

Food web development

Field observations and laboratory evaluations of suspected natural enemies of RBB were conducted by the second author (Dr. Alberto T. Barrion) from 1982 to 1987 while he was working at the International Rice Research Institute (IRRI). This was continued in 2006-07 while he was a consultant entomologist at the Philippine Rice Research Institute (PhilRice) Los Baños.

Library work and internet search were done to gather the necessary information on different *Scotinophara* species and their documented natural enemies. All these information were recorded and compiled to develop a food web.

Predators, parasites/ parasitoids/ pathogens, hyperpredators, and hyperparasites were discussed and categorized to highlight their effects in regulating RBB population.

References about *Scotinophara* spp. and their natural enemies and secondary players were compiled from different parts of the world.

The natural enemies were tabulated according to occurrence and susceptible growth stage of the RBB.

With all the collected information, the food web has been developed (see figure).

Primary natural enemies of RBB: predators, parasites/parasitoids, and pathogens

The following analysis of actions of predators and parasitoids/parasites/pathogens is important in understanding the essential components of biological control in the field.

Predators

The arthropod predators of the RBB can be found throughout the rice field, including the parts below ground, as well as in nearby grasses and paddy. Some predators are specialized in their choice of prey, others are generalists. Some are extremely useful natural enemies of other insect pests. Unfortunately, some prey on other beneficial insects and pests as well.

RBB predators can be found in almost all agricultural habitats. Each group may have different life cycles and habits. Although the life history of some common predators is well studied, information on the biology and relative importance of many predatory species is lacking. In this document, we have included the more common and better understood beneficial predators.

Ants are efficient predators of RBB in the field. Three genera of ants were found effective biological control agents. Red ants, *Solenopsis geminata* (Fabricius) (Hymenoptera: Formicidae) are common in upland environments and in dry-seeded rice fields in rainfed wetlands. Other species are *Monomorium* sp. and *Pheidologeton* sp. These were found feeding on black bugs in all stages of its life cycle (eggs, nymphs, and adults). Ants may also prey on lepidopterous natural enemies such as the armyworm *Mythimna separata* (Walker), which also feeds on black bug egg masses, small nymphs of leafhoppers, planthoppers, and moths.

From the orthopterans, two crickets (family Gryllidae) and two long-horned grasshoppers (family Tettigoniidae) comprise the food web of the RBB. The sword-tailed cricket *Anaxipha longipennis* (Serville) and black cricket *Metioche vittaticollis* (Stål) (Orthoptera: Gryllidae) are predators of RBB eggs and minute nymphs. These predators are found in wetland and dryland habitats. *A. longipennis* and *M. vittaticollis* have the potential to suppress the population of RBB and lepidopterous pests such as eggs of striped stem borers, dark-headed stem borers, leaffolders, armyworms, whorl maggots, nymphs of leafhoppers, planthoppers, and green caterpillars. They are common in rice fields feeding on black bug eggs (Perez 1987).

The meadow grasshoppers, *Conocephalus longipennis* (de Haan) and *Conocephalus maculatus* (Le Guillou) (Orthoptera: Tettigoniidae), although leaf feeders, prefer RBB egg masses than leaves, whenever egg masses are present. These long-horned grasshoppers can consume two to four egg masses per day. When no eggs are present, two grasshoppers can consume an average of 19.7 leaves
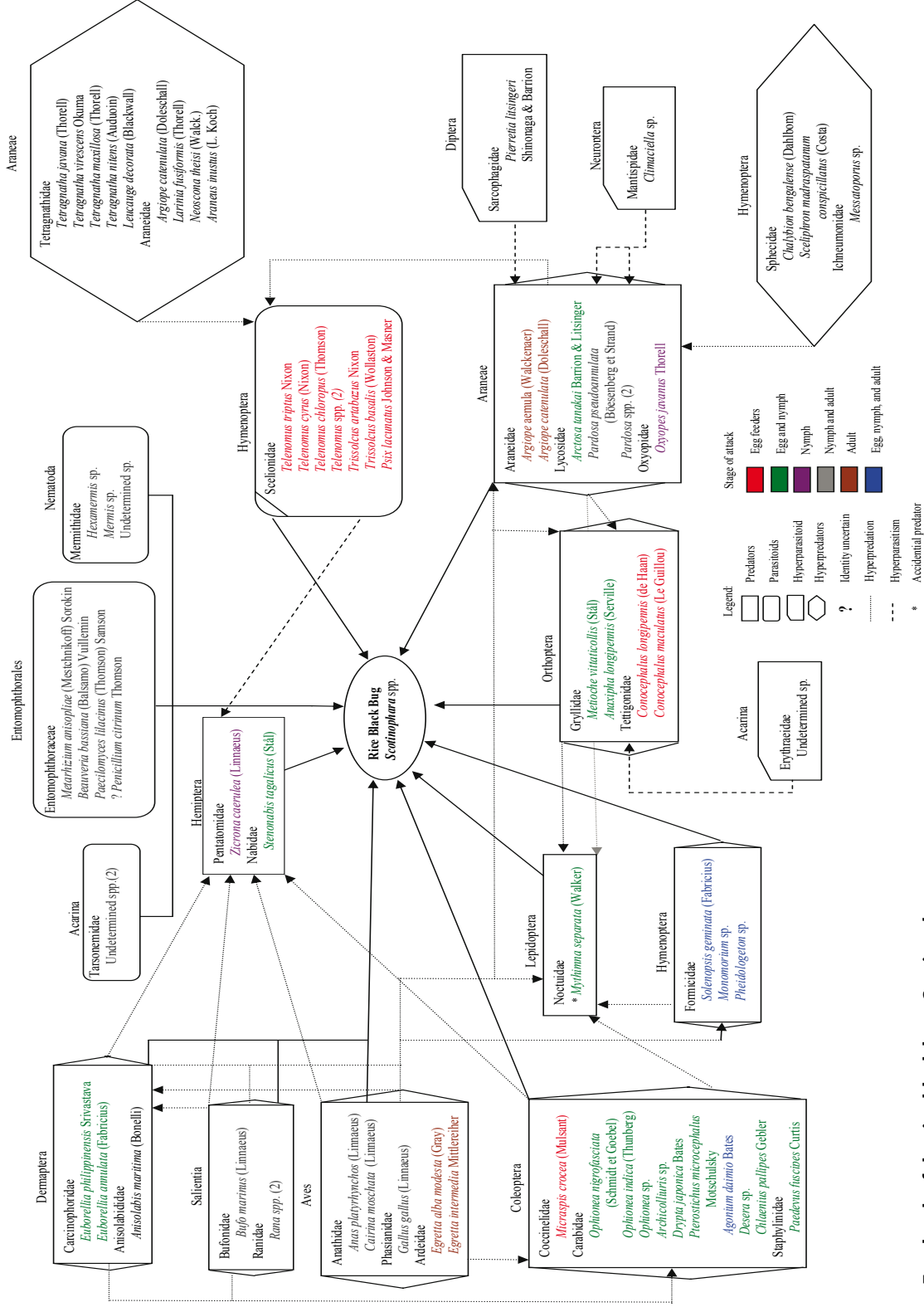
Food web of the rice black bug, *Scotinophara* spp.

per square meter. When egg masses were available, damaged leaves averaged 13.9, and the insect consumed five egg masses daily (IRRI 1988).

The meadow grasshoppers' alternate hosts are egg masses of stem borers, leaf feeders and ear-head bugs, nymphs of planthoppers and leafhoppers, eggs of golden apple snail, and armyworm larvae.

One Acarina belonging to family Erythraeidae was reported to be parasitizing the family Tettigoniidae, but the species is yet to be determined.

Beetles dominate the RBB food web, comprising 11 species (one lady beetle, nine ground beetles, and one staphylinid beetle).

A lady beetle, *Micraspis crocea* (Mulsant) (Coleoptera: Coccinellidae), was observed feeding on egg masses of RBB and first-instar nymphs. *M. crocea* was observed to feed on RBB egg masses in the rice field (Perez 1987). The larvae (grubs) are more voracious than the adults in terms of food consumed. The grubs are much more efficient feeders than the adults.

The lady beetle feeds on RBB eggs and minute nymphs. Its alternate hosts are nymphs of planthoppers and leafhoppers, aphids, scale insects, larvae of leaffolders, armyworms, and stem borers. It is also found on exposed eggs of harmful organisms.

The ground beetles, *Ophionea nigrofasciata* (Schmidt - Goebel), *Ophionea indica* (Thunberg), *Ophionea* sp., *Archicolliuris* sp., *Drypta japonica* Bates, *Pterostichus microcephalus* Motschulsky, *Desera* sp., and *Chlaenius pallipes* Gebler (Coleoptera: Carbide), feed on RBB egg masses and small nymphs. *Agendum daimio* Bates (Coleoptera: Carabidae) feeds on all stages of the RBB. These beetles can be used in the biological control of RBB.

The ground beetles are common in both wetland rice and dryland fields where they also pupate. They feed on RBB eggs and small nymphs. With their wide array of hosts, they may also feed on small soft-bodied insects and their eggs, planthopper nymphs and hairy caterpillars, semi-loopers, and newly hatched larvae of stem borers, armyworms, and leaffolders.

The staphylinid beetle, *Paederus fuscipes* Curtis (Coleoptera: Staphylinidae), is common in all cultivated ecosystems in the tropics. It feeds on RBB eggs and other soft first- and second-instar nymphs. It moves quickly over the foliage and often drops from the plant when disturbed. Adults and grubs are both predacious. It also feeds on other hemipterans, lepidopterans, and other soft-bodied insects and their eggs.

Spiders are efficient RBB feeders as well. Orb-web spiders, wolf spiders, and lynx spiders are natural enemies of RBB.

The orb-web spiders, *Argiope aemula* (Walckenaer) and *Argiope catenulata* (Doleschall) (Araneae: Araneidae), build webs to catch its prey. They are common in all rice environments, especially where RBBs are present as food. These spiders feed on RBB adults that are trapped in its web, mostly during the lunar cycle and during RBB migration. They also prevent RBBs from entering the rice fields.

Being generalist predators, *Argiope aemula* and *A. catenulata* may also feed on other arthropods present in the field, both the natural enemies and the pests themselves. These are the planthop-

pers, leafhoppers, caseworms, whorl maggots, stem borer adults, large butterflies, beneficial wasps, crickets, and grasshoppers.

The wolf spiders, *Arctosa tanakai* Barrion and Litsinger, *Pardosa pseudoannulata* (Böesenberg et Strand), and two undetermined species of *Pardosa* (Araneae: Lycosidae), are very active spiders. Spiders hunt for their prey such as RBB nymphs and adults. At high population density, spiders eat each other.

Wolf spiders are generalist predators, feeding on other arthropods in the field: planthoppers, leafhoppers, caseworms, leaffolders, whorl maggots, newly hatched larvae and moths of stem borers and armyworms.

The lynx spider, *Oxyopes javanus* Thorell (Araenae: Oxyopidae), is a direct hunter. It does not build webs. The spider prefers drier habitats and colonizes rice fields after canopy development. It feeds on a wide array of hosts such as RBB nymphs and small arthropods.

Lynx spiders may also feed on other arthropods such as armyworm larvae, planthoppers, leafhoppers, caseworms, leaffolders, stem borer moths, rice seed bugs, and whorl maggots.

The earwigs, known to be very important biological control agents in the field, can also be a natural enemy of the RBB. Three potential species of earwigs, *Euborellia philippinensis* Srivastava, *Euborellia annulata* (Fabricius) (Dermaptera: Carcinophoridae), and *Anisolabis maritima* (Bonelli) (Dermaptera: Anisolabididae), feed on RBB eggs and minute nymphs. They hide in the soil or in plant parts until night time when they search the rice plants for RBB egg masses and small RBB nymphs. They also feed on smaller soft-bodied insects. Earwigs may also feed on other species such as grubs of the family Carabidae, armyworm larvae (*Mythimna separata*), and other hemipteran eggs such as *Stenonabis tagalicus* and *Zicrona caerulea* (Linnaeus), both important predators of RBB.

Two hemipterans from the families Pentatomidae and Nabidae function as natural enemies of the RBB. A pentatomid, *Zicrona caerulea* (L.), and a nabid, *Stenonabis tagalicus* Stål, are important in controlling RBB populations.

Zicrona caerulea (Hemiptera: Pentatomidae) is an impressive predatory sucking bug that is capable of attacking and killing RBB nymphs (sucking the juices). Barrion and Litsinger (1987) reported results of their study on the node-feeding black bug, *Scotinophara latiuscula* (Breddin). The eggs of this predator are often parasitized by scelionid wasps and are preyed upon by beetles of the coccinellid, carabid, and staphylinid families. Dermapterans from families Carcinophoridae and Anisolabididae may hunt for egg masses of *Zicrona caerulea* and feed on them.

Stenonabis tagalicus Stål (Hemiptera: Nabidae) prey on egg masses and nymphs of RBB. It was first reported to be attacking the eggs and nymphs of the node-feeding black bug, *Scotinophara latiuscula* (Breddin) (Barrion and Litsinger 1987). The eggs of this predator are also preyed upon by beetles of the coccinellid, carabid, and staphilinid families. Adults are preyed upon by vertebrates such as Salientia and Aves.

A lepidopteran, the common armyworm or the rice ear-cutting caterpillar, *Mythimna separata* (Walker) (Lepidoptera: Noctuidae) is a well-known insect pest of rice but was reported to be feeding also on eggs and minute nymphs of RBB in Japan. *Mythimna separata* feeds on the leaves of the rice

plant and, during rice defoliation, devours the RBB egg masses present on the leaves (Katsumata 1930).

Although reported as a pest itself, *M. separata* is also a natural enemy of the RBB, feeding on the egg masses and first-instar nymphs of the RBB.

Amphibians such as frogs, *Rana* spp. (Salientia: Ranidae) and toads, *Bufo marinus* (Linnaeus) (Salientia: Bufonidae), being semiaquatic omnivores, prefer insects, behaving more like insectivores than omnivores themselves. They thrive in rice fields, especially when these are flooded, and in wet conditions and prey on every insect present such as *Scotinophara* spp. When rice fields are heavily infested with RBB, frogs and toads prove to be excellent biological control agents.

These amphibians, however, have a wide array of hosts. They may feed on other RBB natural enemies such as spiders from the family Araneidae; ants such as *Solenopsis geminata* and *Monomorium* sp. and *Pheidologeton* sp.; coleopterans such as the coccinellid, carabid and staphylinid beetles; Orthoptera (Gryllidae and Tettigoniidae), Dermaptera (Carcinophoridae and Anisolabididae), Lepidoptera (Noctuidae), and other hemipterans such as the pentatomid *Z. caerulea* and nabid *Stenonabis tagalicus*.

The birds are ravenous feeders of RBB as well. Domesticated fowls such as chickens, *Gallus gallus* (Linnaeus) (Aves: Phasianidae), and ducks, *Anas platyrhynchos* (Linnaeus) (Aves: Anatidae) and *Cairina moschata* (Linnaeus) (Aves: Anatidae), can consume great amounts of RBB when herded into the rice field.

Domestic fowls were observed to feed on the black bugs. It makes one wonder about the potential of using these fowls to control RBB while at the same time saving on feed cost (Ooi 1988).

In Japan, some experiments on the use of ducks to control *Scotinophara lurida* have been conducted at some agricultural experiment stations since 1924. Results showed that ducks effectively suppressed the insect population before the heading stage of the rice crop (Yamadoki 1926).

Other occasional feeders were migratory birds such as egrets *Egretta alba modesta* (Gray) and *Egretta intermedia* Mittlereiher (Aves: Ardeidae). They feed on the bigger nymphs and adults of RBB.

Being at a higher level in the food chain, these birds feed not only on RBBs but on beneficial insects and other pests as well. The alternate hosts of these birds are beetles, ants, crickets, bugs, planthoppers, leafhoppers, grasshoppers, stem borers, leaffolders, earwigs, and spiders.

Parasitoids/pathogens/parasites

The value of parasitoids as natural enemies is derived from the fact that insect parasitoids have an immature life stage that develops on or within a single insect host, eventually killing the host. Adult parasitoids are free-living and may be predacious. Parasitoids are often called parasites, but the term parasitoid is more precisely correct.

Only the Scelionidae family in the order Hymenoptera was found to be effective egg parasitoids against RBB. There were eight species of scelionid wasps recorded that parasitized the egg masses of RBB. Five species came from the genus *Telenomus*: *Telenomus triptus* Nixon, *Telenomus cyrus*

(Nixon), *Telenomus chloropus* (Thomson), and two undetermined species; two were from the genus *Trissolcus*: *Trissolcus artabazus* Nixon and *Trissolcus basalis* (Wollaston); and one from the genus *Psix, Psix lacunatus* Johnson and Masner.

Among the egg parasitoids of the RBB, *Telenomus triptus* Nixon was found to be the most effective in controlling the RBB population. Two *Telenomus* species were also proven to be effective, but they are yet to be determined. The other identified species, *Telenomus cyrus* (Nixon) and *T. chloropus* (Thomson), were also effective RBB parasitoids.

Another genus that controls the RBB population is the *Trissolcus* spp. *Trissolcus artabazus* Nixon and *T. basalis* (Wollaston) adults mate immediately after emerging from the host eggs. The female typically inserts one egg into a RBB egg. The heaviest parasitoid egg production occurs during the first few days after emergence.

Ooi (1988) reported two scelionid wasps, *Trissolcus artabazus* (Nixon) and *Telenomus triptus* Nixon, parasitizing the eggs of RBB and keeping the RBB populations at low levels in Malaysia.

Psix lacunatus Johnson and Masner is a small and black scelionid wasp and an egg parasite of moths and black bugs. It oviposits on the egg and leaves a scent, preventing other parasitoids from parasitizing the same egg. Parasitized eggs are grayish, with exit holes, whereas unparasitized eggs are white, with firm egg covers (Rice Doctor 2003).

These parasitoids also parasitize the egg masses of other pentatomids. *Trissolcus basalis* was reported on a wide range of pentatomid hosts (Quicke 1997). They also prey on *Zicrona caerulea* (L.), a hemipteran natural enemy of the RBB.

Acarina also plays an important role in the RBB food web. Two undetermined species of thread-footed mites belonging to family Tarsonemidae were reported and found parasitic on RBB. The mite feeds on the nymphs and adults of RBB (A.T. Barrion, unpubl.).

Three insect pathogens have been found infecting *Scotinophara* spp. (Hemiptera: Pentatomidae): *Metarhizium anisopliae* (Metschnikoff) Sorokin, *Beauveria bassiana* (Balsamo) Vuillemin, and *Paecilomyces lilacinus* (Thomson) Samson. Although *Penicillium citrinum* Thomson is uncertain, it is also included for further study.

Metarhizium anisopliae attacks RBB nymphs and adults, with the injury characterized by the formation of white extensive hyphal growths within the RBB body. *Metarhizium* mummifies the RBB and white conidiophores grow out through the cuticle within 24 h; profuse green spores follow 1-2 d later.

Metarhizium attacks the RBB with its green spores. These infectious spores germinate once they come in contact with the RBB epidermis. They form extensive hyphal growths within the RBB body, penetrating its blood vessels and invading its body cavity. They produce toxins that paralyze the pest and kill it. Then the fungus that develops on the surface of the dead RBB body initiates a new round of infection for other RBB. This remarkable chain reaction effectively reduces RBB populations in the field (PhilRice 2002).

Beauveria bassiana infection is characterized by the presence of white hyphae and white spores. There is usually a dense white growth of hyphae on the outer surface of the RBB epidermis. The oval, white spores can be seen clumped together into spore balls under high magnification. This fungus has been reported from a wide variety of hosts, including beetles, planthoppers, leafhoppers, stem borers, skippers, moths, earhead bugs, and grasshoppers. It is also commonly found infecting soil- inhabiting insects.

Paecilomyces lilacinus hyphae are white and form a thick mat over the entire RBB nymphs and adults. This fungus has stalks that are clubbed or enlarged at the tips. White oval spores are formed in clumps on the surface of these clubbed structures. This fungus is found to be infecting lepidopterans, coleopterans, and homopterans.

Katsumata (1930) reported *M. anisopliae* on *Scotinophara lurida* (Burmeister) in Japan. Morimoto (1957) reported on *M. anisopliae* and *P. lilacinus* and their use in the biological control of *S. lurida* in Japan. *P. lilacinus* was also reported infecting *S. coarctata* (Fabricius) in Malaysia (Ooi 1988).

Rombach et al. (1986) reported on the microbial control of black bug *S. coarctata* in the Philippines using *B. bassiana, M. anisopliae,* and *P. lilacinus*. In these experiments, single conidia and dry mycelium applications significantly reduced black bug populations over a 2-mo period.

Fernando (1960) reported two fungi, *M. anisopliae* and *Penicillium citrinum* Thomson, infecting *S. lurida* in Sri Lanka. The former is responsible for the green muscardine disease, but the latter has, to date, not been recorded as being entomogenous.

Nematodes are also included in the RBB food web. Three species of the mermithid nematodes were found attacking RBB nymphs and adults. The nematodes were *Hexamermis* sp., *Mermis* sp., and an undetermined species (Nematoda: Mermithidae).

The results are given of an investigation conducted from 1965 to 1970 on the mermithid parasite of nymphs and adults of RBB *Scotinophara lurida*, one of the important insect pests of rice in Turuga District, Fukui, Japan. There was a 38.7% mermithid infection in autumn (Yamamoto and Imamura 1971).

These nematodes enter their prey through body openings and kill their host within several days. The nematodes continue to produce and seek new prey.

The RBB natural enemies (predators, parasites, and pathogens) and the stages attacked are presented in Table 1, while some of its alternate hosts and supporting references are presented in Table 2.

Secondary natural enemies of RBB: hyperparasitoids/ hyperparasites and hyperpredators

The following section discusses the actions of the hyperpredators and hyperparasitoids/hyperparasites.

Table 1. Occurrence of natural enemies and susceptible growth stages of the invasive rice black bug, *Scotinophara* spp.

Egg	Stadia (nymphal instars)					Adult
	1st instar	2nd instar	3rd instar	4th instar	5th instar	
Telenomus triptus Nixon (Hymenoptera: Scelionidae)						
Telenomus cyrus (Nixon) (Hymenoptera: Scelionidae)						
Telenomus chloropus (Thomson) (Hymenoptera: Scelionidae)						
Trissolcus bassalis (Wollaston) (Hymenoptera: Scelionidae)						
Trissolcus artabazus Nixon (Hymenoptera: Scelionidae)						
Psix lacunatus Johnson and Masner (Hymenoptera: Scelionidae)						
Metioche vittaticollis (Stål) (Orthoptera: Gryllidae)	■					
Anaxipha longipennis (Serville) (Orthoptera: Gryllidae)	■					
Conocephalus longipennis (de Haan) (Orthoptera: Tettigoniidae)						
Conocephalus maculatus (Le Guillou) (Orthoptera: Tettigoniidae)						
Micraspis crocea (Mulsant) (Coleoptera:Coccinellidae)						
Agonium daimio Bates (Coleoptera:Carabidae)	■	■	■	■	■	
Archicalliuris sp. (Coleoptera:Carabidae)	■	■				
Chlaenius pallipes Gebler (Coleoptera:Carabidae)	■	■				
Desera sp. (Coleoptera:Carabidae)	■	■				
Drypta japonica Bates (Coleoptera:Carabidae)	■	■				
Ophionea nigrofasciata (Schmidt-Goebel)	■	■				
Ophionea indica (Thunberg) (Coleoptera:Carabidae)	■	■				
Ophionea sp. (Coleoptera:Carabidae)	■	■				
Pterostichus microcephalus Motschulsky	■	■				
Ophionea sp. (Coleoptera:Carabidae)	■	■				
Paedemus fuscipes Curtis (Coleoptera: Staphylinidae)	■	■				
Euborellia philippinensis Srivastava (Dermaptera: Carcinophoridae)	■					
Euborellia annulata (Fabricius) (Dermaptera: Carcinophoridae)	■					
Anisolabis maritima (Bonelli) (Dermaptera: Anisolabididae)	■					
Mytimna separata (Walker) (Lepidoptera: Noctuidae)	■					
					Argiope aemula (Walckenaer) (Araneae: Araneidae)	
					Argiope catenulata (Doleschall) (Araneae: Araneidae)	
Arctosa tanakai Barrion and Litsinger (Araneae: Lycosidae)	■	■	■	■	■	

Table 1 continued.

Egg	Stadia (nymphal instars)					Adult
	1st instar	2nd instar	3rd instar	4th instar	5th instar	
	████ *Pardosa pseudoannulata* (Böesenberg et Strand) (Araneae: Lycosidae) ████					
	████ *Pardosa* spp. (2) (Araneae: Lycosidae) ████					
	████ *Oxypes javanus Thorell* (Araneae: Oxyopidae) ████					
				████ *Metarhizium anisopliae* (Metschnikoff) Sorokin ████		
				████ *Beauveria bassiana* (Balsamo) Vuillemin ████		
				████ *Paecilomyces lilanicus* (Thomson) Samson ████		
					████ *Penicillium citrinum* Thomson ████	
			████ *Hexamermis* sp. (Nematoda: Mermithidae) ████			
			████ *Mermis* sp. (Nematoda: Mermithidae) ████			
					████ *Undetermined* sp. (Nematoda: Mermithidae) ████	
					████ *Undetermined* spp. (2) (Acarina: Tarsonemidae) ████	
	████ *Zicrona caerulea* (Linnaeus) (Hemiptera:Pentatomidae) ████					
████ *Stenonabis tagalicus* Stål (Hemiptera: Nabidae) ████						
████ *Solenopsis geminata* (Fabricius) (Hymenoptera:Formicidae) ████						
████ *Monomorium* sp. (Hymenoptera:Formicidae) ████						
████ *Pheidologeton* sp. (Hymenoptera:Formicidae) ████						
			████ *Bufo marinus* (Linnaeus) (Salientia: Bufonidae) ████			
			████ *Rana* spp. (2) (Salientia: Ranidae) ████			
			████ *Anas platyrhynchos* (Linnaeus) (Aves: Anatidae) ████			
			████ *Cairina moschata* (Linnaeus) (Aves: Anatidae) ████			
			████ *Gallus gallus* (Linnaeus) (Aves: Phasianidae) ████			
			████ *Egretta alba modesta* (Gray) (Aves: Ardeidae) ████			
			████ *Egretta intermedia* Mittlereiher (Aves: Ardeidae) ████			

Table 2. RBB natural enemies and its alternate hosts.

Order	Family	RBB natural enemies	Alternate host	Nature of insect — Rice pest	Nature of insect — Nonrice pest	References
Predators						
Hymenoptera	Formicidae	Solenopsis geminata (F.) Monomorium sp. Pheidologeton sp.	Nephotettix spp. (Homoptera: Cicadellidae)	x		PhilRice, 2003
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		Jerath, 1965
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		Dumbleton, 1957
			Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		Ahmad, 1980
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		Yasumatsu, 1981
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		Shepard et al., 1987
			Aphis spp. (Homoptera: Aphididae)	x		Way, 1998
			Leptocorisa spp. (Hemiptera: Alydidae)	x		
			Nezara viridula (L.) (Hemiptera: Pentatomidae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
			Nymphula depunctalis (Guenee) (Lepidoptera: Pyralidae)	x		
			Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		
			Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		
			Parnara guttata (Bremer et Grey) (Lepidoptera: Hesperiidae)	x		
			Pelopidas mathias (F.) (Lepidoptera: Hesperiidae)	x		
			Cnaphalocrocis medinalis (Guénee) (Lepidoptera: Pyralidae)	x		
			Marasmia exigua (Butler) (Lepidoptera: Pyralidae)	x		
			Rivula atimeta (Swinhoe) (Lepidoptera: Noctuidae)	x		
Orthoptera	Gryllidae	Anaxipha longipennis (Serville) Metioche vittaticollis (Stål)	Chilo spp. (Lepidoptera: Pyralidae)	x		PhilRice, 2003
			Cnaphalocrocis medinalis (Guénee) (Lepidoptera: Pyralidae)	x		Shepard et al., 1987
			Marasmia exigua (Butler) (Lepidoptera: Pyralidae)	x		IRRI Annual Reports
			Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		CABI, 1997
			Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		Reissig et al., 1986
			Spodoptera spp. (Lepidoptera: Noctuidae)	x		
			Hydrellia philippina Ferino (Diptera: Ephydridae)	x		
			Nephotettix spp. (Homoptera: Cicadellidae)	x		
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		
			Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		
			Rivula atimeta (Swinhoe) (Lepidoptera: Noctuidae)	x		
	Tettigonidae	Conocephalus longipennis (de Haan) Conocephalus maculatus (Le Guillou)	Leptocorisa spp. (Hemiptera: Alydidae)	x		PhilRice, 2003
			Nezara viridula (L.) (Hemiptera: Pentatomidae)	x		Joshi, 2001
			Chilo spp. (Lepidoptera: Pyralidae)	x		Shepard et al., 1987
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		Reissig et al., 1986
			Cnaphalocrocis medinalis (Guénee) (Lepidoptera: Pyralidae)	x		
			Marasmia exigua (Butler) (Lepidoptera: Pyralidae)	x		
			Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		
			Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		

Table 2 continued.

Order	Family	RBB natural enemies	Alternate host	Nature of insect Rice pest	Nature of insect Nonrice pest	References
			Spodoptera spp. (Lepidoptera: Noctuidae)	x		
			Nephotettix spp. (Homoptera: Cicadellidae)	x		
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		
			Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		
			Pomacea canaliculata (Lamarck) (Gastropoda:Ampullariidae)	x		
Coleoptera	Coccinellidae	Micraspis crocea (Mulsant)	Nephotettix spp. (Homoptera: Cicadellidae)	x		Rice Doctor, 2003
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		Shepard et al., 1987
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		IRRI Annual Reports
			Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		CABI, 1997
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		PhilRice, 2003
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		Shepard & Rapusas,1989
			Aphis spp. (Homoptera: Aphididae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
			Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		
			Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		
			Spodoptera spp. (Lepidoptera: Noctuidae)	x		
			Cnaphalocrocis medinalis (Guenee) (Lepidoptera: Pyralidae)	x		
			Zicrona caerulea (Linnaeus) (Hemiptera: Pentatomidae)		x	
			Stenonabis tagalicus Stål (Hemiptera: Nabidae)		x	
			Marasmia exigua (Butler) (Lepidoptera: Pyralidae)	x		
	Carabidae	Ophionea nigrofasciata (Schmidt-Goebel)	Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		
		Ophionea indica (Thunberg)	Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		
		Ophionea sp.	Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		Yasumatsu, 1981
		Archicolliuris sp.	Rivula spp.(Lepidoptera: Noctuidae)	x		Ahmad, 1980
		Drypta japonica Bates	Naranga aenescens Moore (Lepidoptera: Noctuidae)	x		Jerath, 1965
		Pterostichus microcephalus Motschulsky	Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		Rice Doctor, 2003
		Desera sp.	Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		Shepard et al., 1987
		Chlaenius palllipes Gebler	Spodoptera spp. (Lepidoptera: Noctuidae)	x		IRRI Annual Reports
			Chilo spp. (Lepidoptera: Pyralidae)	x		CABI, 1997
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		PhilRice, 2003
			Cnaphalocrocis medinalis (Guenee) (Lepidoptera: Pyralidae)	x		
			Zicrona caerulea (Linnaeus) (Hemiptera: Pentatomidae)		x	
			Stenonabis tagalicus Stål (Hemiptera: Nabidae)		x	
			Marasmia exigua (Butler) (Lepidoptera: Pyralidae)	x		
	Staphylinidae	Paederus fuscipes Curtis	Nephotettix spp. (Homoptera: Cicadellidae)	x		
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		CABI, 1997
			Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		PhilRice, 2003
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		

Table 2 continued.

Order	Family	RBB natural enemies	Alternate host	Nature of insect Rice pest	Nature of insect Nonrice pest	References
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		Shepard et al., 1987
			Aphis spp. (Homoptera: Aphididae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
			Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		
			Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		
			Spodoptera spp. (Lepidoptera: Noctuidae)	x		
			Cnaphalocrocis medinalis (Guénee) (Lepidoptera: Pyralidae)	x		
			Marasmia exigua (Butler) (Lepidoptera: Pyralidae)	x		
Araneae	Araneidae	*Argiope aemula* (Walckenaer) *Argiope catenulata* (Doleschall)	*Nephotettix* spp. (Homoptera: Cicadellidae)	x		CABI, 1997
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		PhilRice, 2003
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		Shepard et al., 1987
			Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		Reissig et al., 1986
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		Barrion & Litsinger, 1995
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		Ahmad, 1980
			Nymphula depunctalis (Guenee) (Lepidoptera: Pyralidae)	x		Shinonaga&Barrion,1980
			Hydrellia philippina Ferino (Diptera: Ephydridae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
			Rivula atimeta (Swinhoe) (Lepidoptera: Noctuidae)	x		
			Telenomus spp.(Hymenoptera: Scelionidae)		x	
			Trissolcus spp. (Hymenoptera: Scelionidae)		x	
			Psix lacunatus Johnson and Masner (Hymenoptera: Scelionidae)		x	
			Anaxipha sp. (Orthoptera: Gryllidae)		x	
			Metioche vittaticollis (Stål) (Orthoptera: Gryllidae)		x	
			Conocephalus spp. (Orthoptera: Tettigoniidae)			
			Oxya spp. (Orthoptera: Acrididae)	x		
	Lycosidae	*Arctosa tanakai* Barrion & Litsinger *Pardosa pseudoannulata* (Böesenberg et Strand) *Pardosa* spp. (2)	*Nephotettix* spp. (Homoptera: Cicadellidae)	x		CABI, 1997
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		PhilRice, 2003
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		Shepard et al., 1987
			Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		Reissig et al., 1986
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		Barrion & Litsinger, 1995
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		Ahmad, 1980
			Nymphula depunctalis (Guenee) (Lepidoptera: Pyralidae)	x		Chong et al., 1991
			Hydrellia philippina Ferino (Diptera: Ephydridae)	x		Morrill & Rubia, 1990
			Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		
			Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		
			Spodoptera spp. (Lepidoptera: Noctuidae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Telenomus spp.(Hymenoptera: Scelionidae)		x	
			Trissolcus spp. (Hymenoptera: Scelionidae)		x	
			Psix lacunatus Johnson and Masner (Hymenoptera: Scelionidae)		x	
			Anaxipha sp. (Orthoptera: Gryllidae)		x	

Table 2 continued.

Order	Family	RBB natural enemies	Alternate host	Nature of insect — Rice pest	Nature of insect — Nonrice pest	References
			Metioche vittaticollis (Stål) (Orthoptera: Gryllidae)		x	
			Conocephalus spp. (Orthoptera: Tettigoniidae)		x	
			Oxya spp. (Orthoptera: Acrididae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
	Oxyopidae		Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		Rice Doctor, 2003
			Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		CABI, 1997
			Spodoptera spp. (Lepidoptera: Noctuidae)	x		PhilRice, 2003
			Nephotettix spp. (Homoptera: Cicadellidae)	x		Shepard et al., 1987
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		Yasumatsu, 1981
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		
			Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		
			Nymphula depunctalis (Guénee) (Lepidol̦ptera: Pyralidae)	x		
		Oxyopes javanus Thorell	Cnaphalocrocis medinalis (Guénee) (Lepidoptera: Pyralidae)	x		
			Marasmia exigua (Butler) (Hemiptera: Alydidae)	x		
			Leptocorisa spp. (Hemiptera: Alydidae)	x		
			Nezara viridula (L.) (Hemiptera: Pentatomidae)		x	
			Hydrellia philippina Ferino (Diptera: Ephydridae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Telenomus spp.(Hymenoptera: Scelionidae)	x		
			Trissolcus spp. (Hymenoptera: Scelionidae)		x	
			Psix lacunatus Johnson and Masner (Hymenoptera: Scelionidae)		x	
			Anaxipha sp. (Orthoptera: Gryllidae)		x	
			Metioche vittaticollis (Stål) (Orthoptera: Gryllidae)		x	
			Conocephalus spp. (Orthoptera: Tettigoniidae)		x	
			Oxya spp. (Orthoptera: Acrididae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
Dermaptera	Carcinophoridae		Micraspis crocea (Mulsant) (Coleoptera: Coccinellidae)		x	Rice Doctor, 2003
			Ophionea spp. (Coleoptera: Carabidae)		x	CABI, 1997
			Paederus fuscipes Curtis (Coleoptera: Staphylinidae)	x		PhilRice, 2003
		Euborellia philippinensis Srivastava	Sogatella furcifera (Horvath) (Homoptera: Dephalcidae)	x		Shepard et al., 1987
		Euborellia annulata (Fabricius)	Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		IRRI Annual Reports
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		
			Nephotettix spp. (Homoptera: Cicadellidae)	x		
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		
			Leptocorisa spp. (Hemiptera: Alydidae)	x		
	Anisolabididae	Anisolabis maritima (Bonelli)	Nezara viridula (L.) (Hemiptera: Pentatomidae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
			Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x		

Table 2 continued.

Order	Family	RBB natural enemies	Alternate host	Rice pest	Nonrice pest	References
			Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	x		
			Spodoptera spp. (Lepidoptera: Noctuidae)	x		
			Parnara guttata (Bremer et Grey) (Lepidoptera: Hesperiidae)	x		
			Solenopsis geminata (F.) (Hymenoptera: Formicidae)	x		
			Pelopidas mathias (F.) (Lepidoptera: Hesperiidae)	x		
Hemiptera	Pentatomidae	*Zicrona caerulea* (Linnaeus)	*Nephotettix* spp. (Homoptera: Cicadellidae)	x		
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		
	Nabidae	*Stenonabis tagalicus* Stål	*Sogatella furcifera* (Horvath) (Homoptera: Dephalcidae)	x		CABI, 1997
			Nilaparvata lugens (Stål) (Homoptera: Dephalcidae)	x		PhilRice, 2003
			Laodelpax striatellus (Fallen) (Homoptera: Dephalcidae)	x		Shepard et al., 1987
			Leptocorisa spp. (Hemiptera: Alydidae)	x		
			Nezara viridula (L.) (Hemiptera: Pentatomidae)	x	x	
Salientia	Bufonidae	*Bufo marinus* (Linnaeus)	*Micraspis crocea* (Mulsant) (Coleoptera: Coccinellidae)		x	
			Ophionea spp. (Coleoptera: Carabidae)		x	
			Paederus fuscipes Curtis (Coleoptera: Staphylinidae)		x	
			Solenopsis geminata (F.) (Hymenoptera: Formicidae)		x	
			Anaxipha longipennis (Serville) (Orthoptera: Gryllidae)		x	
			Metioche vittaticollis (Stål) (Orthoptera: Gryllidae)		x	
			Conocephalus spp. (Orthoptera: Tettigoniidae)		x	
			Oxya spp. (Orthoptera: Acrididae)	x		Andrewartha, 1971
			Leptocorisa spp. (Hemiptera: Alydidae)	x		Settle et al., 1996
			Nezara viridula (L.) (Hemiptera: Pentatomidae)	x	x	IRRI Annual Reports
			Nephotettix spp. (Homoptera: Cicadellidae)	x		
	Ranidae	*Rana* spp. (2)	*Recilia dorsalis* (Motschulsky) (Homoptera: Cicadellidae)	x		
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
			Cnaphalocrocis medinalis (Guenée) (Lepidoptera: Pyralidae)	x		
			Marasmis exigua (Butler) (Lepidoptera: Pyralidae)	x		
			Euborellia spp. (Dermaptera: Carcinophoridae)		x	
			Argiope spp. (Araneae: Araneidae)		x	
			Pardosa spp. (Araneae: Lycosidae)		x	
			Oxyopes javanus Thorell (Araneae: Oxyopidae)		x	
Aves	Phasianidae	*Gallus gallus* (Linnaeus)	*Micraspis crocea* (Mulsant) (Coleoptera: Coccinellidae)		x	
			Ophionea spp. (Coleoptera: Carabidae)		x	
			Paederus fuscipes Curtis (Coleoptera: Staphylinidae)	x		
			Solenopsis geminata (F.) (Hymenoptera: Formicidae)	x		
			Anaxipha longipennis (Serville) (Orthoptera: Gryllidae)		x	Andrewartha, 1971
			Metioche vittaticollis (Stål) (Orthoptera: Gryllidae)		x	Settle et al., 1996
			Conocephalus spp. (Orthoptera: Tettigoniidae)		x	

Table 2 continued.

Order	Family	RBB natural enemies	Alternate host	Rice pest	Nonrice pest	References
			Oxya spp. (Orthoptera: Acrididae)	x		IRRI Annual Reports
			Leptocorisa spp. (Hemiptera: Alydidae)	x		
			Nezara viridula (L.) (Hemiptera: Pentatomidae)	x	x	
			Nephotettix spp. (Homoptera: Cicadellidae)	x		
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		
			Cofana spectra Distant (Homoptera: Cicadellidae)	x		
			Chilo spp. (Lepidoptera: Pyralidae)	x		
	Anathidae	Anas platyrhynchos (Linnaeus)	Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
		Cairina moschata (Linnaeus)	Cnaphalocrocis medinalis (Guénee) (Lepidoptera: Pyralidae)	x		
			Marasmia exigua (Butler) (Lepidoptera: Pyralidae)	x		
			Euborellia spp. (Dermaptera: Carcinophoridae)		x	
	Ardeidae		Argiope spp. (Araneae: Araneidae)		x	
			Pardosa spp. (Araneae: Lycosidae)		x	
			Oxyopes javanus Thorell (Araneae: Oxyopidae)		x	
			Argiope spp. (Araneae: Araneidae)		x	
			Pardosa spp. (Araneae: Lycosidae)		x	
		Egretta alba modesta (Gray)	Oxyopes javanus Thorell (Araneae: Oxyopidae)		x	Andrewartha, 1971
		Egretta intermedia Mittlereiher	Conocephalus spp. (Orthoptera: Tettigoniidae)		x	IRRI Annual Reports
			Oxya spp. (Orthoptera: Acrididae)	x		
			Anaxipha longipennis (Serville) (Orthoptera: Gryllidae)		x	
			Metioche vittaticollis (Stål) (Orthoptera: Gryllidae)		x	
Lepidoptera	Noctuidae	Mythimna separata (Walker)	Pest of rice, corn, and sorghum	-	-	Dale, 1994
Parasitoids/parasites						
Hymenoptera	Scelionidae		Leptocorisa spp. (Hemiptera: Alydidae)	x		Arida et al., 1998
			Nezara viridula (L.) (Hemiptera: Pentatomidae)	x		Ahmad, 1980
			Piezodorus hybneri Gmelin (Hemiptera: Pentatomidae)	x	x	Ooi, 1988
		Telenomus triptus (Nixon)	Oxya spp. (Orthoptera: Acrididae)	x		CABI, 1997
		Telenomus cyrus (Nixon)	Mythimna separata (Walker) (Lepidoptera: Noctuidae)	x	x	PhilRice, 2003
		Telenomus chloropus (Thomson)	Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)			Shepard et al., 1987
		Telenomus spp. (2)	Spodoptera spp. (Lepidoptera: Noctuidae)	x		Colazza et al., 1996
		Trissolcus artabazus Nixon	Hydrellia philippina Ferino (Diptera: Ephydridae)	x		Orr et al., 1996
		Trissolcus basalis (Wollaston)	Chilo spp. (Lepidoptera: Pyralidae)	x		Higuchi & Suzuki, 1996
		Trissolcus sp.	Scirpophaga spp. (Lepidoptera: Pyralidae)	x		Quike, 1997
		Psix lacunatus Johnson and Masner	Nephotettix spp. (Homoptera: Cicadellidae)	x		Turner, 1983
			Recilia dorsalis (Motschulsky) (Homoptera: Cicadellidae)	x		
			Cofana spectra (Distant) (Homoptera: Cicadellidae)	x		
Acarina	Tarsonemidae	Undetermined sp.(2)	Unknown		x	A.T. Barrion, unpublished

Table 2 continued.

Order	Family	RBB natural enemies	Alternate host	Nature of insect		References
				Rice pest	Nonrice pest	
Pathogens						
Entomophthorales	Entomophthoraceae	Metarhizium anisopliae (Metschnikoff) Sorokin	Leptocorisa spp. (Hemiptera: Alydidae)	x		Rombach et al., 1994
		Beauveria bassiana (Balsamo) Vuillemin	Locusta migratoria manilensis (Meyer) (Orthoptera: Acrididae)	x		Morimoto, 1987
		Paecilomyces lilacinus (Thomson) Samson	Parnara guttata (Bremer et Grey) (Lepidoptera: Hesperiidae)	x		PhilRice, 2003
			Pelopidas mathias (F.) (Lepidoptera: Hesperiidae)	x		PhilRice, 2000
			Chilo spp. (Lepidoptera: Pyralidae)	x		
			Scirpophaga spp. (Lepidoptera: Pyralidae)	x		
		Penicillium citrinum Thomson	Identification uncertain		x	
Nematoda	Mermithidae	Hexamermis sp.	Helicoverpa spp. (Lepidoptera: Noctuidae)	x		PhilRice, 2003
			Galleria mellonella (Linnaeus) (Lepidoptera: Pyralidae)		x	Shepard et al., 1987
		Mermis sp.	Oxya spp. (Orthoptera: Acrididae)	x		Wharton, 1986
			Leptocoris angur Fabricius (Hemiptera: Rhopalidae)	x	x	
			Aedes spp., Culex spp. (Diptera: Culicidae)		x	
		Undetermined sp.	Unknown		x	

Hyperparasitoids/Hyperparasites

Hyperparasitoids/hyperparasites are parasitoids that attack other species of parasitoids in the food web. The following species and actions of the hyperparasitoids/hyperparasites and their target organisms are considered.

A sarcophagid fly, *Pierretia litsingeri* Shinonaga & Barrion (Diptera: Sarcophagidae), was reported to be hyperparasitizing the egg sac and small spiderlings of the araneids, particularly the *Argiope* spp. This fly is a parasite of the spider *Argiope catenulata* in the Philippines (Shinonaga and Barrion 1980).

An undetermined species of the mite (Acarina: Erythraeidae) has been found to parasitize the nymphs and adults of the long-horned grasshoppers, which are beneficial insects as they feed on the RBB egg masses.

The mantidfly, *Climaciella* sp. (Neuroptera: Mantispidae), hyperparasitizes the wolf spiders, the *Pardosa* species of family Lycosidae, which are of ecological importance for the control of the RBB.

The roles of these hyperparasitoids/hyperparasites are very important when analyzing the fate of the beneficial organisms in the field that control the black bug population.

Hyperpredators

Hyperpredators are predators that feed on the beneficial predators in order to survive in a given environment. These hyperpredators' role in the food web are very essential. The survival of the natural enemies depends on the quantity of hyperpredators that may feed on them other than some kind of pests. Understanding the actions and knowing these hyperpredators and their hosts can point to biological control measures that may be used against RBB. The following were the hyperpredators in the rice field.

The long-jawed spiders, *Tetragnatha javana* (Thorell), *T. virescens* Okuma, *T. maxillosa* (Thorell), *T. nitens* (Audouin), and a big-jawed spider, *Leucauge decorata* (Blackwall) (Araneae: Tetragnathidae), were found to be hyperpredators of scelionid wasps.

The orb-web spiders *Argiope catenulata* (Doleschall), *Larinia fusiformis* (Thorell), *Neoscona theisi* (Walck.), and *Araneus inustus* (C.L. Koch) (Araneae: Araneidae) build webs to catch their prey.

Being generalist predators, *Argiope catenulata*, *Larinia fusiformis*, *Neoscona theisi*, and *Araneus inustus* also feed on different flying insects that are trapped on its web—e.g., scelionids which are egg parasitoids of RBB such as *Telenomus* sp., *Trissolcus* sp., and *Psix lacunatus.*

The sphecid wasps *Chalybion bengalense* (Dahlbom) and *Sceliphron madraspatanum conspicillatus* (Costa) (Hymenoptera: Sphecidae) were found to attack wolf spiders, particularly *Pardosa pseudoannulata,* which are beneficial for the control of the RBB population.

An ichneumonid wasp, *Messatoporus* sp. (Hymenoptera: Ichneumonidae), was found to be preying on *Pardosa pseudoannulata* directly by attacking and killing the spider and laying its eggs inside the host egg cocoon. The spider is a RBB natural enemy.

An understanding of the secondary natural enemies on the food web can help search for and devise the best biological control measures and to assess and conserve the indigenous natural enemies in the field.

Summary

The arthropod food web shows the diversity of natural enemies affecting insect pests of rice. Natural enemies in turn are preyed upon by secondary predators (hyperpredators) and parasitized by hyperparasitoids. The RBB occurs on different areas in South, Southeast Asia, and Africa. As far as is known, RBB from different parts of South and Southeast Asia share the same complex of natural enemies.

Based on the gathered information, the *Scotinophara* spp. food web (see figure) comprises 70 species: 39 predators, 17 parasitoids/parasites including 4 entomopathogens, 32 hyperpredators, and 7 hyperparasitoids. The dominant predators are Coleoptera (11), Araneae (7), Aves (5), Orthoptera (4), Dermaptera (3), Salientia (3), Hymenoptera (3), Hemiptera (2), and Lepidoptera (1). The dominant parasites/ parasitoids/entomopathogens are Hymenoptera (8), Entomophthorales (4), Nematoda (3), and Acarina (2).

There are 39 species of secondary natural enemies, hyperpredators and hyperparasites. The dominant hyperpredators are Araneae (15), Coleoptera (11), Aves (5), Hymenoptera (3), Salientia (3), and Dermaptera (3), whereas the dominant hyperparasitoids are Hymenoptera (4), Acarina (1), Diptera (1), and Neuroptera (1).

The predominant egg parasitoids are the *Telenomus spp.* Ants and a carabid *Agonium daimio* Bates feed on all stages of the RBB. *Metarhizium anisopliae* is an efficient entomopathogen against the RBB. The vertebrates Salientia and Aves were effective as biological control agents for the RBB.

There are 512 linkages that comprise the RBB food web: 56 linkages on predation and parasitism, 7 linkages on hyperparasitism, and 449 linkages on hyperpredation. These linkages show the interaction between RBB and natural enemies in a rice agroecosystem.

Conclusions

A food web has been used to illustrate the information on pest (RBB) and natural enemy relationships in the rice ecosystem. Ecological concepts can systematize information on individual pest-natural enemy interactions into forms that are helpful for understanding the effects of relations on the community of pests and natural enemies. Understanding rice-RBB-natural enemy relationships and the food web can help determine possible biological control agents to be used.

Research using a 'who-eats-whom model' (food web) to study pest (RBB) and natural enemy interactions in the rice ecosystem gives new insights on community-level relations of the RBB and its

natural enemies. A review of the RBB's natural enemies provided evidence that correct information is effective when developing biological control strategies to control the pest.

Rice insect pests in tropical South, Southeast Asia, and the Ethiopian region have a long and close association with their natural enemies. Predators, parasites/parasitoids, and insect pathogens are most important in keeping the RBB under biological control.

Conserving the natural enemies and natural biological control are recommended. Hence, studies of the action of predators, parasites/parasitoids, and pathogens should be part of a continuing research agenda to ensure the successful implementation of integrated pest management programs.

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Cultural, Mechanical, and Physical Control of Rice Black Bugs

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Abstract

A number of mechanical, physical, and cultural control methods can be incorporated into integrated pest management programs for black bug control. The key mechanical control method is handpicking, which is most fit in areas where agricultural labor is less expensive and conducted on an area-wide basis. Light trapping, the physical control method, although can capture many adults, is probably more useful as a detection method than for control. Of the eight cultural control methods, plowing the field after harvest destroys adults and nymphs seeking shelter in cracks in the soil. Flooding is useful to control eggs if water is available. Removal of weeds has an added bonus of discouraging black bugs. Wide spacing and transplanting let in more sunlight that repels black bugs. Early planting is often effective as an escape method, but the results are often site-specific. Synchronous planting has the effect of diluting black bug densities. Combining a number of these methods would enhance suppression.

Key words: water management, tillage, plant density, clean culture, early planting, planting method, synchronous planting, handpicking, light trapping

Introduction

There are two key *Scotinophara* species that damage rice in Asia, *S. coarctata* (Fabricius) (Malayan rice black bug) and *S. lurida* (Burmeister) (Japanese rice black bug). Many species of Pentatomidae (true bugs) damage rice seed, but rice black bugs are different in that they feed on all plant parts preferring tillers, leaves, roots, and, to a lesser extent, milky-stage grains. Rice black bugs initiate infestation on young plants (including seedlings in nurseries) (Fernando 1960), sometimes gathering in large numbers at the base of tillers. Corbett and Yusope (1924) documented up to 67 per plant. They seem to prefer the base of tillers where they gather cryptically to remove plant sap, which causes withering and eventual death. Adults and nymphs can weaken the vitality of the plants such

that seed is not produced. Areas under severe attack appear as patches of stunted plants with leaves turning reddish brown and only occasional plants with panicles can be seen. In single rice systems, their populations alternate between rice and grassy habitats.

Following integrated pest management principles, the first line of defense should be nonchemical methods involving a combination of cultural, physical, and mechanical controls; genetic resistance; and biological control. Cultural methods, if carried out properly, prolong the life span of resistant varieties. They may not give an immediate result as do insecticides but they are generally inexpensive, durable, nonpolluting, ecologically sound, and are readily understood by farmers (Oka 1979).

Cultural control may be defined as the modification of certain farm operations to make the environment unfavorable for the development and multiplication of insect pests but favorable for crop production (Oka 1979). As pointed out by Litsinger (1994), most of these traditional practices were invented by farmers by trial and error and are handed down from father to son within farm communities. Eventually, the more effective ones are 'discovered' by researchers or extension workers who may undertake adaptive trials to test them before adding them to local or national recommendations. It is advocated that more surveys of farmers be undertaken to identify more of these methods that use indigenous materials (Glass and Thurston 1978, Chambers et al. 1989, Thurston 1990).

Many of these indigenous methods use a combination of practices such as raising the water level and then manual collection. In this chapter, we discuss light trapping, which is classified as a physical control method; manual collection, which is a mechanical control method; with the balance involving use and adoption of normal crop husbandry practices, which are classified as cultural control methods (Pimentel and Perkins 1980).

Manual collection

Undoubtedly the oldest control method was removal by hand or handpicking. Over the years, techniques improved to make the method more efficient. It was noted that black bugs aggregate in wet seedbeds and lay eggs at base of seedlings. Thus, the best timing would be just before transplanting when eggs and nymphs were picked clean from seedlings during the bundling process. Care was taken such that every seedling taken from the nursery is free from the bugs (Corbett and Yusope 1924).

Another useful period for hand collection was during weeding 5-6 wk after transplanting (de Alwis 1941). Furthermore, hand removal of eggs and bugs from patches of damaged areas was encouraged to prevent dispersal to neighboring fields (Corbett and Yusope 1924). In Japan, it was recommended to hand collect during winter from overwintering sites when they are aggregated (Kuwana 1930).

Next, farmers constructed nets to more efficiently collect black bugs in the field. It was recommended to net nymphs and adults in the morning when they are resting high on foliage (Corbett and Yusope 1924). A further improvement on use of nets was to flood the field and net bugs floating on water, then drain afterwards (Dammerman 1929, Commun 1937, Kalshoven 1981).

Ayyar (1929) relates an experience in India during a severe outbreak involving several hundred hectares and a community of farmers tilling 200 ha. Handpicking was first tried but because each

farmer does it when he wants, re-infestation rapidly occurred to negate the method. This was followed by hand netting, but the black bugs did not easily detach from the foliage, except when the plants were already dead and wilted. The bunds were too small and low to allow complete submergence of the plants, but partial flooding caused the bugs to crawl up the plants. Bugs then were dislodged with bamboo or ropes, but eventually brooms were found to be most effective. Brooms allowed the floating bugs to be herded into a corner of the bunded field for collection with nets and eventual disposal in buckets of water and kerosene. A half dozen low-wage workers could easily depopulate a number of fields of black bugs each day and the method was cost-effective. With such success, most farmers joined in and through their area-wide cooperation were able to quell the outbreak.

A further improvement was developed to spare egg parasitoids (Corbett 1924). Hand-collected eggs should not be crushed but placed in a box with a tight lid, which has a glass tube protruding. The light attracts the egg parasites. The boxes should be checked daily and parasites liberated in the field after emergence.

Light trapping

Black bugs are most active at night, which includes flight (Fernando 1960), and adults are highly attracted to artificial light sources. Piles of bugs are often found in heaps below electric light posts in rural settlements during infestations. This observation has led to the idea that light traps could be used in the control of black bugs in the same way that light traps have been used to suppress populations of other rice insect pests such as stem borers, leafhoppers, and planthoppers among a longer list compiled in Litsinger (1994). For example, in China, grids of over one million electric traps were set out at the rate of one trap per 2.3 ha for rice stem borer control in the 1970s (NAS 1977). A number of researchers have recommended light traps placed along field borders for the control of black bugs—e.g., Sri Lanka Department of Agriculture (1941) and Sosamma and Bai (1988) in India.

Electric-powered light traps are more effective than kerosene traps, as those who stated that light traps were not sufficiently attractive probably were not using electric-powered ones (Corbett and Yusope 1924, Ayyar 1929, Rodrigo 1941). Ito et al. (1993) in a 5-yr study found that the size of the catch from electric light traps fluctuated synchronously with the lunar phase; large catches occurred around the full moon phase and very few adults were trapped around the new moon. A review of black bug habits is helpful in interpreting the timing of their capture in light traps and the use of light traps in population suppression.

Scotinophara bugs are not long-distance migrants and pass the off-seasons in either aestivation or hibernation, depending on the species or location. Thus, fat body buildup occurs as a measure of survival when plant hosts are not present but not primarily for use as flight fuel. After rice harvest in periods when rainfall is scant, adults and nymphs seek out moist areas for shelter to pass the off-season without feeding (Fernando 1960). The off-season means the winter in temperate areas and the dry season in tropical areas when no rice is grown and annual weeds are desiccated for the most part. If rains continue and rice is not cultivated, black bugs can feed on alternate plant hosts.

When food sources become scarce, black bugs seek out moist habitats to pass the periods between rice crops. When moist conditions can be found, adults and nymphs congregate at the base of vegetation. If moist sites are not found, they descend into cracks in dry soil sometimes up to 2 ft (Fernando 1960). These off-season resting sites can be in the rice field itself but more likely in rice bunds or on nearby higher ground or upland areas. In Korea, *S. lurida* overwinters as adult in the foothills, along riverbanks, and rice paddy levees (Lee et al. 2004). Both black bug species are known to seek moist areas such as marshlands or wooded areas. They remain motionless for the most part during this dormancy period, often in groups of 5-20 (Fernando 1960). They appear to be in a state of turpor but will move if disturbed.

Whether the resting state is a quiescence or a true diapause needs to be determined (Denlinger 1986). The fact that both adults and nymphs enter into the resting period seems to point to the latter. In a true diapause, fat bodies engorge at the expense of reproductive system development, insects enter and end this physiological state based on signals from the environment such as temperature, photoperiod, plant host growth stage, or rainfall and it occurs in a specific stadium. A good example is the white stem borer *Scirpophaga innotata* (Walker), which aestivates as a last-instar larva, entering the quiescent state conditioned when daylength <11:45 h and triggered when younger larvae feed on older rice plants, but termination is based on rainfall (Litsinger et al. 2006). Greater larval survival actually occurs in the driest seasons as moisture arriving too early can drown larvae before they are ready or encourage fungal diseases.

Leptocorisa spp. rice seed bugs also enter aestivation and seek moist habitats such as wooded areas (Sands 1977) and seem to mirror the off-season behavior of black bugs. Black bugs seek shelter under much the same conditions, but rice bugs are not found in the soil and only aestivate as adults. Black bugs however seek sites in the ground and both adults and nymphs appear together. Both groups seek wooded areas or trees, amass in groups, and reactivate in response to rainfall.

Thus, it is no surprise that black bug infestations have been associated with forested areas. Morrill et al. (1995) noted that rice fields near wooded areas are more prone to attack. In addition, Corbett and Yusope (1924) observed outbreaks in newly created rice fields on land that was formerly secondary forest. When rains resume and rice is planted, both adults and nymphs leave the resting sites and disperse to rice fields. Nymphs make their way over land to nearby fields while adults fly longer distances.

Shepard et al. (1986) in Malaysia and the Philippines found that the sex ratio of light-trapped *S. coarctata* adults was biased toward males, unlike that of the cage-reared black bugs, which was 1:1. Most of the trapped females were sexually immature or without eggs, although some appeared to have oviposited previously. Ito et al. (1993), in Malaysia, corroborated this finding. Light-trap collections may be biased to males as they undertake flight not only to feed and seek shelter but also to find mates, whereas females take flight only to find food or shelter but not to mate. This difference in behavior can explain the sex ratio being biased toward males in light traps.

Further studies by Ito et al. (1993) found that light-attracted adults showed a considerable tolerance for starvation and survived for 20-30 d when given water, but for only 2 d in the absence of

water. When the light-attracted females were supplied with food, their ovaries developed rapidly and females with mature eggs were produced after 9 d. When the starvation period was prolonged, the ovaries remained immature and the fat bodies are reduced in size. This indicates that bugs collected in light traps are dispersing in an immature stage; thus it would be efficient to collect them by light traps to prevent egg laying. This is in contrast to other species such as rice stem borers where the majority collected in light traps were females and eggs had been laid (Litsinger 1994).

Research has shown that aquatic species disperse during periods of full moon in order to be able to locate standing water by the reflection of the moon (Bowden and Church 1973, Perfect and Cook 1982). Rice is correlated with standing water but, as not all standing water harbors rice, many perish as a result. But this behavior assures that some will survive and can colonize new rice plantings. As black bugs also infest dryland or hill rice, they must use other host-seeking behaviors as well. It is highly probable that the mass flight of black bugs may be less frequent when rice as a food source is readily available. As rice is harvested, adults are compelled to disperse.

From the above evidence, we conclude that dispersal can occur on four occasions: 1) seeking aestivation sites, 2) returning to rice fields from aestivation sites, 3) seeking another rice crop after rice harvest, or 4) males seeking mates.

Light traps in general have been found to be expensive to operate, particularly those powered by electricity and much of the enthusiasm shown in former years for their benefit has mostly fallen into disfavor. Despite catches of piles of black bugs, severe damage is still noted in the field. But capturing so many black bugs does provide farmers with a psychological benefit but, at best, such a measure would have to be used with other control methods in order to make an impact.

Strategies to achieve greatest efficiency from the use of light traps based on the studies cited would be to 1) choose fields next to sites where black bugs are known to seek shelter in the off-season, 2) place the light trap between the off-season area and the field, 3) use electric light traps, and 4) operate them only 1 wk before and 1 wk after the full moon period. This would give the greatest efficiency of use, but whether it is economical needs to be determined. A second priority would be to place light traps at a time when black bugs are moving from an older rice crop to a newly planted crop. Least efficient would be to time the light traps when black bugs are dispersing to their shelter areas or to capture males dispersing to find females.

In addition, Ito et al. (1993) noted that light trap collections were low during periods of bad weather, thus savings could be gleaned from not operating light traps during rainfall periods. Black bugs collected at light traps can be utilized to feed ducks, chickens, or pigs. Ducks are even recommended to be herded in fields infested with black bugs so despite their foul odor, black bugs are heartily consumed by farm animals.

Water management

In Malaysia, *S. coarctata* became a pest when the rice area suffered a drought, but black bug densities became lower with moister weather. South (1921) stated that, with a good rainfall, there is seldom danger from this pest. Perhaps, in these cases, the heavy rains dislodged the bugs and caused them

Egg mortality (%)
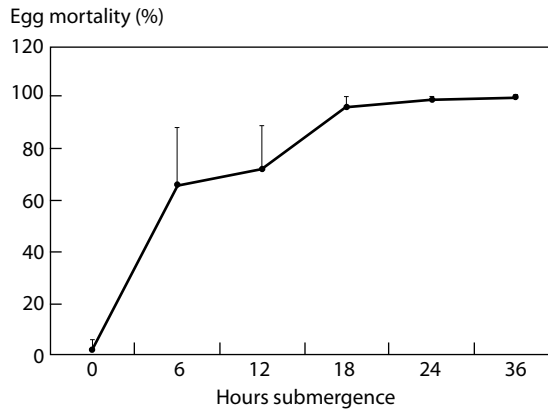
Fig. 1. Effect of flooding on the survival of *S. coarctata* black bug eggs. Trial conducted in the greenhouse at the International Rice Research Institute, 1988. Data adapted from Parducho et al. (1988).

to drown and be flushed away. Corbett and Yusope (1924) noticed that heavy rains can reduce black bug numbers by knocking them off the plants, with young nymphs becoming buried in the mud and being carried off in outflows from the field.

Other researchers recommended flooding the field to control all stages of black bug. In Sri Lanka, de Alwis (1941) stated rice should be watched from the third to the sixth week of growth and flooded if black bugs appear. It is difficult, however, to drown nymphs and adults. Fernando (1961) determined adult mortality reached 65% after 7 h after submergence but in order for flooding to work against these stages, the whole plants have to be submerged. Thus, it is only practical during early growth. Flooding directed against nymphs and adults has been more popular as an aid in hand collection described earlier.

Focusing on the egg stage was seen as more practical (Kasumata 1930, Chen 1934) as eggs are sedentary. Parducho et al. (1988) determined that submergence for 24 h was sufficient to kill all eggs (Fig. 1). A number of researchers showed that most eggs of *S. lurida* and *S. coarctata* are deposited on plants from 6-20 cm above ground level (Commun 1930, Lever 1955, Shepard et al. 1986). In China, fields should be flooded to a depth of 10-13 cm every fourth day between 1st and 20th Jul and the water allowed to stand for about 1 d (Liu 1933). If this were to become a regular practice, it was recommended that bund height be raised and bunds be enforced.

Some researchers recommended combining flooding with chemical control using indigenous products to enhance lethality. When the field was flooded, a little kerosene was added to the water to increase mortality, particularly if the bugs were then swept off plants with brooms so they fell on the oily water (de Alwis 1941). Kerosene, of course, floats on the water surface and coats the bodies of black bugs, blocking the spiracles. The kerosene-water mixture should be drawn off quickly after 3-6 h; otherwise, it will harm the rice plants (Rodrigo 1941). In Japan, Iso (1954) recommended, instead
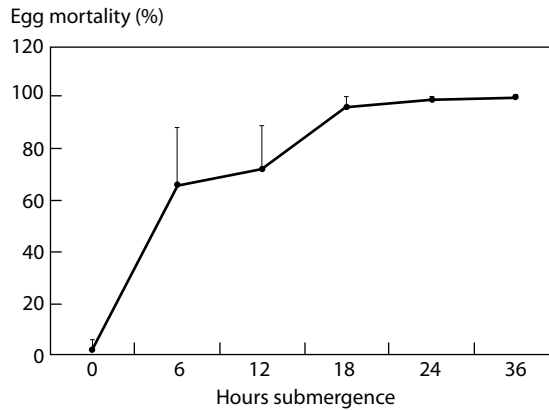
Fig. 2. Survival of adult and nymphal stages of *S. coarctata* black bugs after plowing immediately after rice harvest, Palawan, Philippines 1986. Data based on Shepard and Perez (1986).

of first flooding, the lowering of paddy water and adding tobacco and slaked lime. This is followed by raising the water level overnight to cause the bugs to be coated with the lethal mixture.

Most of the water management methods are tailored more to irrigated rice culture. But fields can be flooded during heavy rains, and in fact, in rainfed wetland rice culture, the bunds are higher with a view to capture as much water as possible during periodic rains. Often, fields are linked so that black bugs could even be flushed from fields after heavy rains.

Tillage

As black bugs were observed to hide in the field after harvest, plowing down the stubble right after harvest has been recommended in double-cropped areas (de Alwis 1941, Kalshoven 1981). Shepard and Perez (1987) conducted a trial to determine the effect of tillage as a cultural control measure. Immediately after harvest, cages were placed in plowed and unplowed portions of fields. Black bugs were recorded from 4-31 d after plowing by searching through the soil by hand. Ten times more adults were found than nymphs (Fig. 2). Percentage mortality was calculated using 4 d after plowing in the control plots as reference point. The results showed similar patterns in both stages. At 4 d, the figure approximates the number killed outright by plowing and later from starvation due to lack of host. After 24 d, mortality of nymphs and adults reached 98%.

Plant density

Kalshoven (1981) noted that black bugs are most active from late afternoon through the night until mid-morning and thus avoid the brightest time of day. Fernando (1960) further observed that, during the day, black bugs hide in the crown of the rice plant or in the mud near the roots when ponding

is low. Black bugs as documented by Kalshoven (1980) are lethargic and avoid light and were more prevalent in dense plantings. Katsumata (1930) noted *S. lurida* also preferred densely planted fields. Dammerman (1929) made a recommendation for wide spacing to allow more light into the base of plants, hopefully discouraging black bug buildup. The mechanism would be to reduce the relative humidity (RH), which would increase egg mortality. Fernando (1960), using different salts to achieve a range of six humidities in small chambers from 22 to 92%, found that eggs developed normally at >75% RH. At 43 and 64% RH, embryos developed within eggs but did not hatch.

Wide spacing would allow decreased humidities, especially during windy weather. Brown planthopper *Nilaparvata lugens* (Stål) is another insect pest that is more abundant in dense spacings (Dyck et al. 1979). The most open planting configuration in later studies was 5 × 40 cm, which would allow the greatest aeration and light penetration and thus the greatest population reduction. Use of the system of rice intensification (SRI) (Uphoff 2002) recommendations even suggests transplanting single plants at 50 × 50 cm distances. Even wider spacings have been tested as well. The objective of wider spacing was to save time in transplanting as new rice varieties tiller profusely. This practice should have the added benefit of reducing black bug densities as well.

Weeding and clean culture

Entomologists noticed that when weedy fallows were cleared for planting rice, black bugs were more of a problem (Corbett 1924, Rodrigo 1942). Others noted higher populations in weedy rice fields. Weeds act both as alternative hosts but also to create a more moist and dark microclimate at the base of rice plants favored by black bugs. Eggs were noted by Corbett and Yusope (1924) to desiccate under low-moisture conditions and weeds crowding between hills of rice create an ideal habitat for black bugs.

Weeds should be removed in a rice crop first for agronomic reasons but as well as to discourage black bug development. They also serve as alternate food sources between seasons as well as provide habitat for dormancy in areas bordering rice fields. Fernando (1960) noted that weedy rice bunds were a favorite habitat as well, thus recommendations for weeding and burning rice bunds (in the dry season) have been made (Corbett and Yusope 1924, de Alwis 1941, Sosamma and Bai 1988). Furthermore, Corbett and Yusope (1924) and Commun (1930) recommended that fields should be cleaned up from rice stubble as thoroughly as possible after harvesting the crop, the stubble should be burned, and irrigation canal banks kept clear of weeds.

Early planting

Katsumata (1930) recommended early planting in the spring in Japan to escape *S. lurida* buildup. The objective would be to plant rice before black bugs leave their overwintering site. In Japan and in neighboring countries, nurseries are established in the early spring under mesh or plastic to protect from cold temperature. This practice gives a jump-start to the season and an escape from pest buildup in general. Corbett and Yusope (1924) noted that older rice plants are less susceptible to black

bug injury. Thus, the mechanism behind early planting is to avoid young rice plants when fields are colonized in the late spring.

Planting method

With the increase in rural labor, many rice areas are turning to direct-seeded rice. Rice seeds are pregerminated and broadcast on puddled soil, which takes much less time than making a seedbed and transplanting seedlings in hills. The amount of seed for direct seeding is over twice that of transplanting and the seeds are uniformly sown, producing a dense stand. The close spacing and denser canopy render the habitat more suitable to black bugs, which shun sunlight and prefer moister and darker microclimates (Hirao and Ho 1987). Direct seeding also leads to greater weediness and even denser stands of vegetation in which black bugs flourish. Thus, transplanting would be preferred to direct seeding as a preventative tactic in black bug areas.

Synchronous planting

Hirao and Ho (1987), comparing the single crop to the newly introduced double cropping system in the Muda irrigation system, concluded that black bug infestations were more in the new system. In the early years of the Muda scheme, planting was highly asynchronous, where in one location one could see rice in many different growth stages. Likewise, Ayyar (1929) in India noted severe infestations leading to crop failure in the year-round irrigation site in Madras where farmers could plant five crops in 2 yr. This site was also highly asynchronously planted.

The objective of synchronous planting is to create a rice-free period of several months, particularly in the dry season. A dry-season timing of the rice-free period would cause greatest desiccation of plant hosts, including killing off the ratoon, and annual weed alternate hosts as well as preventing germination of volunteer seed. From the results in Figure 1, we see that the greatest mortality would accrue from the combination of an early plowing at the start of the rice-free period and waiting less than a month for greatest population suppressive effect.

Conclusion

A general critique of the use of cultural, mechanical, and physical methods for black bug control is that few experiments have been conducted to demonstrate the beneficial effect. None was found in the literature in the context of managing a crop so there is a critical need to test these practices with farmers and compare them to a control and then measuring the yield benefit. Much of the literature was based on research staff visiting black bug-infested areas and noting what practices the farmers were doing.

Most of the cultural control measures and light trapping are preventative, while manual collection and water management can be used in response to a heavy infestation. We saw that manual removal is more effective if adopted on neighboring farms as a community-wide effort. All the methods mentioned in the chapter would be more effective if carried out on an area-wide basis. Manual

collection methods are most appropriate in areas where rural wages are low. Water management involving submergence of eggs would be most effective in areas where irrigation water is available on demand and would be most appropriate in areas where farm labor is costly.

Plowing the field after rice harvest will result in high mortality of adults and nymphs seeking shelter in cracks in the soil. To be effective, however, this practice would have to be adopted on a community-wide basis to reduce population buildup to the next crop.

In an odd quirk of nature, black bugs during the day shun sunlight and seek dark and moist niches, while at night adults reverse this behavior and become highly attracted to light, either from the moon or from man-made sources. Light trapping is a preventative measure and, to be effective in attracting black bugs, the traps should be powered by electricity. Making a good trap and finding electrical connections in rural farms is often a limitation for its use. Experience on other crops has shown that the value of this technique needs to be verified.

Among the preventative cultural practices, maintaining a field as free of weeds as possible is desirable for good yields, even without black bug. Transplanting would therefore be preferred to direct seeding. Removing weeds from bunds and dikes will also have negative impacts on beneficial arthropods and should be carefully considered. Wider plant spacing would seem to be practical but often this increases cost of crop establishment so the benefit should be determined by field trials before a stronger recommendation can be made.

Experience shows that the effects of many of these practices will be site-specific and crop-specific in a double-cropped system. Early planting is an example of this concept as it may or may not work, depending on the surrounding cropping systems. Also, there should be increased value in combining different practices not only among those discussed in this chapter but with other control methods mentioned in the book.

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Notes

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Neem: Its Potential for the Management of the Rice Black Bug *Scotinophara coarctata* (Fabricius)

Ramesh C. Saxena

Abstract

Over the past 30 yr, the neem tree (*Azadirachta indica* A. Juss.) has come under scientific scrutiny as a source of natural pest control materials. More than 100 bioactive compounds, mainly "triterpenes" or "limonoids," have been isolated from various parts of the tree. Though subtle, neem's effects, such as insect repellence, feeding and oviposition deterrence, growth inhibition, mating disruption, chemosterilization, failure of eggs to hatch, and others are far more desirable than a quick 'knockdown' in IPM programs as they reduce the risk of exposing the pest's natural enemies to poisoned food or starvation. Approximately, 40 species of true bugs, including the rice black bug (RBB) *Scotinophara coarctata*, and others have been found sensitive to neem materials, such as extracts of leaves, seed or kernel, or azadirachtin, when treated topically, injected, or exposed to treated food or food plants. In trials conducted at three locations in farmers' fields in Palawan, Philippines, from April to September 1986, compared with untreated controls, fewer RBB individuals per 10 rice hills were recorded in plots planted to susceptible IR64 and tolerant IR13149-71-3-2 cultivars, infested with RBB at 30 DT, and then sprayed with an "Electrodyn" neem oil formulation at 0.75 L ha^{-1} at 30 DT and then at fortnightly intervals. Grain yield at two locations was significantly higher in neem oil-treated plots than in untreated controls; the treatment protected both susceptible and tolerant cultivars equally well against RBB damage. Also, at the third location, compared with the control, yield was relatively higher with neem treatment. Treatment with *Metarhizium anisopliae* at 10^{12} spores ha^{-1} alone or together with neem oil sprays did not confer any significant yield advantage over neem oil treatment. In Tamil Nadu, India, application of 5% neem seed kernel extract at 10% ETL was highly effective against RBB. Likewise, high-volume spray applications of 3% neem oil controlled brown planthoppers, stem borers, leaf thrips, RBB, and sheath rot in rice. The efficiency of neem sprays can be further increased by using additives to protect the bioactive neem components from UV light and by improving penetration of plant surfaces. For pest management by an average rice farmer, the use of readily available, relatively inexpensive, but equally effective neem materials, such as neem cake, aqueous extract of seed or kernel, or emulsified oil should be promoted by building awareness of neem's control potential, imparting hands-on training, and conducting on-farm trials and demonstrations in farmers' fields at strategic locations.

Key words: *Azadirachta indica*, neem, pest management, rice, rice black bug, *Scotinophara coarctata*

Introduction

Over the past 30 yr, neem (*Azadirachta indica* A. Juss.), 'the free or noble tree of India,' a botanical cousin of mahogany (family Meliaceae), has come under close scientific scrutiny as a source of unique natural pest control materials, herbal medicines, and other useful products. Since 1980, eight international and numerous national neem conferences and symposia have been held across the world. The growing interest in neem is attributed to the fact that neem-based pest control materials with diverse modes of action are not only effective against insect pests but also safer and less persistent in the environment than synthetic insecticides. At the same time, they are less prone to problems related to development of insecticide resistance and cross-resistance among insect pests. A report by an ad hoc panel of the Board on Science and Technology for Industrial Development stressed that "...this plant may usher in a new era in pest control, provide millions with inexpensive medicines, cut down the rate of human population growth, and even reduce erosion, deforestation, and the temperature of an overheated globe..." (National Research Council 1992).

Neem is an evergreen, tall, fast-growing tree, which, when full-grown, can reach a height of 25 m and a girth of 2.5 m. It has an attractive crown of deep green foliage and masses of honey-scented flowers. The tree thrives even on nutrient-poor dry soil. It tolerates high to very high temperatures, low rainfall, long spells of drought, and salinity. It is propagated by seed; 9- to 12-mo-old seedlings transplant well. Birds and bats also disperse the seed. Fruiting begins in 3–5 yr. The fruit is about 2 cm long and, when ripe, has a yellow fleshy pericarp, a white hard shell, and a brown oil-rich seed kernel. Fruit yields range from 30 to 50 kg per tree, depending on rainfall, isolation, soil type, and neem ecotype or genotype. Fifty kilograms of fresh fruit yields 30 kg of seed, which gives about 6 kg of oil and 24 kg of seed cake. Seed viability ranges from 6 to 8 wk, but thoroughly cleaned and properly dried and cooled seeds remain viable up to 6 mo.

Neem is being planted on a large scale in tropical regions of the world, from Australia to Brazil and in several Caribbean and some Mediterranean countries. During the last century, neem was introduced in the arid zones of Africa. Neem was introduced in the Philippines in 1978. By 1990, the International Rice Research Institute (IRRI), in collaboration with the Philippine Rice Research Institute (PhilRice), had distributed and planted more than 120,000 neem seedlings. They are now full-grown and thriving on at least eight islands in the country. Over the past 5 yr, 20 million neem trees have been grown in southern China. Neem has become an integral part of the huge afforestation program in northeast Brazil. India has ~22 million neem trees, but programs have been initiated under which more will be grown on degraded and marginal lands, especially in drier areas.

What makes neem unique

Neem is bitter in taste. The bitterness is due to the presence of an array of complex chemicals called "triterpenes" or more specifically "limonoids." More than 100 bioactive compounds have been isolated from various parts of the neem tree; still more are being isolated. The formidable array of highly bioactive compounds makes neem a unique plant with potential applications in management of crop

pests. The limonoids in neem belong to nine basic structure groups: azadirone (from oil), amoorastaitin (from fresh leaves), vepinin (from seed oil), vilasinin (from green leaves), gedunin (from seed oil and bark), nimbin (from leaves and seed), nimbolin (from kernel), salannin (from fresh leaves and seed), and aza (from neem seed) (Kraus 2002). The azadirachtin content in neem could vary considerably due to edaphic, climatic, or genotypic differences.

Azadirachtin and its analogs have been most widely investigated because of their varied modes of action against insect pests (Saxena 1989; Schmutterer 1990, 2002). Azadirachtin is singularly most unique in that it affects not only at the whole-insect level but even at cellular levels where the basic lesion(s) occur. The varied actions of azadirachtin against insects have been reviewed in depth (Mordue Luntz 2004). The wide-ranging biological effects in insects come about in two different ways: first, by direct effects of azadirachtin on cells and tissues and second, by indirect effects exerted through the endocrine system following direct effects in the neuroendocrine tissues themselves. The diversity of neem compounds and their concerted effects on insect pests seems to confer a built-in resistance mechanism in neem.

Though subtle, neem's effects such as repellence, feeding and oviposition deterrence, growth inhibition, mating disruption, chemosterilization, and failure of eggs to hatch are now being considered far more desirable than a quick knockdown in integrated pest management (IPM) programs as they reduce the risk of exposing the pests' natural enemies to poisoned food or starvation (Saxena 2004). Despite high selectivity, neem derivatives affect more than 500 species of insect pests belonging to different orders, including hemipterans/heteropterans (Schmutterer and Singh 2002). Neem-based pest control materials are expected to capture 10% of the global pesticide market by the next decade.

How neem affects hemipteran/heteropteran bugs

Hemipterans/heteropterans were among the first insect species to be tested for their sensitivity to neem extracts (Abraham and Ambika 1979, Leuschner 1972, Steets 1975) and azadirachtin (Ruscoe 1972). Approximately 40 species of true bugs, including some economically important species, such as *Dysdercus* spp., *Helopeltis antonii*, *Nezara viridula*, *Scotinophara coarctata*, *Tessaratoma papillosa*, and others have been found to be sensitive to neem materials (Schmutterer and Singh 2002), but few trials have been conducted for their management in the field.

Topical application of methanolic extract of neem leaves on 5th-instar nymphs of the beet leaf bug, *Piesma quadratum*, caused high mortality during development and the few becoming adults had crippled wings (Steets 1975). Likewise, mortality was high when acetone extract of neem leaves or kernel was topically applied on 3rd-, 4th-, and 5th-instar *Dysdercus cingulatus* nymphs and the few survivors molted to abnormal supernumerary nymphs (Abraham and Ambika 1979). This physiological effect was attributed to possible juvenile hormonelike activity of neem extracts. Topical application of methanol or acetone extract of neem seeds also caused morphogenetic disturbances in *Dysdercus fasciatus*, but JH-mimicking activity was not observed (Ochse 1981/82). Recently, Singha et al. (2007) reported that topical application of aqueous neem kernel suspension or hexane extract to 4th-instar *N. viridula* nymphs caused loosening of the proboscis, along with separation and

deformation of mouth parts in the stylets of 5th-instar nymphs, adults, and interstadial molts, which rendered them incapable of feeding and led them to die. The mouthpart deformities and consequent insect mortality were dose-dependent for both aqueous and hexane extracts, but the aqueous extract caused deformities in more bugs.

Azadirachtin, the principal bioactive chemical of neem, has been tested against heteropterans by topical application, injection, or by ingestion. Spray application of azadirachtin directly on freshly molted 5th-instar *D. fasciatus* nymphs or offering them sprayed cotton seeds induced permanent nymphs (Ruscoe 1972). In addition to molting inhibition, feeding inhibition was also observed. The growth disruption was attributed to impairment of normal hormone balance in the insects. Injection of azadirachtin over a broad concentration range in the milkweed bug, *Oncopeltus fasciatus,* 5th-instars, prevented the development to adult stage and created permanent nymphs (Dorn et al. 1986a, 1987).

Histological examination of permanent nymphs showed a clear dose-dependent effect of azadirachtin on molting cycle. Doses ≤0.06 µg nymph^{-1} increasingly suppressed ecdysis but not apolysis and cuticulogenesis; higher doses blocked ecdysis completely, but at ≤0.25 ug nymph^{-1}, only apolysis was suppressed and not cuticulogenesis; higher doses blocked apolysis but still not cuticulogenesis (Dorn et al. 1987). The 'prolonged development' in azadirachtin-treated *Dysdercus koenigii* nymphs was also attributed to their failure to undergo ecdysis (Koul 1984a). As in *O. fasciatus*, a new procuticle was present below the apolized old cuticle and it was therefore suggested that azadirachtin, in some way, hindered the eclosion factor.

Some studies on hemipterans/heteropterans suggest that azadirachtin treatment in some way disturbs the ecdysteroid metabolism (Dorn et al. 1986a; Garcia et al. 1986; Redfern et al. 1981, 1982). In *O. fasciatus*, the ecdysteroid peak associated with the adult molting process is delayed and reduced by azadirachtin in a dose-dependent manner. The 'anti-ecdysteroidal' activity of azadirachtin is considered the main reason for molt inhibition and is demonstrated by the counteraction of exogenous ecdysteroids in 100% of the treated nymphs of *Rhodnius prolixus* (Garcia and Rembold 1984). Also, aside from a direct effect on the prothoracic gland, azadirachtin seems to interfere with the neurosecretory system of insects (Koul 1984a, Dorn et al. 1987). Azadirachtin treatment of last-instar *O. fasciatus* nymphs also postponed oviduct and vas deferens transformation (Dorn 2002).

Injection of azadirachtin at 1 µg per 0-d-old female of *D. koenigii* considerably affected its body weight during further development (Koul 1984b). Unlike the doubling of weight of control females by day 7, that of azadirachtin-treated females remained constant, obviously due to failure of vitellogensis. Consequently, egg deposition by treated females also did not occur. At higher doses of azadirachtin (4-16 µg female^{-1}), the treated *O. fasciatus* barely moved and hardly fed (Dorn 2002). Their wings also became inflated due to blood congestion, possibly due to disturbance of neurohormonal regulation of diuresis and other metabolic processes. Although the copulatory behavior of treated *O. fasciatus* females remained normal, their fecundity was drastically reduced at doses >0.125 µg female^{-1}. Generally, male bugs are more resistant to azadirachtin treatment than females with respect to longevity, but doses as low as 0.125 µg caused male infertility or impotence (Dorn 1986).

Neem's potential in RBB management

The RBB is distributed in several countries in South and Southeast Asia (Anonymous 1976). In Malaysia, its occurrence on rice was recorded as early as 1918 in Pekan, Pahang where nearly every rice field was attacked by RBB (Corbett and Yusope 1928). An infestation of the RBB in the rice crop in the Philippines was first reported in Bonobono, Bataraza, southern Palawan, in September 1979 (Barrion et al. 1982). Following the field infestation in 1979, a major outbreak occurred in 1982, covering 4,500 ha of rice fields (Cuaterno 2006). By February 1986, RBB became a serious rice pest in Palawan. In 1992, RBB was observed in Mindanao, specifically Zamboanga City, affecting 2,070 ha. Three years later, it invaded the whole Region 9, including the Autonomous Region of Muslim Mindanao. In 1996, the pest invaded Region 12, leading to an outbreak the following year. In 1998, the pest was spotted in the Visayas, particularly in Negros Occidental. It then spread to Siquijor Island, then to Bohol. The pest is now the center of attention in Iloilo Island and also already spotted in the southernmost part of Luzon.

RBB is difficult to manage by routine control measures because it attacks the rice plants from early vegetative stage to maturity. Maximum tillering to ripening stage is most susceptible and the damage could result from severe crop loss to complete yield loss during heavy infestation. Only a few rice cultivars moderately tolerant of RBB have been identified (Heinrichs et al. 1987). Unfortunately, the use of pesticides complicates the problem due to consequent elimination of the indigenous natural enemies of the pest.

In view of the above, the efficacy of integrating a tolerant rice cultivar, an insect pathogen, and an 'electrodyn' formulation of neem oil was evaluated against natural RBB infestations in three trials conducted on farmers' fields at Tigman, Bagong Sicat, and Malinao in Palawan during Apr-Sep 1986 (Abdul Kareem et al. 1988). More specifically, the treatments were 1) *Metarhizium anisopliae* 10^{12} spores ha^{-1}, emulsified in water with 0.01% 'Tween 80,' sprayed once at 30 d after transplanting (DT); 2) 'Electrodyn' formulation of neem oil sprayed at 30 DT and then at fortnightly intervals at 0.75 L ha^{-1}, until 2 wk before harvest; 3) one-spray application of *M. anisopliae* and one application of 'Electrodyn' formulation of neem oil at 30 DT; and 4) untreated control. These treatments were applied to a tolerant cultivar IR13149-71-3-2 and their effectiveness was compared with those applied to IR64, a susceptible rice variety. To ensure uniform infestation at each site, 24 net cages (1.5 × 1.5 m) were randomly installed in 8- × 8-m test plots at each location and 250 RBB adults were introduced into each cage at 30 DT. The field trials had a split-plot design and were replicated thrice at each location. RBB individuals on 10 randomly selected hills outside each cage were counted at 30, 45, 60, 75, and 90 DT in plots at each location, while bugs inside the net cages were counted at 7, 21, 35, 49, and 63 d after infestation. Percent unfilled grains and grain yield (t ha^{-1}) were recorded after harvest.

The results (Tables 1-3) showed that fewer RBB individuals were recorded in plots sprayed with the 'Electrodyn' formulation of neem oil at 45, 60, 75, and 90 DT as compared with the untreated controls at the three locations. Grain yield was also significantly higher in plots sprayed with neem oil at Bagong Sicat (Table 2) and Malinao (Table 3) but only relatively higher in Tigman as compared with

Table 1. Efficacy of integrating a RBB-susceptible or -tolerant cultivar, *M. anisopliae* (MA), and an 'Electrodyn' formulation of neem oil neem (NO) against RBB.[a] Tigman, Palawan, Philippines, Apr-Aug 1986.

Treatment	RBB (no.) 10 hills⁻¹ at DT[b]					Egg parasitization (%)	Unfilled grains (%)	Yield (t ha⁻¹)
	30	45	60	75	90			
IR64 (susceptible)								
MA	40a	567b	163bc	167b	116ab	9.9ab	51c	1.36a
NO	30a	305a	118a	69a	99a	7.5ab	37a	1.83a
MA & NO	34a	372ab	156b	147ab	130b	11.5b	46b	1.48a
Control[c]	42a	639c	200c	199b	149b	5.6a	53c	1.17a
IR13149-71-3-2 (tolerant)								
MA	40a	495b	174bc	180b	170b	6.0a	66b	0.34ab
NO	28a	320a	134a	92a	59a	3.6a	55a	0.51ab
MA & NO	34a	424ab	171b	141ab	105ab	5.8a	76b	0.62a
Control[c]	40a	824c	194c	223b	97a	7.7a	79b	0.28b

[a]Within columns, means followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test (DMRT); av of three replications. [b]DT = days after transplanting. [c]Untreated.

Table 2. Efficacy of integrating a RBB-susceptible or -tolerant cultivar, *M. anisopliae* (MA), and an 'Electrodyn' formulation of neem oil neem (NO) against RBB.[a] Bagong Sicat, Palawan, Philippines, Apr-Sep 1986.

Treatment	RBB (no.) 10 hills⁻¹ at DT[b]					Egg parasitization (%)	Unfilled grains (%)	Yield (t ha⁻¹)
	30	45	60	75	90			
IR64 (susceptible)								
MA	15a	93ab	78a	25b	13b	3.5a	62c	1.03ab
NO	10a	51a	63a	12a	5a	0.8a	38a	1.26a
MA & NO	30ab	63ab	105ab	23b	12ab	2.9a	57b	1.08ab
Control[c]	44b	107b	111b	23b	12ab	4.6a	64c	0.79b
IR13149-71-3-2 (tolerant)								
MA	19a	66ab	116b	28b	11ab	2.1a	44b	0.95b
NO	4a	43a	44a	11a	5a	1.4a	33a	1.26a
MA & NO	11a	65ab	71ab	26ab	14ab	2.3a	45b	1.10ab
Control[c]	31b	100b	104	30b	25b	4.6a	62c	0.98b

[a]Within columns, means followed by the same letter do not differ significantly at the 5% level by DMRT; av of three replications. [b]DT = days after transplanting. [c]Untreated.

Table 3. Efficacy of integrating a RBB-susceptible or -tolerant cultivar, *M. anisopliae* (MA), and an 'Electro-dyn' formulation of neem oil neem (NO) against RBB.[a] Malinao, Palawan, Philippines, Apr-Sep 1986.

Treatment	RBB (no.) 10 hills^{-1} at DT[b]					Egg parasitization (%)	Unfilled grains (%)	Yield (t ha^{-1})
	30	45	60	75	90			
	IR64 (susceptible)							
MA	1a	82b	60ab	41b	47ab	6.8a	65b	1.03b
NO	0a	48a	45a	24a	24a	4.4a	53a	1.49a
MA & NO	0a	103bc	84b	33b	50b	5.6a	63ab	1.07b
Control[c]	1a	145c	84b	73c	55b	7.0a	66b	0.92b
	IR13149-71-3-2 (tolerant)							
MA	0a	89b	79ab	49a	57ab	8.2a	46c	1.66b
NO	0a	51a	48a	35a	40a	5.1a	30a	2.34a
MA & NO	0a	83b	90ab	58a	58ab	8.3a	40b	1.89b
Control[c]	0a	136c	125b	84b	73b	10.2a	49c	1.98b

[a]Within columns, means followed by the same letter do not differ significantly at the 5% level by DMRT; av of three replications.
[b]DT = days after transplanting. [c]Untreated.

the untreated control (Table 1). At both locations, neem oil treatment protected both the susceptible and tolerant cultivars equally well against RBB damage and significantly increased their yield.

Treatment with *M. anisopliae* alone or together with neem oil did not confer any significant yield advantage over the neem oil treatment. Yield was also significantly higher in caged plots treated with neem oil at Tigman and Malinao (Tables 4 and 5), but yield data could not be obtained in Bagong Sicat because the net cages were vandalized.

Occasional outbreaks of RBB have also been recorded in Tamil Nadu, India, in 1977 (Venkata Rao and Muralidharan 1977) and 1984 (Uthamasamy and Mariappan 1985). Spray applications of insecticides such as Dieldrex 20, Agrocide 26DP, or Fenthion then reportedly suppressed the infestation. Recently, in field trials conducted at the Rice Research Station at Tirur, Tamil Nadu, spray application of 5% neem seed kernel extract at 10% ETL was found to be highly effective against RBB (G. V. Ramasubramanian, pers. commun.). High-volume spray applications of 3% emulsified neem oil also controlled brown planthoppers, stem borers, leaf thrips, RBB, and sheath rot in rice at Aduthurai, Tamil Nadu (Sadakatullah et al. 2000). Likewise, application of neem cake- (10 kg ha^{-1}) blended urea (50 kg ha^{-1}) to rice fields not only reduced nitrogen loss but also controlled sheath blight, brown leaf spot, and insect pests. The use of ecofriendly pest control materials, such as neem, is now receiving due attention in India.

Table 4. RBB population and yield in caged plots planted with a susceptible or tolerant cultivar and treated with *M. anisopliae* (MA), an 'Electrodyn' formulation of neem oil neem (NO), or MA and NO against RBB. [a] Tigman, Palawan, Philippines, Apr-Aug 1986.

Treatment	RBB (no.) cage^{-1b} at days after incubation					Yield (t ha^{-1})
	7	21	35	49	63	
IR64 (ssceptible)						
MA	259b	450c	547bc	608b	702ab	2.01c
NO	169a	173a	158a	180a	191a	2.98a
MA & NO	220ab	356b	504b	634b	695ab	2.51b
Control[c]	385c	544d	670c	792b	900b	2.03c
IR13149-71-3-2 (tolerant)						
MA	396b	572c	619c	976bc	1202b[d]	0.20d
NO	194a	176a	223a	263a	328a	1.93a
MA & NO	223a	338b	472b	583ab	727ab	1.17b
Control[c]	396b	572c	738c	1058c	1177b[d]	0.73c

[a]Within columns, means followed by the same letter do not differ significantly at the 5% level by DMRT; av of three replications. [b]Thirty-six hills in caged plot. [c]Untreated. [d]Bugburn.

Table 5. RBB population and yield in caged plots planted with a susceptible or tolerant cultivar and treated with *M. anisopliae* (MA), an 'Electrodyn' formulation of neem oil neem (NO), or MA and NO against RBB.[a] Malinao, Palawan, Philippines, Apr-Sep 1986.

Treatment	RBB (no.) cage^{-1b} at days after incubation					Yield (t ha^{-1})
	7	21	35	49	63	
IR64 (susceptible)						
MA	187a	450c	547bc	608b	702ab	2.01c
NO	158a	173a	158a	180a	191a	2.98a
MA & NO	202a	356b	504b	634b	695ab	2.51b
Control[c]	227a	544d	670c	792b	900b	2.03c
IR13149-71-3-2 (tolerant)						
MA	216a	259ab	335a	403a	515b	0.69c
NO	148a	162a	198a	238a	313a	2.54a
MA & NO	155a	180a	238a	299a	425ab	1.77b
Control[c]	234a	284b	338a	382a	522b	1.51b

[a]Within columns, means followed by the same letter do not differ significantly at the 5% level by DMRT; av of three replications. [b]Thirty-six hills in caged plot. [c]Untreated.

RBB management with neem: expectations and reality

RBB specializes in excessively sucking photosynthates from the rice plant. It has been estimated that a RBB feeding on a rice plant could kill the plant in 16-17 d (Ooi 1981). However, if 20 bugs were to feed on a rice plant, the plant would perish in 2 d. Under this situation, the repellency and antifeedant effects of neem derivatives may provide protection to treated rice plants from the feeding damage by RBB, but, on the whole, the growth-disrupting properties of neem seem to be more valuable. The latter effects, though not immediate, are chronic and lead to irreversible disturbances in pest physiology, especially the neuroendocrine homeostasis. The concurrence and variety of physiological and cellular disturbances would also affect the behavior and activity of the pest and upset its colonization process and buildup on plants.

The efficiency of neem materials could be augmented by the use of additives to protect neem's bioactive component from UV light and to improve the penetration of plant surfaces. Also, the use of synergists, better formulation, and improved methods of application—e.g., ultra-low volume (ULV) sprays or "Electrodyn" formulations of neem oil or seed kernel extract, complemented with soil application of deoiled neem cake—would certainly enhance the efficacy of neem against RBB. If employed within the framework of IPM programs, neem derivatives will be of enduring value in RBB management and reduce our dependence on toxic, synthetic insecticides.

Conclusion

Neem materials, such as deoiled cake, have had a long history of use for minimizing damage caused by insect pests to rice crop in the Indian subcontinent (Saxena 2002). The use of neem materials for pest control was experience-driven and originated as a need and not as a science in early years. With the development of better analytical tools and techniques for detection, isolation, and identification of bioactive neem constituents and with a better understanding of how they affect pest behavior and physiology and even changes at cellular and molecular levels, the scientific basis of neem-based pest control has emerged on a sound footing. Today, nearly 100 azadirachtin-rich formulations have been patented and more than 50 brands of neem products are being marketed worldwide. But the high cost of these commercial formulations limits their use for insect control in rice. For rice insect pest management by the average rice farmer, the use of readily available, relatively inexpensive, but equally effective neem cake, aqueous extracts of neem seed or kernel, or emulsified neem oil should be promoted by building awareness of neem's pest control potential, imparting hands-on training, and conducting on-farm trials and demonstrations in farmers' fields at strategic locations. Fortunately, the neem tree is well established now in the Philippines and other countries in South and Southeast Asia. Therefore, availability of raw neem material for pest control should not be a problem. Adding inexpensive UV-protectants or sunshields, such as carbon (Saxena 1987a,b) and adjuvants, activators, and synergists (Lange 1984, Walter 1999) to neem-based or azadirachtin-based pest control materials could further enhance their activity and reduce the cost of application. In contrast to synthetic pesticides, the use of standardized neem cake, neem seed or kernel extract, or emulsified oil for rice

insect pest management is preferable and has the additional benefit of weak or inconsequential effects on the pests' natural enemies and other ecologically important nontarget organisms, which is an important consideration in successful IPM programs today. These considerations should pave the way for increased acceptance of neem materials for use in rice insect pest control (Saxena 2002).

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Notes

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Resistance and Yield Responses of Rice Cultivars to the Black Bug *Scotinophara coarctata* (Fabricius)

E. A. Heinrichs

Introduction

There are a number of black bug species belonging to genus *Scotinophara* that are found in rice fields (Miyamoto et al. 1983). The major black bug *Scotinophara* spp. that attack rice in Asia are *S. coarctata* (Fabricius)*, S. lurida,* and *S. latiuscula*. The distribution of these three species is as follows:

     S. coarctata (Fabricius): Bangladesh, Cambodia, India, Indonesia, Malaysia, Myanmar, Pakistan, Philippines (Palawan), Sri Lanka, Thailand, Vietnam (Fig. 1)
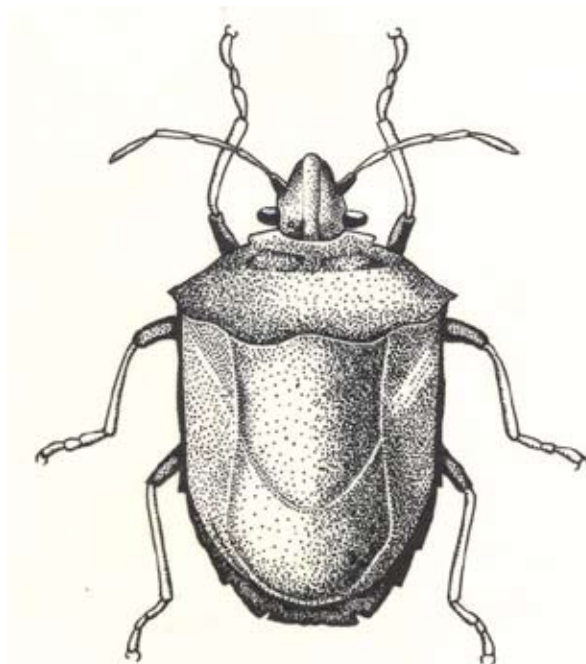
Fig. 1. Line drawing of *Scotinophara coarctata*.
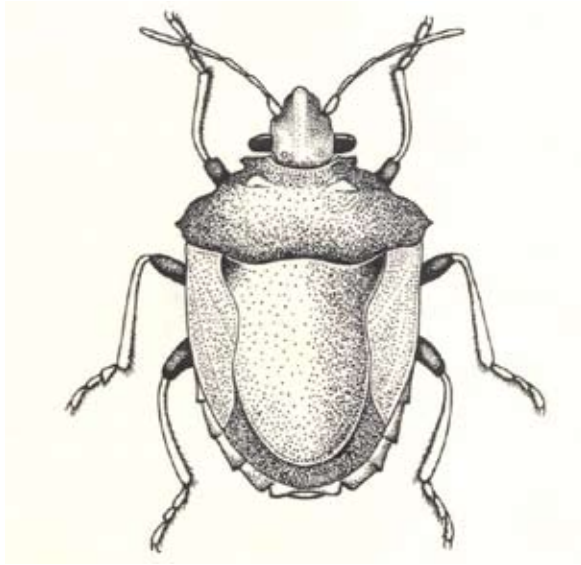
Fig. 2. Line drawing of *Scotinophara lurida*.
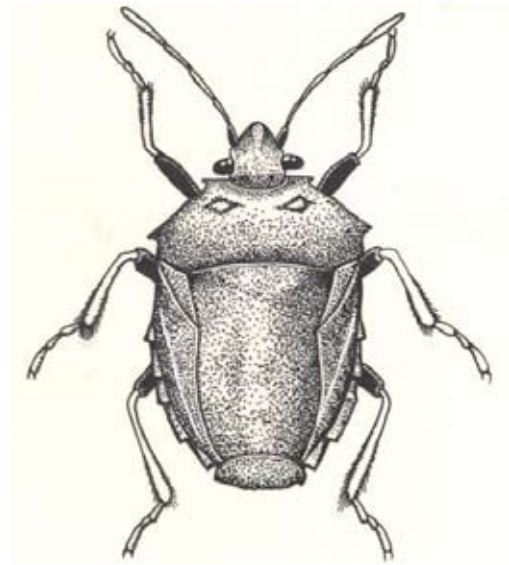
Fig. 3. *Scotinophara latiuscula*.

S. lurida (Burmeister): Bangladesh, Cambodia, China, India, Indonesia, Japan, Malaysia, Pakistan, Papua New Guinea, Philippines (Mindanao), Sri Lanka, Thailand, Vietnam (Fig. 2).

S. latiuscula (Breddin): Indonesia (Sumatra), Philippines (Luzon) (Fig. 3).

Among these, *S. coarctata,* the Malayan rice black bug, and S. *lurida*, the Japanese rice bug, are the most important in Asia where they are pests of rice in rainfed wetland and irrigated wetland environments.

Fig. 4. Egg parasite *Telenomus* nr. *triptus* on *Scotinophara latiuscula* egg mass.

The biology was described by Dale (1994). Female bugs deposit their eggs on the basal portion of the rice plant near the water surface. A female lays about 200, 1-mm-long greenish eggs in masses of up to 15 eggs each during her lifetime and guards them until they hatch. Eggs later turn pinkish and hatch in about 4−7 d (Fig. 4). Nymphs molt four to five times and become adults in 25−30 d. The life cycle is about 45 d and there are up to three generations per rice crop.

The adults pass the winter or the dry season in a dormant state in cracks in the soil or in grassy areas. When the weather is favorable, they fly to the newly planted rice crop and reproduce over several generations and again return to their resting sites after the rice harvest. Adults are capable of migrating long distances. Both nymphs and adults have a wide range of alternative hosts.

Scotinophara coarctata was reported as a pest of rice in Malaysia (Corbett and Yusope 1924). In the Philippines, the first infestation of *S. coarctata* was observed in Palawan Island in 1950 where it has now become a serious pest. Other species, such as *S. latiuscula*, occurs on Luzon Island, *S. lurida* is seen in Mindanao Island. But populations are extremely low and they are not serious economic pests. Although Corbett and Yusope reported the black bug as a pest of rice in Malaysia in 1924, black bugs were considered minor pests of rice until the 1970s when outbreaks were first reported in Indonesia and Malaysia in 1978 and 1979, respectively. The first reported *S. coarctata* outbreak in the Philippines was in Bonobono, Bataraza, southern Palawan, in 1982 and a major infestation occurred in the subsequent months (Barrion et al. 1982).

Black bugs attack rice plants at all crop growth stages, especially from maximum tillering to ripening (Reissig et al. 1985). Both nymphs and adults remain at the base of the plants or in cracks in the soil during the day and at night and feed at the base of the plant where they suck plant sap. Stem nodes are preferred feeding sites because large reservoirs occur there, which meet the high feeding requirements of these insects. During the tillering stage, their feeding causes stunted plant growth and "deadhearts," and tiller number is reduced. Feeding during reproductive stage affects panicle development and exsertion, and panicles have empty grains (whiteheads). Sap removal by nymphs and adults causes plants to turn reddish brown or yellow. When the bugs occur in high numbers, plants wilt and dry and are 'bugburned,' similar to the damage caused by the brown planthopper, *Nilaparvata lugens* (Stål) (Fig. 5). Yield losses are due to unfilled grains, a decrease in tiller number, and few grains per panicle.

Fig. 5. Rice field 'burned' by feeding of *Scotinophara coarctata* in Palawan, Philippines.

Research

Cultural practices and biological control agents are available to manage black bugs (Reissig et al. 1985), but they are not sufficiently effective to prevent outbreaks. Because of their feeding habits, the economics and problems of environmental pollution have not been a panacea. For these reasons, we initiated a search for genetic resistance to *S. coarctata* at IRRI in 1983.

Rice cultivars were first screened for black bug resistance in a farmer's field at Maasin, Brooke's Point, Palawan, Philippines, in July-December 1983 (Fig. 6). Three hundred rice breeding lines were sown in thermo cups and transplanted in caged plots of 1.5 × 3 m at 15 test entries per plot and 10 hills per entry, 2−3 seedlings per hill. Water was maintained 3−5 cm deep for 20 d after transplanting (DAT). Field-collected black bug adults were introduced 20 DAT at five bugs per hill (750 black bugs per test cage plot). Immediately after infestation, the field was drained, which favored black bug survival. The field remained saturated throughout the experiment. Damage recordings were based on a 0−9 rating scale:

- 0 = no damage
- 1 = wilting of youngest leaf
- 3 = wilting of youngest leaf and partial yellowing of the first, second, and third older leaves
- 5 = wilting of more than two leaves and pronounced yellowing of the first, second, and third older leaves
- 7 = more than half the plants wilting or dead and remaining plants severely stunted
- 9 = all plants dead or "bugburned"

Fig. 6. IRRI entomologist, E. A. "Short" Heinrichs observing black bug varietal resistance screening experiments in Palawan, Philippines, 1983.

Fig. 7. BG379-1, a rice variety moderately resistant to black bug *S. coarctata*, damaged by feeding of *S. coarctata* in Palawan studies. Initially infested with 40 bugs per hill.

Of the 300 rices screened, 20 were selected on the basis of damage reaction. They were retested in the same field in Jan-May 1984 with 35 black bug adults per hill and treatments in four replications. The number of black bugs in five randomly chosen hills per test entry was recorded 20 d after infestation (DAI). Plant damage was rated at 20, 40, and 60 DAI based on the 0−9 scale.

Of the 20 cultivars, IR13149-71-3-2 and IR10781-75-3-2-2 were the most resistant, while four cultivars, IR18350-175-2-3, BG 379-1 (Fig. 7), IR19661-23-3-2-2, and B2791b-Mr-257-3-2 had low levels of resistance (Table 1). The first five test entries tolerated high black bug population at 40 DAI (see table). However, IR13149-71-3-2 and IR10781-75-3-2-2 were the only entries that survived to 60 DAI. IR10781-75-3-2-2, which matures in 131 d, is a high-yielding line (7 t ha^{-1} in 1980 dry season), is resistant to brown planthopper biotypes 1 and 3, and moderately resistant to green leafhopper.

A third experiment with these six cultivars was conducted that examined the relationship between level of resistance and yield and determined the economic injury levels (Heinrichs et al. 1987). The experiment was conducted in the field at the Palawan National Agricultural College in Aborlan, Palawan, Philippines, during the wet season, July to November 1984. Six cultivars selected from the field test conducted in Palawan in May 1984 (Table 1) were selected for further evaluation. A local cultivar grown by farmers at that time, Tjeremas, was used as a susceptible check.

Black bugs were reared by artificially infesting rice plants. Field-collected adults were placed on 45-d-old potted IR36 plants and covered with a 16-cm-diameter by 95-cm-height cylindrical mylar film cage with a nylon mesh top and two nylon mesh windows for ventilation. After oviposition,

Table 1. Reaction of selected breeding lines at 20 d after infestation (DAI) to black bugs, Palawan, Philippines, 1984 dry season.[a]

Breeding line[b]	Black bugs (no. hill⁻¹ at 20 DAI)	Plant damage at indicated DAI		
		20	40	60
IR13149-71-3-2	149 abc	3.5 a	4.0 a	5.0 a
IR10781-75-3-2-2	133 ab	4.0 a	4.0 a	5.5 a
IR18350-175-2-3	155 abc	3.5 a	5.5 ab	7.5 ab
BG379-1	200 c	3.5 a	5.5 ab	8.0 b
IR19661-23-3-2-2	126 ab	5.0 bc	5.5 ab	8.0 b
IR12721-24-3-1	173 bc	5.0 bc	6.5 abcd	8.0 b
BW295-4	129 ab	4.5 bc	7.5 cdef	8.0 b
BR316-15-4-4-1	131 ab	5.5 bcd	6.0 abc	8.5 b
BR445-60-1	162 bc	5.0 bc	7.0 bcdef	8.5 b
IR13240-108-2-2-3	134 ab	6.0 c	7.0 bcdef	8.5 b
IR25774-3-1-1	169 bc	4.5 bc	7.0 bcdef	8.5 b
IR36 (check)	167 bc	5.5 bcd	7.0 bcdef	8.5 b
Tjeremas (purple base)	109 ab	7.0 d	8.0 def	8.5 b
BG400-1	134 ab	5.5 bcd	8.5 g	9.0 c
B2791b-Mr-257-3-2	145 abc	4.5 bc	6.5 abcd	9.0 c
B3981c-Pn-200-2-2	97 a	7.0 d	8.5 g	9.0 c
Cul. 6914	170 bc	5.0 b c	8.5 g	9.0 c
IR12979-24-1	133 ab	5.5 bcd	7.0 bcdef	9.0 c
IR13415-9-3	161 bc	5.0 bc	7.0 bcdef	9.0 c
C1754-5	121 ab	5.5 bcd	7.5 cdef	9.0 c
IR31917-31-3-2 148 abc	148 abc	5.5 bcd	8.0 def	9.0 c
Tjeremas (green base- local check)	203 c	5.0 bc	7.5 cdef	9.0 c

[a]Av of four replications. In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. [b]Breeding lines selected from 300 test entries screened in July-December, 1983. Lines in boldface selected for further evaluation.

leaves with eggs were removed daily and placed in plastic trays with a moist paper towel. Five days later, the nymphs hatched and were transferred to 4-d-old IR36 plants in rearing cages. The food plants were changed weekly. To change the food plant, the old plants were placed in a bucket with water forcing the bugs to move to the leaf tips. The plants were then removed from the water and the leaves tapped over fresh plants in the rearing cage to dislodge the bugs.

Plants for the field test were grown in a wetbed nursery in the field. The nursery was divided into seven equal plots of 1.5- × 1.5-m with one plot for each cultivar. The field consisted of a 21- × 56-m plot. Before transplanting, fertilizer was applied at 60-30-30 kg NPK, respectively, and $ZnSO_4$, at 20 kg ha⁻¹. The plants received a broadcast application of N at 25 DAT at 25 kg ha⁻¹. The field was divided into four equal plots, each plot representing one replication. Each plot was subdivided into 35 subplots (7 cultivars × 5 bug levels) of 1.5- × 1.5-m each, with 1 m between subplots. Seedlings of the cultivars were transplanted 21 d after sowing at three seedlings per hill and at a spacing of 25 cm between hills. Each treatment consisted of 36 hills in the 1.5- × 1.5-m subplot. Immediately after transplanting, each treatment was enclosed in a 1.75- × 1.75- × 1.5-m high fiberglass net cage, which was supported at the four corners by bamboo stakes. The base of the netting material was pushed into the soil and the net remained in place until harvest (Fig. 6).

At 30 DAT, the plants were artificially infested at the rate of 0, 1, 5, 10, and 20 pairs of bugs (males and females) per hill. Each treatment, consisting of a given cultivar and bug level, was replicated four times. To provide a favorable environment for survival and multiplication of black bugs, water in the field was drained immediately after infestation, but saturated conditions were maintained during the remainder of the test. All measurements, except yield, were based on 10 hills selected at random in each plot. Plant height measurements were recorded at 1 d before bug infestation and again at 30 and 60 DAI. Number of tillers, panicle length, and percentage of tillers having whiteheads (i.e., panicles with empty grains) were recorded just before harvest at 85 DAI. Plant damage ratings were recorded at 90 DAI according to the 0−9 scale earlier shown (Domingo et al. 1985). Bugs were counted at 30 and 60 DAI as based on 10 hills per plot and numbers expressed as bugs per hill. Grain yield data were based on a 5-m^2 area consisting of 10 hills and was expressed in grams per square meter. At harvest, the number of grains per panicle and percentage of filled grains were determined. Percentage yield loss was calculated from differences in yield between samples from the uninfested check and the treated plants.

Based on the results of the yield loss test, two cultivars, IRI0791-75-3-2-2 and IR13149-71-3-2, were further evaluated to determine the nature of resistance involved. They were compared with two common parents, Remadja and BG90-2, from Sri Lanka and the most recently (at that time) released IR cultivar in the Philippines, IR64. Tjeremas was used as the local susceptible check cultivar.

Tests were conducted to determine the survival and population growth of *S. coarctata* on the cultivars and to determine the plant damage caused. Survival was evaluated on plants of four age categories−15, 30, 45, and 60 d after sowing (DAS). Seedlings were transplanted in soil in 18-cm-diameter clay pots at the rate of three seedlings per pot. The plants were covered with a mylar film cage, 16 cm diameter by 95 cm in height. Ten 2nd-instar nymphs were introduced into each cage. Treatments were replicated seven times. Surviving insects were recorded at 30 DAI.

In the population growth and plant damage test, two pairs (males and females) of *S. coarctata* were placed on the 15 DAS plants of six cultivars from the survival test. Plants were 45 DAS when the test began. Treatments were replicated seven times. The number of bugs, dry weight of the bugs, and plant damage ratings were recorded at 50 DAI.

The results indicated that numbers of *S. coarctata* at 30 and 60 DAI were significantly different among cultivars only at 40 bugs per hill, the initial infestation level (Table 2). At both 30 and 60 DAI, the lowest numbers in the 40 bugs per hill treatment were recorded on IR10781-75-3-2-2. For most treatments, the number of bugs per hill doubled by 60 DAI. A few bugs were found in the uninfested checks, and it is possible that small nymphs entered through the screen or bugs may have invaded the plots when the cages were removed for observation.

Bug infestations reduced the plant height of all cultivars. At 30 DAI, reduction in Tjeremas was 27%, whereas it was only 7% in IR13139-71-3-2 and 12% in IRl078l-75-3-2-2. At 60 DAI, in Tjeremas, the local cultivar, height reduction was the highest in the uninfested check at 161 cm, while the other treatments ranged from 94 to 118 cm. Reduction was highest in Tjeremas where rates of one bug per hill significantly reduced plant height. With 40 bugs per hill, reduction in Tjeremas was

30%. In IR13149-71-3-2, there was no significant reduction in plant height with 20 bugs per hill and reduction at 40 bugs per hill was only 9%.

The linear regression of plant height on number of bugs per hill is shown in Figure 8A. The slope was steepest in Tjeremas where there was a 1.2-cm decrease in plant height for every bug per hill. The slope is most gradual for IRl078l-75-3-2-2 and IR13149-71-3-2 where there was only a 0.3 and 0.2 cm reduction, respectively, for each bug per hill. Similar trends occurred in the other cultivars.

"Whitehead" counts taken at 85 DAI were extremely high on all cultivars (Table 3). There, however, were significant differences among cultivars with Tjeremas and B279lb-Mr257-3-2 having the most "whiteheads" and IR10781-75-3-2-2 and IR13149-71-3-2 the least. In Tjeremas, there was a significant difference between the uninfested check and the 10-bug-per-hill treatment, while in IR10781-75-3-2-2, a significant difference occurred only at the 40-bug-per-hill level. At 40 bugs per hill, "whitehead" percentage was 86 in Tjeremas and only 27 in IRl078l-75-3-2-2 and 41 in IR13149-71-3-2. "Whiteheads" in other cultivars at 40 bugs per hill ranged from 52% to 82%.

Plant damage ratings taken at 90 DAI were related to initial bug level (Table 4). All cultivars had a damage rating of 1 at an infestation level of two bugs per hill. Differences in cultivars were evident at 10 bugs per hill, with Tjeremas having the highest rating. At 40 bugs per hill, IR10781-75-3-2-2 and IR13149-71-3-2 had the lowest damage ratings of 4.5 and 4.0, respectively, while ratings of the other cultivars were similar, varying from 7 to 8. Some Tjeremas plants were "bugburned."

S. coarctata had a significant effect on tiller production (Table 5). In Tjeremas, there was a significant reduction at the 10-bug-per-hill level. At 40 bugs per hill, tiller number was decreased by 50%. In IR10781-75-3-2-2, there was no significant reduction, even at 40 bugs per hill. In the other cultivars, tiller number was significantly decreased only at the 40-bug-per-hill level.

Grain yield potential of cultivars differed significantly as indicated by yield of uninfested checks (Fig. 8B). Yield of IRI3149-71-3-2 was the highest at 543 g m^{-2} (5.4 t ha^{-1}) and was not significantly different from those of B2791b-Mr-257-3-2 and IRl0781-75-3-2-2. There was a significant yield decrease at two bugs per hill only in IR18350-175-2-3 and in Tjeremas. At 10 bugs per hill, there was a significant decrease in all cultivars, except IR13149-71-3-2. At 40 bugs per hill, yield of five cultivars was less than 90 g m^{-2}, while it was 188 and 151 g m^{-2} in IRl0781-75-3-2-2 and IR13149-71-3-2, respectively. The linear regression of grain yield on initial number of bugs per hill indicated the most gradual slope for IR10781-75-3-2-2 (Fig. 8B). For every bug per hill, there is a 6.7 g m^{-2} or 67 kg ha^{-1} decrease in grain yield. Decrease in yield of the other cultivars ranged from 8 to 12 g m^{-2}.

Percent yield loss was highest in Tjeremas at bug levels of 2–20 per hill (Table 6). At 10 bugs per hill, yield loss was 54% in Tjeremas, whereas it was only 11% in IRI3149-71-3-2. At 40 bugs per hill, yield loss was greater than 83% for all cultivars, except IR10781-75-3-2 and IRI3149-71-3-2, which were 58% and 72%, respectively.

The linear regression of percentage yield loss on number of bugs per hill indicated the most gradual slope for IRI0781-75-3-2-2 and IR13149-71-3-2 with a 1.5% and 1.8% yield loss for each bug per hill, respectively (Fig. 8C). Yield loss for the other cultivars ranged from 2.1% to 2.7% for each bug per hill. Based on the predictive equation at 40 bugs per hill, there was a 95% yield loss in

Fig. 8. Response of seven rice cultivars when infested with black bug, _S. coarctata._ VI = BG379-l, V2 = B279lb-Mr-257-3-2, V3 = IRl078l-75-3-2-2, V4 = IR13149-71-3-2, V5 = IR18350-l75-2-3, V6 = IR1966l-23-3-2-2, V7 = Tjeremas. (a) Regression of plant height on number of _S. coarctata_ per hill at 60 d after infestation (90 d after transplanting). (b) Regression of yield on number of _S. coarctata_ per hill. (c) Regression of percent yield loss on number of _S. coarctata_ per hill. (d) Regression of percent yield loss on plant damage at 90 d after infestation (120 d after transplanting).

Plant height (cm)

V1: ŷ = 99.74 − 0.29 x, r = -0.52*
V2 : ŷ = 112.78 − 0.59 x, r = -0.86**
V3: ŷ = 115.27 − 0.27 x, r = -0.64**
V4: ŷ = 111.16 − 0.22 x, r = -0.42*
V5: ŷ = 89.64 − 0.41x, r = -0.81**
V6: ŷ = 91.85 − 0.30 x, r = -0.60**
V7: ŷ = 157.03 − 1.20 x, r = -0.82**

Bugs hill⁻¹ (no.)

Yield (g m⁻²)

V1: ŷ = 383.73 − 8.61 x, r = -0.95**
V2 : ŷ = 528.83 − 11.98 x, r = -0.95**
V3: ŷ = 457.74 − 6.74 x, r = -0.84**
V4: ŷ = 549.59 − 9.78 x, r = -0.87*
V5: ŷ = 378.41 − 8.08x, r = -0.92**
V6: ŷ = 416.71 − 8.90 x, r = -0.92**
V7: ŷ = 334.96 − 7.88 x, r = -0.83**

Bugs hill⁻¹ (no.)

Yield loss (%)

V1: ŷ = 2.24 x
V2 : ŷ = 2.27 x
V3: ŷ = 1.47 x,
V4: ŷ = 1.78 x
V5: ŷ = 2.14x
V6: ŷ = 2.14x,
V7: ŷ = 2.35

Bugs hill⁻¹ (no.)

Yield loss (%)

V1: ŷ = 14.38 x, r = -0.90**
V2 : ŷ = 11.54 x, r = -0.95**
V3: ŷ = 13.79 x, r = -0.73**
V4: ŷ = 17.30 x, r = -0.81**
V5: ŷ = 11.34 x, r = -0.85**
V6: ŷ = 11.56 x, r = -0.92**
V7: ŷ = 14.49 x, r = -0.91**

Damage grade

Table 2. Numbers of *S. coarctata* per hill at 60 d after infestation.

Initial bugs hill[-1] (no.)	Cultivar[a]						
	BG3791	B2791b-Mr-257-3-2	IR10781-75-3-2-2	IR13149-71-3-2	IR18350-175-2-3	IR19661-23-3-2-2	Tjeremas (local check)
0	2.3a	1.3a	1.0a	0.9a	1.5a	0.8a	1.7a
2	10.4a	10.6a	8.1a	6.1a	8.3a	13.5a	13.5a
10	18.1a	16.7a	14.5a	17.3a	16.5a	19.9a	22.1a
20	59.1a	50.5a	35.7a	36.1a	36.3a	60.1a	56.3a
40	92.9ab	119.7a	62.8b	80.0b	97.9ab	88.1ab	94.3ab

[a]In a row, means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

Table 3. Percent whiteheads on rice cultivars when infested with different numbers of *S. coarctata*.

Initial bugs hill[-1] (no.)	Cultivar[a]					
	BG3791	B2791b-Mr-257-3-2	IR10781-75-3-2-2	IR13149-71-3-2	IR19661-23-3-2-2	Tjeremas (local check)
0	0.0c (a)	0.0c (a)	0.0b (a)	0.0b (a)	0.0c (a)	0.0d (a)
2	0.0c (a)	2.5c (a)	0.0b (a)	1.1c (a)	2.3c (a)	3.4cd (a)
10	5.8c (a)	5.8c (a)	2.3b (a)	3.6c (a)	4.5bc (a)	6.6c (a)
20	24.5b (ab)	28.1b (ab)	7.6b (c)	18.7b (bc)	17.0b (abc)	39.5b (a)
40	51.9a (b)	81.7a (a)	26.9a (bc)	41.1a (bc)	80.5a (a)	85.6a (a)

[a]In a column and in a row (with parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. Because of early maturity, whitehead count on IR18350-175-2-3 was not done.

Table 4. Plant damage ratings[a] at 90 d after infestation[b] with different numbers of *S. coarctata*.

Initial bugs hill[-1] (no.)	Cultivar[c]					
	BG3791	B2791b-Mr-257-3-2	IR10781-75-3-2-2	IR13149-71-3-2	IR19661-23-3-2-2	Tjeremas (local check)
0	0.0d (a)	0.0d (a)	0.0c (a)	0.0d (a)	0.0d (a)	0.0d (a)
2	1.0d (a)	1.0d (a)	1.0c (a)	1.0cd (a)	1.0d (a)	1.0d (a)
10	2.5c (b)	2.5c (b)	2.5b (b)	2.0bc (b)	3.0c (b)	4.5c (a)
20	4.5b (bc)	5.0b (b)	3.5ab (d)	3.0ab (d)	4.5b (bc)	6.5b (a)
40	7.0a (a)	8.0a (a)	4.5a (b)	4.0a (b)	7.5a (a)	8.0a (a)

[a]0 = no damage; 1= wilting of youngest leaf; 3 = wilting of youngest leaf and partial yellowing of the first, second, and third oldest leaves; 5 = wilting of more than two leaves and pronounced yellowing of the first, second, and third oldest leaves; 7 = more than half of the plants wilting or dead and the plants severely stunted; and 9 = all plants dead or bug burned (Domingo et al. 1985).
[b]120 d after transplanting. [c]In a column and in a row (with parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. Because of early maturity, plant damage ratings on IRI8350-I75-2-3 were not made.

Table 5. Tiller production (no. m^{-2}) of rice cultivars infested with different numbers of _S. coarctata_.

Initial bugs hill^{-1b}	Cultivar[a]						
	BG3791	B2791b-Mr-257-3-2	IR10781-75-3-2-2	IR13149-71-3-2	IR18350-175-2-3	IR19661-23-3-2-2	Tjeremas (local check)
0	246.8a (a)	243.3a (ab)	233.3a (ab)	276. 5a (a)	270.5a (a)	237.3a (ab)	202.5a (b)
2	250.0a (ab)	243.3a (ab)	220.2a (bc)	269.5ab (a)	232.0ab (ab)	236.8a (ab)	190.0ab (c)
10	245.0a (a)	222.0a (b)	212.8a (a)	256.0ab (a)	229.3ab (a)	215.8ab (a)	157.3b (b)
20	184.5b (bc)	162.0b (c)	211.3a (ab)	230.8b (a)	215.5b (ab)	192.8b (abc)	102.5c (d)

[a]In a column, and in a row (with parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. [b]Due to bug burn in some plots, tiller number was not statistically analyzed on the 40-bug-per-hill treatment.

Table 6. Grain yield (g m^{-2}) and percent grain yield loss of cultivars infested with different numbers of _S. coarctata_.

Initial bugs hill^{-1b}	Cultivar[a]						
	BG3791	B2791b-Mr-257-3-2	IR10781-75-3-2-2	IR13149-71-3-2	IR18350-175-2-3	IR19661-23-3-2-2	Tjeremas (local check)
Grain yield (g m^{-2})							
0	393.7a (c)	529.7a (ab)	461.7a (abc)	543.4a (a)	433.3a (bc)	431.6a (bc)	414.2a (c)
2	377.7a (bc)	480.3ab (a)	448.8ab (ab)	513.3b (a)	354.8b (bc)	413.3a (abc)	325.4b (c)
10	297.0b (bc)	442.9b (a)	381.9bc (ab)	478.6^a (a)	251.9c (cd)	296.9b (bc)	186.9c (d)
20	171.2c (de)	283.4c (abc)	326.6tc (ab)	357.7b (a)	189.8c (cde)	227.9b (bcd)	11.0d (e)
40	58.9d (b)	45.3d (b)	188.1d (a)	150.6c (ab)	80.5d (b)	73.2c (b)	69.8d (b)
Grain loss (%)							
2	3.9d (a)	8.8c (a)	4.2c (a)	5.5c (a)	16.0c (a)	4.2c (a)	18.0c (a)
10	23.7c (bc)	16.0c (c)	17.6bc (c)	11.3c (c)	41.6b (ab)	31.b (bc)	53.5b (a)
20	56.0b (ab)	46.9b (bcd)	28.6b (d)	35.9b (cd)	55.1b (bcd)	46.8b (bcd)	72.4a (a)
40	84.0a (a)	92.2a (a)	58.1a (b)	71.9a (ab)	80.9a (a)	83.0a (a)	83.1a (a)

[a]In a column and in a row (with parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

Tjeremas and only a 59% yield loss in IR10781-75-3-2-2. Based on the linear regression of percentage yield loss on damage rating, IR13149-71-3-2 was found most sensitive to damage (Fig. 8D). The predictive equation indicated a 17% yield loss for each damage grade, while in IRI8350-175-2-3, the corresponding yield loss was 11%.

Black bug feeding significantly reduced panicle length only in IR18350-175-2-3 and IRI9661-23-3-2-2. The number of grains per panicle, however, was reduced in BG379-1, B2791b-Mr-257-3-2, IRI9661-23-3-2-2, and Tjeremas (Table 7). In the latter cultivars, grains were reduced from 160 per panicle in the uninfested check to 118 at 40 bugs per hill. The most significant effect of black bug feeding on yield components was evident in the percentage of filled grains (Table 7). Filled grains in

Table 7. Number of grains per panicle and percent filled grains of rice cultivars infested with different numbers of *S. coarctata*.

Initial bugs hill[-1b]	Cultivar[a]						
	BG3791	B2791b-Mr-257-3-2	IR10781-75-3-2-2	IR13149-71-3-2	IR18350-175-2-3	IR19661-23-3-2-2	Tjeremas (local check)
Grains (no. panicle[-1])							
0	145.8a (a)	176.0a (a)	152.5a (a)	159.5a (a)	110.0a (b)	141.5a (ab)	160.3a (a)
2	134.3ab (ab)	161.3a (a)	146.8a (a)	156.5a (a)	103.5a (b)	131.5a (ab)	143.0ab (a)
10	128.3ab (ab)	161.3a (a)	142.5a (a)	147.5a (a)	98.3a (b)	129.0a (ab)	131.0ab (ab)
20	123.3ab (ab)	149.5a (a)	136 .8a (a)	142.0a (a)	90.5a (b)	119.3a (ab)	129.0b (a)
40	107.3b (ab)	71.0b (c)	129.3a (a)	138.8a (a)	80.8a (bc)	62.3b (c)	118.0b (a)
Filled grains (%)							
0	76.2a (ab)	82.0a (ab)	85.1a (a)	86.9a (a)	85.6a (a)	78.8a (ab)	66.8a (b)
2	71.3ab (ab)	81.4a (a)	78.5ab (ab)	80.8a (a)	75.6a (ab)	68.7ab (a)	62.6ab (b)
10	67.7ab (ab)	77.7a (a)	73.7ab (ab)	77.0ab (a)	75.2a (ab)	65.4ab (ab)	57.8ab (b)
20	54.1b (ab)	68.0a (a)	69.2bc (a)	61.9bc (ab)	72.0a (a)	60.6b (ab)	46.3b (b)
40	35.3c (bc)	18.6b (d)	55.3c (a)	52.1c (ab)	34.6b (bc)	21.9c (d)	28.5c (cd)

[a]In a column and in a row (with parentheses), means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

B2791b-Mr-257-3-2 and IR19661-23-3-2-2 decreased from 80% at an initial infestation of 0 bugs per hill to 20% at 40 bugs per hill. Filled grains in IR10781-75-3-2-2 and IR13149-71-3-2 only decreased from 86% at 0 bugs per hill to 52% at 40 bugs per hill.

The economic injury level for *S. coarctata* infestation was calculated from estimates of yield reduction, cost of chemical control, and price of rough rice as of January 1985. Monocrotophos was considered an effective insecticide for *S. coarctata* control (IRRI 1985), and at least two applications at 0.5 kg ai ha^{-1} are generally required to control this pest. Two applications of monocrotophos cost US$41 ha^{-1} ($35 for the insecticide + $6 labor for application). Rough rice price in the Philippines was $0.21 kg^{-1} in January 1985. The gain threshold (Gth) expressed in terms of kg ha^{-1} was calculated as

$$\text{Gth (kg ha}^{-1}) = \frac{\text{Cost of control (\$ ha}^{-1})}{\text{Market value of rough rice (\$ kg}^{-1})}$$

The economic injury level (ElL) was based on the number of bugs per hill or plant damage ratings that reduced yield by 196 kg ha^{-1} or 19.6 g m^{-2}. The number of black bugs per hill to produce the ElL was calculated from the predictive equations for yield (Fig. 8B). The ElLs were similar for all cultivars and ranged from 1.6 to 2.9 bugs per hill. On B2971b-Mr-257-3-2, 1.6 bugs per hill decreased yield by 19.6 g m^{-2}, whereas on IR9781-75-3-2-2 2.9, bugs were required. Expressed in numbers per m[2], the ElLs ranged from 26 to 46 bugs per m[2] on the different cultivars.

On 45 and 60 DAS aged plants, *S. coarctata* survival at 30 DAI differed significantly among the six cultivars (Table 8). Survival at 45 DAS was lowest in BG90-2, whereas at 60 DAS, survival was

Table 8. Percent survival of *S. coarctata* as affected by plant age at time of infestation.[a]

Cultivar	Plant age (d after sowing) when infested				
	15	30	45	60	Cultivar means
IR10781-75-3-2-2	69a (a)	67a (a)	56ab (a)	43b (a)	59b
IR13149-71-3-2	63a (a)	83a (a)	71a (a)	76a (a)	73a
IR64	69a (a)	76a (a)	60ab (a)	50b (a)	64ab
Remadja	67a (a)	71a (a)	63ab (a)	46b (a)	62ab
BG90-2	71a (a)	71a (a)	39b (b)	43b (b)	56b
Tjeremas	63a (a)	74a (a)	71a (a)	54ab (a)	66ab

[a]Survival was recorded at 30 d after infestation with 10 second-instar nymphs per replicate. Treatments were replicated seven times. Means in a column and in a row (in parentheses) followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

Table 9. Population growth of *S. coarctata* and plant damage ratings at 50 d after infestation with two pairs (males and females) of adults per plant at 45 d after sowing.[a]

Cultivar	*S. coarctata* plant⁻¹ (no.)	Plant damage rating[b]
IR10781-75-3-2-2	137a	3.9c
IR13149-71-3-2	135a	4.7c
IR64	161a	8.4a
Remadja	131a	8.7a
BG90-2	131a	7.0b
Tjeremas	163a	8.7a

[a]In column, means followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test. [b]Based on a 0–9 scale; 0 = no damage, 9 = plant dead.

lowest on IRI0781-75-3-2-2, IR64, Remadja, and BG90-2. Based on the means from four plant ages, survival was lowest on IR10781-75-3-2-2 and BG90-2. On BG90-2, survival decreased from 71% on the 15 and 30 DAS plants to 39% and 43% on the 45 and 60 DAS plants, respectively.

S. coarctata dry weight differed significantly between cultivars and plant ages. Generally, bugs on older plants weighed the least. On BG90-2, weight on the 60 DAS plants was one half that on the 15 DAS plants. On 60 DAS plants, only insects on Remadja and BG90-2 weighed significantly less than those on Tjeremas.

There were no significant differences among cultivars in terms of population growth of *S. coarctata* on plants infested at 45 DAS (Table 9). At 50 DAI, the progeny resulting from the initial infestation with two pairs of bugs ranged from 135 to 163. The plant damage ratings were, however, significantly different. Most of the IR64, Remadja, and Tjeremas plants were killed, resulting in mean ratings of 8.4−8.7. BG90-2 had less damage with a rating of 7.0, whereas IR10781-75-3-2-2 and IR13149-71-3-2 had lower ratings of 3.9 and 4.7, respectively, indicating only wilting and yellowing of some leaves.

In summarizing the results, on the basis of damage ratings and percent grain yield loss, cultivars IR10781-75-3- 2 and IR13149-71-3-2 were the most resistant to *S. coarctata*. As indicated by the populations at 0 and 60 DAI in the 40-bug-per-hill treatment (Table 2) and yield loss (Table 6) and survival (Table 8) data, the major factor in both cultivars appeared to be tolerance. Because of tolerance in these two cultivars, there was a low level of plant damage in the presence of high *S. coarctata* numbers, equivalent to those on Tjeremas, the susceptible check (Table 9). In addition, these cultivars have high yield potential as indicated in the uninfested check, having produced high yields in IRRI tests. IR10781-75-3-2-2 yielded 7.1 t ha^{-1} in a 1980 dry-season trial; IR13149-17-3-2 produced 6.4 t ha^{-1} in a 1981 dry-season test. IR10781-75-3-2 has been included in the IRRI-sponsored International Rainfed Lowland Yield Nurseries and was among the highest yielding cultivars in Myanmar, Bangladesh, Nepal, Thailand, and the Philippines (Seshu 1985).

IR10781-75-3-2-2 has a maturity of 131 d and is resistant to biotypes 1 and 2 of the brown planthopper *Nilaparvata lugens* (Stål), but it is susceptible to the vector of rice tungro virus *Nephotettix virescens* (Distant). As a result, 40% tungro incidence has been observed on this cultivar. However, tungro is not a serious problem in Palawan. IR13149-71-3-2 has a maturity of 122 d and is resistant to biotypes 1 and 3 of *N. lugens* and has low tungro incidence because of its high resistance to the vector *N virescens*. Both of these cultivars are suitable for cultivation in Palawan and would contribute to yield stability during years of high *S. coarctata* populations.

Management strategy and recommendations

To this day, 25 yr after the above studies were conducted, there continues to be a need for the development of rice varieties with higher levels of resistance to the black bug. Because of its sporadic nature and the fact that there are three key black bug species, it has not been given the breeding attention it needed. With the increasing importance of this pest, there should be a renewed interest in incorporating moderate resistance (which does not cause biotype selection) into breeding lines and combining this resistance in a package of several management tactics (biocontrol, cultural practices, monitoring of fields, and applying selective insecticides when an EIL of three bugs per hill at 30 DAT is reached) to develop a pest management strategy that is both economical and sustainable. Recent information on the role of biocontrol agents in regulating black bug populations should be incorporated into such a management strategy.

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Management of Malayan Rice Black Bugs in the Philippines

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Introduction

This paper presents a brief history of Philippine efforts to combat the Malayan rice black bug, *Scotinophara coarctata* (Fabricius), through breeding and selection of cultivars that are resistant to the pest as well as through use of chemical and biological control methods. It will be seen that infestations from the early 1980s to 2006 had been sporadic and seemingly isolated. Thus, the rice black bug (RBB) was not given the adequate attention that it deserved when the level of infestation rose in 1982 in Palawan.

From the first report of infestation in Palawan to the latest news of black bug attack in 2005 in about 1,400 ha of ricefields in Iloilo (NPB 2006), policymakers and scientists in the Philippines have largely ignored the insect pest for the last 3 decades. The oversight is reflected by three conflicting claims on when the first infestation occurred in Palawan. Heinrichs et al. (1987) report that it was in 1950, De Sagun et al. (1991) and Cuaterno (2006) assert that it was in 1979, and Catindig and Heong (2006) declare that it was in 1982.

The economic importance of the insect pest was in fact reported 25 yr ago, when more than 4,000 ha were infested seriously in south and central Palawan (Mochida et al. 1982 as cited by De Sagun et al. 1991). However, this report was overlooked. It is clear from the minutes of the meetings of the Rice Varietal Improvement Group (RVIG), which started in 1984, that control of the Malayan black bug was not a priority in national rice improvement programs. The insect did not appear to be much of a concern to the RVIG, which has as members staff from the University of the Philippines Los Baños (UPLB), Bureau of Plant Industry (BPI), Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), International Rice Research Institute (IRRI), and the Philippine Rice Research Institute (PhilRice).

Insufficient researcher perception helps explain the lack of R&D efforts on the black bug. In 1984 meeting of the RVIG, Ms. Ginna Geal of PCARRD informed the group of ongoing tests in several locations in Palawan being supported by that agency, noting that the situation of the pest was

"not a normal condition but unexpected." However, since a black bug screening project was being "generously funded" by IRRI and PCARRD, and since the group felt that the black bug problem was "an extremely isolated case," the RVIG decided to "concentrate more on problems of national importance" (RVIG 1984).

Policy also had a role in the neglect of the pest by rice scientists. In the late 1980s, PhilRice became a major source of fund for the National Cooperative Testing (NCT) Program that the RVIG implements; thus, PhilRice effectively has been setting the direction for rice varietal improvement in the Philippines. In those years, rice breeders began shifting their focus from high yield to pest and disease resistance in general. During the mid-year 1990 RVIG meeting, Dr. Santiago R. Obien, PhilRice director, noted the shift and discouraged it; he emphasized the "pressing need to increase our yields if we are to cope with the needs of our growing population" (RVIG 1990). This policy helped explain the insufficiency of Philippine R&D on the management of the Malayan rice black bug.

In 1991, PhilRice Director Obien (RVIG 1991) threw this challenge to the RVIG:

> *"Let us be serious about rice. The honor of the farm sector depends on our ability to produce enough rice. Until we can fully sustain self-sufficiency, our political leaders and those of other professions will not recognize us as truly great ... scientists."*

In the same occasion, Dr. Obien noted that "the history of the RVIG embodies the history of rice varietal improvement in this country" (RVIG 1991). He expressed the vision "that we shall have a variety to satisfy every palate, every occasion, with the diversity of varieties and food products that can be derived from this golden grain." That promise is now being threatened by the Malayan black bug. This is a very serious insect pest of rice and its management should not be left to only chemical or biological control.

Meanwhile, the insect pest continues to damage rice crops significantly in the Visayas (Calubiran 2006). The Department of Agriculture (DA) allocated ₱2 million that year to fight the black bug menace, the funding being spent on the purchase of light traps and on public dissemination of information on how to manage the pest.

Brief history of the pest in the Philippines

Not native to the Philippines, the Malayan black bug may have come to the islands first through Palawan, with adults traveling on prevailing winds from North Borneo (De Sagun et al. 1991). The insect is reported to be distributed in Bangladesh, China, India, Indonesia, Malaysia, Pakistan (PAN Germany 2006) as well as in Cambodia, Myanmar, Sri Lanka, Thailand, and Vietnam (Miyamoto et al. 1983).

In 1981, monocrotophos was found the most effective insecticide against the black bug, while carbaryl was ineffective (Argente 1981). Maximum residue levels of only lindane and carbaryl in the harvested grains were found below the tolerance limits established by FAO/WHO.

Interagency rice-based cropping system evaluations of rice varieties and selections were conducted in 1985 and results were reported in an October 1986 interagency workshop on the black bug held in Palawan (IRCSPPEP 1986). Two IR selections were found to have moderate resistance to the black bug under transplanted, irrigated-wetland conditions during the 1985 dry season; there was no selection during the wet season.

Taylo (1986) reported that the preferred alternate host of the black rice bug (syn. *Leptocorisa oratorius*) was *Echinochloa colona* (L.). The usual feeding sites on panicles of the host plants (*Echinochloa* spp.) were the lemma and the area between the lemma and the palea.

IRRI studies to select rice varieties resistant to the black bug were conducted in 1984 (Heinrichs et al. 1987). On 18 May 1987, the line IR13149-71-3-2 was recommended as a stop-gap variety for the highly infested black bug areas of Palawan (RVIG 1987a). This was amended on 16 Oct 1987, when the same line was recommended as the standard variety in Palawan, pending results of the eating-quality test (RVIG 1987b).

In 1991, an IRRI study reported that *S. coarctata* was found only in Palawan; it was not observed in field surveys conducted in Mindoro, Panay, Negros, Zamboanga del Norte and Sur, and other parts of Mindanao, Luzon, Leyte, Bohol, and Cebu (De Sagun et al. 1991). Since then, this species has spread to the Visayas, Mindanao, and Luzon. The bug has become an economically important pest in the country (Catindig and Heong 2006). The pest has been reported from Sorsogon in 2005 (Bordado 2005), Catanduanes in 2006 (Gianan 2006), and Iloilo also in 2006 (NPB 2006, Suyom 2006). It is now a major threat to rice production in the Philippines.

Burdeos and Gabriel (1995) studied the pathogenicity of the green muscardine fungus *Metarhizium anisopliae* against the black bug and reported that field application of the conidial suspension of the fungus at 1×10^{12} reduced the bug population by 91% 2 wk after spraying in the field. Justo (1995) recommended the following measures to combat the pest:

1. Use tolerant varieties.
2. Plant early-maturing varieties.
3. Conserve beneficial insects and microorganisms that attack black bugs.
4. Practice weed control as weeds are alternate hosts of the insect.
5. Use trap crops such as *gabi*.
6. Plow immediately after harvest.
7. Flood the field.
8. Release ducks in the field.

In three towns in Nueva Ecija (Carranglan, Muñoz, and Talavera), two weed host plants of the black bug were identified, *Echinochloa colona* and *E. crus-galli* of the family Poaceae (Estoy 1996). The presence of the bugs was also observed on ratooned rice in Muñoz and Talavera, suggesting that the ratoon crop supported the population.

USM (1996) reported on the University of Southern Mindanao's use of Daluson rice selection to control RBB.

Continuing on the study reported by Burdeos and Gabriel (1995), Tuan and Gabriel (1997) found that the white muscardine fungus *Beauveria bassiana* was highly pathogenic to the RBB and was less virulent to natural enemies and safe to other organisms, including humans.

Based on a study in Mindanao, Apao et al. (1998) recommended the following integrated control strategies for the control of the black bug:

1. Practice synchronous planting (not too early, not too late).
2. Grow resistant or tolerant varieties: IR44526, PSBRc 4, PSBRc 10, PSBRc 20, PSBRc 34.
3. Dikes should be at least 20 cm high and properly plastered to minimize water losses.
4. Maintain 3-8 cm water level from tillering to heading stage.
5. Irrigate intermittently–to take care of egg masses in the field.
6. Plow the field immediately after harvest to destroy rice stubbles and alternate host weeds.
7. Submerge the field after plowing for at least 12 h to spoil egg masses and kill the nymphs.
8. Conserve and enhance the potentials of spiders, red ants, and frogs in the field.
9. Use insecticides as recommended.
10. Do light-trapping 5 d before and after a full moon to catch and kill the adults.

In the RVIG annual meeting at the Bicol Integrated Agricultural Research Center (BIARC), IR69726-29-1-2-2-2-2 was reported to be resistant to tungro as well as to the black bug and was recommended for multilocation adaptation trials (RVIG 2000).

According to the *Rice Doctor* (IRRI 2003), two IRRI varieties (not identified) shown to be resistant to the Malayan black bug have been developed.

Malabanan (2004) reports that the GMA Rice Program assisted farmers in the biological control of black bug by setting up *Metarhizium* laboratories and distributing light traps.

According to PhilRice, the best way to avoid black bug infestation is to do synchronous planting (Gado 2006). Calubiran (2006) reports that then Agriculture Secretary Domingo Panganiban said that infestation could be stopped in 4−5 mo if only farmers would cooperate. He recommended synchronous planting to break the cycle of the black bug. Staggered planting with intervals beyond 3-4 wk ensures the survival of rice pests throughout the year, while synchronous planting maximizes the growth of populations of natural enemies of the pest (IRRI 2006).

In Leyte, Gerona (2006) reported that rice varieties/lines R2-6, PR4B, IR6019 R, and GU199 were found to be resistant to RBB.

In 2006, the provincial board of Catanduanes declared 6 out of 11 towns in the province to be 'under a state of calamity' due to the spread of the black bug; the board allotted P600,000 to produce the *Metarhizium* (Gianan 2006). The bugs had been blown from Sorsogon by Typhoon Caloy.

Research and development on control measures

To develop any control measure against any pest, it is important that its ecology be studied first. In 1981, an IRRI study showed that black bug prefers feeding at the top of the panicles during the milk

stage, at the middle during the soft stage, and at the bottom during the dough stage of rice (Gyawali 1981).

Since the early 1980s, IRRI has been trying to develop control tactics by integrating chemical and biological methods along with plant host resistance. After their study in Palawan in 1984, Heinrichs et al. (1987) recommended growing of resistant cultivars, monitoring of fields, and application of insecticides when the economic injury level is reached.

Domingo and Heinrichs (1986) reported on two promising rice lines tolerant of the bug after a field screening conducted in Palawan in July-December 1983.

In her bioecological studies on the black bug, Cahatian (1999) found that natural mortality factors acted most heavily on the young stages of the insect, particularly the first and second nymphal instars. She identified *Echinochloa crus-galli, Sphenochlea zeylanica*, *Ludwigia octovalvis,* and *Ipomoea aquatica* as alternate hosts of the bug. She noted that monoculture favored the continuous generation of the black bug.

Anenias (2001) reported that *Metarhizium* has been found to be a reliable countermeasure against the black bug. *Metarhizium* is a fungus that can kill crop pests such as diamondback moth, cabbage worm, and RBB 2 d after application. The cost was P250 ha^{-1}.

The bug was reported to have attacked 1,400 ha of ricefields in Iloilo Province alone (NPB 2006). The DA staff had a hard time convincing farmers to adopt synchronous planting to counter the bugs by depriving them of a host to lay eggs on.

The bug was reported to have plagued many towns in Iloilo in 2006; when Typhoon Caloy struck, it destroyed many RBB adults and eggs (Suyom 2006). This dramatized the fact that an effective control measure is flooding the field.

Implications and insights

The implications seen and insights gained from this little study of the Malayan rice black bug cover the following areas:

1. Containment. One of the current policies of the DA regarding the Malayan rice black bug is containment, controlling the infestation when it is already there. Containment is necessary, but the way it is being done entails too much cost, as shown by the P2 million allocation for the purchase of light traps and public information alone in 2006.

2. Prevention. There must be continuous efforts on the part of DA personnel to disseminate prevention strategies, such as destroying alternate hosts of the pest and encouraging the growth of natural enemies.

3. Control. The threat of the Malayan rice black bug destroying thousands of hectares of rice all over the country is very clear, while management of the pest relies mainly on farmers cooperating with the DA in applying control measures such as synchronous planting and use of *Metarhizium*. However, farmer cooperation is wanting. To prevent infestation, host resistance offers a countermeasure against the pest whose result is dependent neither on farmer cooperation nor on resources of the DA. Already, there are cultivars available that have shown resistance to RBB. To have more

impact, public awareness efforts are needed, supported by a systematized seed production of resistant lines.

4. Public awareness/information campaign. To ensure farmer cooperation in combating the pest, it is further recommended that significant demonstration plots in affected areas be set up to serve as learning zones for farmers in those villages and vicinities.

5. Funding for R&D. Lack of funding for R&D on the Malayan rice black bug is taking its toll as evidenced by the dearth of information on systematic testing and verification of control approaches, including the setting up of village plots where synchronous planting will be strictly observed. The government should seriously allocate funds for such purposes.

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Chemical Control of Rice Black Bug *Scotinophara coarctata*

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Abstract

Rice black bug (RBB) *Scotinophara coarctata* (Fabricius) is the most commonly occurring insect pest of rice in Malaysia, Philippines, Sri Lanka, Thailand, and Vietnam. It is also referred to as Malayan black bug (MBB). Besides this pest, other species such as *Scotinophara lurida* and *Scotinophara bispinosa* also occur in some other parts, including India. It is gradually spreading to Bangladesh, Myanmar, Indonesia, Cambodia, Pakistan, and India. Since adult bugs congregate at the base of the rice plants, immediately above the water level during the day and move up the rice plants at night, control measures are to be done only during daytime. Insecticide sprays should be directed toward the base of the rice plants so that the sprayed fluid falls as mist and hits the bugs. A knapsack sprayer or motor blower may be used as needed. Several insecticides were found effective in RBB control. However, insecticides belonging to the cyclodiene group are banned, except for endosulfan, and some organophosphates are hazardous to the rice ecosystem. The efficacy of propuxur was confirmed in field experiments and is recommended for use. Likewise recommended were six conventional insecticides (monocrotophos, carbosulfan, endosulfan, fenthion, triazophos, and carbofuran 3G at 0.5 kg ha^{-1}). Among synthetic pyrethroids, only lambda cyhalothrin could be used, but with caution. Insecticides such as BPMC, carbaryl, carbofuran, carbosulfan, endosulfan, fenthion, monocrotophos, triazophos, profenophos, acephate, fipronil, and imidacloprid have ovicidal action on RBB eggs and cause 100% egg mortality. These could be used in the initial stages to prevent further buildup of the pest population; they could also be used to control adult bugs. Because of continuous use of certain pesticides, several insect pests have developed insecticide resistance, triggering resurgence. Hence, only selective pesticides should be used on the basis of economic threshold level of the pest population. Since some of the plant products have also shown better efficacy on RBB eggs and adults, these can be employed as a component in integrated pest management. The right dosage of each insecticide, timing of application, appropriate method of application, and interactions between *S. coarctata* and other insect pests should be considered.

Key words: rice black bug, *Scotinophara coarctata,* control, insecticide, pesticide, rice

Introduction

Every human being has the urge to meet his need for food, clothing, and shelter; this has been so since the beginning of human civilization. The production of food grains is a natural consequence to satisfy the hunger of human beings without disrupting/destroying the coexisting living beings. From 1900 to 1924, food grain production increased at the rate of 0.3 %, but from 1924 to 1948, there had been some reduction and the annual increases declined, probably due to the world war. The introduction of DDT for malaria control, just after the last world war, started a new era in plant protection. This was followed by HCH (BHC) and subsequently other cyclodiene compounds (David 1992).

Globally, the use of synthetic organic insecticides has helped control insect pests to unimaginable levels, thereby contributing to increased food production. Conventional insecticides belonging to various groups such as chlorinated hydrocarbons (cyclodienes), organophosphates, carbamates, and synthetic pyrethroids have helped in controlling various insects pests belonging to insect orders. In the past five decades, they minimized pest incidence and, consequently, losses in agricultural production. Entomologists at the time have planned control measures well in advance—for instance, Shziro Ishii from Kyoto University, Tokyo, established a forecasting model to predict the occurrence of rice stem borer (*Chilo suppressalis)* in Japan.

Among the synthetic organic insecticides, however, we have different groups of insecticides possessing their own strengths and weaknesses. Their continuous use has created problems such as resurgence in pest population; buildup of resistance in several insects to insecticides; and pesticide residues contaminating treated products, thereby posing risks to consumers. However, the use of synthetic organic insecticides helped solve several pest problems in agricultural production—e.g., public health problems brought about by vector-borne diseases. In view of these problems, there is a continuous search for new molecules of pesticides and we have today reached a stage from "catch and kill" to the use of genetic engineering for the control of crop pests. The pesticide industry is one of the most researched and regulated industries, even more stringent than the pharmaceutical industry. Nearly 11 % of the revenue is invested annually in R & D. It usually takes about 8-10 yr and US$100,000 million investment to discover and introduce a new molecule in the market. Continuous extension efforts are exerted by the pesticide industry to educate farmers on "the safe and judicious use of pesticides."

This chapter reviews work carried out on the chemical control of rice black bug (RBB) *Scotinophara coarctata* (Fabricius).

Signs of attack and symptoms of damage

Adult, eggs, and nymphs of RBB on rice

Catindig and Heong (2003) indicated that both RBB adults and nymphs remove plant sap from seedling to maturity growth stages, by using its sucking mouthparts. Feeding is concentrated at the base of the stems, often below the water level. They prefer the stem nodes because of the large sap reservoirs. Infected plants are often stunted, leaves turn reddish-brown, and grain formation fails to

Fig. 1. Life cycle of RBB *Scotinophara coarctata* on rice.

take place. Direct injury to the panicles is also common. Heavy infestation and "bug burn" is usually visible when rice approaches heading maturity. Severe infestation may cause plant death. Feeding damage is characterized by half-filled and empty grains. Ten adults per hill can cause losses of up to 35% in some rice varieties. RBB hides itself in soil cracks during water stress, but it requires a certain degree of moisture for its development. One of the cultural control practices to reduce their population is to maintain a clean field by removing the weeds and drying the rice field during plowing. Rice varieties with similar growth duration may be planted to break the RBB life cycle (Fig. 1). Direct-seeded rice crops tend to have fewer tillers at one planting point and thus may discourage the bug population growth. During early infestation, the water level in the field may be raised for 2-3 d to force the insects to move upward. Flooding the fields results in higher egg mortality. After harvest, fields might be plowed to remove the remaining insects. For chemical control, foliar spraying of insecticides directed at the base of the rice plant (Fig. 2) was found most effective.

Reissig et al. (1986) presented an illustrated guide to integrated pest management in rice in tropical Asia, which also included RBB. The shiny dark brown or black adults aggregate at the base of rice plants immediately above the water level during the day. They move up the rice plants at night and use their sucking mouthparts to remove plant sap from tillers. The long-living adults pass the winter or dry season in a dormant state in soil cracks or in grassy areas. With favorable weather, they fly to the rice crops and reproduce over several generations. They return to their resting sites after rice harvest. Adults are capable of moving long distances. Adults are attracted to a high-intensity light trap, and catches peak during a full moon. Kerosene light traps are not bright enough to attract

Fig. 2. Foliar sprays directed at the base of the rice plant was most effective

RBB. Adults give off an offensive odor when distributed. A female lays about 200 eggs during her lifetime. The greenish pink eggs are laid in masses of up to 15 in several parallel rows on lower leaves near the water level. It was further emphasized that understanding the biology of the pest is a must for planning chemical control measures.

Control measures

Use of indigenous methods

In the beginning of the 19th century, agriculture was in the primitive stage and pest control measures consisted of "cut and burn" or "catch and kill." But people then were so methodical that they did not allow any pest to damage the entire crop. They went to the fields regularly and monitored the pest populations, suggesting control measures to farmers.

South (1920) mentioned spraying with kerosene emulsion and extract of derris root as a remedy for *Podops coarctata* [*Scotinophara coarctata*]; it was tried with uncertain results.

Krishna Ayyar (1929) reported an outbreak of the rice pentatomid bug (*Scotinophara lurida*, Burmeister) in Madras in July 1925. On an average, one to four bugs per plant were observed but this number was considered of minor importance. Various control measures such as hand-picking,

use of light traps, dusting with calcium cyanide, and others were tried but without success. Spraying with oil emulsions was more effective and was recommended for further evaluation. The bunds were too small and low to allow complete submergence of the plants, but partial flooding caused the bugs to crawl up the plants. Coolies were then employed to dislodge them, sweep them up with brooms, and then destroy them by immersion in kerosene and water. This method was cheap; it soon became popular among cultivators and was extensively employed.

In the 19th century, when synthetic organic insecticides were not yet available, De Alwis (1941) carried out various control measures under field conditions to control *S. lurida* and suggested that, when bugs are numerous, the rice crop should be watched from the third to the sixth week of growth and flooded. He further recommended that a little kerosene be added to the water to increase bug mortality, but that the oily water must be run off after 3−6 h. Hand collection during the fifth or sixth week, when the fields are weeded, was also suggested.

Use of plant products

Use of plant products/extracts for pest control is not a new approach; it has been practiced since the beginning of the 19th century. Research work on the control of RBB by using plant products is presented.

Ponce de Leon and dela Rosa (1993) studied the efficacy of botanical pesticides for RBB (*S. coarctata*) control as rice yields in Palawan, Philippines, declined from 1982 to 1985 due to heavy bug infestation. Petroleum-based chemicals are commonly used to control pests but their cost is prohibitive. There is a need to explore available indigenous plant species with pesticidal properties against RBB. In Palawan, several promising plant species are in abundance and can be used for RBB control. Studies in the then Palawan National Agricultural College identified some of these plants: "lagtang" (*Anamarita cocculus*), "macasla" (*Chroton tiglium*), and "tubli" or "tuba" (*Derris elliptica*). Other plants with potential are "makabuhay" (*Tinospora rumphii*), "cacawati" (*Gliricidia sepium*), "hagonoy" (*Chromolaena odorata*), "calot" (*Dioscorea hispida*), and "siling labuyo" (*Capcisum frustescens*).

Ponce de Leon (1990) studied the efficacy of botanical pesticides, evaluating the pesticidal effects of four plant extracts and 11 extract combinations against RBB. The use of lagtan solution resulted in a significantly higher RBB mortality than other treatments using tubli, langkawas, red pepper extracts, and their combinations. A similar study was also conducted using tubli, lagtang, makabuhay, and red pepper extract; lagtang solution gave the best results in terms of mortality. Another plant species with pesticidal property is *Croton tiglium*, locally known as macasla. The seeds of this plant had been found to be very effective in controlling RBB. Laboratory toxicity tests of seven plant materials (lagtang, macasla, tubli, cacawati, hagonoy, makabuhay, and red pepper) against RBB showed that macasla leaves and seeds, makabuhay stem, and tubli roots were effective 8 h after the application of the extract. After 24 h, a significantly high mortality was also obtained in treatments with macasla and tubli extracts. The effects of makabuhay stem, cacawati leaves, hagonoy leaves, and carrot tubers on RBB were compared; the findings showed that carrot extract was effective with a mortality of 51.66% 12 h after test insect introduction, 65% after 24 h, and 98.73% after 48 h. With

lagtang seeds, tubli roots, makabuhay stems, and red pepper fruits, results revealed that lagtang seed solution gave a mortality of 100% 12 h after test insect introduction, and tubli roots gave 71.10% after 24 h and 84.44% after 48 h. Makabuhay and red pepper extract gave a very low mortality of 8.88%. Results revealed no significant differences among the five treatments using different concentrations of lagtang seed (1:30, 1:40, 1:50, 1:60, and 1:70).

Mallorca and Garcia (2000) evaluated the use of botanical plants against RBB at Sultan Kudarat, Philippines, during the wet and dry seasons of 1998. Parameters used were population counts of RBB adults 45 d after transplanting (DAT) and of nymphs at 65 DAT, RBB damage at 85 DAT, and grain yield. *Azadirachta indica* A, Juss. (neem seeds), *Dioscorea hispida* D. (wild carrot/kayos), and *Tinospora rumphii* B. (makabuhay) were found effective, economical, convenient, applicable, and acceptable at 45 DAT on adults, 65 DAT on nymphs and at 85 DAT on damaged hills. Effectiveness was comparable with that of chemical treatments. Increased grain yield in IR62 treated with botanical plants was noted and found comparable with carbaryl-treated plots. Low grain yields were recorded from untreated plots.

Anandhi and Pillai (2006b) studied ovicidal activity of some insecticides against RBB in using five insecticides and 21 plant products. Both neem seed kernel extract and neem oil caused 56.25% egg mortality.

Chemical control

Fernando (1960) studied the susceptibility of *S. lurida* to insecticides in Sri Lanka. In the laboratory, 10 insecticides were tested. Bugs that were freshly emerged, sexually mature or aestivated were treated by topical application of acetone solutions to the abdomen, and the order of decreasing toxicity (based on LD_{50}) to the sexually mature adults was found to be gamma/BHC, endrin, dieldrin, parathion, trichlorphon (dipterex), chlorthion, diazinon, guthion, malathion, and DDT. The adults of the aestivating generations, at least prior to becoming sexually mature, were markedly more resistant to all the insecticides than were sexually mature bugs of uninterrupted development, with resistance ranging from twofold to 19-fold that of the latter. There was some indication that tolerance for insecticides does not necessarily increase with increasing age and sexual maturity of normal adults. Thus, whereas the organophosphorus insecticides became less effective with increasing sexual maturity, with DDT and endrin, the bugs appeared to become more susceptible as maturity progressed. With gamma BHC and dieldrin, there was little change.

In field tests, 14 insecticides as emulsion sprays were compared. DDT and chlordane were slow in action, a concentration of about 0.45% or more resulting in only about 85% mortality in 24 h; toxaphene was still less effective. Aldrin and isodrin at 0.06% gave about 90% kill in 24 h. The other materials gave complete or almost complete mortality in that period. The minimum concentrations required were 0.02% for parathion or guthion, 0.03% for endrin or chlorthion, 0.03-0.04% for trichlorphon, 0.06% for dieldrin, malathion, or gamma BHC and 0.07% for diazinon. Of the dusts tested, gamma BHC at 1.3% and dieldrin at 2.5% gave complete control in 24 h when applied under the still and dewy conditions obtaining in the morning. Under dry, windy conditions, gamma BHC

at 1.3% and 3% gave better control than did dieldrin or aldrin. Parathion, dieldrin, endrin, methyl demeton (Metasystox) and thiometon (Ekatin) were tested for persistent action. Parathion left the most effective residue, which was toxic for a period of 2 d, followed by dieldrin. Methyl demeton and thiometon were tested as foliar sprays and as root treatments for their systemic action in rice plants 3 and 10 wk old. Systemic action of a low order was demonstrated in all cases, but the poor results achieved and the high rates of application involved did not warrant practical field use.

Grist (1969), in his book *Pests of rice*, indicated that a number of chemicals are now employed to control the Japanese RBB, *Scotinophara lurida* (Burmeister), and mentioned certain pesticides in descending order of effectiveness: gamma-BHC, endrin, dieldrin, parathion, dipterex, chlorthion, diazinon, guthion (azinphos methyl), malathion, and DDT. The aestivating insects are more resistant to chemicals than the non-aestivating ones. In Sri Lanka, quick and economical control, combined with good residual action, has been obtained with dieldrin 2 % emulsifiable concentrate (EC), using 1 fl oz in 2 gal of water or 1 fl oz 20% gamma BHC or endrin EC in 7 ½ gal of water. The diluted material is applied at 10−20 gal acre^{-1} within 24 h, depending on crop growth. Further trials established the value of parathion which, applied at a concentration of 0.02% active ingredient (ai), gave 100% control.

Anonymous (1970) indicated that application of chemicals just before flowering gave adequate control. Contact poisons such as DDT or BHC, at 0.25% spray or 5% dust, aldrin 2.5% dust, chlordane 5% dust, or 0.25% ai spray of malathion 50 EC had been very effective in controlling RBB in most of the countries where it occurs. Endrin, Sevin, Gusathion, Sumithion, and Thiodan had also been tried. Finally, it was stated that the choice of chemicals often depended on the economics of application. In the USA where work has been done on losses caused by these pests, it is recommended that control measures should be applied when there is an average of 10 bugs per 100 head of rice.

Lim Guan Soon (1972) studied chemical control of rice insects and diseases in Malaysia and indicated that BHC (Gammaxene) at 0.05−0.1% ai was one of the most effective insecticides, and, among others, was also effective against other hemipterans [*Leptocorisa oratoria* (F.), *Scotinophara coarctata* (Fabricius), and *Nezara viridula*].

Venkata Rao and Muralidharan (1977) reported about the incidence of RBB (*Scotinophara coarctata*) on rice in Nellore District, probably a first record from south India. Incidence was noted in late May 1977 and it was observed that the bugs preferred young rice seedlings. In some places, nurseries of CO 29 and IET2508 were totally destroyed. In heavily infested plots, about 200 bugs hill^{-1} were observed, mostly at the base of the plant. Surprisingly, not a single bug was found in the dry nurseries. Farmers were advised to spray dieldrin, gamma BHC, and methyl parathion, malathion, or dichlorovos (DDVP). Less expensive chemicals such as DDT or BHC, either as dust or spray, were found to be equally effective.

Wahyu (1979) studied the efficacy of three insecticides (carbofuran, diazinon, and carbaryl) applied to rice plants in the greenhouse and in the field using five methods and compared their efficiency in controlling RBB. The results showed that the effectiveness of each insecticide changed considerably with application method. The soaking method was effective just after treatment, but

the effective period was short. Foliar spray was also effective just after treatment, but effectivity was short, except with endosulfan when it was longer. The gelatin capsule treatment became effective gradually, reaching the peak around 1–2 wk after treatment, after which effectiveness gradually dropped. Broadcast and mud-ball treatments showed some intermediate tendencies between foliar spray and capsule method. Carbofuran was effective with all five methods, except in the greenhouse, where foliar spray was ineffective. Diazinon and carbaryl were effective as foliar sprays. Fenitrothion and endosulfan were effective either as spray or broadcast.

Abdul Latif et al. (1982) studied the incidence and chemical control of the MBB in West Malaysia. In their field studies, the results revealed that propuxur 50WP@ 0.1% and dicrotophos 24 WSC@ 0.1%, 1 and 24 h after spraying, gave 100% bug mortality. Again, propuxur was effective 48 h after spraying, fenitrothion + lindane 30EC, acephate 75WP, chlorpyriphos + BPMC 20EC, fenthion 50EC, Carbaryl + BHC 10WP, BPMC 50EC, and endosulfan 35EC were effective 24 h after spraying with more than 80% mortality. Finally, the efficacy of propuxur was confirmed in the field experiment. They further suggested that spray application must be directed to the base of the rice plants, in order to hit the bugs (Fig. 2). Since this may not be possible with a close plant canopy, the use of a motor blower is suggested.

De Sagun (1983) studied in detail the efficacy of different insecticides at minimum rate for effective control of RBB at different stages of its development. In the 1983 wet season, six insecticides (deltamethrin, permethrin, fenthion, monocrotophos, carbosulfan, and endosulfan) showed more than 90% mortality, whereas three insecticides (carbofuran, triazophos, and mexacarbate) showed more than 90% mortality at 46 DAT. Cypermethrin showed 95% mortality at 62 DAT. In the 1984 dry season, monocrotophos, deltamethrin, and carbosulfan consistently showed more than 87% mortality, whereas fenthion, endosulfan, and carbofuran showed more than 90% mortality once or twice out of three applications. Two insecticides (triazophos and mexacarbate) always showed less than 85% mortality, and permethrin showed 85% mortality once out of three replications. In the 1984 wet season, use of permethrin, carbosulfan, monocrotophos, and deltamethrin resulted in more than 80% adult mortality at 32, 46, and 62 d after treatment (DT). Three insecticides (endosulfan, fenthion, and carbofuran) showed more than 70% mortality at 62 DT, while triazophos and mexacarbate showed more than 75% mortality at 32 DT. In the 1985 dry season , monocrotophos, deltamethrin, and permethrin showed more than 80% mortality at 32, 46, and 60 DT, whereas carbosulfan, endosulfan, triazophos, fenthion, and mexacarbate showed more than 70% mortality at 60 DT, while carbofuran showed 85% mortality at 60 DT.

Thus, out of 19 insecticides under preliminary testing for two rice cropping seasons, eight were confirmed to effectively control RBB for four seasons. It was recommended that six conventional insecticides (monocrotophos, carbosulfan, endosulfan, fenthion, triazophos, and carbofuran 3G at 0.5 kg ha^{-1}) and two synthetic pyrethroid insecticides (deltamethrin at 0.0125kg ai ha^{-1} and permethrin at 0.05 kg ai ha^{-1}) be used for RBB control. He emphasized the importance of considering these factors: right dosage in each insecticide, timing of application, appropriate method of application, and interactions of RBB with other insect pests.

Uttamasamy and Mariappan indicated that, in April-July 1984, RBB appeared in large numbers in Tiruchurapalli District. At flowering, the population averaged 20 bugs hill^{-1}. They found that spraying 600 ml of fenthion ha^{-1} controlled RBB effectively.

Subramanian et al. (1986) indicated that, in early 1985, RBB adult and nymphal populations reached 10 individuals hill^{-1}. Studies were made to evaluate the effectiveness of five insecticides on 45-d-old IR50 and, among the insecticides tested, monocrotophos at 0.04% concentration was most effective, reducing 91% of the RBB population. The other insecticides—endosulfan, phosalone, quinalphos, and dichlorovos—reduced the pest population by 58−61% (see table below).

Mochida (1986) tested monocrotophos at 0.5 kg ai ha^{-1} against the RBB and indicated that the cost to benefit ratio was 0.64 for one application and 0.48 for two applications; using seven applications was not economical.

Anonymous (1986) studied the efficacy of neem seed kernel, three commercial neem formulations, and monocrotophos in controlling bugs in rice. Monocrotophos has been used in Guyana to control paddy bug for the last 28 yr, yet grain damage caused by this bug remains high. This study attempted to compare the efficacy of neem products against monocrotophos in controlling paddy bugs; to determine paddy bug population at various time intervals after spraying with neem products and monocrotophos; and to determine % damaged grain from treated plots. Neem kernel extract, three commercial neem products (Agroneem, Neemactin, and Neem-X) and monocrotophos were used. The test variety was BR444. The experiment used a randomized complete block design with four replicates. The area was divided into 24 plots, each 75 m^2, with a l-m "buffer zone" between blocks. Routine agronomic practices were carried out, namely, controlling water level, pesticide, herbicide, and fertilizer application. Bug counts were taken from 70 to 87 d after sowing (DAS) and spraying was done at 90 DAS. Bug count was taken 1, 4, 7, 10 13, and 18 d after spraying to compare efficacy and % damaged grain was determined at the end of the experiment. Plots sprayed with Neem-X had the lowest % damaged grains, whereas plots sprayed with Agroneem had the highest. There was no significant difference in % damaged grain of plants treated with monocrotophos and Neemactin, Neem-X, and neem kernel. Bug population was lowest for monocrotophos at 1, 4, 7, and 10 d after spraying, whereas Neemactin and neem kernel had the lowest population at 13 d after spraying. The residual effect for all treatments lasted for 24 h.

Insecticide	Concentration	Reduction of RBB population over control[a]
Monocrotophos	0.04% spray	91a
Endosulfan	0.05% spray	66b
Phosalone	0.5% spray	61b
Quinalphos	0.05% spray	59b
Dichlorovos	0.05% spray	58b

[a]Separation of means by DMRT at the 5% level.

Barrion and Litsinger (1987) studied the bionomics, karyology, and chemical control of the node-feeding black bug, *Scotinophara latiuscula* (Breddin) in the Philippines. Twelve insecticides were evaluated at 0.50 kg ai ha^{-1} against eggs, nymphs, and adults as foliar sprays using MIDI aerosol sprayer, at three life stages. Compounds included were six organophosphates: acephate 75SP, azinphos-ethyl 40EC, fenthion 50EC, diazinon 20EC, monocrotophos 30EC, and triazophos 40EC; four carbamates: BPMC 50EC, carbaryl 85WP, carbofuran 12F, and carbosulfan 20EC; a chlorinated hydrocarbon: endosulfan 40EC; and a synthetic pyrethroid: permethrin 10EC. Eggs laid on potted plants were sprayed and mortality was recorded 4 d later. Nymphs and adults were sprayed as they rested on plants and mortality was recorded after 24 h. Each treatment was replicated four times with a bug density of 10 third- or fifth-instar nymphs or five adult pairs. The results indicated that nine insecticides, BPMC, carbaryl, carbofuran, carbosulfan, endosulfan, fenthion, monocrotophos, and triazophos, applied as foliar sprays were highly effective as ovicides and effectively caused 100% egg mortality. Permethrin, acephate, and azinphos ethyl were less ovicidal and gave 77−79% egg mortality. Acephate, BPMC, carbofuran, fenthion, monocrotophos, and triazophos were equally effective against nymphs and adults.

Chang et al. (1991) studied the migration and chemical control of the MBB in the Kerian area of Malaysia. From the trials, they observed that endosulfan, fenthion, and BPMC, in descending order, were effective in providing rapid knockdown of field populations. However, they indicated that, since endosulfan is highly fish-toxic, fenthion was selected for field use in Kerian. They further mentioned that fenthion remained effective, despite an extended period of use since the 1980s.

Ponce de Leon and dela Rosa (1993) reported that use of petroleum-based insecticides was the most common method for the immediate control of RBB in Palawan, Philippines, but not all insecticides were effective. Monocrotophos, methyl parathion, chlorpyriphos + BPMC, endosulfan, and malathion were found effective in the control of RBB.

Apao et al. (1998) indicated that studies on integrated RBB control were conducted at the Western Mindanao Integrated Agricultural Research Center (WESMIARC) in 1993−96 under laboratory, screen pot, screen field, and open field conditions to package the most practical and environmentally sound control technologies. Results of contact toxicity tests of different insecticides against RBB indicated that all insecticides tested (g ai ha^{-1}) under laboratory conditions were toxic to RBB. Cypermethrin (12.5), cyfluthrin (12.5), and deltamethrin (3.5) ranked first, in which 100% mortality was observed 15 min after application (MAA). Ethofenprox (25), lambda cyhalothrin (6.25), BPMC (200), carbaryl (425), and chlorpyriphos + cypermethrin (62.2 + 6.22) ranked next, in which 100% mortality was noted at 20 MAA. A combination of diazinon and cypermethrin (100 + 12.5) and carbofuran (1,000) totally killed RBB at 50 MAA, whereas chlorpyriphos (300) gave total kill at 55 MAA. Diazinon alone (400) was the slowest killer (150 MAA). Studies on foliar spray testing of different insecticides against RBB indicated a similar trend of efficacy under both laboratory and field conditions. However, the insecticides with quick knockdown effect on RBB were cypermethrin, chlorpyriphos + cypermethrin, and diazinon + cypermethrin. Slow-killing insecticides were BPMC, carbaryl, and chlorpyriphos. Efficiency was enhanced by increasing paddy water level to more than

8 cm at maximum tillering and heading stages during spraying. Apparently, this is brought about by the increased chemical contact to the pest. Carbofuran (0.4 kg), diazinon (0.4 kg), and fipronil (30 g), following manufacturers' recommended rates and timing of application, were also effective against RBB in simulated rainfed or upland rice environments. Diazinon and carbofuran killed all RBB 24 h after application; fipronil after 72 h.

Anonymous (1998) studied the effect of flooding on insecticide efficacy in RBB control in the Philippines. It was mentioned that RBB females were commonly found with their egg masses near the base of plants. When water level was raised, the egg masses were flooded, and the bugs moved higher up the plants. Hence, they were more likely to be exposed to insecticide treatments. A field was flooded to force bugs to go to the upper portion of the plants. Monocrotophos 30EC at 0.125 kg ai ha^{-1} was applied as spray. Bug populations were counted 2 d after treatment. The number of bugs was significantly reduced by this treatment. Reducing the amount of insecticide would result in savings to the grower and in reduced effects on nontarget organisms.

Sosamma Jacob and Bai (1998) indicated that, though RBB is a minor pest in Kerala, it caused severe damage to the rice crop at Kuttanad during kharif of 1988. They showed that weed control, erecting light traps, and spraying 0.05% monocrotophos at the base of the plants were effective in controlling the pest population.

The Central Research Institute for Dryland Agriculture found a RBB problem during 2005 kharif cropping in Thrissur central and recommended spraying of carbaryl or malathion or metacid for its control (Anonymous 2005).

Anandhi and Pillai (2006a) observed in their field studies that acephate (0.05%) and monocrotophos (0.036%) were the most effective insecticides against RBB, followed by chlorpyriphos, profenophos, imidacloprid, neem oil 3%, and neem seed kernel extract 5%.

Anandhi and Pillai (2006b) conducted laboratory studies to determine the efficacy of five insecticides and 21 plant products against the eggs of RBB. The results indicated that acephate and imidacloprid were the most effective, causing 100% and 95.83% mortality, respectively, followed by chlorpyriphos, profenophos, and monocrotophos (with 91.67, 89.62, and 87.25% mortality, respectively). Both neem seed kernel extract and neem oil caused 56.2% egg mortality.

Economic threshold levels for deciding pesticide application

It is essential to establish the economic threshold levels (ETLs) in consonance with integrated pest management programs launched for various crops. Razak ((1993) opined that, only for a limited number of pests, ETLs have been developed by international and national research institutions, but these were on a single pest vis-á-vis crop basis, without consideration of the naturally occurring biological control potential. These values have been developed for specific crop-pest-climatic situations and so are sometimes not applicable in other areas where conditions are different. There is a need to develop appropriate ETLs to meet specific crop-pest situation under different agroclimatic regions. A simple manipulation of ETL values will help avoid unnecessary pesticide applications.

ETLs have been envisaged as a measure to rationalize pest management decisions, depending on the interaction between insect density/damage and yield. To get an estimate of ETLs, it is important to gain an understanding of loss assessment due to pests (Sharma and Nwanze 1996). Economic injury level (EIL) is defined as the insect pest abundance or amount of damage that results in economic yield loss. It is an objective and a determinable value. In contrast, the ETL—an insect abundance level at which remedial control is required to prevent an insect pest that is increasing in abundance from reaching the EIL—is subjective. In most cases, the economic threshold, action threshold, or treatment threshold is lower than the EIL, to allow time for curative action to take place. ETLs are a dynamic phenomenon, and they vary with cultivars grown, cost control, expected value of the crop, productivity potential, and socioeconomic factors.

Work carried out by various scientists on the losses caused by RBB and progress made in arriving at the ETLs for this pest is reviewed hereunder, which forms a basis for pesticide application.

Anonymous (1970) indicated that, in the USA, it is recommended that control measures be applied when there is an average of 10 bugs per 100 head of rice.

Wan (1971) estimated population sizes in a field in the course of an infestation: 9800-28,600 egg masses; 24,700 to 834,800 nymphs; and 30,100 to 102,600 adults present per acre. In damage assessment, it was found that rice plants could tolerate feeding by up to four insects per hill from 2 wk after transplanting to grain formation, but if more than eight were present, a reduction in yield occurred. Plants infested with 32 insects per hill produced more tillers than uninfested plants, but they were stunted and yield was reduced.

Lim (1975) found that, in Malaysia, heavy infestations (15 adults or more per plant) caused severe stunting and yellowing of plants and killed them in 3−4 d. One insect could kill a plant in 16−17 d. It was not known whether plant mortality was due to the introduction of insect toxin or to the removal of plant sap and nutrients.

Venkata Rao and Muralidharan (1977) indicated that a sudden outbreak of RBB occurred on rice in Nellore District, Andhra Pradesh, India, in late May 1977 and yield losses of 60−85% were recorded; young seedlings seemed to be preferred. In heavily infested plots, about 200 bugs hill[-1] were found, mostly at the base of the plants. No bugs were found in dry nurseries.

Barrion et al. (1982) mentioned that, in February 1982, RBB was found damaging rice for the first time in the Philippines at Bonobono, Bataraza, south Palawan. A heavy outbreak occurred in March-June and spread to the central and northern parts of the province, affecting 4,500 ha. The estimated populations averaged 79−188 adults m[-2] and were as high as more than 400 m^{-2} in one field.

Anonymous (1983) reported that RBB was first reported to be causing severe damage to rice on the island of Palawan, the Philippines, in 1979. Since then, large numbers of bugs have caused substantial damage to irrigated rice on farms up to 250 km from the original infestation site.

Uthamasamy and Mariappan (1985) recorded heavy infestations with *Scotinophara lurida* on rice varieties infested from 30 d after transplanting to harvest, during which time, populations increased substantially. At the late flowering stage, populations averaged 20 bugs hill[-1]. Infestations occurred regularly during the previous 3 yr. In July-September, the area infested was about 800 ha.

Subramanian et al. (1986) mentioned that, in early July 1985, adult and nymphal populations of *Scotinophara coarctata* on rice in Tamil Nadu, India, reached 10 individuals hill[-1]. The population density on 11 different varieties ranged from 6 to 12 bugs per 10 hills. There were no significant differences in population size between varieties 30 d after transplanting.

Heinrichs (1987) indicated that yield losses were due to unfilled grains and decreased number of tillers and grains per panicle. Percentage yield loss at an infestation rate of 10 adults hill[-1] ranged from 15 to 18% in resistant cultivars to 23% in susceptible ones. Based on a linear regression of yield on number of adults per hill, an EIL of about three adults hill[-1] was noted.

Mohd Norowi Hamid and Shuhaimen Ismail (1994) indicated that the rice crop can compensate for MBB infestation in the vegetative phase, but it is sensitive during the early part of the reproductive phase, especially during spikelet formation. This is a common phenomenon of crop compensatory mechanism to insect infestation. The result of this study suggests that a general equation can be used to describe energy acquisition by an organism in a certain trophic level from a lower trophic level. The model can be used by extension officers in Malaysia as a tool to support their decision in managing MBB infestation. The management (i.e., insecticide application) of MBB infestation is the responsibility of the extension staff in the Department of Agriculture. If MBB density exceeds the ETL, the government, through recommendations of extension agents, will subsidize insecticides to farmers. Therefore, simulation results can be used to recommend insecticide subsidy to farmers, not only on the basis of MBB density but also on cultivar characteristics, crop development stage, and current knowledge on the advantages and disadvantages of insecticide application. Work carried out by Heinrichs et al. (1987) on the proposed ETLs for RBB and the results obtained in the present study agreed and ETL was set at three insects hill[-1].

Morrill et al. (1995) mentioned that adults of RBB are highly mobile, and heavy populations may quickly invade rice fields. Attack on seedlings reduced plant growth significantly after 1 or more days of feeding. Damage was characterized by desiccation of leaves and plant death. RBB attack of newly emerged panicles significantly reduced the number of filled grains after reaching feeding intensities of one or two bugs for 4 d and when four and six bugs fed for 4 or 6 d. The weight of grain per panicle was significantly reduced when six bugs fed for 4 or more days.

Lee Ki Yeol (2004) indicated that eggs were oviposited from early July to early August and its peak appeared in late July. Nymphs were observed from mid-July to late September with its peak in mid-August. The newly eclosed RBB were found in late August and its peak in mid-September. The RBB overwintered as adults at mountain foot, banks, and rice paddy leaves.

Effect of pesticides on predators and parasites in the rice ecosystem

Navarajan Paul and Thyagarajan (1992) reviewed the work on toxicity of pesticides to natural enemies of crop pests in India. They mentioned that many natural enemies are susceptible to a variety of pesticides used in crop protection. Such susceptibility often results in disruption of pest populations due to drastic reduction in natural enemy populations in the treated agroecosystems.

Pesticides (and their characteristics/mode of action) reported for use in the control of RBB *Scotinophara coarctata* (Fabricius).

Group/ pesticide	Toxicity LD 50 Oral: Dermal	Characteristic/ property/ action	Dose recommended (g ai ha^{-1}) **
Cyclodienes		**Highly persistent, cumulative toxicity, causes secondary pest infestation, resistance development in insects, high dose, slow action.**	
DDT (RP)[b]	Toxicity: LD 50 Oral: 113 mg kg^{-1} Dermal: 2510 mg kg^{-1}	Stomach and contact poison with high persistence. Ineffective on mites attacking crops. Phytotoxic on cucurbits. Affects the sensory organs and nervous system both in vertebrates and invertebrates.	Not recommended
BHC (banned)		It is a mixture of five isomers and their properties differ widely. The insecticidally active isomer is γBHC (see lindane).	Not recommended
γBHC (RP)	Toxicity: LD 50 Oral: 270 mg kg^{-1} Dermal: 900-1000 mg kg^{-1}	Nonsystemic, stomach and contact poison with fumigant action and long residual effect. Poisonous to honey bees. Phytotoxic on certain crops and imparts off flavor on some crops, if used in excess.	Not recommended
Aldrin (banned)	Toxicity: LD 50 Oral: 67 mg kg^{-1}	Persistent insecticide, stable in strong alkali. In living tissues of insects, mammals, and plants, it is converted to dieldrin. Most effective on soil insects.	Not recommended
Chlordane (banned)	Toxicity: LD 50 Oral: 457-590 mg kg^{-1} Dermal: 700 mg kg^{-1}	Persistent stomach and contact insecticide, has a light fumigant action. Toxic to bees. Useful for the control of household pests, termites, grasshoppers, and soil insects.	Not recommended
Dieldrin (banned)	Toxicity: LD 50 Oral: 46 mg kg^{-1} Dermal: 90 mg kg^{-1}	Persistent chemical of high contact and stomach insecticidal activity. Most effective on soil insects.	Not recommended
Endrin (banned)	Toxicity: LD 50 Oral: 7.5 mg kg^{-1} Dermal: 15 mg kg^{-1}	Persistent insecticide and stable under acidic and alkaline conditions. Effective on a wide spectrum of crop pests. Highly toxic, near-harvest use on fruit trees, vegetable crops, and fodder crops is banned.	Not recommended
Endosulfan	Toxicity: LD 50 Oral: 70 mg kg^{-1} Dermal: 4000 mg kg^{-1}	Nonsystemic, contact and stomach poison, safe to parasitoids, safe to apply when crops are in flowering stage.	525
Organo- phosphates		**Irreversible cholinesterase activity. Resistance in insects. High dose. Cross resistance within Ops-PHI (preharvest interval) is long.**	

Pesticides (and their characteristics/mode of action) reported for use in the control of RBB *Scotinophara coarctata* (Fabricius).

Group/ pesticide	Toxicity LD 50 Oral: Dermal	Characteristic/ property/ action	Dose recommended (g ai ha^{-1}) **
Acephate	Toxicity: LD 50 Oral: 945 mg kg^{-1} Dermal:>2000 mg kg^{-1}	Systemic and contact insecticide, moderate persistence, toxic to bees.	584
Chlorpyriphos	Toxicity: LD 50 Oral: 135-163 mg kg^{-1} Dermal:>2000 mg kg^{-1}	Nonsystemic stomach and contact poison, processes fumigant action, nonphytotoxic, useful for seed treatment, seedling root dip treatment, soil application for the control of root-feeding insects, white grub, and termites.	250-375
Diazinon	Toxicity: LD 50 Oral: 300-400 mg kg^{-1} Dermal:>2150 mg/kg	Contact, stomach poison, with fumigant action and penetrating capacity. Nematicidal action also.	180-200
Dicrotophos (Refused registration by CIB-Faridabad)	Toxicity: LD 50 Oral: 16.5-22 mg kg^{-1} Dermal: 168-224 mg kg^{-1}	Systemic insecticide and acaricide. Effective on a wide range of pests.	Not in use in India
(DDVP) Dichlorovos	Toxicity: LD 50 Oral: 50 mg kg^{-1} Dermal: 300 mg kg^{-1}	Nonsystemic, stomach and contact poison, a fumigant with weak penetration properties, extremely fast knockdown effect on insects.	375-500
Fenthion	Toxicity: LD 50 Oral: 250 mg kg^{-1} Dermal: 2800 mg kg^{-1}	Stomach and contact poison with long residual activity. Has translaminar action. Nonphytotoxic.	500
Fenitrothion	Toxicity: LD 50 Oral: 500 mg kg^{-1} Dermal: 1300 mg kg^{-1}	Nonsystemic, stomach and contact poison. Has good penetrating properties into the plant, fast acting with long residual toxicity.	500-750
Dimethoate	Toxicity: LD 50 Oral: 290-325 mg kg^{-1} Dermal: >800 mg kg^{-1}	Systemic insecticide. Stomach and contact poison. Also acts as acaricide.	200
Monocrotophos	Toxicity: LD 50 Oral: 18-20 mg kg^{-1} Dermal: 130–250 mg kg^{-1}	Systemic insecticide with stomach and contact action. Acaricide. Fast acting with strong systemic action. Penetrates into the plant tissues rapidly. Broad-spectrum insecticide with long residual action.	500
Malathion	Toxicity: LD 50 Oral: 1375-2800 mg kg^{-1} Dermal: 4100 mg kg^{-1}	Nonsystemic, stomach and contact poison , also acaricide. Less toxic to humans and mammals. Safe for use.	575-750
Methyl parathion (RP)	Toxicity: LD 50 Oral: 6 mg kg^{-1} Dermal: 45 mg kg^{-1}	Nonsystemic, stomach and contact insecticide. Broad spectrum with long residual action. Good penetration. Fast acting and rapid knockdown action and nonphytotoxic at recommended doses.	500-750

Pesticides (and their characteristics/mode of action) reported for use in the control of RBB *Scotinophara coarctata* (Fabricius).

Group/ pesticide	Toxicity LD 50 Oral: Dermal	Characteristic/ property/ action	Dose recommended (g ai ha^{-1}) **
Phosalone	Toxicity: LD 50 Oral: 120-175 mg kg^{-1} Dermal: 1500 mg kg^{-1}	Nonsystemic contact insecticide, has acaricidal action. Effective on a wide spectrum of pests.	500-900
Profenophos	Toxicity: LD 50 Oral: 613 mg kg^{-1} Dermal: 3300 mg kg^{-1}	Nonsystemic stomach and contact insecticide and acaricide. Good translaminar action.	750-1000
Phosphamidon	Toxicity: LD 50 Oral: 18-30 mg kg^{-1} Dermal: 374-530 mg kg^{-1}	Systemic insecticide, stomach poison with slight contact action.	250-500
Chlorfenvinphos	Toxicity: LD 50 Oral: 24-39 mg kg^{-1} Dermal: 31-108 mg kg^{-1}	Contact insecticide and acaricide with long residual action. Nonphytotoxic.	10-30
Quinalphos	Toxicity: LD 50 Oral: 71 mg kg^{-1} Dermal: >1750 mg kg^{-1}	Nonsystemic stomach and contact insecticide and also has acaricidal properties. Broad spectrum with quick knockdown effect with residual effect on insects. Good penetration into plant tissues.	375-500
Thiometon	Toxicity: LD 50 Oral: 88 mg kg^{-1} Dermal: >830 mg kg^{-1}	Systemic insecticide with stomach and contact action. Also has acaricidal properties. Nonphytotoxic.	150-250
Triazophos	Toxicity: LD 50 Oral: 57-68 mg kg^{-1} Dermal :>2000 mg kg^{-1}	Nonsystemic stomach and contact insecticide, having penetrating action into plant tissues. Acaricide and provides good initial kill with residual action on insects.	600-800
Mipcin (Isoprocarb)	Toxicity: LD 50 Oral: 450 mg kg^{-1} Dermal:>500 mg kg^{-1}	Systemic insecticide. Controls sucking insects like leafhoppers, planthoppers, plant bugs, aphids. etc.	
Trichlorfon	Toxicity: LD 50 Oral: 600 mg kg^{-1} Dermal:>2000 mg kg^{-1}	Nonsystemic stomach and contact insecticide with selective action. Phytotoxic to sorghum. Toxic to bees.	250-500
Buprofezin	Toxicity: LD 50 Oral: 2198 mg kg^{-1} Dermal: Not available	Insecticide-larvicide. Acts on sucking insects like mealy bugs, rice planthoppers, scales, and white flies.	
Carbaryl	Toxicity: LD 50 Oral: 850mg kg^{-1} Dermal: >4000 mg kg^{-1}	Broad-spectrum. Nonsystemic stomach and contact insecticide. Good residual activity, toxic to bees. Nonphytotoxic.	750-1000
Carbofuran	Toxicity: LD 50 Oral: 8 mg kg^{-1} Dermal:>3000 mg kg^{-1}	Systemic. Stomach and contact insecticide. Nematicide and acaricide. Nonphytotoxic.	750

continued on next page...

Pesticides (and their characteristics/mode of action) reported for use in the control of RBB *Scotinophara coarctata* (Fabricius).

Group/ pesticide	Toxicity LD 50 Oral: Dermal	Characteristic/ property/ action	Dose recommended (g ai ha^{-1}) **
Synthetic pyrethroids		**Low dose, very critical periods for application and stage of insect. Indiscriminate use leads to secondary pest problems. Quick knockdown of treated insects. Antifeedant. Acts as adulticide and kills moths moving in the field.**	
Deltamethrin	Toxicity: LD 50 Oral: 135 mg kg^{-1} Dermal: >2000 mg kg^{-1}	Stomach and contact insecticide, nonphytotoxic. Broad spectrum of activity and has ovicidal action. Antifeedant.	Not recommended for paddy; for other crops, 10-12.5
Permethrin	Toxicity: LD 50 Oral: 430–4000 mg kg^{-1} Dermal :>4000 mg kg^{-1}	Stomach and contact insecticide, nonphytotoxic. Broad-spectrum insecticide. Good residual activity. Antifeedant.	Not recommended for paddy; for other crops, 100-150
Ethofenprox	Toxicity: LD 50 Oral: 42,800 mg kg^{-1} Dermal: 2140 mg kg^{-1}	Nonsystemic, contact insecticides. Fast knockdown on certain insects like BPH, mango hoppers, green jassids. Nonphytotoxic.	50-75
Nitroguani-dine group		**Action is by interfering with transmission of nerve impulses in insects. In contrast to acetylcholine, which is quickly degraded by the enzyme acetyl cholinesterase, imidacloprid is either not degraded or only slowly degraded. The products' prolonged action disrupts the operation of the insect's nervous system, which results in its death.**	
Imidacloprid	Toxicity: LD 50 Oral: 450 mg kg^{-1} Dermal: 5000 mg kg^{-1}	Systemic compound with acute contact and stomach action.	
Fipronil	Oral: 97 mg kg^{-1} Dermal :>2000 mg kg^{-1}	Fiproles class: systemic, contact and stomach poison having residual action.	0.5-0.75 kg

[a]Major uses of pesticides – registered under the Insecticide Act of 1968. (Published by the Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, Directorate of Plant Protection, Quarantine and Storage, N.H.IV, Faridabad 121001, Haryana, India.1997. [b]**RP**-restricted pesticide. **Banned:** Pesticide banned for manufacture, import, and use as per the Central Insecticides Board, Directorate of Plant Protection, Quarantine and Storage, Government of India, Faridabad (Haryana), India. **Refused** registration by CIB-Faridabad (Haryana), India.

Conclusions

With the development of new molecules suitable for inclusion in IPM programs, it is essential to study the toxicity of these molecules to parasites and predators surviving under that ecosystem. A review of the literature on RBB revealed that a large number of predators and parasites exist under different agroclimatic conditions in various parts of these rice-growing countries. Furthermore, several other species are existing under the genus *Scotinophara* and, within a genus, different species of natural enemies are observed to differ in susceptibility to various pesticides. With this in view, the timing of application of pesticides is crucial to safeguard the natural ecosystem. Any deviation (overapplication, misuse, and abuse of pesticides) leads to a disruption of the agroecosystem, resulting in a pest flare-up. Hence, it is suggested that pesticides be used "safely and judiciously" to enable farmers to get the full benefits from the use of pesticides. Adoption of IPM is the best solution to all the pest problems.

The following suggestions ensure that full benefits of the pesticide are obtained when applied on the crop. Such practices need to be critically examined and the information passed on to farmers.

Operational and management factors that affect pesticide effectiveness

- Crop stage and plant architecture (attractiveness to pests, ease of pest management intervention)
- Plant health (optimum use of fertilizers and soil nutrients)
- Chemical nature of chosen insecticides (pest specificity, persistence)
- Quality of pesticides
- Dose rate (over- or underdosage)
- Application technique
- Targeting incorrect life stage of the pest or presence of overlapping generations
- Knowledge of the spray operator (laborer) in handling and application of pesticide
- Use of tank mixtures of different insecticides

Good plant protection practices

- Be able to identify the pest and natural enemies in the fields and understand their life cycles.
- Use the correct product and the appropriate method.
- Since pesticides form an important component of IPM, adopt proper plant management to avoid establishing favorable conditions for pest multiplication. Difficult spraying environment is linked to excessive crop canopy growth.
- Practice cultural practices such as deep plowing and stubble incorporation into the soil.
- Select pest-resistant crop varieties.
- Use crops with early maturity to reduce the number of potential pest generations in a season and prevent pest buildup due to unfavorable weather conditions.
- As far as possible, encourage and protect the natural enemies.

Classification of pesticides based on toxicity values.

Classification	Extremely toxic	Highly toxic	Moderately toxic	Slightly toxic
LD50, mg kg^{-1} Oral acute toxicity	1-50	51-500	501-5000	>5000
LD50, mg kg^{-1} Dermal toxicity	1-200	201-2000	2001-20,000	>20,000
Color indication on label	Red triangle, with skull & two bones-poison	Yellow triangle-poison	Blue triangle-danger	Green triangle-caution
Products	Chlorfenvinphos Chlorfenvinphos Carbofuran, Dicrotophos Methyl parathion, Monocrotophos, Methyl demeton Phosphamidon	γBHC, Endosulfan, BPMC, Carbosulfan, Chlorpyriphos, Cypermethrin, Dimethoate, Deltamethrin, Diazinon, Dichlorovos, Fenthion, Fenitrothion, Fipronil, Imidacloprid Lambda -cyhalothrin Phosalone Profenophos, Quinalphos, Thiometon, Trichlorofon, Triazophos, Carbaryl + lindane	Acephate, Carbaryl, Cartap – Hydrochloride, Malathion Propuxur, Permethrin, Ethofenprox	Azadirachtin and neem derivatives

- Include efficient cultural/biological control practices in pest control programs.
- Time the application of pesticides against the most susceptible life stages, based on sound, locally applicable economic thresholds.
- Use different classes of chemicals alternately throughout the season.
- Use pesticides at recommended spray rates and volume and intervals.
- Monitor susceptibility to currently used insecticides.

Details of different pesticides (characteristics, mammalian toxicity-LD_{50}, recommended doses) used by different authors and referred to in the present paper are presented in the appendix (Anonymous 2002).

A perusal of the above data indicates that, in many cases, the oral LD_{50} to rat is less and dermal LD_{50} is more, but in the case of ethofenprox, the oral LD_{50} is more compared with dermal LD_{50}, but this is not much of a significance to us. Generally, in a rice ecosystem, farmers apply insecticides either with a knapsack sprayer or motor-operated mist blower, without protective clothing. This is

Comparative mammalian toxicities of some commonly used rice insecticides.

Name of insecticide	Oral LD$_{50}$ mg kg^{-1} body weight for rat	Dermal LD$_{50}$ mg kg^{-1} body weight for rat
Endosulfan	70	4,000
Chlorpyriphos	135 -163	>2,000
Dimethoate	290 -325	>800
DDVP(dichlorovos)	50	300
Acephate	945	>2,000
Phorate	3 .7	6.2
Monocrotophos	18 - 20	130 -250
Quinalphos	71	>1750
Phosphamidon	18 -30	374 - 530
Methyl parathion	6	45
Phosalone	120 -175	1500
Carbofuran	8	>3,000
Carbaryl	850	>4,000
BPMC (fenbucarb)	524	>5,000
Ethofenprox	>42,800	2,140

a common phenomenon in most of the rice-growing tracts and the spray operator's body is inadequately covered. Under these circumstances, when pesticides are applied, which have low dermal LD$_{50}$ value, it is likely that the insecticide enters his body through the skin. It is critical that, whenever insecticides are recommended for rice/paddy pest control, they should be selective insecticides; safe to predators, parasites, and other nontarget organisms; and safe to the spray operator. Efforts should be made to educate the farming community on the safe and judicious use of pesticides in the rice ecosystem. The data are presented in a bar graph (Fig. 3a,b). A perusal of the graph (dermal toxicity data) indicates that if the bar is long, that particular insecticide is safe; if the bar is very short, it is more harmful to the spray operator.
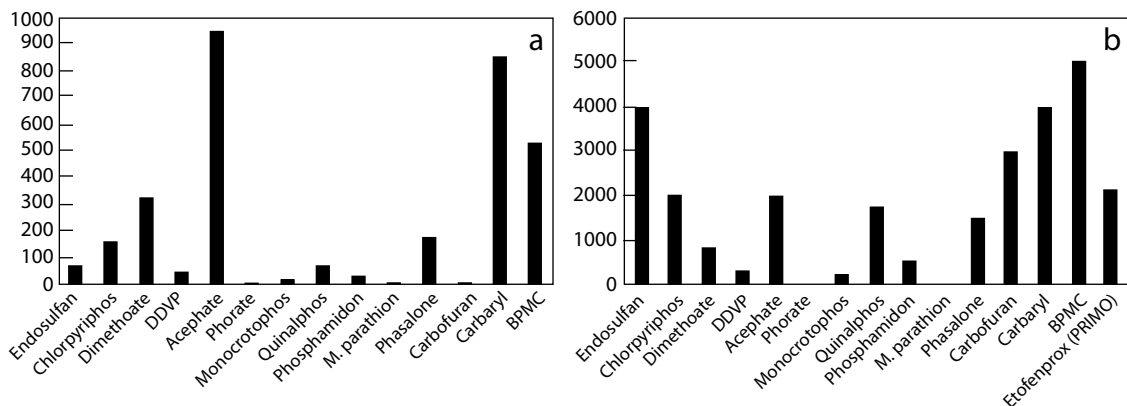

Fig. 3. Comparative mammalian toxicities of some commonly used rice insecticides.

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Pesticide Management of Rice Black Bug and its Impact on Beneficial Arthropods and the Rice Ecosystem

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Abstract

The management of rice black bug (RBB) using pesticides and its effects on nontarget organisms and beneficial arthropods was reviewed in this chapter. Historical use and changes in chemical, environmental, and toxicological properties of insecticides in rice were discussed. The movement of the invasive RBB and control efforts, coupled with comparative bioefficacy trials done by researchers to identify effective pesticides, was documented. The studies initiated by the researchers was a response to the imminent spread of RBB and by the limited recommended pesticides for RBB by the Fertilizer and Pesticide Authority (FPA). The current FPA-recommended pesticides for RBB (deltamethrin, esfenvalerate, lambda cyhalothrin, carbosulfan, thiamethoxam, and clothianidin) are not fully utilized by farmers. The most commonly used insecticide by the farmers is registered for rice but not for RBB. A comparative evaluation of properties of FPA-recommended insecticides for RBB and those of insecticides used by farmers was discussed. The use of insecticides directed against RBB could have direct or indirect impact on nontarget beneficial arthropods. The discussion was extended to nontarget beneficial arthropods of other rice pests and to the use of fungal pathogens as alternative control methods. The article discussed the impact of insecticides on the rice ecosystem in general, showed data gaps, and described regulatory efforts of the FPA to minimize the impact of these insecticides on nontarget organisms. This includes environmental and ecotoxicological properties of FPA-recommended pesticides for RBB. Risk evaluation and minimization of RBB pesticides, along with risk management techniques for reducing impact of RBB pesticides, were recommended. The discussion focused on a holistic ecological approach, knowledge of pest, and use of nonpesticidal alternative methods and approaches to reduce environmental contamination/impact of pesticides.

Key words: registered pesticides for rice black bug, selectivity, beneficial arthropods, rice ecosystem, risk assessment, pyrethroids, nicotinoids

Pesticide usage pattern in rice

Pesticides have always been used as part of the pest management scheme in rice production. The intensity of pesticide application in rice is low compared with that used in mango, pineapple, banana, and vegetables. In the Philippines, the production of rice is extensive over large areas, resulting in highest pesticide usage in rice compared with other crops. The insecticides used in rice had changed over the years, from organochlorines to organophosphates to carbamates to new-generation pyrethroids, and now, with low-dose alternatives with different chemical structures and mode of action. Historically, organochlorine pesticides used in rice, such as lindane and endosulfan, were broad-spectrum and nonspecific, affecting both target as well as nontarget species. A reduction in the populations of pests and well as beneficial organisms was observed, following the application of organochlorine insecticides. Persistent pesticide residues were detected in the environment and effects were noted on a number of nontarget organisms. Organochlorine insecticides were replaced by organophosphates (diazinon, chlorpyrifos, metamidophos, etc.) and carbamates (carbofuran, carbosulfan, BPMC, etc.), which are cholinesterase inhibitors and are less persistent in the environment. Health risks are associated with the use of organophosphates and carbamates due to their effect on the neurotransmitter, acetylcholine, which is also present in man. Pyrethroids, with lesser health and environmental risks, are now replacing the organophosphates and carbamates. The early-generation pyrethroids have lower toxicity to man compared with organophosphates and carbamates, but they have a strong knockdown effect on pests. Pyrethroids are generally less persistent in the environment and are easily degraded under sunlight. The new-generation pyrethroids, including cypermethrin, alpha-cypermethrin, deltamethrin, and lambda cyhalothrin, are more stable in sunlight and application rates per unit area are much lower than those of older generation insecticides. Etofenprox, a pseudo pyrethroid, was mentioned by farmers for rice black bug (RBB) *Scotinophara coarctata* (Fabricius) control. New-generation insecticides with new chemistry involved have lower application rates per hectare, lower spray concentration, and high pest specificity. Examples are esfenvalerate and, more recently, the nicotinoids thiamethoxam and clothianidin. The pesticides mentioned here are used either by farmers or registered by the pesticide regulatory agency (Fertilizer and Pesticide Authority [FPA]) for RBB control. The shift from organophosphates and carbamates to pyrethroids was also the result of a ban on a number of pesticides by FPA in 1993. Historically, application rates had decreased from kilograms to grams active ingredient per hectare and from broad spectrum to highly pest-specific pesticides, with minimal effect on beneficial insects and other organisms.

RBB invasion and researchers' comparative insecticide bioefficacy studies

The use of synthetic insecticides has been the salient feature of rice insect pest control, especially against RBB. Judicious use of these synthetic insecticides could result in tremendous benefits, but indiscriminate use can cause considerable harm to man and his environment. RBB was first reported in Bonobono, Bataraza, Palawan, in September 1979. During the major outbreak in southern Palawan in June 1982, the provincial government formed Task Force Black Bug, which orchestrated the mas-

sive and intensive insecticide applications in the hope of controlling this highly devastating invasive insect pest. However, the RBB population and damage continued to spread toward the central part of the province up to the northern areas, which covered about 4,500 ha of rice fields. Since there were no recommended insecticides against RBB at that time, De Sagun (1986) immediately evaluated 16 conventional and three synthetic pyrethroid insecticides as foliar spray and/or granular, broadcast application in Maasin, Brooke's Point, Palawan, from August 1983 to April 1985. He reported that, of the 19 insecticides tested for RBB in two rice cropping seasons, eight were found effective (deltamethrin at 0.0125 kg ai ha^{-1} and permethrin at 0.025 kg ai ha^{-1}; monocrotophos, carbosulfan, endosulfan, triazophos, fenthion, and carbofuran G at 0.50 kg ai ha^{-1}). Likewise, monocrotophos, carbosulfan, endosulfan, fenthion, triazophos, carbofuran G, deltamethrin, and permethrin at the same rates of application recommended by De Sagun were found effective against RBB (Mochida 1998).

Pesticide application is normally targeted on nymphs and adults of RBB, being the most destructive stage and the most visible. Barrion and Litsinger (1987) found acephate, BPMC, carbofuran, fenthion, monocrotophos, and triazophos to be effective against nymphs and adults of another species of black bug, *Scotinophara latiuscula* (Breddin). In India, a laboratory study of RBB eggs revealed that acephate and imidachloprid were the most effective, causing 100% and 95.83% mortality, respectively, followed by chlorpyrifos, profenofos, and monocrotophos (91.67%, 89.62%, and 87.52% mortality, respectively) (Anandhi and Pillai 2006). The ovicidal property of the pesticide is considered a positive secondary effect. According to Cahatian (1999), control intervention should start during the egg stage, which justifies the search for insecticides with ovicidal properties. Barrion and Litsinger (1987) found BPMC, carbaryl, carbofuran, carbosulfan, diazinon, endosulfan, fenthion, monocrotophos, and triazophos as effective ovicides (Table 1).

Table 1. Effect of insecticide foliar sprays on S*cotinophara latiuscula*. IRRI greenhouse, Feb 1984 (Barrion and Litsinger 1987).[a]

Insecticide	Mortality (%) per dosage	Unhatched eggs (%)			
		0.50 kg ai ha^{-1}	0.25 kg ai ha^{-1}	0.50 kg ai ha^{-1}	0.25 kg ai ha^{-1}
Acephate 75 SP	78 b	100 a	95 ab	100 a	85 ab
Azinphos ethyl 40 EC	79 b	85 b	75 c	68 bc	53 cd
Diazinon 20 EC	100 a	100 a	88 abc	80 abc	65 bcd
Fenthion 50 EC	100 a	100 a	88 abc	90 a	83 ab
Monocrotophos 30 EC	100 a	100 a	95 ab	98 a	83 ab
Triazophos 40 EC	100 a	100 a	100 a	88 ab	85 ab
Carbaryl 85 WP	100 a	100 a	83 abc	88 ab	53 cd
Carbofuran 12 F	100 a	100 a	100 a	95 a	90 a
Carbosulfan 20 EC	100 a	100 a	78 bc	93 a	65 bcd
BPMC 50 EC	100 a	100 a	88 abc	100 a	100 a
Endosulfan 40 EC	100 a	100 a	83 abc	80 abc	53 cd
Permethrin 10 EC	77 b	93 ab	75 c	60 c	38 d
Control	0 c	0 c	0 d	0 d	0 e

[a]Av of four replications. In a column, means followed by a common letter are not significantly different (P=0.05) by DMRT.

Because of the RBB menace, the Philippine Rice Research Institute (PhilRice) led an inter-agency task force in 1989 to contain RBB in Palawan. PhilRice recommended the planting of IR1314 (RBB-tolerant variety), release of parasitic wasps, and strict quarantine measures. However, 10 yr after its outbreak in Palawan, RBB was observed in Curuan, Zamboanga City, in late June 1992. Toward the end of the year, about 2,000 ha have been heavily damaged by RBB. In March 1995, RBB has become a serious pest of rice in the region, including the Autonomous Region of Muslim Mindanao. In June 1996, RBB further invaded Cotabato, Sultan Kudarat, and Saranggani provinces. Outbreaks occurred in these areas in 1997 and, in the following year, infestation was observed in Magsaysay, Davao del Sur. The RBB infestations in Mindanao and the Palawan experience were strikingly similar. The Mindanao RBB Task Force also relied heavily on massive insecticide applications in severely infested regions, but RBB population and damage still spread to the neighboring places. A year after the RBB outbreak in Mindanao, the Western Mindanao Integrated Research Center (WESMIARC) evaluated nine insecticides as foliar spray against RBB (Apao et al. 1998). Results showed that the effective insecticides mostly belonged to the synthetic pyrethroid group (cypermethrin, cyfluthrin, and deltamethrin), followed by ethofenprox and lambda cyhalothrin. BPMC, carbaryl, and the combination of chlorpyrifos + cypermethrin were also effective. The application of three granular insecticides in potted plants under simulated rainfed or upland conditions resulted in RBB mortality within 24 h for diazinon and carbofuran at 0.4 kg ai ha^{-1} and within 72 h for fipronil at 0.30 kg ai ha^{-1}.

Despite warnings about the possible spread and possible damage of RBB in areas where the pest is not yet found, RBB was reported in Kabangkalan, Negros Occidental, in late 1998. RBB spread to other places in the Visayas: Siquijor in January 1999 and Bohol in September 1999. Then the pest was reported again in 2000 in Mindanao in the Caraga Region. RBB continued to spread and inflict damage in the Visayas: Leyte in 2001 and Samar in 2003. In early 2006, the presence of RBB in Sorsogon in Luzon Island was reported and confirmed. Due to the proximity of Quezon province to the Bicol Region, the threat of RBB invasion in Quezon is real and, from there, it could easily move to Laguna province. This will be the RBB's gateway to other major rice-producing areas in Luzon Island.

FPA-recommended insecticides for RBB

Pesticide use continues to be a significant component of agricultural practice. In the Philippines, the FPA is the government agency mandated to regulate the pesticide industry and is in charge of all matters related to pesticides such as registration, use, monitoring, and training, among others. The use pattern (dose, rate, frequency of application, preharvest interval, etc.) and target pests are indicated in the pesticide label. Any deviation from the label usage may be considered as misuse. FPA facilitated the registration of effective pesticides for RBB as a response to the severity of RBB infestation.

Pesticides currently registered for the control of RBB (Table 2, FPA 2007) include beta cy-fluthrin, deltamethrin, esfenvalerate, lambda cyhalothrin, carbosulfan, thiamethoxam, and clothi-anidin. Pesticides used by farmers for RBB control, expressed in terms of percentage of the farmer respondents are cypermethrin (67.5%), followed by lambda cyhalothrin (11.4%), deltamethrin (7.9%),

Table 2. Registered insecticides against rice black bug as of 31 Dec 2006 (FPA 2007).

Insecticide group	Active ingredient	Product name	Company	Target pests other than RBB
Synthetic pyrethroids	Deltamethrin	Anaconda 2.5 EC	Richland Agrc'l. Supply	GLH, SB, WM, RB
		2 Fast 2.5 EC	Enviro Cropnet Products, Inc.	GLH, SB, WM, RB
		Hi-Action 1.25 EC	Enviro Cropnet Products, Inc.	GLH, SB, WM, RB
	Esfenvalerate	Sumi-Alpha 2.5EC	Agri-Care Service Corp.	LF, SB, RB
		Legend 2.5 EC	Jardine Distribution Inc.	GLH, WM, LF, BPH
	Lambda-cyhalothrin	RPG 2.5 EC	Abigail Farm Supply	GLH, AW, LF, RB
		Star Lambda 2.5 EC	AgenVi Life Science, Inc.	GLH, AW, LF, RB
		Chaku 2.5 EC	Leads Agri Product Corp.	GLH, AW, LF, RB
		Arnis 2.5 EC	Kemistar Corp.	GLH, AW, LF, RB
		Alert 2.5 EC	Jocanina Corp.	GLH, AW, LF, RB
		Arrest 2.5 EC	Diomachan Chemicals Mktg.	GLH, AW, LF, RB
		Autokill 2.5 EC	HQ Agricare Trading	GLH, AW, LF, RB
		Higante 2.5 EC	Cardinal Farm Supply	GLH, AW, LF, RB
		Ariba 2.5 EC	Texicon Agrichem Corp.	GLH, AW, LF, RB
		Deliver 2.5 EC	Agway Chemicals	GLH, AW, LF, RB
		NS lambda-cyhalothrin 2.5 EC	NS Northern Organic Fertilizer	GLH, AW, LF, RB
		Kriss 2.5 EC	CropKing Chem., Inc.	GLH, AW, LF, RB
		Bida 2.5 EC	Aldiz Incorporated	GLH, AW, LF, RB
		Inferno 2.5 EC	Jeels Masagana Farm Supply	GLH, AW, LF, RB
		Cyhatex 2.5 EC	Threadstone Chemicals Corp.	GLH, AW, LF, RB
		Slam 2.5 EC	Vast Agro Solutions Inc.	GLH, AW, LF, RB
		Jolina 2.5 EC	SL Agritech Corporation	GLH, AW, LF, RB
		Garand 2.5 EC	Just Marketing Oper. Multi. Coop	GLH, AW, LF, RB
		Arsenal 2.5 EC	Gold Orchard Distribution Inc.	GLH, AW, LF, RB
		Armas 2.5 EC	Altrade	GLH, AW, LF, RB
		Torch 2.5 EC	Altacrop Protection Corp.	GLH, AW, LF, RB
		Spectra 2.5 EC	Agropoint Inc.	GLH, AW, LF, RB
		2.5 Karat	Farm Care Corp.	GLH, AW, LF, RB
		Sumo 2.5 EC	Agchem Mfg. Corp.	GLH, AW, LF, RB
		Krypton 2.5 EC	Mars Agri-Chem & Supply Co.	GLH, AW, LF, RB
		Bigboss 2.5 EC	PhilAgrow, Inc.	GLH, AW, LF, RB
		Revolt 2.5 EC	Monarch Agric'l. Products,Inc.	GLH, AW, LF, RB
		Sugod 2.5 EC	Vann Hawk Agrochem., Inc.	GLH, AW, LF, RB
		Carat 2.5 EC	United Agro Trade Corp.	GLH, AW, LF, RB
		Jakpot 2.5 EC	TeamAgro Trading	GLH, AW, LF, RB
		Karate 2.5 EC	Syngenta Phils, Inc.	GLH, AW, LF, RB
		X-Plode 2.5 EC	Sun Blest Agric. Realty Dev. Serv. Inc	GLH, AW, LF, RB
		Bug Seek 2.5 EC	RNE Enterprises	GLH, AW, LF, RB
		Terminator 2.5 EC	Radisson Agrochem. Corp.	GLH, AW, LF, RB
		Descarte 2.5 EC	Planters Product, Inc.	GLH, AW, LF, RB
		Excalibur 2.5 EC	Berris Agricultural Corp.	GLH, AW, LF, RB
Neonicotinoids	Clothianidin	Dantotsu 16 WSG	Agri-Care Service Corp.	GLH, AW, BPH, LF, SB
	Thiamethoxam	Actara 2.5 WG	Syngenta Phils, inc.	GLH, BPH, WBPH, RB
Carbamates	Carbosulfan	Marshal 200 SC	DuPont Far East, Inc.	GLH, BPH, LF, SB RB
		Lead Marshal 200 SC	Leads Agri Product Corp.	GLH, LF, SB, RB

AW = armyworm, BPH = brown planthopper, GLH = green leafhopper, RB = rice bug, SB = stem borer, LF = leaffolder.

and chlorpyrifos + BPMC (2.6%). Carbofuran, diazinon, cypermethrin + chlorpyrifos, etofenprox, fipronil, metamidophos, and monocrotophos were also used by a few farmers (PhilRice 2004). Cypermethrin, which is commonly used by farmers, is marketed under 100 brand names (CPAP 2007) and is registered for other rice pests but not for RBB (FPA 2007). The labels of all 100 brand names

containing cypermethrin are uniform in terms of target pests and rates of application, but this does not include RBB. However, cypermethrin is of a similar class with FPA-registered pyrethroids such as beta cyfluthrin, deltamethrin, esfenvalerate, and lambda cyhalothrin, which are recommended for RBB. The farmers' continued use of cypermethrin for RBB may be indicative of its bioeffectivity. This could be due to the similarity in structure and mode of action of cypermethrin with RBB registered pyrethroids. However, the problem on the use of pesticides not recommended by FPA against RBB is that no bioefficacy trials have been done on RBB by the pesticide companies marketing these products. On the other hand, Apao et al. (1998) reported that cypermethrin resulted in 100% RBB mortality 15 min after application under laboratory conditions. Cypermethrin and its mixture with either chlorpyrifos or diazinon were effective under field conditions. Although the residue situation may not be a problem for cypermethrin on rice, considering the long preharvest interval (PHI), this would be a problem for short PHI crops. If there are any problems as a result of this application, this usage pattern is not covered by the pesticide company. Monocrotophos was also mentioned by the farmers, but this bugs was already banned by FPA in 1993. However, monocrotophos was found the most effective of the five insecticides evaluated for RBB on 45-d-old IR50 at 1-2 d after treatment with an average control of 91% (Subramanian et al. 1986). Except for the use of deltamethrin and lambda cyhalothrin, farmers' management practices are considered a misuse by FPA. The insecticides may not be bioeffective on RBB at the rates used for other rice pests, the residue picture was not studied and the environmental impact is unknown. This is a situation with high environmental, occupational, and dietary risk.

Generally, the insecticides used against RBB in Palawan and Mindanao were limited to four chemical groups: synthetic pyrethroids, organophosphates, carbamates, and chlorinated hydrocarbons. Unfortunately, among the long lists of insecticides evaluated by researchers and used by farmers against RBB in Palawan and Mindanao, only deltamethrin, lambda cyhalothrin, cyfluthrin, and carbosulfan are currently approved by FPA. The researchers' observations of the effectiveness and quick knockdown effect were typical of the mode of action of pyrethroids. Some of the previously evaluated insecticides by researchers and those used by farmers (endosulfan, monocrotophos, and methyl parathion) were banned by FPA in 1993. Apao et al. (1998) reported that the efficacy of spray insecticides was enhanced when water level in the paddy was raised up to 8-12 cm at maximum tillering and heading stages during spray applications. This was brought about by increased chemical contact to the RBB or the disturbance of the RBB, resulting in movement to the leaves, making it more prone to spray application (Estoy et al. 2000). Bioeffectivity could also be enhanced by directed spray application.

The effectiveness of insecticides not recommended by FPA, either used by farmers or evaluated by researchers against RBB, will not be discussed further. It must be understood that the list of insecticides recommended by FPA changes with time as new groups of promising insecticides with different chemistry and mode of action become available in the market. If the insecticides pass the required rigid bioefficacy trials, including other tests related to toxicity, environmental effects, environmental fate and transport, residues, specification data, then FPA includes it in the official list

of insecticides for use against RBB. The current FPA-recommended insecticides for RBB primarily belong to the synthetic pyrethroids, one carbamate, and, recently, the nicotinoids as exemplified by thiamethoxam and clothianidin (Table 2) (FPA 2007). For pyrethroids, there are 36 generic products for lambda cyhalothrin and three for deltamethrin. Systemic nicotinoids have low application rates and are highly pest-specific with low occupational and dietary risks. The spray concentrations are 0.03-0.035 g ai L^{-1} and 0.09 g ai L^{-1} for clothianidin and thiamethoxam, equivalent to 0.0035% and 0.009%, respectively. The use of low-dose systemic insecticides reduces the toxicity to natural enemies and nontarget organisms, which are normally associated with conventional insecticide applications. Clothianidin and thiamethoxam act by interfering with post-synaptic nicotinic acetylcholine receptors. Nicotinoids do not inhibit cholinesterase or interfere with sodium channels with a mode of action different from organophosphate, carbamate, and pyrethroid insecticides (Kenyon and Kennedy 2001). Nicotinoids can therefore be used interchangeably with pyrethroids and carbamates to manage RBB and to minimize the development of resistance.

Insecticide application, though effective against RBB, may offer temporary control, and thus may require repeated applications. The use of insecticides is not only prohibitively expensive; it may also be toxic to nontarget organisms and could adversely affect man and the environment. Massive insecticide application was the strategy employed in controlling RBB at the height of the infestations in both Palawan (1982) and Mindanao (1992). Despite heavy insecticide applications, RBB still spread to the other regions, which could be due to the elimination of indigenous natural enemies in the area. The repeated use of insecticides of the same class/type may result in resistance problems, increase in population of secondary pests, and resurgence, among others.

Effects of pesticides on nontarget organisms: beneficial arthropods

The effect of insecticides may either be direct or indirect. Direct effects include mortality or acute effects on either the pest or nontarget organisms present in the immediate environment. Wrong timing of insecticide application can kill beneficial organisms and their food source, especially when application is over large areas as in the case of RBB control. Indirect effects include chronic effects on growth and behavior of target or nontarget organisms. Research on these areas is virtually non-existent in the Philippines.

During pesticide application, the nontarget organisms are unintentionally affected due to their proximity to the site of application. To assess these risks, FPA require data on environmental effects and fate and transport data on insecticides for the purpose of pesticide registration. This includes data on toxicity to birds, fish/aquatic organisms, bees, and soil macroorganisms/microorganisms to represent different trophic levels. Bioefficacy studies for agricultural insecticides require the inclusion of effects on beneficial insects such as parasites and predators. However, the population of the nontarget organisms in the field may at times not be sufficient to justify valid scientific conclusions.

Several species of beneficial arthropods are found associated with RBB. To obtain maximum benefits from these beneficial arthropods and at the same time effectively manage RBB using pesticides, there is a need to recognize and identify these arthropods since they are responsible for regu-

Table 3. RBB natural enemies reported in the Philippines (Arida et al. 2006).

Beneficial arthropod	Scientific name	Stage of RBB attacked
Parasitoids		
Wasp	*Telenomus triptus* Nixon	Egg
	Psix lacunatus Johnson & Masner	Egg
Predators		
Ground beetle	*Agonium daimio* Bates	Egg, nymph, adult
Wolf spider	*Pardosa pseudoannulata* (Boessenberg & Strand)	Nymph, adult
Lynx spider	*Oxyopes javanus* L.	Nymph
Long-jawed spider	*Tetragnatha virescens* Okuma	Nymph
Cricket	*Metioche vittaticollis* (Stål)	Egg
	Anaxipha longipennis (Serville)	Egg
Red ant	*Solenopsis geminata* (Jerdon)	Egg, nymph
Coccinellid beetle	*Micraspis crocea* (Mulsant)	Egg, nymph
Damsel bug	*Stenonabis tagalicus* (Stål)	Egg, nymph
Pathogens		
Fungus	*Metarhizium anisopliae* (Metschnikoff) Sorokin	Nymph, adult
	Beauveria bassiana (Balsamo) Vuillemin	Nymph, adult
	Paecilomyces lilacinus (Thompson) Samson	Nymph, adult

lating RBB population below damaging levels. In general, when an invasive pest like RBB colonize a new ecological zone, the damage becomes alarming and highly devastating because of the absence of beneficial arthropods. Records show that an outbreak of RBB may cause up to 90% yield loss (Santiago 2001). However, 2–3 yr after the introduction of the insect pest, the damage may decline since natural enemies can now recognize the pest.

The major group of indigenous natural enemies associated with RBB in Palawan Island, Philippines, was studied by Perez et al. (1989) and summarized by Arida et al. (2006) (Table 3). The eggs of RBB are preyed upon by two species of crickets [*Metioche vittaticollis* (Stål.) and *Anaxipha* sp.], coccinellid beetles [*Micraspis crocea* (Mulsant)], ground beetles, and spider species belonging to genera *Pardosa, Oxyopes,* and *Tetragnatha.* In addition, the nymphs and adults are susceptible to infection of *Metarhizium anisopliae* (Motsch.), *Beauveria bassiana* (Bals.), and *Paecilomyces lilacinus* (Thom.) (Rombach et al. 1986).

The hymenopteran parasitoid, *Telenomus triptus* Nixon (Hymenoptera: Scelionidae), has been reported from the eggs of RBB (Grist and Lever 1969). This indigenous parasitoid species was also reported parasitizing the eggs of RBB in Palawan (Barrion and Litsinger 1987). The effectiveness of *T. triptus* and four other introduced parasitoids (*T. cyrus, T. chloropus, Trissolcus basalis,* and *Psix lacunatus)* were evaluated against RBB. It was found that more than 90% of the parasitoids that emerged from parasitized RBB eggs were the indigenous *T. triptus* (Arida et al. 1988). A survey of RBB eggs parasitized by *T. triptus* in three provinces in Mindanao in 1996 revealed very high egg parasitism (Table 4). Among the parasitoids, *T. triptus* was the most dominant and most effective since it could parasitize about 39.8% of RBB eggs during ripening stage of the plant but could cause

Table 4. Percentage parasitization of *T. triptus* (Nixon) on RBB eggs taken from different outbreak areas in Mindanao, March 1998 (Cahatian 1999).

Area	Year of occurrence	Percent parasitization	
		% egg mass parasitized	% egg parasitized
Labangan, Zamboanga del Sur[a]	1996	50.00	12.16
Tiguma, Pagadian City[a]	1996	81.79	42.39
Tukuran, Zamboanga del Sur[b]	1996	88.88	50.56
Bayog, Zamboanga del Sur[b]	1994	69.52	36.49
Pigcawayan,Cotabato[b]	1995	85.10	19.33
Kabacan, Cotabato[b]	1996	78.00	36.45
Magsaysay, Davao del Sur[b]	1997	32.17	22.58
Lower Balutacay, Hagonoy, Davao del Sur[b]	1997	39.34	17.19

as high as 88.88% egg parasitism (Cahatian 1999, Irog irog and Cahatian 2001). When parasitized eggs were submerged in water for 24 h, more than 50% adult *T. triptus* was recorded (Parducho et al. 1989). Cahatian (1999) further indicated that it is likely that *T. triptus* is phoretic to RBB due to the presence of individuals retrieved from RBB collected from light traps. Clausen (1976) confirmed that phoresy occurs in Scelionidae, wherein the female parasitoid clings tightly to the host species and immediately attacks the host's eggs upon oviposition Although RBB adult females exhibit maternal care for their eggs until after hatching, they are only partially protected from egg parasitism by *T. triptus*.

The common sword-tailed cricket*, Metioche vittaticollis* (Stål.) is a very common predator in rice fields in the Philippines. However, the cricket preferred the eggs of *Chilo suppressalis* (Walker) over those of *Scotinophara latiuscula* Breddin, when offered in a choice test. Likewise, it preferred younger nymphs of brown planthoppers (BPH) and green leafhoppers over later instars of RBB (Rubia 1985).

The RBB are highly susceptible to deuteromycetous fungal species as shown through the collection of nymphs and adults that are infected with *Metarhizium anisopliae, Beauveria bassiana*, and *Paecelomyces lilacinus* (Rombach et al. 1986, Barrion and Litsinger 1987, Irog-irog and Cahatian 2001, Anandhi and Pillai 2006). Infection by *M. anisopliae* under field conditions was mostly on older RBB nymphs and adults. However, in potted experiments, infection was also observed on the second, third, fourth, and fifth nymphal instars, and adult RBB. No infection was observed on the different species of spiders and adult parasitoid, *T. triptus* (Cahatian 1999). The application of entomopathogenic fungi *B. bassiana, M. anisopliae,* and *P. lilacinus* significantly reduced the RBB population compared with the control over a period up to 9 wk (Rombach et. al. 1986). The major advantage of using pathogenic fungus is that it can be efficiently and economically mass produced. *M. anisopliae* is widely used against RBB in Mindanao and the Visayas and, recently, in Sorsogon (Luzon).

Despite the presence of a wide array of effective biological control agents associated with RBB, complete biological control and subsequent elimination of pesticide use could be difficult to

achieve in the rice agroecosystem. Due to the multipest system and the absence of effective natural enemies for certain key pests, the use of insecticides will continue to be a component in the development of management strategies against rice insect pests. However, biological and chemical control is generally incompatible because insecticides are quite toxic to natural enemy populations. In fact, the adverse effect of insecticide application on the effectiveness of RBB natural enemies had been properly documented in rice in the Philippines. The subsequent discussion will be based on the effects of insecticide treatments on the natural enemies of other rice insect pests.

The effects of insecticides on biological control agents can be direct and indirect. Direct effects include short- and long-term impacts on natural enemies due to direct contact with insecticides or its residues (Johnson and Tabashnik 2004). After insecticide application, the most immediate effect on natural enemies is short-term mortality within 24 h. Short-term mortality is determined by exposing a specific stage of the natural enemy to several insecticide concentrations under laboratory or field conditions and quantified as lethal dose (LD) or concentration (LC) that will be deleterious to natural enemies. Fabellar and Heinrichs (1984) evaluated the effects of rice insecticides on predators of BPH, the spider *Lycosa pseudoannulata,* the mirid bug *Cyrtorhinus lividipennis,* and the ripple bug *Microvelia atrolineata*. Among the insecticides applied as contact poison to the predators by using Potter's spray tower method, acephate, BPMC, carbophenothion, endosulfan, ethylan, monocrotophos, and propoxur were selective to *L. pseudoannulata*. Carbophenothion and ethylan were selective to *C. lividepennis,* while all insecticides, except cypermethrin and deltamethrin, were selective to *M. atrolineata*. All insecticides were selective as stomach poison to *L. pseudoannulata* and *M. atrolineata,* except deltamethrin to the latter. Acephate, carbophenothion, ethylan, and propoxur were selective to *C. lividipennis* as stomach poisons. With BPH nymphs as prey, deltamethrin was selective as a stomach poison to *M. atrolineata*. When insecticides were applied as foliar sprays, all the insecticides, except deltamethrin, were selective to *L. pseudoannulata* and *M. atrolineata*. On *C. lividipennis,* none was selective at 1 DAT but toxicity of BPMC and ethylan decreased at 3 DAT. The predatory activity of *L. pseudoannulata* on BPH adults was inhibited when the spider was placed on deltamethrin-sprayed plants. Deltamethrin was also highly toxic to *C. lividipennis* and *M. atrolineata* when placed on foliar-sprayed plants.

A study of the recolonization and buildup of BPH and white backed planthoppers*, N. lugens, Sogatella furcifera* (Horvath), and their selected predators on resistant and susceptible rice varieties, and the application of deltamethrin at the rate of 8 g ai ha^{-1} at 21 and 68 d after transplanting (DAT) during the 1986 wet season and at 43 DAT in the 1987 dry season was monitored. The population of *C. lividipennis* followed BPH population buildup more closely than did the spiders. Varietal resistance and insecticide spray reduced mirid predator and spider population buildup. The adverse effect of insecticide was more direct on beneficial insects than on planthoppers (Joshi 1988).

Selectivity ratios of eight insecticides to female nymphs of BPH and *L. pseudoannulata* were established based on the LD_{50} and LC_{50} or LC_{95} values (dose or concentration resulting respectively in 50% or 90% mortality). All methods of insecticide application tested showed that buprofezin, acephate, and propaphos were highly selective or nontoxic to the spider when applied on the foliage (Thang

1985). Apao et al. (1998) reported that etofenprox, a pesticide used by farmers for RBB, was safe to spider genera *Lycosa, Argeope,* and *Oxyopes,* including red ants and frogs. The relative toxicities of four insecticides to *M. vittaticollis* based on the LD_{50}, in descending order were cypermethrin > carbosulfan > monocrotophos > BPMC (Rubia 1985). The safety of insecticides to natural enemies can be further ascertained by comparing its toxicity to the target pest. Metcalf (1984) indicated that it may more valuable to use an insecticide that kills 50% of the pest population but is nontoxic to its natural enemies than one that kills 95% of the pest population but at the same time eliminates the natural enemies.

On the other hand, when the impact of the insecticide is mediated through the natural enemy host or prey, these are considered indirect effects (Waage 1989). Indirect effects may be caused by several factors such as reduction of host or prey population that serves as food sources for natural enemies (Powell et al. 1985), a change in host or prey distribution (Waage 1989), and ingestion of insecticide-contaminated prey or host (Goos 1973). Although the greatest impact of insecticides to natural enemy is the acute mortality, the reduction in population density of the host that serves as food sources for natural enemies is possibly the greatest detriment to natural enemy population (Powell et al. 1985). The use of systemic insecticides may partly solve the high acute toxicities associated with most conventional insecticide applications. However, even when systemic insecticides are used, problems may occur when pest densities are reduced to very low levels, resulting in natural enemy decimation due to lack of prey or hosts (Boyce 1936, Barlett 1964), especially when the natural enemies are highly host-specific (Heatcote 1963).

The ingestion of pesticide-contaminated host or prey may also pose deleterious effect on the natural enemy population. The mortality of coccinellid predators like *Menochilus sexmaculatus* (Fab.), *Coccinella undecimpunctata* (Lin.), and *Scymnus syriacus* Le Conte has been reported following consumption of aphids previously sprayed with malathion (Satpathy 1968) and demeton (Ahmed 1955). Even emerging adult endoparasitoids can be killed from insecticide residues left in the host as they bore through contaminated host integument, egg chorion, or scale covers (Delorme et al. 1985, Cohen et al. 1988).

The application of fungal pathogens such as the *M. anisopliae* and *B. bassiana* may also reduce the natural enemy population. Navasero (2007) indicated that *M. anisopliae* should not be applied in corn since it could also kill the flower bug *Orius tantillus* (Motschulsky), an effective Asian corn borer predator. The application of fungicides directed against major rice fungal diseases may possibly reduce the efficiency *M. anisopliae* and *B. bassiana.* Since there are very limited studies on the effect of insecticide treatments on RBB natural enemies, research along this line would be very useful in the implementation of IPM programs.

Insecticides and their effect on the rice ecosystem

The impact of pesticide application may be present long after the visual observation of RBB mortality. A possible scenario is when the concentration of the pesticide several days after application may no longer be bioeffective on the pest but may still be affecting nontarget organisms due to the residues

present in the immediate environment. The environmental impact of these residues and its effects on beneficial nontarget organisms have not been regularly monitored. The research gap is due to lack of financial resources, trained personnel, as well as laboratory facilities for pesticide residue detection. Partnership between residue chemists, trained insect ecologists, and ecotoxicologists to determine the effects of residues on nontargets and the rice ecosystem is virtually nonexistent. However, the impact of insecticide use may be predicted and therefore minimized on the basis of several factors during application—environmental conditions, properties of the insecticide, and the dynamics of the rice ecosystem where the pesticide is applied.

The current recommendation for RBB control involves the use mainly of pyrethroids (beta cyfluthrin, deltamethrin, lambda cyhalothrin, and esfenvalerate), a carbamate carbosulfan, and nicotinoids thiamethoxam and clothianidin. Generally, the pyrethroids degrade fast in the environment and these are biologically and chemically less persistent than organophosphates. The pyrethroids, due to their structure and low water solubility, tend to cling to organic matter, and may thus not impact on nontarget organisms living in close proximity to water, unless there is direct contact upon application. Pyrethroids have high fish/aquatic toxicity when applied directly in water under laboratory conditions. However, under field conditions, pyrethroids have strong affinity and bind strongly to organic matter of the soil and are not bioavailable to cause mortality to aquatic organisms or to leach, as in the case of lambda cyhalothrin. The use of pyrethroids poses less environmental risks due to low application rates and less persistence but high knockdown effect. However, since cypermethrin is used frequently and in a number of crops aside from rice, resistance and secondary pest problems may occur.

Carbosulfan, a carbamate pesticide, and its degradation product, carbofuran, are both systemic and with insecticidal properties. Carbosulfan and carbofuran will therefore be more effective against sucking insect pests such as RBB and others. Thiamethoxam and clothianidin also have systemic activity with low application dosage per hectare and with metabolites similar to the structure of nicotine with very low mammalian toxicity. In comparison, the organophosphates and carbamates used by farmers for RBB may give higher risk to nontarget (higher water solubility than pyrethroids) organisms, longer residual toxicity than pyrethroids, and higher farmer occupational risk due to the effect on cholinesterase. However, the continuous use of pyrethroids may cause resistance or cross-resistance problems.

Clothianidin and thiamethoxam have properties and characteristics associated with chemicals detected in groundwater (mobile, persistent, stable to hydrolysis, highly water soluble). However, once adsorbed to the soil, these nicotinoids are less likely to be removed into the aqueous phase and leach into groundwater (Kenyon and Kennedy 2001). There is minimal direct acute or chronic risk to nontarget organisms like freshwater and estuarine/marine fish, or a risk to terrestrial or aquatic vascular and nonvascular plants (EPA 2003). Based on differences in mode of action, chemical properties and its fate, and effects on the environment, it is recommended that the pyrethroids be used in rotation with nicotinoids and the only carbamate pesticide recommended for RBB.

Evaluation and minimization of risk associated with insecticides in RBB control

Environmental contamination and the effect on nontarget organisms can be minimized by putting in mind that an amount of risk is involved in every insecticide application. Insecticides should not be thought of as *gamot* (Filipino word for medicine) but as *lason* (Filipino word for poison).

In every pest problem, IPM or any recommended non-insecticide technology should be used as the first line of defense. It is recommended that IPM strategies and tactics, which are compile with conservation of biodiversity, be adopted. Special consideration should be given to avoid lethal effects on species that are vulnerable to pesticides, such as aquatic, univoltine, and carnivorous or monophagous species (Kiritani 2005). The use of *M. anisopliae, B. bassiana,* and *P. lilacinus* is effective and recommended (Rombach et al. 1986) but these must be used judiciously as they may also affect other beneficial insects (Navasero 2007). Prevention of migration should be practiced and reducing population buildup can be done by cultural and physical control, including knowing the pest and taking care of the beneficial organisms. Prevention also involves proper quarantine procedures, especially for RBB. If the pest population goes beyond the injury level, application of insecticides is the last line of defense and should be a community effort. Application of pesticide should be directed, coupled with proper water management and directed spray application. Care should be taken that label instructions are followed as to the recommended rate, frequency, and timing of application. The use of FPA-recommended insecticides will reduce "unknown" risks associated with misuse. An insecticide may not be effective on the pest you intend to control, may not be appropriate for the crop or cropping pattern, and its residue profile may not have been studied. A case study in Leyte found that, of the 841 sprays applied by 300 farmers in rice, with an average of 2.8 applications per farmer, only 23% may be considered as being applied at the right time and for the intended pest (Heong et al. 1995).

We can keep the amount of pesticides to a minimum by applying knowledge of the behavioral ecology of the pests (Kiritani 2005). Farm management should not only consider the economic injury level (EIL) but an alternative EIL in which the "E" refers to "ecological or environmental" injury level, which is yet to be established (Kiritani 2005). Increasing the dosage beyond the recommended rate will not increase pest mortality or bioefficacy significantly, but it will not be cost-effective. In-creasing the frequency of application will increase the environmental load of insecticide residues at below bioeffective levels, which is the right environment for the development of pest resistance and which may also affect beneficial nontarget organisms in the rice ecosystem. Timing of application as recommended in the insecticide label is related to the pest population peak in relation to crop growth, considering the beneficial organisms. To minimize contamination of paddy water when applying pesticides for RBB or rice pest control, a community catch basin is recommended for harvesting paddy water runoff/rainwater. Water in the catch basin can be held in reserve from 2 wk to 1 mo to allow degradation before it is discharged to the waterways. Bioaccumulation of persistent biotoxins is far greater in aquatic systems than in terrestrial systems (Kiritani 2005).

Knowledge is the most powerful tool to manage and minimize the movement of the invasive pest, the RBB. Strict quarantine procedure, coupled by community effort, is needed to contain this pest. Insecticides still play a vital role when pest populations are exceedingly high, but alternative non-insecticidal management schemes are available. Public information dissemination and community effort are the most important affordable tools to understand and implement crop protection alternatives for RBB. Securing information on non-insecticidal options for RBB control, environmental risk management associated with insecticide application, movement of RBB in the country, and all the basic information on the biology and life cycle of RBB must be a community effort to be able to manage the RBB problem in the Philippines.

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Country Reports

Rice Black Bug in Bangladesh

Zahirul Islam, Mainul Haq, Mahfuj Ara Begum, and Nadira Afsana

Abstract

Bangladesh is a small South Asian country (24 00 N and 29 00 E) that enjoys a subtropical monsoon climate. Rice is intensively grown in three overlapping seasons–*boro* (dry-season rice), *aus* (summer rice), and *aman* (wet-season rice). To meet the ever increasing demand for rice, the country's production system has gone through phenomenal changes during the last half century. These included area expansion; increase in cropping intensity; and adoption of high-yielding modern varieties and associated technologies such as use of irrigation water, inorganic fertilizers, and pesticides. Currently, rice is grown in about 10.8 million ha, which is about 76% of the total cultivated area of the country. Area under boro rice increased dramatically from a few hundred thousand hectares to 4 million ha, which compensated for some relatively rice-free period of the year. As a result, rice is almost continuously grown year-round. So far, no outbreak of the rice black bug (RBB) has been encountered; it was never recorded as a pest in Bangladesh. However, the literature and recent taxonomic studies revealed that at least three species of *Scotinophara* bugs are present in Bangladesh. These are *Scotinophara coarctata* (Fabricius), Japanese black bug *Scotinophara lurida* (Burmeister), and *Scotinophara limosa* Walker. The RBB caused localized outbreaks in Malaysia and Indonesia in the 1970s and in Palawan Island in the Philippines in 1980. Until the mid-1980s, the Japanese black bug was a serious pest of rice in Japan in areas along the Japan Sea. The incidence of *Scotinophara* bugs seems to have increased in Bangladesh during the last two decades, appearing relatively higher in the aus than in other seasons, and in rice ratoons than in other habitats in the rice environment. The ecology of RBB in the context of Bangladesh agroclimatic conditions is little understood.

Key words: rice black bug, *Scotinophara*, rice, Bangladesh, pest

Bangladesh climate

Bangladesh is one of the mostly densely populated (1000 km^{-2}) countries of the world. It is a predominantly agricultural country in South Asia at 24 00 N and 29 00 E geographic coordinates (Fig. 1). The country is mostly flat alluvial delta, except in hilly regions in the east and southeast. Bangladesh enjoys a subtropical monsoon climate characterized by wide seasonal variations in rainfall, moderately warm temperature, and high humidity. Three seasons are generally recognized: a hot, humid summer from March to June; a cool, rainy monsoon season from June to October; and a cool, dry winter from October to March. In general, maximum summer temperatures range between 32 °C and 38 °C. April is the warmest month in most parts of the country. January is the coldest month, when the average temperature for most of the country is around 10 °C. Heavy rainfall is characteristic of Bangladesh. In the relatively dry western region of Rajshahi, annual rainfall is about 1600 mm, while most parts of the country receive at least 2000 mm per year. The region of Sylhet in northeastern Bangladesh receives the greatest average annual rainfall, between 3280 and 4780 mm. About 80% of rain falls during the monsoon season. Average lowest daily humidity in March ranges between 45 and 71%; the highest in July, between 84 and 92%.

Rice in Bangladesh

The small country of 144,000 km^2 currently supports about 145 million people. Rice is the most important crop and the staple food of the population. It is a rice country, with rice occupying about 10.8 million ha (75.7%) of the total cultivated area of 14.22 million ha (2002-03). Per capita annual rice intake is about 165 kg. About 70% of daily calories and 50% of protein come from rice. Rice contributes more than 60% to the agricultural gross domestic product and employs about 60% of the agricultural labor force.

Rice is grown in three overlapping season—*boro* (dry-season or winter rice), *aus* (summer rice), and *aman* (wet-season or monsoon rice). There are three ecotypes of aman: transplanted aman (traditional or modern varieties grown in 0−30 cm water depths); tidal wetland rice (mostly traditional varieties grown in the southern coastal region in fluctuating tidal waters); and broadcast aman (traditional varieties, maximum water level may reach 70−250 cm). In the past, aman was the dominant rice crop in terms of area coverage (about 60% rice area) and contribution (60%) to total production. Aus was an important crop with about 30% rice area coverage, contributing about 24% to total production. Boro was a minor crop, occupying less than 5% of the rice area.

However, during the last four decades, phenomenal changes in rice cropping systems took place. To cope with the increasing demand of the rapidly increasing population, Bangladesh made huge investments on R&D, irrigation facility development, and modern variety adoption. As a result, boro rice (mostly MVs) emerged as the most important crop, with about 40% rice area coverage, contributing about 55% to total production. Aman remained on top in terms of area coverage (51%) but second only to boro in terms of contribution to total rice production (39%). Boro rice mostly replaced aus and deepwater rice. The deepwater rice followed by the nonrice rabi (winter) cropping

system in the low-lying, flood-prone environment was mostly replaced by a boro–fallow system. In the past, December/January–March/April were mostly rice-free dry winter season, except for some boro cropping in localized low-lying depressions. At present, boro rice is grown under extensive irrigation throughout the country, bridging the gap in the dry winter months.
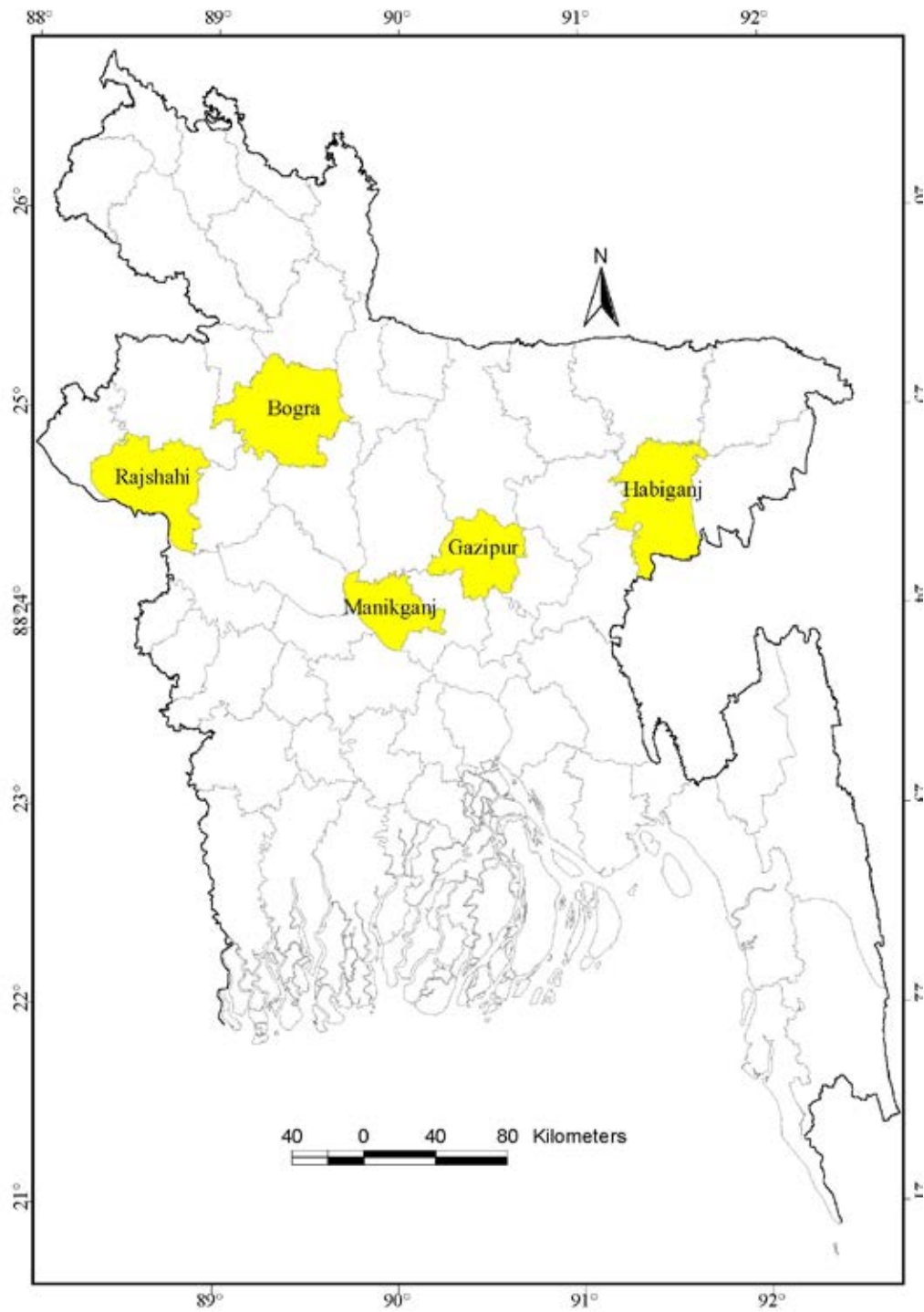
Rice black bugs in Bangladesh

Historical record

So far, *The Fauna of British India including Ceylon and Burma, Rhynchota* Vol. 1 (Heteroptera) by W.L. Distant (1902) provided the first record of the presence of *Scotinophara* bugs in Bangladesh (Table 1). Distant (1902) recorded *Scotinophara (Podops) lurida* (Burmeister) and *P. obscura* Dall. in Assam, and S. (*P.) dentate* Distant and *S.* (*P.) limosa* (Walker) in Calcutta. The geographical area of current Bangladesh occupies about two-thirds of the then Bengal and part of Assam. Calcutta was part of the then Bengal and was the capital of British India for more than a hundred years; it is now part of West Bengal, India.

From the middle of the 20th century, entomologists from time to time produced lists of rice insect pests in East Pakistan (1947-71) and Bangladesh (since 1971). Among the more important ones are those of Hazarika (1952), Alam et al (1964), Alam (1965), Alam (1977), Catling (1980), Alam et al (1981), Karim (1985), Islam et al (2003), and Islam and Catling (2004). None of these lists considered the rice black bug (RBB) as a pest of rice. However, Catling (1980), Alam et al (1981), and Islam et al (2003) reported the presence of *Scotinophara* bugs. Catling (1980) observed several unidentified pentatomids in deepwater rice before flooding, which were very rarely seen after flooding. He could not identify the species but suspected one of them may be *Scotinophara coarctata* (Fabricius). However, Alam et al (1981) reported *S. coarctata, S. lurida,* and a *Scotinophara* sp. identified from Bangladesh Rice Research Institute's (BRRI) experimental farm at Gazipur. During the monitoring of insect pests and natural enemies on boro and aus rice ratoons at the BBRI experimental farm in 1985, black bugs were frequently encountered (Anonymous 1985). Dale (1994) included Bangladesh in the list of countries where *S. coarctata* and *S. lurida* are distributed. Much later, Islam et al (2003) found *S. lurida* in irrigated rice-rice systems at Manikgonj and Bogra districts (Fig. 1).

Scotinophara bugs were frequently encountered at the experimental farm of BRRI since the mid-1980s. It was also reported from the BRRI experimental station at Rajshahi, northwest of the country. In the late 1990s, there was feedback from Rangpur District in northern Bangladesh about the high incidence of some bugs on the flowering aus rice. They suspected that these bugs may cause severe grain sterility and yield reduction. The specimens were identified as *Scotinophara* bug. A simple test was conducted by confining *Scotinophara* bugs in nylon mesh cages at high density (20 hill[-1]) separately at the flowering stage in the 1999 boro season. Another set of hills was caged without bugs and a third set of hills was kept un-caged. Caging increased grain sterility by about 9.0% but *Scotinophara* bugs did not cause grain sterility (Anonymous 1999). Recently, Barrion (2007, pers. commun.) identified *S. coarctata* and *S. limosa* (Walker) from light trap samples collected from the BRRI experimental station at Gazipur (Table 1).

Fig. 1. Map of Bangladesh showing locations where rice black bugs were recorded.

Table 1. *Scotinophara* bugs recorded in Bangladesh.

Species	Location	Reference
Scotinophara (Podops) lurida (Burmeister)	Assam BRRI experimental farm, Gazipur Manikgonj and Bogra	Distant (1902) Alam et al (1981) Islam et al (2003)
S. (P.) obscura Dall.	Assam	Distant (1902)
S. (P.) dentate Distant	Culcatta (Bengal)	Distant (1902)
S. (P). limosa (Walker)	Calcutta (Bengal) BRRI experimental farm, Gazipur	Distant (1902) Barrion (2007)[a]
S. coarctata (Fabricius)	Different areas in deepwater rice BRRI experimental farm, Gazipur BRRI experimental farm, Gazipur	Catling (1980) Alam et al (1981) Barrion (2007)[a]
Scotinophara sp.	BRRI experimental farm at Gazipur	Alam et al (1981)

[a]Personal communication with A. T. Barrion in 2007.

Literature records and recent taxonomic studies suggest that at least three *Scotinophara* species are present in Bangladesh and that two other species may also be present, but this needs confirmation.

*Scotinophara* bugs definitely present in Bangladesh:

- Rice black bug - *Scotinophara coarctata* (Fabricius); Pentatomidae: Hemiptera
- Japanese black bug - *Scotinophara lurida* (Burmeister); Pentatomidae: Hemiptera
- *Scotinophara limosa* Distant; Pentatomidae: Hemiptera

*Scotinophara* bugs that may be present in Bangladesh but needs confirmation:

- *Scotinophara obscura* Dall.; Pentatomidae: Hemiptera
- *Scotinophara dentate* (Walker); Pentatomidae: Hemiptera

Incidence of RBB at BRRI experimental tations

Incidence of insect pests and their arthropod natural enemies in rice fields and adjoining nonrice habitats was monitored throughout the year by collecting samples using sweep nets at weekly intervals. Habitats sampled other than rice fields included rice nurseries, rice ratoons, fallow fields with grasses, grassy bunds between rice fields (rice bunds), and grassy bunds between fallow fields. A total of 100 sweeps were made per habitat at each sampling occasion. Sweep net sampling data of two aus, five aman, and four boro seasons in six habitats were pooled. Results demonstrated that *Scotinophara* bugs are present in all three rice seasons of the year, but they occur in low numbers (Fig. 2). Their abundance fluctuates between rice seasons, the highest being in aus, followed by aman, and least in boro (Fig. 2). Higher seasonal abundance in the aus rice season confirmed field observations.

Abundance (no. 100 sweeps)$^{-1}$
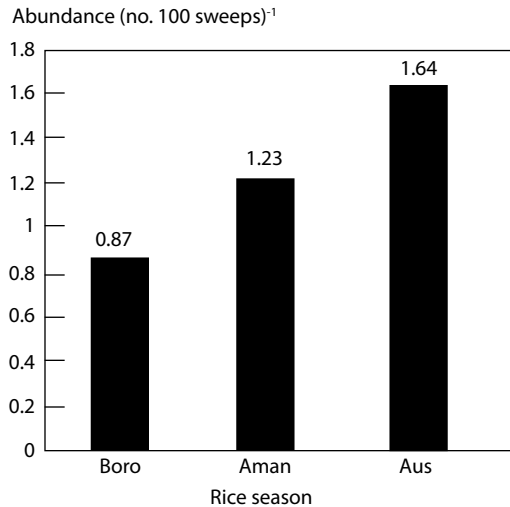
Fig. 2. Abundance of *Scotinophara* bugs in different rice seasons at the experimental farm of BRRI, Gazipur, Bangladesh (of two aus, five, and four boro seasons).

Abundance (no. 100 sweeps^{-1})
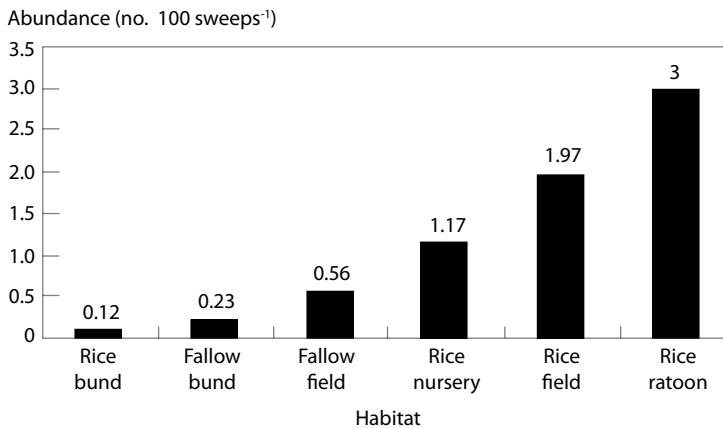
Fig. 3. Abundance of *Scotinophara* bugs in rice fields and adjacent habitats at the experimental station of BRRI, Gazipur, Bangladesh (av of two aus, five aman, and four boro seasons).

Abundance of *Scotinophara* bugs in different habitats varied, the highest number being observed on rice ratoons, followed by rice fields and rice nurseries (Fig. 3). Rice bunds, bunds between fallow fields, and fallow fields were the least preferred habitats of *Scotinophara* bugs.

The light trap data revealed that *Scotinophara* bug populations usually remain low (Fig. 4). Populations peaks in April-May, corresponding to the aus season. However, abundance may vary between locations, with more bugs noted in the northern areas (Rajshahi and Rangpur districts) of central Bangladesh (Gazipur).
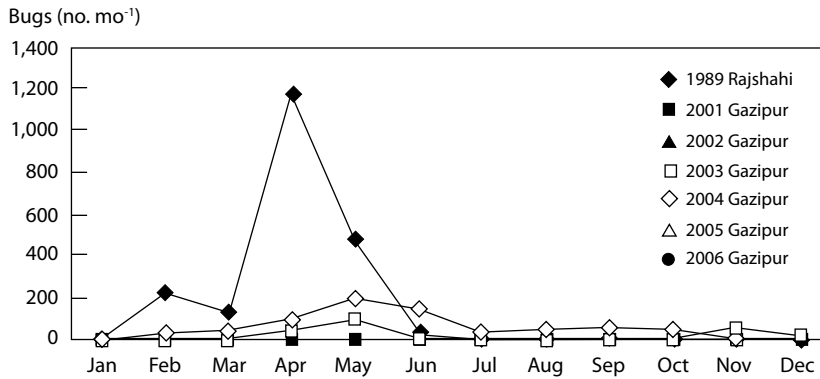
Fig. 4. *Scotinophara* bugs caught in light traps at the experimental farms of BRRI at Gazipur and Rajshahi, Bangladesh.

Current status of understanding

Although 21 species of *Scotinophara* bugs are known in Asia (Mochida et al. 1986), only two species, *S. coarctata* and *S. lurida,* are considered important pests of rice (Reissig et al. 1985). The Malaysian black bug was described from India (when Bangladesh was also part of India) but it is regarded an important pest of rice in Malaysia and Indonesia. Localized outbreaks occurred in these two countries in the late 1970s and in Palawan Island of the Philippines in the early 1980s. On the other hand, the Japanese black bug, the temperate species, is widely distributed from India to Japan. It was a serious pest of rice only in a few prefectures along the Japan Sea. Since the mid-1980s, RBB has not been a problem. So far, the detailed ecology of any of these species has not been studied. It is not clear what factors are responsible for time- and location-specific high abundance of these two species of *Scotinophara* bugs. What factors maintain RBB populations to a very low level in most places and most times? Are these regulating factors environmental (climatic and/or crop management) or biological (natural enemies) or both? So far, little is known in this regard.

Because RBB was never considered a rice pest in Bangladesh, there was no attempt to study this pest in the country. The relatively higher incidence of *Scotinophara* bugs during aus season in northern areas of Bangladesh, their presence in BRRI experimental stations throughout the year, and occasional reports in farmers' fields in different areas such as Bogra and Manikgonj districts (Islam et al 2003), in deepwater rice (Catling 1980), and in Habiganj district strongly indicate that they are probably present throughout the country. Frequent encounters, especially during the last decade or so, raise several questions: is incidence of *Scotinophara* bugs in Bangladesh increasing? If it does, what factors are responsible? Does the phenomenal shift in rice cropping (extensive boro rice cropping under irrigation) increase RBB incidence? So far, no answers are given. Pests with such potential to greatly reduce yield deserve more attention—i.e., their ecology and population dynamics must be understood. Such knowledge will be very useful if its abundance increases further.

Conclusion and recommendation

Rice black bugs were never considered as pests of rice in Bangladesh. Records show that at least three species, *S. coarctata*, *S. lurida,* and *S. limosa,* are present in the country. During the last decade or so, black bugs were more frequently encountered, an indication of an increase in incidence. As RBB possess high damage potential, a detailed knowledge of its ecology would be very useful. Ecological studies should be undertaken in the country.

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The Rice Black Bug, *Scotinophara coarctata* (Fabricius): A Potential Rice Insect Pest in Cambodia

Visarto Preap, Pol Chanty, Soeur Somany, and Sim Puthea

Abstract

The rice black bug *Scotinophara coarctata* (Fabricius) is regarded as a potential pest of rice in Cambodia. This paper presents the bugs' history, description, and pest status and describes control methods.

Key words: Cambodia, outbreak, prone area, Svay Rieng, Prey Veng, rice black bug, *Scotinophara coarctata*

Introduction

Rice accounts for 97% of the cereal consumption in Cambodia (Hossain and Pingali 1998). Depending on the rice ecosystem, farmers in Cambodia grow lowland, deepwater, or upland rice (CIAP 1995). Of the total rice-growing area of Cambodia, 94% is devoted to rainfed lowland rice, 4% to deepwater rice, and 2% upland rice (Javier 1997). Unlike most Asian countries, Cambodia still has favorable endowments of land, with two to four persons per hectare. Hossain (1995) reported that, in theory, Cambodia has considerable excess capacity to achieve food security and to meet potential rice shortage in other countries in South and Southeast Asia.

From 1953 to 1963, Cambodian farmers enjoyed comparatively good seasons (rainfall) and rice sale brought good profits. In the 1960s, rice production area in Cambodia reached 2.2 million ha, with 2.3 million t of rice grain harvested every year; an 800,000 t per year overproduction was noted in the1950s (Munson et al. 1968).

Rice production, however, has suffered greatly from political turmoil and agronomic problems since the 1970s. Official statistics showed that rice production at the time declined by 84% (Helmers and Bleakley 1996). This declining trend from 1970 to 1975 was due in part to insect pest problems.

In the pre-independence French colonial period, the identity, severity, and control of insect pests in Cambodia were poorly recorded (Nickel 1979). The major insect pests in rice and other crops were identified by Nickel and his collaborators (Nickel 1979). However, the rice black bug (RBB) *Scotinophara coarctata* species was not reported. With the Cambodia-IRRI-Australia Project (CIAP) collaboration, rice researchers in Cambodia have identified and recorded these major insect pests in rice: *Nilaparvata lugens* Stål, *Orseolia oryzae* Wood-Mason, *Scirpophaga incertulas* Walker, *Chilo suppressalis* Walker, *Sesamia inferens* Walker, *Nephotettix viresens* Motsch, and *Scotinophara coarctata* (Fabricius). Even farmers reported that rats and weeds were a major rice production constraint. The RBB [*Scotinophara coarctata* (Fabricius): Pentatomidae, Hemiptera] is regarded a potential rice pest as its population was occasionally high during field monitoring activities.

Description

The RBB is known by its local name, *SangKeoch Khmao*. The eggs of this insect pest are round and greenish/pinkish in color. The eggs are laid in groups of 15 in parallel rows on the lower leaves near the water surface, on stems, roots, and soil cracks. Egg incubation takes about 4−7 d. The nymphs are brown or yellow in color (Fig. 1). Black spots are visible on their bodies. Different nymphal instars vary in sizes. Six nymphal instars are completed in 29−35 d. The adult is white and tinged with green and pink, turning shiny brownish black to shiny black as it matures. It is 8−9 mm long (Fig. 1). The adult is very active. It prefers to feed on the rice stem than on the leaves. During the day, the adults are found at the base of the plant; at night, they move upward.

Both the adults and nymphs suck the plant sap. They prefer to infest the bases of the rice stems and drains them of sap, causing the plants to weaken. Heavy infestation causes stunted growth, formation of whitehead, half-filled or empty grains, browning of leaves (bug burn), and death.

Fig. 1. Eggs and adults of RBB in a rice crop in Prey Veng Province (Photos by Pol Chanty 2007).

Fig. 2. Rice black bug distribution and outbreak-prone areas in Cambodia.

Pest status

The RBB occasionally occurs in rice fields. They are considered a minor pest of rice in Cambodia. However, outbreaks have been increasingly observed, particularly in fields where rice is planted under high fertilization conditions with additional irrigation.

The RBB injures the rice crop at the early stages and from tillering to booting stages. Both nymphs and adults feed at the base of the stems where they remove plant sap. The damage caused by the bugs becomes more serious as a result of intensification of rice production. Severe infestations of this pest in Cambodia were reported in some areas. It occurred in the provinces of Svay Rieng, Kandal, and Prey Veng in 1996, 1999, and 2003–07 (Anonymous 2007). The infestation of this insect pest in the provinces around Tolesap Lake, where most farmers grow one crop of rice per year (wet season, Fig. 2) was less frequent and less severe. However, in the southern provinces of Svay Rieng and Prey Veng, RBB outbreak has occurred every wet season since 1996 up to the early wet season of 2007. Outbreaks of RBB in Cambodia, however, are very localized and on a small scale, representing a serious problem for subsistence rice farmers in Cambodia. Farmers who lose their entire crop must borrow money to replant or buy food, throwing them into a year of debt.

Outbreaks of RBB in Cambodia from 1996 to 2006 were recorded in both traditional and high-yielding cultivars. The 1997 outbreak was recorded in a small spot at Kap Srau station and in farmers' fields around the station; an area of about 10 ha. In September 1999, adults of RBB were observed in high density (20-60 per hill) on a traditional rice cultivar during tillering stage at Kap Srau in Phnom Penh. However, crop loss due to this insect was not studied. In 1999, outbreaks of RBB were noted

Fig. 3. Chemical control to combat the invasion of rice black bugs in Prey Veng Province in the 2007 early wet season. The rice crop at tillering stage with heavy RBB infestation was being sprayed by a provincial intervention team (Photo: Pin Channa 2007).

in rainfed lowland rice field ecosystems planted with traditional rice cultivars and advanced released varieties (CAR4 and CAR11). In late September of the same year, when the rice crop reached tillering stage, 8 ha in Noreatean and Cheu Teal of Svay Rieng Province (Fig. 3) were damaged by bug burn. From 2000 to 2007, population outbreaks of RBB were recorded in small spots in some fields in Prey Veng and Svay Rieng, whereas in other areas, incidence was low.

Control methods

A long-term strategy for RBB management in Cambodian rice ecosystem will involve crop management, breeding of short-duration cultivars, natural enemy management through proper use of insecticides, and improved forecasting systems to decide on the best time for intervention.

Visiting the field weekly would yield information for timely control of RBB. For example, local farmers in Prey Veng Province called for intervention from the government (insecticide application, Fig. 3) as they observed a high number of RBB in their rice crop (60 adults per hill). However, chemical application should be carefully assessed in terms of environmental impact as there are many natural enemies existing in the rice fields in Cambodia.

Using cultural practices such as weeding to minimize the number of alternative hosts of RBB and growing shorter duration cultivars to cut down on the population buildup throughout the year are recommended.

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Occurrence and Control of Rice Black Bug in China

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Abstract

The rice black bug (RBB) *Scotinophara lurida* (Burmeister) is a common pest in rice fields. This paper presents the history, distribution, and impact of RBB. Research on RBB in China is reviewed, including the bug's biological and ecological characteristics. Finally, integrated management strategies of RBB are discussed.

Key words: *Scotinophara lurida* (Burmeister), occurrence, biological characteristics, ecological characteristics, management

Introduction

The rice black bug (RBB) *Scotinophara lurida* (Burmeister) belongs to Pentatomidae (order: Hemiptera) (Fig. 1).

The first infestation occurred in Jiangdu and Baoshan counties of Jiangxi Province in 1929. This was followed by a major outbreak in Fanyu County, Guangdong Province, in 1936. It was a dominant species—dating back from the time China was founded to the birth of the republic—invading especially rice fields along the river banks. After the 1960s, RBB damage has obviously been

Fig. 1. *Scotinophara lurida* (Burmeister).

reduced by using organochlorine pesticides, shoveling grass in winter and spring, and repairing field bunds well. But, in the 1980s, when organochlorine pesticides were banned and hybrid rice became popular, RBB populations in some rice fields picked up. The "deadheart" that RBB causes in paddy

seedling stage has exceeded the one caused by stem borers in the field. Now it appears to be continuously spreading. In recent years, as with changes in the ecological environment of the farmland, crop layout, and kind of pesticides used, RBB was provided favorable conditions for growth and multiplication. RBB occurrences increase gradually, and damage becomes serious day by day.

The RBBs are distributed in East Asia, Southeast Asia, India, Sri Lanka, and other places (see map). In our country, the north boundary does not extend beyond Huaihe River, Jiangdu of Jiangsu Province, Hefei of Anhui Province, Zhushan of Hubei Province, and Xinyang of Henan Province; south to Hainan Province; west to Sichuan, Yunnan, and Guizhou provinces; and east to each coastal provinces and Taiwan Province. The RBBs occur more frequently on rice districts in each province, which are located south of the Yangtze River.

The RBB is mainly harmful to paddy. Its host may also include wheat and corn, millet, sugarcane, legume, potato, orange, as well as various gramineous weeds. Adults and nymphs take the sap of stem, stalk, and fringes of paddy grain by their piercing-sucking mouthparts. The rice plants have yellow spots; they wither after suffering from injury at the seedling and tillering stages. Severely damaged paddy is stunted; later it withers and dies (Fig. 2). TheRBB damages paddy from booting

Map of China showing sites where RBB outbreaks were observed.

Fig. 2. Rice seedlings damaged by RBB.

to maturity, resulting in white fringes of grain and causing 3-5% losses in output. Rice yield can be decreased by 20-30% in some regions; the most serious rice yield loss may be more than 50%.

The RBB adults and nymphs avoid sunlight, hiding at the bottom of the plant during the day and feeding on top of the crop in the evening. Adult bugs that live through winter begin copulating and laying eggs around 10 d when they settle in a rice field. The eggs are lodged in leaf sheaths located near the water surface. Each female can lay 30−40 eggs. The 1st-instar nymphs feed on the base of rice plant near the egg piece, then begin to scatter after two instars, and transfer to the fringes after three instars.

Biology

Life history

The RBB are attracted to light, but both adults and nymphs avoid sunshine. So they always conceal themselves in the lower part of the rice plant while fetching food in the daytime; they feed in the upper part during evening, early morning, or on overcast days. They live in aggregation and will

Table 1. The life cycle of *Scotinophara lurida* (Burmeister), Deyang, Sichuan, 2002–03.[a]

Month	1	~	3	4			5			6			7			8			9			10			11	~	12
	F	M	L	F	M	L	F	M	L	F	M	L	F	M	L	F	M	L	F	M	L	F	M	L	F	M	L
Stages	(+)	(+)	(+)	(+)	+	+	+	+	+	+	+	+	+	+													
										0	0	0	0	0	0	0	0	0	0								
											-	-	-	-	-	-	-	-	-	-						
																+	+	+	+	+	+	+	+	+	(+)	(+)	(+)

[a] +adult; ( ) overwintering stage; 0 egg; - nymph. F: the first 10 d of a month; M: the middle 10 d of a month; L: the last 10 d of a month.

feign death or escape when frightened or attacked. With underdeveloped wings, they have no strong flying ability; spread is mainly through flowing water, cattle manure, and transport of rice plants and grains. Being sluggish, the bugs reach only a limited area of the field. There is usually an obviously damaged center; generally the border is more seriously damaged than the middle of the field.

Overwintering adults usually begin to copulate 10 d after they move into the rice fields. Oviposition takes place 7 d after copulation. Adults copulate usually at 0600–0800 and 1600–1900. The period of ovipositing is 30–40 d. Female and male copulate several times and oviposit several times in their lives. The average number of eggs laid by one female is about 30–40. The female deposits its eggs mostly on the leaf sheath of rice plants, 3–10 cm above the water surface. Occasionally the eggs are deposited on the leaves. Eggs form an agglomerate. Every egg pod has two to four lines, mostly two lines (Fig. 3). The nymph stage is divided into five. Newly hatched nymphs are dark brown

Fig. 3. RBB egg pods.

and oval-shaped. They usually assemble around eggshells and climb slowly. The 2nd-instar nymphs disperse and fetch food in the lower part of rice plants. Like the adults, the 3rd- and 4th-instar nymphs lurk in the lower part of rice plants in the daytime and climb to the upper part during evening, early morning or when there is overcast sky.

In Sichuan Province where one generation of RBB occurs annually (Table 1), overwintering adults begin to move about in the weed in middle April and move into paddy fields in succession in late April. The adults begin to oviposit in early June, the ovipositional peak period being from middle to late June. Eggs reach the hatching peak in late June. The eclosion peak period of the adults in middle August is simultaneous with rice grain filling. The eclosion adults assembling on the fringe eat immature grain. After staying in paddy fields for about 20 d, when the rice crop matures in early and middle September, the adults move to their overwintering habitat.

In Nanchang City of Jiangxi Province where two generations of RBB occur annually, overwintering adults move into paddy fields in middle and late May and begin to oviposit from early June to middle of July. The nymphs of the 1st generation hatch from middle of June to middle of July. The adult emergence time is middle of July, and the adults oviposit from early August to mid-September. The nymphs of the 2nd generation hatch from early August to middle of September. The eclosion time is from late August to late September, and the adults begin to overwinter in middle and late October. The egg stage is about 4–5 d in the 1st generation and 4–6 d in the 2nd generation. The nymph stage is about 28–35 d in the 1st generation and about 35–48 d in the 2nd generation. An adult's life span is about 21–29 d in the 1st generation and 8–9 mo in the 2nd generation.

In Xinhui County of Guangdong Province where 2–3 generations of RBB occur annually, overwintering adults move into paddy fields in mid-April after the reviving stage of early rice and begin to oviposit in late April. Nymphs and adults occur one after the other, from late May to early July. When early rice ripens, adults of the 1st generation move to overwintering habitats (seedling fields of late rice, cane fields, and roots of weeds nearby). When late rice revives and tillers in the middle of August, adults return to paddy fields and copulate, lay eggs, and produce the 2nd generation. They damage late rice until it ripens in late October, and then leave the paddy fields to overwinter.

Number of generations per year

It can complete one generation per year in Guizhou, Sichuan, Chongqing, and Jiangzhe provinces; two generations in Jiangxi and Hunan; and two to three generations in Guangdong and Guangxi.

Pest status

The RBB belongs to order Hemiptera and family Pentatomidae. Its scientific name is *Scotinophara lurida* (Burmeister).

Yield loss

Adults and nymphs pierce-suck the sap of rice plants, especially the fringe. At tillering stage, RBB damages the leaves, stem, stalks, and fringes of rice plants, causing purple brown spots to appear.

When the population density of RBB is high, the leaves are scorched, plants perish, subsidiary tillers become manifold, and deadheart occurs. At booting, RBB damages the leaves, stem, and stalks, and the plants turn yellow. After heading, RBB quickly moves to suck the fringe and grain of plants, causing wrinkled empty capsules, deadheart, or whitehead. RBB harms the fringe most seriously, with the reduction of compensatory capacity after the growth period of paddy.

RBB mainly occurs in paddy fields with weeds, usually damaging within 1–3 m border of fields. The rice yield can be decreased by as much as 3–5%, 20–30%, or more than 50% in some regions. In the Qingbaijiang region of Sichuan Province, RBB first occurred in Jingfeng village in 1986. This covered only two fields. After that, the damaged area increased year after year. RBB invaded more than 4.0 hm^2 (1 hm^2 = 1 ha = 15 mµ) and were distributed in two villages in 1987; 6.7 hm^2 and four villages in 1988; 333.3 hm^2 and nine villages in 1989; and 666.7 hm^2 and 13 villages (especially Mimou, Huayan, Xiushui, and Yaodu near Jingfeng) in 1990. Average injury is 1.38 butt pests per clump; the clump rate of pest inhabitancy is 66.7% and yield loss is 10–30%. Serious injury is 2.08 pests, clump rate of pest inhabitancy of 72.9%, and yield loss of 50–60%. An investigation by the Mianzhu Agricultural Bureau of Deyang City showed that, in 2001, the area of damaged rice field in Yuquan town reached 3.3 hm^2. In 2002, the damaged area increased to 6,666.7 hm^2. Along with the other small damaged regions, the total area affected was 7,466.7 hm^2. In 2003, there was heavy RBB infestation in Deyang City, reaching 43,000 hm^2, which covered 35.24% of the rice-growing area. In 2004, the damaged area went up to 47,000 hm^2 covering 38.32% of the area.

In Jiangsu Province, RBB incidence was noted in the Xufu and Zhenzhou areas by the late 1980s, which covered only 7 hm^2. Then, it gradually spread to Qingshan, Xincheng, Maji, and other counties, with fields near the hills being the most seriously affected. Up until 1996, RBB invaded more than 1 myriad hm^2 and was distributed in more than 10 villages, taking about 60% of the whole rice area. There were 50–100 pests for every hundred holes on an average field, 5000 in some seriously infested areas, resulting in 5–20%, even 50% yield loss. During heavy infestation, there would be complete yield loss.

In 1983, the percent deadheart of some early rice varieties such as Zayou and Guicha was 5-7% in Dalongtong area, Daishan County, Guangdong Province. The average number of pests per mµ was 12,000–18,000. In the same year, the pests per mu were as many as 25,000–30,000 in late rice fields where Erbaiai was planted late in Heshui Farm. In 1985, the average deadheart rate for 13 paddy fields of hybrid rice in Pingzhou area, Nanhai City, was 3.9%, with the highest reaching 9.2%.

The Chuzhou Agricultural Bureau of Anhui Province reported that RBB infestation area in Langya in 1998, 1989, and 1990 was 0.3 myriad mu, 3 myriad mu, and 5 myriad mu, respectively. In 1991, RBB invaded 6–7 myriad mu, distributed in 12 villages.

Diapause

RBB overwinters as adults who pack in weeds, shatter, bark, moss, gaps of block near paddy fields, or rice stubble (Fig. 4). Except for some adults, there are a few nymphs that overwinter in Guangzhou Province.

Fig. 4. Overwintering adults.

RBB oversummers in July and August every year. Their oversummering habitat is the same as their overwintering habitat. Overwintering and oversummering adults usually pack in habitats where many RBB of the last generation or the previous year remain.

Food plants

RBB is mainly harmful to paddy. Its host also includes wheat, corn, millet, sugarcane, legume, okra, as well as various gramineous weeds. Sporadically, RBB harms potato and orange.

Natural enemies

RBB's main natural enemy is *Telenomus gifuensis* Ashmead (Hymenoptera: Scelionidae) (Fig. 5). More than 30% of the eggs of RBB were parasitized. The natural enemies play an important role in controlling the population of RBB.

Beauveria bassiana and *Paecilomyces lilacinus* (Thom.) Samson were the major pathogens. There are some natural predators—some species of Reduviidae, spiders, frogs, and birds. For example, dead bodies of RBB were found in the stomach of *Sturnus contra*, so it may be a kind of beneficial bird, which preys on RBB.

Ecology

Seasonal occurrence and abundance

Seedling

RBB usually occurs in thick and green paddy fields, which are seeded early or are near river banks and hills. Years with little rainfall are favorable to RBB.

Fig. 5. *Telenomus gifuensis* Ashmead.

RBB usually attacks the mid-season paddy fields, which are seeded early. But, with the filling stage 7-10 d later than mid-season rice, the barley (or wheat)–rice system that is seeded late is more easily attacked. It is the reason that, after 10 Aug, nymphs come into their 3rd stage and would more easily damage barley (or wheat)–rice system at heading and flowering stages, resulting in more wrinkled empty capsules.

Tillering

Farmers accept the zero-tillage system because it minimizes labor problems and increases yield. Zero-tillage areas are 6.05 myriad hm^2, covering 44.73% of the whole cultivated area. The trend is increasing, but some farming practices are ignored. For example, no one eradicates weeds near fields, channels, rivers, wastelands, and the like such that tufty weeds provide ample overwintering sites for RBB.

An investigation in April 2003 showed that the average number of overwintering RBB packing in ridges of field and weeds per m^2 was 19.8, while the number of pests in ditches, weeds around ridges of fields, and gaps of block was 89.4 per m^2. Death rate was 12%. Another study made in March 2004 showed that the average number of overwintering RBB in ridges of field and weeds per m^2 was 36, larger than what was observed the previous year. The average number of RBB packing in ditches, weeds around ridges of fields, and gaps of block was 119.2 per m^2. The weighted average number was 52.2 per m^2, increasing by as many as 6.3. The death rate was 4.77%, decreasing by 7.23%.

Booting to flowering

The RBB peak occurs during heading and flowering of rice, giving the most serious injury at these stages.

Maturity

The occurrence of old instars peaks at full heading and at grain-filling stage. This time is critical in RBB control.

Nonrice habitats or surrounding areas

Fields with weeds around or those near sugar cane fields are usually damaged by RBB.

Flight activity and outbreak pattern

Adults fly slowly. They usually move and attack lamps at night. RBB, which is a serious locally occurring pest, may not become common in the future because of its biological characters (a few generations) and ecological limits.

Monitoring and field population assessment techniques

The adult and nymph population spatial pattern is characterized by aggregate distribution in the fields. The parallel sampling method is thought to be suitable for RBB.

Considering the living habits and characteristics of RBB, the following measures may be taken:

Excavate the soil after each overwintering period. We may forecast RBB occurrence after comparing historical data obtained from soil samples.

Do the forecast according to RBB's light-seeking behavior. It is warranted that we make a forecast of amount and time when those under the lamps are at their peak. Investigate during the egg stage. Plant diseases and insect pest invasion occur mainly in middle and late July. The number of eggs can be observed along with the monitoring of *Cnaphalocrocis medinalis* Guenée, *Borbo cinnara* Wallace, and *Thanatephorus cucumeris* (Prank Donk).

Investigate pest density in the field and check RBB development by looking at planthopper populations. We can get exact data by examining planthoppers' white tray at the low-instar nymph stage. But we also need to visually survey at the high-instar nymph stage because the RBB habitat is rather high and not all of them fall into the tray.

Yield loss assessment techniques

In pot experiments, different amounts of RBB are transferred to 100 bundles of rice. Yields and yield loss per bundle are calculated.

Management

Biological control

The RBB's natural enemy is a parasitic bee (*Telenomus gifuensis*). Its parasitical rate may be higher than 30%, which may have a great effect on RBB occurrence. It is reported that the bee parasitized the first-generation eggs, with parasitism about 68.5%. In a study in Guangdong by Zhu Yiquan, the parasitic rate of the second-generation eggs ranged from 72.9–81.8% in 1991 to 68.3–75.7% in 1992. *Beauveria bassiana* and *Paecilomyces lilacinus* can, to some extent, control RBB. There are other predatory natural enemies that can prey on the adults and nymphs, including some species of Reduviidae, spiders, frogs, and birds.

Cultural control

Prevention of RBB incidence should be combined with agricultural measures. Weeds must be removed from fields and ditches, the environment where RBB overwinters should be made unfavorable, in the process eliminating the pest source. After harvest, the RBB moves into the weeds to perch; the overwintering pest also stays on the weeds first before it moves into the rice field. After harvest, elimination of weeds can destroy the base on which the RBB thrives.

Every morning and evening and during cloudy and rainy days, farmers can catch these pests and collect eggs from the sides and ridges of the field.

To avoid an RBB outbreak, sowing time must be scheduled properly and plants with suitable maturity be chosen.

Before booting, ducks may be used to control RBB.

Varietal control

To cut down on RBB infestation, avoid growing paddy, sugarcane, and beans in the same area at the same time.

Chemical control

At the low-instar nymph stage, pesticides may be used to control RBB. Administer 10 WP diluted 1500s, trichlorfon 90% crystalloid diluted 600s to 800s, DDVP 80 EC diluted 1500s to 2000s or decis 25 EC diluted 2000s; 50−60L is used per 667 m^2.

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The Rice Black Bug in China

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Abstract

This paper presents the distribution, biological and ecological characteristics, occurrence and control of rice black bug in China. In recent years, with the development of resistance to pesticides and changes in farming systems, the infestation of this bug and the resultant damage tended to be more severe in China. In some areas, it has even become a major pest. Under these circumstances, through strict monitoring and implementation of integrated pest management (with agricultural, biological, and chemical control as major components), the pest was fairly well controlled.

Key words: rice, black bug, occurrence, control

Introduction

Rice black bug (RBB), *Scotinophara lurida* (Burmeister), commonly known as small stinky bug or black shell bug, belongs to family Pentatomidae, order Hemiptera. This insect is distributed from the northern boundaries of southern Hebei and Hainan provinces in the south to the western provinces of Sichuan, Yunnan, and Guizhou to the eastern coastal provinces and Taiwan. The insects can be occasionally found in Shandong and in northern Jiangsu, but they are commonly seen in provinces south of the Yangtze River.

Biology

Morphological characteristics

Adult. Oval shaped, body length of male adults 4.5−8.5 mm, that of female adults 9−9.5 mm. Adults totally black or dark gray, harsh shell full of small black knobs. Antennae five segments. Both lateral

angles of pronotum project horizontally like short spines. Scutellum tongue-shaped, almost reaching the end of abdomen with a light-spot on both sides (Fig. 1).

Egg. Cup-shaped, reticular shell densely covered by puncta and white powder, has a round cover surrounded by many small protuberances. Light-green at first, red brown later on, and brown before hatching (Fig. 2).

Nymph. Five instars, the newly hatched nymphs cluster in the vicinity of egg mass, 1st instar body length 1.3 mm, nearly circular, head and thorax brown, compound eyes reddish, abdomen tan to reddish brown with reddish brown areas on the back; 2nd instar body length about 2 mm, head and thorax mostly yellow brown to dark brown, dark brown areas on the back of abdomen sparsely covered with small red spots, suture red with white stripes, compound eyes red black; 3rd instar body length 3.3 mm, head and thorax mostly light brown or brown, abdomen light brown sparsely covered by small reddish-brown spots; 4th instar body length 5 mm, body color similar to that of 3rd instar, the gland area on the back light yellow brown, buds of forewings identifiable; 5th instar body length 7.5–9 mm and width 5 mm, grayish brown, buds of both fore and posterior wings clearly identifiable. The fourth to sixth pleomera each has a pair of scent glands, gland holes black brown (Fig. 2).

Life history

In Jiangsu and Zhejiang where there is one generation a year, overwintering adults migrate to paddy fields from May to July, oviposition peaks in mid- and late July and the peak period of hatching is from late July to early August. Most nymphs emerge in early September and then start to overwinter 1−2 wk later. In areas with two generations a year (e.g., Nanchang in Jiangxi Province), overwintering adults migrate to paddy fields in mid- and late May and oviposit from early June to mid-July. Nymphs of the first generation are hatched from mid-June to mid-July; they start to emerge in mid-July, and oviposit from early August to mid-September. Nymphs of the second generation are hatched from

early August to late September and start to overwinter in mid- and late October. In Xinhui County, Guangdong Province, overwintering adults start to migrate to paddy fields in mid-April when paddy stands turn green and begin laying eggs in late April; large numbers of nymphs and adults occur from late May to early July; in early July, when early rice ripens, the adults of the first generation move to fields of late rice, sugar cane, and nearby areas covered with weeds. In mid-August, when late rice starts to tiller, the adults move back to paddy fields, mate, oviposit, and reproduce the second generation, which then damages late rice. They then move to overwintering sites after late rice ripens in late October.

Pest status

The RBB is the dominant bug species in China that historically has caused severe damage in the country. After the 1960s, owing to the wide use of organochlorines and the regular cleaning of fields and ridges during spring and winter, the RBB population in paddy fields declined significantly and it became a minor insect pest. At the turn of the 1980s, the use of organochlorines was banned and field cleaning was, to some extent, neglected. The population of RBB started to rise. In recent years, the ban on highly toxic pesticides and changes in cropping system resulted in more severe RBB infestations. Currently, in some areas in Guangdong and Sichuan, RBB has become a major pest, posing some threat to rice production.

Yield loss

Slight damage to rice led to a 3−5% loss; the loss could amount to 20−30% in some plots with heavy RBB infestation and up to 50% or even more in plots with severe infestation.

Diapause

Research on the diapause mechanism of RBB is scarce. Most studies focus on overwintering and oversummering sites and times. RBB overwinters at the adult stage, rarely as nymphs of elder instars. Starting time depends on the locality and climate conditions. In Sichuan, RBB begins to move to overwintering sites in early and mid-September, whereas it starts in late November in Guangdong. Overwintering sites include roots of weeds, places under rocks, soil sutures, rice stubbles, sugarcane fields, citrus orchards, and tree bark joints. From April to May the following year, the overwintering adults live in the weeds and then migrate to paddy fields to feed and oviposit.

Some studies showed that the RBB has an obvious oversummering period in Guangdong Province. RBB oversummers in the vicinity of paddy fields from July to August every year, the oversummering sites are similar to overwintering places. Most RBBs prefer shady, cool, and moist areas covered by weeds; some also hide in leaf sheaths of ratoon rice or sugar cane. In the same period, some RBB nymphs, which have not emerged, continue to feed and develop on ratoon rice. The oversummering adults migrate to paddy fields in late August. When overwintering or oversummering, more RBBs inhabit the surrounding areas of fields where severe infestation occurred in the

preceding year or generation. RBB has a clustering habit, usually groups of tens or even more are found in suitable sites.

Food plants

In addition to rice, RBB also feeds on wheat, maize, sugar cane, beans, millet, water bamboo, potato, citrus, and various gramineous weeds.

Natural enemies

The parasitic natural enemies of RBB are mainly the *Telenomus* sp, which can parasitize more than 30% of the RBBs and have a significant impact on their population. Some studies identify wolf spiders and Staphylinidae as predators of RBB, though other studies report that they do not prey on RBB at all.

Ecology

Seasonal occurrence and abundance

<u>Rice fields</u>

Seedling stage. About 10 d after early or late rice transplanting, a large number of adults begin moving into the fields. Ten days later, they start ovipositing.

Tillering stage. There are two ovipositing peaks at early rice tillering stage with an interval of around 10 d. Since the migration of adult RBBs into fields of late rice lingers over a period, there are several RBB ovipositing peaks in late rice.

Heading stage. The heading period of both early and late rice coincides with the peak emergence period of RBBs. Nymphs and adults damage rice ears at the same time; the heading period is thus regarded as crucial in RBB control.

Harvesting. There are still quite a number off adult RBBs in early rice fields during the harvest period, but they are seldom found in late-rice fields when rice is harvested.

Postharvest. Rice stubbles in paddy fields are among the overwintering sites of RBBs; adults could be detected in stubbles in winter and spring.

Nonrice habitats or surrounding areas

Rice is the main host as other crops are seldom infested. Habitats outside the paddy fields mainly include overwintering or oversummering sites such as the roots of weeds, rice stubbles, places under rocks, soil sutures, sugarcane fields, citrus orchards, or tree bark joints.

Flight activity and outbreak pattern

Adults are capable of flying, but the ability is weak. Except for instances when they are attracted by light traps in the evening and for migration, flight seldom takes places in the fields. Adults have

positive phototaxis in the evening and this is stronger with adults just migrating into paddy fields than with newly emerged ones.

Generally, fields with earlier transplanted rice crop, those with more vigorous plants, and terraces in hilly or mountainous areas are more severely infested. Plots with ridges overgrown with weeds or with sugarcane and some other crops in proximity also succumb to heavy infestation. Both adults and nymphs are afraid of the sunshine and they hide at the base of the rice plant during the day. In the evening or in cloudy days, they move to the upper parts, feeding on and damaging the rice plants. Adults and nymphs like moisture; they hide at the center of the rice stand base or bury themselves under a thin soil layer when humidity is low. Adults prefer more tender tissues; plots with earlier developing and vigorous plants attract more adults. Adults are sluggish and only fly short distances in the fields. Usually, more insects are observed in the peripheral areas than at the center of the plots, hence the border areas succumb to more severe damage.

Monitoring and field population assessment techniques

Excavation survey. During overwintering period, the number of RBBs found per unit volume of soil can be documented yearly and forecast can be made by comparison between years.

Light trapping. Apparent peak migration can be detected with light trapping. The timing and size of migration are useful information to predict time of occurrence and degree of infestation.

Egg investigation. Inasmuch as several rice pests occur in mid- and late July, an egg investigation can be conducted in combination with a field survey of longitudinal leaf moth, *Parnara guttata*, and rice sheath blight.

Investigation of nymph density and developmental stage. It can be conducted in combination with a survey of planthoppers; the porcelain plates used for the planthopper survey can be used to collect on low-instar RBBs as well. Since high-instar nymphs and adults usually inhabit the higher plant parts, only a few fall on the porcelain plates. Visual detection is thus more preferable in this case.

Management

Cultural control

To kill the overwintering adults, weeds surrounding the paddy fields or those along irrigation ditches are removed, nearby fields such as sugarcane plots and citrus orchards are cleaned, and the debris destroyed.

In July, the peak ovipositing period of RBB, water level in paddy fields is first lowered to induce the RBBs to lay eggs on the lower parts of the rice stand, water level is then increased to 10−15 cm once every 5 d, and that water level is maintained for 24 h. The process is repeated four to five times. A large number of egg masses can be killed this way.

Sowing at the proper time or selecting varieties with a suitable growing period will prevent the rice heading period coinciding with the peak period of RBB occurrence.

Adults are caught or egg masses are picked up on the field fringes or ridges in the morning, evening, or during cloudy days.

Biological control

If RBB damage is observed before heading, ducks can be released to feed on RBBs. *Telenomus* sp. can also be released for biological control.

Chemical control

As the transplanted rice plants turn green and if a large number of RBBs can be found in paddy fields, chemical control is called for. Pesticide application should be scheduled in the morning or evening of sunny days or on cloudy days. Usually, pesticides could be applied to areas within 3 m from the ridges. However, if infestation is severe, these should be applied to the whole plots. The following may be used: 1500x dilution of 10% imidacloprid WP and 600-800x dilution of 90% trichlorfon crystals. 1500x dilution of 2.5% lambda-cyhalothrin EC, 2000x dilution of 20% fenvalerate EC, or 800x dilution of 90% trichlorfon crystal can be used against low-instar nymphs. The application is repeated 15 d later.

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Notes

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Rice black bug *Scotinophara lurida* (Burmeister) in China

Youping Yin and Zhongkang Wang

Abstract

Scotinophara lurida (Burmeister) is widely distributed in rice production areas of China. The damage caused by the bugs became serious in recent years, especially in southern China where farmers had 20–50% yield loss in some areas. This paper describes the biology, ecology, damage, and yield loss caused by rice black bugs, their natural enemies, and effective control strategies in mainland China.

Key words: *Scotinophara lurida*, biological habit, life cycle, natural enemies, management and control, utilities

Introduction

Scotinophara lurida (Burmeister) (Hemiptera: Pentatomidae) are familiar rice pests in mainland China. In the past, they had not caused very serious damage to rice production so literature on this insect in China is scanty. But, in recent years, due to changes in cultivation technology, environment, and ecology and the wide application of chemical pesticides, rice black bug (RBB) outbreaks have been reported and this bug has become one of the most important rice pests in some areas or in some years.

The many control measures used by farmers in China included biological, cultural, and chemical control strategies. The RBB also has certain medicinal value as traditional Chinese healers use it to treat epilepsy, measles, scrofula, and other diseases.

Biology

Life cycle

Rice black bug undergoes four forms: egg, nymph, pupa, and adult. They have various generations per year in different areas because of differences in climate and the environment. In Guizhou, Sichuan, Zhejiang, Jiangsu, and Chongqing provinces and municipalities, the insects have one generation per year. There are two generations in Jiangxi and Hunan provinces, and three generations in Guangdong Province and Guangxi Municipality. The adults and older nymphs are gregarious, overwintering under deciduous, apertures, rhizosphere of grasses near rice fields or in rice stubbles. In Deyang City of Sichuan Province, where the bugs have one generation in a year, the overwintering adults begin their activity in the grasses in early March. The bugs migrate to rice seedbeds from late April to early May and move to rice fields after seedlings are transplanted. Adults begin to oviposit in early June, and the eggs hatch by the end of June. The adult emergence peak is in the middle of August during the rice grain-filling period. The RBB adults feed on ears of rice and suck the immature grain. After about 20 d, as the rice crop reaches maturity in September, the adults leave the rice fields to overwinter.

In Xinhui County, Guangdong Province, adults after overwintering migrate to rice fields and produce the first generation. The first-generation adults migrate to rice seedbeds, sugarcane fields, corn fields, banana trees, or weeds on the ground after the first crop harvest. They migrate back to the rice paddy and disserve the rice, producing the second generation. In the later part of the second-crop growth, adults of the second generation move out of the rice paddy to go to their overwintering place. They will be the headstream of next year's batch. (See figure for a sample life cycle.)
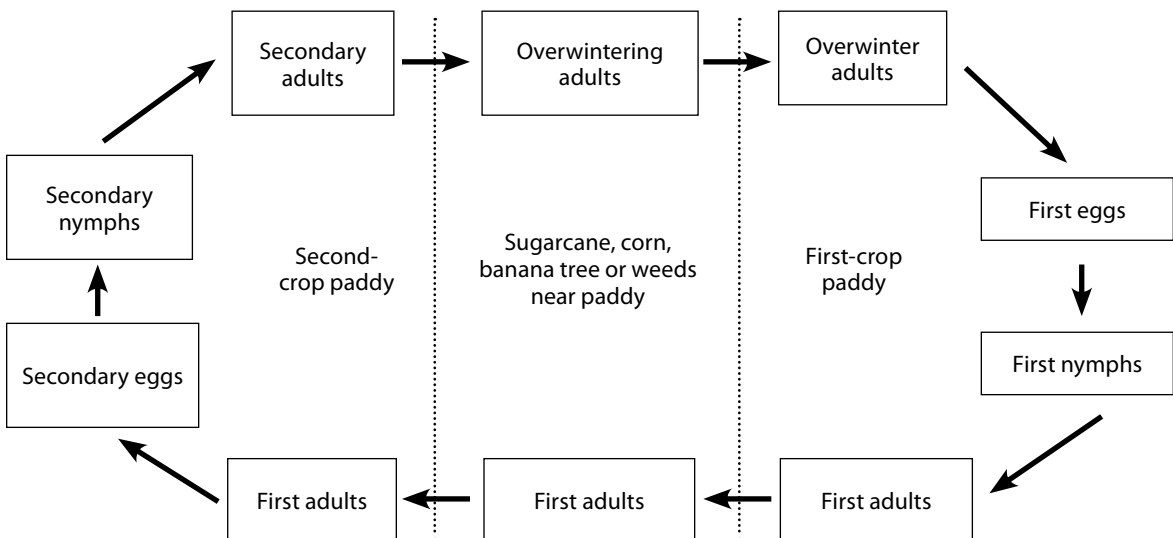
Life cycle of the rice black bug in Xinhui County, Guangdong Province.

Biology

Rice black bugs mainly harm wheat, millet, corn, sugarcane, beans, potato, and citrus. The adult bugs are attracted by light at night, but they do not like strong sunshine. They generally hide, sucking under the base part of the rice plants during the day, but feed on top of the rice plants when the sky is cloudy and during evening and early morning. The adults exhibit swarming behavior. When they are afraid or are struck, they will drop down and die or escape. Adult bugs can fly but they do not travel long distances. This is why the bugs usually cause serious damage near the outermost part of the field. In Deyang County, Sichuan Province, adults emerge from April to May. They migrate to paddy fields and mate in the middle of May. Most mating occurs in the evening or morning, and the bugs (both males and females) can mate a few times. Research showed that all eggs will be impregnated through one-time mating (Zhu 1995). The females will oviposit 7 d after mating, normally in early June. The oviposition period will last for about 30−40 d, from early June to July, but the peak is in the middle or end of June. A female lays 5−8 egg masses, about 60−70 eggs. Adults live up to 40−50 d, and will die 1−2 d after final oviposition (Liao 2004).

Females normally lay their eggs on the rice stem near the surface of the water and a few are laid on the back of leaves. Each egg mass usually has 7−19 eggs, arranged in two lines. Eggs will hatch in 6 d at 26−28 ºC.

Newly hatched larvae are gregarious and harm the area around the egg masses; they will spread out after the first molting. The nymphs generally suck the sap of the rice plant before the 3rd instar. After that, nymphs will continue sucking at the bottom part during daytime and move to the top of the plant at night as adults. During the 40-d development, nymphs will molt four times and have five instars.

Pest status and yield loss

Rice black bugs are distributed in most rice production areas in mainland China; south of Hebei Province is the far end of north distribution. The pests are popular in the provinces of south China, and seldom can they be found in Shandong and Jiangsu provinces. The bugs had been minor pests in most areas. But they recently caused more and more serious damage to rice because of higher levels of chemical application, change from intensive to extensive cultivation, the warmer winter, and the increase in number of overwintering pests. In Deyang City, Sichuan Province, there were only 3.3 ha of rice fields infested in 2001 when bug damage was first reported. It increased to 666.7 ha in 2002; 43,000 ha in 2003; and 38.3% of a total 47,000-ha rice paddy in 2004. In Mianyang City in the same province, a great number of bugs were overwintering safely because of the warmer winter; the mean number of bugs in the levees reached 52.2 per square meter, and 50−90% of the rice fields were affected by RBB the following year. There were more than 1,000 egg masses per 667 square meters, and egg hatching was as high as 88%. Serious outbreaks in Guizhou, Jiangsu, and Anhui provinces have been reported in recent years.

The adults and nymphs can both damage the rice crop. They suck the sap of the rice plant, feeding on stems, leaves, sheaths, immature spikelets, peduncles of spikelets, and immature grains. The

symptoms include leaves turning yellow, tiller number decreasing, growth being stunted, center of the plants withering, and tillers dying. The development of caryopsis and morphogenesis of the endosperm will be affected when the plant is harmed during anaphase. The incidence of imperfect rice grains such as white core rice kernel, whitebacked rice, milky-white rice kernel, embryoless rice kernel, distorted rice kernel, and abortive rice kernel will increase. Yield can go down 30% or more.

Ecology

Field distribution

Wang and Fang (1993) studied the distribution of the bugs in the field. The data were grouped, arranged in frequency tables, and the mean value (X) and variance (S^2) between groups calculated to show the congregation pattern of the bugs in paddy field with a dispersal index. The spatial distribution and the reasons for congregation were analyzed by using frequency distribution testing, mean average congestion degree and mean regression, and mean of group congregation. The results showed that the spatial distribution of the nymphs is a congregate model (Table 1). There was higher nymph density in the boundaries of the field than in the center, and many more insects are in peak green clusters than in normal clusters. Possible reasons may be that (a) the field boundary is close to overwintering places, and (b) nymphs tend to go toward peak green rice. Research indicated that nitrogenous fertilizer levels have a marked impact on the average quantity of bugs in the fields. An excess of nitrogenous fertilizers will cause the seedling grow peak green and attract gregarious bugs to the clusters of rice plants (Wu 2001).

Yield loss and economic threshold

Ye and Zhu (1999) investigated yield losses caused by adults of RBB in two different varieties grown in pots and in the field. The results are shown in Table 2.

Table 1. Agreement of the congregation index.

Fields (no.)	X	S^2	M*	m* $\sqrt{x}$	(λ)	Cλ	I	I_δ	k
1	2.35833	8.8746	5.12143	2.1716	1.4811	1.1716	2.7631	2.1719	0.7856
2	0.56567	1.3464	1.94587	3.4399	0.2445	2.4402	1.3802	3.4418	0.4771
3	0.58233	1.0832	1.44243	2.4770	0.3303	1.4771	0.8601	2.4785	0.6543
4	0.28300	0.5198	1.11950	3.9558	0.0877	2.9560	0.8365	3.9586	0.3832
5	0.68803	1.9036	2.45477	3.5678	0.3603	2.5681	1.7667	3.5699	0.4202
6	0.89267	2.3497	2.52489	2.8285	0.4791	1.8285	1.6322	2.8297	0.6036
7	0.51700	1.1874	1.81379	3.5083	0.1950	2.5082	1.2968	3.5091	0.4298
8	0.48967	0.8559	1.23757	2.5274	0.2958	1.5274	0.7479	2.5291	0.7278
agreement				m* $\sqrt{x}$ >1	(λ)<2	Cλ>1	I I>1	Iδ>1	K<1
				Congregation distribution		Congregation distribution	Congregation distribution	Congregation distribution	

Table 2. Yield loss caused by different numbers of RBB in two different varieties.

Insects/ clusters hundred	Shanyou 63				Jingxian 63			
	Pot plant		Spot plant		Pot plant		Spot plant	
	Yield (g/cluster)	% loss (g/cluster)	Yield (g/cluster)	% loss (g/cluster)	Yield (g/cluster)	% loss (g/cluster)	Yield (g/cluster)	% loss (g/cluster)
0	20.56	-	30.86	-	13.06	-	19.21	-
33.3	20.21	1.7	30.25	1.98	12.93	1.15	19.11	0.52
66.7	20.04	2.53	29.70	3.76	12.72	2.68	18.54	3.49
100	19.65	4.43	29.43	4.63	12.42	5.05	18.34	4.53
133.3	19.53	5.01	29.33	4.96	12.34	5.66	18.23	5.05

When black bugs infest during the tillering stage, rice leaves become perforated or broken, stems get slimmer, growth is stunted, and some plants become dwarf and even die. Correlation analysis of data between yield loss and total number of seeds in each cluster, single-plant seed yield, and thousand-grain seed weight showed that yield loss of Shanyou 63 was negatively correlated (-0.9972) with single plant seed yield per cluster. The correlation coefficient between yield loss and weight of one thousand grains and single plant seed yield was -0.5341 and -0.7780, respectively. On the other hand, variety Jingxian 89 showed a negative correlation between yield loss and number of total grains and single plant seed yield (-0.9535 and -0.9819, respectively) and apparent correlation coefficient (-0.6712) between thousand-grain seed weight and yield loss. Path analysis showed that the direct path coefficient of total grain number, single plant seed yield, and thousand-grain seed weight of Shanyou 63 was 0.0541, -0.8722, and -0.1275, respectively, and the residual path coefficient was 0.04615. The direct path coefficient of Jingxian 89 between yield loss and total grains and that between yield loss and single plant seed yield was 0.0734. All the results showed little differences in yield loss components between varieties Shanyou 63 and Jingxian 89. For early rice Shanyou 63, yield loss was mainly caused by the decrease in single plant seed yield and seed weight of one thousand grains. For Jingxian 89, yield loss was mainly caused by the decrease in single plant seed yield. By the economic threshold value format proposed by Chiang, the economic threshold value of rice black bug control can be determined using

$$ET = \frac{CC \cdot FC}{EC \cdot y \cdot P \cdot yr \cdot sc}$$

In the equation, ET is economic threshold value, CC is control cost, EC is control effect, y is rice yield, p is price of rice, yr is the loss rate caused by a population density per unit proportion, sc is natural survival of RBB, and FC is a critical factor. Thus minimal control should be 68 bugs per 100 clusters of rice plants according to cost and rice price.

Management of rice black bugs

Biological control

The reported enemies of RBB include fungi, parasites, and predators. The fungi *Paecilomyces lalicinus* Samson and *Beauveria bassiana* Buill can parasitize nymphs and adults. Two species of egg parasites, *Aholcus* sp. (*Telenomus* sp.) and *Telenomus gifuensis* Ashmead, were found in paddy fields in almost all the rice-growing areas. Both egg parasites are engaged in monoparasitism. It was reported that more than 30% of the bugs are parasitized in Guangdong Province. Assassin bugs (*Reduvius* L.), some spiders, frogs, and birds can be predators of RBB. But predation tests revealed that some common predators such as wolf spider, micro-spider, rove beetles, and ladybugs are not interested in spying on the bugs (Chen et al. 1987). In some areas, farmers breed ducks and let them go to the fields to prey on bugs before the rice heading stage. Reports showed that control rate can reach up to 90%; one duck can catch more than 1,000 rice black bugs per day.

Cultural control

The Chinese traditional method of intensive cultivation yielded good results in terms of pest control. The following measures can be done in combination with agronomic approaches.

(1) Based on the growth of RBB and combined with cropland repair and construction, weeding the paddy fields and surrounding areas can effectively decrease the radius of RBB next spring (Cai 2004).

(2) In areas with good irrigation, the method can be used to kill most eggs and newly hatched nymphs. The field is drained to allow the RBB to lay their eggs on the lower part of the rice stems and then the eggs are flooded for 24 h; the operation is repeated three to four times a month (Liao 2004). This strategy is based on the fact that adult bugs lay their eggs on rice stems near the water surface, and eggs do not hatch successfully if they are soaked in water for more than 24 h. Picking up and killing the overwintering adults and egg masses by hand in the morning and evening or on cloudy days during peak oviposition time or shaking the rice plant to make bugs drop in a container with water are also being done in some places in China.

(3) Adjust planting time or choose suitable rice varieties so that the crop's heading stage does not coincide with the peak occurrence of RBB.

(4) Catch the bugs with light traps and kill them with frequency vibration (Wang et al. 2006).

Chemical control

Chemical control is the most widely used method nowadays.

Experiments indicated that the best time for chemical spraying is during the nymphs' lower instar stage, when there is higher mortality and there are better chances of striking down the bugs faster. Otherwise, the bugs will be more resistant and control efficiency will be affected by their growth and development. Normally, the first spraying is done when seedlings turn back to green

after transplanting. If bug density is high, a second spraying will be necessary 15 d later. Spraying should be avoided during sunny days (Wu et al. 1997).

The most commonly used chemicals for RBB control had been organic phosphorus a few years ago in mainland of China. But now, many of those have been banned. Regent, Fipronil, and pyrethrins are common pesticides used to control RBB. The list below shows some of the chemicals widely used in China (Cai 2004, Liao et al 2004).

- 2.5% Bulldock (beta-cyfluthrin) emulsifiable concentrate 1500× spraying
- 20% Esfenvalerate emulsifiable concentrate 2000 spraying. It can be sprayed again after 15 d, if necessary.
- 10% Imidacloprid Lynn (t) wettable powder (strikes down the bugs slowly, but lasts for a long time, 25−30 d), 2000× spraying or 1 500 ×with high bug density
- 2.5% Kung Fu (cyhalothrin) emulsifiable concentrate 2000× to 5000× spraying. The dosage should be about 750-900 L ha^{-1}.
- 5% Regent suspension is another choice for it can control not only RBB but also kill brown planthoppers (*Liburnia sordescens* Mostschulsky), whitebacked planthoppers (*Sogatella furcifera* (Horvath)), and rice thrips (*Chloethrips oryzae* (Williams)). The dosage is about 450-600 mL ha^{-1}.

Benefits of rice black bugs

In folk China, RBB has been used as medicine to cure many diseases. According to traditional Chinese pharmacopoeia, it has aphrodisiac, tonic, detumescence, and dispelling capacities. Liu (1990) in Heibei Baoding Children's Hospital has reported some success in treating cases using pure RBB preparation. The indications, prescriptions, and usage are as follows.

For epilepsy: Six adult RBBs are baked dry and powdered. Take orally once a day for 7 d; skip for 2 days. Two months is the treatment period. The author has cured five epileptic persons. There was no disease recurrence in 3 years so far.

For measles: one bug is crushed to pulp and eaten with warm water. This can be used to hasten eruption of red spots of babies affected by measles.

For cervix cancer: place 10 bugs in boiling water; wash and smoke private parts when the water is hot.

For scrofula and stand canker: use 10 RBB powdered with little borneol, and then mixed with sesame oil; daub on the affected part twice a day. Avoid poignancy food during treatment. This prescription has cured a sufferer who had the disease for 30 yr.

For erosional bedsore: powder 20 RBB with 20 g rosin, 50 g white sugar, and 5 g borneol, and then mix with sesame oil to cream. Daub on the affected part twice a day. Prohibit poignancy food during treatment.

For burn, scald, and trauma: burn 20 RBB with 50 g unrefined sugar, 10 g dry ginger, 15 g zhirumeige, and 5 g borneol, and then mix with sesame oil to cream. Daub on the affected part twice a day. Prohibit poignancy food during treatment.

Museums/institutions with insect collections of RBB

The Shanghai Entomological Museum (SEM) is subordinate to Shanghai Institutes for Biological Sciences (SIBS), Chinese Academy of Sciences (CAS). Formerly known as an insect department of Musée Heude, it was established by a French priest, P. M. Heude, in 1868 and then founded at Xujiahui, Shanghai, in 1883. The museum was moved to South Chongqing Road (former Luban Road) in 1931, and then merged with CAS in 1953. Funded by CAS, the Shanghai Municipal Government, SIBS, and Xuhui District Government, SEM was rebuilt in 2002. Over 100 years, SEM has become a comprehensive entomological museum, which currently holds more than 1,000,000 specimens of insects from all over China.

Insect museum of Sun Yat-Sen University

The Insect Museum of Sun Yat-Sen University was formerly known as Natural Museum of Lin-Nan University. There are more than 600,000 insect samples, including 6,000 named insects and almost 600 types. The earliest samples were collected in 1914. The samples came from all over the country, especially from South China, Hongkong and Taiwan. Some of them came from Japan, the former Soviet Union, America, Philippines, Indonesia, Malaysia, Myanmar, India, Pakistan, Sikkim, Australia, England, France, Israel, and Africa.

Guangdong Entomological Institute

The Guangdong Entomological Institute was founded in 1958. Originally, the Institute was responsible to Academia Sinica and was known as the Entomological Institute of Central-Southern China. The present name was adopted in 1972 when the Institute joined the Guangdong Academy of Sciences. The Museum stored more than 176,000 insect and other animal samples. Although primarily an entomological institute, it also conducts research on mites, nematodes, and vertebrate animals, including birds and mammals. Insect Museum of Northwest A&F University.

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Rice Black Bug or Malayan Black Bug in India

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Abstract

Rice black bug (RBB) or Malayan black bug is a common name for the different species of genus *Scotinophara* that attack the rice crop. These bugs inflict damage to the crop from early tillering to flowering stage. The insects drain plant sap with their sucking mouthparts, causing symptoms similar to hopperburn in cases of severe infestation. For this pest, wet paddies are preferred over upland rice fields. Maize is an important alternate host among the cultivated crops. Since 1972, the pest has been reported from insect collections in surveys from Orissa, Manipur, and Arunachal Pradesh. Moderate to heavy field incidence has been observed in Nellore district of Andhra Pradesh, Tanjavur district of Tamil Nadu, and Kuttanad area of Kerala. Normally, up to 20 bugs per hill have been recorded. But, in severe cases, up to 200 bugs per hill have been noted. As to future strategies, the importance of correctly identifying the different species of *Scotinophara* occurring in different states is emphasized. Because maize is an important crop in India and because it can serve as a potential reservoir during off-season, management of the pest on the maize crop has been stressed. Future strategies regarding RBB management as part of an overall integrated management approach to control rice insect pests are discussed.

Key words: rice black bug species, damage, distribution, India, management, biology, alternate hosts, life table

General information

Rice black bug (RBB) or Malayan black bug is a common name for a group of Pentatomids belonging to the genus *Scotinophara*. As the very name indicates, these sucking insect pests are black in body color. Besides India, the pest has been reported in Bangladesh, Myanmar, Indonesia, Cambodia, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam. These insects drain plant sap

and damage the crop from seedling to flowering stage. In severe cases, burning of the crop similar to hopperburn occurs.

Four species of RBB are reported in world literature: *Scotinophara coarctata* (Fabricius), *Scotinophara lurida* (Burmeister), *Scotinophara latiuscula* Breddin, and *Scotinophara bispinosa* (Fabricius) (Pentatomidae; Hemiptera).

Of these, only *S. coarctata, S. lurida,* and *S. bispinosa* have been reported to be occurring in India (Dale, 1994).

Damage

Nymphs and adults feed at the base of rice stems, removing the plant sap. However, the symptoms differ, depending on the growth stage of the rice plant. If infestation occurs during tillering, initially there will be formation of deadhearts. Continued feeding results in leaves turning chlorotic or having reddish brown color. Tiller number is reduced and growth is stunted. Deadhearts caused by black bugs can be differentiated from those caused by stem borers, in that the former cannot be easily removed by pulling. If black bug damage occurs at the booting stage, it results in panicles with empty grains, white ears similar to those caused by stem borers. When bugs feed directly on panicles in the milky stage, the injury results in grains having a spotted brown appearance. In severe cases of infestation, the fields show the same appearance as hopperburn.

Host plants

Among host plants other than rice, maize (*Zea mays* L.) is the most important cultivated crop. Maize is grown in areas with no sufficient water supply to grow rice, and the crop is distributed in all upland areas interspersed with rice-growing tracts. It is already reported that black bugs have the ability to fly over large distances. Hence, there is a danger that black bugs will assume a major pest status in India in the future. Therefore, there is a need to develop maize hybrids and composites having resistance to or tolerance for black bugs. Furthermore, it is necessary to develop management practices in the maize crop to contain the pest in localized areas and to avoid its migration to rice.

Among other alternate hosts, which are mostly weeds in the uplands and lowlands, the following are important: *Hibiscus esculentus* L., *Colocasia esculenta* (L.) Schott, *Hymenachne pseudointerrupta* C.Muell, *Panicum amplexicaule* Rudge Pl.Guian, *Scirpus grossus* L, *Scleria sumatrensis* Retz, and *Vigna unguiculata* L.

Saroja et al. (1993) observed that black bugs could survive on *Cyperus rotundus, C. irida*, and *Echinochloa colona;* survival ranged from 68 to 75% as compared with 85% survival on rice. As these are the most common weeds in paddy fields, these can be potential alternative hosts in the rice ecosystem.

Biology and ecology

The adults are 9 mm long and brownish black in color. Distinct yellowish spots are present on thorax,

which bears spines below the anterior angles. These insects give off a typical offensive odor when disturbed. The adults can live up to 7 mo.

Each female can lay up to 200 eggs at the basal portion of the rice plant near the water surface. The eggs are 1 mm long; usually greenish when freshly laid, but they turn pink before hatching. Incubation period is 4−7 d. The nymphs are light brown with yellowish green abdomen. Nymphal period lasts for 25−30 d with four to five nymphal instars.

The bugs hide in cracks in the soil during periods of water stress and during the winter months. After overwintering, the bugs fly to the rice crop and reproduce over several generations. They again return to the resting sites after the harvest of the rice crop. Black bugs aestivate in cracks of bunds in the adult or late nymphal stage.

Rice black bugs generally prefer irrigated or rainfed lowlands over uplands. Among the irrigated crops, the insects are more abundant in the dry-season crop than in the wet-season crop. Asynchronous double cropping results in having the crop at all stages of growth, thereby facilitating the faster multiplication of bugs and causing severe damage.

Distribution

In India, field occurrence of black bugs as a group has been recorded in the southern states like Tamil Nadu (Tanjavur District), Kerala (Kuttanad area) and Andhra Pradesh (Nellore District). In the eastern states such as Orissa and the northeastern states such as Manipur and Arunachal Pradesh, different species of *Scotinophara* have been recorded. Among the northern states, black bug has been reported in light trap collections from Chatha in Jammu and Kashmir (DRR, 2006), Aduthurai (Tamil Nadu) (DRR, 2006), and Nellore District of Andhra Pradesh (DRR, 1995, 2000, 2002). There are unconfirmed reports on the presence of these bugs in the states of Maharashtra and Gujarat (Fig. 1).

Historical perspective

A historical view of black bug occurrence may be gleaned from the following reports from different parts of the Indian subcontinent.

Orissa: Diwakar (1972) conducted a survey in the eastern state of Orissa for three successive rice seasons in 1971−72 and established that some of the insect pests were on the increase after the introduction and large-scale cultivation of high-yielding rice varieties. In that context, he observed that *S. lurida* occurred in several places, along with other arthropod pests of rice.

Arunachal Pradesh: Datta and Chakravarthy (1977) recorded the existence of black bug *S. lurida* (Burm) in the insect collections from Arunachal Pradesh conducted during the zoological survey of India. This insect was one of 25 species of Pentatomidae recorded for the first time from the state.
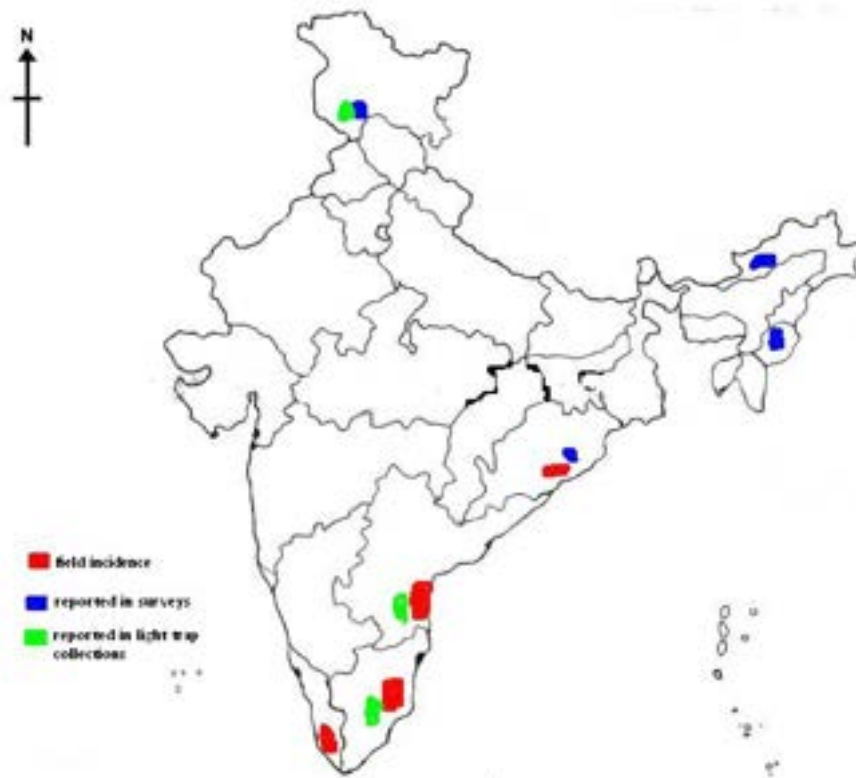
Fig. 1. Rice black bug distribution in India.

Andhra Pradesh: During the same year, 1977, there was a report on the field occurrence of *S. coarctata* in Nellore District of Andhra Pradesh. (Venkata Rao and Muralidharan, 1977). The insect was found to severely damage the rice crop in about 150 ha during *rabi* season. The varieties CO 29 and IET2508 were damaged at the time of flowering. Yield losses were estimated to be 60−85 %. In the subsequent *kharif* season, black bugs also seriously damaged IET2508 in about 100 ha in Nellore. The authors observed that the bugs preferred young seedlings and the field with standing water harbored higher populations of the bugs. However, the weather at the time of incidence was mostly dry. In heavily infested plots, about 200 bugs per hill could be observed mostly at the base of the hills. During the peak infestation of black bugs in wet nurseries; the dry nurseries were almost bug-free, revealing the high level of preference and suitability of wet rice paddies compared with dry or upland rice (Venkata Rao and Muralidharan, 1977).

Tamil Nadu: Uthamasamy and Mariappan (1985) observed heavy infestation of *S. lurida* in Tiruchirapalli District of Tamil Nadu. The varieties affected from April to July 1984 were ADT36 (which was particularly susceptible), along with CO 29 and BCP1. The crop was infested from 30 d after transplanting up to harvest stage. The population of black bugs increased with an increase in

crop age. On average, the population of the bugs was 20 insects per hill at flowering stage; bugburn occurred in many fields in an area of about 800 ha. Uthamasamy and Mariappan (1985) also learned from farmers that black bug infestation occurred regularly in the previous 3 yr. Field observations suggested that fenthion spray was effective in controlling the black bugs. Subramanian et al. (1986) also reported that *S. coarctata* damaged rice in Coimbatore in early July, 1985. The population of the bugs on 11 different varieties ranged from 6 to 12 bugs per 10 hills. There were no significant differences among the varieties at 30 d after transplanting. The peak populations reached 100 insects per 10 hills. Among the five insecticides evaluated on 45-d-old IR50, monocrotophos was the most effective, reducing 91% of the pest population, as against 58-61% reduction caused by insecticides endosulfan, phosalone, quinalphos, and dichlorvos. Ravi (2006, pers. commun.) from Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu, observed a severe RBB outbreak in a 4-acre area in a farmer's field in the summer of 2004 in Tanjavur District of Cauvery Delta of Tamil Nadu. Again, in summer 2006, the outbreak affected 6 acres. The varieties involved were ADT43 and ADT36.

Kerala: From another major rice-growing state of India, Kerala, situated in the southern part of the country, black bug incidence on rice was reported in 1998 (Ambikadevi, 1998; Jacob and Bai 1998). Ambikadevi (1998) reported that *S. bispinosa* was observed regularly during *kharif* or in the wet-season crops of 1996-98 in Kuttanad area, Kerala. Heavy damage was observed in badly drained fields, and the wet-season crop was more seriously damaged than the dry-season crop. All the varieties commonly grown in the area such as Jyothi, Matta, Triveni, and others were susceptible to the pest. Jacob and Bai (1998) observed *Scotinophara* sp. causing serious damage in *kharif* or wet-season crop during 1998 in the same Kuttanad area. To control the pest, they suggested cultural methods such as weed control and clean cultivation, as well as use of light traps. Among the chemical control methods, spraying with 0.05% monocrotophos at the base of the plants was effective in lowering the pest populations and limiting its spread.

Manipur: Singh and Singh (1987) conducted surveys in major rice-growing districts of Manipur from September to November 1986. *S. coarctata* was one of four Hemipterans reported to damage the rice crop in the milky stage. *S. coarctata,* along with two other Pentatomids, *Dolycoris indicus* and *Menida histrio,* constituted 3−6% of hemipteran infestation and was considered by the authors to be of minor importance.

Detailed studies

Saroja et al. (1993) from the Rice Research Station in Tirur, Tamil Nadu, conducted the first detailed studies on RBB in India. Through light trap collections, they have confirmed that *S. coarctata* accounted for 97% of the population, while *S. lurida* comprised the remaining 3%. The female bugs laid 25−50 eggs with a mean of 45 eggs in masses in 3−5 longitudinal rows on leaves and stems near the water surface and soil crevices. They also observed that, when egg masses were submerged in water for 24 h, only 3% of the eggs hatched as compared with 96% of egg hatching in the case of unsubmerged eggs. This shows the possibility of using flooding as a cultural method to manage RBB.

In their light trap studies, Saroja et al. (1993) observed that an 80-watt black light could attract more bugs than a 125-watt MV lamp and a 40-watt incandescent lamp. They also confirmed earlier observations that more bugs were attracted to light traps during full moon compared with low/no-moon week. The seasonal incidence studies revealed that January, April, May, June, August, September, and December were the periods of RBB abundance. After conducting a detailed field study at the Tirur Rice Research Station, Saroja et al., 1993 fixed the ETL for S. *coarctata* as 10% leaf damage at tillering stage or five bugs per hill.

In further studies, Saroja et al. (1993) identified 13 cultures as less damaged, revealing 3.0 damage score on a 0−9 scale. These were IR52341-60-1-2-1, IR58099-41-2-3, IET12901, IET12872, IET12875, IET12887, IET13381, IET12398, IET12402, IET12403, IET12419, ACM60, and CO 37. Among the insecticides and neem products evaluated at Tirur, acephate, followed by monocrotophos, was the best insecticide, recording the least leaf damage by the black bug.

Anand Prakash and Jagadiswari Rao (1999) from CRRI, Cuttack, conducted detailed studies on the biology and life table of RBB in India. The Malayan black bug, *S. coarctata* was originally collected from the farmers' fields and mass-reared on developing milky panicles of the rice plant in the net house. The experiments were also conducted on plants containing the milky-stage grain. The results revealed that the longevity of the ovipositing female ranged from 28 to 52 d (mean of 38 + 8.7d), while the male survived for 36−50 d (mean of 42.2 + 5.49). Premating period was 5 d, while oviposition period was found to be 9−13 d. (mean of 10.8 +1.32). The nymphal period lasted for 27 d. Egg period was 3−4 d (3.3 + 0.45 d). Maximum mean female progeny production per day was 2.8 on the 4th day and egg laying completely stopped on the 16th day. The intrinsic rate of natural increase (r_m) was 0.084 female per day, while the rate of multiplication was 28.0 times in a mean generation time of 39.9 d. The finite rate of increase was 1.08. The weekly multiplication was 1.79; the male-female ratio was 1:1.47.

Anandhi and Pillai (2006a) conducted field and screenhouse studies in Killikulam, Tamil Nadu, India, on the infectivity of two entomopathogenic fungi, *Metarhizium anisopliae* and *Beauveria bassiana* to *S. coarctata* in relation to the age of the rice crop. The infection was first observed at 16 d after transplanting (DAT) and peaked at 72 DAT. Under controlled net house conditions, maximum infection and mortality were observed 7 d after treatment. Anandhi and Pillai (2006b) observed in their field studies that acephate (0.05%) and monocrotophos (0.036 %) were the most effective insecticides against black bug, followed by chlorpyriphos, profenophos, imidacloprid, neem oil 3% and neem seed kernel extract 5%. Anandhi and Pillai (2006c) screened seven rice cultivars in terms of resistance to RBB under greenhouse conditions. CO 37 was moderately resistant, while AS16, IR36, IR20, and White Ponni were susceptible. IR64, IR50, and ADT36 were highly susceptible to black bug. Anandhi and Pillai (2006d) determined the efficacy of five insecticides and 21 plant products against the eggs of *S. coarctata*. They observed acephate and imidacloprid as the most effective insecticides, causing 100% and 95.8% mortality of eggs, respectively. Chlorpyriphos, profenophos, and monocrotophos followed, recording 87−92% ovicidal action, whereas neem seed kernel extract and neem oil caused 56% egg mortality.

Future strategies

Taxonomic aspects

A critical analysis of the scientific names of the black bugs observed in the different regions of India revealed the inadequacy of identifying specimens up to the species level. For instance, from the same state of Tamil Nadu, different authors reported different species such as *S. coarctata* and *S. lurida*. From the neighboring state of Kerala, *S. bispinosa* and *Scotinophara* sp. have been reported from the same region (Kuttanadu). Therefore, any further attempt to devise management strategies for black bugs should necessarily remove these taxonomic inadequacies. This taxonomic aspect should be the forerunner of research efforts on RBB.

Alternate hosts

As earlier suggested, alternate host studies have to be initiated to contain the black bug populations on maize, the most important alternate host and a cultivated crop. More information on other alternate hosts, which are mainly weeds, need to be generated for different species of black bugs. At times, it is possible that alternate hosts of different species of the same genus may differ substantially.

Management options

Any strategy to be devised to manage black bugs on rice should be within the framework of integrated pest management (IPM).

1. Cultural methods such as clean cultivation and removal of weeds on the bunds and surrounding noncultivated areas should be a part of RBB management as there are many weeds acting as alternate hosts for this pest.
2. Light traps can be used to attract black bugs; these will then be killed by chemical means. But this may not be a sound strategy as the major population of the bugs in the field are nymphs, which cannot fly to the light traps. Therefore, light traps can just be used for monitoring the presence of bugs.
3. Avoiding excessive N and following a balanced fertilizer application is a general strategy for the management of all rice pests. It is in fact an important component of rice IPM.
4. Water inundation will enhance the multiplication rate of black bugs (they in fact prefer wet paddies to upland rice). Hence, alternate wetting and drying of the rice fields, wherever possible, should be part of the cultural method of managing black bugs in wetland paddies.
5. Of late, it is thought that indiscriminate use of nonrecommended insecticides like synthetic pyrethroids might also be responsible for the emergence of black bugs as a pest, along with hoppers. Therefore, strict compliance with the use of only recommended insecticides should be enforced at the farm level. This, which is also a part of rice IPM, should be useful to contain black bug populations in endemic areas.
6. Generate information on the effectiveness of all insecticides available in the market and also those in the pipeline, so that the most effective ones in terms of bioefficacy and cost effectiveness are chosen.

7. General recommendations like thorough coverage of the crop and directing the spray fluid toward the base of the plants where black bugs feed hardly need any emphasis.

8. There is negligible information available on host plant resistance to different species of black bugs. Hence, efforts in this direction need to be initiated as a broader strategy of using host plant resistance as part of rice IPM. The best and quickest way to use this tool is to screen varieties already released to farmers for their reaction to black bugs. In addition, cultures or varieties with multiple resistance, which have known levels of resistance to other pests like planthoppers and gall midge, can also be the first material tested for black bugs.

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Status Report on Rice Black Bug Situation in India

P. Narayanasamy

Abstract

This report gives an overview of the rice black bug situation in India. Various aspects of the insect, including pest status, nature and symptoms of damage, bionomics, life table, and management measures are discussed. Of the six species reported, two species, *Scotinophara lurida* and *S. coarctata,* are predominant and they appear to march in their depredatory nature toward major pest status.

Key words: hopperburn, bug burn, intrinsic nature, longevity, M chromosome

Introduction

The rice plant is infested most commonly by, among other pests, black bugs (Hemiptera: Pentatomidae) at various stages, including the milky stage. So far, six species of black bug have been recorded. They are the Japanese rice black bug, *Scotinophara lurida* (Burmeister), Malayan rice black bug, *S. coarctata* (Fabricius) (Pawar 1975, Anonymous 1976, Vasantharaj David and Kumaraswami 1994), *S. bispinosa (*F.*), S. cinerea* (Le Guill.), *S. obscura* (Dall.), and *S. dentata* Distant (Ferreira et al. 2001). Recently, *S. bispinosa* has been reported from Kuttanad, Kerala, causing heavy losses (Ambikadevi 1998). Singh and Singh (1987) reported the incidence of black bug in Manipur. Sosamma Jacob et al (1998) reported *Scotinophara* spp. as a minor pest of rice in the Kuttanad area in Kerala. (Fig. 1). Today, the black bug has reached a significant status as a potential pest of rice in many countries, including India. Considering this, an attempt has been made to describe the black bug incidence in India.

Fig. 1. Occurrence and outbreaks of rice black bug species in India.

Bionomics

Black paddy bug/Malayan rice black bug *Scotinophara coarctata*

The adult bug has a body length of 8-9 mm; it is brownish black with a few indistinct spines lower to the anterior angles; tibiae and tarsi are pinkish. Adult females oviposit their eggs in clusters of 29-34 eggs apiece, usually on the basal stalks of the rice plant but very close to the water level. The eggs are shiny, pale greenish grey, cylindrical, and finely retracted, measuring 1 mm long and 0.65 mm wide. The top portion of the egg is grayish white, indicating the cap, which later splits to let the nymphs emerge. Ordinarily, the female guards the eggs by staying on top of the egg mass. Average incubation period is 4-7 d, and the nymphal stage encompassing five instars last for 26-34 d. Young nymphs are brown with yellowish green abdomen and some black spots. The adult has a longevity of 4-7 mo in rice fields.

Japanese rice black bug *Scotinophara lurida*

The bugs are brownish black with a prominent scutellum and pronotum having a spine on either side. Eggs are whitish, laid in parallel lines into the leaves. Incubation period is 6 d. First-instar nymphs are brownish and undergo four moltings to become adults in 6-7 wk.

Cytology of black bug, *Scotinophara* sp. (Junde 1960)

The presence of a special pair of chromosomes called M chromosomes is characteristic of Gymnocerata, Coreidae, and Lygaeidae. They differ from the other autosomes by their smaller size; they were observed for the first time at the diplotene stage during meiosis as overcondensed bodies. Further, they do not form any chiasma and undergo 'touch and go' pairing during the first meiotic division (Plate 1).

Metaphase I shows seven elements. Of these, four are autosomal bivalents; two are sex chromosomes, and the remaining small one, the M chromosome pair. The latter shows a precocious anaphase disjunction. During metaphase II, there are six elements seen, the smallest of which is the M chromosome. The latter divides equally during this phase.
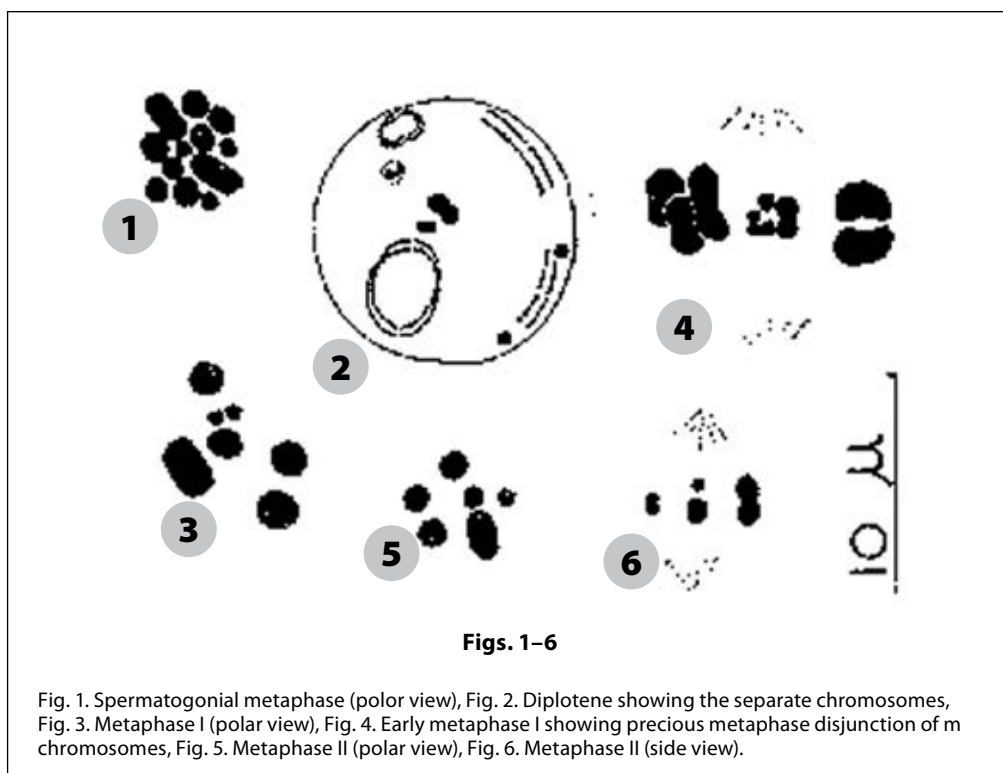
The deviation in diploid number of chromosomes of this species from type number (12 + XY) of the family Pentatomidae as well as of its congeneric species, *Scotinophara horwathi* (Toshioka) suggests a recent origin of the M chromosomes in this species.

Number of generations a year

Both *S. lurida* and *S. coarctata* produce one generation a year.

Pest status/yield loss

Before 1950, the black bug was recorded as an occasional pest in India, but later on, it has occurred periodically in large numbers, inflicting extensive damage to rice varieties in some rice-growing states of India. Since then, the black bug has steadily increased in number when many high-yielding rice varieties were cultivated.

Figs. 1–6

Fig. 1. Spermatogonial metaphase (polor view), Fig. 2. Diplotene showing the separate chromosomes, Fig. 3. Metaphase I (polar view), Fig. 4. Early metaphase I showing precious metaphase disjunction of m chromosomes, Fig. 5. Metaphase II (polar view), Fig. 6. Metaphase II (side view).

PLATE 1. Cytological features of rice black bug *Scotinophara* sp. (Junde 1960).

Datta and Chakravarty (1977) reported the incidence of *S. lurida* for the first time in Arunachal Pradesh, India. Rao (1977) witnessed a sudden outbreak of *S. coarctata* in Nellore District of Andhra Pradesh during the later part of May 1977, causing 60−80% yield loss. Young seedlings seemed to be preferred in heavily infested fields. Sundarababu et al (1984) recorded the black bug as a serious pest with sporadic outbreak. Later, Saroja (1991) reported a severe incidence of the black bug in Chengalpat District, Tamil Nadu, in January, April, May, and December, causing very heavy yield losses. *S. coarctata* was recorded to be the predominant species, which showed a peak damage of 97% as evidenced by the species complex studies conducted during 1989–91 at the Rice Research Station, Tirurkuppam, Tamil Nadu (Saroja et al. 1993). It was inferred then that the species, in conjunction with gall midge and hispa, emerged as a major pest of rice in Kanchipuram and Tiruvallur districts in Tamil Nadu.

Outbreaks of *S. lurida* were recorded in Paiyur in Dharmapuri District of Tamil Nadu during 1991, which bore large-scale infections of 95% of adults and nymphs with *Paecilomyces farinosus* (Holm. ex Gray) Brown & Smith (Narayanasamy 1994). Following this, in 1999, large-scale depredation of *S. lurida* was noticed in Manjakollai, a hamlet in Chidambaram Taluk in Tamil Nadu State. Various stages of the rice crop (variety Ponni) comprising vegetative and inflorescence initiation

2a. Leaf yellowing and tip drying.

2c. Shredding of spikelets.

2b. Drying of foliage (advanced level).

PLATE 2. Symptoms of damage in rice bug, *S. lurida* (Narayanasamy, 1999).

stages were damaged. The author witnessed an entire crop with damage similar to that of the brown planthopper's hopperburn. The damage was assessed at 40–49% and the plants in the vegetative stage were stunted (Narayanasamy, 1999, pers. commun.).

Economic threshold level (ETL)

The ETL of the black bug was studied at Rice Research Station, Tirur, Tamil Nadu, and rice yield loss was recorded, with 8−15 % leaf damage during maximum tillering caused by four−six bugs per hill. Based on this, ETL was ascertained at 10% leaf damage during tillering stage or at five bugs per hill (Saroja et al. 1993).

Symptoms of damage

Both adults and nymphs feed mainly at the base of the stems, often just below the water level. The bugs feeding at the base of the plant cause ears and leaves to become chlorotic or reddish brown; heavily damaged leaves become twisted and yellow; ultimately deadhearts develop, and the grain does not fill completely. When the bug feeds at the growing point of the plant, tillering is affected. Direct injury to panicles is also common. Infested grains have brown spots (Plate 2). Above all, severe

infestation culminates in hopperburn-like injury and death of the plant (Dale 1994; Narayanasamy, 1999, pers. commun.).

Gupta et al. (1989) stated that pentatomid bugs, including the black bug, reduced rice grain quality in the paddy fields of Orissa.

Food plants

The rice plant is the main host of the black bug. Other alternate host plants include *Echinochloa colona* (L.) Link, *Echinochloa crus–galli* (L.) Sw, *Fimbristylis miliacea* (L.) Vahl, and Zea *mays* (L.)

Natural enemies

Black bugs under natural habitats are attacked by a few species of natural enemies that comprise parasitoids and entomogenous fungi.

Rao (1977) recorded an egg parasitoid, *Telenomus* sp.; it is active even at low host density and could tolerate extreme temperatures.

Gupta et al. (1989) found that pathogenic fungi reduced the population of pentatomid bugs in Orissa.

Ecology

Collection of *S. coarctata* and *S. lurida* could be achieved with a 125-w mercury vapor lamp. Balasubramani et al. (1998) observed a higher catch by the full moon. The Malayan black bug (*S. coarctata*) flies to light in large quantities. It can be gathered in light traps in the largest mass 5 d before and after the full moon.

Life table

Life table studies on *S. coarctata* were done with particular reference to age-specific fecundity and intrinsic rate of increase of the bug on the developing panicle of the rice plants under net-house conditions at Cuttack during February-April (Anand Prakash and Jagadiswari Rao 1999). The findings revealed that longevity of the ovipositing female ranged from 28 to 52 d with an average of 38.00 ± 8.70 d, whereas the male survived for 36-50 d. Oviposition period lasted for 9-13 d and mean duration of immature stages was 27 d. Incubation period lasted for 3-4 d and maximum mean female progeny production per day was 2.80 with reproduction ceasing on the 16th day. Intrinsic rate of natural increase was 0.084 per female per day, whereas the finite rate of increase was 1.08. Weekly multiplication was 1.79. Male to female ratio was 1:1.47 (Table 1).

Seasonal occurrence and abundance

Diwakar (1976) conducted a survey in Orissa State during three successive rice seasons in 1971–72 and the study revealed that *S. lurida* caused little damage earlier and that its increased population buildup coincided with the introduction of high yielding rice varieties.

Table 1. Life table statistics of S. coarctata.

Parameter	Statistic
Developmental time	1–33 d
Maturation time	5–6 d
Age at first reproduction	34th d
Net reproductive (R_0)	28.00
Mean generation time (T)	39.00 d
Cohort generation time (T_e)	40.80 d
Innate capacity for increase (T_e)	0.081
Intrinsic rate of increase (r_m)	0.084
Finite rate of increase	1.081
Sex ratio (male:female)	1:1.47
Weekly multiplication (er_m)	1.79
Incubation λ	3.330.455 d
Oviposition	10.80 ± 1.32 d
Longevity of female	38.10 ± 8 .70 d
Longevity of male	42.2 ± 5.49 d

Source: Anand Prakash and Jagadiswari Rao (1999).

Saroja (1991) reported severe incidence of the black bug in Chengalput District, Tamil Nadu, during January, April, May, and December, causing very heavy yield loss. Ambikadevi (1998) observed *S. bispinosa* in Kuttanad area of Kerala causing more damage in the wet season than in the dry season.

Rice fields

Tillering
Rice variety Ponni at active tillering stage was infested by heavy populations of *S. lurida* in Manjakollai area of Chidambaram Taluk, Tamil Nadu. Such infested plants were stunted and tillering was also hindered (Narayanasamy, 1999, pers. commun.).

Booting to flowering
Rice plants at booting to flowering stages were also damaged by the adults and nymphs of *S. lurida* in Tamil Nadu. The panicles of the infested flower were chaffy and shredded (Narayanasamy, 1999, pers. commun.).

Management

Biological control
Studies on biological control of black bug are scarce.

Parasitoids/parasites

An egg parasitoid, *Telenomus* sp., has been recorded to effectively control the bugs.

Predators

Ducks are employed for the control of rice striped bug *Tetroda hysteroides* and other pentatomid bugs, including black bug in rice crop. A flock of about 1,000 ducks can clear a badly infested crop of about 5 ha in 1−2 d, each bird accounting for about 500 bugs in a day (Vasantharaj David and Kumaraswami, 1994).

Pathogens

In Paiyur of Tamil Nadu, a heavy population of the black bug *S. lurida* occurred, inviting *Paecilomyces farinosus* at 95% infection (Narayanasamy 1994). It was interesting to note that only the ventral side of the black bugs had fungal infection (Plate 3).

In an outbreak of *S. lurida* which occurred during 1999 in the Chidambaram region of Tamil Nadu, fungi-like *Metarrhizium anisopliae* (Metsch.) Sorokin. and *Beauveria bassiana* (Bals.) Vuill. infected both adults and nymphs of the bug. (Plate 3). The cadavers had fungal growth on their ventral side along the body margins (Narayanasamy, 1999, pers. commun).

Under greenhouse conditions, Bio-power *(Beauveria bassiana)*, Bio-magic (*Metarrhizium anisopliae*), and Bio-catch *(Verticillium lecanii)* were evaluated against rice black bug *S. coarctata.* Nymphal instars and adults of *S. coarctata* reared in the screenhouse supported on 40-d-old plants of IR50 were studied (Pillai and Deepa Maheswari 2006).

All the formulations recorded a significantly higher percentage of mortality when compared with untreated control. The maximum mortality (19.58%) was recorded with Bio-magic @ 10 g liter[1], followed by treatments involving Bio-catch and Bio-power at the same dosage. As to chemical insecticides, Fenthion (1 ml liter[1]) had the highest mortality (100%). The present study has brought to light the potential of using commercial entomopathogenic fungal formulations in the control of RBB.

The efficacy of entomopathogenic fungi *M. anisopliae* and *B. bassiana* was studied in Killikulam during 2000-02 under field conditions. The study revealed that, although both pathogens showed virulence against the bug, they varied significantly in relation to crop age (Anandhi and Pillai 2006a). Maximum infection of the black bug was recorded at 72 DAT (Fig. 2).

Varietal

Few studies, including that of Anandhi and Pillai (2006c), focused on varietal management of black bugs in India.

Uthamasamy and Mariyappan (1985) reported heavy infestation of *S. lurida* on rice varieties such as ADT36, CO 129, and BCP1 in Trichy District. The crops were infested 30 d after planting until harvest, during which time the population increased substantially. The area infested was about 800 ha.

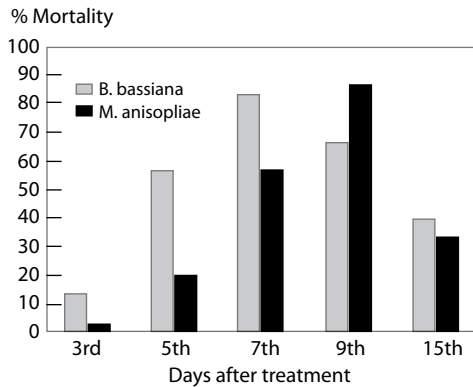3a. Adult infected with *P. farinosus*.

3b. Adult infected with *M. anisopliae* –dorsal view.

3c. Adult infected with *M. anisopliae* –ventral view.

PLATE 3. Mycoses of *S. lurida*.

Fig. 2. Efficacy of *M. anisopliae* and *B. bassiana* (Anandhi and Pillai,. 2006).

Later, Subramanian et al (1986) stated that nymphs and adults of the black bug were found on more varieties—IR36, IR60, Vaigai, ADT36, IR56, PY3, IR50, ADT31, TKM9, Rasi, and PY2—in July in Coimbatore. The population ranged from 6 to 12 days hill^{-1}. They witnessed a dense population of the RBB at 6-12 per 10 hills on these varieties and there was no significant difference in number on the different varieties at 30 DAT.

Varieties CO 37 and ACM40 were found moderately resistant to the black bug (Anonymous 1992). Ambikadevi (1998) reported that varieties Jyothi, Matta, and Triveni in Kuttanad, Kerala, were susceptible to *S. bispinosa*.

Botanical control

Only a few studies have been made with respect to utilization of plant products in the management of black bug. Effective management of the black bug has been achieved with neem seed kernel extract used at doses of 5% and 10% in the rice fields of Tirurkuppam, Tamil Nadu, and because of the potency, this product has been included in the management package in the *Crop Production Guide* for Tamil Nadu for the year 2005 (Anonymous 2005).

Chemical control

Studies on the chemical control of the black bug are limited. Rao (1977) reported that black bug was brought under control in an endemic area by massive pesticide spraying with monocrotophos, deltamethrin, permethrin, carbosulfan, dimethoate, or malathion.

Subramanian et al. (1986) evaluated the efficacy of five insecticides against the black bug on 45-d-old IR50 and reported that monocrotophos reduced the population most effectively. Saroja et al (1993) conducted a screenhouse study and reported that acephate, monocrotophos, nine insecticides and two neem derivatives controlled the black bug effectively. Sosamma Jacob (1998) reported that spraying of monocrotophos (0.05%) at the base of the plants was effective in controlling the *Scotinophara* sp. in Kerala.

Ovicidal activity of certain insecticides was made known against *S. coarctata* (Anandhi and Pillai 2006b).

From the above it becomes clear that insecticides such as monocrotophos, dimethoate, malathion, and a few synthetic pyrethroids are effective against the black bug population.

Complete management practices have evolved to control RBB. The Rice Research Station in Tamil Nadu Agricultural University, Coimbatore, recommended spraying of neem seed kernel extract 5% (25 kg ha^{-1}), acephate (625 g ha^{-1}), and monocrotophos 36 SL (1000 ml ha^{-1}) at 10% ETL (Anonymous 2005).

Name of country museum/institution with insect collections of rice black bugs and officer in- charge of the collection

The Director
Zoological Survey of India
Kolkata, India

The Head
Division of Entomology
Indian Agricultural Research Institute
Pusa, New Delhi
India

Potential uses of RBB

The use of insects as human food is common in many rural and tribal communities in India and elsewhere. Specifically, grasshoppers, eggs of giant water bugs, termites (winged forms), bees, and cicadas are delicacies for the rural folks. Moreover, there are certain insects like blister beetle (Meloidae: Coleoptera) that are used to treat ulcers. Interestingly, the RBB has been found to cure certain diseases like epilepsy (Balasubramani et al. 1998). A very common practice followed in Chhattisgarh State is to use adult bugs. In the form of dry powder, adults are mixed with herbal preparations. The combination is burned and patients are advised to inhale the smoke. Many times, healers use the dry insect alone for this purpose. The smoke provides great relief to patients during epileptic attack. Also, in normal days, the patients are advised to inhale the smoke at least once a week to delay further attack. Many healers said that, in small doses, the powder can be taken internally, but most healers are not in favor of internal use.

In the treatment of Mirgri, adult bugs are used in another way. Fully fed bugs are collected and boiled in base oil. When all watery contents evaporate, boiling is stopped and the solution filtered. The filtrate is kept for future use. As base oil, Til (sesame seed) oil is used. The special oil is massaged in the sole of patients as treatment.

Traditional healers say that this massage is also beneficial for people with mental depression.

To increase the potency of the special oil, many healers add medicinal herbs, but in most cases, the oil prepared from adult bugs prove to be effective. Black bugs feeding on seedlings are considered more useful as a medicine than those feeding on mature plants. As mentioned earlier, the nymphs are preferred less. No other medicinal uses of RBB are known.

It has been observed that RBB is not listed as a medicinal insect in the literature. The old traditional healers said that, in the early days, when medicinal rice varieties were under cultivation in different parts of Chhattisgarh, RBB feeding on specific medicinal rice variety was used in treating various illnesses. Attempts are now being made to gather more information on the medicinal value of the black bug.

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Rice Black Bug: a Potential Rice Insect Pest in Indonesia

Hendarsih-Suharto, Tatang Suryana, and SE Baehaki

Abstract

The rice black bug *Scotinophara* spp. (=*Podops* spp.)(Heteroptera: Pentatomidae) is dull black in color and produces a bad odor. It is one of the insects that live on the rice ecosystem—lowland, tidal swamp, peat soil, marshy land, and sometimes, upland. Most of the time, the rice black bug (RBB) lives in dark and damp habitats such as in the middle of a rice hill. Its life cycle depends on the habitat conditions: when bred in a young rice plant, nymph duration was longer and mortality was higher than those bred in a tillering rice plant. The life cycle in a tillering rice plant was 37–57 d, longer under dry conditions. The insect is nocturnal and attracted to light, but its flight was influenced by lunar light. During full moon, the number of RBB catches in the light trap was the highest in a month. Yield loss caused by the same RBB population during the maturity stage of the rice plant was higher than that at tillering stage.

Key words: rice ecosystem, flight behavior

Introduction

Among the insect species that live in the rice plant is the rice black bug (RBB) *Scotinophara* spp. (=*Podops* spp.) (Heteroptera: Pentatomidae). The RBB is easily recognized by its bad smell and dull brown black color. This insect sucks the plant sap, especially from the leaf sheath, causing a disturbance in plant metabolism. Infestation at the vegetative stage showed withered leaves due to damage tissue at the base of the rice plant. With high RBB population, the plant became stunted, turned yellow, and died. Some infestation resulted in 'bug burn', which was just like hopperburn caused by brown planthoppers. Bug burn occasionally happened in the Subang, West Java area. The RBB is considered a potential pest of rice, with an average area of less than 10,000 ha being infested

by RBB in 8 yr (Anonymous 1985-1993). In the last 15 yr, the area infested by RBB had decreased; no official record on RBB exists.

As it is not an important insect pest, only a very few references on RBB can be found in Indonesia. The authors have reviewed these papers and their findings presented in this paper. Though it did not cover all aspects of the RBB, this compilation will contribute to present-day knowledge of the RBB.

Biology

The most common RBB species in Java is *Scotinophara cinerea LeG (= vermiculata* Voll), (Kalshoven and Laan 1981). Dr. Mochida in 1976 identified RBB in Sukamandi as *S. coarctata* F. The insect is 7−10 mm long and with 4 mm wide. Most live in plants under the Gramineae family, including rice (*Oryza sativa).* RBB occur in rice fields (lowland = sawahs) and in land where maize, oats and some grasses grow. They hide during daytime and adults avoid sunlight. In the rice plant, they crowd in the middle of tiller, in the part of the plant close to the roots, or in the base of the plant. RBB lay eggs 12−17 d after being hatched. The eggs are cylindrical and greenish in color and become pink close to hatching. They are laid in batches, about 30 per batch, at the base of the plant and are arranged in three rows. Incubation period is 7 d. The adult female tends to the eggs until they hatch and become nymphs. The nymph has five instars, white in color then gradually becoming brown. In a laboratory in Malaysia, the total life cycle was observed to be 33−41 d, longer under dry conditions. The adult lives up 7 mo (Kalshoven and Laan, 1981).

The life cycle of the RBB depends on the habitat where they grow. Under Sukamandi, West Java conditions, with average annual rainfall of 1,200 mm and minimum night/day temperature of 21/32 oC, there were differences in the life cycle of RBB bred in young plants and those in tillering ones. When RBB are bred in a young rice plant (20-d-old rice seedlings), the duration of the nymphal period was 31−50 d. When bred on tillering rice plant (50-d-old seedlings), duration was 26−34 d. Nymph mortality on the young plant was 95% and that on the tillering plant was 58%. The pre-oviposition period was 7−28 d on the tillering rice plant, egg period was 4−7 d; total life cycle was 37−57 d (Kertoseputro and Hendarsih-Suharto 1986). This case showed that RBB developed well under dense tillers, which damper and low intensity during the day.

Pest status

In early reports about the pest condition before World War II, RBB sometimes caused serious damage such as that at Palembang, South Sumatera, and in marshy land near Kahayan River in Kalimantan *(*Kalshoven and Laan 1981). This condition did not differ much from the present situation. RBB is one of the rice pests that occur year-round in **a** tidal swamp area in South Sumatra (Suwalan et al 1993). Sometimes, RBB infestation was high in a certain area, causing heavy damage. During the last 33 years in Sukamandi West Java, there were several instances of bug burn due to RBB. Dr. Mochida noted bug burn in 1979 (unpubl. data). The first author witnessed serious rice damage at Sukamandi
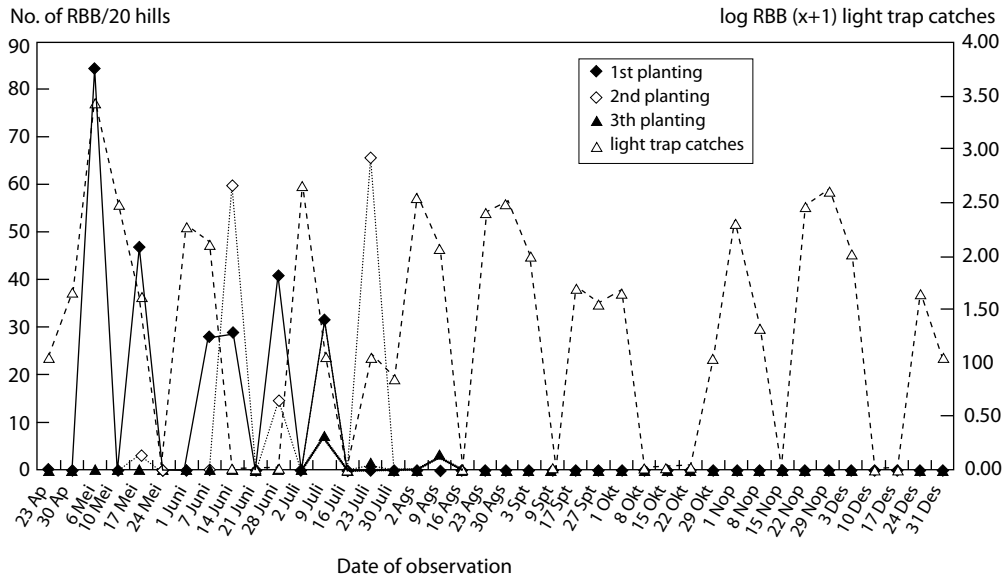
Fig. 1. the rice black bug population, Sukamandi 2004.

in 1982 (Fig. 1), 1997, and, recently, in 2007. The third author noted damage in 1997. Five hectares of rice variety IR64 was severely attacked by RBB, causing bug burn and producing no yield. Another 30 ha were 85% damaged with RBB averaging 141 hill[-1] (Baehaki 2005). Lately, in February 2007, many bug burn spots (Fig. 2) were found in a hybrid rice variety with a RBB population of 43−126 hill[-1] (av 74) (Hendarsih-Suharto and Kurniawati 2007).

Recent official data, either from the Agriculture Department or the Central Bureau of Statistics, are not available, as only a small area was affected by RBB. Data from 1985 to 1990 showed that RBB-infected areas were small (Table 1) compared with the total cultivated area in Indonesia. In 1990, the area planted to lowland rice was 7,385,800 ha, whereas that planted to upland rice was 1,064,600 ha (Anonymous1990). The lowland area is more damp than the upland area and this may be the reason for the higher RBB infestation in the lowland. Most of the reported areas with RBB infestations were in the islands west of Indonesia (Fig. 2). The islands in the western part get higher rainfall and are more wet compared with the eastern islands.

Yield loss due to RBB on a high-tillering rice (IR36) variety was low in the young plant. At maximum tillering stage (30 d after transplanting, 25 RBB hill[-1] reduced rice yield by 29%. At primordial rice stage (55 d after transplanting), rice yield reduction was 52% (Hendarsih-Suharto 1985).

Natural enemies

In Java and Malaysia a scleonid parasite, *Trisolcus* or *Asolcus* is found (Kalshoven and Laan 1981). The fungal pathogen *Beauveria bassiana* is also found attacking RBB (Baehaki 2005).

Fig. 2. Rice black bug infestation in Indonesia. Source: Central Bureau of Statistics 1985-90.

Table 1. Area infested by the rice bug in Indonesia, 1985–90.

Year	Lowland		Upland		
	Area (ha)	Damage intensity (%)	Area (ha)	Damage intensity (%)	Infested sites
1985	1894	22.1	153	41.4	West Java
1986	2710	13.9	211	39.7	South Sulawesi and Jogyakarta
1987	3440	9.2	0	-	-
1988	7782	15,4	586	29.5	South Sumatra
1989	4110	14.8	195	26.8	Central Kalimantan, South Sulawesi, West Kalimantan, Jogyakarta
1990	2153	12.9	112	15.9	Aceh, North Sumatra, South Sumatra, Central Kalimantan

Source: Central Bureau of Statistics (1985-90).

Flight behavior

Baehaki (2005) observed that RBB was a nocturnal insect that is active at night. The RBB started to come out from hiding at 1700 h, then they moved up and down the rice plant or to other plants, the movement becoming more intense toward 1800 h. At this time, many of RBB were on the rice leaves and flew at a 45o angle. Visually, at the beginning of the flight, they did rotational movements; later they flew directly or bent. During this moment, some of the RBB mated. The number of RBB gradually increased, with the peak at 2200–2400 h, it declined afterward. The ratio of flying male to female depended on the time; at 1800−2200 h, male to female ratio was 1:1; at 2200–0200 h, it was 2:1; and at 0200−0400 h, 1:1.

RBB flight was influenced by the lunar light. The Arabic calendar is based on the lunar calendar, with every month having 30 d. One month could be divided into three periods: the first period is from date 1 to date 10, the second period is from date 11 to date 20, and the third period, from date 21 to date 30. Light intensity in the second period is higher than those in the first and the third periods; the

highest light intensity is during full moon (13th to 15th of each month). The number of RBB catches in the light trap during the second period was higher than at the other two periods, with the highest catches obtained during full moon.

Fluctuation in population

The population of RBB at Sukamandi has been monitored since 1975 using light traps. The average catches each month from 1978 to 1985 (8 yr) showed that the lowest average catch was in January (605 RBB mo^{-1}); this later increased and, starting March, catch was more than 13,154 RBB mo^{-1}. The higher average catches were taken in September−November, more than a 100,000. The highest average catch of 34,.050 was in October; the number declined in December. Cathes in other months varied, but catches in January and Desember were always low (Henderson- Suharto and Kertoseputro 1986). The total number of catches was variable across years, the lowest in 1982 (47,855) and the highest in 1979 (2,902,665).

Record on RBB catches in the last 3 yr (2004−06) showed similar patterns with higherst catches in a month during the full moon. Compared with 30 yr ago, the population of RBB from 2004 to 2006 was lower. Catches in 2004 was lower than in 2005 and 2006. In 2004, the highest catches were noted only in May (Hendarsih-Suharto and Kurniawati 2007).

Monitoring of the population in the field was done by direct counting. The relationship between light trap catches and population in the field was evaluated from the 1978 wet season up to 1979; 12 plantings were done with 1-mo interval for each season. In the July, August, September, and November plantings, RBB were found on young rice plants 3 wk after transplanting. In other planting months, RBB were found 6 wk after transplanting (Hendarsih-Suharto and Kertoseputro1986).

Three plantings with 2-wk intervals were done in the 2004 dry season. The relationship between RBB catches and RBB on the plant was shown in Figure 1. At the first planting (2 wk before famers' planting date), RBB were found 3 wk after transplanting (4 May), which coincided with high RBB catches. For the second planting time, which was simultaneous with that of the farmers, RBB were found in the plant 7 wk after transplanting. On the third planting, population of RBB was low in young plants, increasing at 9 and 13 wk after transplanting (Hendarsih-Suharto and Usyati 2005). From those two experiments, it was shown that the population on the plant depended on the RBB catches only during off-season planting.

Thirty years ago, RBB catches were high, but RBB population on the plant was low (Hendarsih-Suharto and Kertoseputro 1986). In recent years, RBB catches were low, but population on the plant was high (Hendarsih-Suharto and Kuniawati,2007). There seems to be a behavior change of the RBB. Changes in cropping pattern may have influenced the behavior of this insect. 30 yr ago. Then, rice varieties were of long duration, such as Pelita I/1(145−150 d). Nowadays, there are medium-duration varieties such as IR64 (110−115 d). Besides, 30 yr ago, a large area of the Sukamandi station land was fallow. Today, all land was cultivated, with the same planting date as the fallow period at the same time for 2−3 mo. As RBB could live in other grasses, *Scirpus* spp. and other broadleaf plants (Dale 1986), than fallow are may a sanctuary and breeding site durin. ?????

Relationship between rice plant type and number of RBB

Experiments with seven rice varieties, which consisted of hybrid rice, high-yielding variety, and new plant type, showed that only new plant type Fatmawaty had consistently lower bug population than other varieties. The reason for this phenomenon is the fact that the new plant type has few tillers, only 8−19 tillers hill^{-1}, compared with others that have 15 tillers or more. A plant with many tillers is more favorable for RBB, as it is lighter and more damp in the middle of the hill.

In general, RBB in the young rice plant are low in number. Later, RBB number increased, depending on the rice variety. On Pelita I/1, the population of the RBB in the rice plant followed a quadratic equation:

$Y = -64.6286 + 29.3532X - 0.85399X2$ (r2 = 0, 81*),
where Y = no. of RBB and X = plant age, wk after transplanting

This equation says that the population of RBB is low on a young plant, it later increases following the age of the plant and decreases as the plant enters the maturity stage (Kertoseputro and Hendarsih-Suharto 1986). In medium-duration rice variety (110-115 days), population of the RBB in rice plant follows a linear equation:

$Y = -23, 61 + 27X$ (r2 = 0, 81 *),
where Y = number of RBB and X = plant age, wk after transplanting

It can be inferred from this equation that population increases following plant age (Hendarsih Suharto and Usyati 2005). Observations on rice variety Ciherang (110-d duration); RBB was observed 2−3 wk after transplanting, its number increasing with plant age, then later decreasing before harvest. The population in the dry season or during the second planting was higher than that in the wet-season planting (Suryana 1999).

Control methods

In the field, farmers rely on insecticides to control RBB. Many insecticides are found effective against RBB. Of these, monocrotophos and chlorpyrifos were used in tidal swamp areas (Suwalan et al 1993). Under Sukamandi conditions, cypermethrin, monocrotophos, and chlorpyrifos were also effective against RBB (Baehaki 2005).

Experiments with fungal pathogen *Beauveria bassiana* Vuill showed that a concentration of 108 conidia ml^{-1} was effective against RBB nymphs, whereas 1010 conidia ml^{-1} was effective against RBB adults (Suryana and Aryani 2001).

Cultural control methods were simultaneous planting and removal of weeds surrounding the rice field (Suwalan et al 1993).

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Pest Management of Rice Black Bug *Scotinophara lurida* Burmeister (Heteroptera, Pentatomidae) in Japan: Past and Present Efforts

Terunobu Hidaka

Abstract

In this paper, the pest status of the rice black bug (RBB) *Scotinophara lurida* Burmeister (Heteroptera, Pentatomidae) was investigated in two stages: as a serious pest of rice before 1957 and as a minor insect since 1960. The RBB population density Has been remarkably reduced by use of insecticides such as BHC, parathion, and others; thereafter, the bug was not given conditions to recover. There was no use of resistant varieties to control the bug at that time. Although the bug has alternate host plants, its population could not increase. The protected rice nursery (including semi-irrigated rice) also helped reduce RBB population. As to biological control, the bionomics of the egg-parasite *Telenomus gifuensis* Ashmead (Hymenoptera, Scelionidae) was studied and found to be a possible and important biological control agent. Predators and their useful activities are clearly monitored in the paddy field. Effective timing of insecticide application to hibernating adults, larvae, and newly emerged adults was demonstrated in the field. There was high mortality of the bugs at the developmental stages, except for the egg stages not controlled by the insecticides. The RBB feeds on leaves, rice stems, and panicles by sucking the sap. White leaves, dead tillers, and pecky rice grains appear and rice yield is greatly decreased. Monitoring of rice pests is being continued by pest control agencies in Japan, but the RBB is at present excluded when it became a minor insect.

Key words: rice black bug, *Scotinophara lurida* Burmeister, egg parasite, *Telenomus gifuensis* Ashmead, change in pest status, Yayoi period, hibernation, migration, univoltine, alternate host plants, biological control, host bugs, parthenogenesis, parasitism, predator, fungi, rice cultural control, insecticide control, rice yield loss, monitoring field

Fig. 1. *Scotinophara lurida* Burmeister (male).

Introduction

The rice black bug (RBB) *Scotinophara lurida* Burmeister, Pentatomidae (Fig.1) was one of the key pests of rice in Japan before 1957; since then, the pest has become a minor insect in the last 50 years.

RBB had been found among relics of an ancient civilization during the Yayoi period in 300 BC. Fossil rice seeds and a part of RBB pronotum were collected in the relics. Rice cultivation in Japan commenced at the time of the Yayoi period. The RBB probably entered Japan through rice plants coming from a foreign country. In AD 3rd century, the pest had been confirmed to occur on rice plants in Japan; a serious occurrence was also described in 1752.

In Japan, three kinds of *Scotinophara* are known: *S. lurida* Burmeister 1854, *S. scotti* Horvath 1879, and *S. horvathi* Distant 1883. *S. scotti* is distributed in Japan (Honshu and Kyushu), Taiwan, and Korea, but its population is lower than that of other black bugs. This species feeds on weeds of the family Graminaceae. *S. horvathi* is distributed in Japan (Honshu, Kyushu, and Shikoku), and China. This species is not very common and feeds on reeds and rarely on rice plants.

Life history

RBB adults hibernate in weeds, under stones, in dead tree trunk, and levees near paddy fields during winter (Table 1). Hibernating in mass group at these sites from October to May every year, they have no activity in relation to feeding and movement.

These adults start to migrate partly to the flooded rice nursery in May, but population is very low. At present, the protected rice nursery is mainly established in a plastic house or in a semi-irrigated nursery outdoors; the RBB is completely shut out through the use of plastic cover defense from 1956. Then, rice transplanting is begun in late May in central Honshu and in late June in southern Kyushu.

The adults migrate to rice plants in the field, gathering on basal parts (roots) of rice hills.

RBB mating starts after migration to paddy field and egg laying begins in late June. The peak of the oviposition is seen in the middle of July. The egg laying continues until the beginning of August in Fukui and Ishikawa prefectures in central Honshu. On the other hand, in southern Kyushu, oviposition is noted from the end of July to the beginning of September. Peak egg laying occurs in mid-August.

The egg is of barrel shape, 1.2 mm in diameter, with greenish color just after egg laying changing to light brown before hatching. An egg mass consists of 14 eggs in two rows (Fig. 3);these are

Table1. Life history of *Scotinophara lurida* in Central Honshu and Southern Kyushu, he mark + represents adult stage, O egg stage, and — larval stage respectively.

Bugs from	V	VI	VII	VIII	IX	X
Central Honshu	+ + +	+ + +	+			
		O	O O O	O		
			— — —	— —		
				+ + +	+ + +	+ + +
Southern Kyushu	+ + +	+ + +	+ + +	+ +		
			O	O O O	O	
				— — —	— —	
				+ +	+ + +	
					O O O	O
					— —	— —
					+	+ + +
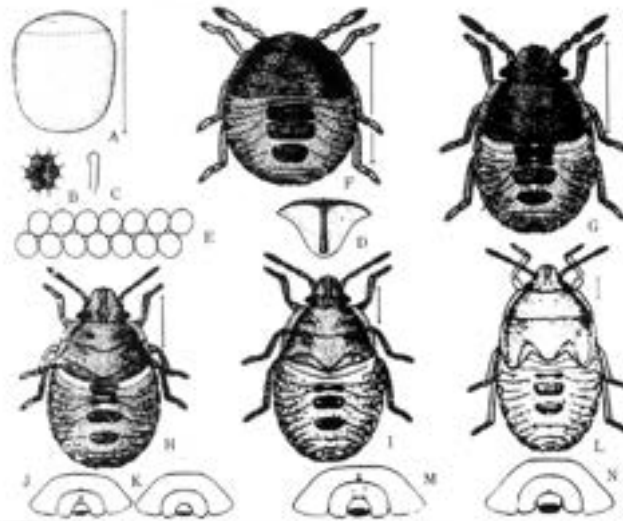
Fig. 2. Developmental stages of *Scotinophara lurida* Burmeister. A: egg, B: reticulate chorion, C: process for spermatheca, D: chorion mastax, E: egg mass, F: 1st instar larva, G: 2nd instar larva, H: 3rd instar larva, I: 4th instar larva, J: ventral genital segment of 4th instar larva, K: ditto male, L: 5th instar larva, M: ventral genital segment of 5th instar larva, N: ditto male, vertical line represents 1 mm long (Kobayashi, 1963).

usually deposited on leaf sheaths or on the back of leaves. The number of eggs per female is 189.4 on average with a maximum of 611. Between 6.0 and 12.8 eggs are laid. Incubation period is 7.4 days at the end of June and 4.1 days between the middle of July and August. Larval period is about 35 days on average. The larva has five ecdysis from 1st instar to 5th instar (Fig. 2), and then new adults emerge as the first generation of the year. The longevity of female adults is about 380 days and that of male bugs is 350 days.
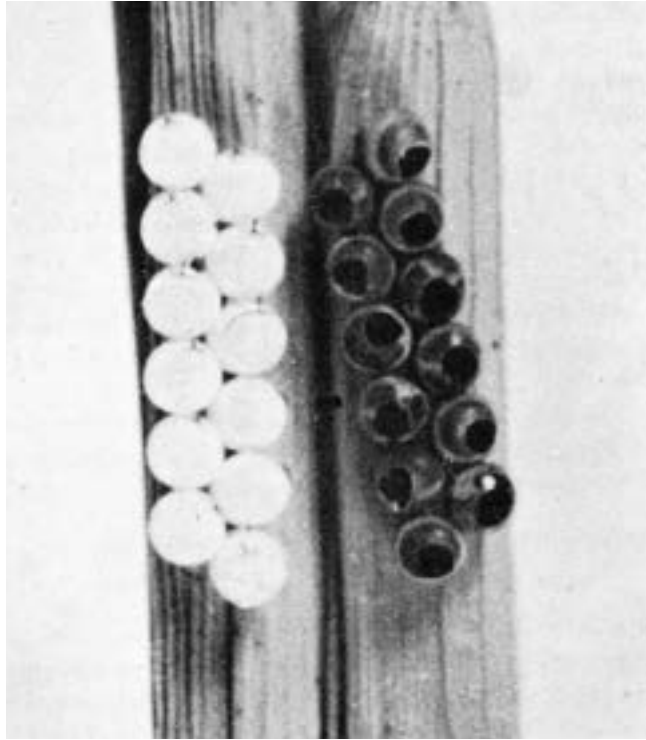
Fig. 3. The egg-masses of the black rice bug, *Scotinophara lurida* Burmeister. Right, parasitized egg mass by the parasite. Left, unparasitized egg-mass of the black rice bug.

During summer, newly emerged adults are attracted to green-colored light, however, the number of adults is rather low.

In Japan, the RBB has one generation per year. In central Honshu, adults move from their hibernation sites to paddy fields starting in August; in southern Kyushu, adults migrate in September.

Pest status

Outbreaks of RBB occur in areas where early-maturing varieties or early planted rice is grown in the Niigata and Fukushima prefectures, Honshu. The RBB prefer to feed on rice plants, although they feed a little on Japanese millet, *Echinochloa frumentacea* in paddy fields (family Graminaceae), and wild Indian rice (Japanese name, *makomo*), *Zizania latifolia* Turcz. (Graminaceae). The 4th- and 5th-instar larvae and newly emerged adults preferably gather on neck of panicles. Ripening is especially prevented from rice heading by the serious injury caused by the RBB. No rice yield is reported if a pair of RBB is observed in one rice hill, as it results in an increase in population because of RBB reproduction. This suggests the need for optimum timing in pest control. Overwintering adults also cause injury during the active tillering stage, with damaged stems and leaves dying off.
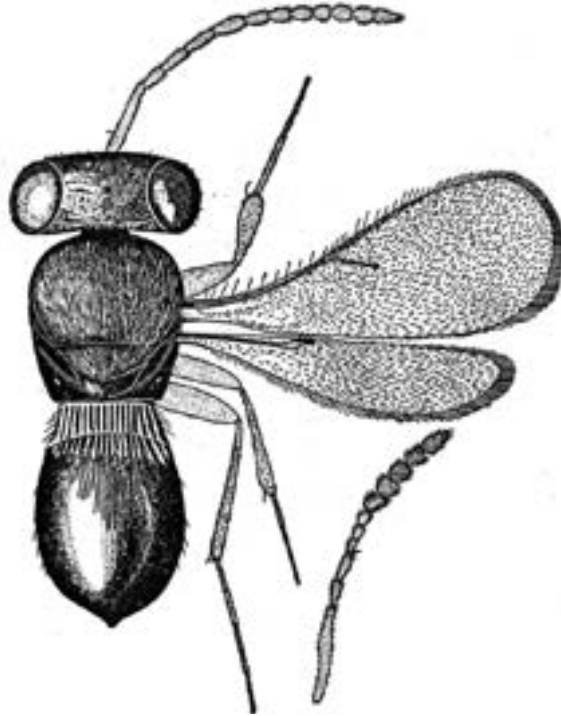
Fig. 4. Male of Telenomus gifuensis Ashmead and antenna of the female (Hidaka, 1958).

RBB outbreaks were seen in paddy fields in Ishikawa, Wakayama, Honshu, and Miyazaki prefecture, Kyushu. As a matter of fact, Nakagawa reported serious damage in more than 4 ha in Ishikawa prefecture in 1882 where 100% of the rice plants died. All the RBB collected in the paddy fields amounted to 5,990 liters.

Changing pest status of the rice black bug

DDT and BHC were introduced into Japan after World War II, followed by parathion in 1952. Chemical control against rice pests had been intensively and mechanically advanced and, after three decades of strong chemical control of rice pests, some species had decreased rapidly and disappeared in most localities in Japan by the end of 1960 (Fig. 4).

The RBB, a univoltine species, had no measurable population and no infestation in the paddy
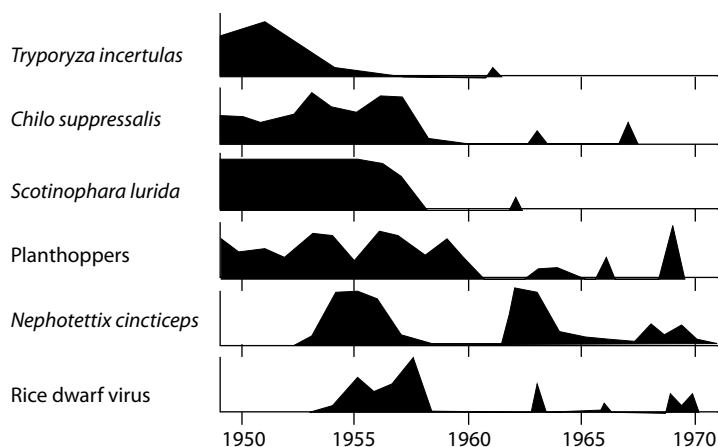
Fig. 5. Fluctuation in acreage of paddy field infested by different rice pests during last two decades in Kochi Prefecture (Kiritani 1972).

field since 1960, along with *Tryporyza incertulas* and *Chilo suppressalis*. The paddy areas infested by these pests were also remarkably reduced in Japan. Insecticide treatments in paddy fields resulted in the reduction of populations of RBB and those of others.

Noteworthy is the decrease in population of its natural enemies as a consequence of the insecticide application. The RBB could not recover because of the heavy pressure of insecticide application.

Food plants

The following are food plants of RBB in Japan.
1. Graminaceae
    Rice plant *Oryza sativa* Linnaeus
    Barnyard millet *Echinochloa furumentaceae* Link
    Barley *Hordeum vulgare* Linnaeus
    Wheat *Triticum aestivum* Linnaeus
    Job's tears *Coix lacryma-jobi* Linnaeus
    Small foxtail millet *Setaria italica* Beauv.
    Common millet *Panicum miliaceum* Linnaeus
    Corn *Zea mays* Linnaeus
    Sugarcane *Saccharum officinarum* Linnaeus
    Reed *Phragmites longivalvis* Steud.
    Makomo (Jpn) *Zizania latifolia* Turcz.

2. Cyperaceae
    Hikagesuge (Jpn) *Corex humilis* Less

3.   Leguminosae
     Pulse crop

4.   Solanaceae
     Potato *Solanum tuberosum* Linnaeus

5.   Compositae
     Yanagi yomogi (Jpn) *Erigeron kamschaticus* DC.

More than 15 kinds of these host plants are known in Japan. Rice plants are the main host plants, but other plants are utilized as temporary food sources. There is no evidence that the RBB has a completed life history.

Biological control

Hymenopterous egg parasite
In Japan, *Telenomus gifuensis* Ashmead was found to be an egg parasite of RBB from Ishikawa prefecture, Hokuriki district in Honshu during the outbreak of *S. lurida* Burmeister (Katsumata 1929). The parasitism of *T. gifuensis* has frequently been observed throughout paddy fields in Kyushu, Shikoku, and the western half of Honshu.

Developmental stages of *T. gifuensis*
Egg: The average size of a newly deposited egg is 0.20 mm in length and 0.17 mm in width. The newly hatched larva begins to feed upon the contents of the host egg after a few minutes.
       The 1st-instar larva: The larva is of teleaform type. The body just after hatching is 0.25 mm in length and 0.09 mm in width.
       Mature larva: Larval period is 4 or 5 days after oviposition; larva is grayish white, body is 1.10 mm in length and 0.17 mm in width. After voidance of its meconium, egg color of the host changes to black (Fig. 3).
       Pupa: The body is oval. The average size is 1.3 mm long and 0.85 mm wide. Body is yellowish white, but eyes become red after pupation and antennae, head, and abdomen become black. Pupal duration is 4−5 days.
       Adult: The adult is 1.11−1.25 mm long, wing length is 1.45 mm. Coloration is entirely pithy black, with the exception of the legs which are yellow.

Seasonal life history of *T. gifuensis*

The copulation of the parasite occurs on egg masses immediately after the emergence of the female. The parasite, which has passed the winter season as an adult increases its activity at the beginning of August, incessantly wandering or flying to search for host eggs in the paddy fields or in the sur-

Table 2. Number of generations of *Telenomus gifuensis*. Observations were carried out in two districts, *i.e.* Fukuoka Prefecture (Northern Kyushu) and Miyazaki prefecture (Southern Kyushu). The parasites collected in Fukui and Ishikawa Prefecures, Central Honshu, were brought to Fukuoka and Miyazaki where the experiments were performed.

Parasites from	V	VI	VII	VIII	IX	X
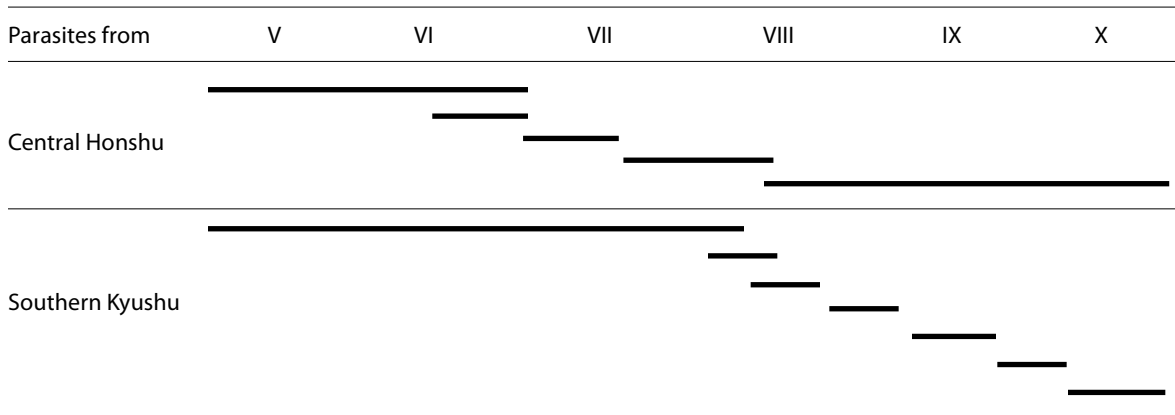
rounding meadows. It parasitizes as many host eggs as possible and may pass 2 or 3 generations in about a month.

Table 2 shows the life cycle of *T. gifuensis* in central Honshu and southern Kyushu. There are four generations in central Honshu and six generations in southern Kyushu. The first generation appears in June in Honshu and in August in southern Kyushu. It is understood that the first generation in Honshu comes 2 mo earlier than the first generation in southern Kyushu.

Host bugs

Species of the genus *Telenomus* are parasitic mainly to the eggs of Hemiptera and Lepidoptera. The hosts of *T. gifuensis* recorded in the fields are listed as follows.

(Host bug) (Species)	**(Host plants)**	**(Reference)**
Pentatomidae		
Scotinophara lurida Burmeister	rice plants	Katsumata (1930)
Piezodorus rubrofasciatus Fabricius	bean plants	Watanabe (1951)
Eusarcoris ventralis Westwood	rice plants	Watanabe (1951)
Eusarcoris sp.	chrysanthemum	Hidaka (1958)
Eusarcoris parvus Uhler	rice plants	Hidaka (1958)
Dolycoris baccarum	chrysanthemum	Watanabe (1951)
Nezara antennata Scott	rice plants	Hidaka (1958)
Coreidae		
Acanthocoris concoloratus Uhler	bean plants	Hidaka (1958)
Riptortus clavatus Thunberg	bean plants	Hidaka (1958)

It is interesting to note that egg shape and thickness of the Coreidae are greatly different from those of the Pentatomid bugs. *T. gifuensis* may have a wide range of hosts. The progeny of the parasite that emerge from these bugs are morphologically quite the same as in the case of RBB eggs.

Length of life cycle

The length of the life cycle of *T. gifuensis* at various temperatures is set out. The period required for the development of the egg parasite from egg to adult is between 10 and 17 days in southern Kyushu and between 12 and 19 days in central Honshu. The incubation period of the parasite eggs is 13 h. The larval period is slightly more than 5 days and the pupal one being 4−5 days in the southern location. On the other hand, the egg requires 19 h in the central site.

Larval stage is 6−7 days and pupal stage is 5−7 days. It is interesting to note that the life cycle of the parasite from southern Kyushu is longer than that from Honshu. The egg-parasite from central Honshu can have four complete generations annually; that from southern Kyushu has six generations in the field (Table 2).

Time of emergence

The time of emergence of the parasite from RBB eggs is from 6 to 11 a.m. in most cases. However, some of them emerge in the afternoon. The total time required for emergence is about 10−15 min.

Parthenogenesis and total number of eggs laid per female

The female produces parthenogenetically 75 progenies on the average, all of them male. However, the phenomenon may be rare in the field, even if parthenogenesis occurs in some cases, because none of the egg masses parasitized in the field produced only male progenies as far as it can be observed.

The total number of eggs laid by a single parasite from central Honshu is 82 on the average, the maximum being 106 and the minimum, 38.

Similarly, the parasite from southern Kyushu given no food is 43, the maximum being 40, the minimum, 37. When fed, the corresponding numbers are 107, 143, and 95. Oviposition of the parasite last for about 12 days at high temperature; low temperature remarkably prolongs that period.

Sex ratio

The average ratio of male to female is 1:3.6 in southern Kyushu and 1:4.1 in central Honshu.

Method of oviposition

A female parasite taps the host egg with antennae for several minutes and exerts its short ovipositor against one of the eggs. She then extends her body, vibrating her antennae just before egg laying. Total time required for oviposition is 2.51 min per egg on average. Most frequently, the ovipositor is inserted obliquely to the egg shell close to the operculum, sometimes to the lower half of the egg shell.

After laying the first egg and before ovipositing the second one, it crawls over the egg mass, vibrating her antennae and trying to examine various parts of the egg for 25 s on an average. The total time spent for oviposition on one egg mass is 45 min, including the inspection interval mentioned above. It may be seen that the parasite never deposits on a host egg that is already parasitized.

A single host egg mass is usually attacked by a few parasites; the first occupant of the host egg becomes the owner of the egg mass and pushes away the other female individuals from the egg after struggling with them. The parasites always run up and down the stem and leaves of the rice plants without flying until they discover a new host egg mass.

General habit of the parasite

It is interesting to note that the male parasite always emerges earlier than the female. The adult parasite makes an irregular opening on the operculum of the host egg (Fig. 3). The male copulates with his mate immediately after his emergence. The time required for copulation is 5 s. When two males emerge from the host egg mass at the same time, they combat with each other on the host egg mass for about 3 min, and the winner can mate with a female on the same egg mass. The parasite always shows distinct positive phototaxis. In the field, the parasites continue their activity from early morning to sunset. The diurnal activity of the parasite seems to be remarkable in the morning.

Percentage of parasitism

According to investigations made by Kawase (1954), the eggs of the RBB are parasitized from early June in central Honshu; during the middle of the month, 55.5% of the host eggs are injured by the parasite. The number of parasites rapidly increases 2 wk after their appearance in the fields and the percentage of parasitism reaches 88.2% at the end of July (Table 3).

On the other hand, in southern Kyushu, the percentage of parasitism of the parasites is lowest from 24 Jul to 3 Aug, even though it gradually increases to about 100% at the end of August. However, parasitism percentage is slightly different between the central and marginal portions of the paddy field. In mid-August, parasitism reaches 60%. The number of host eggs are most abundant at that time of the month. Therefore, host eggs are highly parasitized by the parasites and are almost killed by gregarious attack of the parasites.

Practical control of RBB by the parasite

The host eggs harboring the parasites used in the experiment on RBB control were collected from paddy fields of Fukui and Ishikawa prefectures from 14 Jul to 27 Jul and transported to Miyazaki Prefecture in southern Kyushu from 24 Jul to 4 Aug. The adult parasites were thus reared from the materials. The parasites thus reared usually emerged 1 mo earlier than did the parasites from southern Kyushu under natural conditions. An extensive dispersal of the parasites was made to the following districts to study the effectiveness of the parasite in the paddy field: Kamigano, Minamigano, Nakano, Kiyotake machi, and Kobayashi City in Miyazaki Prefecture. The results indicated clearly

Table 3. Percentage of parasitism of *Telenomun gifuensis* from Central Honshu and Southern Kyushu. (A) Number of egg-masses, (B) Number of egg-masses paratized by the parasites.

Locality	Date of collection	No. of eggs	No. of hosts emerged	No. of parasites emerged	Percentage of parasitism	Average percentage of parasitism
			(A)		(B)	
Kamiyauchi, Kanazawa	July 14	1237 (94)	575	662 (55)	53.5 (58.5)	
City, Ishikawa Pref.	20	296 (26)	138	158 (15)	53.4 (57.6)	64.5
	27	897 (70)	122	748 (63)	83.3 (90.0)	
Reihokuku, Fukui Pref.	16	333	148	185	55.5	
	20	505	100	405	80.1	74.1
	23	425	59	346	81.4	
Reinanku, Fukui Pref.	16	83	20	63	75.9	
	20	168	3	165	98.2	88.2
	23	360	50	310	86.1	
Kiyotake, Miyazaki Pref	24	130 (10)	130	0	0	
	29	244 (18)	204	40 93)	12.2 (16.6)	
	August 3	363 (28)	332	31 (3)	8.5 (10.3)	
	8	430 (34)	235	195 (17)	43.9 (50.0)	56.5
	13	322 (26)	73	249 (20)	81.8 (76.9)	
	18	437 (34)	74	363 (28)	74.8 (82.3)	
	23	267 (20)	43	224 (17)	72.9 (85.0)	
	28	290 (24)	0	290 (24)	100.0 (100.0)	

that the parasites thus liberated are indeed effective in controlling the bugs in southern Kyushu. The parasitism of the parasites mentioned above was much higher than those that emerged in southern Kyushu in natural conditions in lateJuly.

Is *T. gifuensis* a promising parasite?

Superparasitism does not occur in *T. gifuensis* as in the case of some parasitic species. This parasite is very active and has an excellent ability to find the host eggs. Its parasitism is exclusively concentrated to eggs of RBB. This phenomenon may be explained by the fact that the population density of the RBB is almost always much higher than that of other bug species and the number of the parasites is very large in the field. Consequently, parasitism reaches to 70−90%, thus achieving an almost complete commercial control of the bugs.

The problem is that the parasites usually appear in the paddy field comparatively later than the beginning of the oviposition of the bugs in natural conditions and, consequently, a fairly large number of the host bugs can escape from the attack of the parasites. If the parasites appear in the paddy field much earlier, it may be possible to control almost all the eggs of the bugs. This point was clearly clarified by the author's experiment mentioned above. Future research must focus on the study of mass production of the parasite, *T. gifuensis*, in the insectary. If the mass-rearing method can be established, we can put the parasites directly in the field at the right time.

Predators of the RBB

Many predators are known to attack RBB in Japan. However, ecological investigations of the predators are fragmented so that only a partial list of these predators is given in this paper.

Pterostichus microcephalus Motschulsky (Coleoptera, Carabidae)**.** This is an important predator, consuming eggs and young larvae of the bug in some localities in Japan. This species is distributed in Hokkaido, Honshu, Shikoku, and Kyushu in Japan; Korea; China; and Russia (Siberia and Sakhalin).

Rana nigromaculata Hallowell (Amphibia, Anura, Ranidae). This is the common frog found in paddy fields and ponds. The adults hibernate in the soil and appear during spring. The frogs begin predator activity against the rice pests in the fields. One of the important predators of RBB in Japan, this species is distributed in all islands of the country.

Anas domestica Linnaeus (Anatidae). The young house ducks are released to the paddy field as an important predator of RBB and fishes. Duck release is done during the vegetative growth stage, after the crop has taken roots; then, the ducks are withdrawn just before the heading stage of rice. Seventy-day-old female ducks are released to the paddy field for 1 h in early morning, taking about 200 RBB. After resting for 2 h, the ducks are again released for another hour, catching about 70 % of the rice pests. The ducks are effective predators of rice pests.

Predacious spider of *Meta doenitzi* Bues. et Str. (Arachnida). A high population of the spiders inhabit the paddy field and its surrounding weed areas, just before RBB emergence at the end of October in southern Kyushu. The spider begins to weave a good many webs from 1800 to 2200 at night. One web is about 83−105 cm^2. A large number of these webs are observed in paddy fields compared with a small number of bugs in the field. The web weaving of spiders is suggested to be a suitable activity to catch migrating bugs as they fly away from the paddy field. In fact, the spiders killed 25% of the bugs through the webs.

Parasitic fungi

Beauveria sp. The parasitic fungi are important control agents against RBB. The *Beauveria* sp are prominent during the larval to adult stages of the bugs. In some localities, the percentage of parasitized larvae and adults reached more than 80% in the middle of September.

Rice cultural control

The RBB seemed to give serious damage to the early planted paddy field and the early-maturing varieties. It is recommended that middle or late plantings and use of late-maturing varieties be considered to effectively control the bug's incidence.

Control countermeasures

At first, the hibernating adults have to be collected by hands and killed instantly and mechanically.

After the adults migrate to the rice nursery and the paddy field, they increase in population so fast that these migrating adults should be immediately controlled.

The regular monitoring of the bugs' movement from the hibernation sites to the paddy field is very important to check the bug dispersion in the paddy field.

As mentioned above, the bugs have an inclination to gather in early planted paddy field, therefore, 'sacrificial' paddy fields may be set up to trap the bugs. After all the bugs move to these fields and are then controlled, rice transplanting can safely start to spare the rest of the area from RBB infestation.

Insecticide application for control of the bugs

Before 1960, chemical insecticides had been used in paddy fields to control rice pests in Japan. Many kinds of insecticides had been tried against RBB as they are regarded as one of the most serious rice pests at that time, both in experiment stations and farmers' groups. Among many insecticide trials, BHC γ3% (powder formulation) was found to be effective at the rate of 30 kg ha^{-1}. Also noted to be very effective was parathion, which can control simultaneously RBB and stem borer *Chilo suppressalis* Walker, the rice, (Lepidoptera, Pyralidae), another serious rice pest in Japan at that time. The mortality of hibernating adult bugs was 81.5% through application of BHC 3% at 18 kg per 0.1 ha.

BHC 1% powder was also very effective against migrating adults. BHC 1, 2, 3% powder against first-instar larvae were also practical in the field experiments. Mortality figures of newly emerged adults and fully grown larvae reached 59.2 and 65.0%, respectively, with BHC 3% powder.

The optimum timing to apply parathion in Toyama Province was in the middle of July. On the other hand, that in Ishikawa Province was indicated to be at the end of June and the beginning of July. However, more than two-time spraying of insecticides was necessary as the migrating number of hibernated adults increased (Kawase et al. 1956). There was a need to check the resistance to insecticides by the newly emerged adults.

Studies on RBB resistance to BHC and parathion were carried out under room conditions in Tokushima Prefecture, Shikoku, Japan (Kobayashi 1956, 1957). It was found that the egg was the most resistant to BHC and parathion. During larval stages, resistance was lowest in the first instar; however, it consistently increased with the growth of the larvae. The third-instar larvae were more resistant than the overwintering adults, whose resistance was strongest in February. After hibernation, the adults become more susceptible to the insecticides.

Damage caused by RBB

Direct damage on the rice plants caused by the RBB larvae and adults is earlier described. In this section, yield loss of rice grains is mainly summarized as follows.

Rice grain damage known as "pecky rice" is caused by a total of 65 species of heteropterous bugs in Japan. However, little is known about pecky rice caused by RBB, although the bugs feed mainly on the rice leaves and stems. Sometimes, whitehead rarely appears when adults feed on stems where the young panicles are formed.

Judging from the results obtained by the feeding experiments, Kawase (1956) reported that husked rice infested by the bugs showed green rice kernels, ventrally whitish kernels and dying kernels. He also clarified a regression equation between number of hibernated adults per hill of rice plants (X) and panicle weight (Y) as follows:

Y= 703.82-362.0 X

The equation suggests that heavy loss of panicle weight is clearly seen at the time the maximum number of hibernated adults is achieved, during maximum tillering of the rice plants. Tomonaga (1956) investigated the relationship between percentage of yield decrease and number of bugs per rice hill. The results obtained showed that yield decrease by hibernated adults was 60.6−100%; larvae, 39.1−86.0 %; and newly emerged adults, 51.6−84.1%.

Monitoring of RBB

Before 1950, the bugs had been one of the key pests of rice. At that time, bug monitoring had been carried out by using light traps.

A random collection of adults and larvae in the paddy field was done, including hibernating adults in overwintering sites. Seasonal occurrence of the bugs has been traced throughout the year. These data were used to determine the best time to apply insecticides in the paddy field.

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Notes

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The Rice Black Bug in Japan

Dr. Kiyomitsu Ito

Abstract

Scotinophara lurida (Burmeister), the rice black bug in Japan, had been one of the most serious pests of rice in the country before the 1960s, but after synthetic chemical insecticides came into widespread use, it was effectively controlled and was no longer considered harmful. However, because of changes in insecticide usage, injuries by this bug have recently become conspicuous in some places. *S. lurida* has one generation a year and overwinters in the adult stage. An egg parasitoid, *Telenomus gifuensis* Ashmead, was recorded as an important natural enemy, and ducks were considered effective control agents in rice fields. Several neonicotinoid and organophosphorous insecticides are effective against the bug. Studies on the biology, ecology and management of *S. lurida* conducted in Japan were reviewed.

Key words: rice black bug, *Scotinophara lurida*, damage, ecology, control

Introduction

It is probably safe to say that the pest black bug attacking the rice plant in Japan is only one species, *Scotinophara lurida* (Burmeister), though two other species, *S. horvathi* Distant and *S. scotti* Horváth are distributed in Japan, as well. The general morphology of the egg and nymphal stages of these three species has been described by Kobayashi (1963). The rice black bug (RBB) *S. lurida* is observed in mainland Honshu, Shikoku, Kyushu, Okinawa Islands, Korea, Taiwan, China, and Southeast Asia (Tomokuni et al. 1993). *S. lurida* had been one of the most serious pests of rice before the 1960s when synthetic chemical insecticides came into widespread use. These effective insecticides controlled the bugs well, and it was no longer considered a harmful pest. Moreover, it has been difficult to even find these bugs in the rice fields. The problem was so well resolved that farmers already forgot the damage caused by *S. lurida*. Thus, most biological and ecological studies were done more than

50 years ago, and very few papers on the subject matter were published between the mid-1960s and the 1990s. However, very recently, injuries by *S. lurida* have become conspicuous in some places in Japan. This change in bug occurrence may be attributed to changes in the use of insecticides in rice fields—i.e., the amount of insecticides used has decreased and the insecticide itself has changed (lower residual and narrow-spectrum insecticides have been in common use).

Biology

Life history

Overwintering adults of *S. lurida* are observed under fallen leaves, among mosses, and around the base of weeds (e.g., *Carex lanceolata* Bott) in hilly areas, especially on the sunny south parts of hills near rice fields or among weeds on levees (Fukui Agricultural Experiment Station 1926; Katsumata 1930; Tomonaga 1960). The sex ratio of overwintering adults is 1:1 (Kawase and Katsumoto 1955, Kawase et al. 1959). Moderate humidity is necessary for adults during hibernation (Kawase 1955, Kawase et al. 1959). Since the overwintering adult of *S. lurida* is intolerant of dry conditions, Katsumata (1930) considered that a hibernacula covered with snow might be suitable for overwintering adults because such places would be humid and stable in temperature (0 °C). Kawase and Katsumoto (1955) reported that the highest density in the hibernacula was 186.7 adults m^{-2}. Two other *Scotinophara* species, *S. horvathi* and *S. scotti*, are sometimes found at the same hibernacula (Abe and Ueda 1956).

Overwintered adults of *S. lurida* move into the rice field in mid- or late June (Fukui Agricultural Experiment Station 1926, Niigata Agricultural Experiment Station 1926, Katsumata 1930). Copulation usually occurs 1−2 wk after bug migration into the rice field at the bottom of the rice plant hill, lasting for 2−3 h on average, mainly from 5 p.m. to 12 midnight (Fukui Agricultural Experiment Station 1926, Katsumata 1930), or 4−10 p.m. (Niigata Agricultural Experiment Station 1926).

Females start laying eggs 6.4 d on average after copulation (Fukui Agricultural Experiment Station 1926). Oviposition occurs from 7 p.m. to 12 midnight (Fukui Agricultural Experiment Station 1926) from late June to late August; it is at its peak in late July (Katsumata 1930). Females usually lay 14 eggs as a mass in two or three rows (Fukui Agricultural Experiment Station 192,; Niigata Agricultural Experiment Station 1926, Katsumata 1930), reflecting the number of ovarioles (7 + 7) (Fukui Agricultural Experiment Station 1926, Katsumata 1930). The female takes about 1 h to lay an egg mass and stays on the mass for a while protecting the eggs (Katsumata 1930). This behavior is different from the Malayan black rice bug, *S. coarctata*, which stays for a few days after hatching (van Vreden and Abdul Latif 1986). Eggs are mainly laid in the part below the middle of the rice plant hill (both leaf sheath and leaf blade) (Fukui Agricultural Experiment Station 1926, Katsumata 1930). Eggs are sometimes laid on sedges, as well as on the rice (Niigata Agricultural Experiment Station, 1926). A female lays 3.5 egg masses on average throughout her life (Niigata Agricultural Experiment Station 1926). Newly hatched nymphs remain on the egg shells for 1−2 d (Fukui Agricultural Experiment Station 1926).

The developmental periods of each stage—egg, 1st, 2nd, 3rd, 4th, 5th and 1−5th instars—varied. They last for 5.4, 4.1, 8.7, 8.3, 9.4, 15.2, and 43.9 d, respectively (Fukui Agricultural Experiment Sta-

tion 1926); or 4.5, 3.7, 9.1, 10.6, 11.6, 12.5, and 47.1 d, respectively (Niigata Agricultural Experiment Station 1926); or 4.8, 4.4, 8.6, 6.4, 7.3, 11.0, and 37.7 d, respectively (Katsumata 1930).

Newly emerged adults mainly appear in September and move to hibernacula from the evening until about 8 p.m. (Fukui Agricultural Experiment Station 1926, Niigata Agricultural Experiment Station 1926, Katsumata 1930). Adult longevity is about 1 yr (Katsumata 1930).

Number of generations a year

S. lurida has one generation per year (Fukui Agricultural Experiment Station 1926, Niigata Agricultural Experiment Station 1926, Katsumata 1930). If overwintered adults are reared under 30 °C in April, it would have two generations by September (Katsumata 1930). Field observations in 1924 showed that copulations occurred from June 27 to August 10, eggs were found from July 8 to August 15, nymphs were found from July 18 to September 27, and new adults appeared from August 16 to October 17. In 1925,the corresponding dates were June 28−August 21, July 1−August 29, July 9−September 30, and August 13−October 23 (Fukui Agricultural Experiment Station 1926).

Pest status

As an example, the annual change in rice field area in Kochi Prefecture, where *S. lurida* occurred, is presented in Figure 1. During and after the mid-1960s, bug density in the area became much lower than that in the 1950s. This is true, even if considered on a countrywide scale. *S. lurida* had been an injurious pest of rice in the past, but, for more than 30 yr, finding this species in the field (except in a few areas) has been very difficult. The decline in pest status may be due to the widespread use of effective chemical insecticides. Since these chemicals are considered to seriously affect monophagous pest insects having one generation per year, species such as *S. lurida* and another rice bug, *Lagynoto-mus elongates* (Dallas), have been eliminated from rice fields (Nakasuji 1973).

However, circumstances have changed in some areas recently. In Ibaraki Prefecture, in spite of the very rare occurrence of *S. lurida*, it was noted that there has been a gradual increase since 2000

RBB occure d (ha)
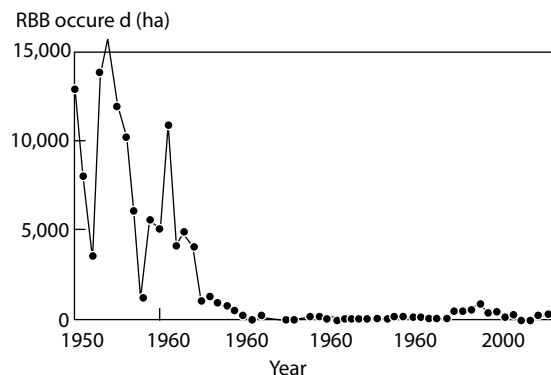
Fig. 1. Annual changes in rice area where *S. lurida* occurred in Kochi Prefecture. Data in 1975 and afterward added to Nakasuji (1973).

(Yoneyama 2005). In Mie Prefecture, a warning against *S. lurida* occurrence was issued in 2003 and 2005 (Kitagami and Nishino, 2006).

Yield loss

The following damages of rice by *S. lurida* are known: delayed growth, stunted growth, deadheart, whitehead, plant death, and decrease in number of grains (Fukui Agricultural Experiment Station 1926, Kawase et al. 1959, Kitagami and Nishino 2006). Matsuzawa and Hidaka (1952) reported that bugs were distributed evenly over entire fields, injuring rice plants. At heading, they moved to the ear, which resulted in great damage: the rice field most severely attacked showed a 50% decrease in rice production (Matsuzawa and Hidaka1952).

In Fukui Prefecture in 1924, *S. lurida* occurred in 1,053 ha of rice fields, and farmers hand-picked a total of 4,434 liters of bugs, but 227 ha had a yield loss of 20% or more (Fukui Agricultural Experiment Station 1926). In the same year, an outbreak of *S. lurida* was recorded in Sado Island in Niigata Prefecture and Enuma County in Ishikawa Prefecture. The damaged area of the former was about 200 ha and yield loss was 30% on average (Niigata Agricultural Experiment Station 1926). The damaged area of the latter was 1,677 ha and yield loss averaged 17.7% (Katsumata, 1930).

Diapause

There are no experimental reports on diapause in *S. lurida*.

Food plants other than rice

Katsumata (1930) reported on host plants of *S. lurida* other than rice, finding that nymphal development was completed on barnyard grass (*Panicum crus-galli* L.), barley (*Hordeum sativum* Zessen var. *hexastichon* Hack.), wheat (*Triticum sativum* L.), Manchurian wild rice (*Zizania latifolia* Hance), maize (*Zea mays* L.), foxtail millet (*Setaria itarica* Beauv.), and common millet (*Panicum mileaceum* L.). However, Okajima (1928) stated that rice is almost nearly an exclusive host plant. Since the host plant of *S. horvathi*, a morphologically similar species, is foxtail millet (Miyamoto, 1956), the host plants of *S. lurida* should be reconsidered.

Natural enemies

Telenomus sp. was recorded as an egg parasitoid of *S. lurida* (Fukui Agricultural Experiment Station 1926, Niigata Agricultural Experiment Station 1926, Katsumata, 1930). Hidaka (1958) studied a parasitoid, *Telenomus gifuensis* Ashmead (Hymenoptera: Scelionidae), in detail. He reported that the parasitoid had partially two generations a year in southern Kyushu and host insects other than *S. lurida* were *Nezara antennata* Scott, *Eysarcoris guttiger* Westwood, *E. ventralis* Thunb., *E. parvus* Uhler, *Dolycoris baccarum* L., *Piezodorus rubrofasciatus* Fabricius, *Acanthocoris concoloratus* Uhler, and *Riptortus clavatus* Thunb. He examined the relationship between host egg age and adult emergence rate of the parasitoid, and the results obtained were >80% when the age was 1–3 d, 54% when it was 4 d, but 0% when it was 6–7 d. He also stated that adult longevity of the parasitoid was

2.8 d when neither food nor water was supplied, 7.0 d when only water was supplied, 34.7 d when honey was supplied, and it was prolonged to 77.7 d when honeydew of aphid was supplied. Percentage parasitism of field-collected *S. lurida* eggs was 64.5% (N=2,430) in Ishikawa Prefecture during the period from July 14 to July 27, 78.7% (N=1,874) in Fukui Prefecture from July 16 to July 23, and 56.5% (N=2,483) in Miyazaki Prefecture from July 24 to August 28 (Hidaka 1958).

Fukui Agricultural Experiment Station (1926) reported that two species of carabid beetles and a ladybird (scientific names not written) were predators attacking hatched nymphs of *S. lurida*. Frogs and ducks were also observed to feed on nymphs of *S. lurida*. Katsumata (1930) reported on some carabid beetles as predators of nymphs: *Pterostichus microcephalus* Motsch. (Coleoptera: carabidae) was a common species and 1−2 individuals per rice plant hill were often observed. The insect also fed on eggs under laboratory conditions. *Agonum daimio* Botes. (Coleoptera: carabidae) fed on 3−4 instar nymphs under laboratory conditions. He also listed *Chlaenius pallipes* Gebl. (Coleoptera: Carabidae), *Anisdabis maritime* Guen. (Anisolabididae: Dermaptera), a spider, a frog (*Rana nigromaculata* Hallowell (Ranidae: Anura), and a duck as predators of *S. lurida*. A total of 145 individuals of *S. lurida* were found in the stomach when 100 individuals of *R. nigromaculata* were dissected, and the number of *S. lurida* found was larger than that in other insect species (Katsumata 1930). Hidaka (1954) described many *S. lurida* adults being caught in webs of *Meta doenitzi* Boesenberg et Strand (Araneidae: Arachnomorphae).

Oospora destoractor Del. was recorded as a fungus pathogen of *S. lurida*, and its infection rate was high during summers when temperature and rainfall are high. This fungus infected the adults and nymphs of *S. lurida* (Katsumata, 1930). From September to December, overwintering adults of *S. lurida* were infected with this fungus, but infection rate was low (2.4%) (Kawase and Katsumoto 1955).

Ecology

Life table

There is no report concerning a life table analysis of *S. lurida* in Japan thus far.

Seasonal occurrence and abundance

Rice fields

Overwintering adults of *S. lurida* started to migrate to the rice field in late June and showed a peak in mid-July (Fukui Agricultural Experiment Station 1926). Others report peaks from late June to early July (Katsumata 1930, Kawase et al. 1959). Niigata Agricultural Experiment Station (1926) reported that migration startied on June 10, peaked on June 20, and stopped in early July. Oviposition started in late June, peaked in mid-July and ceased in early August.

As adult bugs in the rice field seemed to dislike sunshine, they usually stayed at the bottom of rice plant hills during daytime, occasionally appearing on the leaves on cloudy and rainy days (Fukui Agricultural Experiment Station 1926, Niigata Agricultural Experiment Station 1926). The peak density observed was 40 adults per hill (Fukui Agricultural Experiment Station 1926).

Smaller nymphs (1st−3rd instar) usually stayed on the inner wet part of the rice plant hill (Fukui Agricultural Experiment Station 1926). Adults and nymphs occasionally fed on rice panicles (Fukui Agricultural Experiment Station 1926). Outbreaks usually occurred in summers of humid and high temperature (Niigata Agricultural Experiment Station 1926) but not in summers of low rainfall (Katsumata 1930).

Newly emerged adults started to appear in late August. The peak was in mid-September and adult emergence ceased in early October. Kawase et al. (1959) stated that the peak of appearance of newly emerged adults was in late September. These adults moved to the hibernacula from early September to late October (mainly mid-September to late September) (Fukui Agricultural Experiment Station 1926, Niigata Agricultural Experiment Station 1926, Katsumata 1930). Late-emerging adults (after mid-October) were observed to move to nearby levees, overwintering without flight due to the low temperature (Katsumata 1930).

Nonrice habitats or surrounding areas

There are no reports concerning seasonal occurrence in nonrice habitats in *S. lurida* in Japan thus far.

Flight activity and outbreak pattern

Overwintered adults of *S. lurida* were able to fly for a distance of more than 100 m (Fukui Agricultural Experiment Station 1926) or more than 500 m (Katsumata 1930). Flight occurred mainly from 6 p.m. to 10 p.m. at 20 °C or more in the absence of rain (Katsumata 1930, Tomonaga 1960). The Niigata Agricultural Experiment Station (1926) reported that mass migration was not observed and a small number of adults were attracted to light traps, though Katsumata (1930) described that overwintering adults showed some phototaxis and a total of 200 adults had been collected by a light trap for 10 d. Light trap data of Katsumata (1930) and Niigata Prefecture in 1951 (Abe and Ueda 1956) revealed that no relationship was found between trap catch and the lunar phase. This is different from the Malayan black rice bug, *S. coarctata*, which shows a clear synchronization with the lunar phase; large catches occurred during the full moon (Ito et al. 1993). Flight activity was low during the period of copulation and oviposition, even when the temperature was favorable in the rice field (Katsumata 1930).

Monitoring and field population assessment techniques

Kawase and Katsumata (1958) reported that forecasting the time of adult migration into the rice field was possible on the basis of light-trap catches and that the quantity of adults could be forecast based on the density of adults in the hibernacula in March or April. Tomonaga (1960) has derived an equation, $Y=46.85X-431.65$ ($r=0.947$), where X = adult density per 3.3 m^2 in hibernacula on April 25 and Y= maximum adult density in the rice field per 100 m^2.

Yield loss assessment techniques

Tomonaga et al. (1956) and Tomonaga (1960) studied yield loss of rice caused by infestation of *S. lurida* using a screenhouse. When overwintered adults were released on rice at densities of 4, 8 and 16 per hill from June 23 to July 29, yield loss was 60.6%, 80.6%, and 100%, respectively. When nymphs (stage not mentioned) were released at densities of 30, 60, and 120 from July 30 to September 4, yield loss was 39.1%, 72.9%, and 86%, respectively. When new adults were released at densities of 15, 30, and 60 from September 5 to October 11, yield loss was 51.6%, 73.5%, and 84.1%, respectively. These results showed that damage at the vegetative stage by overwintered adults was important (Tomonaga 1960).

Local distribution

In the early season in the rice fields, heavy infestation by overwintering adults was observed in the outer one−two rows adjacent to the levee, particularly the weedy levee (Fukui Agricultural Experiment Station 1926). As the season progresses, adult distribution became uniform (Matsuzawa and Hidaka 1952, Tomonaga 1960).

Management

Biological control

Parasitoids/parasites. Hidaka (1958) studied an egg parasitoid, *T. gifuensis*, and reported its excellent ability to find the host eggs. However, the problem was that the parasitoids usually appeared in the rice field later than the beginning of the oviposition of *S. lurida* under natural conditions. Consequently, a fairly large number of the host eggs could escape from the attack of the parasitoids. If the parasitoid could appear in the rice field much earlier, it might be possible to control the population well. The study of mass production of the parasitoid should be promoted (Hidaka, 1958).

Predators. A 3-mo-old duck was fed 0.18-0.36 liters of *S. lurida* a day (Fukui Agricultural Experiment Station 1926). When 15 ducks were released in a 70-m^2 rice field, they consumed 60−70% of the bugs within a few hours, but it is necessary for someone to keep watch on the ducks to prevent them from leaving the field (Fukui Agricultural Experiment Station 1926). A starved duck (100 d old) preyed on 200 bugs per hour initially, but this number decreased with time. Water was essential for the predation of the duck (Katsumata 1930). Abe and Ueda (1956) also pointed out that ducks were very effective in controlling *S. lurida*.

Cultural control

The earlier rice was transplanted, the more overwintering adults swarmed into the field as the adults preferred bigger plants (more shade) (Fukui Agricultural Experiment Station 1926, Katsumata 1930, Kawase et al. 1959). For this reason, the Fukui Agricultural Experiment Station (1926) recommended preparing a "scapegoat field" where rice was transplanted 1 wk earlier than the surrounding fields at

a ratio of 0.05 ha to1 ha. Farmers could concentrate on eliminating the bugs from this field. Heavy manuring and use of early-maturing cultivars increased damage, but the damage decreased under deep flooding culture (Fukui Agricultural Experiment Station 1926, Niigata Agricultural Experiment Station 1926, Katsumata 1930). High planting density (Katsumata 1930, Kawase et al. 1959) and close proximity of the field to hibernacula (Niigata Agricultural Experiment Station 1926) also brought about damage.

Before synthetic chemical insecticides came into widespread use, farmers trapped the bugs into a "boat-shaped tray" (80 cm x 15 cm x 12 cm) into which a small amount of kerosene was poured and floated between rows of rice plants. They also hand-picked overwintering adults and eggs from the field. In those days, some prefectural governments had a system of buying these adults and eggs. For instance, records showed that, in Hamochi Village in Niigata Prefecture, a total of 1,633.5 liters of bugs was purchased from July 11 to 21, and more than 21,000 egg masses from June 11 to July 21 were bought in 1925 (Abe and Ueda, 1956).

Katsumata (1930) described the deep-flooding control of eggs. Water level should be kept lower from mid- to late July (=oviposition period, females would lay eggs on the lower part of rice plant hills); the level should be kept higher to drown them. He recommended repeating this control measure twice every 3 d. Tomonaga and Yamamoto (1958) examined the ovicidal action by flooding and concluded that 0% hatchability was obtained by 4 d of dipping in water at 26.5 ºC, 3 d at 30 ºC, and 2 d at 4 ºC.

Chemical control

After World War II, many synthetic chemical insecticides were developed and examined for their efficacy against *S. lurida*. Among these, parathion, methyl parathion, BHC, and dieldrin were found effective (Kawase 1955, Abe and Ueda 1956, Mochizuki and Morita 1956, Kawase et al. 1956a,b; Kobayashi and Noguchi 1956, Kobayashi and Noguchi 1957). Timely control was very effective in reducing the field population, which resulted in reduced number of hibernating adults (Kawase 1955). Kawase and Katsumata (1958) reported that the density of overwintering adults in Ishikawa Prefecture decreased from 16.5 m^{-2} (N=1,775) in 1953 to 1.7 m^{-2} (N=1,363) in 1957 due to chemical control in the rice field. Tomonaga (1960) also showed an example in Fukui Prefecture where a 2-yr intensive cooperative control reduced the local population of *S. lurida* (Table 1).

However, since these insecticides have high mammalian toxicity, their use is now prohibited by law. At present, neonicotinoid insecticides such as thiamethoxiam, dinotefuran and clothianidin and organophosphorous insecticides such as malathion, phenthoate, trichlorfon, and EPN are registered (Japan Plant Protection Association, 2006).

Table 1. Effect of chemical control against S. lurida in Kado District, Fukui Prefecture.

Year	No. of overwintering adults m^{-2} in hibernacula	No. of overwintering adults caught by light traps
1952[a]	26.7	11,980
1953[a]	10.0	3,536
1954	1.0	90
1955	0.7	25
1956	0.9	29

[a]Intensive cooperative control carried out.

Name of country museum/institution with insect collections of rice black bugs and officer-in-charge of the collection

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The Black Bugs, *Scotinophara* spp. (Hemiptera: Pentatomidae) in Kenya, East Africa

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Abstract

Although regarded as minor pests, the rice black bugs (RBB) in the genus *Scotinophara* have, in recent years, been associated with many outbreaks. With the potential this genus has of becoming invasive in the future and becoming a threat to food security, we provide information that could be used by future workers in East Africa to identify the species with ease. We report a list of species at the National Museums of Kenya (NMK) collection, provide a key to identifying these species, and give additional information on their geographical distribution in East Africa.

Key words: rice black bugs, invasive, food security, identification key, East Africa

Introduction

Because rice black bugs (RBB) are marsh-loving insects, these sap-feeding pentatomid insects have long been associated with rice cultivation in tropical Asia. In the past and in very recent years, many outbreaks have been recorded in spite of the fact that these insects are regarded as minor insect pests of rice.

A different situation exists in the Ethiopian region. While rice had been commonly distributed and grown in some regions in both East and West Africa, no RBB problems had ever been recorded so far. As far as we know, only one species of black bug is known to be associated with rice ecosystems. The bug *Scotinophara mixta* Linnavouri was reportedly collected from rainfed lowland rice in Cote d'Ivoire, Nigeria, and Ghana. The species has not been reported yet from Kenya (Heinrichs and Barrion 2004).

Irrigated rice in Kenya is restricted to the Mwea and Ahero areas in the central and southwestern parts of the country, a kind of habitat suitable for RBB. However, to date, no report of its

occurrence had been documented. It may be in Kenya, but perhaps the lack of visible damage to rice and the rarity in number mean that little attention is placed on this insect. However, with rice being an important food crop in the region, there could be threats to food security if a species outbreak occurs and affects the rice crop.

We reviewed the collections of pentatomid bugs kept in the National Museums of Kenya (NMK) and found a number of specimens belonging to the genus *Scotinophara* Stål. In lieu of potential outbreak of this highly invasive species and its likely infestation in rice and maize farmlands in Kenya, we develop a short diagnostic description for each of the three species available in our insect collection to enable future workers to identify the black bug species in Kenya. A key to identification of the species is also provided and digital photos are also included to help workers identify the insects. In addition, information about the distribution of these species is shown in Figure 1 and Tables 1–3.

Knowledge on *Scotinophara* found in the Ethiopian region, including that of the Kenyan fauna, is based on the works of many European entomologists (Horvath 1892; Stål 1895; Schouteden 1903, 1912 a, b & c, 1937; Linnavouri 1965, 1974). From these works, a check list of Kenyan black bugs was developed.
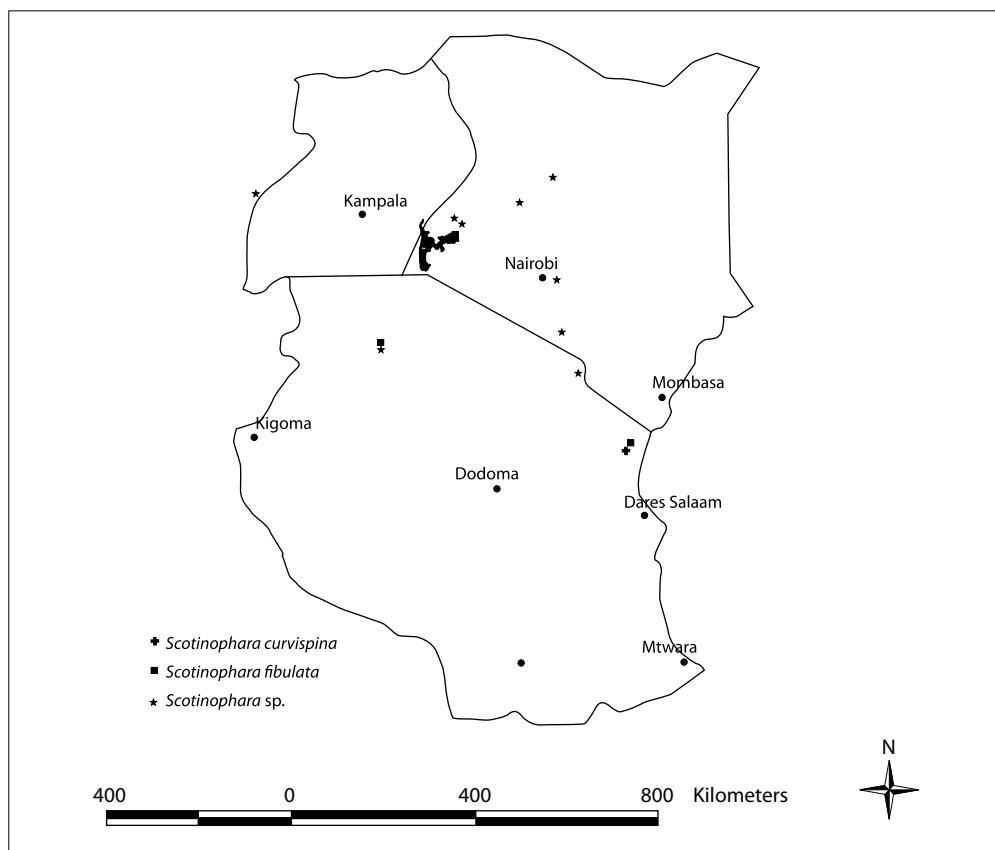
Fig. 1. Map of Kenya. (NOTE: please provide complete caption for this)

Table 1. Occurrence of *Scotinophara fibulata* Germ.

Country	Locality	Specimens (no.)
Kenya	Kiboko	1
Tanzania	Mlingano	14
"	Ilonga	25
"	Ukiriguru	2

Table 2. Occurrence of *Scotinophara curvispina* Schout.

Country	Locality	Specimens (no.)
Tanzania	Ilonga	16
"	Dar es salaam	1

Table 3. Occurrence of *Scotinophara* sp.

Country	Locality	Specimens (no.)
Kenya	Nairobi	4
"	Kaimosi	4
"	Taveta	4
"	Ngong	1
"	Baringo	1
"	Kakamega	1
"	Kajiado	2
"	Kibos	1
Uganda	Bwamba forest	1
Tanzania	Mlingano	4
"	Ilonga	8
"	Ukerewe	7

Black bugs present in Kenya

1. *Scotinophara fibulata* (Germar, 1839)
2. *Scotinophara curvispina* Schouteden, 1903
3. *Scotinophara* nr. *madagascariensis* Schouteden, 1903

Diagnostic features

1. *Scotinophara fibulata* (Germar 1839)

Small-sized brownish yellow bugs, 6.6 mm long and 3.60 mm wide across the prehumeral spines in males, and 7.30 mm long and 4.20 mm wide across the prehumeral spines in females.

The bugs have black head, antenniferous tubercles, collar, cicatrices, and body venter. Females have reddish brown body venter. The antennae are yellow brown, except the incrassate reddish brown basal segment. The legs have black femur I. Femora II and III black only in the apical one half, reddish brown in the outer latero-basal half, and brownish to light brownish red in the inner basal half. The tibiae are reddish brown to yellowish brown dorsally and dark reddish brown ventrally. All tarsi are uniformly yellow. The proboscis is yellowish brown.

The head is relatively wide anteriorly with a slightly notch middle portion. It is one and a half times wider than long, roughly punctuated, and bears short hairs. The central plate is usually shorter to as long as the lateral plates, its median area raised and the latter produces a wide and rounded anterior margin. The antenniferous tubercles cut medially, developing two unequal points, a narrowly acute inner process and a rounded outer process. The antenna has five segments and the length of the antennal segments in decreasing order is V>IV>III>II>I in males and V>IV>III>I>II in females. Both sexes have short proboscis, reaching only coxae II or just slightly beyond coxae II.

The pronotum is rough with numerous punctures and twice wider than long. The anterior lateral margin is straight, forming a laterally projected yellow spine. The lateral side is slightly sigmoid shape. The prehumeral spine is distinctly shorter than the anterior lateral spine. Anterior disc of pronotum with elevated tubercles is surrounded by yellow spots on the ridges anterior of the transverse depression.

The length of the legs in decreasing order is III>I>II in males and III>II>I in females. Tibia II is usually with three spines in the inner lateral margin arranged in vertical row.

The forewings show no closed marginal cells but have six longitudinal veins, of which the second vein bifurcates towards the apex. The hindwings have a small and less pointed vein R + M-CuA triangle coupled with poorly formed knoblike process and a quadrate fusion point of veins R and M.

Scutellum not reaching the tip of the abdomen, ratio of basal width: narrowest point and length is 2.3:1.9:3.8 in males and 2.70:2.25:4.60 in females. The tip of scutellum is subtruncate and its base has three short longitudinal bands.

The cross-sectional view of the male pygophore shows a truncate tergite X and the clasper with a deep cavity in the mid-apical tip and its outer portion strongly sclerotized. According to Linnavouri (1974), the clasper of *S. fibulata* demonstrates five forms of variations in shape.

Important features
- Laterally projected anterior lateral spine of the pronotum that is usually yellow
- Slightly sigmoid lateral margin of the pronotum
- Anterior lateral spine distinctly longer than the prehumeral spine
- Subtruncate to slightly emarginate tip of scutellum
- Cleft antenniferous tubercles with unequal processes
- Scutellum subtruncate to slightly emarginated, apex not reaching abdominal tip
- Tergite X truncate

Geographical distribution: Kenya, Uganda, Tanganyika, Sudan, Ethiopia, Zaire and Guinee (Linnavouri 1974) (Table 1).

2. *Scotinophara curvispina* Schouteden, 1903

Medium-sized blackish brown bugs, 8.50-9.10 mm long and 5.10-5.30 mm wide across the prehumeral spines.

Although blackish brown in color, it has black head, antenniferous tubercles, cicatrices, lateral margins and spines of the pronotum, and body underneath. The antennae are reddish brown with the apical three-fourths of segment V brownish yellow. The legs are black with reddish brown tinge on the dorsum of tibia III and all tarsi are brown.

The head is wider than long with an apical median cut formed by the central plate being shorter than the lateral plate. The anterior lateral margin of the lateral plate slightly oblique and not rounded as shown in *S. fibulata*. The antenniferous tubercles are cleft, the lower inclined part thin and narrow, while the raised portion obtuse. The length of the antennal segments in decreasing order is V>IV=III>II>I. The proboscis reach is between coxae II and III.

The pronotum is two times longer than wide, roughly punctured, and clearly covered with hairs. It has a concave anterior margin, cattle hornlike anterior lateral spines projected forward that curves near the sides of the compound eyes, serrate and medially convex lateral margins and moderately acute prehumeral spines. The anterior median disc has elevated humps anterior of the transverse groove. The prehumeral spines are shorter than the anterior lateral spines.

The legs bear no spines in the inner lateral sides of tibia II. The length of legs is III>II>I.

The forewings bear three closed marginal cells and six longitudinal veins. The wing's corium has a yellow line running somewhat parallel to the vein R & M towards the tip. The hindwings have a large R +M-CuA triangle and the merging point of veins R and M distinctly longer than wide.

The scutellum is almost at the tip of abdomen, its anterior end rounded and the ratio of basal width:narrowest point:length is 3.40:2.65:5.0. The hairs present on the anterior tip of the scutellum relatively long and each hair is approximately as long as the distance between two punctures.

The cross-sectional view of the pygophore shows the semi-truncate to slightly emarginated tergite X and the clasper with a medially concave anterior margin.

Important features
- Distinct antenniferous tubercles with a small and short inwardly curved process and a long and pointed outer process
- Cattle hornlike anterior lateral spine of the pronotum
- Distinct cavity below the anterior lateral spine of the pronotum
- Serrated and convex lateral margin of the pronotum
- Absence of inner lateral tibial spines in leg II
- Shape and hair pattern in the clasper

Distribution: Kenya and Tanganyika, Table 2.

3. *Scotinophara* sp.

Medium-sized dull brown yellow bugs, 7.40 mm long and 4.40 mm wide across the prehumeral spines in males, and 8.00 mm long and 4.50 mm wide across the prehumeral spines in females.

The dull brown bug has yellow mottles on the pronotum, scutellum, and forewings. The head is also black, similar to the antenniferous tubercles and scutellar pit. The antennae are yellow but reddish brown along apical three-fourths of segment V. The proboscis is yellow. The legs are black to reddish brown but femora II and III blackish brown along apical one half and reddish brown in basal half. The coxa of leg I is black but II and III are reddish brown. The head and thorax black ventrally and abdomen ventrally reddish brown with yellow spots around the spiracular areas.

The head is coarsely punctured and covered with short hairs. It is about 1.6 times wider than long and notched medially due to the shorter central plate and longer and expanded lateral plates. The antenniferous tubercles are minutely cleft, the elevated outer process rounded in males. The antennae are almost subequal in both sexes, the order of length is V>III>IV>I>II. Proboscis reach anterior of coxae III in females and between coxae II and III in males.

The pronotum is twice wider than long, coarsely punctured, and hairy. Anterior lateral margin narrow to slightly concave to straight with the spine projected latero-forward. Lateral margin convex to sinuate towards the prehumeral spines. Prehumeral spine more robust than the anterior lateral spines but equal in length. Cicatrices with moderalely elevated humps.

The legs have four spines in the inner lateral sides of tibia II, length of legs is III>II>I in both sexes.

The forewings have two closed marginal cells and five longitudinal veins. First closed marginal cell about twice the size of the second cell. The second longitudinal vein divided apically.

The cross-sectional view of the pygophore shows the cleft tergite X in males. The clasper has a narrow median posterior plate and a sharply pointed tip of blade directed laterally. Aedeagal cap has a deeply concave lateral sides.

Important features
- Apically narrowed central plate and expanded lateral plate
- Shape and direction of the anterior lateral spine
- Convex to slightly sinuate lateral margin of pronotum
- Forewings veination
- Presence of four tibial spines in leg II

Distribution: Kenya, Table 3.

Identification keys

1. Lateral margins of pronotum serrated; anterior lateral spine cattle hornlike.............................
....*Scotinophara curvispina* Schouteden
1. Lateral margins of pronotum not serrated; anterior lateral spine projected laterally.............. 2
2. Lateral margins of pronotum sigmoid; anterior lateral spine yellow projected laterally, base of spine with a small V-shape cavity; lateral plate of head wide anteriorly...................................
....*Scotinophara fibulata* (Germar)
2. Lateral margin of pronotum slightly convex towards the anterior; anterior lateral spine projected obliquely upward; base of anterior lateral spine with a moderately deep cavity; lateral plate of head narrowed anteriorly ....*Scotinophara* sp.

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Scotinophara lurida (Hemiptera: Pentatomidae) in Korea

Hunsung Kim and Joon-Ho Lee

Abstract

In Korea, *Scotinophara lurida* (Burmeister) has been considered a minor pest in rice since it was first reported in 1966. Since 1997, it has increased in occurrence and distribution, causing damage in some provinces. It has one generation per year and overwinters as an adult in habitats near rice fields, with hillocks as the preferred overwintering habitat. Overwintering adults are in the reproductive diapause state and the beginning and termination of diapause are affected by photoperiod and temperature. A degree-day model for immigration flight of overwintered adults was developed, which enables us to predict the timing and daily and/or accumulative proportion of immigration. *S. lurida* occurs in rice fields from early June to mid-October and shows a distinct phenological change. A phenology simulation model was developed to predict the phenology of *S. lurida* in the field. The spatial distribution pattern of overwintered adults and eggs of *S. lurida* are random, while nymphs and new adults mainly exhibited an aggregated distribution pattern. The spatial pattern of *S. lurida* showed strong temporal stability throughout the season and the spatial pattern of the previous developmental stage affects the spatial pattern of the following developmental stage. Besides rice, six plant species could be alternative hosts for *S. lurida*. Three natural enemy species of *S. lurida* were observed. Management of *S. lurida* in Korea is mainly based on chemical control.

Key words: *Scotinophara lurida*, spatial distribution, model**,** biology, ecology

Introduction

In Korean rice fields, 21–28 hemipteran species are known to occur (Go et al., 1988; Cho et al., 1991; Park et al., 2004). Of them, two species, *Scotinophara lurida* Burmeister and *S. horvathi* Distant, cause damage on rice in some provinces (Park et al., 2004), and *S. lurida* has occurred in higher density than *S. horvathi* in most of the rice fields.

In Korea, the presence of *S. lurida* was first reported in 1966 (Koo, 1966). Due to its low occurrence levels, it has been considered a minor pest. However, in 1997, its population abruptly increased up to outbreak proportion and caused a serious problem in places in the west coastal region such as Seosan-si and Dangjin-gun, Chungcheongnam-do (Lee et al., 2001). Because almost no study was conducted on *S. lurida* in Korea until 1996, very limited information was available to deal with it. Therefore, since 1997, several studies have been conducted to elucidate its biological and ecological characteristics. Also, efforts are now being made to determine the long-term effect of climate change (such as global warming) on the population dynamics of *S. lurida* in Korea.

Biology

Life history

In Korea, *S. lurida* produces one generation per year and overwinters as an adult in habitats near rice fields (Lee et al., 2001). Overwintered adults then fly into the rice fields during the early rice-growing season. Eggs are laid in batches (12-14 eggs per batch) on the basal parts of the rice plants. The mean total fecundity of a female *S. lurida* was 234.5 ± 142.6 (SD) under greenhouse conditions, with daily average temperature ranging from 19.98 to 30.96 °C (Kim and Lee, 2007). First-instar nymphs hatched out of eggs usually do not disperse and aggregate together until they develop into the second-instar stage. Second- and third-instar nymphs usually stay and feed on the basal part of rice plants. Fourth- and fifth-instar nymphs move up to and feed on the grains of rice plants when the rice plants reach the heading stage. The new adults move back to overwintering habitats near rice fields at the end of the rice-growing season.

Pest status

S. lurida has been initially considered a minor pest. Then, since 1997, it has increased in occurrence and distribution, causing frequent damage on rice in several provinces (Lee et al. 2001). Figure 1 shows the changes in *S. lurida* occurrence in Korea from 1997 to 2001, mainly being limited to the west coastal area in 1997 but occurring in most of the rice-growing regions in 2001. Since 2001, occurrence level of *S. lurida* has stabilized and has even decreased, but it still has the potential to do some damage in some regions if not controlled.

Overwintering

Overwintering habitats

Overwintering habitats of *S. lurida* are usually paddy levees, banks, and hillocks, which are located near paddy fields. The hillocks seem to be the most preferred overwintering habitat. Lee et al. (2004) found that 78.9% of overwintering adults were found in a hillock, while 15.8% and 5.3% of them were found in banks and paddy levees, respectively. One important aspect of overwintering habitats, regardless of habitat type, is that it faces south in order for sunlight to reach it mostly during the day. Also,
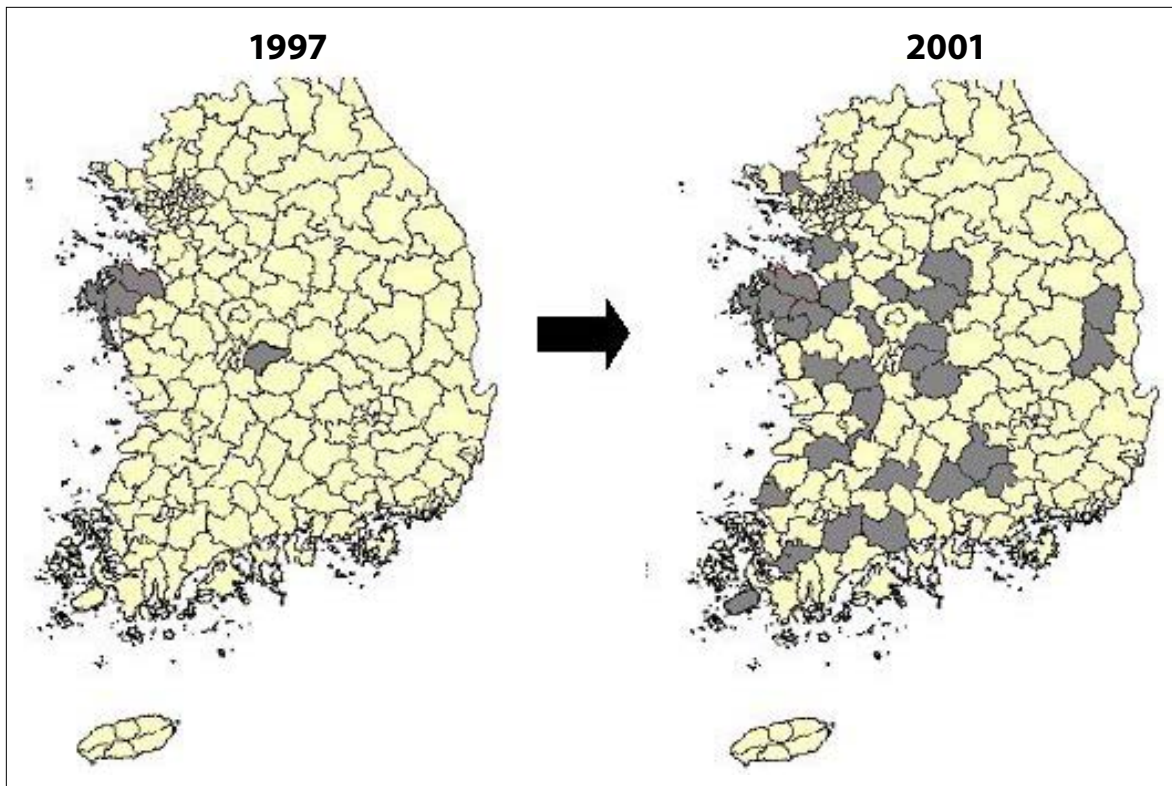
Fig. 1. *S. lurida* regions of occurrence in 1997 and 2002 in Korea. Black-colored regions are where *S. lurida* occurs.

almost all the overwintering habitats where adults were found have some degree of slope. It seems that *S. lurida* prefers overwintering habitats where the soil remains somewhat dry and warm.

Overwintering adults are usually found in clusters. Two to more than 30 adults are aggregated together in one spot. Beneath the crevices of soil, small cracks of stones or rocks, and underneath fallen leaves can adults be commonly found. In general, a higher number of overwintering adults are observed in soil crevices than underneath the fallen leaves (unpubl. data). Lee et al. (2004) found 68.4% of overwintering *S. lurida* beneath the crevices of soil, whereas 31.6% were underneath the fallen leaves.

Reproductive diapause

Overwintering adults are in the reproductive diapause state. There is no sign of development of the ovary or accessory glands until early June in overwintering adults. They were found to be fully developed in overwintered adults collected from rice fields in late June (Cho, 2004). It appears that the development of ovary or accessory glands of overwintered adults begins after they move into the rice fields.

Photoperiod and temperature have an effect on inducing and terminating the reproductive diapause of *S. lurida*. Cho (2004) conducted a series of experiments to examine the factors influencing the induction and termination of reproductive diapause. Under high temperature condition (>30 °C), *S. lurida* did not enter reproductive diapause, regardless of photoperiod. Meanwhile, in mid-temperature condition (20-25°C), it exhibited critical photoperiodic responses in entering reproductive diapause state. In low temperature condition (< 15 °C), *S. lurida* entered reproductive diapause even under a long photoperiod condition. Also, *S. lurida* seemed to be more sensitive to photoperiod and temperature in inducing diapause in the fourth-instar than in the adult stage.

Termination of reproductive diapause of *S. lurida* was enhanced as photoperiod and temperature increased (Cho, 2004). When temperature condition is above 15 °C, the reproductive diapause could be terminated regardless of photoperiod. However, at <15 °C, it could not be terminated with any photoperiodic combinations. Cho (2004) also found that topical application of fenoxycarb (juvenile hormone analogue) accelerated the termination of reproductive diapause of field-collected overwintering adults.

Cold hardiness

The mortality of overwintering adults may be closely related to temperature conditions during the winter period, not only in terms of how low the temperature condition is but also how long the low temperature period lasts. Cho (2004) examined the supercooling point, defined as the temperature at which ice nucleation occurs, of *S. lurida* at each developmental stage and, also, the survival of *S. lurida* in various combinations of low temperatures and maintained durations. The average supercooling points of laboratory-reared (in the condition of 25 °C and 16 L: 8 D-h photoperiod) *S. lurida* varied with developmental stage, ranging from -7.6 °C in the adult stage to -10.7 °C in the first-instar stage. When the field-collected adults were examined, it varied, depending on the collection date; significantly lower for adults collected in January than in December, February, March, and April. Also, only the adults collected in January showed significantly lower supercooling point than the laboratory-reared adults.

When the egg, first- and third- instar-, and adult stages of laboratory-reared *S. lurida* were exposed to −10 °C condition up to 60 min., survival decreased significantly as exposure time increased. As for adults collected on various occasions (from November to May) and were exposed to various combinations of low temperature (-5, -10, and −15 °C) and exposure durations, the survival rate varied, depending on collection date, temperature, and exposure duration. When they were exposed to −5 °C, no adults collected in November were able to survive up to 1 d of exposure duration, while those collected in February showed 100% survival. The survival rate of adults exposed to −5 °C for 1 d increased from 0% among those collected in November to 100% among those collected in February and then, it decreased to 80 and 70% among those collected in April and May, respectively. When exposed to −10 °C, adults collected only in January and February were able to survive up to 50 min. No survival was observed at −15 °C for 50-min exposure condition.
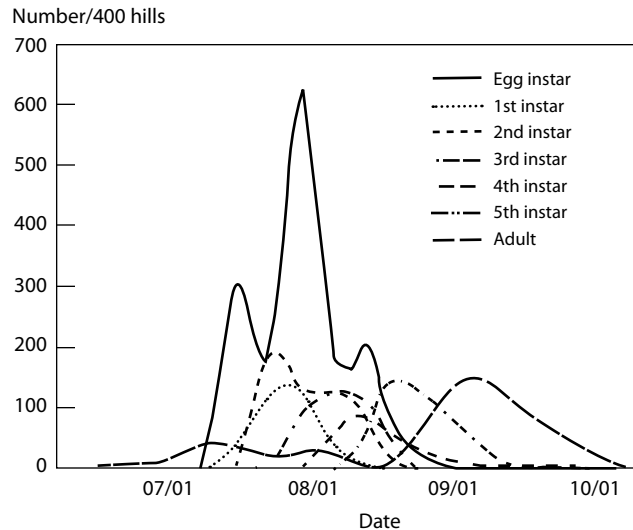
Fig. 2. Phenological changes of _S. lurida_ in rice fields (Dangjin Hannong experimental field, 2000).

Food plants

Even though rice is considered a main host plant species for _S. lurida_ in Korea, there are some other plant species on which it completes development. Lee et al (2001) showed that some upland crops such as barley (_Hordeum vulgare_ L.), wheat (_Triticum aestivum_ L.), and maize (_Zea mays_ L.) could be alternative host plants in laboratory-feeding experiments. They also found that _S. lurida_ developed to an adult on weed species such as barnyard grass (_Echinochloa crusgalli_ (L.)), flat sedge (_Cyperus serotinus_ Rottb.), and water chestnut (_Eleocharis kuroguwai_ Ohwi).

Natural enemies

No reports have been made on natural enemies of _S. lurida_ in Korea. However, during our field studies, we observed a water strider (_Aquaris paludum_ (Fabricius)) and a wolf spider (_Pirata subpiraticus_ (Boes)) attacking nymphs and adults. Also, we found an unidentified egg parasitoid species. Efforts should be made to survey the natural enemies of _S. lurida_ in the future.

Ecology

Seasonal population dynamics

S. lurida shows a distinct phenological pattern in the rice field (Fig. 2). In rice fields, overwintered adults are usually first observed in mid-June, reaching a peak density in early to mid-July. Eggs begin to occur in early July, then reach a peak in mid- to late July (Fig. 2; Lee et al. 2004; Kim et al. 2007). First-instar nymphs occur from mid-July to early August and 2nd-, 3rd-, 4th-, and 5th-instar
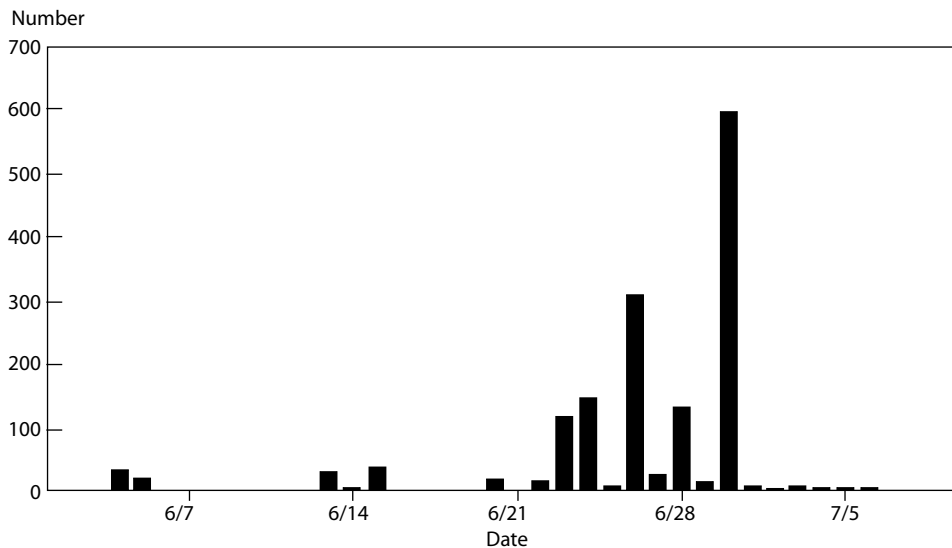
Fig. 3. Light trap catches of overwintered _S. lurida_ adults (Daesan, 1999).

nymphs mainly occur from late July to mid-September. New adults start to appear in mid-August and reach a peak in mid-September. From mid- to late September, new adults start to move back to overwintering habitats (Lee et al. 2004, Kim et al. 2007).

Immigration flight

Overwintered adults begin to move into the rice fields in late May–early June, and the peak time for immigration is late June–early July (Kim and Lee, 2007). After the peak flight time, immigration drastically decreases and almost no immigration occurs after mid-July (Fig. 3). Most of the overwintered adults seem to move directly from the overwintering sites to the rice fields. We observed a high population number of overwintering adults in overwintering habitats until early June.

Based on our 3-yr light trap studies, we developed a degree-day model for immigration flight of overwintered adults using a two-parameter Weibull function (Kim and Lee, 2007). The base temperature (7 °C) for the flight of overwintered adults was determined as the temperature that yielded the low coefficient of variation (CV) for degree-day points at first and 50% cumulative capture, and showed higher accuracy in overall model prediction. The empirical model showed relatively high accuracy in predicting the proportion of immigrating adult population and the time (Fig. 4). Also, there was a high linear relationship between light trap capture and field population density of overwintered adults (Fig. 5).

Phenology simulation model

A phenology simulation model of _S. lurida_ was developed to predict its phenological change and occurrence levels in the rice field (Kim and Lee, 2007). The major components for the model were

Cummulative % capture

Degree-day (Base temp. 7ºC)
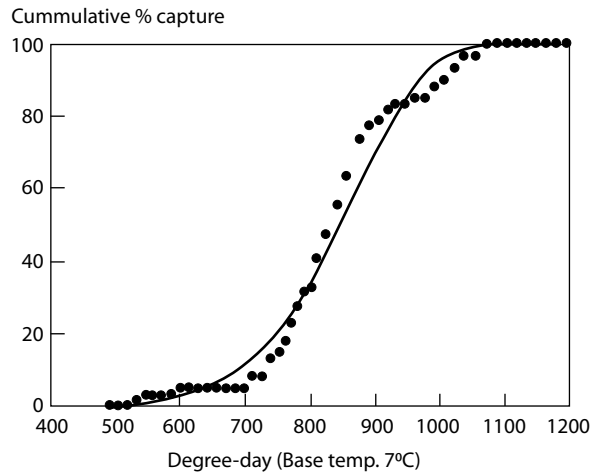
Fig. 4. Observed and predicted cumulative capture of overwintered *S. lurida* adults in an experimental rice field in Yesan, 2002. The observed data were collected daily (• observed, — predicted).

Field density
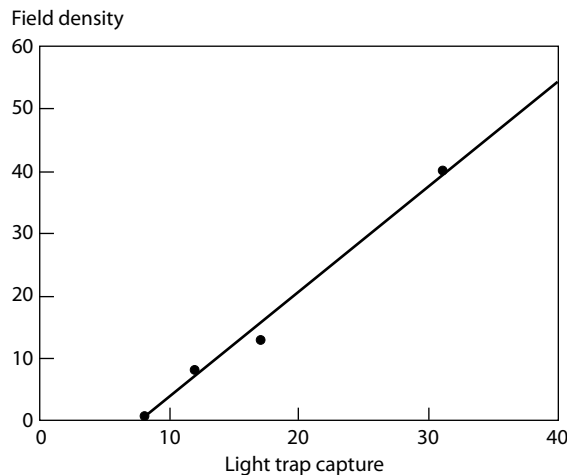
Light trap capture

Fig. 5. High linear relationship between number of overwintered *S. lurida* adults observed in rice fields and those captured in light traps ($r^2 = 0.99$, Dangjin, 2000).

a degree-day immigration flight model of overwintered adults, stage emergence models composed of a temperature-dependent developmental rate function and a cumulative distribution function of development times for the respective stages, and the adult oviposition model composed of average total fecundity, cumulative oviposition rate function, and survival rate function. The simulation model could predict the time and occurrence level of each development stage with relatively good accuracy.
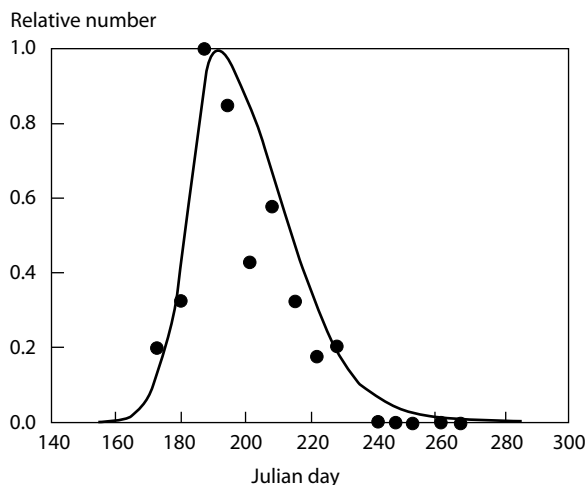
Fig. 6. Proportional patterns of *S. lurida* (observed [●] and simulated [-]) in overwintered adult stage. The numbers of *S. lurida* population were scaled to a ratio against the respective peak number. Observed data were collected in the Dangjin experimental field in 2000.

When the model was evaluated by comparing the model outputs with field-sampled data, the model predictions basically followed the pattern of observed data (Fig. 6).

Spatial distribution

Kim et al. (2007) conducted samplings of *S. lurida* in two rice fields for 2 yr and analyzed the spatial pattern of each developmental stage of *S. lurida* in the field and also, the temporal stability of the spatial patterns using spatial analysis by distance indices (SADIE). SADIE provides methods to measure overall spatial pattern for a single set of data (Perry 1998) and to test spatial association between two sets of data (Perry and Dixon 2002). It provides an index of aggregation (I_a) and overall clustering indices ($\overline{v_i}$ and $\overline{v_i}$) to examine the overall spatial pattern for a single data set and an index of association (X) to test whether two data sets are spatially correlated.

When overwintered adults move into the rice field from an overwintering habitat, they appeared to land on the rice field randomly. Kim et al. (2007) showed that overwintered adults mainly exhibited random distribution pattern having an index of aggregation (I_a) value close to 1. The random distribution pattern of overwintered *S. lurida* seemed to result in random distribution pattern of eggs. It appears that randomly landed overwintered adults would rarely disperse for oviposition and lay eggs without much discrimination of host plants. Most of the I_a values for nymphs of *S. lurida* were >1, indicating an aggregated distribution pattern. The sedentary life style of nymphs probably enhances the aggregated spatial pattern (Kim et al., 2007). The aggregated spatial pattern is common for newly emerged adults, having I_a values >1. The strong aggregated spatial pattern exhibited by
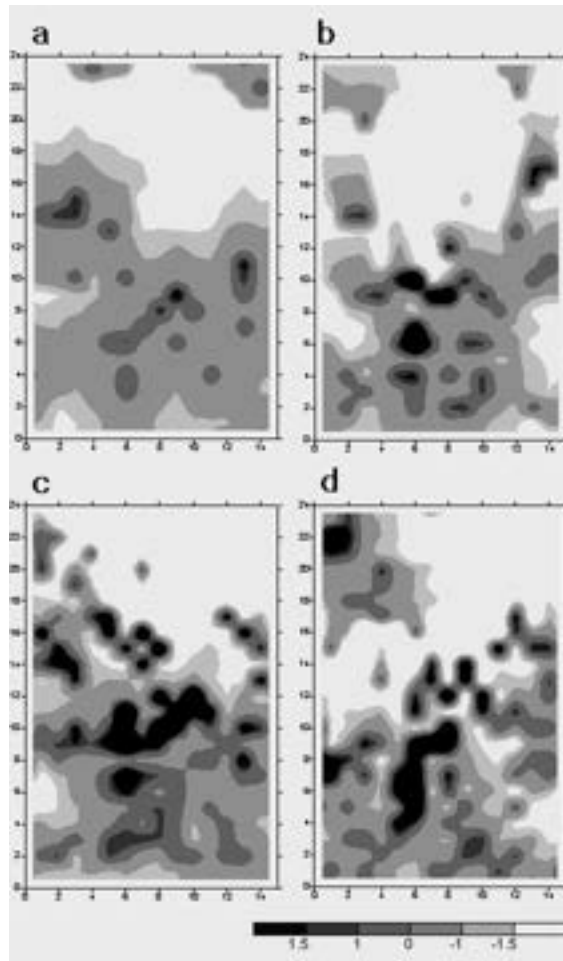
Fig. 7. Maps of clustering (v_i, v_j) for *S. lurida* in the Dangjin rice field in 2000. a) overwintered adult, b) egg, c) nymph, d) new adult. The $\overline{v_i}$ indicate the overall index of clustering into patchiness. The $\overline{v_i}$ indices indicate the overall index of clustering into gap. Large positive values of v_i (v_i > 1.5) indicate patchiness, while large negative values of v_j (v_j < -1.5) indicate the clustering into gap.

newly emerged adults becomes random as they move back to the overwintering habitat in the later part of the season.

The spatial pattern of *S. lurida* is temporally very stable throughout the season and the distribution of overwintered adults affected the spatial pattern of later developmental stages (Kim et al., 2007). As shown in Figure. 7, the position and size of clusters (gaps and patches) were highly consistent throughout the developmental stages of *S. lurida*. Large gaps (white part of the map) presented at the upper portion of the field in the contour map for overwintered adult are consistent with those of egg, nymph, and new adult. Also, large patches (black part of the map) presented mostly from mid to lower portion of the field are consistent with those of egg, nymph, and new adult.

Management

The occurrence of *S. lurida* is usually high in rice fields near the hillocks. Thus, careful monitoring is needed in those fields. Management of *S. lurida* in Korea has been mainly dependent on chemical control because of very limited biological and ecological information on this insect. Early seasonal application of carbofuran has been recommended to farmers to control immigrating overwintered adults in the field; Lee (2001) found that an application of carbofuran at the peak immigration time caused 95% mortality and the application of carbofuran in the early season (early June) caused 74% morality.

Results of recent studies on *S. lurida,* such as those dealing with spatio-temporal patterns and phenology simulation models could be an important basis for developing a rational management strategy for *S. lurida*. These information will greatly reduce the time and effort for sampling and monitoring and also improve the control tactics for *S. lurida*.

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Notes

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Some Studies on Malayan Black Bug, *Scotinophara coarctata,* in Malaysia

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Abstract

The rice black bug (RBB) is considered an occasional pest of rice in Malaysia. Outbreaks of bug infestation were more frequently reported during the pre- and early post-WWII period, when rice was planted for only one season annually. However, RBB infestation became high during the 80s and early 90s. Since then, occurrence has been sporadic and limited to a few rice-growing areas. Although the bugs are quite commonly found attracted to street lights, especially during the full moon, their number has not been found to correlate to crop damage. Due to its pest status, not much research has been conducted on RBB in the country, although the Malaysian Department of Agriculture, through its surveillance unit, kept good records of pest infestation in the country. Some of the studies conducted on the biology, ecology, damage, and survival of RBB, and on insecticide screening were reported here. In view of current developments regarding RBB infestations in neighboring countries, as well as indications of development of insecticide resistance, more serious attention has to be given to this insect pest to prevent it from becoming a serious pest.

Introduction

Though rice is a staple food in Malaysia, the rice-growing area in Peninsular Malaysia is only 400,000 ha, occupying about 12% of the cultivated agricultural area. These are concentrated mainly in eight designated granary areas in Peninsular Malaysia (Fig. 1). Among them, the Muda irrigation area is the largest, with a total of more than 96,000 ha of planted area. The average farm size in Muda is only 1.67 ha, while in Kemubu (another rice-growing area in the east coast of Peninsular Malaysia), farms are even smaller (0.7 ha). At the other extreme is a rice estate started by FELCRA in 1982 at Seberang Perak, which has 5,000 ha of land with a standard plot size of 1.2 ha. The centrally managed rice operation has attained an average yield of more than 5.5 t ha^{-1}. There are also a number of

intermediate-sized areas cooperatively managed by farmer groups and private entrepreneurs. The perceived trend is that the size of farmholdings will increase in the future.

Malaysia's birth rate is anticipated to remain high relative to that of developed nations, and rice production has to meet the demand of the increasing population. A current understanding of the population dynamics of rice brown planthoppers (BPH) in Malaysia allows us to develop suitable strategies for the management of this serious rice pest.

Yunus and Ho (1980) reported a total of 150 insect species that attacked rice, but only about 20 caused significant yield losses. Vreden and Abdul Latif (1986) listed 12 species of noxious insect species found in rice that are of major economic importance and another 20 species as minor pests. Tan (1981) listed 11 insect species, including *Scotinophora*, as major pests of rice.

Normiyah and Chang (1996) reported that more than 60% of the farmers in Muda and Kemubu recognized paddy pests such as rice bug (*Leptocorisa* spp.), Malayan black bugs (*Scotinophara coarctata*), leaf feeders, and stem borers. With regard to BPH, only farmers in the Muda area could recognize them, whereas the farmers in Kemubu did not even mention it. This was probably due to the fact that BPH was a constant threat to Muda farmers. Increase in cropping intensity, use of high-yielding varieties, and increased use of inorganic fertilizers have been cited as major causes of higher planthopper incidence.

Natural enemies play an important role in suppressing rice pests, especially the BPH population. Misuse and inappropriate choice of insecticides during the early crop season will adversely affect natural enemy populations, often resulting in BPH outbreaks in the later crop period. This disturbed/destabilized environment with impoverished natural enemies appears to promote rapid increase of BPH populations, since BPH is well adapted to fully exploit the imbalance, often resulting in hopperburn.

Rice black bugs, *Scotinophara coarctata* (Fabricius), locally known as *kutu beruang* is considered an occasional pest in Malaysia. Although RBB outbreaks occurred sporadically, it is considered more of a nuisance when the bugs get attracted to street lights and enter human dwellings. In the past, when only one crop of rice was planted annually, RBB were considered a major pest with outbreaks frequently reported. With the current practice of double cropping of rice, incidences of black bug outbreak have been less common and restricted to a few rice-growing areas. Infestation by black bugs and the attendant crop losses caused were reportedly high during the 80s and early 90s. Since then, the problem has become less important with only a few hectares of rice areas being infested. However, with reports that the bugs are becoming more resistant to the recommended insecticides, more serious attention has to be given to prevent any major outbreak of the pest in the future.

The importance of Malayan black bug

One of the earliest documentations of *Scotinophara coarctata* on rice in Malaysia was a report by Lewton-Brain (1919) on paddy in Pahang. Yusope (1920) reported stem borers as common pests of paddy. *Scotinophara (Podops) coarctata, Schoenobius bipuncifer, Nephotettix bipunctata,* and *Leptocorisa variconis* were the other insect species reported. Jack (1923) mentioned also that the
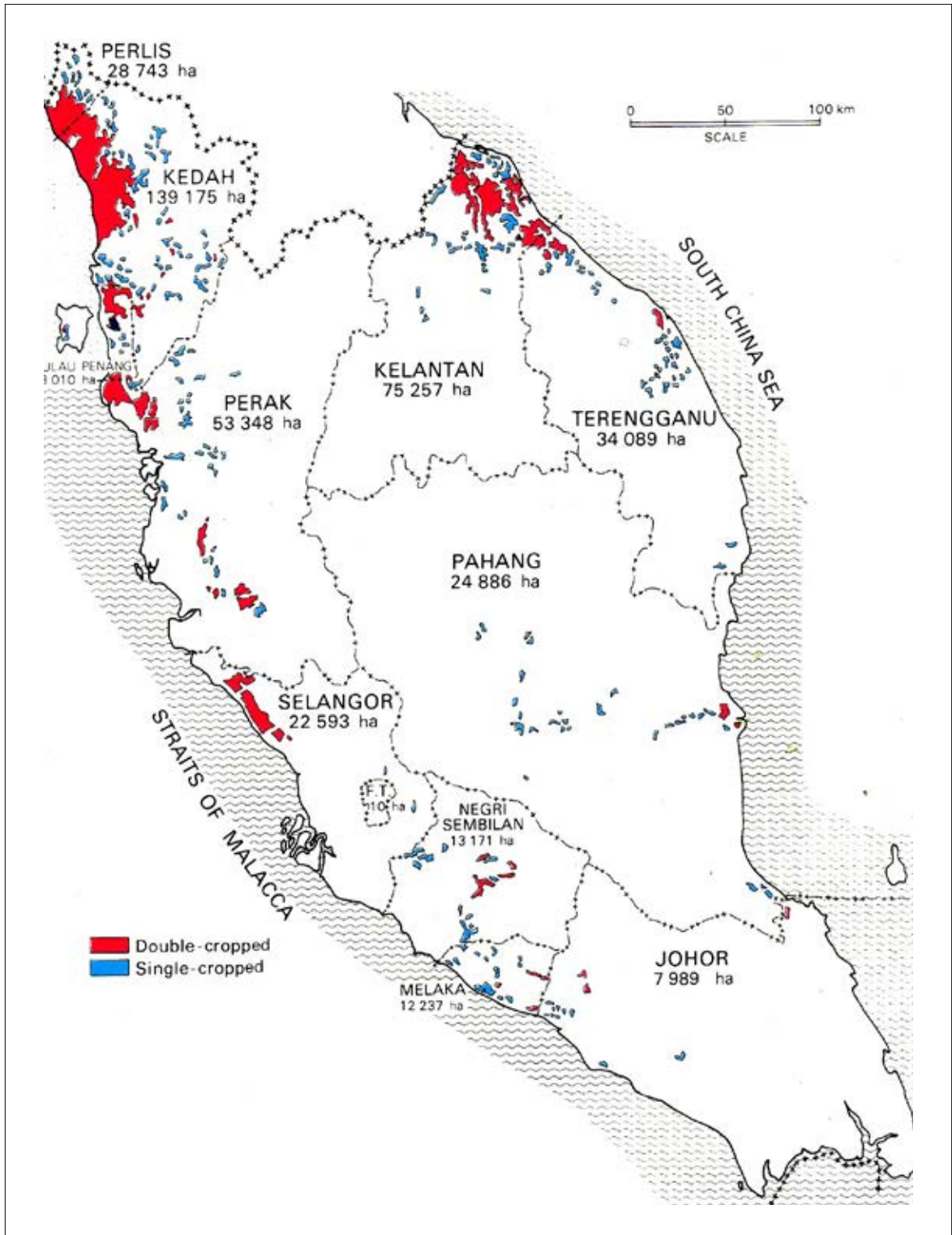
Fig. 1. Rice-growing areas in Peninsular Malaysia.
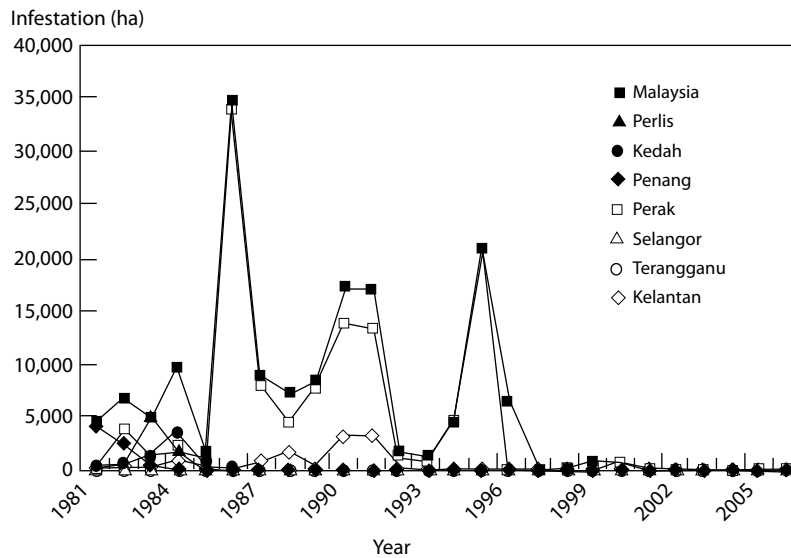
**Fig 2. Infestation (ha) by Malayan black bug in Malaysia (1981-2006).
Source: Muda Agriculture and Development Authority, FELCRA Seberang Perak and
Department of Agriculture Pest Surveillance and Forecasting Section.**

chief paddy pests that sucked plant sap were *Scotinophara* (*Podops*) *coarctata*. Miller and Pagden (1930), on the other hand, recorded 74 insect species on paddy. *Scotinophara coarctata* was among the most important pests of paddy that included also *Leptocorisa acuta, Sogata pallescens, Diatraea auricilia, Schoenobius incertellus, Sesamia inferens, Nymphula depunctalis, Spodoptera mauritia,* and *Spodoptera pecten*.

An outbreak of *S. coarctata* was reported as early as 1924 in Pahang, where the entire rice area was completely destroyed. Outbreaks were also reported in 1930 in Perak (Corbett 1931), in Johore in 1936 (Corbett 1937), and in Perak and Seberang Perai, Penang, in 1946 (Burnett 1947). The outbreak of *S coarctata* was again reported in Perak in 1947 (Burnett 1948).

After double cropping, *S. coarctata* was no longer regarded important as outbreaks occurred only sporadically. However, it become a serious pest of rice in Malaysia in the 80s and early 90s, especially in Kerian, Perak, and both within and outside MADA. Occurrence has recently increased, especially in the FELCRA rice estate and in Kelantan. It is also a serious pest in dry cultivated paddy. Figure 2 shows the infestation record in Malaysia from 1981 to 2006.

The highest infestation recorded was in 1986 when 35,000 ha of paddy were infested; and again in 1995, when 21,000 ha were infested. Most of the infestations occurred in the state of Perak, especially in the Sg Manik/Kerian area. The other granary areas (Muda in Kedah, Kemubu in Kelantan, and Sekinchang/Tanjung Karang in Selangor) did not experience heavy infestation.

Lately, low infestation by Malayan black bug was noted in all granary areas, especially Muda (Fig. 3), but it increased in FELCRA Seberang Perak (Fig. 4). The 2007 off-season record for FEL-CRA Seberang Perak was the highest, with 30% of the area infested.
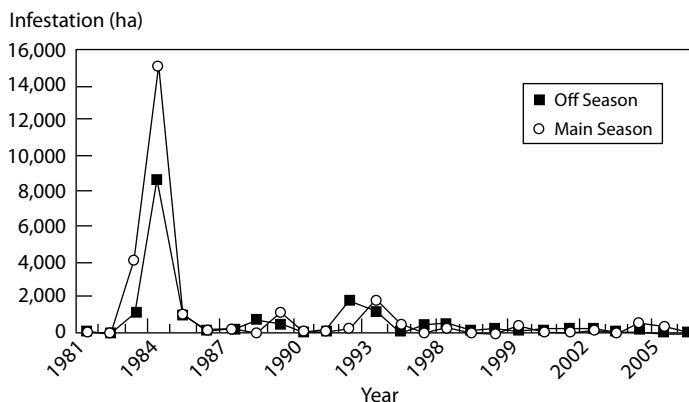
**Fig. 3. Infestation (ha) by Malayan black bug in Muda.
Source: Muda Agriculture Development Authority.**
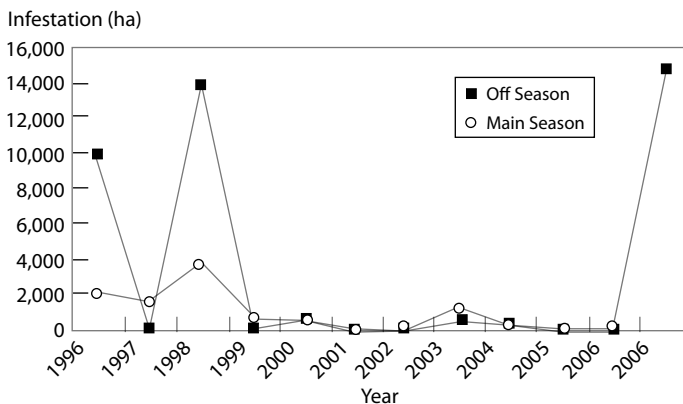
**Fig. 4. Infestation (ha) by Malayan black bug in FELCRA Seberang Perak.
Source: FELCRA Seberang Perak Surveillance Unit.**

Biology

Besides *Scotinophara coarctat*a, four other species of *Scotinophara* have been recorded in Peninsular Malaysia: *S. lurid*a, *S. bispinosa*, *S. cinerea,* and *S. malayensis*. Except for *S. malayensis*, the other species have been listed as pests of rice. At present, *S. coarctata* is the most important rice pest. Though a female bug is bigger than a male, size alone cannot be used as criterion to differentiate the sexes. However, the female ovipositor can be seen protruding out of the last abdominal plate.

The egg is grey to pink in color and is deposited in rows. The total number of eggs laid by a female can reach 683 in 104 d. Incubation period varies from 4 to 7 d. The female protects her eggs by covering these with her body (Fig. 5).

The nymphs are light brown ventrally and dark brown dorsally. Corbett and Yusope (1924) reported six nymphal stages, which take an average of 32 d to complete. Abdul Latif et al (1982)

Fig. 5. Female *Scotinophara coarctata* protecting her eggs.

reported that the bug undergoes five nymphal stages and reaches the adult stage in about 35 d. The total life cycle under normal condition takes 1 mo, but under dry condition, it is doubled (Vreden and Abdul Latif, 1986). Adults are dark brown to black in color and are well adapted to a variable environment. Observations by Corbett and Yusope (1924) showed that the female lives for a maximum of 212 d, that of the male is only 27 d.

Yield losses

Both nymphs and adults feed at the base of the plant, causing yellowing and stunting. Heavy feeding by *S. coarctata* causes the plant to dry up completely and to show symptoms similar to hopperburn caused by BPH (Figs. 6 and 7). Lim (1975a, b) observed that, with one insect per plant, plants die within 16-17 days, while it only takes 2 d with 20 insects per plant. Yellowing also occurs when an average of eight bugs per hill are found.

Surveys carried out in 1979 showed outbreaks occurring in the east coast of Peninsular Malaysia, where several locations in the Besut area had insect numbers as high as 30-50 per hill. In the west coast, about 200 ha of paddy area in Kerian and South Kedah were affected and counts were as high as 40-60 bugs per hill. However, only 1.6 ha of rice area in South Kedah was found to have hopperburn. In other parts of Perak, close to the area, *Scotinophara* was also abundant but only near street lights at night.

Based on the empty-grain pot studies, correlation between number of filled grains and number of black bugs per hill was determined. It was shown that, when bugs attacked during tillering stage, the number of filled grains was affected substantially (Fig. 8). More than 26 bugs per hill can cause 100% loss of filled grains. Thus, if the tolerable level is 5% empty grain, then the ETL should not be more than two bugs per hill.

Fig. 6. Paddy field in Alor Setar, Kedah, completely destroyed by *Scotinophara coarctata*.

Fig.7. *Scotinophara coarctata* at the base of the rice plant.
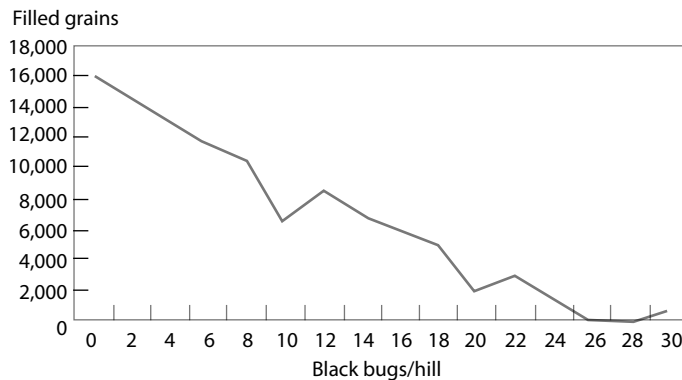
Fig. 8. Effect of the Malayan black bug on grain filling.

Incidence of rice bug in transplanted and direct-seeded fields

In the 1983-84 main season, a comparison was made between insect populations in transplanted and direct-seeded fields in Semuba, a rainfed area (west bank of Kelantan River) and in Padang Halban (east bank). For the 1984 off season, similar observations were made at Tal Tujuh (west bank). The results (Tables 1, 2, and 3) did not indicate any clear pattern of insect pest infestation. However, BPH and *Leptocorisa* were more prevalent in all three locations and *Scotinophara* was significant only at Tal Tujuh. In all areas, natural enemies, especially spiders, were abundant. This indicated field-to-field differences in insect populations, emphasizing the need to check individual fields regularly.

Table 1. Number of insects in insecticide-free transplanted and broadcast direct-seeded fields, Semuda, Kelantan, 1983-84 main season.

DAT/DAS[a]	BPH 1	BPH 2	GLH 1	GLH 2	Leptocorisa 1	Leptocorisa 2	Scotinophora 1	Scotinophora 2	Spider 1	Spider 2	Cyrtorhinus 1	Cyrtorhinus 2	Paederus 1	Paederus 2	Carabid 1	Carabid 2
21	2	0	0	0	0	0	0	0	9	0	0	0				
28	15	0	2	0	0	0	0	0	11	0	1	0				
35	Flood															
42	Flood															
49	2	24	0	1	0	0	0	0	15	28	0	2	1	0	0	0
56	32	65	2	10	0	0	0	0	16	36	3	7	0	0	0	1
63	28	3	12	0	0	0	0	1	16	17	3	2	0	1	1	2
70	4	14	0	4	3	3	0	0	15	14	3	3	2	2	2	3
77	22	7	1	0	2	2	0	0	25	10	3	2	0	0	2	1
84	9	0	2	2	9	8	0	0	20	16	0	0	0	3	4	5
90	13	1	1	0	9	22	1	0	26	19	0	3	1	6	5	1
98	13	15	1	2	10	27	0	0	19	16	0	0	0	6	1	4
106	0	10	0	0	10	11	0	0	13	27	0	0	2	12	4	8
113	1	0	0	1	13	19	12	32	18	14	0	0	1	1	1	5
120	0	0	0	0	23	22	7	9	8	13	13	0	3	2	3	1
127	0	–	0	–	35	–	16	–	16	–	0	–	0	–	5	–

aTransplanted/broadcast direct-seeded on 1/11/83. 1 = transplanted field. 2 = broadcast direct-seeded field. Count of all insects from 20 x hill or 1-ft² samples.

Table 2. Number of insects in insecticide-free transplanted and broadcast direct-seeded fields, Tai Tujuh, Kelantan, 1984 off season.

DAS/ DAT[a]	BPH		GLH		Leptocorisa		Scotinophora		Spiders		Cytorhinus		Paederus		Carabids	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
21 / 30	16	9	3	2	2	4	3	0	8	8	2	0	0	0	2	0
28 / 37	97	120	7	0	3	0	0	20	0	19	25	0	1	4	5	6
35 / 44	123	86	13	2	4	0	1	15	29	36	14	2	4	3	3	5
42 / 51	55	23	4	4	7	0	10	3	24	16	5	2	2	2	1	0
49 / 58	39	21	6	0	7	5	0	0	38	21	6	5	4	2	2	3
56 / 65	98	35	2	0	9	6	28	43	30	36	8	0	4	2	0	4
63 / 72	19	7	2	0	22	10	4	17	22	10	0	0	3	3	2	4
70 / 79	23	1	0	0	14	2	19	18	22	17	8	5	1	2	0	2
77 87	22	9	0	0	15	7	32	4	23	18	0	0	3	2	0	0
84 / 94	17	8	0	0	16	33	15	19	12	7	0	0	3	0	4	3
91 / 101	16	9	0	0	18	8	11	5	14	8	0	0	2	3	0	0
98 / 108	15	9	0	0	20	12	19	4	22	12	0	0	3	0	6	0
105 / –	12	–	3	–	28	–	10	–	11	–	0	0	3	–	2	–
112 / –	13	–	0	–	25	–	17	–	16	–	0	0	0	–	4	–

[a]Transplanted on 30/5/84. Broadcast direct-seeded on 26/ 5/84. 1 = transplanted field. 2 = broadcast direct-seeded field. Count of all insects from 20 x hill or 1-ft² samples.

Table 3. Number of insects in insecticide-free transplanted and broadcast direct-seeded fields, Padang Halban, 1983-84 main season.

DAS/ DAT[a]	BPH		GLH		Leptocorisa		Scotinophora		Spider		Cytorhinus		Paederus		Carabids	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
28 / 30	10	1	7	1	0	0	1	0	23	16	3	2	0	1	0	1
35 / 37	63	23	16	2	2	0	0	0	12	11	8	3	1	0	0	1
42 / 44	64	17	35	1	0	0	1	0	15	12	6	7	1	0	1	0
49 / 51	52	3	23	1	6	1	0	0	11	6	5	4	5	0	4	1
56 / 58	44	2	13	1	5	0	0	0	9	5	7	4	2	1	3	0
63 / 65	156	4	15	1	5	0	0	0	22	8	16	0	4	0	3	0
70 / 72	79	8	13	4	5	0	0	0	12	9	4	2	3	0	0	0
77 / 79	27	12	6	2	8	0	0	0	10	9	5	3	2	0	1	0
84 / 86	31	14	5	4	5	0	0	0	44	18	0	5	3	1	1	2
91 / 93	10	14	5	0	9	0	0	0	30	20	0	17	3	0	0	1
98 / 90	63	3	0	0	3	2	5	0	22	2	5	0	0	0	0	1
107 / 109	2	3	0	0	12	15	0	2	12	14	0	0	3	2	3	1

[a]Transplanted on 19/2/84. Broadcast direct-seeded on 17/2/84. 1 = transplanted field. 2 = broadcast direct-seeded field. Count of all insects from 20 x hill or 1-ft² samples.
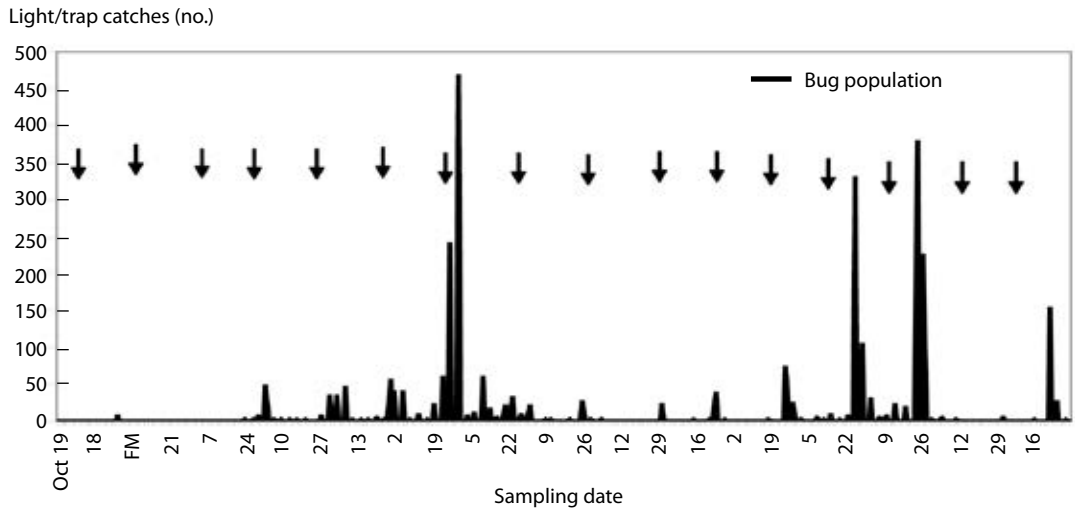
Fig. 9. Light-trap catches of *Scotinophara coarctata* at Sungai Petani, Kedah Malaysia.

Large aggregations of *Scotinophara* made their noxious presence felt in 1980. They received particular attention because of their attraction to house and street lights, constantly irritating people because of their pungent odor. Figure 9 summarizes the 20-watt fluorescent light trap catch operated between 1800 and 2100 daily. These were collected every 3−4 d. March and October recorded the highest bug catches. Visual inspection in the fields near the light traps showed that *Scotinophara* was only present on 2 Sep. A total of 188 adult bugs were counted on 80 hills. The crop was harvested a week later, so we were unable to follow the population further. Seasonal fluctuation of the catches was related to the growth stage of the rice crop and it coincides with time of harvesting.

There appears to be a strong correlation between flight aggregation of *Scotinophara* and the lunar cycle (Fig. 7). On or around days with a full moon, unusually high catches were recorded. Observations by Ito et al (1993) on catches from light traps set up at MARDI Alor Setar research station showed that more males were trapped than females (43.2%) and more than 95% of the females showed underdeveloped ovaries. Two seasonal peaks of the catches were observed in Muda, from January to March and from July to September, and these coincided with harvesting period.

Survival without water and on *Scirpus grossus*

A trial was conducted to evaluate the survival of black bugs. Ten male and 10 female Malayan black bugs were placed in two separate test tubes. They were either given cut padi stems as source of water and food, or wet cotton as source of water only, or nothing as control. In general, female bugs survived longer than males. The black bugs can only survive for less than 12 h without food and water (Table 4). However, with the presence of water, the bugs survived up to 5 d; it was twice as long when food and water were present. In another trial, 10 male and 10 female bugs were placed in two separate

Table 4. Survival of *Scotinophara coarctata* in relation to food and water sources.

Food/water source	Time of survival (d)	
	Male	Female
No water source	0.3	0.5
Wet cotton	5.0	5.0
Padi stem	8.0	8.0

Table 5. Ability of *Scotinophara coarctata* to survive on *Scirpus grossus*.

Host	Time of survival (d)	
	Male	Female
Oryza sativa	32	36
Scirpus grossus	42	54

test tubes: one with cut padi stems and the other with cut stem of *Scirpus grossus*. The black bugs survived better on *S. grossus* than on rice (Table 5). The females survived better than males. Ito et al (1993) observed that light-attracted adults displayed a considerable tolerance for starvation. The bugs were able to survive for 20-30 d without food but died within 2 d without water.

Management of Malayan black bug

Corbett and Yusope (1924) observed that bugs feed on various grasses and they suggested weeding the padi area and banks during off season to decrease pest buildup. Kerosene emulsion and *tuba* root (*Derris* sp.) could kill *S. coarctata* at various growth stages, but large-scale use would not be economical. Jack (1923) suggested that if fields under attack were flooded, *S. coarctata* nymphs and adults would rise to the surface and these could be collected and destroyed. Lim (1971) found fenthion, BHC, and phosphamidon as promising insecticides in the control of RBB.

Early studies by Corbett and Yusope (1924) showed that only eggs of *S. coarctata* were being parasitized by a chalcidoid, while the adults and nymphs seemed free from attacks. In 1937, Nixon reported *Telenomus triptus* as an egg parasitoid. Lever in 1955 again reported *Telenomus triptus* and another new species, *Microphanurus artabazus* Nixon, as egg parasite of *S. coarctata*. It was also reported that ducks were known to seek and eat *S. coarctata* at the base of the rice plant (Lever 1955).

The bacterium *Pseudomonas aeruginosa,* which was responsible for high mortality in BPH colonies during screening for resistance in 1979, persisted throughout the 1980s despite sanitation measures taken. The disease is easily transmitted by water and contamination during the mass rearing of hoppers. A preliminary investigation was conducted on the pathogenicity of *P. aeruginosa*

Table 6. Insect mortality 5 d after treatment with *P. aeruginosa* suspension.

Species	% mortality
Spodoptera mauritia (larvae)	100
Cnaphalocrocis medinalis (larvae)	80
Leptocorisa oratorius	90
Cyrtorhinus lividipennis	100
Scotinophara coarctata	0
Oxya chinensis	20
Nilaparvata lugens	100
Nephotettix sp.	40

on a number of other pests, since *Cyrtorhinus lividipenis*, a predator of BPH, was also affected in the rearing cages. Dead purple-colored hoppers were collected and macerated in distilled water at a ratio of 2 ml liquid to 1 mg body weight. About 5 ml of the filtered suspension was atomized inside a closed mylar film cylinder containing a potted rice plant and 10 insects. The mortality as shown in Table 6 was high for most insects, except for *Oxya* and *Nephotettix* sp., which were less sensitive, while *Scotinophara coarctata* was not affected by the organism at all. *Scotinophara* was still unaffected even when completely smeared with a paste of the dead hoppers.

In another trial, isolates of *Beauveria bassiana* were found very pathogenic to BPH but not to the Malayan black bug adult and leaffolder larvae (Fig. 10). It starts to kill the BPH after 3 d.

Insecticide screening

Insects used for testing at Alor Setar were adults collected from street lights during full-moon migration and placed in cages for a few days. These migrating bugs often caused problems to the farmers and, if not sprayed, could cause bug burn in a few days. Plants for the test were taken from the field and potted at one hill per pot. The plants were sprayed with the tested insecticides up to dripping wet using a 1-liter polysprayer. After the treatments, the plants were caged. Twenty black bugs were placed in each cage 1 d after spraying. The treatments were replicated four times with each cage as a replication. Results (Table 7) showed that propoxur gave a fast knockdown, whereby 80% of the tested insects were dead 1 h after release. Fenthion, currently recommended for the control of black bug, gave 100% mortality 4 h after release, while propoxur had an effect after 8 h and the other tested insecticides, after 24 h.

In another insecticide evaluation trial, Confidor 20EC (imidacloprid) at the rate of 20 g ai ha⁻¹ gave good control of *S. coarctata* populations. A mixture of fenitrothion (20%) and BPMC (20%) at a concentration of 0.1% ai gave a good control (100% mortality) 24 h after treatment. Alphacypermethrin at 0.01% ai gave 100% mortality 1 h after treatment. Fenthion, the current recommended insecticide, still effectively controlled the bugs with 100% mortality was noted 2 h after treatment. An evaluation of etofenprox showed that it was not effective at lower rates as was the case for other

Fig. 10. Healthy Malayan black bugs with *Beauveria bassiana*-infected brown planthoppers.

Table 7. Insectary evaluation of several insecticides for black bug control through foliar sprays.

Treatment[a]	Mortality percentage			
	1 h	4h	8h	24h
Propoxur 50 WP	80.00	98.75	100.00	100.00
Bendiocarp 20 WP	57.50	90.00	91.12	100.00
Carbaryl 85 WP	27.50	72.50	90.45	100.00
Carbosulfan 20 EC	26.25	66.25	91.12	100.00
Fenthion 50 EC	26.25	100.00	100.00	100.00
BPMC 50 EC	16.25	57.50	92.37	100.00
Fentitrothion + lindane 3 0EC	1.75	70.00	85.25	100.00

[a]Insecticides were applied by polysprayer at 0.1% ai until they drip. Insects were released 24 h after treatment. Mortality were adjusted using Abbott's formula. Results were not significantly different at 8 and 24 h after release.

pests (BPH, GLH, rice thrips, leaffolders, and rice bug). The lowest rate for Malayan black bug was found to be 250 g ai ha^{-1}.

Discussion

In the past, *S. coarctata* was regarded as a major pest though it occurred sporadically. However, since 2005, its occurrence has increased in the FELCRA rice estate and in Kelantan. In FELCRA, the estate was surrounded by oil palm, whereas in Kelantan, the paddy area was close to a nonrice habitat. Elsewhere, the bugs still occurred sporadically. These bugs were observed to attack during the crop's early tillering stage.

Light trap catches showed populations being highest at or around full-moon days, especially in March and October. It coincides with the harvesting period. If water is available, the light–attracted adults were able to survive longer, thus enabling them to search for new habitats.

Besides chemical control data, information on other control methods are lacking. New chemicals were found effective but at rates higher than what is normally recommended. Fenthion is still popular among farmers, since it is much cheaper and gives a fast knockdown. FELCRA staff reported the inability of fenthion to control the bugs during the 2007 current season. Thus, further studies are needed to find a better solution for *S. coarctata* control.

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The Rice Black Bug *Scotinophara coarctata* in Malaysia

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Abstract

The biology (life cycle, pest status, yield loss, food plants, natural enemies); ecology (seasonal occurrence and abundance, flight activity and outbreak pattern); and management (cultural control, chemical control) of the rice black bug (RBB) *Scotinophara coarctata* in Malaysia are reviewed. Data on the extent of infestations by the RBB from 1981 to 2006 in Peninsular Malaysia are presented.

Key words: *Scotinophara coarctata*, rice black bug, biology, ecology, management, extent of infestation, Peninsular Malaysia, Sarawak

Introduction

The principal species of rice black bug in Malaysia is *Scotinophara coarctata* (Fabricius). It is known in the vernacular by many names—*kutu beruang* (bear louse), *kutu air* (water louse), *kepinding air* (water bug), *benah kura* (tortoise hopper), *kesing kura* (tortoise bug), *empangan kura* (tortoise dam), and others (Borneo Literature Bureau). The other species that have been recorded (particularly in Sarawak) include *S. cinerea*, *S. lurida*, *S. serrata,* and *Scotinophara* sp.

Destruction of large rice areas by the rice black bug (RBB) in Malaysia was reported in Pahang, Peninsular Malaysia as early as 1918. Sporadic outbreaks continued to occur in both wet and dry upland rice areas. It has been reported that crop losses during certain years amounted to millions of dollars.

Biology

Life cycle

The adults are dark brown to black in color. Newly emerged adults are white, tinged with green and pink. They are about 8–9 mm long and may live for some 200 d (Khoo et al., 1991; van Vreden and Ahmadzabidi, 1986).

In both wet and hill paddy, the RBB are found near the bases of the stems (Khoo et al., 1991; van Vreden and Ahmadzabidi, 1986; Wan, 1971; Yunus and Balasubramaniam, 1981). They hide in the soil and trash during the daytime. During drought and fallow periods, the adult bugs stay at the base of the old stubble, in cracks of the soil, or under heaps of paddy straw.

Oviposition occurs about 12-17 d after mating. Eggs are laid in clusters/rows on the leaves and stems (generally near the base), and sometimes under dry condition on the roots and trash and in cracks of the soil. Each cluster may contain 8–66 eggs, up to 143 per cluster. As many as 680 eggs may be laid over a period of several months. The eggs are gray to pink in color. They hatch in about 3-7 d. The female bug exhibits parental care, protecting the eggs by covering them with her body, and the nymphs for a few days after hatching.

The young nymphs are brown in color, with the ventral surface lighter and with some black spots. They molt five times and reach the adult stage in about 28–35 d. Under dry conditions, the complete life cycle may take twice as long.

Pest status

Both the nymphs and adults suck sap during daytime mainly on the base of the stem, but they may feed on the midrib of the leaves and panicles in the milky stage during early morning and evening or on overcast days when the bugs move higher up on the plant (Khoo et al., 1991; van Vreden and Ahmadzabidi, 1986; Yunus and Balasubramaniam, 1981). The plants become stunted and are reddish-brown in color. They bear fewer or no panicles or have empty seeds. Severe attack results in death of the plants, giving a scorched appearance resembling the effects of hopperburn caused by planthoppers (Khoo et al., 1991; Lim, 1975).

Heavy infestations (15 adults or more per plant) could kill the plants in about 3–4 d, while one bug could kill a plant in 16–17 d (Lim, 1975). Nonetheless, the paddy plant could tolerate feeding by up to four bugs per hill from 2 wk after transplanting until grain formation. In a 1970 outbreak in Sarawak, more than eight bugs per hill resulted in yield reduction. Plants infested with 32 bugs per hill produced more tillers but were stunted and had reduced yield (Wan, 1971).

Yield loss

Estimations on crop losses are hard to make since many cases, especially the milder infestations, are often not detected, and others are not reported at all. Available estimates in Peninsular Malaysia indicate that less than 5% of the affected paddy areas suffered total destruction. These include the following states: (1) Terengganu–4.07% or 10/246 ha in 1994, and 0.64% or 1.5/234 ha in the 2005 first season;

(2) Kerian, Perak–2.90% or 56/1929.1 ha in 1995; (3) Kelantan–2.70% or 4/148 ha in 2002; and (4) Kedah–4.44% or 2/45 ha in the 2004 second season (Fig. 1).

In the 1970 outbreak in hill paddies in Sarawak, the yield of untreated plots was 731 ± 140 kg ha^{-1} and that of insecticide-treated plots was 1381 ± 61 kg ha^{-1}, with a yield loss of 650 kg ha or a loss of some 47% grain yield due to RBB (Wan, 1971).

Food plants

Besides paddy, the RBB feeds on maize (*Zea mays*) and various grasses (*Hymenachne pseudointerrupta*, *Panicum amplexicaule*, *Scirpus grossus,* and *Scleria sumatrensis*) (Khoo et al., 1991; van Vreden and Ahmadzabidi, 1986).

Natural enemies

Three species of wasps have been recorded to be egg parasites (Khoo et al., 1991; Wan, 1971)—*Microphanurus artabazus*

Fig. 1. Map of Peninsular Malaysia.

Nixon (Hymenoptera: Scelionidae), *Telenomus triptus* Nixon (Hymenoptera: Scelionidae), and an unknown species of *Trissolcus* Ashmead (Hymenoptera: Scelionidae). In Sarawak, the degree of egg parasitization by *Trissolcus* sp. in the 1970 outbreak ranged from 0.5% at the beginning of the outbreak to 75% 8 wk later (Wan, 1871). In addition to the parasitoids, an entomogenous fungus (*Paecilomyces farinosus*) has been recorded to infect the adult bugs in the field (Khoo et al., 1991).

Ecology

Seasonal occurrence and abundance

Outbreaks of the RBB occur occasionally. It attacks the crop during all growth stages, with the highest number usually observed during maximum tillering (van Vreden and Ahmadzabidi, 1986). Large numbers may also be encountered in the nurseries and in areas with staggered planting.

Seasonally, the RBB, as indicated by daily light trap catches, are abundant from January to March and from July to September, with few individuals from May to June and October to November (Ito et al., 1993). The seasonal fluctuations are related to the growth stages of the rice plant.

Table 1. Seasonal infestation (extent in ha) by *Scotinophara coarctata* during 2001-06 in Peninsular Malaysia.[a]

Year (season)	Perlis	Kedah	Perak	Selangor	Pahang	Terengganu	Kelantan
2001 (first)	-	50.3	25.8	-	-	10.0	-
(second)			14.9	-	-	-	-
2002 (first)	-	19.3	-	-	-	17.1	-
(second)		18.4	3.4	-	-	11.0	148.0
2003 (first)	2.7	-	46.0	3.6	5.0	-	34.5
(second)	-	2.0	138.0	-	-		
2004 (first)	1.0	45.0	64.0	3.6	44.0	-	20.0
(second)	-	15.0	92.0	4.0	-	-	0.8
2005 (first)	26.0	-	9.0	-	-	234.0	1.7
(second)							
2006 (first)	-	1.3	2.4	-	-	-	-
	-	3.8	-	-	-	40.0	-

[a]Unpublished data of the Department of Agriculture.

Data on infestation during different planting seasons from 2001 to 2006 in Peninsular Malaysia (Table 1) indicate that either a single season or both seasons in a particular area may be affected. Where both seasons in an area were affected, either the first or second season may encounter more severe infestation by the RBB.

The sex ratio of adult bugs differs in field collections (64% females) and light-trap catches (40% females) (Shepard et al., 1986).

During the 1970 outbreak in Sarawak, the bug population was concentrated in damp places near a stream in the outbreak area. The total population (adults and nymphs) during the peak of the outbreak (about 10 wk after planting of the hill paddy) was estimated to be 2.24 million individuals ha^{-1} in untreated plots. Four weeks after insecticidal applications at fortnightly intervals, the population was about 407,710 individuals (Wan, 1971).

Flight activity and outbreak pattern

Swarming of the RBB occurs during certain times of the year (notably January to April, and August to November), and especially on nights of the full moon (van Vreden and Ahmadzabidi, 1986). During such mass flight, the bugs are readily attracted to lights on the roads and human dwellings. Because of their offensive odor, they are a serious nuisance. Large numbers of the bug may also be carried by strong winds to nonhost crops and vegetation, including oil palm.

Table 2. Extent of infestation (ha)[a] by *Scotinophara coarctata* from 1981 to 2000 (except in 1996) in Peninsular Malaysia. Figures for 2001-06 are given in Table 1.

Year	Perlis	Kedah[b]	Penang	Perak[c]	Selangor	Terengganu	Kelantan
1981	-	400.0	4032.0	-	-	-	34.0
1982	-	290.0	2467.0	3774.0	-	-	-
1983	65.4	1557.2	50.0	1200.0	18.3	60.2	118.1
1984	1967.1	3728.3	54.0	2170.7	-	741.1	689.4
1985	227.6	532.3	29.0	838.0	20.0	2.4	44.4
1986	339.2	286.3	177.0	3404.7	22.8	-	59.0
1987	6.6	71.1	109.0	7821.0	-	101.9	710.2
1988	36.0	420.3	-	4361.6	-	511.0	1741.0
1989	12.5	338.3	40.0	7520.0	-	230.0	102.0
1990	-	171.9	-	13801.6	-	218.0	2967.0
1991	141.2	94.3	333.0	13266.5	-	89.0	3038.0
1992	0.1	388.7	10.0	1134.1	-	23.0	183.3
1993	1.7	320.3	2.0	484.0	-	20.0	86.0
1994	-	50.6	9.0	4502.8	-	246.0	55.0
1995	-	17.1	14.0	2092.4	-	6.0	4.0
1997	-	0.5	-	166.8	-	-	-
1998	-	-	-	233.0	-	-	-
1999	[d]	[d]		[d]		[d]	[d]
2000	0.5	28.2	No data	727.1	-	-	-

[a]Unpublished data of the Department of Agriculture. [b]Including the Muda Agriculture Development Authority scheme. [c]Including Kerian, Sg Manik and Seberang Perak. [d]Total for all states = 632.0 ha.

In light-trap catches, the majority of the females are nulliparous, indicating that adult bugs that migrate or disperse are mainly newly emerged adults or females that have already laid their eggs (Shepard et al., 1986; van Vreden and Ahmadzabidi, 1986).

The infestation data for Peninsular Malaysia from 1981 to 2006 are summarized in Tables 1 and 2. The extent of the infestation varies from year to year and from place to place. Compared with the previous decades, infestations in the past few years appear to be less severe.

Monitoring and field population assessment techniques

Field observation during the growing season by sampling leaves and scouting for pests has been the usual practice for detection and assessment.

Recently, automated identification and counting of RBB and other insect pests in paddy fields have been studied by image analysis (Abdul Rashid Mohamed Shariff et al., 2006). This involves a digital image analysis algorithm based on fuzzy logic using digital values of color, shapes, and texture features. Images are acquired under natural lighting using digital and analog cameras. Discriminating analysis is performed with eCognition image processing software. A 100% accuracy in pest extraction and classification has been reported.

Adult rice black bug (Department of Agriculture, Malaysia).

Eggs of rice black bug (Department of Agriculture, Malaysia).

Management

Cultural control

It has been suggested that clean weeding of the area around the paddy field would reduce the pest (Khoo et al., 1991; van Vreden and Ahmadzabidi, 1986). If possible, flooding by raising the water level in the paddy field for 2–3 d could be practiced (Yunus and Balasubramaniam, 1981). Other measures include plowing or burning the stubble after harvest as well as keeping the area free of alternative host plants.

Chemical control

In the early days, kerosene emulsion and tuba root extracts were used to control the RBB. Insecticides are recommended after an average of five bugs per hill in 20 random hills have been detected. These include spraying with 0.1% active ingredient solutions of BPMC, MIPC, fenthion, or propoxur (Khoo et al., 1991; van Vreden and Ahmadzabidi, 1986). Spray is directed to the base of the paddy plants where the bugs rest. Other pesticides have also been used—BHC, carbaryl, diazinon, dimethoate, malathion, and others (Yunus and Balasubramaniam, 1981).

Museum/Institution with Rice Black Bug Collection

Collections of rice black bugs are available in several government agencies, research institutions, and universities: Crop Protection and Plant Quarantine Division, Department of Agriculture; MARDI;

Universiti Putra Malaysia; and University of Malaya. At the University of Malaya, the officer-in-charge of the insect collections is Professor Dr Mohd Sofian Azirun of the Institute of Biological Sciences.

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The Rice Black Bug *Scotinophara* spp. (Heteroptera: Pentatomidae) in Myanmar

Nwe Nwe Yin

Abstract

The rice black bug (RBB) *Scotinophara* spp (Heteroptera: Pentatomidae) is a major insect pest in rice-growing areas. It is a minor insect pest on rice. There is no detailed study of RBB in Myanmar. We found more RBB populations in monsoon rice than in summer rice.

Key words: rice black bug, minor pest, insect population

Introduction

There are reports of yield losses caused by rice black bug (RBB) *Scotinophara* spp. in current rice-producing areas in Southeast Asia. Although there has not been any comprehensive report on the extent of damage in Myanmar, the problem is expected to be worse as a result of continuous rice cultivation and growing of susceptible high-yielding rice varieties. This is compounded by imbalanced application of nitrogenous fertilizer, especially in the irrigated tract. At present, Myanmar needs to produce more than 21 million metric tons of rice for domestic consumption and foreign export. To boost total rice production and productivity per unit area, Myanma farmers need to practice integrated pest management.

**Distribution of Rice black bug (Scotinophara sp.) in Myanmar
(Dr. Mu Mu Kyaw)**

**In Myanmar rice black bugs are considered as minor pests of rice. They distributed in Ayeyarwady
Division, Kayin State, Kayah State and Sagaing Division (Morris,H. and Waterhouse, D.F.,2001).**

Distribution Pattern of Rice Black Bug in Myanmar

Biology

There is no detailed study of the biology of RBB in Myanmar.

 Life history (Nil)
 Number of generations per year (Nil)
 Pest status (Minor pest)
 Yield loss (Nil)
 Diapause (Nil)
 Food plants (Nil)
 Natural enemies

 There are a lot of natural enemies in the rice field such as small wasps that parasitize the eggs; ground beetles, spiders, crickets, red ants, and coccinellid beetles that attack the eggs, nymphs, and adults.

Ecology

There is no detailed study of ecology of RBB in Myanmar. In Myanmar, rice fields are species-rich.

Seasonal occurrence and abundance

We found RBB adults from the seedling stage to the vegetative stage in Myanmar. More can be seen in monsoon rice than in summer rice.

Management

We use only natural control for RBB.

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Black Bugs of Rice, *Scotinophara* spp. (Heteroptera: Pentatomidae: Podopinae) in Pakistan: Taxonomy, Biology, Damage, and Control

Imtiaz Ahmad, Muhammad Ather Rafi, and Parveen Najam

Abstract

Rice black bug *Scotinophara limosa* (Walker) appears to be a potential pest of rice in lower Sindh, Pakistan. It invades only those fields with no standing water and sucks the sap from paddy stem as a result of which the panicles fail to develop, the leaves turn reddish brown, and sometimes the whole plant is stunted. All developmental stages devour the paddy plant. Drying up of a paddy field may invite these bugs in large numbers, even a few days before harvest. Flooding of the rice field causes the bugs to escape to adjacent sedges and grasses, which serve as their alternate hosts. It appears to be a close relative of *S. coarctata* (F.), which is known as the Malayan black bug and is known as a pest of rice in several Asian countries, including Malaysia and the Philippines, Sarawak, Thailand, the Salem district of the former British India, and Bangladesh. In addition to *S. limosa*, which is also known from the lower and upper Punjab and NWFP, *S. dentata* (Distant) is known from upper Sindh and *S. scutellata* (Scott) from lower Sindh and upper Punjab in Pakistan but not as a pest of rice. A key is given for 14 species in addition to four variant forms (undescribed spp.) known from the Indo-Pakistan subcontinen *S. affinis* Haglund, *S. bispinosa* (F.), *S. coarctata* (F.), *S. ceylonica* (Distant), *S. dentata* (Distant), *S. limosa* (Walker), *S. longispinosa* Schouteden, *S. lurida* (Burmeister), *S. obscura* (Dallas), *S. ochracea* (Distant), *S. nigra* (Distant), *S. scobinae* (Distant), *S. scutellata* (Distant), and *S. serrata* (Vollenhoven) to separate Pakistani species from those represented in the adjacent areas of India and former East Pakistan (Bangladesh), along with detailed descriptions with special reference to metathoracic scent complex, male and female genitalial apparatus, and distribution of three species (*S. dentata*, *S. limosa* and *S. scutellata*) represented in Pakistan. Biology, immature systematics, and a key to the instars are also given of *S. limosa*, the only pest of rice in Pakistan.

Key words: *Scotinophara limosa, S. dentata, S. scutellata*, description, adult and instar keys

Introduction

Rice is the staple food of Pakistan, covering an area of 2 million ha and occupying a predominant position in the country's agricultural economy. From being a subsistence crop grown in traditional rice-growing areas of Punjab, Sindh, and high-altitude valleys in the north, it has emerged as a major export commodity. The Punjab and Sindh provinces are main rice-growing regions, with nearly 50% of the area in each province devoted to rice. The coarse IRRI varieties are grown in Sindh and both Basmati and coarse rices are grown in Punjab. Rice cultivation in Pakistan is mainly concentrated in the following four, more or less, distinct agroecological zones (Chaudhri, 1986).

Zone 1 consists of the northern mountainous areas of the country and irrigated rice is grown either in flat valleys or terraced valley sides. The climate is subhumid, monsoonic, with 750−1000 mm average rainfall, mostly concentrated during summer. The maximum day temperature is 35 °C and active rice-growing period is 3 mo, which is adequate for coarse varieties.

Zone 2 lies in the broad strip of land between Ravi and Chenab rivers where both canal and subsoil water are used for irrigation. The climate is subhumid and subtropical with 400−700 mm of rainfall mostly in July−August. Maximum day temperature is 40 °C and rice-growing season is fairly long and suitable for cultivating fine aromatic as well as some IRRI varieties. The Kalar tract, abode of the world-famous Basmati rice, is located in this zone.

Zone 3 consists of the large tract of land on the west bank of Indus River. It has an arid sub-tropical climate with 100 mm of average rainfall and maximum temperature higher than those of zones 1 and 2. The impeded drainage and judicious water application to rice has resulted in a high water table. The long, extremely hot summers are well suited to growing coarse rice varieties.

Zone 4 is the Indus delta, which consists of vast spill flats and basins, the latter mostly irrigated. The climate is arid tropical marine with no marked season and is highly suited to cultivation of coarse (crude) varieties.

Insect pests of rice in Pakistan

In Pakistan, paddy is attacked by many species of insect pests. Of these, stem borers, planthoppers, leafhoppers, grasshoppers and rice black bugs (RBB) are the most serious. The abundance of pest species varies from one region to another. For instance, rice stem borers are predominant in the Punjab, planthoppers and leafhoppers in Sindh, and grasshoppers in Swat Valley. The yellow stem borer, *Scirpophaga incertulas* (Walker), occurs throughout the country (Inayatullah et al 1986). The RBB *Scotinophara limosa* (Walker) has been recorded as a pest of paddy in lower Sind (Ahmad and Afzal 1976, Ahmad and Mohammad 1980). Inayatullah et al (1986) reported *S. coarctata* L. from Bangladesh as a periodic pest of rice, which has, though associated with paddy plants, seldom assumed a serious status. Ahmad (1980), in his insect fauna of Pakistan and Azad Kashmir in the tribe Podopinae, recorded eight genera and 20 species, including 11 manuscript species with *S. dentata,*

Rice production Zones in Pakistan.

S. limosa, and *S. scutellata* from different areas of Pakistan. Aukema and Rieger (2006) reported *S. scutellata* from Pakistan without giving its distributional range.

Distribution and economic importance of Podopinae

Podopinae is widely distributed and represented in almost all zoogeographical regions of the world (Amyot and Servile 1845). These are found mainly in damp marshy or muddy habitats. Certain species of *Scotinophara* Stål are serious pests of rice and cereal crops in Asia and Africa (Schuh and Slater 1995). These are commonly known as black bug of rice. Panizzi et al. (2000), Corbett and Yusope (1924), and Barrion et al. (1982) reported the Malayan black bug *S. coarctata* (F.) as a pest of rice in several Asian countries, including Malaysia and the Philippines. It was also reported in Indonesia, Myanmar, Sri Lanka, India (Distant 1902, Kirkaldy 1909), and Bangladesh (former East Pakistan) (Ahmad et al. 1974; Ahmad 1981, 1982, 1985). It is attracted to rice fields where the bugs concentrate and quickly reach high population levels (Ito et al. 1993).

Field infestations occur at any plant growth stage. Insects feeding on young plants cause decoloration with desiccation of leaves, and plants may die under heavy attack. The attack on older plants may cause dead panicles. Newly emerged panicles, according to Morrill et al. (1995), had the number of filled grains reduced with one or two bugs feeding in 4 d. Heinrichs et al. (1985) established the injury level to be at three bugs per hill.

Ahmad (1985) has reported that six species of *Scotinophara* (including manuscript species) are found in Pakistan, but only *S. limosa* (Walker) is known to be associated with paddy, especially in the areas of lower Sindh (Ahmad and Afzal 1976). These authors have reported this species in large numbers from rice fields in Sujawal. Yunus and Rothschild (1967) have listed *S. coarctata* (F.), *S. cinerea* (Le Guillou), *S. lurida* (Burmeister), and *S. serratta* (Vollenhoven) from Malaysia and Sarawak. The former species has also been recorded from Thailand by Wongsiri and Kovitvadhi (1967) and *S. lurida* from Sri Lanka by Fernando (1960, 1967). Rider and Zheng (2005) reported S. *scutelata* Scott, *S. coarctata* (F.), *S. limosa* (Walker), and *S. obscura* (Dallas) from Pakistan, but *S. coarctata* and *S. obscura* were reported only from the former East Pakistan.

Taxonomic notes on the tribe o subfamily Podopinae

Amyot and Serville 1843 gave a checkered history of the bugs, varying from subtribe to family status and many literature references are under the name Graphosomatinae Stål, a polyphyletic group with some of its members belonging to the Podopinae and most of the others to Pentatominae (Schuh and Slater 1995). Schaefer (1981) also stated earlier that the classification and status of two tribes in the Podopinae are confused. In the same work, Schaefer also said that the status of Stål's (1872) tribes Tarisaria Stål, Trigonosomataria Stål, and Graphosomataria Stål, included by Schouteden (1905, 1906) within his tribe Graphosomataria, also remained unclear. (Schaefer 1981 treated them as subtribes under Graphosomatini Stål.)

Leston (1953) earlier included the Podopinae sensu stricto in the Pentatomidae, suggesting that it might be dropped further in rank and, consequently in 1958, he did not mention Podopinae, either as a subfamily within Pentatomidae or as a family excluded from Pentatomoidea. Probably, by 1958, Leston had concluded that the Podopinae (s.s.) should be dropped to a tribe, probably (as Schaefer mentioned it with a question mark) within Pentatominae. This state of affair led Schaefer (1981) to conclude that confusion reigned and the questions remained—should Podopinae (*sensu lato aut stricto*) be reduced to a tribe within Pentatominae or should both groups (Podopini and Graphosomatini) be included within Pentatominae? If so, what are the relationships between the two tribes and there would also be the question of validity of the Graphosomatinae subtribes, too. It would have needed further study because most genera had never been placed in any of Stål's subtribes. Schaefer (1981) further stressed that the generic arrangement within the two tribes was also confused because the generic assignments given by Schouteden (1906) appeared different from the sequence of Kirkaldy (1909), who divided the list of genera into two groups without explanation.

Davidovã-Vilimová and Stys (1994) presented a new concept of the higher classification of the subfamily Podopinae. They removed the tribe Procleticini and several genera from Podopinae. The remaining genera were classified by them into five tribes—Podopini, Graphosomatini, Tarisini, and two manuscript tribal names (not yet available). They considered their newly defined Podopinae as a monophyletic group. In the following year, 1995, Davidovã-Vilimová and McPherson gave a detailed review of earlier works on Podopinae, highlighting the existing confusion in the classification, the phylogenetic status of Podopinae, the tribal groups, and even the generic groups included therein in support of their earlier subfamilial and monophyletic concept of Podopinae, which, according to them, was adopted by most of the earlier workers.

However, it remains questionable if most workers would really give Podopinae a subfamilal rank and if they would consider it monophyletic (Schaefer 1981, 1983; Hasan and Kitching 1993).

With reference to the podopine fauna of the Indo-Pakistan subcontinen, the confusion is even greater. Distant (1902) treated six podopine genera in his subfamily Graphosomatinae close to and equal in rank with his Scutellerinae to accommodate 16 species from this region. In 1908, Distant added three more species to his subfamilial fauna of Indian subregion: *Scotinophara* under (*Podops) longispina* Schouteden and *S. scobinae* (Distant) (he considered *Podops* and *Scotinophara* congeneric), in addition to his new genus *Burrus* to accommodate his new species *spicatus* from Bombay. Its relationship with any of the subgroups of Podopinae is still obscure. Hoberlandt (1954) and Putshkov (1965) have described the Palaearctic podopine fauna from Iran, Afghanistan, and Ukraine (Russia) adjacent to Pakistan. Ahmad et al. (1974) and Ahmad (1978, 1980, 1981) listed eight genera and 22 species and considered the group at the tribal rank, following Ahmad and Khan (1973). Ghani and Beg (1966) and Chaudhry et al. (1970) have listed two unidentified species from different areas of Pakistan (including the former East Pakistan). Abbasi (1986) included only two representatives of his tribe Podopini from Pakistan and Bangladesh.

In view of these, the need to study Podopinae in general and the podopine fauna of this region, which embraces Oriental, Palaearctic, and Ethiopian fauna (Qadri, 1968), is further emphasized.

Recently, Najam (2003) described 15 genera and 32 species in addition to informal descriptions of 16 variant forms of already described species of this economically important and most disputed group, with descriptions of one new genus and one new species and 28 newly recorded species from areas in Pakistan. A cladistic analysis of all the studied genera was also done to understand the relationships and probable placement of these genera in one or the other described tribes in the literature to date.

Taxonomic history of the genus *Scotinophara* Stål

The genus *Scotinophara* falls under the tribe Podopini of **Pentatomidae, commonly known as** rice black bugs (RBB). Before the work of Stål in 1867, the insects that are presently known as *Scotinophara* were classified under several names: *Cimex*, *Tetyra*, and *Podops*. The establishment of' *Podops* as a distinct genus from *Cimex* and *Tetyra* by Laporte (1832) attracted many workers who had significant interest in the two genera. As a result of his detailed analyses and studies of *Podops*, Stål was able to subdivide the members of the genus into several groups and to establish many new genera, among which was *Scotinophara*. In his description of *Scotinophara*, Stål used *S. fibulata* Germar, as the type species of the genus. Several revisions were made after this first attempt [(Stål 1876; Horvath 1883; Distant 1902, 1908, 1918 (who were of the opinion that *Scotinophara* and *Podops* were synonymous)]. Kobayashi (1963) described generic diagnoses and biological notes on four Japanese *Scotinophara*—*S. lurida* (Burmeister); S. *horvathi* Distant; S. *scotti* Horváth, and *S. scutellata* Scott. from Japan.

Discrepancies exist as one goes from one system of description to another. Moreover, the confusion of genus *Scotinophara* with the genus *Podops* Laporte de Castelnau and some other related genera created more interest. With the aim of adding more detailed information to existing descriptions, Puchkov and Puchkova (1956), Decoursey and Allen (1968), Cobben (1968, 1978), Decoursey (1971), Ahmad and Khan (1973), Ahmad et al. (1974), and Ahmad (1978, 1981, 1985) noted a few characters of the tribe Podopini. Esselbaugh (1946), Southwood (1956), and Cobben (1968, 1978) resolved problems of disputed phylogenies, especially in the order Heteroptera and considered the disputed taxonomic status of the genus *Scotinophara* Laporte (Ahmad and Mohammad 1980) and indeed of the entire tribe Podopini (McDonald 1966, Ahmad and Khan 1973). Wongsiri (1975) revised the genus *Scotinophara*. Ahmad and Mohammad (1980) revised the status of *Podops limosa* Walk. to *Scotinophara limosa* (Walker) on the basis of biology and immature stages. Recently, Aukema and Rieger (2006) separately treated the genus *Scotinophara* and reported 15 species from the Palaearctic region, which are housed in different museums of the world.

Najam (2003), in her PhD thesis entitled "Systematics and biology of cereal bugs of sub family Podopinae of Pakistan," attempted not only to solve the question of disputed phylogeny but also to resolve the question of taxonomic status of both tribal and generic ranks within Podopinae. She also described in detail the genus *Scotinophara*, keyed 14 described (and four variant forms of already described species), and described all of them in detail from the Indo-Pakistan subcontinent.

Results and discussion

Classification

Order	:	Heteroptera Latreille, 1810 Family: Pentatomidae (Leach, 1815)
Subfamily	:	Podopinae (Amyot and Serville, 1843)
Tribe	:	Podopini
Genus	:	*Scotinophara* Stål, 1868 (rice black bugs)
Genus	:	*Scotinophara* Stål
Scotinophara Stål 1867	:	502; 1876: 33; Distant 1879: 44; Horváth 1883: 165; Schouteden 1903: 120; 1905: 33
Podops	:	Dallas 1851: 52; Walker 1867: 73, 74; Distant 1901: 241; 1902: 72. (type species: *P. inuncta* (F.) 1775.

Body generally ochraceous with brown; eyes globular, ochraceous black; ocelli orange; antennal segments light brown; labial segments dark brown; scutellum with basal yellowish spots. Body oblong, deeply and coarsely punctate. Head broader than long, more or less sinuate in front of eyes; antenniferous tubercles visible from above; labium usually reaching or passing beyond posterior coxae. Pronotum broader than long, anteriorly deflected, medially humped; scutellum much longer than broad, sinuate at apex, not passing beyond abdomen; metathoracic scent gland auricle moderately developed, evaporatoria well developed. Abdomen convex beneath; lateral angles of seventh abdominal sternum in female subacute; connexiva partially exposed with margins reflexed.

In male genitalia, pygophore broader than long; proctiger well developed; paramere with well-developed blade but short stem, apex somewhat inwardly deflected, inner margin not smooth; inflated aedeagus usually with well-developed semi-scierotized thecal appendages, penial lobes semi-scierotized, vesica stout and straight, passing beyond penial lobes.

In female genitalia, lateral angles of ventro posterior margin of seventh abdominal sternum rounded; eighth paratergites separated, not longer but wider than first gonocoxae and subequal to ninth, latter wide apart, reaching apices of eighth; spermathecal bulb ovate with or without any fingerlike process, pump region elongate, subequal to distal duct of spermatheca.

Type species: *Scotinophara fibulata* (Germar) 1839

Comparative note

This genus is closely related to *Podops* in having humeral angels distinctly pointed or proceeding into spinelike processes and paraclypei anteriorly subrounded, but it can easily be separated from the same in having antenniferous tubercles entirely visible from above, anterior angles of pronotum produced into thornlike processes, and femora blackish brown in contrast to antenniferous tubercles only slightly visible from above, anterior angle of pronotum with more or less rounded or blunt teeth, and femora usually light yellow in *Podops*.

Key to 14 species of *Scotinophara* known from the Indo-Pakistan subcontinent and four variant forms (undescribed/manuscript species)

1. Anterior angles of pronotum longly spined, granulose and sharply obliquely directed forward, lateral angles continued in front of the usual slope in granulose spine longer than anterior spines, directed transversely, lateral margins between two spines nearly straight and entire ....*longispina* Schouteden.

-- Anterior angles of pronotum not as above, not much obliquely directed forward, lateral angles not as much produced into longer transverse spines than the anterior one, lateral margins between two spines not as above straight and entire 2

2. Head long with a strong spine before each eye ....*nigra* (Distant)

-- Head not as above, spine before each eye absent 3

3. Lateral margins of pronotum spined below the anterior angles ....*coarctata* (F.)

-- Lateral margins of pronotum spined near or on the anterior angles 4

4. Anterior angles of pronotum more or less horizontally produced.. 5

-- Anterior angles of pronotum anteriolaterally produced 12

5. Lateral margins of pronotum serrate or dentate 6

-- Lateral margins of pronotum straight or convex 9

6. Robust lateral spine between eyes and base of antennae present 7

-- Knoblike or slight acute projection between eyes and base of antennae present, spine absent.. 8

7. Lateral margins of pronotum before the base of lateral angles much convex, transversely depressed in front of lateral angles, before this depression a transverse series of fine tubercles of which lateral ones more elongate and a little less prominent, lateral angles subacutely prominent, anterior angles less prominent, base of scutellum not gibbous ....*scobinae* (Distant)

-- Lateral margins of pronotum before the base of lateral angles not as much convex as above, transversely not depressed in front of lateral angles as above, lateral angles of pronotum obtusely spinous, anterior angles laterally directed, spinelike, more prominent, scutellum a little gibbous at base ....*serrata* (Vollenhoven)

8. Head anteriorly narrowed, antennae with third segment equal to second, labium passing beyond posterior coxae, spermathecal bulb oblongate, paraclypei with subacute apices....................... ....*dentata* (Distant)

-- Head anteriorly broad, antennae with third segment longer than second, labium reaching to posterior coxae, spermathecal bulb globular, paraclypei with round apices.................*form IV*

9. Lateral margins of pronotum almost straight, transverse impression on pronotum well pronounced ....*lurida* (Burmeister)

-- Lateral margins of pronotum convex, transverse impression on pronotum less pronounced 10

10. Body small, length 7.0 mm, lateral margins of pronotum simply convex ......*ceylonica* (Distant)

--   Body large, length 9.0 mm, lateral margins of pronotum convexly sinuate 11
11.   Body above grayish black, transverse impression on the pronotum rugosely pronounced ....
        ....*affinis* Haglund
--   Body generally piceous, transverse impression on the pronotum not as above ....
        ....*obscura* (Dallas)
12.   Humeral angles of pronotum produced into a prominent spine, anterior angles strongly produced
        anteriad ....*bispinosa* (F.)
--   Humeral angles of pronotum produced into a small spine, anterior angles moderately produced
        anteriad 13
13.   Lateral margins of pronotum convex 14
--   Lateral margins of pronotum sinuate 15
14.   Body ochraceous, of large size, 8.0 mm or slightly more in length .... *ochracea* (Distant)
--   Body dull ochraceous, of small size, length 5.6−5.8 mm ....*limosa* (Walker)
15.   Anterior angles of pronotum just reaching posterior margin of eyes, humeral angles subacutely
        produced ....*form* I
--   Anterior angles of pronotum passing beyond half of the eyes, humeral angles bilobed 16
16.   Apical margin of scutellum almost straight, blade of paramere broad ....*form* II
--   Apical margin of scutellum concave, blade of paramere more or less narrow 17
17.   Apices of paraclypei truncate, spermatheca with 2 fingerlike processes on bulb ....*form* III
--   Apices of paraclypei round, spermathecal bulb without fingerlike process ....*scutellata* (Distant)

Rice black bugs have constantly been reported as pests of considerable importance of rice plants in many parts of Asia. In spite of the importance of the genus *Scotinophara* to the economy of several countries in Asia, still little work has been done on it, leaving some species undescribed and others with inadequate descriptions.

Two important *Scotinophara* species, *S. coarctata* (F.) and *S. lurida* (Burmeister) of Southeast Asia, have significant importance as rice pests and detailed studies of *S. limosa* have been made by Ahmad and Afzal (1976) and Ahmad and Mohammad (1980) from Pakistan. More detailed descriptions of *S. dentata, S. limosa,* and *S. scutellata,* which have been reported from Pakistan, are also given below,.

1. *Scotinophara coarctata* (F.)

Malayan rice black bug and black rice shield bug

In Malaysia, Corbett and Yusope (1924), Grist and Lever (1969), Wan (1971), and Van Vreden and Ahmadzabidi (1986) reported *S. coarctata* as being widespread and one of the more important enemies of the rice plant. The species was also found to attack rice in Thailand by Ladell (1933). Barrion et al. (1982) reported *S. coarctata* for the first time from the Philippines; later on, MBB (Malaysian black bug) became a serious pest of rice in the Mindanao region. At present, it is spreading to other regions in Mindanao (PhilRice 2000).

This species also occurs in other Asian countries such as south China, Vietnam, Brunei, Indonesia, Malaysia, Cambodia, Sri Lanka, Thailand, Myanmar, India, and Bangladesh (probably also erroneously identified from Pakistan [Reissig et al., 1986; Subramanian et al., 1986; Ferrer and Shepard, 1987; Ito et al., 1993; Rice IPM CD, 2001]). Inayatullah et al. (1986) reported species of *Scotinophara* as a periodic pest of rice from Pakistan without mentioning their distribution.

Host plants

Rice (*Oryza sativa* L.), sugarcane (*Saccharum officinarum* L.), *Pennisetum japonicum* Trin., *Digitaria ciliaris* Pers., and *Poa annua* L. are the host plants (Kobayashi 1963). It also feeds on a number of grasses and broad leaves (Mochida et al., 1982; IRRI 1983; Miyamoto et al., 1983; PhilRice, 2000).

2. *Scotinophara lurida* (Burmeister)

Japanese rice black bug

This bug has been reported to occur widely and cause severe damage to rice crops by Fernando (1967); it was observed in Sri Lanka by De Alwis (1941) and Fernando (1960); in China by Kobayashi (1963) and Katsumata (1929);; in Japan by Kawasi (1955) and Kawada et al. (1954). Its occurrence as a rice pest was also noted in India (Kobayashi 1963), Formosa (Esaki 1927), and Indochina (Commun 1930)

Host plants

Rice, water oat (*Zizania latifolia* Turcz), Deccan grass (*Panicum* spp.), millet (*Setaria italica* Beauv.), Indian corn (*Zea mays* L.), barley (*Hordeum vulgare* L.) sugarcane (*Saccharum officinarum* L.) Kobayashi (1963)

3. *Scotinophara dentata* (Distant) [Fig. 1]

Podops dentata. Distant 1901: 242; 1902: 75

Coloration

Body color ochraceous; sparingly and densely punctured with brown; eyes globular; ocelli orange; antennal segments light brown; labial segments dark brown; scutellum with two black and two ochraceous basal spots and longitudinal brownish bands.

Body shape

Body subovate, elongate (Fig. 1)

Head

Broader than long; anteocular distance more than posterior of head including eyes; paraclypei longer than clypeus, lateral margin sinuate with apices subacute; clypeus humped in middle; eyes globular, raised; ocelli minute; antenniferous tubercles slightly visible dorsally, first antennal segment not reaching apex of head, length of antennal segments I 0.5 mm, II 0.5 mm, III 0.5 mm, IV 0.6 mm, V 0.9 mm, antennal formula 1=2=3<4<5; bucculae well developed not raised, enclosing entire basal labial segment; labium reaching beyond posterior coxae, length of labial segments I 0.5 mm, II 0.4 mm, III 0.5 mm, IV 0.1 mm, labial formula II<III<I=IV; anteocular distance 0.7 mm; posterior portion of head including eyes 0.5 mm; width 1.7 mm, interocular distance 0.7 mm.

Thorax

Pronotum broader than long, more than 2X as broad as long, anteriorly and laterally deflected, outer margins very slightly sinuate, anterior angles subacute, spine very sharp, laterally directed, lateral margins dentate with subacute tooth before the humeral angles, latter broadly rounded, length of pronotum 1.6 mm, width 3.3 mm; metathoracic scent gland ostiole (Fig. 2) oval without peritreme, evaporatoria fully developed; scutellum longer than broad, subrounded at apex but not passing beyond apex of abdomen, lateral margins not parallel, slightly sinuate in middle; hemelytra except part of clavus and corium covered by scutellum, membrane slightly exposed on sides; length of scutellum 3.5 mm, width 2.2 mm; length base scutellum-apex clavus 1.2 mm; apex clavus-apex corium 1. 2 mm; apex corium-apex abdomen including membrane 0.2 mm; apex scutellum-apex abdomen including membrane 0.5 mm.

Abdomen

Convex beneath, lateral margins of seventh abdominal sternum in female subacute or subrounded, connexiva poorly exposed at repose. Total length of female, 6.5-6. 8 mm.

Female genitalia

In female genitalia (Figs. 3 and 4), posterior margin of seventh abdominal sternum deeply sinuate, fairly depressed near apices, with apices somewhat round; first gonocoxae separated, with posterior margins sinuate, not longer than ninth paratergites but longer than first gonocoxae; arcus and triangulin fused, posterior margins of triangulin notched in middle; spermatheca (Fig. 4) triangular with bulb oval, without any process, pump region elongate with distinct proximal and distal flanges. Males not available for study.

Material examined

5 females, Pakistan, Islamabad, Sindh, Sakrand, Gulamullah, on *Dicanthium annulatum* (Forssk.) Stapf., 26, 27.4.1976, 30.5.1978, leg Imtiaz Ahmad, in Natural History Museum , Department of Zoology -Entomology, University of Karachi

Fig.1. *Scotinophara dentata* (Distant), entire body

0.75 mm
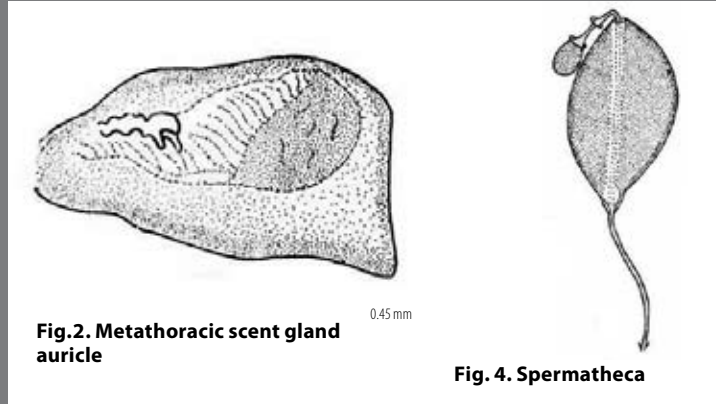
Fig.2. Metathoracic scent gland auricle

0.45 mm

Fig. 4. Spermatheca
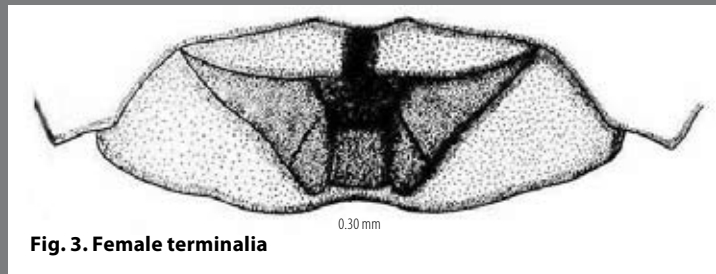
Fig. 3. Female terminalia

0.30 mm

Comparative note

This species is most closely related to *Scotinophara* sp. form IV in having lateral slightly acute projection between eyes and base of antennae knoblike but it can easily be separated from the same in having head anteriorly narrowed, third segment equal to second and labium passing beyond posterior coxae in contrast to head anteriorly broad, antennae with third segment longer than second and labium reaching to posterior coxae in form IV.

4. *Scotinophara limosa* (Walker) [Fig. 5]

Podops limosa Walker 1867: 72; Distant 1902: 76

Coloration

Body brownish ochraceous; scutellum with basal yellow spots; antenniferous tubercles, last labial segment, entire femora, basal joints of tibiae black; eyes reddish brown, ocelli orange.

Body shape

Body oblong to elongate and comparatively smaller (Fig. 5).

Head

Broader than long; anteocular distance more than posterior of head including eyes; paraclypei entire, slightly extending beyond clypeus, lateral margins slightly sinuate, with apices subacute; eyes stalked; ocelli very minute; antennae with antenniferous tubercles visible from above, well developed, basal antennal segments not reaching apex of head, second antennal segments smallest, length of antennal segments I 0.4 mm, (0.4-0.5 mm), II 0.3 mm (0.3-0.3 mm), III 0.5 mm (0.5-0.6 mm), IV 0.6 mm (0.6-0.7 mm), V 0.9 mm (0.8-0.9 mm), antennal formula II<I<III<IV<V; bucculae raised, enclosing basal labial segment, labium slightly passing beyond intermediate coxae, length of labial segments I 0.3 mm (0.3-0.3 mm), II 0.5 mm (0.5-0.6 mm), III 0.3 mm (0.3-0.3 mm), IV 0.3 mm (0.3-0.5 mm), labial formula I=III=IV<II; anteocular distance 0.6 mm (0.6-0.7 mm); posterior portion of head including eyes 0.4 mm (0.4-0.5 mm); width 1.1 mm (1.1-2.0 mm); interocular distance 1.5 mm (1.5-1.6 mm); interocellar distance 1.0 mm (1.0-1.1 mm).

Thorax

Pronotum much broader than long, anterior margin smooth slightly sinuate, anterior angles sub-rounded, lateral margins deeply sinuate with subacute humeral angles, later broadly rounded, posterior margin truncate, length of pronotum 1.5 mm (1.5-1.8 mm), width 3.0 mm (3.0-3.5 mm); scutellum longer than broad, posteriorly deflected, medially raised, not reaching beyond apex of membrane; hemelytra except exposed part of corium and outer margin of membrane with two very prominent longitudinal bands, lateral margins very sharp not parallel; metathoracic scent gland complex (Fig. 6) with oval auricle, somewhat annulate, evaporatoria well developed; length of scutellum 3.1 mm (3 1-3 7 mm), width 2.4 mm (2.4-2.5 mm); length base scutellum apex clavus 1.0 mm (1.0-1.3 mm); length base scutellum-apex corium 1.5 mm (1.5-1.6 mm); length apex corium- apex abdomen including membrane 0.9 mm (0.9-1.2 mm); length apex scutellum-apex abdomen including membrane 1.3 mm (1.3-1.6 mm).

Abdomen

Convex beneath; posterior margin of seventh abdominal sternum in female subround; connexiva well exposed at repose. Total length male 6.0-6.2 mm, female 6.25-6.5 mm.

Male genitalia (Figs. 7 and 8):

Pygophore (Figs.7 and 8) quadrate, slightly broader than long, posterior margin sinuate, proctiger sclerotized with posterior margin notched in middle with tuft of hairs present on both sides, lateral angles acutely knobbed, well exposed; paramere (Fig. 9) with a well-developed blade, apex subacute, inner margin not smooth, outer margin sinuate; inflated aedeagus (Figs. 10 and 11) with pair of dorsal membranous conjunctival lobes well developed with apex broadly rounded, pair of ventral semisclerotized flap-shaped appendages, connected with a well-developed ventral lobe, apices subrounded, vesica sclerotized basal plate well developed.

Female genitalia

Posterior margin of seventh abdominal sternum concave; first gonocoxae with inner margin sub-straight, outer margin convex; second gonocoxae fused medially; eighth paratergites about as long as first gonocoxae; posterior margins of ninth paratergites about reaching fused posterior margin of eighth paratergites.

Material examined

Five males, 10 females, Sindh, Thatta, Sujawal, Tandojam, and Chooharjamali, 28.8.16, 20.10.1975, 15.11.1975, leg Azhar A. Khan, Imtiaz Ahmad, S. Kamaluddin, in Natural History Museum, Department of Zoology -Entomology, University of Karachi and Ahmad's Collection

Comparative note

This species is most closely related to *S. ochracea* (Distant) in having anterior pronotal spines forwardly extended and lateral margins of pronotum almost straight but it can easily be separated from the same in having body dull ochraceous of small size (6.0-6.5 mm) in contrast to body much longer, ochraceous (8.0-8.1mm) in *ochracea*.

Immature stages

Eggs

These (Fig. 12) are deposited in batches of 30-50; each egg being 0.75-0.9mm long and pinkish green in color. The incubation period is 3-8 d. The egg burster is similar to that of other pentatomines (Ahmad 1978, Ahmad and Mohammad 1980).

First immature stage (Fig. 13)

Body oval, punctate, general color pale ochraceous; except black fourth antennal segment; head nearly as long as broad, clypeus longer than the paraclypei; antenniferous tubercles slightly visible from above; 1st, 2nd, and 3rd antennal segments almost equal in length, fourth longest; labium reaching to 1st abdominal segment. Thorax with pro- and mesonotum equal in length, anterior margin truncated; posterior margin slightly sinuate; abdomen ovate, dorsal abdominal scent gland ostioles appearing as slits between tergites 3-4, 4-5, and 5-6; abdominal connexiva distinct.

Second immature stage (Fig. 14)

Shape and color similar to that of first stage; slightly longer than the paraclypei; second antennal segment slightly longer than 1st and 3rd segments separately, labium passing beyond hind coxae; lateral margins of pro- and mesonota crenulated; posterior margin of meso- and metanota becoming deeply sinuate, dorsal scent gland plates between tergites 3-4, 4-5, and 5-6 increased in size.

Third immature stage (Fig. 15)

All characters similar to above stage, except head becoming broader than long; paraclypei almost equal to clypeus; second antennal segment longer than 1st and 3rd segments separately; labium reaching to hind coxae; meso- and metanotal wing pads appearing; a slight sign of calli appearing, mesonotum showing early development of scutellum; dorsal abdominal scent gland ostioles darker in color and more distinct.

Fourth immature stage (Fig. 16)

Head becoming much broader than long: clypeus and paraclypei equal in length; antenniferous tubercles with blunt projection; second antennal segment subequal to fourth; labium passing beyond intermediate coxae; anterior pronotal angles subacute; scutellum well developed reaching to posterior margin of third abdominal segment; plates of scent gland ostioles and lateral connexival plates greatly developed in size.

Fifth immature stage (Fig. 17)

Body broadly oval; ocelli present, clypeus medially raised; antennal plug acute; sides of pronotum crenulated; calli distinct; anterior angles acute; meso-and metanotal wing pads increased in length reaching on to middle of third abdominal tergites; scutellum well developed reaching on to 3rd abdominal segment; other characters similar to that in the preceding stage.

Key to various immature stages of *Scotinophara limosa* (Walker)

1. Length not more than 2.98 mm, head triangular in form, antenniferous tubercles very slightly visible from above, paraclypei very slightly extending beyond clypeus, scutelluin and metathoracic wing pads not yet developed 2

➤   Length more than 3.9 mm, head not as above, antenniferous tubercles distinctly visible from above, paraclypei and clypeus almost equal in length, scutellum and metathoracic wing pads making their appearance.. 3

2. Very small in size, length not more than 1.9 mm, head very slightly deflected, antennae with 1st three segments equal in length, labium reaching 1st abdominal segment ....1st stage

➤   Comparatively large in size, length more than 1.9 mm, but not more than 2.98 mm, head much deflected, antennae with second segments longer than 1st and 3rd segments separately, labium not reaching 1st abdominal segment ....2nd stage

3. Body oblong, antenniferous tubercles entire, scutellum and metathoracic wing pads extended only onto lateral border of metathorax, humeral angles not yet developed...................3rd stage

➤   Body oval or broadly oval, antenniferous tubercles produced into blunt projections or into sabacute spine, scutellum and metathoracic wing pads extended up to second abdominal segment or beyond the second segment, humeral angles making appearance 4
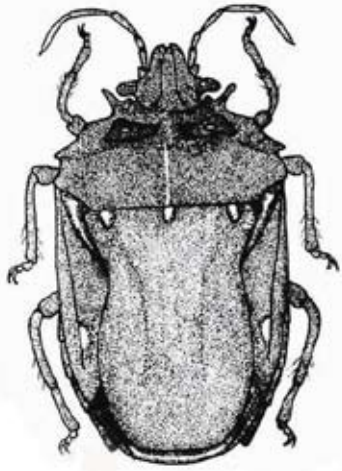
Fig. 5. *Scotinophara limosa* (Walker) (dorsal view)
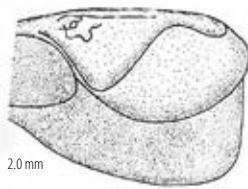
Fig. 6. Metathoracic scent gland auricle (ventral view)
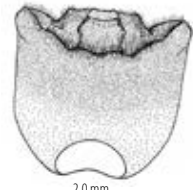
Fig. 7. Pygophore (dorsal view)
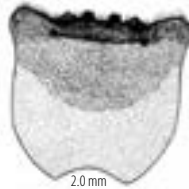
**Fig. 8. Pygophore (ventral view)**
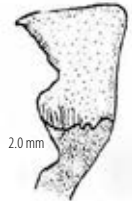
Fig. 9. Paramere (inner view)
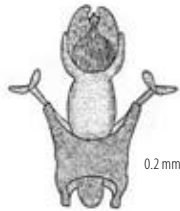
Fig. 10. Inflated aedeagus (ventral view)
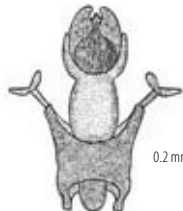
Fig. 11. Inflated aedeagus (dorsal view)

Fig. 12. Eggs of *Scotinophara limosa* (Walker)
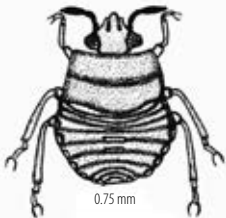
Fig. 13. First instar of *Scotinophara limosa* (dorsal view)

Fig. 14. Second instar of *Scotinophara limosa* (dorsal view)

Fig. 15. Third instar of *Scotinophara limosa* (dorsal view)

Fig. 16. Fourth instar of *Scotinophara limosa* (dorsal view)

Fig. 17. Fifth instar of *Scotinophara limosa* (dorsal view)

4. Head with clypeus slightly medially raised, antennal plug distinctly acute, anterior pronotal angles acute, scutellum and wing pads reaching to middle of 3rd abdominal segment .... 5th stage

➤ Head with clypeus not medially raised, antennal plug with blunt projection, anterior pronotal angles subacute, scutellum and wing pads reaching to second abdominal segment .... 4th stage

3. *Scotinophara scutellata* (Scott) new combination [Fig. 18]

Podops scutellata Scott 1880: 307; Distant 1902: 77

Body ochraceous with dark brown punctures; ocelli oval of lemon color, eyes brownish black; scutellum with three basal spots and three longitudinal brownish bands; first to last antennal segments black; labial segments brownish ochraceous, second basal labial segment yellowish brown.

Head

Broader than long; anteocular distance slightly more than posterior portion of head including eyes; paraclypei as long as clypeus with apices surrounded; eyes large; sessile, transversely projected; ocelli very minute; antenniferous tubercles produced into somewhat blunt projections, placed at same plane with lateral margins of head, not very distantly placed; antennae with first segment approaching to apex of head, length of antennal segments I 0.3 mm (0.3- 0.4 mm), II 0.3 mm (0.3-0.4 mm), III 0.5 mm (0.5- 0.6 mm), IV 0.5 mm (0.5- 0.6 mm), V 0.6 mm (0.5-0.8 mm), antennal formula 1=11<111=1V<V; bucculae raised, entire; basal labial segment enclosed; labium just reaching to posterior coxae, length of segments I 0.4 mm (0.4-0.5 mm), II 0.9 mm (0.0.9 -1.0 mm), III 0.6 mm (0.6-0.7 mm), IV 0.4 mm (0.4-0.5 mm), labial formula 1=1V<III<II; anteocular distance 0.6 mm; posterior portion of head including eyes 0.5 mm (0.5-0.5 mm); width 1.7 mm (1.7-2.0 mm); interocular distance 1.2 mm (1.2-1.4 mm); interocellar distance 0.6 mm (0.6-0.8 mm).

Thora

Pronotum broader than long, anterior margin with a collar, truncate, having a toothlike process just behind each anterior angle, latter subrounded below the eyes, lateral margins raised curved, posterior lateral margins sinuate, anteroposterior margins truncate, humeral angles rounded; length of pronotum 1.7 mm (1.7-1.8 mm), width 3.8 mm (3.8-3.8 mm); scutellum much longer than broad, truncated at apex, not broader than base, nearly reaching the apex of membrane, lateral margins depressed somewhat before middle; metathoracic scent gland ostiole (Fig. 19) oval with a very short elongate, curved peritreme, auricle raised; length of scutellum 3.8 mm (3.8-3.9 mm); width 2.6 mm (2.6-2.7 mm); length base scutellum-apex clavus 1.2 mm (1.2-1.3 mm); length apex clavus-apex corium (1.5-1.6 mm); length apex corium-apex abdomen including membrane 1.0 mm (1.0-1.3 mm); length apex scutellum-apex abdomen including membrane 0.4 mm (0.4-0.7 mm).

Abdomen

Posteriorly deflected, lateral angles of seventh abdominal sternum in female slightly notched; connexiva poorly exposed at repose. Total length male, 6.7-6.9 mm and female 6.9-7.2 mm.

Male genitalia (Figs. 20-24)

Pygophore (Figs. 20 and 21) almost quadrate, slightly broader than long, ventroposterior margin sharply medially sinuate with irregular fine hairs, lateral lobes with acute inwardly pointed tips; proctiger well developed; paramere (Fig. 22) with a broad blade, entire inner margin dentate, apex inwardly subrounded; inflated aedeagus (Figs. 23 and 24) with pair of well-developed sclerotized thecal appendages, covering on both sides, dorsal membranous conjunctival appendages well developed, apically scierotized appendages present, apices subrounded, vesica stout, reaching up to the apices of penial lobes.

Female genitalia (Figs. 25 and 26)

Posterior margins of seventh abdominal sternum slightly notched in the middle with apices subrounded; first gonocoxae separated with posterior margins slightly sinuate; eighth paratergites larger than ninth, longer than first gonocoxae; arcus and triangulin fused, posterior margins of triangulin sinuate; spermatheca (Fig. 25) with spermathecal bulb without any process, pump region elongate with distinct proximal and distal flanges.

Material examined

Fifteen males, 20 females, Sindh, Sujwal, on *Desmostachya bipinnata* Stapf., 20.10.1975, 30. 12.1976, leg. Azhar Ali Khan, Dr. Syed Kamaluddin and Dr. Imtiaz Ahmad, lodged at Natural History Museum, Department of Zoology, University of Karachi and in Ahmad's collection.

Comparative note

This species is most closely related *to Scotinophara* sp. form III having apical margin of sternum concave and blade of pramere less broad but it can easily be separated from the same in having apices of paraclypei rounded and spermathecal bulb without fingerlike process in contrast to apices of paraclypei truncated and spermatheca with 2 fingerlike processes on bulb.

Control strategies

To avoid outbreaks of black bugs, pyrethroids (cypermethrin or cyhalothrin) are applied. Despite the vast amount of information regarding pest species and control measures used, their damage potential to crop production remains high (Panizzi et al., 2000). More information is needed regarding the time of invasion of overwintering populations into crops and the movements of bugs between wild and cultivated crops. This knowledge will increase the efficacy and efficiency of insecticide use and the potential manipulation of natural enemies inhibiting these systems. Usually, infestation is tolerated

Fig. 18. *Scotinophara scutelatta* (Scott) **(dorsal view)**
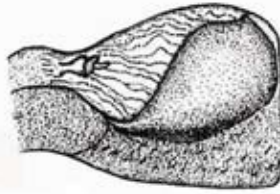
0.45 mm

Fig. 19. Metathoracic scent gland auricle (ventral view)
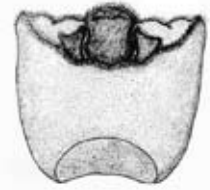
Fig. 20. Pygophore (dorsal view)
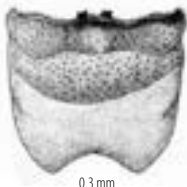
0.3 mm

Fig. 21. Pygophore (ventral view)

Fig. 22. Paramere (inner view)

0.25 mm

Fig. 23. Inflated aedeagus (dorsal view)

0.25 mm

Fig. 24. Inflated aedeagus (ventral view)
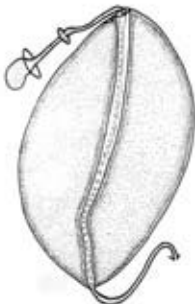
0.3 mm

Fig. 25. Spermatheca (ventral view)
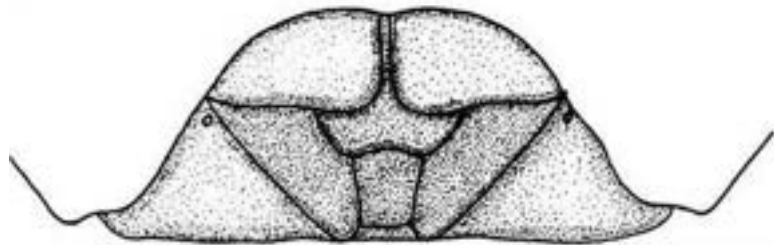
0.45 mm

Fig. 26.Female terminalia (lateral view)

up to an economic injury level and then insecticide is applied to keep crop losses to a minimum. Sometimes, to avoid black bug infestations in the primary crop, trap crops are planted. Other options are planting early- or late-maturing varieties that escape black bug migrations and planting varieties that are resistant to black bug feeding. Finally, enhancing parasitoid populations by inoculative / inundative releases, two-stage harvesting in cereals, destroying alternate plant hosts in or around cultivated fields, avoiding the planting of certain ground cover crops, and spraying alternate crops with insecticides before the bugs move to the primary crops are also effective management practices.

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Insect Faunal Biodiversity Associated with Rice in Pakistan, with Particular Reference to Rice Black Bug

Anjum Suhail, Muhammad Asgher, and Muhammad Arshad

Abstract

Rice is the second staple food in Pakistan, contributing more than 2 million t to national food requirement. The Kaller Tract of Punjab produces the Basmati variety. This crop not only provides food for the people, it is also host to more than 800 species of insect herbivores, which cause low yields, about half of those observed in most of the developed countries. A 2004-06 survey in Pakistan showed that about 180 insect species are associated with rice, of which, about 70 species attack the crop, and that leaffolders, stem borers, and surface grasshoppers are the most injurious insects to rice. A small population of rice black bug was observed in the rice nursery and in rice plants up to maturity. They were mostly found on grasses in the adjoining areas of rice fields. From the collected specimens, two species, *Scotinophara coarctata* and *S. limosa,* were clearly identified, whereas some specimens have a similar size but with features apparently different from those identified. Most of the specimens were collected using light traps and Malaise traps; some specimens were collected by sweep nets (on average, one bug/100 sweeps) from the rice nursery and the transplanted crop.

Key words: insects, rice black bug, biodiversity, rice, Pakistan

Introduction

Pakistan is situated between latitude 24 and 37 degrees north and longitude 62 and 75 degrees east. The country borders Iran in the west, India in the east, Afghanistan in the northwest, China in the north, and the Arabian Sea in the south. The great mountain ranges of the Himalayas, the Karakorams, and the Hindukush form Pakistan's northern highlands of the northwest frontier province and the northern area. Punjab Province is mostly flat, alluvial plain, with five major rivers—Indus, Jhelum, Chanab, Ravi, and Satluj, dominating the upper region, eventually joining the Indus River flowing south to the Arabian Sea. A specific place in between two rivers Chanab and Ravi is known
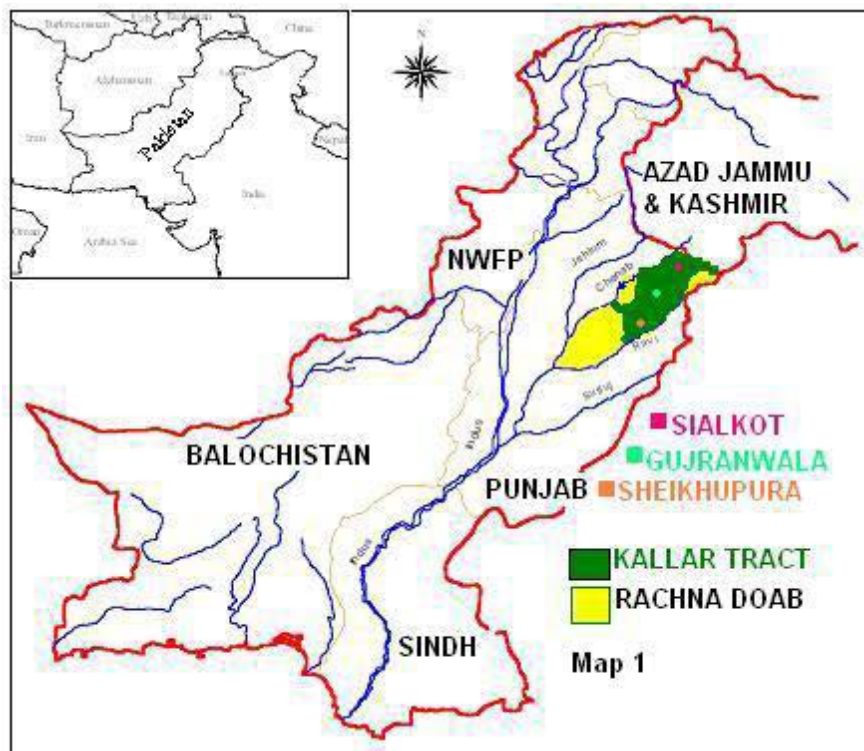
Map 1

as Rachna Doab (Ra: Ravi & Chna: Chnab while Doab: two water's land); here, aromatic Basmati rice is grown in districts Sialkot, Gujranwala, and Sheikhupura. This is known as the Kaller Tract (Map 1). Sindh Province is bounded on the east by the Thar desert and the Rann of Kutch and on the west by the Kirthar range. The Balochistan Province plateau is an arid table land, encircled by dry mountains.

In Pakistan, rice is the second staple food, contributing more than 2 million t to the national food requirement. It occupies 2.5 million ha (10.9% of the total cultivated area) with a production of 5.1 million t of milled rice. The rice industry is an important source of employment and income for the rural people and contributes greatly to the country's foreign exchange earnings. For instance, in 1999-2000, about 2 million t of rice worth 26 billion rupees has been exported. It is therefore imperative that the competitiveness of rice in the international market is improved.

Pakistan is divided into 10 distinct agroecological zones with diverse climatic, hydrological, and edaphic conditions. Rice is grown in zones I and IVa (Maps 2 and 3).

Zone I: Indus Delta. Climate is arid tropical marine. Mean monthly summer rainfall is 75 mm; winter rainfall is less than 5 mm. Mean daily temperature is between 34 °C and 40 °C in summer and between 19 °C and 20 °C in winter. Soils are clayey and silty. Rice, sugar cane, banana, and pulses are the major crops.

I Indus Delta
II Southern irrigated
III Sandy desert (a & b)
IV Northern irrigated plain (a & b)
V Barani lands
VI Wet mountains
VII Northern dry mountains
VIII Western dry mountains
IX Dry western plateau
X Sulaiman Piedmont

Map 2

AGRO-ECOLOGICAL
ZONES OF PAKISTAN

Cotton-wheat
Rice-wheat
Mixed crops
Pulses-wheat
Maize-wheat-oilseed
Maize-wheat
Orchard-vegetables-wheat
Peri-urban around Quetta
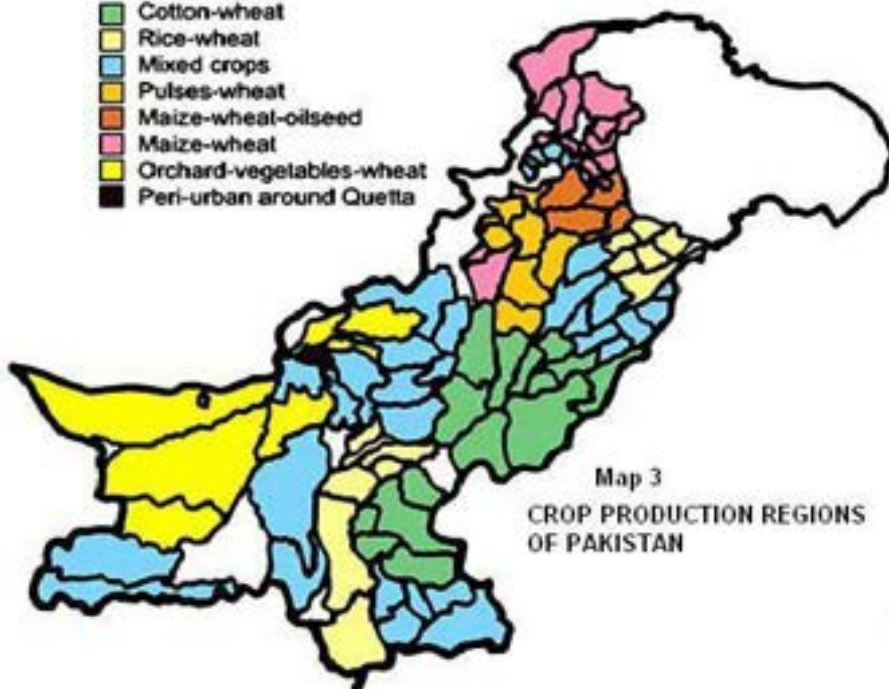
Map 3

CROP PRODUCTION REGIONS
OF PAKISTAN

Zone II: Southern Irrigated Plain, the Lower Indus Plain. Climate is arid and subtropical. Mean monthly summer rainfall is 18 mm in the north and 45–55 mm in the south. Soils are silty and sandy loam but the upper areas of the flood plain are calcareous loamy and clayey. Cotton, wheat, and sugar cane are grown on the left bank of the Indus and rice, wheat, and gram on the right bank (Zone IIIa).

Zone IIIa: Sandy Desert (a). Maximum rainfall is 300 mm. Soils are sandy and loamy fine sand. The land is used for grazing.

Zone IIIb: Sandy Desert (b)—sand ridges and dunes. The rainfall is between 300 and 350 mm. Soils are sandy and loamy fine sand. The land is used for grazing.

Zone IVa: Northern Irrigated Plain (a)—Floodplains and bar uplands. Climate is semi-arid to arid. Mean annual rainfall is 300–500 mm in the east and 200–300 mm in the southwest. Soils are sandy, loam clay, and loam. The canal-irrigated crops are wheat, rice, sugar cane, oilseed, and millet in the north and wheat, cotton, sugar cane, maize, citrus, and mangoes in the center and south.

Zone IVb: Northern Irrigated Plain (b)—alluvial valleys of Peshawar and Mardan. Climate is semi-arid. Mean monthly rainfall is 20–30 mm. Soils are silty clay and clay loam. Main crops are sugar cane, maize, tobacco, wheat, berseem, sugar beet, and orchards.

Zone V: Barani (rainfed) Land. This covers the Salt Range and the Potwar Plateau. In the north, mean monthly rainfall is 200 mm in summer and 35–50 mm in winter. Climate in the southern part is semi-arid and hot. Mean monthly rainfall is 85 mm in summer and 30−45 mm in winter. The main crops are wheat, millet, oilseed, and pulses.

Zone VI: Wet Mountains -High Mountains. Mean monthly rainfall is 235 mm in summer and 116 mm in winter. Soils consist of silt loam to silty clay. A small area is under rainfed agriculture, but most of it is under forest.

Zone VII: Northern Dry Mountains. Mean monthly rainfall is 25–75 mm in winter and 10–20 mm in summer. Valley soils are deep and clayey. Most of the area is used for grazing.

Zone VIII: Western Dry Mountains. They are composed of barren hills with steep slopes. Mean monthly rainfall is 95 mm in summer and 63–95 mm in winter. The soils in the valleys are deep and loamy. Most of the land is used for grazing. On part of the loamy soils are grown wheat and fruit crops.

Zone IX: Dry Western Plateau—mountainous areas. Mean monthly rainfall is 37 mm in summer. The coastal belt receives a sea breeze. The land is used mainly for grazing. Melons, fruit crops, vegetables, and wheat are grown where water is available.

Zone X: Sulaiman Piedmont—plains of the Sulaiman Range. Climate is arid and hot. The mean monthly rainfall is less than 15 mm. Irrigation relies on floods of the hill torrents. Wheat, millet, and gram are the main crops.

The Basmati variety predominates in the traditional rice tracts of the Punjab (zone IVa). In Swat (zone VI) at high altitudes and mountainous valleys, temperate japonica rice is grown. In the south of NWFP, Sindh and Baluchistan (zones IV, II, and VIII), IRRI-type long-grained, and heat-tolerant tropical rice is grown. There was a great increase in rice production in the sixties as a result of large-scale adoption of high-yielding and semidwarf varieties. Since then, a marginal increase in production has been observed. The rice area is also gradually increasing. In most of the cases, critical problems in rice production and protection are specific to a particular zone. A production technology package is developed, keeping in view the distinct agroecological conditions in each zone.

Rice not only provides food for people but also shelter to more than 800 species of insect herbivores, which cause low yield (about half the yield in most developed countries). In Pakistan, the rice crop's insect fauna of 128 species is reported from some parts of Sindh and Azad Kasmir (Ahmad 1985); 125 species are found associated with rice in Gujranwala, Punjab. This crop is attacked by about 70 species, the most pervasive and injurious of which are stem borers and leaffolders (Iftikhar et al 2004). An important practice to enhance yield in Pakistan is to control the insect pests of rice using a large number of chemical pesticides. These insecticides, on the other hand, result in biological disturbance and other environmental problems such as resistance, resurgence, and appearance of new pests and loss of biodiversity. Therefore, the present project has been undertaken to investigate the insect biodiversity associated with the rice crop in the Kaller tract of Pakistan. The project involves the exploration of insect fauna of the rice crop and an assessment of species richness and species evenness.

For this purpose, the Kaller tract in zone II was selected in 2004; six different localities were chosen as study sites. Three sites received inputs as per recommendations of the Agriculture Department, Punjab, Pakistan, whereas the remaining three sites, which were managed by farmers, used low inputs. The insect population was monitored every fortnight by using nets (sweep and dip nets) and traps (pit-fall, light and Malaise traps) in the selected areas. The collected specimens, properly preserved, were placed in the Insect Biodiversity and Biosystematics Laboratory. After identification of this fauna, the data were subjected to statistical analysis to measure species richness and evenness and the effects of high and low inputs on insect biodiversity were compared.

The rice black bug (RBB) was reported in Pakistan by various researchers—Ahmad and Afzal (1976), Ahmad (1985), Reissig et al. (1986), Subramanian et al. (1986), Singh and Singh (1987), Ferrer and Shepard (1987), and Iftikhar et al. (2004). Specimens were collected from low-input areas, but these were very few. The population in each specific experimental area was very small and the same was noted in adjoining areas and on other host plants. Most of the specimens were collected with light traps and Malaise traps and a few were obtained using sweep nets. In adjoining areas, nurseries, and rice fields, one specimen on average was collected in every 100 sweepings of the net. These specimens were observed near the bases of tillers and cracks in the dry field.

The collected specimens were thoroughly studied and the identity confirmed from available literature (Distant 1902).

Species I

Scotinophora coarctata, **Dorsal view**

Scotinophora coarctata, **Ventral view**

Scotinophora coarctata, **Lateral view**

Species II

Scotinophora limosa, **Dorsal view**

Scotinophora limosa, **Ventral view**

Scotinophora limosa, **Lateral view**

Species III

Dorsal view

Ventral view

Lateral view

Species III is confused with *Scotinophora coarctata,* the additional character of pink strip at the lateral margin of abdomen may be a new species, if new then named as *scotinophora rosea* (Anjum).

Morphology

Genus: *Scotinophara* (Stal, 1868) Hem. Fabr. (*Podops,* Fabr (1798), Entomol. Syst. (Suppl. 44-45). This genus has two species.

Scotinophara coarctata Fabr (1798), Entomol. Syst. (Suppl. 44-45).

Generally yellowish-ochraceous with black pointed dots (punctate); body 5.5–6 mm long, 3.25–3.75 mm wide in between pronotal angles and 3 mm wide in the middle.

Head

Greatly bent downward, broad, blackish-brown; eyes ovate, black with yellow margins; antennae pale, segmental margin blackish; proboscis blackish-brown, reaching up to the end of meta-sternum and slightly touching the 1st abdominal sternum.

Thorax

Pronotum greatly convex and punctate with black dots, its anterior margin smooth, anterior half yellow, posterior half brown, lateral margin smooth, bluntly angled midway. Scutellum slightly raised from the center with one yellow rounded spot on each side at the anterior side, beautifully punctate. Wings long, cover the abdomen 1 mm beyond. Legs hairy, slender, similar and pale; femur and tibiae almost similar in size (3−2.75mm); tarsi and tarsal claws black.

Abdomen

Ovate, shorter than wings, its middle sternum shiny brown, lateral margin yellow. In some specimens, lateral yellow margins are with pink extremities.

Scotinophara limosa Walk. (1867), Cat. Het. p 72.

Generally ochraceous-brown, very coarsely black punctate; body 6–6.75 mm long, 3 mm wide in between pronotal angles and 4 mm wide from the middle of the body.

Head

Slightly bent downward, narrow, dark blackish-brown; eyes elongate, protruded on sides, blackish-brown; antennae brown; proboscis blackish-brown, hardly reaching up to the meta-sternum.

Thorax

Pronotum convex, punctate, with black dots, its anterior margin with a long slightly incurved spin reaching up to the anterior margin of the eye on each side, anterior half light brown, posterior half black, lateral margin smoothly angled with a notch and spine. Scutellum slightly raised from the center, with obsolete light-colored elongated marking on each side at the anterior sides to half of the

scutellum, punctate. Wings short, almost equal to abdomen. Legs long, hairy, slender, and similar; femurs black, shorter (2.75−3 mm) than pale-brown tibiae (3.25−3.5 mm); tarsi and tarsal claws pale-blackish.

Abdomen
Ovate, 1st & 2nd abdominal segments slightly wider; sternum almost blackish-brown, shiny, lateral margin yellow.

Both species have already been reported by Ahmad in 1985. There is confusion with species I having a pink strip at the lateral margin and species II having a well-developed spine on the anterior margin; these are confused with species *C. lurida* and *C. bispinosa.*

Ecology

Specimens were collected mostly with light traps, Malaise traps, and sweep nets from nursery to maturity stage in rice-growing areas of the Kaller Tract from April to December. In Pakistan, nursery is grown in May, transplanted from 20th May to mid-June into main fields where average temperature remains at 40−45 ºC and 40−50% relative humidity increase in July to September averages 70−80%. The crop remains in the fields up to November−December. After harvest, in most places, wheat is grown in the same fields. The adjoining areas, specially roadsides and banks of water channels with grasses and weeds, offer alternate host plants for insects associated with the rice crop as well as to RBB too. Maximum numbers are collected from May to September, when small amounts of granules for insect pest control are applied. Most of the specimens are observed at the base of the rice plants and, in adjoining areas, in cracks and crevices on the ground. RBB specimens are seen crawling on the mud and some are found on leaf blades also.

From these observations, the status of the RBB is difficult to determine because its population is much lower than those of leaffolders, leafhoppers, planthoppers, grasshoppers, and borers, which are the top insect pests of rice in Pakistan. Ahmad (1985) reported only one species of RBB (*S. limosa*), while Ahmad and Afzal (1976) reported six species of this insect associated with paddy in lower Sindh. Ahmad and Mohammad (1985) observed that the insect is of minor importance, attacking rice ears during harvest. This insect may have the potential to be a pest as it is reported in many other countries of the Orient, especially in the Southeast Indio-Malayan region.

Name of country museum/institution with insect collections of RBB and officer-in-charge of the collection: Pakistan, Insect Biodiversity and Biosystematics Laboratory, Department of Agri. Entomology, University of Agriculture, Faisalabad, Pakistan.

Officer in charge: Prof. Dr. Anjum Suhail

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Current Status of Rice Black Bug and its Management in the Philippines

Wilma R. Cuaterno

Abstract

According to Bureau of Plant Industry (BPI) records, the rice black bug (RBB) has been in the Philippines since 1948. It just came into the attention of farmers and the Department of Agriculture (DA) when the first infestation occurred in Palawan in 1972. It was declared a pest of rice 10 yr later. The insect has such inherent plasticity that it can cope with any management strategy after a certain period of time. We do not know if the species in every given time of infestation is the same or not and we are not sure if RBB is endemic to the country. The Philippines is starting to verify this. Up to this time, the country is considering RBB a major pest of rice and has been monitoring its presence on other plants, especially corn. The DA, in coordination with local government officials, is trying to prevent its spread from the Bicol Region toward the north of Luzon. RBB infestation in every region is localized. Some areas in a region are not infested with the pest. Millions of pesos are lost to RBB each year though the exact figures are not available in every region. Management for the pest is evolving, learned from experiences derived in every infestation. Like any other pest, management of RBB should not rely on one strategy, it needs an IPM approach. But we can conclude that biological control is one of the major strategies that will manage the RBB better though community action is still the best for any pest because they do not respect boundaries.

Keywords: rice black bug, infestation, IPM, biological control, plasticity, endemic

Introduction

The Philippines is one of the countries in Southeast Asia which was severely hit by the rice black bug (RBB). As per specimen record found in the Bureau of Plant Industry (BPI), RBB has been in the country since 1948. The collector found it in the city of Manila, which was then a grassland area. But the first infestation ever recorded in the country occurred in Bonobono, Bataraza, Palawan.

Palawan is the only province in the Philippines which is at the Wallace Line with reference to its flora and fauna.

Apparently, in that infestation, the source of RBB was believed to have come from Malaysia or Sarawak, Indonesia. It occurred in September 1979; this is considered the 'mother of RBB infestation' in the country. At present, the pest is already in the three island groups of the country: Luzon, Visayas, and Mindanao. Though some provinces are not affected by the pest; it remains a threat to our 3.2 million ha of rice fields.

Route of RBB spread in the Philippines

In February 1982, RBB was recorded as a new pest of rice in the country after the recorded infestation in Palawan in 1979. The DA tried to contain the infestation using different insecticides. To no avail, major outbreaks followed in March and June, which spread toward the central and northern parts, covering an estimated area of 4,500 ha. RBB spread in succeeding years in outbreak proportions all over Palawan, which may be due to the elimination of indigenous natural enemies of RBB in the area as a result of massive and intensive spraying of insecticides in affected municipalities. The RBB outbreaks stopped in Palawan when the Task Force employed quarantine measures, biological control, and used a tolerant rice variety. At present, RBB is now part of Palawan's rice field ecology and is being regulated by natural enemies that are endemic in the area.

A decade after that serious infestation in Palawan, an infestation of RBB was recorded in Zamboanga in 1992. RBB started to invade the island of Mindanao. concerned DA and local government officials tried to protect their rice again, employing massive spraying of insecticides. In 1995, it spread toward the Autonomous Region of Muslim Mindanao, Region 12, and the CARAGA Region.

It is a repeat of what had happened in Palawan, when the natural enemies of the pest present in the field were killed by the insecticides sprayed in the infested areas. The light of sea vessels plying the Palawan-Zamboanga route is also one of the suspected means of the spread of the pest in Mindanao. The RBB are so attracted to the light that it goes with the vessels.

The pest was also recorded in the Negros provinces of the Visayas. From 2000 to 2003, RBB infestations were recorded in Bohol, Leyte, and Samar. What brought the pest to the islands, particularly in Leyte, were the rice seeds that were infested with RBB, which escaped the quarantine measures at the concerned ports.

The recent infestations recorded are already in Luzon Island. It started in the coastal towns of Sorsogon where aquaculture is strong. The strong lights that surround the aquaculture farms attracted the RBB and the insects begun to wreak havoc to surrounding rice areas. The DA was able to contain it for 5 mo, employing integrated pest management that focuses on biological control and physical and quarantine measures. Later, it was able to spread to Camarines Sur. Only the provinces of Camarines Norte and Masbate of the Bicol Region remain free from the pest at present. Efforts are being exhausted to prevent the RBB from spreading toward the northern parts of Luzon where the Central Plain, the rice granary of the Philippines, is located.

RBB status in affected regions

Our reports on RBB infestations from 2004 to 2006 came only from Regions 9 and 12. There are a total of 3,197.73 ha damaged (i.e., there is significant economic loss to farmers) and 12, 815 ha affected (i.e., RBB is present but damage is not significant; the area still serves as host to the pest). Though the figure is not conclusive, it tells us that RBB is still a major pest to watch out for in our rice fields.

Region 1

Pest surveillance and monitoring using farmer field schools are being done in the different barangays of the municipalities of the respective provinces of the region. At present, RBB is not yet present in the area.

Region II

At present, RBB is not yet present in the region The region has a system of monitoring pests in rice, corn, and other agricultural crops.

Region III

The region is already vigilant in their monitoring system. They have already set up light traps in Casiguran, Quezon, a municipality near the sea, for early detection of RBB presence. The region is still RBB-free.

Region V

RBB was previously reported in four provinces of the Bicol Region: Sorsogon, Albay, the provincial island of Catanduanes, and Camarines Sur. That was the status before 30 Nov 2006, when a strong typhoon hit the region. The latest was that there was no sign of infestation at present. The Regional Crop Protection Center is still verifying and checking the reported hot spots.

The region employed integrated pest management approaches in managing the pest, particularly the use of entomopathogenic fungus *Metarhizium*. Chemical control was not recommended because it will also kill the natural enemies of the pest. *Metarhizium* sp. were distributed free to farmers. In addition, the RCPC conducted seminars on how to manage the RBB in the surrounding areas, both non-affected and affected ones. They are also monitoring the population of the pest through light traps during and before the full moon. The full moon is the time the RBB fly in swarms, congregate, and infest a new field.

Region VI

The region reported on the status of RBB only in the northern Iloilo Province. RBB was first noted in the municipality of Ajuy, Iloilo, in March 2006. Seven municipalities were affected by the pest. The total area infested was 2,226 ha, with an estimated 109 ha damaged. A yield loss of 15% was estimated in the two biggest municipalities of the province, Ajuy and Concepcion.

RBB Task Force Iloilo, during the height of infestation in 2006, conducted a massive information campaign, did weekly monitoring and assessment of RBB infestation, conducted trainings and conferences on RBB, and distributed information materials. Around 519 kg of RBB were caught during training and light trapping operations after a typhoon on 16 May 2006.

At present, after monitoring activities conducted by the Regional Crop Protection Center, a minimal population of RBB can be found in Ajuy and Concepcion. An average of five bugs per hill was noted in these two towns. Other municipalities were found to have no RBB at the time.

The hands-on IPM training provided by the Northern Iloilo RBB Task Force greatly contributed to the reduction of RBB in the area. They are now confident that RBB can be managed through use of light traps, application of *Metarhizium,* and intermittent flooding. Some are even putting ducks in their field after harvest.

However, the Regional Crop Protection Center still advises them to be vigilant and to continue monitoring work.

Region VIII

RBB is already a part of the rice ecosystem. They are using IPM in managing the pest, combining cultural and physical methods and the use of the pathogen *Metarhizium*.

Region IX

Zamboanga of Region 9 is the first province in Mindanao that was affected by RBB 15 yr ago. The DA is not certain where the RBB came from, but they suspected the vessels in the then very active trading route between Zamboanga and Palawan. During the first years of infestation, they have resulted in massive insecticide spraying, which may have caused the rapid spread of the pest in Mindanao.

The later years showed the development of RBB management schemes in the region. They started light trapping and biological control by using *Metarhizium*. Every region then in Mindanao started to mass produce this entomopathogenic fungus, especially the Regional Crop Protection centers. *Metarhizium* became readily available. Now, they rely on integrated pest management for RBB control. *Metarhizium* is now a common fungus in the field mummifying RBB.

Recent monitoring efforts revealed that the provinces of Zamboanga del Norte, Zamboanga Sibugay, and Zamboanga City showed no signs of RBB infestation. It is only in the field and near street lights of Zamboanga del Sur where they observed the presence of RBB.

Region X

RBB is present in some rice areas of Valencia City, Bukidnon, where the population is higher than in the previous cropping seasons. However, the presence of RBB in Misamis Occidental and Lanao del Norte still has to be confirmed. No pest status updates were given for Camiguin and Misamis Oriental. The region is implementing IPM to better control the pest.

Region XI

RBB at present is a problem only in two provinces, Compostela Valley and Davao del Norte. Farmers in other provinces are implementing IPM. In the two problematic areas, the pest is contained with the use of *Metarhizium* and water management. They are always on guard especially when the full moon is approaching. Sometimes, they use chemicals when there is heavy infestation.

Region XII

Sultan Kudarat is the only province in Region 12 regularly being reported to have RBB infestation. From 2004 to 2006, an estimated 3,283.5 ha were damaged by the pest. Annual losses to rice ranged from P3 million to P42 million pesos in that period.

In 2005, RBB were already seen in *Bt* corn planted in some areas of the region. Region 12 is employing IPM for RBB. But implementation and transfer of technology in the area is quite difficult because of the peace and order situation.

RBB is still a big problem in Region 12, especially when the full moon comes. Heavy populations of the pest congregate in lighted posts of residential areas, causing nearby ornamental plants like *Palmera* to die because of the large number of RBB.

Region XIII (CARAGA)

In CARAGA Region, farmers are used to seeing RBB in their field. It is now a part of their local field ecology. Water management is the most popular method of managing the pest in the area. Farmers know the importance of biological control in the management of the pest; aside from using *Metarhizium,* they also enhance the natural enemies in the field by limiting the use of pesticides. Like other regions with RBB, they are also monitoring RBB populations, especially during the full moon.

ARMM

The RBB is present in the region. It is already a part of their rice ecosystem. In areas were farmer field schools are conducted, they are implementing IPM. However, in areas where peace and order is a problem, the pest status is unknown.

Integrated pest management for RBB

I. Farmers' education/awareness

Through trainings/seminars and the use of multimedia to
-know the biology of the pest
-know the ecology of the pest

II. Management options

A. *Without standing crops*
1. Pre-planting time

MECHANICAL CONTROL
-flooding the field to submerge all stubbles and grasses
BIOLOGICAL CONTROL
-herding of ducks to feed on RBB in stubbles and grasses

2. <u>During planting time</u>
CULTURAL MANAGEMENT
-synchronous planting
-direct seeding of crop
-use of resistant/tolerant variety

B. *<u>With standing crops</u>*
CULTURAL MANAGEMENT
-monitoring the RBB population
-sanitation
-intermittent water regulation
MECHANICAL MANAGEMENT
-light trapping
BIOLOGICAL CONTROL
-enhancement and conservation of natural enemies
-release of mass-produced biological control agents
-herding of ducks

C. *<u>During harvest</u>*
MECHANICAL MANAGEMENT
-light trapping
-flooding
-submerging all stubbles and grasses
-plowing under all stubbles and grasses immediately after harvest

D. *<u>During outbreaks</u>*
MECHANICAL MANAGEMENT
-reporting the incidence to the nearest DA office
-informing neighboring farmers to prepare for possible infestation
-plowing under of infested fields
-light trapping

LEGAL MANAGEMENT
-Enforcement of quarantine rule

E. How to get ready for possible infestation during full moon

-monitor

-get ready with *Metarhizium* spray and cultured biological control agents

-check water control

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Rice black bug, *Scotinophara lurida* (Burmeister) (Hemiptera: Pentatomidae), in Sri Lanka

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Abstract

This article compiles Sri Lankan literature on rice black bug *Scotinophara lurida* (Pentatomidae) and summarizes information on the insect's spatial and temporal distribution, bionomics, ecology, and control measures. The economic significance of *S. lurida,* one of the species attacking rice, has varied over the last 70 years in Sri Lanka. It was an economic pest from the 1940s to the 1960s. During this period, repeated outbreaks of *S. lurida* occurred, affecting several thousands of hectares of rice fields in the southern province of Sri Lanka. The species occurred in many other parts but in low numbers. At present, *S. lurida* survives in all most all rice-growing areas but solid information on occurrence is only reported in areas where agricultural research and extension work is active. The external morphology of adults and nymphs, together with life history, has been well studied and is reported here. This species aestivate in nearby high grounds, along water channels, and bunds. Upon completion of aestivation, they migrate to the young rice crop and resume biological activities. *S. lurida* completes four generations per year over two seasons of rice crops. Management of *S. lurida* has been achieved with conventional chemicals though these chemicals are no longer in use. In addition, physical and cultural strategies have been tried and variable results have been achieved. Natural enemies of *S. lurida* exist in Sri Lankan rice fields, but studies were limited to identification of the species and to a narrow research area. One egg parasitoid, *Telenomus triptus* and two entomopathogenic microbes, *Metarhizium anisopliae* and *Penicillium citrinum,* have been reported. There are many biological and life history data that are important to fully comprehend the bionomics of *S. lurida,* but these data are not available in Sri Lankan literature.

Key words: *Scotinophara lurida,* rice black bug, bionomics, life history, distribution, Sri Lanka

Introduction

Rice black bug (RBB), *Scotinophara lurida* (Burmeister) (Hemiptera: Pentatomidae), is considered an economically important pest of rice in some South and Southeast Asian countries (Pathak and Khan 1994). In Sri Lanka (5⁰ 55' - 9⁰ 50' N; 81⁰ 50' - 79⁰ 42' E), *S. lurida* has been an insect of interest before the 1960$_s$ (Alwis 1941, Joachim 1951-56, Rhind 1951, Fernando 1959a,b; 1960a). In the 1970s and 1980s, it was considered as a minor or occasional pest (Wickramasinghe 1980, Nugaliyadde et al 2003). However, since the1990s, it has become an important pest of rice, requiring intervention approaches for its management. As a result of varying interests on *S. lurida* over the years, local literature on this species is scattered. The objective of this paper is to compile the local literature and summarize information on *S. lurida* with respect to distribution, biology, ecology, damage, and control measures.

Rice black bug

Rice black bug (RBB) refers to species *Scotinophara lurida* (Burmeister), *S. coarctata* (Fabricius), *S. latiuscula* Breddin, *S. scotti* (Horvath), and *S. ochracea* (Distant) (Justo 1995). We observed confusion in the identification of *Scotinophara* species from Sri Lanka. The presence of *S. lurida* in Sri Lanka is well documented (Alwis 1941, Fernando 1960a, Grist and Lever 1969). Dale (1994), through available records, indicated that both *S. lurida* and *S. coarctata* exist in Sri Lanka. However, Pathak and Khan (1994) stated that only *S. lurida* exists in Sri Lanka and not *S. coarctata.*

Geographical and temporal distribution

Scotinophara lurida has been documented as a rice-feeding insects before 1940 in Sri Lanka (Rodrigo 1938 Pathak and Khan 1994) but it is not considered a pest. Subsequently, *S. lurida* became an economically important pest through 1940s−60s. *S. lurida* has been recorded in the districts of Matara, Kalutara, and Hambantota in the southern province, in addition to the districts of Kurunegala (northwestern province) and Gampaha (in the western province) (Alwis 1941). In 1940, an outbreak of *S. lurida* was reported in areas near Walawe River (Hambantota District) (Alwis 1941) where more than 4,444 ha of paddy were affected (Fernando 1960a). In the same year, a high population of *S. lurida* was observed at Okkampitiya in Monaragala District in Uva Province and in Polonnaruwa District in the north-central province (Fernando 1960a). Another outbreak of *S. lurida* has occurred in 1949 at the same sites near Walawe River, again affecting 4,444 ha of paddy (Rhind 1951). This was followed by high population levels in Ambalantota area (Hambantota) in 1950 (Joachim 1951).

A moderate level of *S. lurida* population was noted through 1951 in Ambalantota and a mild outbreak appeared in the Dehiowita area (Kegalle District) and in Anuradhapura area (Anuradhapura District) in 1951 (Joachim 1952). Another major outbreak of *S. lurida* occurred in Walawe river left and right bank colonization scheme in 1953, affecting 445 ha of paddy (Joachim 1954). *S. lurida* was reported in the Ambalantota area in the same year. In 1954, *S. lurida* appeared in the northwestern, central, and north-central provinces of Sri Lanka. An outbreak of *S. lurida* occurred in 1955 at

Walawe river banks (Hambantota District). In 1960, another *S. lurida* outbreak occurred in Matara and Trincomalie districts. *Scotinophara lurida* has been considered a major economic pest of rice since the1960s (Fernando 1964, 1966).

In the 1970s and 1980s, *S. lurida* was not considered an economically important pest (Wickramasinghe 1980, Nugaliyadde et al 2003) and, as a result, less attention was given to collecting information on *S. lurida* (Kudagamage and Nugaliyadde 1990a, 1990b; Wickramasinghe 1978, 1980).

However, there was an outbreak of *S. lurida* in 1990 at Mahaweli System B in Aralaganwila (Polonnaruwa District) (Premaratna Bandara, pers. commun.). Department of Agriculture staff report that, at present, *S. lurida* exists in almost all rice-growing areas in Sri Lanka, particularly in the districts of Kalutara (Labuduwa, Bombuwala, Horana, Bulathsinghala), Hambantota, Matara, Kurunegala (Batalagoda), and Anuradhapura (Maha Illuppullama), where the bugs are either collected in large numbers or observed by the scientists. Rajendram and Devarajah (1990) found *S. lurida* in Batticaloa District (Karadianaru). Furthermore, we have observed rice crops severely damaged by *S. lurida* in Matara District (total area, 0.5 ha).

Biology and ecology

The biology and ecology of *S. lurida* in Sri Lanka have been well documented by Fernando (1960a) and Alwis (1941). The following account is mostly from Fernando (1960a) and Alwis (1941).

Adult insects

The adult insect is a typical pentatomid bug; with body length and width 9−10.5 and 5−5.5 mm, respectively. It has adark brownish, oval shaped body. The antennae are long, about half the length of the body, consisting of five segments in flagellum. The pedicel cannot be viewed from the dorsal view. The first segment of the flagellum is distinctly shorter than the second segment. The last segment is slightly thicker than the rest of the segments in the flagellum. The two ocelli are placed laterally. The thorax is almost black, with a coarsely punctate surface. Pronotum has straight lateral margins with distinct spines near each anterior angle. The scutellum is narrowed posteriorly and extends backward almost to the apex of the abdomen. Coxa and femur of legs are black and the other parts are brown. There are three tarsomers in the leg. The ventral side is black but becomes brownish toward the margin. Male and female insects are very similar, except for the apex of the abdomen (Alwis 1941, Fernando 1960a).

Infestation of rice crop starts with the migration of adults that aestivated in nearby highland areas. They are active during early morning (Alwis 1941). Fernando (1960a) and Manikkawasagar (1964) indicated that they are very active at dusk and are in flight in large numbers. Rice black bugs seem attracted to light (Fernando 1960a), but trapping adults and nymphs using light trap was not effective enough to manage the population level (Rodrigo 1941). Nocturnal migration is more obvious among adults which are at the end of the aestivation period (Fernando 1960a).

Adult insects do not prefer strong sunlight, staying at the base of the rice plant near the water surface (Alwis 1941). If there is no standing water in the field, adult bugs go into cracks in the soil

(Alwis 1941, Fernando 1960a). Migrating adults congregate on stems and leaves of 3−4-wk-old rice plants. When the crop is under heavy infestation, 96 adults and 48 nymphs per square meter is common (Fernando 1960a). Extremely high numbers, as high as 125 adults per square meter has also been reported (Fernando 1960a). Infestation is usually unevenly distributed in rice fields and the level of infestation is positively correlated with healthy and well-grown green plants. In addition, infestation is common in fields with standing water compared with dry fields, especially in irrigated rice fields. This pattern of distribution has been observed, irrespective of population density of RBB. Adult distribution in the fields varies with population level as well as time of rice cultivation (Fig. 1) (Fernando 1960a).

Adults and nymphs of *S. lurida* feed on rice plants, taking sap from the upper part of rice seedlings and even from the upper surface of the leaves (Fernando 1960a). They continue to feed during the day, avoiding strong sun and hiding under the leaves. *Scotinophara lurida* remains on the rice plant until harvest. In mature crop, *S. lurida* tends to stay at the base of the plant stem. If there is no standing water in the field, *S. lurida* stays on the soil, among short grasses and debris in the rice stems. *S. lurida* does not usually feed on the upper parts of mature rice plants, including the panicle (Fernando 1960a). However, infestation on panicles has been observed, perhaps under exceptional ecological conditions.

After adults migrate to the seedling crop, they continue to feed on the rice plants for about 1 wk and then start copulating. Copulation of the first-generation adults takes place when the crop is at shooting stage. These bugs copulate at all hours of the day and eggs are laid 10 after copulation (Fernando 1960a).

Oviposition

Usually, eggs are laid on the lower surface of the terminal part of the rice leaf blade of rice seedlings and rarely on the stem (Fernando 1960a). Sometimes, *S. lurida* lays eggs on weeds that are common in rice fields (e.g., *Isachne globosa* and *Echinochloa crus-galli).* Eggs have also been observed on Cyperaceae weeds (e.g., *Cyperus difformis, C. flavidus, C. iria, C. rotundus, Fimbristylis miliace,a* and *F. dichotoma).* In addition, Marsileaceae weeds (*Marsilea quadrifolia)* and Pontederiaceae weeds (*Monochoria vaginalis)* have been observed as alternate hosts of *S. lurida* (Fernando 1960a). When the rice crop is mature, oviposition takes place on leaf sheaths at the basal part of the rice stem (Fernando 1960a).

Eggs

Eggs are laid in rows, usually in two−three parallel rows, seven eggs per row on average (Alwis 1941, Fernando 1960a). The maximum number of eggs per row is 13 (Alwis 1941). Generally, 8-15 eggs are found per egg mass (Fernando 1960a). The bug usually lays 2-3 egg masses within 2 wk and dies during the following week (Fernando 1960a). Freshly laid eggs have variable colors: yellow, pink, orange, grey, blue-grey, and light brown (Fernando 1960a). When eggs are at maturity stage, they turn deep orange red; compound eyes, egg buster, and other nymph structures become apparent through
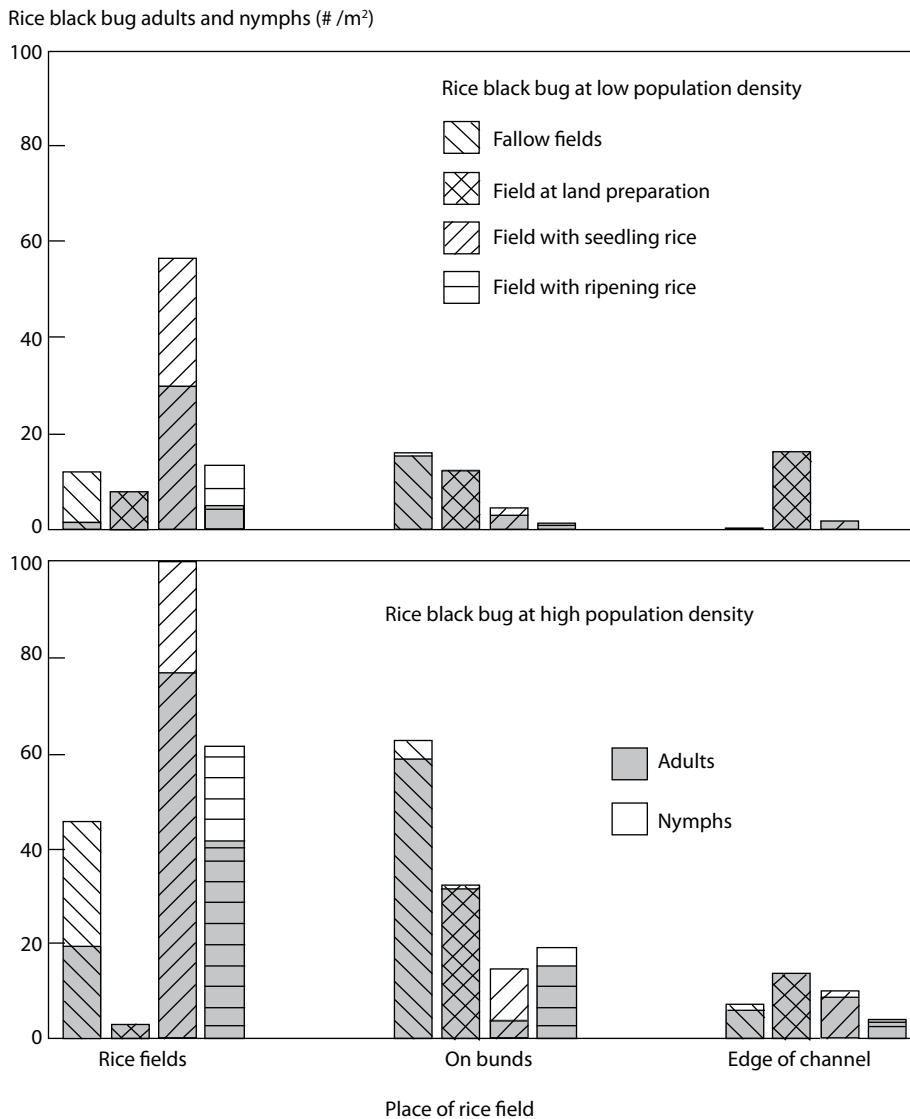
Fig. 1. Abundance of adults and nymphs of *S. lurida* at different sites with respect to rice cultivation schedule at high and low population levels (Fernando 1960a).

chorion (Fernando 1960a). Egg size is about 1 mm long and 0.75 mm wide (Alwis 1941). The average incubation period is 5-6 d at 25-28 °C and 75% relative humidity (Alwis 1941, Fernando 1960a).

Nymphs
Scotinophara lurida passes five nymphal instars and morphology slightly differs from the initial nymphal instars. The first-instar nymph is about 1 mm long with a circular body. Head and thorax are

dark brown and finely punctured. The prominent compound eyes are black; abdomen is light brown with fine black dots; the mid-dorsal region of the abdomen has three dark brown transverse bands. The first band is narrower compared with other bands (Alwis 1941). The first nymphs remain near the egg mass for about 1-2 d, then disperse toward the lower region of the plant (Fernando 1960a). The first nymphal instar lasts for about 5-6 d at room temperature (Alwis 1941, Fernando 1960a).

The second-instar nymph is about 2.5 mm long; head and thorax are yellowish brown finely punctured with black. Compound eyes are reddish brown and prominent. Irregular brownish markings on either side of the pro- and mesothorax are visible. Antennae and legs are pale yellowish brown. Abdomen is dark brown with fine punctures. Transverse bands on the abdomen are similar to the bands of the first nymph. The second nymph takes about 11-13 d to become a third-instar nymph (Alwis 1941). Fernando (1960a) reported it as 9 d (7-11) at 25-28 °C and 75% relative humidity.

The third nymph is about 3.5 mm long; the characteristics of the head, thorax, and transverse bands on the abdomen are the same as those of the second-instar nymph. Antennae are pale brown with dark brown terminal segments. Legs are pale brown and abdomen is pinkish brown with black dots (Alwis, 1941). It takes 8-11 d for the third-instar nymph to become a fourth-instar nymph (Alwis 1941). Fernando (1960a) reported the required time as 7 d at 25-28 °C and 75% relative humidity.

The fourth-instar nymph is morphologically similar to the third nymphal instar. Body length is about 5 mm (Alwis 1941) and the nymph takes 9-10 d to reach the fifth-instar stage (Alwis 1941, Fernando 1960a).

The fifth-instar nymph is about 8 mm long; the head and thorax are brown. Wing-pads are distinct. Antennae are pale yellowish brown, except the terminal segment, which is dark brown. The abdomen is dark brown, with fine black punctures and transverse lines are similar to those of fourth-instar nymphs. It takes about 11-13 d for the nymph to become an adult (Alwis 1941, Fernando 1960a). The egg-to-adult cycle of *S. lurida* is about 49-59 d.

Generally, *S. lurida* completes four overlapping generations per year on two rice crops in Sri Lanka. Aestivating adults starts to lay eggs on rice seedlings in late April-mid-May in southern Sri Lanka where the population dynamics was examined. Adults from those eggs become apparent in early July. A few adults lay eggs from mid-August to mid-September, with the remainder migrating to aestivation sites. The nymphs of those eggs complete the life cycle on grass or migrate to aestivation sites and become adults. The adults of both the first and second generations invade the second rice crop in the following season and complete one full generation and partial second generation on the second rice crop. Hence, there are four overlapping generations per year in southern Sri Lanka (Alwis 1941, Fernando 1960a).

Damage to rice plants

Adults and nymphs of *S. lurida* feed on the rice plant, puncturing and extracting sap and exhibiting four different symptoms (Alwis 1941, Fernando 1060)a:
- highly localized, clearly marked light-dark brown lesions on leaves,
- extensive chlorotic marking on leaves,

- death of central shoot or part of it, and
- death of the entire plant.

Control measures

Chemical spraying or dusting has been practiced to bring down the population level in outbreak situations (Fernando 1959b, 1960a,b). Many chemicals, including chlorinated hydrocarbons and organophosphates, have been screened and used in the early 1960s (Fernando 1960b). Today, these chemicals are outdated and no longer in the market. Aestivating adults are more resistant to chemicals (Fernando 1959a); hence active adults and nymphs are the targets of chemical control. At present, chemical application is not generally recommended. The Department of Agriculture of Sri Lanka has given tentative recommendations (not approved yet) regarding insecticide use to control of *S. lurida*.

Alternative management methods

In addition to chemical control, many other alternative strategies have been practiced to bring down the *S. lurida* population. Through physical disturbances, lodging of adults and nymphs to standing water with a thin layer of kerosene on top has been practiced (Alwis 1941, Grist 1959). Water with kerosene oil should not be retained in the field for longer hours and should be drained after 3-5 h from the time bugs have lodged. Cultural practices such as clearing of bunds and adjoining lands and plowing of stubble after harvest have been done to reduce the number of aestivating adults (Alwis 1941, Manikkawasagar 1964). Maintaining tall bunds in rice fields also has a negative effect on *S. lurida* population (Alwis 1941). Advanced cultivation of some rice in the field as a trap crop has also been practiced (Alwis 1941). Use of light tras to collect adult insects has been suggested, but the efficacy of the practice or a quantitative assessment of population reduction has not been determined.

Natural enemies

Predation of *S. lurida* in Sri Lankan fields was not documented, but parasitization of eggs and entomopathogenic diseases on aestivating adults have been observed (Fernando 1960a). *Telenomus triptus* Nixon (Hymenoptera, Scelionidae) parasitizes *S. lurida* eggs and with a level of parasitism varying from 30 to 36% during a 1953-55 field study (Joachim 1956, Fernando 1960a). In some occasions, parasitism level has reached 89% (Alwis 1941, Joachim 1955). *T. triptus* is a solitary parasitoid and parasitizes 1−3-d-old *S. lurida* eggs. It takes 11 d to complete the life cycle (Alwis 1941, Fernando 1960a). The level of parasitism in the fields has been significantly decreased with chemical spraying in rice fields. In 1941, parasitism level was 89% and it was 0% in 1954 in farmers' fields (Joachim 1955). In addition, a braconid species has been reported as a parasitoid of *S. lurida,* but no data on its identification or biology exist (Rodrigo, 1941).

Two entomopathogenic fungi, *Metarhizium anisopliae* and *Penicillium citrinum,* have been isolated from aestivating adults (Fernando 1960a). However, there is no evidence of these pathogens being used as a population control strategy.

Rice black bug collections

At present, museum collections of RBB are available at the following institutes: Horticultural Crop Research and Development Institute (HORDI), Gannoruwa, Peradeniya (tel.: +94 81 238 8011, 8012, 8013), and at the Rice Research and Development Institute (RRDI), Batalagoda, Ibbagamuwa (tel.: +94 37 225 9881).

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The rice black bug *Scotinophara lurida* (Burmeister) in Taiwan

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Abstract

The rice black bug *Scotinophara lurida* (Burmeister) is one of the destructive insect pests of rice in Taiwan before 1950, causing severe damage, especially in the south. After 1970, damage has been negligible; RBB became a potential pest. Occurring in both north and south Taiwan, the bug takes two generations a year. They overwinter in the adult stage and gregariously hibernate in stubbles, leaf litter of grove and bunch grasses on levees, or soil cracks in the surrounding sugarcane plantations. Adult bugs survive for 4–6 mo. They are attracted to light, but their flight activity is affected by the lunar cycle. Adults invade rice fields during tillering in the first and second cropping seasons. A female is able to lay about 200 eggs intermittently in her lifetime. The incubation period of eggs is 5–12 d. After hatching, the first- and second-instar nymphs live together; they then disperse to live as adults after the third instar. The bugs inhabit the basal part of rice plants during daytime and they are active in the upper part of rice plants from dusk to dawn, drying out from rice plants in the next morning or in cloudy days. The nymphs molt four times to reach the adult stage in 30–59 d. The bugs are known to attack the rice plants at various stages. Heavy infestation usually occurs after the heading stage of rice. It causes not only incomplete spikelets and unfilled or spotted grains but also leads to death of rice plants. *Saccharum officinarum* L. and *Zizania latifolia* L. are the alternative food plants in Taiwan. The population buildup, sampling techniques, and the methods suggested for controlling the bugs are also briefly described.

Key words: rice black bug, *Scotinophara lurida,* biology, seasonal occurrence, control measures

Introduction

Several species of black bug (Hemiptera: Pentatomidae) that attack the rice plants are recorded in Asia (Miyamoto et al. 1983, Mochida et al. 1986, de Sagun et al. 1991, He 1992). The two most common and important species of the rice black bug (RBB) are *Scotinophora lurida* (Burmeister) and the

Malayan RBB (*S. coarctata* (Fabricius) (Chang et al. 1991, Dale 1994, Pathak and Khan 1994). The Malayan RBB is widely distributed in south and southeastern Asia, from the Philippines to India, and many pest outbreaks have been reported in southeastern Asia since the 1970s. On the other hand, *S. lurida* is distributed in east, southeast, and south Asia, from Japan westward to China and Pakistan; then southward to Indochina, Philippines, and Indonesia. This species is considered a potential pest of rice in recent years, though it has been reported as an important insect pest of rice in Japan and Taiwan in the past (Dale 1994, Pathak and Khan 1994, Mochida 1998, Chu 1973). In Taiwan, the RBB is used to juxtapose plant- and leafhoppers, rice hispa, rice leaf beetle, and stem borers as the five most destructive insect pests of rice before the 1960s, causing severe damage periodically in southern Taiwan (Anonymous 1909, 1944; Chu 1973). However, the bug population decreased rapidly thereafter, probably due to intensive use of insecticides to control rice pests. Later, it only occurred in the southern and northern parts of Taiwan, but damage was negligible after 1970 (Cheng 1980). Even so, this species is still considered as a potential important insect pest of rice, especially in regions where rice is cultivated using organic methods.

Biology

The adult is an elliptic, reddish black bug with numerous prominent features on the apical and humeral pronotum, and the latter spine extending beyond the margin of the eyes; antennae and tarsi are grayish brown. Average body length is 9.0−9.5 mm for female and 4.5−8.5 mm for male; body width is 4−6 mm (Fig. 1c). Adults usually rest in the basal part of rice plants during daytime and they become active in the upper part of the plants from dusk to dawn, drying out from rice plants in the next morning or in cloudy days. They are attracted to light, but their flight activity toward the light traps is strongly affected by the lunar cycle. Adult bugs survive for 4−6 mo. The females lay their egg mass on leaf sheaths or leaves in the basal part of the rice plant, about 5−10 cm over the water surface. Each egg mass contains 12−13 eggs arranged in two to three rows (Fig. 1a). A female is able to lay about 200 eggs intermittently during her lifetime, guarding them carefully until they hatch.

The egg is in the shape of a drum about 0.8 mm wide and 1.0 mm high. It is pale greenish gray when laid and turns to pale reddish brown as it matures. The incubation period is 6−12 d in spring and 5−8 d in summer (Cheng 1980, Lee 1986, Huang 1982).

The newly hatched nymph is nearly circular, about 1 mm in length, with reddish brown body and red eyes. The antenna has four segments. As it grows gradually, its body becomes elliptical, body color deepens, and three transverse brownish stripes appear on the dorsal part of its abdomen (Fig. 1b). The nymphs molt four times to reach the adult stage in 30−40 d in summer and 45−59 d during spring and autumn. The first- and second-instar nymphs usually live together around the hatching site, thereafter, they disperse to live and become adults (Huang 1982, Cheng 1980).

The RBB takes only one generation a year in Japan and mid-eastern China, two generations in Taiwan and southeastern China, and three or four overlapping generations in Sri Lanka. It shows that the number of generations breeding in an area is affected not only by temperature but also by cropping system.

Fig. 1. The egg mass (A), nymph(B), and adult(C) of
***Scotinophara lurida* L.**

The RBB are known to attack the rice crop at various growth stages. Nymphs and adults feed mainly at the base of the rice plants where they remove plant sap. Infestation at the tillering stage of rice results in leaves turning chlorotic or reddish brown, and plant height being reduced. Infestation during booting stage contributes to stunted panicles, no panicles, or panicles with empty grains. After the heading stage, injured panicles have a higher percentage of incomplete spikelets, and unfilled and spotted grains. Severe infestation at any stage may lead to death of rice plants in the whole field, a condition known as bugburn (Cheng 1980, Chen et al. 1982, Lee 1986, Pathak and Khan 1994).

Besides rice, other hosts recorded in Taiwan are *Saccharum officinarum* and *Zizania latifolia* (Chen et al. 1982). On the other hand, Miyamoto et al. (1983) listed 14 other species of food plants for RBB. The food plants belong to Gramineae and include *Oryza minuta, Triticum aestivum, Hordeum vulgare, Zea mays, Setaria italica, Echinochloa crus-galli, Phragmites communis, Coix lacrima-jobi,* and *Imperata cylindrica;* those belonging to Cyperaceae (*Carex lancealata*) and other families that include legumes, Irish potato, *Artemisia monophylla*, and citrus trees.

The natural enemies of RBB recorded in Taiwan are *Agonum daimio* Bates (Col. Carabidae) on eggs and nymphs; spider predators (*Pardosa pseudoannulata* (Boesenberg and Strand) and *Tetragnatha* spp.) on young nymphs; and *Cephalosporium* sp. (fungi imperfecti *Moniliales*, Moniliaceae) on adults (Yen and Han 1968, Yen 1973).

Seasonal occurrence and abundance

The RBB overwinters in the adult stage, most of them hibernating in the leaf litter of windbreak grove or bunch grasses on levees, stubbles in paddy fields, or in soil cracks in surrounding sugarcane plantations. It is usually gregarious during the rice fallow period. The ratio of overwintering female to male is about 1:1.

The adults of the overwintering generation invade the first-cropping rice in the tillering stage from mid- to late March and from mid-April to early May in south and north Taiwan, respectively; while the first-generation adults invade the second-cropping rice 1−2 wk after transplanting (Fig. 2) (Chen et al. 1982, Lee 1986). The adults start to lay eggs about 2 wk after invasion and the highest number of eggs is observed during the 4th−6th wk and 3rd−4th wk in the first and second cropping season, respectively. The number of eggs laid on rice plants after heading declines dramatically. The nymphal population usually peaks in late April to middle of May in the south, and from mid-May to mid-June in the north in the first cropping season. The higher population of adult is usually recorded after heading in both first and second cropping seasons in south and north Taiwan (Fig. 2). After harvest of the first-cropping rice, adults and nymphs move to feed on weeds in the levees or banks, while they move to hibernation sites after harvest of second-cropping rice (Lee 1986).

The population of RBB is generally higher in the second-cropping rice than in the first-cropping rice (Figs. 2, 3) (Liu 1979, Lin 1980, Lee 1986). The earlier planted rice and the paddy fields near banks or hills, in particular those receiving heavy fertilizers, are usually damaged more severely than those planted in plain areas at regular season (Wu 1966, Huang 1982).

The population of RBB can be monitored either by direct counting or indirect assessment, including the use of light traps and net sweeping. Because the activities of the bugs are greatly affected by the lunar cycle, direct counting is better than indirect methods for determining RBB populations (Fig. 3). It is done in a monitoring field, which is usually divided equally into four plots. The number of RBB on the plants is observed once a week from planting to harvest. By applying the parallel line sampling method, 20−50 in hills each plot are sampled, depending on spatial distribution and population density of the pest.

Yield loss caused by RBB can be assessed either by caging a known number of bugs at a certain stage of rice plant for a certain period or by using insecticide-checking method to keep the population of the insect below some indicated level. The data obtained from these experiments can provide not only information on the relationship between bug population and yield loss of rice but also the

Bugs (log (x+1)) / 100 hills
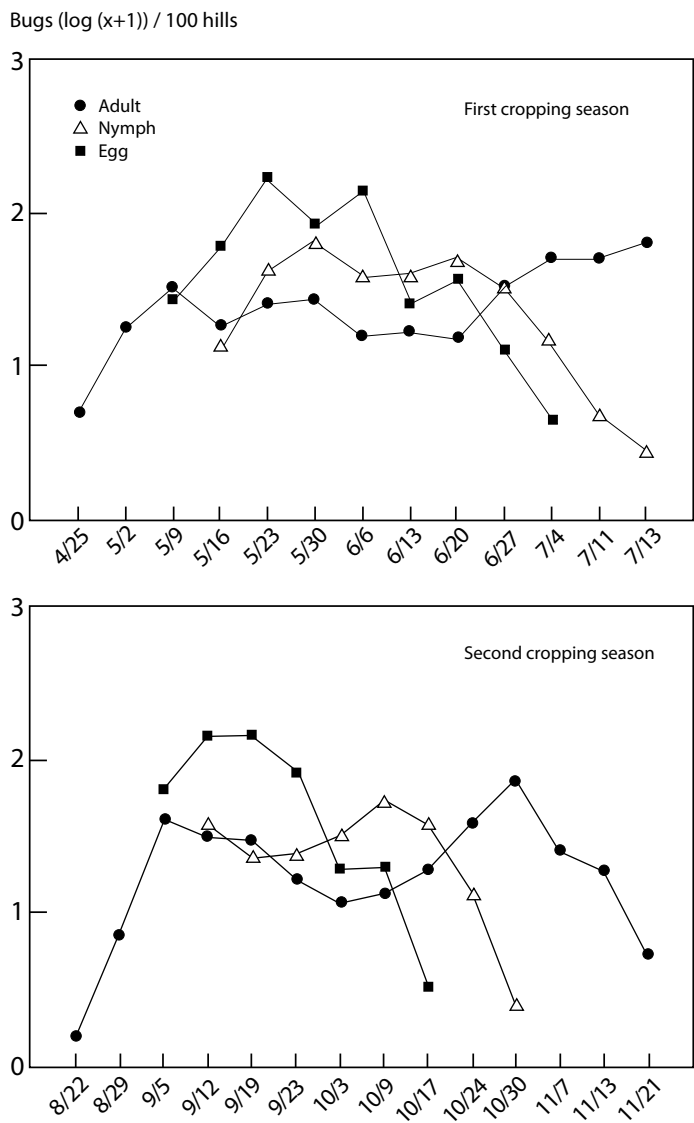
Fig. 2. Seasonal population fluctuation of *Scotinophara lurida* in the first and second cropping season in north Taiwan, Taoyuan, Taiwan, 1984 (Lee 1986).

economic threshold. The results of a preliminary experiment with the caging method indicated that grain yield was reduced with an increase in number of caged bugs per hill (see table). When the number is higher than eight, yield loss was almost equal to 5% of total grain yield production, a tentative economic threshold for an insect pest (Lee 1986).
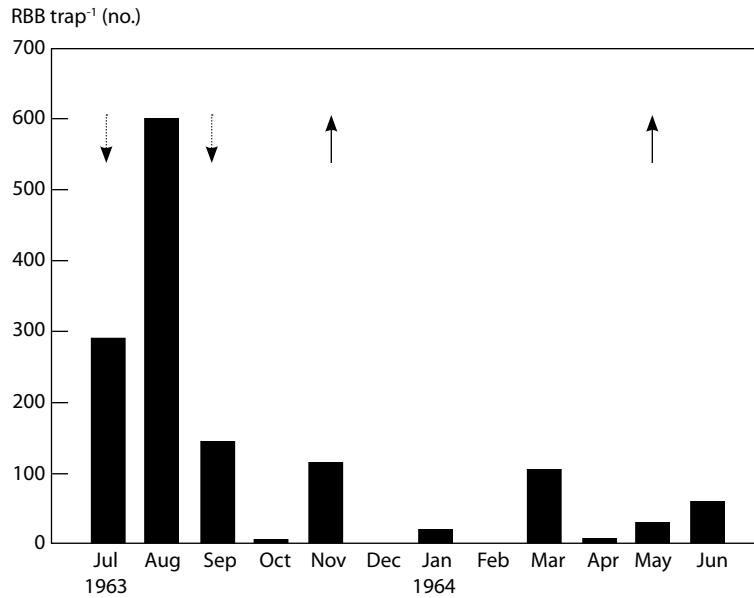
Fig. 3. Light trap catches of *Scotinophara lurida* adults in south Taiwan, Pingtaung, 1963-64 (Chu 1973). (Downward arrows indicate the time of rice transplanting, upward arrows indicate harvest of rice; solid arrows indicate first cropping season, dotted arrows indicated second cropping season.)

Effect of *Scotinophara lurida* adult infestation on grain yield of rice (Lee 1986).

Bugs hill^{-1} (no.)[a]	Yield (t ha^{-1})	Perfect grain (%)	Spotted grain (%)
0	6.49	86.43	0.33
2	6.47	83.57	0.67
4	6.19	85.87	0.67
8	6.17	81.83	1.33
16	6.12	80.27	1.57
32	5.82	79.63	1.67

[a]At 40 hills per treatment, the adult bugs were caged on each hill of rice after heading stage for 30 d in the second cropping season, 1986.

Management

Cultural control

Plowing the rice field soon after harvest helps to kill the pests and destroy their host plants and hibernation sites. Eggs are killed by submerging the basal part of the rice plant to a depth of about 10 cm from the soil surface for 24 h at 7-d intervals during the peak egg-laying period.

Biological control

The use of biological agents to control RBB is not yet fully studied in Taiwan. However, parasitized eggs (by *Telenomus* spp.?) and adults (by fungi) can be easily observed in paddy fields. Also reported is the lower population of the bugs because of ducks in paddy fields feeding on them.

Chemical control

Most insecticides commonly used to control rice insect pests are also effective in controlling the bugs. Insecticides have to be sprayed directly at the base of the rice plants.

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Rice Black Bugs in Thailand

Dr. Apichart Lawanprasert

Abstract

The project on integrated pest management (IPM) in rice fields has been conducted since 2004 to control rice black bug (RBB). As IPM is an important component of good agricultural practice (GAP), it should result in increased production of quality rice for both domestic consumption and export markets. The project focuses on alternative ways to control RBB by using insect-resistant varieties, biological control methods, and improved cultural practices. Chemical application would be the last choice to control RBB—insecticides would be used only when necessary. An early warning system has also been the focus of studies in the research centers of the Rice Department. The RBB population in the rice field is frequently monitored and the information is used to warn farmers when this population reaches the economic threshold. Studies indicated that RBB could cause serious damage if no control action was taken. Some paddy fields were in critical condition and control measures were necessary. Chemical pesticides would kill RBB immediately, while herbal pesticides and other control measures could only prevent occurrence. However, no serious outbreak of RBB was observed during this period.

Key words: rice black bug, *Scotinophara coarctata*, Thailand, integrated pest management, good agricultural practice

Introduction

The rice black bug (RBB) [*Scotinophara coarctata* (Fabricius); Pentatomidae, Hemiptera] occasionally occurs in rice fields and is considered a minor pest of rice in Thailand. However, pest outbreaks caused by this pest has increased, particularly in fields where rice is planted in high density. They are distributed in both irrigated and rainfed lowland rice ecosystems, and they attack during the vegetative stages of the rice crop. They prefer continuously cropped irrigated rice areas and poorly drained fields. Damage is observed more frequently in wet-season rice crops and densely planted

fields. A direct-seeded rice field is damaged more severely than a transplanted rice field. Conditions favorable to growth are high moisture, staggered planting of the rice crop, and excessive nitrogen application. The presence of alternate host plants favors population buildup during nonrice periods. This rice pest is a sucking insect that removes sap from the xylem and phloem tissues of the plant. The RBBs prefer infesting the bases of rice stems, causing the plant to weaken. Severely damaged plants dry and take on the brownish appearance of rice plants damaged by fire (bugburn). RBB presence also results in stunted growth, formation of whitehead, and half-filled or empty grains. Heavy infestation is usually visible after heading or maturity stage. This pest entered Thailand from the southern region and has slowly spread to the central region.

The control of RBB is urgently required, but control often causes environmental problems and increases production cost through the additional use of various insecticides. The RBBs cause many problems in the rice growing region of the world. To establish countermeasures to prevent their spread and to minimize their economic and environmental impacts, it is necessary to examine the expansion of this serious invasive pest and to predict the population dynamics of RBB in the region. For this purpose, it is very important to discuss the current RBB situation and the environmental impacts or risk of impacts and to develop a database of recent information on RBB that rice-growing countries can share through the Internet.

Biology

Life history

The mature adult of this pest is shiny brownish black or shiny black. It is 7–8 mm. long. The female adult is usually larger than the male adult. The adult is very active. It prefers to feed on the rice stem than on the leaves. During the day, the adults are found at the base of the plant and at nighttime they move upward. Each female bug deposits about 200 eggs during its lifetime on the leaf sheaths near the base of the plant stem or on the ground. The greenish or pinkish rounded eggs are laid in groups of 20-26 in parallel rows. Newly hatched nymphs are brown or yellow with black spots on their bodies. Young nymphs start feeding on the area around the egg masses and then move toward the plant base. The nymphs feed on rice in groups until 2-6 instar stages and after that, disperse one by one. Different nymphal instars vary in size before the emergence of adults. The newly emerged adult is white and tinged with green and pink.

Number of generations/year

Generally, the RBB has one generation a year, depending on climatic effects and systems of rice culture.

Pest status

The RBB injures the rice plant at both tillering and booting stages. Nymphs and adults feed chiefly at the base of the stems where they remove plant sap. The damage caused by the bugs becomes more serious as a result of intensifying rice production. Severe losses caused by this pest in Thailand were

reported in many areas. Infestation occurred in Pattani Province, the southern region in 1995, and in Narathiwat Province in 1999. In the central region, there were outbreaks in Pathumthani Province in 2002 and 2005. Heavy infestation caused wilted plants and incomplete panicle exsertion.

Yield loss

Ten adults per hill can cause losses of up to 35%, depending on the variety.

Diapause

After rice harvest, the long-living adults pass the winter or dry season in a dormant state at the base of plants or in cracks in the soil in paddy fields or in nearby higher grounds (to a depth of 1 ft). Under favorable conditions, they fly to the rice crop and reproduce over several generations.

Food plants

This pest is a polyphagous insect pest. Its primary host plants include rice and maize. Its alternate hosts are *Hymenachae pseudointerrupta* (Steud.) Gilliland, *Salix* sp. (willow), and *Scirpus grossus* L. f. (greater club grass).

Natural enemies

Eggs are parasitized by small scelionid wasps (*Psix* sp.; Hymenoptera: Scelionidae). The parasites are able to attack only the eggs at the outer edge of a mass because the female adult sits over the eggs, protecting them from natural enemies. Frogs and ground lizards prey on nymphs and adults. The larvae and adults of carabid ground beetles (*Ophionea nigrofasciata* Schmidt-Goebel (Coleoptera: Carabidae)) feed on RBB eggs, nymphs, and adults.

Ecology

Life table

The egg stage lasts for about 4-6 d. The nymphal period is about 20-30 d. Nymphs can molt four to five times before they reach the adult stage. Adult bugs live up to 214 d.

Seasonal occurrence and abundance

Rice fields

Seedling: In favorable conditions, adults of RBB migrate to paddy fields and feed on the leaves or leaf sheaths of young plants.

Tillering: On older plants, RBB feed on the leaf sheaths near the plant base, causing stunted growth and reduced tiller number.

Booting to flowering: Infested plants have stunted panicles, incomplete panicle exsertion, and panicles with empty grains.

Maturity: Damage early in the development of the grain prevents the filling of the grain.

Harvest: The outbreak of RBB significantly reduces the number of filled grains and the weight of grain per panicle during the harvest period.

After harvest (stubbles): The RBB return to their resting sites in paddy fields after the rice harvest. They hide in cracks in the soil.

Nonrice habitats or surrounding areas: Generally, adults and nymphs are observed on stubbles and other alternative hosts such as weeds of the grass family.

Flight activity and outbreak pattern: The RBB flight patterns are affected by the lunar cycle, especially on full moon nights. Large numbers of adults swarm to light sources. It was also noted that the infested paddy fields were located near areas surrounded with bright lights at night. The bugs are highly mobile, and heavy populations may quickly invade paddy fields.

Monitoring and field population assessment techniques: Farmers would visit the field weekly during the entire rice crop period to record RBB numbers. They randomly select 20 hills across the paddy field and count the number of adults and nymphs. Mercury bulbs are used as light traps for egg-laying adults. Light trapping of insects should start 5 d before and 5 d after the full moon.

Yield loss assessment techniques: A factorial treatment structure can be used, with several rice varieties and different infestation levels. There are four replications per treatment. To determine yield losses, the RBB is reared in cages and adult bugs are placed on caged plants of rice varieties at different population levels.

Local distribution: Even though the RBB are highly dispersive, they tend to be restricted to specific areas where they recur year after year. These areas tend to be near swampy places.

Management

Biological control

Parasitoids/parasites: In the paddy field, there are biological control agents such as small wasps that parasitize the eggs.

Predators: Ground beetles, spiders, crickets, and red ants attack the eggs, nymphs, and adults of RBB. Both eggs and nymphs are fed upon by coccinellid beetles. Ducks and toads also eat the nymphs and adults.

Pathogens: The parasitic fungi, *Metarhizium anisopilae*, are used as a biological control agents when black bugs are present. The RBB that get in contact with the fungi will be infected, contaminating the other bugs through pairing and mating. Three species of fungi attack the nymphs and adults.

Cultural control

One of the cultural control practices to reduce RBB population is to maintain a clean field by removing weeds and drying the field during plowing. Remove weeds to allow more sunlight to reach the base of the rice plants. Rice varieties of the same maturity date may be planted to break the insect's cycle. Early-maturing varieties are planted to reduce population buildup of RBB. Intermittent flooding and draining of an infested field is also an effective technique to destroy the eggs, which are usually found at the base of the rice plant near the water surface. During early infestation, the water level

in the field may be raised for 2-3 d to force the insects to move upward. These eggs will not hatch when submerged in water for more than 24 h. Flooding the fields can also cause higher egg mortality. Irrigation and plowing of stubbles in newly harvested RBB-infested field will also destroy existing bugs in all stages. Direct-seeded rice crops tend to have fewer tillers in one planting point and thus discourage population growth. After harvest, fields may be plowed to remove the remaining insects. The observance of a 1-mo fallow period in rice planting breaks the life cycle of the RBB and reduces pest population in the subsequent cropping season. Another is synchronous planting and setting up of light traps in cases of high pest population 3 d before and 3 d after the full moon. Light traps are effective for mass trapping of adults.

Varietal control
Two IRRI varieties resistant to black bugs are available.

Botanical control
Neem extract can be used to prevent the attack of RBB in paddy fields.

Chemical control
Foliar spraying of insecticides directed at the base of the rice plant is the most effective. Application of foliar spray with carbosulfan 20% EC at the rate of 80 ml/20 L water was recommended when five bugs hill[-1] were observed. Other insecticides used to control RBB are Thiamethoxam (25% WG) and Dinotefuran (10% SL).

Name of country museum/institution with insect collections
Department of Agriculture, Ministry of Agriculture and Cooperatives.

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Black Bugs of Rice in Vietnam

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Abstract

The rice black bug (*Scotinophara* spp.) is a minor pest of rice in Vietnam. Black bugs occur occasionally and damage rice during the summer-autumn months (April-August) at growth stages from tillering to booting. Outbreaks of this insect have been rare. An outbreak once happened at Tien Giang Province in 2000, and this year, it occurred in Quang Ngai Province. Damage during outbreaks can have significant impacts on the economy.

Key words: Vietnam, minor insect pest, outbreaks, rice, black bugs

Economic importance

In Vietnam, black bugs (*Scotinophara* spp.) on rice are commonly referred to as *Bo xit ñen*. These insect pests are relatively less common and not considered important; for these reasons, a few reports on this insect have been recorded. In north and central Vietnam, black bugs appear in half-mountain, half-plain provinces such as Thai Nguyen, Tuyen Quang, Dien Bien, Quang Ngai, and Binh Dinh. In south Vietnam, bugs occur near swampy places in Dong Thap Muoi such as Long An, Tien Giang, Dong Thap, but rarely in high numbers.

Black bugs rarely appear in the winter-spring season (November-March), but are most common in the summer-autumn season (April-August), due perhaps to the hot-wet weather and rainy-sunny intervals. Black bugs have been noted to damage the tillering to booting stages and also the flowering stage (though rarely). Dry fields, densely sown fields, and those where long-duration varieties are grown have greater damage than irrigated fields, thinly sown fields or those with early-maturing varieties. Besides rice, black bugs have also been observed to damage maize and weeds such as *Scirpus grossus* L. and *Hymenachne acutigluma* Gilliand.

Biology

Nguyen Manh Chinh et al (2003) describe the life cycle of black bugs: about 50−60 d, egg period; 4−7 d, nymphal period; 40−45 d at five nymphal stages; and adult period, 10−15 d. Each female lays around 200 eggs. Eggs are laid in clusters, usually varying from 10 to 15 eggs per cluster, lined along the midrib near the water surface. Newly hatched nymphs are red in color, wingless; the adults are similar in shape with black spots on its back. Adults are black, hexagonal, and 7−8 mm long. They move down in large numbers to the base of the rice plants; at night, black bugs tend go upward, attracted to lights. Nymphs and adults damage by sucking and removing plant sap from tillers; the rice plant becomes dry and few low tillers and many half-filled grains result. When black bugs are abundant, they can cause plants to wilt. Black bugs are also a nuisance because of the strong smell that they emit. In dry fields or during winter, adults seek shelter in cracks in the soil or they move to the grassy bank at the edge of the rice field. When conditions are favorable, the bugs move to the field and damage thee rice crop.

Natural enemies

Nguyen Manh Chinh et al (2003) reported the following natural enemies of black bugs: 1) egg parasites such as *Telenomus triptus*, Nixon and *Microphanurus artabazus*, Nixon; (2) preying mantis; (3) entomogenous fungus: *Paecilomyces farinosus;* and (4) frogs (amphibians) that eat both nymphs and adults.

Management

Integrated pest management options include the following:
- Clean weedy areas around the rice field, especially the edges.
- Sow/transplant at reasonable seed/plant density.
- Apply well-balanced fertilizers. In Long An and Tien Giang provinces, experienced farmers often apply 15−20 kg of calcium nitrate ha^{-1} at 40−45 d after seeding/sowing.
- Do not let rice fields become dry; if there are more than five bugs per hill, specific pesticides must be used.
- To control black bugs, farmers in Tien Giang, Long An, Dong Thap, and Baria-Vung Tau provinces often use contact, digestive or fumigant pesticides (Table 1).

In north Vietnam, farmers often mix Sapen alpha 5 EC with SK Enspray oil 99 EC to attain increased control efficacy time against black bugs (Ñoan Cong Dinh, Plant Protection Center in northern Vietnam).

Table 1. Insecticides used in Vietnam for RBB control.

Trade name	Active ingredient	Pesticide group(s)	Dosage (L ha^{-1})
Fenbis 25 EC	Fenvalerate 3.5% + dimethoate 21.5%	Pyrethroid + organophosphate	0.75−1.5
Dimenate 40 EC	Dimethoate	Organophosphate	1−2
Dragon 585 EC	Chlorpyrifos ethyl 53% + cypermethrin 5.5%	Organophosphate + pyrethroid	0.4−0.5
Sagosuper 20 EC	Chlorpyrifos methyl	Organophosphate	1
Sapen alpha 5 EC + SK Enspray oil 99 EC	Alpha cypermethrin + petroleum spray oil 99%	Pyrethroid + petroleum oil	0.2−0.4 + 0.2−0.3%

In instances where insecticides may be needed to have good control of black bugs, the following practices are necessary:

- After spraying, do not let the field become dry.
- Direct the sprayer nozzle at the base of the rice plant.
- The best time to spray is in the afternoon.
- If rice were sown too densely, irrigate the field, so that the black bugs will move up to the plant canopy; spray the pesticide then.

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Studies on Morphology, Biology, and Ecology of Rice Black Bug (*Scotinophara lurida* Burmeister) and its Management in Ha Nam Province, Vietnam

Pham Thi Vuong and Nguyen Nhu Cuong

Abstract

The rice black bug (RBB) *Scotinophara lurida* (Burmeister) is an important insect pest of rice in Ha Nam Province, Vietnam. Its biology and ecology have been described. There are two generations per year. The first generation occurs in the spring, while the second generation damages the summer crop. Its life cycle is completed within 45–68 d. Adults and nymphs attack the rice crop from tillering to maturity stages. Several natural enemies have been recorded, including hymenopterous species, spiders, lady beetles, and pathogens. Control of overwintering adults was relatively effective in reducing infestation. Biopesticides and cultural techniques were relatively effective in RBB control.

Key words: rice black bug, lifecycle, biology, control measure

Introduction

Rice black bug (RBB) *Scotinophara lurida* (Burmeister) (Hemiptera: Pentatomidae) is one of 10 major insect pests of rice (PGBPPP 1990). It is distributed in some rice-growing countries such as Vietnam and Japan. Its damage is observed in most growth stages, from tillering to maturity. Heavy infestation may result in 60−80% yield loss (PGBPPP 1990).

Rice is of great importance in an agricultural system such as that in Vietnam. In 2004, the total rice-growing area reached 7.325 million ha and output was 35.8 million t. About 3.8 million t was exported. However, the quality of rice grain is still a constraint to high exportation value. Pest infestation is one of the factors that influence rice grain quality. RBB is one of the insect species causing reduction in both rice grain quality and yield. Therefore, a detailed understanding of RBB is needed in order to effectively manage and improve rice yield and quality.

This paper presents the biology, ecology, and control measures of RBB.

Biology

Life history

The RBB female lays from 21–105 eggs (54.86 on average) during her life span. Eggs are laid in the leaves, sheaths, or at the base of the rice stem. Eggs hatch within 3–8 d (5 d on average). Newly hatched nymphs live in clusters, second-instar nymphs disperse to the rice clumps. The nymphal stage takes 35–53 d. The complete life cycle of RBB lasts for 45–68 d (52 d on average).

Number of generations/year

RBB have two generations per year. The first generation occurs from March to April and mainly damages the rice spring crop, while the second generation attacks the autumn crop from July to August.

Pest status

The area of infestation has been increasing with time. During the 1990s, a serious infestation occurred, affecting the summer crop. During 2004 and 2005, the infestation area was much higher in spring than in summer, and bug density is usually greater in the spring crop than in the summer crop.

Yield loss

Serious damage is observed from tillering to flowering. It sucks the sap in leaves and stems, leaving yellow spots. Light damage reduces growth vigor; heavy damage causes death of individual plants or clumps. If the bug attacks at flowering stage, empty grains may be anticipated. Severe infestation leads to 60–80% yield loss.

Diapause

Overwintering usually lasts from September to March, at the adult stage. After harvesting the summer crop in early September, the bugs move to the boundaries of the rice field and around grass clumps. In mid-November, adults move to fissures or holes on the ground. The places with lower moisture are more favorable for overwintering bugs. They also prefer the edges of irrigation canals to rice paddy boundaries.

Food plants

Both nymphs and adults feed by sucking the sap from rice crops. They usually prefer stems to leaves. The tillering stage of rice is most favorable for bug feeding.

Natural enemies of RBB

No.	Scientific name	Order	Family
1	*Telenomus subitus* Le	Hymenoptera	Scelionidae
2	*Solenopsis geminate*	Hymenoptera	Formicidae
3	*Lycosa pseudoannulata* Boes. Et Str.	Araneae	Lycosidae
4	*Oxyopes javanus* Thorell.	Araneae	Oxyopidae
5	*Metarrhizium anisopliae*	Hypocreales	Clavicipitaceae
6	*Beauveria bassiana*	Hypocreales	Clavicipitaceae

Two pathogens have been recorded to infect RBB: *Metarrhizium anisopliae* and *Beauveria bassiana*. The percentage of infected bugs rose steadily in early winter. A slight reduction was observed in mid-winter. There was a dramatic increase in infection rate of bugs during late winter.

Ecology

Seasonal occurrence and abundance

Rice fields. RBB damages rice from seedling to maturity stages, but the high density and heavy damage are observed during tillering and flowering. The first generation damages the spring crop. Population density starts to increase in the early season, reaching the peak in mid-April with first-instar nymphs predominating. Then, bug density drops at the end of the spring crop. Normally, population density on the main spring crop is higher than that in the late spring crop. Initial surveys showed a rapid increase in population density. For example, a density of 47.41 individuals m^{-2} and 80.07 individuals m^{-2} had been recorded for Q5 and Nhi uu cultivars, respectively. It can be explained by the fact that when overwintering adults emerge in March, this coincides with the tillering stage of the main spring crop. Therefore, it suggests that food source plays a very important role in the establishment and reproduction of RBB. The second generation occurs from July to September and mainly damages the summer crop.

Nonrice habitats or surrounding areas. RBB can live in rice field boundaries and edges of irrigation canals. *Echinochloa crus-galli* is an alternative host plant of RBB.

Flight activity and outbreak pattern. Bugs prefer diffused lights; therefore they usually hide below the rice clusters during daytime. Adults crawl most of their time; flight is rarely seen. When exposing to strong physical force or under high density, they will fly short distances (2–3 m).

Monitoring and field population assessment techniques. Random sampling was selected on two crossed lines in each block. Sampling area was 1 m^2. The number of RBB in each developmental stage was noted. Monitoring was done at 7-d intervals.

Yield loss assessment techniques. The experiment may use randomized complete block design with five treatments and three replicates. A number of adults (20, 30, 40, 50) were released in each treatment. The control plants received nothing. The sex ratio of released adults was 1:1.

The releases were carried out in three growth stages of rice: tillering, panicle initiation, and flowering. At ripening stage, each plot was harvested and yield was evaluated.

Local distribution. RBB is mainly distributed in rice-growing areas in whole country. However, it is more common in the midland areas.

Management

Cultural control

Water level in the rice paddy can adjusted using the irrigation system to kill bug eggs. Growing early crops in a small area (around 0.1%) as a trap crop will help reduce population density in the main and late crops.

Varietal control

Greater infestation of RBB was observed in hybrid varieties (Nhi uu 838, San Uu 63) than in pure varieties (Khang dan 18, Ai 32).

Botanical control

Several botanical products are recommended for the control of RBB such as chinaberry (*Mela azedar-ach*), catus, and wormwood (*Artermisia annua*) extracts. Treatment with neem extract (400 L ha^{-1}) showed of 52.92% mortality in 12 h. The neem extract plus Bassa 50 EC obtained 97.58% mortality (Dinh Xuan Huong et al. 1987).

Biological and chemical control

Two entomopathogenic fungi were tested as biopesticides against the overwintering black bugs. The greenhouse trial indicated that the efficacy of *Metarrhizium anisopliae* increased and reached 59.6% 21 d after treatment. The combination of *Metarrhizium* and Cypermethrin 25 EC (Sherpa 25 EC) at 0.05% was highly effective against overwintering black bugs. It reached 94.6 and 97.6% at 14 and 21 d after treatment, respectively (Table 1.).

A field trial was conducted to evaluate the efficacy of *Metarrhizium* and its combination with some chemical pesticides against black bugs during the rice spring crop. The *Metarrhizium* (6.875

Table 1. Efficacy of biopesticides and combinations of biochemical pesticides against overwintering RBB.

Treatment	Dosage	Date of treatment	Habitat	Mortality (%)			
				3 DAT	7 DAT	14 DAT	21 DAT
M. anisopliae	6.875 x 10^6 colonies ml^{-1}	Sep 22	Boundaries of rice paddy	2.6	40.3	50.3	59.6
B. bassiana	6.25 x 10^7 colonies ml^{-1}	Sep 22	Boundaries of rice paddy	0	0.3	0.3	1.0
M. anisopliae + Sherpa	*M. anisopliae:* 6.875 x 10^6 colonies ml^{-1} Sherpa:0.05%	Sep 22	Boundaries of rice paddy	65.6	87.6	94.6	97.6

Table 2. Efficacy of *M. anisopliae* (6.875 x 10⁶ colonies ml⁻¹) and its combination against RBB in the field, spring crop, 2005.

Treatment	Efficacy (%)			
	5 DAT	7 DAT	14 DAT	21 DAT
M. anisopliae + cooking oil	11.43	31.82	60.14	69.09
M. anisopliae + Padan 95 SP (0.05%)	84.81	92.26	91.93	91.14
M. anisopliae + Regent 800WP 0.0025%	91.74	98.45	96.28	95.05
M. anisopliae + Fastax 0.05%	81.83	88.90	86.81	84.46
Fastax 0.1%	75.69	70.61	67.30	65.03

x 10⁶ colonies ml⁻¹) alone had relatively high effectiveness. An efficacy of 69.09% was recorded 21 d after treatment. The combination of entomopathogenic fungi and chemical pesticides showed much greater efficacy than either one alone. For example, a combination of *Metarrhizium* and Regent 800WG gave 95.05% efficacy at 21 d after treatment. (Table 2).

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Biology, Ecology, and Management of Rice Black Bugs in Some Asian Countries

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Abstract

The rice black bug (RBB) is a widely distributed insect pest of rice. The insect has a long life cycle, up to 7 mo, and attacks the rice plant at every growth stage, causing economic losses. Although not frequent, epidemics of RBB have been reported in many countries. Control measures include application of insecticides; cultural practices such as maintaining a clean field, irrigation and water management; and use of light traps. As RBB is a significant pest in some countries and a minor pest in some other countries, its management could be achieved by promoting biological diversity of natural enemies and by curtailing the use of insecticides.

Key words: rice black bug, critical stages of rice, biological management

Introduction

The rice black bug (RBB) (*Scotinophara coarctata*) is known as "turtle bug" and "negro bug" but is commonly and widely known as "black rice bug," "black paddy bug," or "Malayan rice black bug" (Brands 2006). It belongs to order Hemiptera and family Pentatomidae. The RBB is a serious invasive pest of rice in some parts of the world such as Asia (Cuaterno, 2007), while it is regarded a minor pest in others. RBB infestations have also been observed in such Asian countries as south China, Vietnam, Brunei, Indonesia, Malaysia, Cambodia, Sri Lanka, Thailand, Myanmar, India, Bangladesh, and Pakistan (Catindig and Heong 2007). It has been a pest of rice in Malaysia for so many years (Catindig and Heong 2007). In the Philippines, the insect was observed in 1979, invading 12 regions (Cuaterno 2007). In Thailand, this pest entered the southern region and gradually spread to the central region. RBB is one of the rice pests that collectively reduce about 10−20% of the annual

rice production in Sri Lanka (Feakin 1970). The spread of the pest depends on many factors. RBB goes along with the light of the trading vessels plying from island to island.

RBB prefers poorly drained and densely cultivated rice fields as its habitat (IRRI 2003). Usually, it attacks irrigated rice from early vegetative to maturity stage (Cuaterno 2007). The most susceptible are maximum tillering to ripening stages. The insect uses piercing and sucking methods of feeding, directly sucking the plant sap, which leads to stunted growth and formation of whitehead, half-filled, or empty grains (IRRI 2003; Morrill et al. 1995).

The RBB is not easy to manage. Although control of rice bugs is urgently required, it may also cause environmental problems. But, in some countries like the Philippines, farmers are knowledgeable in managing RBB. Enhancing the population of natural enemies and adopting appropriate cultural practices help manage RBB.

Biology of rice black bug

Life history

The mature RBB is shiny black or shiny brownish black in color. The adult is oval-shaped and about 8-9 mm long (Fig. 1) (Abeysiriwardena et al. 2003). The lifespan extends from 3 to 7 mo. Sexes are separate. The female adult is bigger than that of the male. A female lays about 200 eggs during her lifetime and guards the egg until hatching (IRRI 2003). Eggs are deposited on the lower part of the leaves or on the basal part of the rice plant near the water surface (Catindig and Heong 2007). The eggs are laid in masses of 40−60 eggs in each mass in several parallel rows. During dry conditions, a female bug deposits eggs on the leaves and stem of the rice plant (Fig. 1). Eggs are also laid in cracks on the soil and on roots. Freshly laid eggs are greenish in color and turn to pink with age. After incubation, brown and yellow nymphs with black markings come out (Catindig and Heong 2007). Young nymphs start feeding on the area around the egg masses and then move upward on the plants. The nymphs feed on rice in groups until 2−6 instars, and reach adulthood after four to five moltings. The newly emerged adult is white and tinted with green and pink. Like adults, the nymphs also remain in the basal part of the plant during the day, then move up and feed at night. Rice is the main host of this insect pest, but the insect also feeds on a number of grasses and broadleaves (Cuaterno 2007).

Fig. 1. Female RBB deposits eggs in along the leaves (IRRI 2003).

The longevity of oviposition female ranges from 28 to 52 d, with an average of 38.00 ± 8.70 d. Males survive for an average of 42.20 ± 5.49 d. The female maturation period takes 5 d, and the oviposition period lasts for an average of 10.80 ± 1.32 d (Prakash and Rao 1999).

RBB is similar to many other oval-shaped shield or stink bugs that infest rice, but the nonpest species seldom occur in high numbers. RBB could be distinguished from *S. lurida* by the position of the spines on the pronotum (IRRI 2003).

The RBB has incomplete metamorphosis, which means that, from an egg, it will reach a nymph stage and then an adult stage (IRRI 2003); this takes about 3−7 mo. Oviposition takes place 12-17 d from mating. The eggs will be hatched in 3-4 d. The RBB nymph molts four to five times and passes five nymphal instars, which are completed in 25−30 d.

In general, RBB has one generation per year, but this depends on the climatic conditions and the system of paddy cultivation (Cuaterno 2007). Usually, each RBB is capable of producing approximately 680 eggs during its lifespan (PIA 2006). The intrinsic rate of natural increase was 0.084 per female per day, whereas multiplication rate was 28.0 times in a mean generation time of 39.90 d; the finite rate of increase was 1.08 and weekly multiplication was 1.79. The male to female ratio was 1:1.47 (Prakash and Rao 1999).

Pest status

The RBB attacks the rice plants at all stages from early vegetative to maturity, and the crop is most susceptible during maximum tillering to ripening. The pest is usually found at the base of the stem (Abeysiriwardena et al. 2003). Both nymphs and adults feed on plant sap using piercing and sucking modes of feeding, which leads to drying of tissues. Loss of water and drying out, discoloration, death of upper leaves and failure of young leaves to open are basic symptoms of attack. The damage during vegetative stage is called "deadheart," which refers to the dried dead shoot appearing as a result of sucking the plant sap at the base or in a slightly higher position in the emerging new shoot. If RBB attacks during booting, the resulting damage is the formation of dead or empty panicles similar to "whiteheads" caused by stem borers. RBB also feeds during the milking stage, affecting the rice grains. Severe infestations during this stage will result in a condition called "bug burn" and will lead to death. The nymph stage is the most destructive stage of RBB because the pest heavily feeds at the base of the rice plant (Morrill et al. 1995). It also prefers stem nodes because of the large sap reservoir (IRRI 2003). Infected plants become stunted, leaves turn reddish brown, and grain formation fails (Abeysiriwardena et al. 2003). Damage by this pest could result in severe crop losses or complete yield loss during heavy infestation. The extent of damage by RBB depends on the season and the crop stand. Crop damage in the dry season is more severe than in the wet season because nymphs take a longer period of time to reach maturity stage in the dry season (Cuaterno 2007).

Yield loss

Yield losses due to RBB can vary because of a number of reasons, of which seasonal and density (stand) effects are critical. Yield losses in terms of decreased number of tillers and hence decreased panicle number per plant, increased number of unfilled grains, and decreased number of filled grains per panicle are common with the attack of RBB. Ten adults of RBB per rice hill may cause a yield loss ranging from 15 to 35% (Cuaterno 2007, IRRI 2003).

Yield losses due to RBB have been recorded in many parts of Southeast Asia. Severe damage was recorded in the Philippines from 1979 to 1996. The first infestation was recorded in Palawan in 1979, which was followed by a major outbreak in 1982 damaging 4,500 ha of rice fields (Barrion et

al. 1982). The estimated population averaged 79–188 adults/m^{-2} and were as high as more than 400 m^{-2} in one field (Barrion et al. 1982). In late 1992, RBB was observed in Mindanao Island, specifically Zamboanga City, damaging about 2,070 ha (Anonymous 2005). Three years later, RBB invaded the whole of Region 9, including the Autonomous Region of Muslim Mindanao (Cuaterno 2007). In 1996, the pest was observed in Region 12, and an outbreak followed a year after. At present, the pest is already a part of the ecology of the whole Mindanao Island (Cuaterno 2007).

Since 1995, severe crop losses have been recorded in some parts of Thailand (RRC staff, pers. commun., Thailand). Severe losses were recorded in Pattani Province in the southern region in 1995; a major infestation in Narathiwat Province was seen in 1999. There were two outbreaks recorded in Pathumthani Province in the Central region in 2002 and 2005. Heavy infestation caused wilting of plants and incomplete panicle exsertion (RRC staff, pers. commun., Thailand).

Food sources

The primary hosts of RBB are rice (*Oryza sativa*) and maize (*Zea mays*); alternate hosts are *Hymenachae pseudointerrupta* (Steud.) Gilliland, Salix sp. (willow), *Typha angustfolia, Panicum amplixicale, Echinochloa crus galli,* and *Scirpus grossus* L. (greater club grass). The latter three species are very common in rice ecosystems, enabling the RBB to continue with its repeated generations. In addition, the rapid life cycles of these grasses provide palatable food sources, including soft stems and new seeds at the milk stage of seed filling.

Natural enemies

There are numerous natural enemies of RBB in the rice environment. *Telenomus triptus* (scelionid wasps Hymenoptera: Scelionidae) is one of the major natural enemies of the RBB (Fig. 2a). This is an aggressive egg parasitoid. Red ants (*Myrmica rubra*, Hymenoptera; Formicidae) also heavily feed on the eggs of RBB (Fig. 2b). Frogs and ground lizards prey on nymphs and adults. The larvae and adults of coccinellid beetles, carabid ground beetles, or Schmidt-Goebel (*Ophionea nigrofasciata* (Coleoptera: Carabidae)) feed on eggs, nymphs, and adults of RBB (Fig. 2c). The increased diversity of natural enemies has made this pest a minor problem in many countries, including Sri Lanka and Thailand. As the RBB is suppressed by its natural enemies, it has now become a pest of less interest.

Ecology

Seasonal occurrence and abundance in rice habitats

RBB is found at all stages of growth of the rice plant in infested areas. Under favorable conditions during seedling stage, RBB adults migrate to paddy fields and begin feeding on the leaves or leaf sheaths of young plants. During tillering, RBB is found feeding on the leaf sheaths near the plant base, leading to stunted growth and reduced tiller number.

From booting to flowering, RBB attacks the rice plants and the crop shows stunted growth, incomplete panicle exsertion, and panicles with empty grains. At maturity stage, RBB affects the
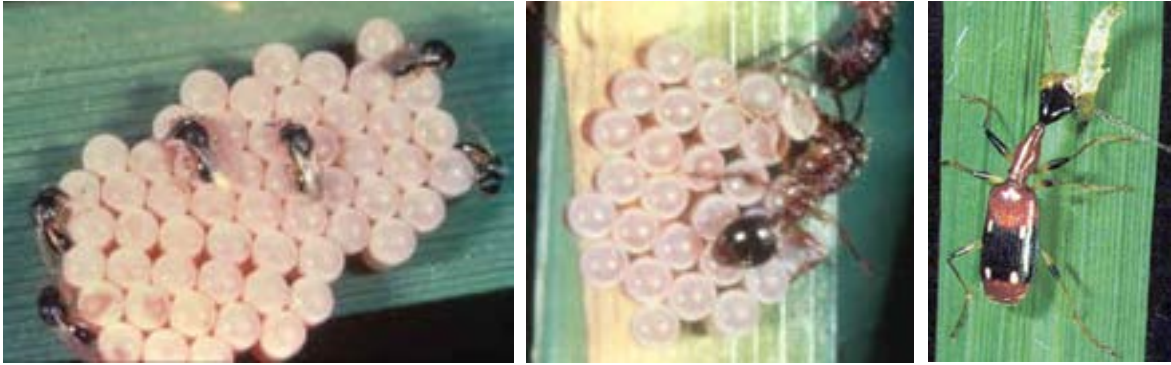
Fig. 2. Natural enemies of rice black bug: (a) *Telenomus triptus*, (b) *Myrmica rubra*, (c) *Ophionea nigrofasciata*.
Source: Figure 2a & 2c: Date seen: 30-07-2007 http://www.knowledgebank.irri.org/Beneficials/Copy_of_Beneficials_files/image102.jpg

early stage of grain development, which preventing the filling of the grain and increasing the number of empty grains.

The outbreak of RBB significantly reduces the number of filled grains and grain weight and hence, total grain weight per panicle during the harvest period.

The RBB return to their resting sites in paddy fields after the harvest of the rice crop. The bugs hide in cracks in the soil. Also, they try to find alternative hosts in the surrounding areas. These hosts are mainly the weeds of the Graminae family.

Flight activity and outbreak pattern of the RBB are mainly based on the light source. The bug is highly mobile and move as a heavy population, which helps to quickly invade a rice field. Flight pattern is affected by the lunar cycle. A large number of adults swarm to light sources 5 d before and 5 d after the full moon (Ito et al 1993). It was also noted that the infested paddy fields are located near areas surrounded with bright light sources at night.

Monitoring and field population assessment techniques can be done by trained farmers. RBB numbers can be recorded weekly during the entire rice crop period. This can be done by randomly selecting 20 rice hills across the paddy field and counting the number of adults and nymphs. The use of light traps (Mercury bulbs) help to count the egg-laying adults as these are attracted to light traps (Ito et al 1993).

Yield loss and assessment techniques can be done by using factorial treatment structure. This can be applied to several rice varieties and different infestation levels. Yield losses can be determined by the cage technique or by marking plants. With the cage technique, RBB are reared in cages. Adult bugs can be placed on plants grown in cages at different population levels and using different varieties. Marking plant technique involves the random marking of infested or damaged and healthy plants in large numbers (Anonymous 2007b).

The presence of alternate breeding sites favors population increase during nonrice periods; staggered planting of the rice crop and excessive nitrogen favor the buildup of the pest (IRRI 2003).

Even though the RBB are highly dispersive, they tend to be restricted in distribution to specific areas where they recur year after year. These areas tend to be near swampy places.

Management

Since RBB causes crop damage in all stages of the rice plant, timely management of RBB is essential to protect rice yield in RBB-infested countries. Numerous management options are found to suppress RBB, and suitable measures could be integrated for effective management. These methods include biological, cultural, and chemical management.

Biological control

Biological management appears to be the most effective in controlling RBB (Catindig and Heong 2007, Cuaterno 2007, IRRI 2003). This is because the pest becomes a prey of another biological agent. Different kinds of biological agents prey on many insect pests. The maintenance of a rice environment favorable to natural enemies would be the most effective method of RBB management. Biological management becomes ineffective when the rice environment is polluted with toxic pesticides as these pesticides equally bring negative effects to the natural enemies as well. Biological management is slow to control RBB, but better management could be achieved with time.

Many parasitoids/parasites may cause damage to RBB. Yet, *Telenomus triptus*, a scelionid wasp, is a very aggressive egg parasitoid that is naturally present in the field (IRRI 2003). These wasps are effective in reducing RBB populations. These parasites can be reared in the laboratories and released to affected fields.

Ground beetles and coccinelid beetles (Fig. 3), spiders, crickets, and red ants (*Myrmica rubra*) are predators of RBB eggs, nymphs and adults. They abound in the fields and are effective in managing the RBB population. Ducks also help control RBB, but their use is very limited. The ducks can be released into the fields at a later stage only when the rice plants are already established.

Metarrhizium anisopliae, a green muscardine fungus, infects the RBB, causing a complete kill of the RBB. The fungal spores attack, overgrow inside the insect present in the field, eventually killing the insect. There are three species of fungi attacking the nymphs and adults: *Metarrhizium anisopliae*, *Paecilomyces lilacinus*, and *Beauveria bassiana* (Rombach 1987). In the Philippines, these fungi are cultured in the laboratory and produced as a filtrate containing conidia, which then is sprayed to the infested fields to control RBB (Cuaterno 2007).

Once the fungi are applied as suspensions of conidia and as suspensions of a dry mycelium product, the mycelium is grown in fermentors, dried, and milled. Conidia are produced on the mycelium clumps and these stick to the plants in the field. When the bugs attach to the plant, these conidia can infect the insects. Then the fungi penetrate into the cuticle of the insect and grow rapidly (Rombach 1987).

Fig. 3. Coccinelid beetles.
Source: http://www.oisat.org/images/Ladybi.JPG
Date seen: 30-07-2007

Cultural control

Numerous cultural methods could be applied to manage RBB. Synchronous planting provides opportunities to avoid the completion of the life cycle of RBB. Maintaining a weed-free field provides more sunlight to reach the base of rice plants. Irrigating the field at 3–10 cm water depth may be done to submerge the eggs within 24–48 h after egg laying. This prevents the eggs from hatching; Submergence after harvest and plowing prevent weed emergence and availability of stubbles, which in turn restricts access to egg-laying sites. The burning of rice stubbles/straws, although discouraged to avoid destruction of organic material, is recommended in RBB-infested fields. These activities help reduce the bug population.

It is appropriate to maintain a clean field by removing weeds and drying the rice field during plowing. Removal of weeds in the field and allowing more sunlight to reach the base of rice plants would help reduce RBB attack. However, Abeysiriwardena et al. (2003) noted that adult bugs are strongly attracted to light.

Intermittent flooding and draining of an infested field is also an effective technique to destroy the eggs of the RBB, which are usually found at the base of the rice near the water surface. During early infestation, the water level in the field may be raised for 2–3 d to force the insects to move upward. These eggs will fail to hatch when submerged in water for more than 24 h. Flooding the fields can also cause higher egg mortality.

Irrigation and plowing of stubbles in newly harvested RBB-infested field will also destroy the existing black bugs in all stages. Direct-seeded rice crops tend to have fewer tillers and this discourages population growth. After harvest, fields may be plowed to remove the remaining insects.

Although there are no specific details of rice varieties resistant to RBB attack, two IRRI varieties have been found to possess resistance to black bugs (IRRI 2003). These are IR13149-71-3-2 and IR10781-75-3-2-2 (Heinrichs et al. 1987, Domingo et al.1985). Cultivation of these varieties may reduce pest incidence in RBB-prone areas. However, farmers would use high-yielding rice varieties to maintain satisfactory rice yields, along with other convenient pest management practices. Rice varieties of the same maturity date may be planted at the same time to break up the insect's life cycle. Early-maturing varieties are also planted to reduce population buildup of RBB (IRRI 2003).

Chemical control

The RBB is controlled with conventional insecticides. In heavy infestations, pesticides are mainly applied to control RBB. Although pesticides are effective, they are expensive and may lead to secondary pest outbreaks as insects develop resistance to the compounds (Rombach 1987).

The most effective method is the use of foliar insecticides with directed application to the base of the rice plant. Application of carbosulfan 20%EC at the rate of 80 ml in 20 liters of water at the stage with five bugs per hill was recommended to control RBB. Other insecticides used to control RBB are Thiamethoxam (25%WG) and Dinotefuran (10%SL) in Thailand (RRC staff, pers. commun., Thailand).

Other methods of control

Botanical pesticides such as neem (*Azadirachta indica*) extracts are known to be effective in preventing RBB attack in paddy fields. In addition, light traps are known to attract RBB. Both have the potential to be important components of an integrated pest management approach for RBB.

Future needs

RBB has already been recognized as a significant pest in some countries, whereas in some others, it appears to be a minor pest. This could generally be associated with the availability of population control measures. Rice environments could not be changed drastically, thus population control measures, integration of the insect into ecosystems, and other means would certainly be most effective. Biological agents such as predators, parasites/parasitoids, as well as disease-causing agents, and changing of habitats would make a negative impact on population increases of the insects. Pesticide use often results in an imbalance of both pest and natural enemy populations, which may or may not be a satisfactory or sustainable method to manage RBB. Therefore, it would be appropriate to enhance biological diversity, where the RBB be integrated into the ecosystem. The design and conduct of detailed studies on these aspects would be imperative for maintaining rice ecosystems with minimal RBB damage. Furthermore, identification of resistant or tolerant rice varieties would be another approach, which requires the concerted efforts of plant breeders, genetic engineers, agronomists, and crop physiologists.

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Information Database

The Crop Protection Compendium: Information for the Management of Crop Pests

Lucinda MF Charles and Lesley McGillivray

Abstract

A brief overview of the Crop Protection Compendium (CPC), an encyclopaedic multimedia knowledge base for crop protection, is presented. The CPC contains detailed information on more than 2,400 pests that damage agricultural or horticultural crops, or forest trees. The type of information held in pest data sheets and examples of decision support tools, such as a diagnostic search and a pest-risk analysis module, are presented. The future development of Compendia is briefly discussed.

Key words: crop protection, pest management, knowledge base, decision support tools, pest risk analysis

Introduction

Accurate scientific information is needed to make decisions on the management of crop pests, whether these are pests are already present in an area and causing damage or whether they represent a risk to livelihoods and/or the environment by their introduction or spread. The Crop Protection Compendium (CPC) is an encyclopaedic multimedia knowledge base that provides detailed data sheets on more than 2,400 pests that damage agricultural or horticultural crops, or forest trees. Basic data are included on a further 10,000 pest species. There are a number of routes into the data, including powerful database searches by which the user can generate a list of pests matching criteria such as country, host plant, or plant part infested and, from there, link to the full details in individual data sheets. The data can be easily located and 'pasted' into reports, or extension and training materials, as required. The CPC is used in more than 80 countries for a wide range of purposes, including pest management. It is one of a series of Compendia published by CAB International on CD-ROM and the Internet. Compendium development is funded and guided by international groups of stakeholders made up of government
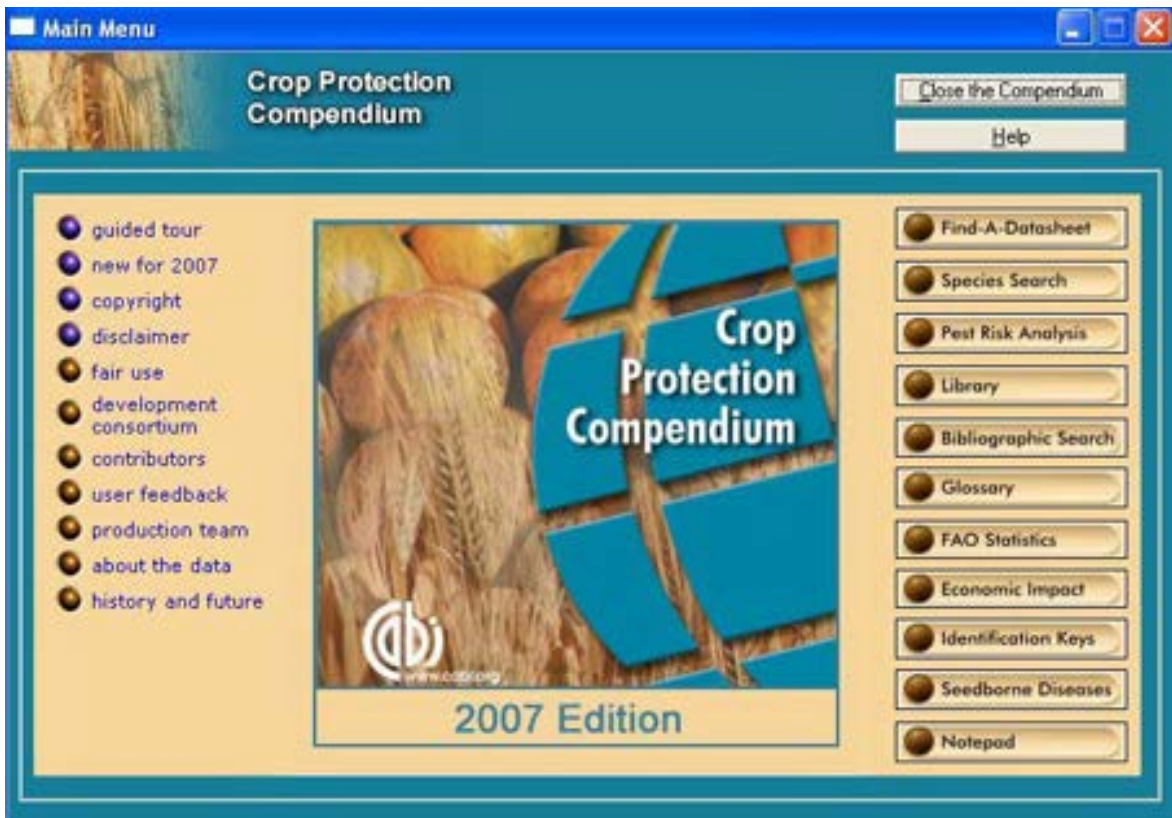
CPC1.jpg - Main menu.

departments, development assistance organizations, and private companies. The Compendium Programme is part of CAB International's not-for-profit 'Knowledge for Development' Programme that aims to increase dissemination of scientific knowledge in the developing world.

A full description can be found at: http://www.cabicompendium.org/cpc.

Pest data

Pest information is presented in a standardized data sheet format, accompanied by distribution maps, color illustrations, a bibliographic database, taxonomic framework, statistical analysis, crop and natural enemy data sheets, and a glossary.

Text sections cover the following aspects:

- Names and taxonomy
- Host range
- Geographic distribution
- History of introduction and spread

- Impact
- Phytosanitary significance
- Summary of invasiveness
- Symptoms

- Biology and ecology
- Seedborne aspects
- Means of movement and dispersal
- Natural enemies
- Morphology
- Detection and inspection
- Control
- References

The fully referenced, detailed data sheets have been compiled by more than 1,000 selected experts, edited by CABI, and verified by specialists. There is a rolling program for reviewing data sheets and the pest distributions are among the data sets updated annually. New data sheets are added with each annual update in response to recent research, news items, and requests. Recent projects have focused on increasing the coverage of invasive plants and forest pests. A detailed data sheet on rice black bug (*Scotinophara coarctata*) is included in the CPC.
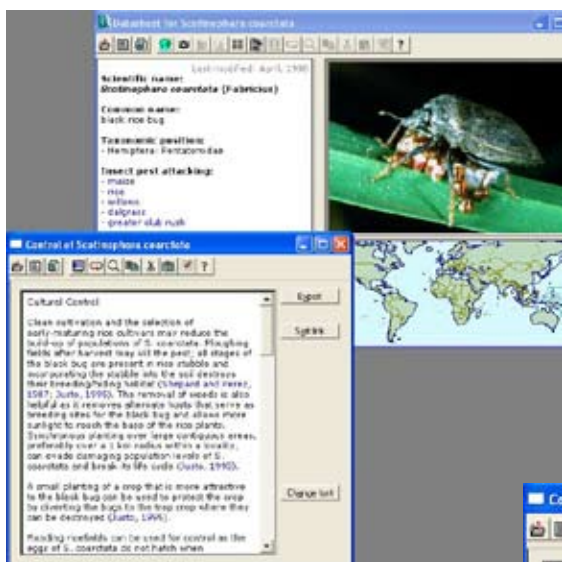
CPC2.jpg - *Scotinophara coarctata* cover page and control section.

CPC3.jpg - alternative to CPC2.jpg - *S. coarctata* cover page.
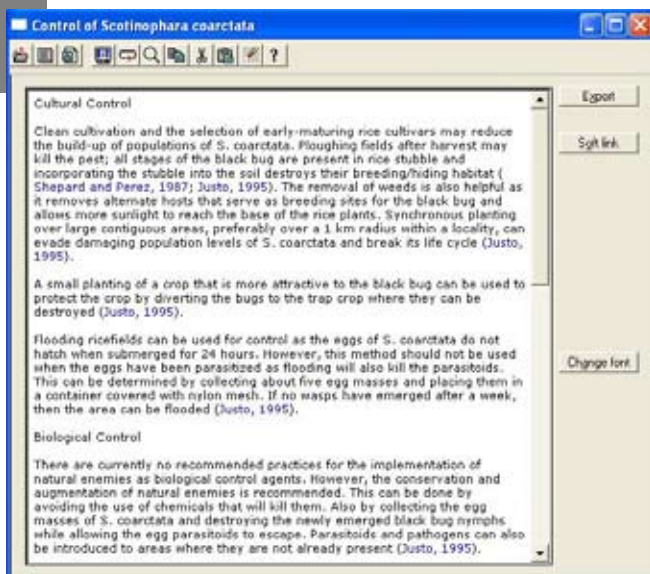
CPC4.jpg - alternative to CPC2.jpg - *S. coarctata* control section.

Decision support

There are several ways to access the data in the CPC. For example, you can **Find-a-datasheet** and search using the preferred scientific name, or any of its synonyms or common names. You can also browse through a set of pests associated with a particular crop or country. The **Diagnostic Search** enables you to generate a list of pests matching such criteria as country, crop host, pest type, symptom, and plant part.
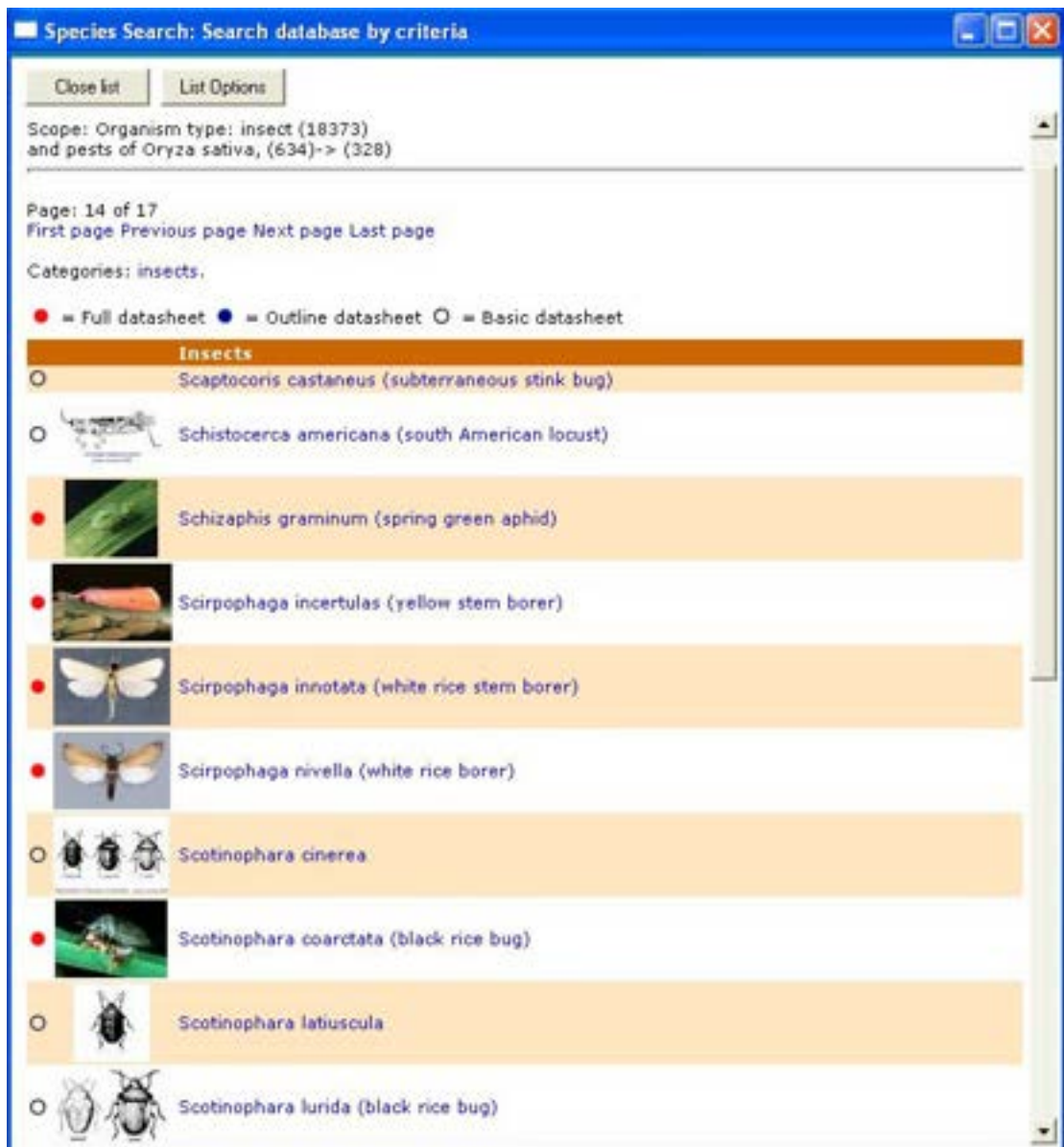
CPC6.jpg – alternative to CPC5.jpg - Diagnostic search on criteria host = rice and pest type = insect produces a list of 328 pests that fulfil those criteria, including *Scotinophara coarctata* and *S. lurida*.

A **PRA (pest risk analysis) module** provides a more detailed framework for conducting a pest risk analysis based on international guidelines. It incorporates specific database searches, access to pest data sheets, opportunities to add your own data, and a report function.

The **Notepad** facility allows you to keep your own notes, which can include text, links to files, websites, and even pictures. These will be available to your colleagues who are using shared Compendium access.

The CPC is used worldwide for various purposes, including pest management, extension, pest risk analysis, research, pest identification, policy development, training, etc. It presents scientific information that may be otherwise inaccessible or poorly compiled and is used as a common reference, for example, for determining quarantine pest lists and rationalizing phytosanitary regulations between countries. It can save time, which would have to be spent searching a range of disparate sources and can be used to quickly prepare reports and teaching aids. Income from sales of the Compendium ensures its sustainability and CABI works with various partners to make it available where it is most needed.

Future development

There is much scope for further development of the CPC and CABI encourages feedback from users on the content and functionality. The Compendium Programme continues to expand and has recently published an Aquaculture Compendium to complement the existing CPC, a Forestry Compendium, and an Animal Health and Production Compendium (see www.cabicompendium.org). A major new project is under way to develop an Invasive Species Compendium (ISC). It will contain data sheets and other information on known invasive species of all taxa that affect all natural and managed ecosystems, except human pathogens. CABI is working with partners to provide training and promote the use of the Compendia in various situations.

Notes

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Online information on the rice black bug at the pesticide action network Germany Website

Dr. Jewel K. Bissdorf

Abstract

Rice black bug is a rice pest commonly found in South Asia. Both the adults and nymphs suck the plant saps. They prefer to infest the bases of the rice stems, causing the plant to weaken. Heavy infestation causes stunted growth, formation of whitehead, half-filled or empty grains, and browning of leaves or bug burn. A control measure is necessary when there are five bugs per hill. The management of the pest includes drying the rice field during land preparation to expose dormant black bugs to the sun and other predators; planting early-maturing varieties to reduce population buildup; removing the weeds to allow sunlight to reach the base of the plants; raising the field's water level for 2-3 d (during early infestation) to force the insects to move upward for easy control and collection; plowing the field after harvest to disturb and kill the insects remaining in the field; placing light traps in strategic areas; and spraying of *Tinospora* water extract.

Key words: natural enemies, nonchemical pest management, online information on nonchemical pest management, plants used in pest control, rice black bug

Introduction to OISAT

In January 2003, PAN Germany launched a project, 'Online Information Service for Non-chemical Pest Management in the Tropics' (OISAT), with the aim of limiting the use of and dependence by poor farmers on hazardous pesticides, as well as reducing the risk that may be incurred; and of providing them with safer alternatives.

OISAT has two components: *OISAT Info* and *OISAT PartnerNetwork. OISAT Info* is a web-based information tool offering trainers, extension workers, and farmers a quick access to up-to-date information for their work and for organizing agricultural learning processes in order to minimize pest

damage in a safer, more effective, and ecologically sound way. Its structure is based on the cropping season of the major crops, indicating key pests for each growth stage and plant part. Furthermore, detailed information is presented on preventive and curative pest management practices with the aim of providing basic and practical information for a holistic approach in pest management, which is both flexible and situation-specific. The descriptions contain illustrations, photographs, and clear advices, together with a glossary of technical terms.

The existence of *OISAT Info* on the internet is not effective enough to reach the farmers significantly. Therefore, PAN Germany is continuously seeking a partnership with carefully identified training and extension providers to whom *OISAT Info* is a potentially appropriate information tool. The resulting *OISAT PartnerNetwork* is a platform for information dissemination, information validation, exchange and feedback to the OISAT database. Through the integration of the online information into training and extension services, an effective and efficient information flow "from Web to field to Web" will be ensured. The final aim is to make OISAT accessible to smallholder farmers and to offer them reliable solutions for their pest problems, which can be adopted by them. The feedback from the field will be stimulated through the OISAT *PartnerNetwork* to further expand and adapt the content and service of *OISAT Info* to the needs of its users in the field, leading to a significant adoption of the information provided.

OISAT was launched online 1 July 2004 with the Web address: www.oisat.org and with the e-mail address: oisat@pan-germany.org

The information for this contribution is also available on the PAN Germany Website www.oisat.org, the Online Information Service for Non-chemical Pest Management in the Tropics.

General information
Common name: Rice black bug
Scientific name: *Scotinophara coarctata*, *S. lurida*
Hemiptera:Pentatomidae

Synonyms: Malaysian rice black bug, Japanese rice black bug

Host plants
Rice and maize

Distribution
Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Philippines, and Thailand

Damage
Both adults and nymphs suck the plant saps. They prefer to infest the bases of the rice stems, causing the plant to weaken. Heavy infestation causes stunted growth, formation of whitehead, half-filled or empty grains, and browning of leaves or bug burn.

Description

Eggs: The eggs are round, greenish, or pinkish in color. The eggs are laid in groups of 15 in parallel rows on the lower leaves near the water surface, on stems, roots, and on soil cracks. Egg incubation takes about 4-7 d.

Nymphs: The nymphs are brown or yellow in color. Black spots are visible on their bodies. Different nymphal instars vary in sizes. Six nymphal instars are completed in 29-35 d.

Adults: The adult is white and tinged with green and pink and turns shiny brownish black to shiny black as it matures. It is 8-9 mm long. The adult is very active. It prefers to feed on the rice stem than on the leaves. During the day, the adults are found at the base of the plant and at nighttime, they move upward.

Management and cultural practices

1. Dry the rice field during land preparation to expose dormant black bugs to sun and other predators.
2. Plant early-maturing varieties to reduce the bug population buildup.
3. Remove the weeds to allow sunlight to reach the base of the plants.
4. During early infestation, raise the field's water level for 2-3 d to force the insects to move upward for easy control and collection.
5. Plow the field after harvest to disturb and kill the insects remaining in the field.

Monitoring

Randomly select 20 hills across the field. Count the number of nymphs and adults. A control measure is necessary when there are five bugs per hill.

Natural enemies

Parasitoids
Braconid
Common name: Bracon
Scientific name: *Bracon* spp.
Hymenoptera: Braconidae

Type
Eggs, larvae, pupae, and adult parasitoid

Hosts
Ants, aphids, armyworms, beetle's larvae, bollworms, cabbageworms, caterpillars, codling moths, corn borers, cutworms, imported tent caterpillars, leafhoppers, leafminers, maggots, midges, plant bugs, scales, tomato hornworms, weevils

Description

Eggs and larvae of Bracons are found inside the hosts' bodies.

The larvae are tiny, cream-colored grubs that feed in or on other insects. Larvae molt five times and undergo five instars.

Pupae of some species live and pupate within the host until they mature; others pupate in silken cocoons on the outside of the body of the host, while others spin silken cocoons away from the host.

Adult wasps are tiny, about 2.5 mm in size, slender black or brown with threadlike waists. Female wasps lay eggs into the eggs of host pests but prefer caterpillar bodies.

In cases where aphids are the host pests, aphids are not killed instantly. Aphids continue to feed on plant tissues until the Braconid larvae inside their bodies completely consume them. The fully grown Braconid larvae cement the dead aphids to the leaf surface, making aphid shells black and mummified. About a week later, the adult Bracon wasps cut round holes in the mummies and emerge. The empty mummies remain on the leaf. The presence of mummies in a colony of aphids is a sign that Bracons are present.

Conservation

Adult Bracons feed on nectar, honeydew, or pollen before laying eggs. Dill, parsley, yarrow, zinnia, clover, alfalfa, parsley, cosmos, sunflower, and marigold are flowering crops that attract the native braconid populations and provide good habitats for them.

Predators : Damsel bug, frogs, ground lizards
1. Damsel bug
Common name: Nabids
Scientific name: *Nabis ferus*, *N. aternatus*, *N. capsiformis*
Hemiptera:Nabidae

Type

Generalist predator

Hosts

Aphids, armyworms, asparagus beetle, Colorado potato beetle eggs and nymphs, corn earworm, corn borer, imported cabbageworm, leafhoppers, mites, moth eggs, sawfly larvae, and tarnished plant bug nymphs. Although they can survive for about 2 wk without food, they will eat each other if no other prey is available.

Description

Eggs are deposited in soft plant tissues where they are so difficult to find.
Nymphs resemble adults and develop through five nymphal stages in about 50 d.

Adults are tiny, about 2-4 mm long, with slender bodies and are yellowish or gray or reddish-brown in color. They have piercing-sucking mouthparts, a four-segmented beak, elongated heads, and four long segmented antennae. They are fast runners with long slender back legs and enlarged forelegs for grasping prey. They are commonly found in most agricultural crops, especially legumes, throughout the year. Adults begin laying eggs soon after emergence.

Conservation
They prefer to live in soybean, grassy fields, and alfalfa. You can collect damsel bugs in alfalfa fields and release them around your garden.

2. Ground beetle
Common name: Carabid
Scientific name: *Calosoma* spp., *Cicinde la* spp., *Megacephala* spp., *Ophionea nigrofasciata, Pterostichus* spp.
Coleoptera:Carabidae

Type
Generalist predator

Hosts
Cabbage root maggots, cutworms, snails, slugs (Ellis and Bradley 1996), leaffolder and planthopper larvae (IRRI and QU 2001).

Description
Eggs are normally laid singly in the soil.

The larva is elongated and tapered toward the end, worm-like in appearance, and has a large head directed forward.

The pupa is brownish black, small, and found in the soil.

Adult ground beetles or Carabids are about 2-6 cm long, dark shiny brown to metallic black, blue, green, purple, or multicolored. They vary in shapes, from elongated to heavy-bodied, tapered head end with threadlike antennae, and have a ringed wing cover. Some species do not use their wings, however; like many other insects, they are also attracted to light. They use their wings to fly at night to be near the source of light. Their heads are usually smaller than their thorax. Both adults and larvae have strong pincher-like mandibles. They have prominent long legs, which enable them to move fast. Most species are nocturnal and they hide during the day in soil crevices, under rocks and stones, decaying logs, leaf litter, or composting materials. When disturbed or when other vertebrates prey upon them, they emit an odor or gas, as a type of defense mechanism, preventing them from being eaten by other predators. Ground beetles live on or below the ground, hence the name. Development from the egg to the adult stage takes about a year, although adults may live 2–3 yr or longer.

Conservation

Mulching in some sections of the field provides a habitat for ground beetles; provide permanent beds and perennial plantings to protect the population; and plant white clover and/or amaranth as ground cover.

Plants used in pest control

Tinospora

Common names: Tinospora, Makabuhay, Boraphet
Scientific name: *Tinospora rumphii*
Family: Menispermaceae

Plant parts used: Roots and stem

Mode of ac: Insecticidal

Formulations

Material	Method of preparation	How to use	Target pests
Makabuhay water extract (PCARRD 2000) 200 g of mature vines 1 liter of water Mortar and pestle Knife Pail Tap water 10-15 kg chopped vines are sufficient to treat rice seedlings needed to plant 1 ha.	Chop vines into small pieces. Pound thoroughly. Add 1 liter of water. Stir with bamboo or wooden stick.	Soak rice seedlings into the water extract overnight before transplanting or spray seedlings before transplanting.	Diamondback moth Rice black bug Rice green leafhopper Rice stem borer
Makabuhay, madre de cacao, hot red pepper extract (Stoer 1997) 1 kg of Makabuhay vines 5 kg of Kakawate 2 cups of hot red pepper Soap 1 tbsp alcohol 3 glasses of coconut milk Knife Pail Strainer	Pound the first 3 ingredients. Add 4 liters of water. Soak and strain. Add the alcohol, coconut milk, and soap as sticker. Stir thoroughly.	For every liter of the extract, add enough water to fill up a 20-liter calibrated sprayer. Spray on rice plants at weekly intervals. Spray early in the morning or late in the afternoon.	Rice pests

Effect on humans

None, Makabuhay is very bitter when swallowed.

Effect on nontarget organisms

None

Standard procedures for preparing and applying plant extracts

1. Select plant parts that are free from diseases.
2. When storing the plant parts for future use, make sure that they are properly dried and stored in an airy container (never use plastic container), away from direct sunlight and moisture. Make sure that they are free from molds before using them.
3. For the extract preparation, use utensils that are not meant for food preparation and for storing drinking and cooking water. Clean properly all the utensils after each use.
4. Avoid direct contact with the crude extract while in the process of preparation and during application.
5. If left overnight, place the plant extract out of reach of children and house pets.
6. Harvest all the mature and ripe fruits before plant extract application.
7. Always test the plant extract formulation on a few infested plants first before going into large-scale spraying. When adding soap as an emulsifier, use a potash-based one.
8. Wear protective clothing while applying the extract.
9. Wash your hands after handling the plant extract.

Physical control

Light trap

A light trap is a device used at night in the field to collect moths and other flying insects.

Place light traps 30 m apart, 5 d before and after the full moon. Adults are very much attracted only to high-intensity light traps, e.g. petromax light traps. The light should be on from 7 pm to midnight.

Making a light trap

Materials

1. Bamboo or wooden poles
2. String or rope
3. Nails
4. Oil/kerosene lamp or electric bulb
5. Shallow basin with water or jute sack

Procedure
1. Install the light trap near or within the field where you want to trap the flying insects.
2. Secure the poles firmly on the ground.
3. Mount the lamp or the bulb on the frame, 5 m from the ground. When using an electric bulb, make sure that the bulb and wiring are not in contact with water to avoid electrocution.
4. Place the shallow basin with soapy water or the jute sack underneath the light.
5. Put the light trap from early evening to early morning.
6. Collect the trapped insects daily and dispose of them properly.

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Related Webpages

OISAT. Rice black bug
http://www.oisat.org/pests/pests__insect_mite/bugs/rice_black_bug.html

OISAT. Braconid
http://www.oisat.org/control_methods/natural_enemies/parasitoids/braconid.html

OISAT. Damsel bug
http://www.oisat.org/control_methods/natural_enemies/predators/damsel__bug.html

OISAT. Ground beetle
http://www.oisat.org/control_methods/natural_enemies/predators/ground_beetle.html

OISAT. Light traps
http://www.oisat.org/control_methods/physical_methods/light_traps.html

OISAT. Tinospora.
http://www.oisat.org/control_methods/plants_in_pest_control/tinospora.html

Notes

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World Bibliography on the Rice Black Bugs, *Scotinophara* spp.

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Introduction

This bibliography is a compilation of significant literature about the rice black bug (RBB), Scotinophara spp. Though, far from complete, it would be of value for researchers for an overview of Scotinophara spp. The Zoological Record issues from 1864 until 2006 were searched using several or a combination of keywords providing important systematic and taxonomical information. Internet search, including the Pentatomoidea home page of Dr. David Rider (http://www.ndsu.nodak.edu/ndsu/rider/Pentatomoidea/) were of great help with the volume of downloadable materials. Literature available from the Zoologische Staatssammlung München and many other libraries were included.

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Glossary

A

Abdomen: The posterior of the three body divisions of an insect. The other two body divisions are head and thorax.

Abdominal venter: Ventral side or the underside of the abdomen.

Abiotic factors: In agriculture, abiotic factors include temperature, humidity, moisture, light, pH etc.

Accelerating voltage: This is the voltage used to accelerate the electron emitted from a cathode in order to irradiate them on a specimen.

Acceptable daily intake (a.d.i.): The daily ingested intake of a pesticide (expressed as mg/kg body weight per day) that, over the entire lifetime of a human being, standard man = 60 Kg, appears to be without appreciable risk on the basis of all known facts at a specified time.

Accessory gland: Insect reproductive system: Glands derived from ectoderm.

Acetylcholine (ACh): A chemical substance present in many parts of the body of animals and important to the function of nerve and nerve-muscle impulses.

Acid phosphatase: An enzyme (phospohomonoesterase from prostrate gland) active in acid medium.

Activator: A substance added to a pesticide that increases its toxicity resulting in more effective control.

Active ingredient (a.i.): The toxic component of a formulated pesticide.

Aculeate: Those members of the Hymenoptera which possess a sting.

Acuminate: Tapering to a long point.

Acute toxicity: The toxicity of a substance determined at the end of 24 hours. The toxicity that causes damage or death from a single dose or exposure.

Acute: Of short duration, characterized by sharpness or severity. Opposite of chronic.

Adhesive (=Sticker): Substance added to a formulation to increase the surface retention (persistence) of a pesticide.

Adult: The mature stage of an insect which occurs after nymphal or pupal stages. Adults have mature sexual organs and usually have wings.

Aedeagal cap: A covering for the aedeagus.

Aedeagus (=aedeagi): Is a reproductive organ of male insects through which they secrete sperm from the testes during copulation with a female insect. The sperm contains capsules called spermatophores, which contain the spermatozoa. In addition to the spermatophores, in some insect species the aedeagus also discharges a spermatophylax, which serves as a nutriment to the female.

Aestivation: Summer dormancy, entered into when conditions are unfavorable for active life i.e. it is too hot or too dry.

Aggregation: A grouping or clustering of separate organisms.

Agricultural chemical: Chemicals used to improve agricultural production and to protect crops (pesticides, plant hormones, chemical fertilizers, etc.).

Agro-ecology: The study of ecology in relation to agricultural systems.

Agro-ecosystem: An agricultural area sufficiently large enough to permit long-term interactions between all living organisms and their nonliving environment.

Air sac: A dilated portion of a trachea

Alate: Winged; having wings.

Aldrin: A synthetic insecticide; a chlorinated hydrocarbon of not less than 95 per cent 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphtha-

lene; moderately toxic to mammals, acute oral LD,, for rats 44 mg/kg; phytotoxicity: none when properly formulated, but some crops are sensitive to solvents in certain formulations.

Alimentary canal: The tube through which food passes.

Aliphatic: A term applied to the "open chain" or fatty series of hydrocarbons.

Alitrunk: Name given to the thorax and propodeum of 'wasp-waisted' hymenopterans.

Alkaline phosphatase: An enzyme (phosphomonoesterase from the blood plasma or milk) active in alkaline medium.

Alkaloids: Substances found in plants, many having powerful pharmacologic action, and characterized by content of nitrogen and the property of combining with acids to form salts'.

Allele: Alternative form of a gene; one of a group of genes that occur at a given locus.

Allopatric: Two or more forms of a species having essentially separate distributions.

Alluvial plain: The land having soil which is formed by deposition through flood water.

Alternate plant host (=Alternative host =Additional host =Food plants): Another plant species that can support a pest for all or part of its life cycle.

Alternating Generations: When two generations are produced within a life cycle each producing individuals of only one sex, either male first and then female or visa-versa.

Alternating generations: When two generations are produced within a life cycle each producing individuals of only one sex, either male first and then female or visa-versa.

Aman: Rice grown in the monsoon or wet season in Bangladesh is collectively known as aman. There are broadcast aman which is deepwater or floating rice and transplanted aman. Broadcast aman planted in April-May harvested in November-December. The area under broadcast aman also reduced from 2.1 million ha to 0.5 million ha. All broadcast aman varieties traditional, photosensitive and elongates with the rising flood water levels. Transplanted aman season is from June-July to December-January. It covers about 4.7 million ha. About 62% transplanted aman area covered by modern varieties and rests by traditional photosensitive varieties.

Amide: Compound derived from carboxylic acids by replacing the hydroxyl of the -COOH by the amino group, -NH2-.

Amine: An organic compound containing nitrogen, derived from ammonia, NH3, by replacing one or more hydrogen atoms by as many hydrocarbon radicals.

Amino acid: Organic compounds that contain the amino (NH,) group and the carboxyl (COOH) group. Amino acids are the "building stones" of proteins.

Ammonia: A colorless alkaline gas, NH3, soluble in water.

Anal angle: The small apical area enclosed by the inner and outer margins of the hindwing.

Anal fold: A fold in the inner margin of the hindwing.

Anal veins: The hindmost or most posterior longitudinal wing veins.

Anal: Pertaining to last abdominal segment which bears the anus.

Animalia: taxonomic kingdom comprising all living or extinct animals.

Annulate: Formed in ring-like segments or with ring-like markings.

Antenna (=Antennae): Pair of segmented appendages located on the head and usually sensory in function. Often referred to as 'feelers'.

Antennal segments: The number of segments caused by constrictions in the antennae, excluding the segment that inserts into the head.

Antennal: Relating to the antenna.

Antennation: Touching with the antenna

Antennifers (=Antenniferous): A pivoting extension allowing free movement of the scape in the antennal socket.

Anteocular: Before the eye.

Anterior: Concerning or facing the front, towards the head.

Anterobasal: In the front and at the base.

Anthesis: The period during which the flower is open.

Antibiosis: An association between two or more organisms that is detrimental to one or more of them.

Anti-feedant: A substance that deters or inhibits feeding by an insect but does not necessarily kill it.

Anus: The posterior opening of the digestive tract.

Aorta: The anterior, non-chambered, narrow part of the insect heart which opens into the head.

Apex: The opposite end to the base. For insect body parts, the base is usually the end attached to the greater part of the insect body; the point where the costal vein and the outer margin of the forewing meet.

Apical area: Of the forewing, the area just inside of and contiguous with the apex.

Apical: At the end, tip, or outermost part.

Apico-dorsal: From the top (dorsal) side to the apex (tip).

Apico-lateral: From the top to the margin (edge).

Appendage: Any limb or other organ, such as an antenna, which is attached to the body by a joint

Appendix: In insects, a short vein, especially a short continuation after the main vein has changed direction.

Arachnida: A class of arthropods which include the scorpions, spiders, mites, ticks, among others.

Araneae: An order belonging to the class Arachnida, comprised of the spiders. They are characterized by two body parts (cephalothorax and abdomen), eight legs, and a pair of fangs (chelicerae).

Arcus: A structure resembling a bent bow or an arch.

Arolium (=Arolia): A small padlike lobe projection between the tarsal claws of some insects and arachnids.

Arolium: A small pad between the claws on an insect's foot. Usually very small.

Aromatic Basmati: Derived from Sanskrit language, consisting of two words: Bas means smell (aroma) and Mati means virgin lady. However this word is referred to Rice means aromatic rice.

Arrhenoyoky: The production of males from unfertilized eggs.

Arthropoda: A phylum within the animal kingdom with segmented body, a thick exoskeleton that is molted from time to time and a number of jointed and paired appendages modified in various ways to form legs, antennae, jaws or cerci.

Arthropods: Adults typically have a segmented body, a sclerotized integument, and many-jointed segmented limbs.

Asymmetrical: Organs or body parts not alike on either side of a dividing line or plane.

Asynchronous double cropping: In many rice growing tracts in India where both Rabi and Kharif rice is grown, it is not possible to have sowing and transplanting done within a limited period of 15 days to one month. It is usually the case in areas under major irrigation projects where there will be a gap of one to one and half months in sowing/ transplanting of areas near the source of irrigation and the tail end areas. Under such circumstances the crop in different stages of growth will be present under the same irrigation source. This asynchrony will be occurring both during wet season and dry season. This is called asynchronous double cropping.

Asynchronous: The irregular planting schedule in a cropping season.

Attractants: Substances which elicit a positive directional response; chemicals having positive attraction for animals such as insects, usually in low concentration and at considerable distances.

Augmentation: Involves rearing a beneficial organism and realizing them in fields infested with target pest.

Aus: Rice grown in the summer in Bangladesh from March-April to July-August is known as aus. During the green revolution aus rice area reduced from 3.0 million ha to just 1.0 million ha. Currently, about 44% area covered by modern varieties. Varieties or cultivars are photo insensitive.

Autosome: Is any chromosome that is not a sex chromosome.

Axon: The process of a nerve cell that conducts impulses away from the cell body.

Azad Jammu & Kashmir: A disputed area in between Pakistan and India.

Azadirachtin: It is one of the active ingredients in pesticides that are produced from the neem tree. It acts as a powerful insect antifeedant and growth regulator.

B

Bacterium (=Bacteria): Primitive one-celled microscopic organism that lacks chlorophyll and multiplies by fission. Some bacteria infect rice and produce disease symptoms.

Balochistan: A province of Pakistan.

Barani areas: Rainfed areas of Pakistan.

Basad: Toward the base.

Basal plate: The foot of aedeagus.

Basal width (BW): Measurements taken at any basal parts.

Basal: At the base or near the point of attachment (of an appendage).

Base temperature: Threshold temperature above which degree-day heat unit is accumulated.

Basitarsus: The Ist segment of the tarsus - usually the largest.

Basolateral pit: The small groove on each side of the base of the scutellum.

Beak (=Proboscis): The long, protruding mouthpart structures of an insect with piercing-sucking mouthparts. This type of mouthparts can be found in the suborders Heteroptera (true bugs).

BEI: The abbreviation of Backscattered Electron Image. This refers to an image formed from incident electrons having a relatively energy that are emitted again from the surface of the specimen. The contrast of the backscattered electron image depends on the topography of the specimen surface and on the mean atomic number of the substances which constitute the specimen.

Beneficial insects: Insect that serves the interest of man. For example insect pest predators and parasitoids that help to keep pest populations under control. Also bees and other pollinating insects are beneficial insects.

Benzene hexachloride (=BHC): A synthetic insecticide, a chlorinated hydrocarbon, 1,2,3,4,5,6-hexachlorocvclohexane of mixed isomers; slightly more toxic to mammals than DDT, acute oral LD51 for rats about 200 mg/kg; phytotoxicity: more toxic than DDT, interferes with germination, suppresses growth and reduces yields except at low concentration.

Bifurcated: Splitting from one branch into two

Bilateral symmetry: Similarity of form, one side with the other.

Bioagent posts: A central repository where farmers obtain microbials for their field use.

Bioassay: A method for quantitatively determining the concentration of biologically active substances by its effect on the growth of living organisms under controlled conditions.

Biodegradable: Capable of being broken down by micro-organisms. It usually refers to biological processes in soil, water and sewage. It can also refer to man-made organic compounds such as pesticides.

Biodiversity: Richness in the life of animals and plants. Here it refers to insect life.

Biological control agent: Any biological agent that adversely affects pests.

Biological control: The control of pests by employing predators, parasites, or disease; the natural enemies are encouraged and disseminated by man. This can be achieved either through conservation and stimulation of indigenous natural enemies, or by the importation and mass introduction of exotic natural enemies.

Biological pesticide: A pesticide the active ingredient of which consists of a living organism or virus.

Bionomics: The study of the habits, breeding, and adaptations of living forms.

Biopesticides: They are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals.

Biorational pesticides: Pesticides based on bacteria, viruses, fungi or protozoa; includes pest control agents, and chemical analogues of naturally occurring biochemicals (e.g. pheromones, insect growth regulators).

Bisexual: Having two sexes distinct and separate; i.e. a species with males and females.

Bivoltine: Having two generations per year.

Blade of clasper: The broad flat section or surface of the clasper.

Blastogenesis: The origination of different castes, within a species, from the egg by means other than genetic.

Blunt: Having a dull edge or point.

Booting stage: The reproductive phase of rice growth and development when the developing panicle causes a swelling of the clum.

Bootleaf: The swollen area of the leaf with a developing panicle.

Boro: Rice grown under in the dry winter season in Bangladesh under irrigation is called boro. The cropping season is from November-December to March-May. In the past boro was a minor rice crop occupying less than 5% of total rice area. However, with the development of irrigation facilities it emerged as major crop which currently occupying 4.06 million ha (about 40% of total rice area), and 95% boro area covered by modern varieties.

Botanical pesticide: A pesticide obtained from plants, e.g. pyrethrum, nicotine, azadirachtin and rotenone.

BPMC: Fenbucarb.

Brand name (=Trade name): Name given to a product sold by a company to distinguish it from similar products made by other companies.

Broadcast application: Application over an entire area rather than only on rows, beds or middles (also referred to as blanket application). For example broadcast application of a pesticide.

Broad-leaved plants: Plants that are not mosses and not grasses.

Broad-spectrum pesticide: A non-selective pesticide that has activity against a wide range of pests. For example, a broad-spectrum insecticide will kill a wide range of insects.

Brood: All of the individual insects that hatch from the eggs laid by one mother or which have become adult at approximately the same time and which live together in a defined and limited area.

Buccula (=Bucculae): A little cheek or distended area; in the plural, elevated plates or ridges on the under side of the head, on each side of the rostrum; flange on the underside of the head lateral to the first segment of the labium.

Bug burn: Burning damage in plants due to sucking pests like plant bugs (black bugs).

Bug: True bugs are insects of the suborder Heteroptera (order Hemiptera). They are wingless or four-winged, with mouthparts adapted for piercing and sucking. The term bug is sometimes used to refer to any insect or similar organisms such as centipedes and mites.

C

Cadaver: Dead animal due to an organism.

Caecum. (=Caeca): A sac or tube like structure open at only one end.

Calcareous: Referring to soils or rocks rich in Calcium.

Callus (=Calli): Area of elevated or fused impressions of the cuticle on the anterior part of the pronotum.

Cannibalism: Any organism which feeds on its own kind.

Canonical variates analysis: A method of multivariate analysis in which the variation among groups is expressed relative to the pooled within-group co-variance matrix. Canonical variates analysis finds linear transformations of the data which maximize the among group variation relative to the pooled within-group variation. The canonical variates then may be displayed as an ordination to show the group centroids and scatter within groups. This may be thought of as a "data reduction" method in the sense that one wants to describe among group differences in few dimensions. The canonical variates are uncor-

related, however the vectors of coefficients are not orthogonal as in Principal Component Analysis. The method is closely related to multivariate analysis of variance (MANOVA), multiple discriminant analysis, and canonical correlation analysis. A critical assumption is that the within-group variance-covariance structure is similar, otherwise the pooling of the data over groups is not very sensible.

Canonical: A canonical description of any statistical situation is a description in terms of extracted vectors that have especially simple ordered relationships. For instance, a canonical correlations analysis describes the relation between two lists of variables in terms of two lists of linear combinations that show a remarkable pattern of zero correlations. Each score (linear combination) from either list is correlated with no other combination from its list and with only one score from the other list.

Canopy: The foliage of the plant.

Capitate: With an apical knob like enlargement.

Carbamates: A chemical class of insecticides. Carbamates are derived from carbamic acid and have anticholinesterase activity.

Carbofuran: Carbamate insecticide, which is used to control insect pests in a wide variety of field crops, including rice, potato, corn and soybean. It has a systemic and contact activity against pests.

Carbohydrate: Any of a group of neutral compounds made up of carbon, hydrogen, and oxygen; for example, sugar, starch, cellulose.

Cardo: The basal segment of the maxilla or secondary jaw.

Carina: A ridge or keel.

Carnivorous: Preying or feeding on animals.

Catalogue: A complete list of museum exhibits, articles, pictures according to subjects and with descriptions.

Caudal: Concerning the tail end or rear part of the body.

Cell: An area of the wing bounded by a number of veins. A cell is closed if it is completely surrounded by veins and open if it is bounded partly by the wing margin.

Cellulose: An inert carbohydrate, the chief component of the solid framework or woody part of many plants.

Cement layer: A thin layer on the surface of insect cuticles formed by the hardened secretion of the dermal glands.

Central disk: In seastars, the central part of the body which contains the mouth, anus, madreporite, and gonopores and from which the rays radiate.

Centroid Size: Centroid Size is the square root of the sum of squared distances of a set of landmarks from their centroid, or, equivalently, the square root of the sum of the variances of the landmarks about that centroid in x- and y-directions. Centroid Size is used in geometric morphometrics because it is approximately uncorrelated with every shape variable when landmarks are distributed around mean positions by independent noise of the same small variance at every landmark and in every direction. Centroid Size is the size measure used to scale a configuration of landmarks so they can be plotted as a point in Kendall's shape space. The denominator of the formula for the Procrustes distance between two sets of landmark configurations is the product of their Centroid Sizes.

Cephalic: Of or pertaining to the head.

Cephalothorax: A body region consisting of head and thoracic segments, as in spiders.

Cercus (=Cerci): One of a pair of feeler-like appendage located near the tip on an insect's abdomen.

Cervical: Concerning the neck region, just behind the head.

Chaetae: Stiff hairs or bristles (singular: chaeta).

Chaetotaxy: The arrangement of the bristles or chaetae on an insect.

Charging Up: When an electron beam irradiates an electrically non-conductive specimen, electrostatic charges build up on the specimen during SEM observation. This phenomenon is called "charging up" (or acquiring electro static charge, or building up electrostatic charge) if the sample acquires the electrostatic charge during observation of a SEM image; the contrast of the image will become abnormal and unstable. Also, it will be impossible to obtain a sharp image. In order to prevent this, the sample is provided with a metal coating, or the image is observed under a low accelerating voltage.

Checklist: A list of items for convenient reference.

Chemical control: Control of pests with synthetic pesticides.

Chemical name: Scientific name of the active ingredient(s) in a formulated pesticide.

Chitin: The tough horny material, chemically known as a nitrogenous polysaccharide, which makes up the bulk of the insect cuticle, also occurs in other arthropods.

Cholinesterase inhibitor: A substance which inhibits the enzyme cholinesterase. It prevents transmission of nerve impulses from one nerve cell to another or to a muscle.

Cholinesterase: An enzyme that is necessary for proper nerve functioning. Cholinesterase is inhibited or damaged by pesticides belonging to the organophosphates and carbamates.

Chordata: A division of animals including all those that have a notochord during some stage of their develop-

ment e.g. fish, amphibians, reptiles, mammals, birds and sea squirts.

Chorion: The inner shell or covering of the insect egg.

Chromosome: Genetic make up of an organism. It is structures that contain the DNA.

Chronic effect: A slow and continuous effect.

Chronic symptoms: Symptoms that appear over a long period of time.

Chronic toxicity: The effect of a chemical following prolonged and repeated exposure.

Chronic: Of long duration e.g. 'chronic disease or infection'. Opposite of acute.

Cicatrice: Scar-like mark.

Ciliated: Bearing minute hairs (cilia).

Cladogram: A diagram showing nothing more than the sequence in which groups of organisms are interpreted to have originated and diverged in the course of evolution.

Clasper: Any of the appendages of the male of certain insects that are used during copulation to hold the female.

Class: A division of the animal kingdom lower than a phylum and higher than an order, for example the class Insecta.

Claval suture: The area between the corium and clavus.

Clavus: Parallel-sided and sharply pointed anal area of hemelytron. At rest, the clavus lies alongside the scutellum. Posterior part of the forewing of heteropteran bugs.

Claw (=Chelae=Pincers): Is a sharp curved pointed pincer-like process or appendage, found at the end of the tarsus in arthropods. The correct term for an arthropod's 'claw' is a chela. Legs bearing a chela are called chelipeds.

Cleft: crevice, crack or cleave.

Cline: A progressive, usually continuous change in one or more characters of a species over a geographic or altitudinal range.

Club: The thickened terminal (farthest from the head) end of the antennae.

Cluster analysis: A method of analysis that represents multivariate variation in data as a series of sets. In biology, the sets are often constructed in a hierarchical manner and shown in the form of a tree-like diagram called a dendrogram.

Clypeus: Lowest part of the insect face, just above the labrum.

Coefficient of variation (CV): The standard deviation expressed as a percentage of the mean.

Coefficient: A coefficient, in general, is a number multiplying a function. In multivariate data analysis, usually the "function" is a variable measured over the cases of the analysis, and the coefficients multiply these variable values before we add them up to form a score.

Cold hardiness: Cold tolerance is characterized by a suite of adaptations which enhance survival at low temperatures.

Collar: Neckline.

Colonization: To establish a colony.

Colony: A small or large locally isolated population.

Commissure: A bridge connecting any two bodies or structures on a body.

Common name: The name of an insect that is used only in a particular region or country.

Common pesticide name: A common chemical name given to a pesticide by a recognized committee on pesticide nomenclature. Many pesticides are known by a number of trade or brand names but have only one recognized common name.

Community: All plants and animals living in a specific region.

Compatible: Two chemical compounds are compatible when they can be mixed without undesirably affecting each other's properties.

Compensation: The ability of plants or plant parts to make up for damage caused to other parts of the plant. For example: a rice plant that lost a tiller because of attack by a stem borer will produce new tillers to compensate for this.

Competition: Competition occurs when two or more organisms, or populations, interfere with or inhibit one another as they strive to secure a resource that is in limited supply. For example weeds compete with crop plants for nutrients, moisture, light and other essential growth factors. Competition can also occur between individuals of the same species.

Complete life cycle: The growth cycle where the young have a different form from the adult and undergo a pupal stage to become the adult. Stages are usually egg-larvae-pupa-adult.

Complete metamorphosis or Complex metamorphosis: Metamorphosis in which the insect develops through four distinct stages, e.g.., ova or egg, larva, pupa, and adult or imago; the wings (when present) develop internally during the larval stage.

Compound eye: An eye consisting of many individual elements or ommatidia each of which is represented externally by a facet.

Concave: Hollowed or rounded inward.

Concentrate spraying: Direct application of a pesticide concentrate without dilution.

Concentrate: Refers to a commercial pesticide preparation before dilution for use.

Concentration: The proportion of active ingredient in liquid or dust pesticide preparation, before or after dilution. The concentration can be shown for example as kilo per litre or as a percentage by weight.

Condenser lens: This is an electromagnetic lens located just below the electron gun in order to make the electron beam emitted from the electron gun into a fine beam. It plays an important role in controlling the electron beam intensity and also the diameter of the electron probe.

Conjunctiva: The membranous infolded portion of the body-wall of insects connecting two segments.

Connective: A longitudinal cord of nerve fibers connecting successive ganglia.

Connexiva (=Connexivum): The prominent abdominal margin of Heteroptera, at the junction of the dorsal and ventral plates.

Consensus configuration: A single set of landmarks intended to represent the central tendency of an observed sample for the production of superimpositions, of a weight matrix, or some other morphometric purpose. Often a consensus configuration is computed to optimize some measure of fit to the full sample: in particular, the Procrustes mean shape is computed to minimize the sum of squared Procrustes distances from the consensus landmarks to those of the sample.

Conservation: Those measures concerned with the preservation, restoration, beneficiation, maximization, reutilization, substitution, allocation, and integration of natural resources.

Conspecific: Belonging to the same species.

Contact insecticide: Insecticide that kills insects by contact with the cuticle.

Contact pesticide: Pesticide which relies on coming into contact with the target organism. For example a contact insecticide.

Contact poison: Pesticide that kills when it contacts some external part of a pest. For example contact insecticide.

Contact: Poison materials killing harmful organisms by contact action, presumably by absorption through the cuticle.

Contiguous: Touching - usually applied to eyes.

Control: In research experiments: The untreated subjects that are compared with those given crop protection treatment. To reduce damage or pest density to a non-damaging level.

Convex: Bulging or rounded outward.

Coordinates: A set of parameters that locate a point in some geometrical space. Cartesian coordinates, for instance, locate a point on a plane or in physical space by projection onto perpendicular lines through one single point, the origin. The elements of any vector may be thought of as coordinates in a geometric sense.

Corium: The main part of the forewing of a heteropteran bug.

Cornicle: One of the pair of small tubular outgrowths on the hind end of the abdomen.

Corpora allata: A pair of small endocrine glands located just behind the brain.

Cosmopolitan: Widely distributed over the globe.

Costa: One of the major longitudinal veins, usually forming the front margin of the wing and usually abbreviated to C. The costal margin is the front edge of the wing.

Costal Cell: The cell between the costa and the sub-costal vein.

Costal Fold: A narrow, thin membrane folded back on the upper surface of the costa of the forewing of butterflies, it contains androconia

Coxa (=Coxae): The basal segment of the leg by means of which it is articulated to the body.

Crenulate: With small scallops, evenly rounded and rather deeply curved.

criteria used. For example, plotting objects according to their scores on the first two

Critical point drying method: The greatest problem attended to drying a specimen is the surface tension of the liquid. This causes shrinking and wrinkles. A method of drying a specimen by adjusting the pressure and temperature so that the distinction between liquid and gas disappears and also the surface tension disappears is called a critical point drying method. Generally, carbon dioxide, which is non-toxic, inexpensive and can be obtained readily, is used in this method.

Crop hygiene: The removal and destruction of heavily infested or diseased plants from a crop so that they do not form sources of reinfestation.

Crop loss: A reduction in the quantity and/or quality of the crop yield.

Crop residue: The unused part of the crop that is not harvested. It is usually returned to the land by ploughing (e.g. straw, cornstalks).

Crop rotation: A method of protecting the soil and replenishing its nutrition by planting a succession of different crops on the same land.

Crop: The dilated section of the foregut just behind the esophagus.

Cross vein: a vein connecting adjacent longitudinal veins.

CRT: This is an abbreviation of Cathode Ray Tube.

Cryptic: Coloring and or pattern adapted for the purpose of protection from predators or prey by concealment.

Cryptobiotic: Leading a hidden or concealed life.

Cubitus: One of the major longitudinal veins situated in the rear half of the wing and usually with 2 or 3 branches: abbreviated to Cu.

Culm: The jointed stem of grass.

Cultivar: A cultivated variety (genetic strain) of a domesticated crop plant.

Cultural control: Use of crop husbandry practices that have a dual role in pest control.

Cumulative pesticides: Pesticides that tend to accumulate or build up in the tissues of animals or in the environment (soil, water).

Cuneus: A more or less triangular region of the forewing of certain heteropteran bugs, separated from the corium by a groove or suture.

Cuticle: The outer noncellular layers of the insect integument secreted by the epidermis.

Cytology: The study of cells and there functioning.

D

D.N.A.: An abbreviation for Deoxyribonucleic Acid a large molecule which stores the data in our genes in the form of a 3 character code. D.N.A. is a self replicating molecule.

Damage: The adverse effect on plants or crops due to biotic or abiotic agents, resulting in economic loss (reduction of yield and/or quality).

DAT: Days after transplanting.

DDT: A widely used synthetic insecticide; a chlorinated hydrocarbon, dichloro diphenyl trichloroethane.

Dead heart: A symptom of insect damage in which the central shoot of the plant dies.

Degree days: Insect development depends on temperature. Below a certain temperature threshold there is no development. Also there is a maximum temperature above which development stops. For a certain day, the number of degree days can be calculated using the threshold and the maximum temperature. If the average temperature of that day is one degree higher than the threshold this will count for one degree day (two degrees above the thresholds is two degree days, etc.) Calculating degree days over a period of time can be used to predict when the development of the insect will be completed.

Delayed toxicity: The effects of a toxic substance may become evident some time after exposure which may delay treatment.

Density dependent: A proportionate increase in mortality (or decrease in fecundity) as population density increases.

Density independent: The mortality or the survival varies independently of population density.

Dentate: Toothed, possessing teeth or teeth like structures.

Denticulate: Bearing very small tooth-like projections.

Deoxyribonucleic Acid (DNA): Is the genetic material of all organisms and is a self replicating molecule.

Deposit: Quantity of a pesticide formulation deposited on a unit area of plant, plant part or other surface at a given application. It may refer to the deposit of the total spray preparation, or it may refer only to the amount of chemical left after the water evaporates.

Depth of field/Depth of focus: The depth of field is the distance between two object planes where the in-focus images can be obtained. The depth of the field L is given by the equation $L = (r/M - d)/2\alpha$. Here, r is the minimum distance between two dots (lines) that can be resolved with the naked eye, M is the magnification, and d is the probe diameter. From this theoretical equation, it can be seen that if a small objective aperture and a long WD is selected, the α becomes small. As a result, the large depth of field is obtained.

Dermal toxicity: Toxicity of a chemical substance as a result of contact with the skin.

Developmental plant host: A plant that serves as a food host for the pest to complete its full life cycle from egg to egg.

Diakinesis: A stage in meiosis where chromosome appear as thick, darkly-staining bodies allowing chromosome counting.

Diapause: A period of dormancy during which the development of the insect is arrested. In the life cycle of many insects especially in the young stages, this period of suspended growth and reduced metabolism will make them more resistant to unfavorable environmental conditions such as low temperatures.

Diaphragm: A horizontal membranous partition of the body cavity.

Dichotomous key: An identification tool to assist a person in identifying an insect (or other organism). It uses paired statements or questions to guide the user to the solution.

Differentiation: Increase in visible distinctive morphology.

Dilated: Expanded or widened.

Dilation: Being dilated.

Dimorphic: Occurring in two distinct forms.

Dimorphism: A difference in size, form, or color, between individuals of the same species, characterizing two distinct types.

Diocious: having the male and female reproductive organs in separate individuals of the same species.

Diploid: Cell containing a double set of chromosomes which are arranged in homologous pairs within the nucleus. Most cells in the body are diploids except gametes which have a single set of unpaired chromosomes.

Discal Cell: Name given to a prominent and often quite large cell near the middle of the wing. The discal cell of one insect group may not be bounded by the same veins as that of another group.

Discal: The central portion of a wing from the costa to the inner margin.

Discriminant analysis: A broad class of methods concerned with the development of rules for assigning unclassified objects/specimens to previously defined groups. See discriminant function.

Dispersal: Movement of individuals out of a population (emigration) or into a population (immigration).

Distal: Concerning that part of an appendage furthest from the body.

Distribution: The geographical range of an organism or group of organisms.

Diurnal: Active during daytime.

Dormancy: A resting stage in which the growth of an organism stops and metabolic rate slows down. It may involve the whole organism or just its reproductive system. It may be a result of unfavorable conditions in the environment.

Dorsad: Towards the top.

Dorsal ocellus: The simple eye in adult insects and in nymphs.

Dorsal shield: The scutum or sclerotized plate covering all or most of the dorsal surface in males and the anterior portion in females, nymphs, and larvae of hard-backed ticks.

Dorsal: Top or uppermost. Referring to the back or upper side.

Dorso-lateral: Towards the sides of the dorsal (upper) surface.

Dorsomedian: middle of the dorsal area.

Dorso-ventral: Running from the dorsal (upper) to the ventral (lower) surface.

Dorso-ventral: Running from the dorsal (upper) to the ventral (lower) surface.

Dorsum: The upper surface or back of an animal.

Dosage (=Dose): The quantity of pesticide applied per individual (plant or animal), or per unit area, or per unit volume, or per unit weight.

Dosage-mortality curve: The curve resulting from plotting percentage mortality of test insects over a period of time against dosage of insecticide. (to draw the dosage-mortality curve usually at least four or five doses are used at logaritmic intervals, e.g dosage 1, 2, 4, 8, 16).

Drift spraying: Method of applying pesticide aerosol sprays for the control of flying insects.

Drift: Movement by the wind of pesticide droplets or dust beyond the intended area of application.

Drop Spectrum: Distribution, by number or volume of drops, of spray into different droplet sizes.

Drought: A period of abnormally dry weather sufficiently prolonged so that the lack of water causes a serious hydrologic imbalance (such as crop damage, water supply shortage, and so on) in the affected area.

Dunn's Posthoc test: compares the differences in the sum of ranks between two columns with the expected average difference (based on the number of groups and their size). It calculates a P value for each pair of columns. These P values answer the question: If the data were sampled from populations with the same median, what is the chance that one or more pairs of columns would have medians as far apart as observed here? If the P value is low, you'll conclude that the difference is statistically significant. The calculations of the P value takes into account the number of comparisons you are making. If the null hypothesis is true (all data are sampled from populations with identical distributions, so all differences between groups are due to random sampling. If the null hypothesis is true (all data are sampled from populations with identical distributions, so all differences between groups are due to random sampling), then there is a 5% chance that at least one of the post tests will have P<0.05. The 5% chance does not apply separately to each individual comparison but rather to the entire family of comparisons.

Dust: An insecticide (or pesticide) which is formulated to be used as a dry powder.

Dustable powder: Free-flowing powder pesticide formulation suitable for dusting.

Dynamics: In population ecology the study of the reasons for changes in population size. For example: Pest dynamics is the study of changes in pest population size.

E

Ecdysis: The molting process, by which a young insect changes its outer skin or pupal case.

Eclosion: The process of hatching from the egg or emergence of the adult.

Ecology: Science dealing with living organisms and their relation to the environment. In IPM: The study that deals with the effect of environmental factors, such as soil, climate, natural enemies, etc. on the occurrence, severity and distribution of plant pests.

Economic damage: The amount of crop injury which will justify the cost of control measures.

Economic injury level (EIL): The lowest pest population density that will cause economic damage.

Economic threshold level (ETL): The density of the pests at which control measures should be applied to prevent an increasing of the population to level where it causes economic damage.

Economic threshold: The pest population level at which control measures should be started to prevent the pest population from reaching the economic injury level.

Ecosystem: The interacting system of the living organisms in an area and their physical environment.

Eco-toxicology: The study of toxic effects of chemical substances in living organisms, especially on populations and communities within defined ecosystems. Eco-toxicology includes transfer pathways of these chemicals and their interaction with the environment.

Ectoderm: The outer embryological layer which gives rise to the nervous system, integument, and several other parts of an insect.

Ectoparasite: A parasite that lives on the outside of its host.

Ectoparasitoid: A parasitoid that develops outside its host. It obtains nutrition by penetration of the host's body wall.

Edaphic conditions: Relating to soil characteristics.

Egg pod: A capsule which encloses the egg mass of grasshoppers and which is formed through the cementing of soil particles together by secretions of the ovipositing female.

Egg: In insects, the reproductive body in which the embryo develops and from which the nymph or larva hatches.

Eggmass: The group of round or oval reproductive body of various organisms, containing the embryo and covered by a shell or membrane.

Ejaculatory duct: Terminal portion of the male sperm duct.

Electromagnetic lens: This is an electron lens which uses a magnetic field to focus an electron beam.

Electron gun: An electron gun is a device that generates an electron beam which is equivalent to the light source of an optical microscope. It consists of a hot cathode (filament) made of a 0.12-mm diameter hairpin shaped tungsten wire, a control electrode (Wehnelt cylinder, or grid), and an anode. The tungsten hairpin type electron gun is generally used in an electron microscope.

Elliptic Fourier analysis: A type of outline analysis in which differences in x and y (and possibly z) coordinates of an outline are fit separately as a function of arc length by Fourier analysis.

Elytra: The hardened forewings used to protect the membranous hind wings in the order Coleoptera.

Emarginate: With a distinct notch or indentation in the margin.

Embolium: A narrow region along the front margin of the forewing in certain heteropteran bugs: separated from the rest of the corium by a groove or suture.

Emergence: The process of the adult insect leaving the pupal case or the last nymphal skin.

Emigration: The movement of individuals out of a population.

Emulsifiable Concentrate (=EC): A liquid pesticide formulation that when added to water spontaneously disperses as fine droplets to form a stable emulsion.

Emulsifier: A substance that promotes the suspension of one liquid in another. Emulsifiers are often added to pesticide formulations (for example to mix oil based pesticide formulations in water).

Endemic: Restricted to a well defined geographical region.

Endocrine: Secreting internally, applied to organs whose function is to secrete into blood or lymph a substance which has an important role in metabolism.

Endocuticle: The innermost layer of the cuticle.

Endoparasite: A parasite which lives inside its host's body. Most of the ichneumons, are endoparasites during their larval stages.

Endoparasitoid: A parasitoid that develops inside its host.

Endopterygote: Any insect in which the wings develop inside the body of the early stages and in which there is a complete metamorphosis and pupal stage.

Entognathous: Having mouthparts within folds of head, this can be protruded when feeding.

Entomogenous fungi (=Entompathogenic fungi): Insect killing fungal organism.

Entomogenous: Growing in or on an insect, for example certain fungi.

Entomophagous: An organism that feeds upon insects.

Environment: The circumstances or total conditions that surround an organism or a group of organisms.

Enzyme: An organic catalyst, normally a protein formed and secreted by a living cell.

Epicuticle: The thin, non-chitinous, surface layers of the cuticle.

Epidermis: The cellular layer of the integument that secretes or deposits a comparatively thick cuticle on its outer surface.

Epigaeic: Living or foraging primarily above ground, compared to Hypogaeic the opposite.

Epimeron (=Epimera): The area of a thoracic pleuron posterior to the pleural suture.

Epinotum: The first abdominal segment when it is fused with the last thoracic one, relating to the higher thin waisted hymenoptera. Also called a propodeum.

Episternum: The anterior part of the side wall of any of the three thoracic segments.

Epithelium: The layer of cells that covers a surface or lines a cavity.

Euclidean space: A space where distances between two points are defined as Euclidean distances in some system of coordinates.

Eukaryote: Is an organism with membrane-bound organelles and nucleus.

Evaporative area: Cuticular modifications surrounding the opening of the metathoracic gland.

Exocuticle: The hard and usually darkened layer of the cuticle lying between the endocuticle and epicuticle.

Exopterygote: Any insect in which the wings develop gradually on the outside of the body, in which there is only a partial metamorphosis and no pupal stage.

Exoskeleton: A skeleton or supporting structure on the outside of the body. Present in all members of the Arthropoda.

Exotic species: An organism that evolved in one part of the world and that now occurs either accidentally or intentionally in a new region. Opposite: native species.

Exserted: Protruding or projecting from the body.

Exuvia (=Exuviae): The cast-off outer skin of an insect or other arthropod.

Eyes: Organs of sight.

F

Facet: The surface of an ommatidium - one of the units making up the compound eye.

Fallow: Land that is ordinarily used for crops but allowed to idle between crops.

Family: A taxonomic subdivision of an order, suborder, or superfamily that contains a group of related subfamilies, tribes and genera. Family names always end in -idae.

Fauna: Describing the animals of an area, here referred to insects.

Fecundity: The potential reproductive capacity of an organism or population, measured by the number of eggs, seed set or asexual propagules. Fecundity is under both genetic and environmental control, and is the major measure of fitness.

FELCRA: Federal Land Consolidation and Rehabilitation Authority.

Femur (=Femora): The 3rd (counting out from the body) and often the largest segment of the insect leg, situated between the trochanter and tibia.

Femur: The 3rd (counting out from the body) and often the largest segment of the insect leg.

Fertile: Capable of producing offspring.

Filament: A thread-like structure, especially one at the end of an antenna.

Filiform: Thread-like or hair-like, applied especially to antennae.

Finite rate of increase: It is the maximum multiplication rate of an insect species in a given period of time. It is usually expressed as number of insects per week or per month. It is denoted as 'λ'.

Flag leaf: The uppermost rice leaf originating just below the panicle base.

Flange: Protuberance or swelling.

Flooding: Filling of ditches or covering of land with water during the raising of rice crops.

Flora: All of the plants found in a given area.

Foliage: Plant leaves are collectively called foliage.

Foliar application: Application of a pesticide to the leaves or foliage or plants.

Foliar: Relating to, or applied to leaves as spray.

Food chain: Sequence of species within a community. Each member serves as food for the next higher species in the chain.

Food web: A modified food chain that expresses feeding relationships at various, changing trophic levels.

Forecasting: To predict on the basis of scientific observations and applied experience.

Foregut: The anterior part of the alimentary canal from the mouth to the midgut.

Forelegs: The front pair of legs.

Forewing membrane: The membranous part of the forewing, which may consist of the whole wing in some forms, but only the rear half of the wing in others that have hemelytra. Some forms that have coleopterous or coriaceous wings have no forewing membrane.

Forewings: The front pair of wings.

Form: In morphometrics, we represent the form of an object by a point in a space of form variables, which are measurements of a geometric object that are unchanged by translations and rotations. If you allow for reflections, forms stand for all the figures that have all the same interlandmark distances. A form is usually represented by one of its figures at some specified location and in some specified orientation. When represented in this way, location and orientation are said to have been "removed."

Formulation: Way in which basic pesticide is prepared and sold for use. A formulation contains the active ingredient(s) and other substances such as carriers and stickers. Examples of formulations include: emulsifiable concentrates, wettable powders, suspension concentrates, dusts, baits, fumigants, aerosols and granules.

Fourier analysis: In morphometrics, the decomposition of an outline into a weighted sum of sine and cosine functions. The chapter by Rohlf in the Blue Book provides an overview of this and other methods of analyzing outline data.

Frass: Plant fragments made by plant-feeding insects, usually mixed with excrement.

Frons: Upper part of the insect face, between and below the antennae and usually carrying the median ocellus or simple eye. In true flies (Diptera) it occupies almost all of the front surface of the head apart from the eyes.

Frontolateral: From the front to the sides.

Fumigant: A chemical compound which acts in the gaseous state to destroy insects and their larvae and other pests in confined/or field or inaccessible locations.

Fuscous: Smokey grey-brown in color, normally applied to wings.

G

Ganglion: A nerve mass that serves as a center of nervous influence.

GAP (Good agricultural Practice): GAP is a practical guideline of the production system at farm level for obtaining good quality of agricultural products that meet standards. Key aspects of GAP are, for example, soil and water management, pest protection, chemical residue control, harvesting and processing at the farm level, good storage, waste management, animal welfare, human health awareness, safety of operators, and biodiversity conservation.

Gaster: The hymenopteran abdomen - apart from the 1st segment (the propodeum) which is fused to the thorax. The front part of the gaster often forms a narrow waist.

Gena: The cheek - that part of the head below and behind the eye.

Gene frequency: The frequency of occurrence of a specified gene in a population compared to its alleles.

Generalized superimposition: The superimposition of a set of configurations onto their consensus configuration. The fitting may involve least-squares, resistant-fit, or other algorithms and may be strictly orthogonal or allow affine transformations.

Generation time: It is the time (days) required for an insect species to complete one stage in its life cycle in a generation to the same stage in the next generation.

Generation: The group of individuals of a given species that have been reproduced at approximately the same time; the group of individuals of the same genealogical rank.

Genetic distance: The degree by which the population of species differ from each other.

Genetic identity: The degree of similarity between populations of species.

Geniculate: Abruptly bent or elbowed.

Genital claspers: Organs of the male genitalia which serve to hold the female during copulation.

Genitalia: The copulatory organs of insects and other animals. The shape and arrangement of the genitalia are often used to distinguish closely related and otherwise very similar species. The reproductive organs, found at the apex of abdomen.

Genotype: The total genetic character of an organism, i.e. all its D.N.A. or genes

Genotypic frequency: The frequency of occurrence of specified genetic constitution in a population of organisms.

Genus: A group of closely related species (plural: genera). The name of the genus is incorporated into the scientific names of all the member species: *Scotinophara coarctata* and *Scotinophara lurida*, for example, both belong to the genus *Scotinophara*. Genus names are written with a capital and should be printed either in italics or underlined.

Geometric morphometrics: Geometric morphometrics is a collection of approaches for the multivariate statistical analysis of Cartesian coordinate data, usually (but not always) limited to landmark point locations. The "geometry" referred to by the word "geometric" is the geometry of Kendall's shape space: the estimation of mean shapes and the description of sample variation of shape using the geometry of Procrustes distance. The multivariate part of geometric morphometrics is usually carried out in a linear tangent space to the non-Euclidean shape space in the vicinity of the mean shape. More generally, it is the class of morphometric methods that preserve complete information about the relative spatial arrangements of the data throughout an analysis. As such, these methods allow for the visualization of group and individual differences, sample variation, and other results in the space of the original specimens.

Gibbous: Hump-baked; very convex; a surface presenting one or more large elevations.

Glabrous: Without hairs.

Gland: A structure which produces a substance essential and vital to the existence of the organism.

Globoid: Somewhat globular or nearly globose.

Gonocoxae (=Gonocoxite): The basal segment of a gonapophysis (gonapophyses: the genitalia collectively; the appendages surrounding the gonopore).

Gonopore: The external opening of the reproductive organs.

Granular insecticide: Insecticide having a grainy structure.

Granule: Particle of inert material which is mixed or impregnated with a pesticide.

Granulose: Roughened with granules or made up of distinct grains.

Grass: Plant belonging to the family Gramineae.

Gravid: Pregnant.

Gregarious: Living in groups.

Growth stage: Process of growth over a period of time.

H

Habitat: A place with a particular kind of environment where plants and animals live.

Habitus: Body-build, general appearance.

Hatch: To break out of the egg.

Hatching: The emergence of a nymph or larval insect from the egg.

Hazard: The probability that a substance will cause harm under conditions of exposure.

Head: The anterior/frontal body region of insects which bears the mouthparts, eyes, and antennae.

Heading stage: Growth stage of grain crops when the seed head of a plant begins to emerge from the sheath.

Hectare: Unit of area denoting approx.2.5 acres.

Hemelytron (=Hemelytra): The anterior wing in the Heteroptera, the basal half of which is thickened and the apical membranous, in most members of the Order; also termed by some authors elytron or tegmen.

Hemimetabola: Insects having a simple metamorphosis, with no pupal stage in the life history.

Hemiptera: The true bugs, an order of the class Insecta characterized by forewings differentiated into a basal area and a membraneous apical region.

Hemolymph: The circulatory body fluid of various invertebrate animals that is functionally comparable to the blood and lymph of vertebrates.

Herbivore: Plant eating. An organism that feeds on plant material (see also carnivore and omnivore).

Herding of ducks: Is releasing of ducks in the field because ducks feed on RBB and other pests thus reducing their number.

Heteroptera: Order of insects containing the true bugs.

Heterozygosity: The state of having two genes at corresponding loci of homologous chromosomes different for one or more loci.

Hexapoda: An animal possessing six legs, more specifically the parent group that contains insects and their close kin.

Hibernate: Overwinter. Spend the winter in a dormant condition.

Hibernation: A type of dormancy that occurs during the winter.

Hillocks: A small, low hill.

Hindgut: The posterior part of the alimentary canal between the midgut and anus.

Hindlegs: The rear pair of legs.

Hindwings: Pair of wings borne on the metathorax.

Holometabola: Higher insects with complete metamorphosis. The life cycle includes egg, larva, pupa and adult.

Holotype: The type specimen of a species is the actual insect from which the original description of that species was produced. If several specimens were used for this purpose, one of them should have been designated as the type. Because the type can be of only one sex, it is usual to designate a certain individual of the opposite sex as the allotype. The original type specimen is then called the holotype. These type specimens' are very important in taxonomy and classification.

Homologous: Organs or parts which exhibit similarity in structure, in position with reference to other parts, and in mode of development, but not necessarily similarity of function, are said to be homologous.

Homology: The notion of homology bridges the language of geometric morphometrics and the language of its biological or biomathematical applications. In theoretical biology, only the explicit entities of evolution or development, such as molecules, organs or tissues, can be "homologous." Following D'Arcy Thompson, morphometricians often apply the concept instead to discrete geometric structures, such as points or curves, and, by a further extension, to the multivariate descriptors (e.g., partial warp scores) that arise as part of most multivariate analyses. In this context, the term "homologous" has no meaning other than that the same name is used for corresponding parts in different species or developmental stages. To declare something "homologous" is simply to assert that we want to talk about processes affecting such structures as if they had a consistent biological or biomechanical meaning. Similarly, to declare an interpolation (such as a thin-plate spline) a "homology map" means that one intends to refer to its features as if they had something to do with valid biological explanations pertaining to the regions between the landmarks, about which we have no data.

Homonym: A scientific name which has been given to two different species. When such an instance comes to light one of the species must be given another name.

Homoptera: Order of insects containing true bugs, cicadas, hoppers, psyllids, whiteflies, aphids and scale insects. They are characterized by uniformly leathery or uniformly membranous forewings, sucking mouthparts, and an incomplete metamorphosis.

Hormone: A chemical substance formed in some organ of the body, secreted directly into the blood, and carried to another organ or tissue where it produces a specific effect.

Host plant resistance: A method of pest control in which resistant crop plants are used.

Host range: The various kinds of host plants that may be attacked by a pest.

Host: The plant on which an insect feeds. The organism in or on which a parasite lives. Organism that furnishes food, shelter or other benefits to another organism of a different species. For example: Rice is a host for the Rice Black Bugs.

Humeral angle: The basal anterior angle or portion of the wing.

Humeral Vein: A small cross-vein running from the costa to the sub-costa in the humeral (basal) region of the wing.

Humeral: Pertaining to the shoulder: located at the anterior basal portion of the wing.

Humerus (=Humeri): The shoulder; the posterolateral angles of the pronotum in Hemipterans.

Humerus: The shoulder; in Heteroptera, the lateral angle of the prothorax.

Humidity: The amount of water vapor in the air.

Hydrological: Relating to characteristics of water or rainfall.

Hygrophilus: Moisture loving.

Hymenoptera: Insect order containing bees, wasps, ants, and sawflies. They are characterized by membranous wings, chewing or chewing-lapping mouthparts, and a complete metamorphosis.

Hyperparasite: A parasitic organism which attacks another parasite.

I

IET: Initial Evaluation Trial.

Imago (=Imagines): The adult insect. The reproductive stage.

Immigration: Movement of insects from one habitat into another habitat.

Incomplete metamorphosis or Simple metamorphosis: Metamorphosis in which the wings (when present) develop externally during the immature stage and there is no prolonged resting stage (i.e. pupa) preceding the last molt; stages included are the egg, nymphal, and adult. Also called gradual or partial metamorphosis, and paurometabolous development. An incomplete metamorphosis is characteristic for insect orders belonging to the exopterygota.

Incrassate: State of being swollen or thickened.

Incubation period: It is the time between oviposition of an egg by the mother insect body and hatching of that particular egg into a larva or nymph.

Incubation: Tenure of embryo development.

Indus: Main river of Pakistan.

Inert ingredient: Any substance in a pesticide formulation that has no pesticidal action.

Inert: A substance having no biological action.

Infest: In insects: to occupy and cause damage.

Infestation: Presence of animal pests (insects, rodents, etc.) on the plant crops.

Inflorescence: The flowering portion of a plant.

Ingest: To eat or swallow.

Injury: Damage of a plant which impairs growth, functioning or appearance, but not necessarily resulting in loss of yield or quality.

Inorganic compound: A compound which does not contain carbon atoms. Except CO2, which is considered an inorganic compound.

Insecta: A 'class' of the 'phylum' Arthropoda, distinguished by adults having three body regions: head, thorax, and abdomen; and by having the thorax three-segmented with each segment bearing a pair of legs. A gonopore is present at the posterior end of the abdomen.

Insecticide: A toxin effective against insects.

Integrated control: The combination of several different methods of pest control.

Integrated Pest Management (IPM): Sometimes referred to as Integrated Pest Control. A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury. Often, the term IPM includes all elements contributing to an effective, safe, sustainable and economically sound crop protection system.

Integument: The insect's outer coat.

Intensive cropping: A system of farming aimed at raising yields per unit area.

Intercalary Vein: An additional longitudinal vein, arising at the wing margin and running inwards but not directly connected to any of the major veins.

Intercropping: The growing of two or more crops simultaneously in the same field.

Intermediate host: The host which harbors the immature stages or the asexual stages of a parasite, a separate organism to that which harbors the sexual stage.

Intermittent irrigation: Is a method of applying irrigation water by which the field is alternately watered and drained. The soil surface is allowed to dry prior to the next application of water.

Internode: An interval or part between two nodes.

Interocular: Between the eyes.

Intraspecific: Refers to a characteristic present to all members of the same species.

Intrinsic rate of natural increase: It is the innate capacity of an insect species to increase in numbers under optimum conditions of food and environment at stable age distribution. It is usually expressed as number of females/ female/ day and is denoted as 'r_m'.

Invertebrates: the phylum comprising all animals that lack a backbone or spinal column.

Ion sputtering device: The ion sputtering device is used to prepare SEM specimens. It creates a glow discharge in a low vacuum of about 10 to 1 Pa, and ionizes the residual gas or introduced argon gas. These gas ions strike a negative potential cathode target at high velocity, sputter the metal of the cathode,

and deposit the sputtered metal on the surface of the specimen in the vicinity. Thus the specimen is metal coated. Alternatively, it can be used to shoot ions at the surface of a specimen instead of the cathode target, so as to remove (etch) an unwanted film on the specimen surface.

Irrigated rice: It is a rice ecosystem in which there is perfect leveling and bunding of the fields and the irrigation water can be controlled. Usually 2.5 to 10 cm of water is maintained throughout the crop growth. Irrigated rice is possible both during Kharif or wet season and Rabi or dry season. In Rabi, assured irrigation is a must to take up the crop.

Isolocus: The zone of activity of protein determined as separate bands.

Isozyme: Any of two or more chemically distinct but functionally similar enzymes.

J

Joint: Strictly speaking, an articulation between neighboring parts, such as the femur and tibia of the leg, but the word is commonly used as a synonym of segment - meaning any of the divisions of the body or its appendages.

Jugal: Pertaining to the jugum, the basal area of the wing, usually set-off by a jugal fold.

Jugum: A narrow lobe projecting from the base of the forewing in certain moths and overlapping the hind wing, thereby coupling the two wings together.

Junction: Merging point of two veins.

K

KADA: Kemubu Agricultural Development Authority.

Kallar tract: A specific area of the Punjab province and well known for its aromatic Basmati Rice. The name kallar was given probably because of alkaline nature of soil of the area in between two rivers Ravi and Chanab consisting three districts i.e., Sialkot, Gujranwala and Sheikhupura.

Karyology: The study of the chromosomal patterns.

Karyotype: Refers to the chromosomal properties of a cell. It refers to the appearance (size, shape, and number) of the set of chromosome of a somatic cell.

Keel: A narrow ridge: also called a carina.

Kg /ha: kilograms per hectare.

Kharif: Kharif or wet season is the main rice growing season in India. It usually starts in the month of May with the onset of monsoon and ends with December. Almost the entire rainfed rice comprising of rainfed uplands, rainfed lowlands and deep water rices are cultivated during this season. Usually long duration varieties of 150 – 165 days are grown in different rice growing tracts depending on the suitability and availability.

Knob-like: A structural swelling.

Kruskall-Wallis: A nonparametric test used to compare 3 or more unpaired groups. It is also called Kruskall-Wallis one-way analysis of variance by ranks. The key results is a P value that answers this question: If the populations really have the same median, what is the chance that random sampling would result in medians as far apart (or more so) as you observed in this experiment?

L

Labrum: The 'upper lip' of the insect mouth-parts: not a true appendage but a movable sclerite on the front of the head.

Labrum-epipharynx: A mouthpart composed of the labrum and epipharynx and usually elongate.

Lamellate: Possessing lamellae: applied especially to antennae.

Landmark: A specific point on a biological form or image of a form located according to some rule. Landmarks with the same name, homologues in the purely semantic sense, are presumed to correspond in some sensible way over the forms of a data set. See Type I, Type II, and Type III landmarks.

Larva: Name given to a young insect which is markedly different from the adult.

Laterad: Toward the side, away from the midline of the body.

Lateral arm: Appendage at the side of the insect aedeagus.

Lateral margin: The join between the dorsal and ventral plates of the Heteroptera abdomen.

Lateral ocellus (=Stemmata): The simple eye in holometabolous larvae.

Lateral oviduct: In insects, one of the paired lateral ducts of the female genital system connected with the ovary.

Lateral: The side of the insect. Lateral view is looking at it from the side.

Lateral: Concerning the sides.

Laterobasal: To the side away from the midline of the body going to the base.

Leaching: The movement of a pesticide or other chemical downward through the soil as a result of water movement.

Leaf sheath: The lower part of the leaf originating from node and enclosing the stem (culm) above the node.

Legislative control: The use of legislation to control the importation and to prevent any spread of a pest within a country.

Legs: A limb or an appendage of an animal or insect, used for locomotion or support.

Leptonema: A stage in meiosis wherein chromosomes look like long, thin and single-stranded threads.

Lethal Concentration 50% (= LC50): Concentration required to kill 50% of test organisms.

Lethal Dose 50% (= LD50): Dose required to kill 50% of test organisms.

Levee: Dike made of soil to retain water in rice fields.

Life cycle: The sequence events in the development of an insect that occur from birth (hatching of the egg) to reproduction (mating and egg laying).

Life history: Habits and changes undergone by an organism from the egg stage to its death as an adult.

Life table: Is a mortality table.

Light trap: A device for collecting insects, consisting of a light source, which attracts insects at night and a mechanism that traps the insects.

Locus (=Loci): The position in a chromosome of a particular gene or allele.

Longitudinal: Lengthwise of the body or of an appendage (leg, wing, antenna, etc.).

Loop: Coils in the spermatheca duct.

Lunar cycle: Is a metonic cycle. The period of 19 years covering all phases of the moon, after which the new moons occur again on the same cycle of the dates.

M

MADA: Muda Agricultural Development Authority.

MANOVA: See multivariate analysis of variance.

Margin: Edge.

Marginal cell: A cell in the distal part of the wing bordering the coastal margin.

Maturity: To come to full development/ripen.

M-chromosomes:

Mechanical control: Use motion and force to control pests such as handpicking, tools, or trapping.

Media: The longitudinal vein running through the central region of the wing in most insects: often the 4th and abbreviated to M.

Medial: Of or in the middle.

Medially: In a medial position.

Median oviduct: In insects, the single duct formed by the merging of the paired lateral oviducts; this duct opens posteriorly into a genital chamber or vagina.

Median: In the middle; along the midline of the body.

Meiosis: A type of cell division which results to halving of the chromosome number; also called, reduction division.

Meiotic Index: used in the quantitative analyses of testicular cells and chromosomes; computed using the formula:

Membranous: Thin and transparent (in reference to wings); thin and pliable (in reference to integument).

Mesepimeron: The epimeron of the mesothorax.

Mesonotum: The dorsal surface of the 2nd thoracic segment - the mesothorax: usually the largest thoracic sclerite.

Mesopleuron: The sclerite or sclerites making up the side wall of the mesothorax.

Mesoscutellum: Hindmost of the three major divisions of the mesonotum, often triangular or shield-shaped: usually abbreviated to scutellum.

Mesoscutum: The middle and usually the largest division of the mesonotum.

Mesosternum: The ventral surface or sclerite of the mesothorax.

Mesothorax: The second segment of the thorax bearing the second pair of legs.

Metal coating: When observing or analyzing an electrically non-conductive specimen with a SEM or EPMA, the surface of the specimen is coated with a thin film of electrically conductive material in order to prevent a buildup of electrostatic charge on the specimen. For observation of a SEM image, the specimen is coated with a heavy metal such as gold, gold-palladium alloy or platinum, while for X-ray analysis, the specimen is coated with a light substance such as carbon or aluminum, using a vacuum deposition device or ion sputtering device.

Metamorphosis: a change in the appearance or function of a living organism, by a natural process of growth or development.

Metanotal wing pads: The plates for the hind wings or second pair of wings.

Metanotum: The dorsal surface of the metathorax. It is often very small and its sub-divisions are usually obscured.

Metapleuron (=Metapleura): The lateral sclerite(s) of the metathorax.

***Metarhizium anisopliae*:** Also known as "green muscardine", is a fungus that kills major insect pests such as diamondback moth, cabbageworm, Asian corn borer, coconut beetle, mango leafhoppers, rice black bug, oriental migratory locust, and nematode. It has powdery masses of dark green to yellow-green columns of conidia which arise from white mycelium. The fungus looks the same in pure culture as on the insect.

Metasternum: The ventral surface or sclerite of the metathorax.

Metatarsus: The basal segment of the tarsus or foot: usually the largest segment.

Metathoracic scent gland: A thoracic structure responsible in realizing the excess body fluids through the scent gland opening.

Metathorax: The third thoracic or segment, which bears the hind legs and second pair of wings; variably distinct;

sometimes closely united with the mesothorax and sometimes appearing as a part of the abdomen.

Microbial control: Control of insects (or other organisms) by the use of micro-organisms (including viruses).

Microbial insecticide: A pathogenic micro-organism or its products (toxins etc.) that is applied in the same way as a conventional pesticide to control a pest population. Similar terms microbial pesticide, biotic insecticide, microbial control product.

Microbial pesticides: Living micro-organisms, such as fungi, bacteria, viruses, protozoa and nematodes, as well as metabolites produced by micro-organisms that are used in pest control. For example: *Metarhizium* spp.

Micropyle: A minute opening or group of openings into the insect egg through which the spermatozoa enter in fertilization.

Microsculptured region: An area in the metapleuron and mesopleuron.

Midanterior: Front near the middle

Midclasper: middle of the appendage of the male of certain insects that are used during copulation to hold the female.

Middorsal: center of the upper most portions.

Midgut: The middle part of the alimentary canal and the main site of digestion and absorption.

Midlateral: Center of the side or lateral portion.

Midlength: Median measurement lengthwise.

Midposterior: center of the hind or rear area.

Midposterodorsal area: Middle of the dorsal area going to the rear potion.

Midventer: center of the ventral or underside of the body.

Migration: The periodic movement of organisms to new areas or habitats.

Milk stage: Stage of ripening phase of rice growth and development when the contents of the grain are at first watery, but later turns milky in consistency.

Molt: to shed the outer skin (exoskeleton) in the process of growth.

Moniliform: Composed of bead-like segments, each well separated from the next.

Monomorphic: Having a single form, structural pattern or genotype.

Monophagous: Feeding upon only one kind of food, for example one species or one genus of plants.

Morphometrics: From the Greek: "morph," meaning "shape," and "metron," meaning "measurement." Schools of morphometrics are characterized by what aspects of biological "form" they are concerned with, what they choose to measure, and what kinds of biostatistical questions they ask of the measurements once they are made. The methods of this glossary emphasize configurations of landmarks from whole organs or organisms analyzed by appropriately invariant biometric methods (covariances of taxon, size, cause or effect with position in Kendall's shape space) in order to answer biological questions. Another sort of morphometrics studies tissue sections, measures the densities of points and curves, and uses these patterns to answer questions about the random processes that may be controlling the placement of cellular structures. A third, the method of "allometry," measures sizes of separate organs and asks questions about their correlations with each other and with measures of total size. There are many others.

Mortality: Death rate, a measure of the number of deaths in some population.

Mu: Is the area term ($1mu = 666.7m^2$)

Mulch: A mixture of organic matter, such as straw, leaves, that is spread over soil to prevent evaporation, maintain an even soil temperature, prevent erosion, control weeds, and enrich soil.

Multiple discriminant analysis: Discriminant analysis involving three or more a prior idefined groups.

Multivariate analysis of variance: MANOVA. An analysis of variance of two or more dependent variables considered simultaneously.

Multivariate morphometrics: A term historically used for the application of standard

multivariate techniques to measurement data for the purposes of morphometric analysis.

N

Natural control: The collective action of environmental factors to maintain a pest population size at an acceptable level over a period of time.

Natural enemies: Biological control agents of the harmful organisms (rice black bug).

Natural host: A host in which the pathogenic micro-organism or parasite is commonly found and in which it can complete its development.

Natural selection: Selection among a group of animals or plants by the forces of nature. It allows those of the group best fitted to survive in the particular environment to live and reproduce, while those not fitted to that environment will die. By this means, the species or group gradually adapts to the environment as poorly adapted individuals are gradually eliminated over many generations.

Nematode: Is an unsegmented round, thread-, ell-worms.

Neurone: The entire nerve cell including all its processes.

Neurotoxin: A substance that damages nerves or the nervous system.

Nm: The abbreviation of nanometer. This is a unit of length. $1 \text{ nm} = 10^{-9}\text{m}$.

Nocturnal: Active at night.

Node: The solid portion of the joint stem. Leaves, tillers, and adventitious roots arise from nodes on the stem.

Nomenclature: A systematic arrangement of distinctive names employed in any science.

Non-target organisms: Those organisms which are not the intended targets of a particular use of a pesticide.

Notaulix: One of a pair of longitudinal grooves on the mesonotum of certain hymenopterans, dividing the mesonotum into a central area and two lateral areas (plural notaulices).

Notum: The dorsal or upper surface of any thoracic segment: usually prefixed by pro-, meso-, or meta- to indicate the relevant segment.

Nucleolus organizer: A special portion on certain chromosomes that is associated with nucleolus formation; abbreviated as NOR.

Nucleolus: Is a spherical body in eukaryotes; active in ribosome synthesis.

Nucleus: The spheroid body within a cell that has the major role in controlling and regulating the cell's activities and contains the hereditary units or genes.

Nulliparous: an organism that has never borne its young one.

Nurse cells: Cells that are located in the ovarian tubes of certain insects and that furnish nutriment to the developing eggs.

Nursery: A place where seedlings are grown before transplanting in the field.

NWFP: North-West Frontier Province, A province of Pakistan.

Nymph: The immature stage of paurometablous insects that usually resembles the adult in shape and general appearance.

O

Objective lens: The objective lens is the lens that is nearest the specimen. In SEM, it is used to focus the electron beam on the specimen surface (focusing).

Ocellus (=Ocelli): One of the simple eyes of insects, usually occurring in a group of three on the top of the head, although one or more may be absent from many insects.

Ochraceous: Yellow with a slight tinge of brown.

Ommatidium (=Ommatidia): One of the units which make up the compound eyes of arthropods.

Oral toxicity: The toxicity of a compound when ingested. The oral toxicity of a pesticide is expressed in milligrams of chemical per kilogram of body weight. It is the amount which when given orally in a single dose will kill 50% of the animals.

Order: A subdivision of a class or subclass containing a group of related families.

Ordination: A representation of objects with respect to one or more coordinate axes.

Organelle: Is one of many formed bodies floating in the cytoplasm of eukaryotic cells that possess specialized functions.

Organochlorine insecticide: One of the many chlorinated hydrocarbon insecticides. For example: DDT, dieldrin, chlordane, BHC, Lindane.

Organophosphates: Organic compounds containing phosphorous; an important group of synthetic insecticides belong to this class of chemicals. Organophosphates inhibit the functioning of the enzyme cholinesterase.

Ostiole: In Heteroptera, one of the lateral metasternal external openings of the stink glands, placed near the coxa in the adult; paired and dorsal on the abdomen of the nymph.

Outbreak: Sudden flare-up of population of harmful organisms resulting in economic damage to the rice crop.

Outline: A mathematical curve that stands for the two-dimensional image of a physical boundary. Outline data can be archived as a sequence of point coordinates, but such points do not share the notion of homology associated with landmarks.

Ovary: An egg-producing reproductive organ found in female organisms.

Ovate: Oval shape resembling with an egg.

Over-wintering: To remain alive through winter, to pass or spend the winter.

Ovicide: Pesticide that destroys eggs.

Oviparous: Producing eggs which are hatched outside the body of the female.

Oviposit: To lay or deposit eggs.

Oviposition: The act of laying or depositing eggs.

Ovipositional plant host: A plant which the female of the pest will lay its eggs.

Ovipositor: A specialized structure in many insects for depositing eggs. The external genitalia of the female.

P

Pachytene: A stage in meiosis characterized by tightly paired chromosomes and by the occurrence of crossing-over between non-sister chromatids of homologous chromosomes.

Paddy: Rough rice. The rice kernel with the husk on.

Palaearctic Region: Temperate countries like Japan, Korea, North China.

Panicle: The terminal shoot of the rice plant that produces grain.

Parameres: Two lateral processes or lobes of the gonapophyses; the smaller inner pair of male gonapophyses, closely associated with the aedeagus.

Parasite: An organism that spends all or part of its life in close association with another species, taking food

from it but giving nothing in return. Ectoparasites live on the outside of their hosts, while endoparasites live inside the host's body.

Parasitism: A symbiotic relationship in which the host is not harmed, but not killed immediately, and the species feeding on it is benefited.

Parasitoids: Are insects mostly belonging to the orders Hymenoptera (wasps) and Diptera (flies). Adult females lay their eggs on or near the host insect. The larvae hatching from eggs feed on the host either internally or externally killing it during their development.

Paratergite: The lateral marginal region of the notum.

Paratype: A biological specimen other than a holotype used for the development of the original description of a taxonomic group.

Parthenogenesis: A special type of sexual reproduction in which an eggs develops without entrance of sperm.

Partial Least Squares: Partial Least Squares is a multivariate statistical method for assessing relationships among two or more sets of variables measured on the same entities. Partial Least Squares analyses the covariances between the sets of variables rather than optimizing linear combinations of variables in the various sets. Their computations usually do not involve the inversion of matrices.

Partial warp scores: Partial warp scores are the quantities that characterize the location of each specimen in the space of the partial warps. They are a rotation of the Procrustes residuals around the Procrustes mean configuration. For the nonuniform partial warps, the coefficients for the rotation are the principal warps, applied first to the x-coordinates of the Procrustes residuals, then to the y-coordinates and, for three-dimensional data, the z-coordinates. Coefficients for the uniform partial warps are produced by special formulas.

Partial warps: Partial warps are an auxiliary structure for the interpretation of shape changes and shape variation in sets of landmarks. Geometrically, partial warps are an orthonormal basis for a space tangent to Kendall's shape space. Algebraically, the partial warps are eigenvectors of the bending energy matrix that describes the net local information in a deformation along each coordinate axis. Except for the very largest-scale partial warp, the one for uniform shape change, they have an approximate location and an approximate scale.

Pathogen: A disease-producing agent; usually refers to living organisms.

Pecky rice:

Pedicel: The second antennal segment.

Pedipalp: The second pair of appendages of an arachnid, used to crush prey.

Pedunculate: Located on stalk penial plates.

Pentagonal: Having five sides and five angles.

Penultimate: The next to the last member of a series.

Perception: Is the process of acquiring, interpreting, selecting and organizing sensory information.

Persistence: The characteristic of chemicals or microbial insecticides those remain active for a long period of time after application. In chemicals, persistence is the result of low volatility and chemical stability. Certain organochlorine insecticides such as DDT are highly persistent.

Pest insect: An insect causing damage to man's crops, domestic animals or possessions.

Pest intensity: The total number of pests per unit of habitat or area.

Pest: A harmful organism that causes damage to man's crops, animals, or possessions.

Pesticide resistance: Genetically selected tolerance of pest populations to pesticides. Resistance is caused by the repeated exposure of the pest population to pesticide treatment. Sensitive individuals are killed, while the resistant individuals will continue to reproduce. Resistance can develop to both chemical and microbial pesticides.

Pesticide: Any substance (chemical or microbial) which because of its toxicity is used to control pests. Pesticides include: acaricides, bactericides, fungicides, herbicides, insecticides, nematicides, rodenticides, etc.

Petiolate: Attached by a narrow stalk.

Phallotheca: The basal component of the male aedeagus.

Phenology: The study of periodic or cyclical biological phenomena (reproductive cycles, life cycles etc) in relation with edaphic factors, climate and weather changes.

Pheromone: Any substance secreted by an animal which influences the behavior of other individuals of the same species.

Phloem: A complex tissue in the vascular system of higher plants, consisting of sieve tubes and companion cells and usually also parenchyma and sclerenchyma. It serves especially in conduction, but also in support and storage.

Phoresis: The usage by one animal of another solely as a means of transport.

Photoperiod: The entire cycle of illumination and darkness to which an organism is exposed. Conventionally expressed as L: D and totaling 24 on a day length (e.g. L8: D16; L14: D10).

Phylum (=Phyla): A major division of the animal kingdom, containing various suborders and classes etc.

Physical control: The use of mechanical and physical methods of controlling pests (e.g hand pick, heat treatment, radiation).

Phytophagous (=Herbivorous): Feeding on plants.

Phytophagous: Feeding upon plants.

Phytosanitation: The removal and destruction of infested or diseased plants from a crop so that they do not form a source of infestation for healthy plants.

Phytotoxic: A material which causes damage to plants.

Pilose: Densely clothed with setae (hairs).

Pilosity: Hairyness.

Pivot: A process in the male aedeagus that provides attachment.

Plantae: taxonomic kingdom comprising all living or extinct plants.

Pleura (=Pleuron): The lateral region of a thoracic segment.

Pleural Suture: A vertical or diagonal groove on each of the thoracic pleura, separating the episternum at the front from the epimeron at the back.

Pleural: Concerning the side walls of the body.

Pleuron: The side wall of a thoracic segment.

Plow-under: Plowing under and submerge heavily infested fields to kill the eggs, nymphs and adults.

Poison: Any chemical or agent that can cause illness or death when eaten, absorbed through the skin, or inhaled by humans or animals.

Polyembryony: The production of several embryos from a single egg, as in some chalcids.

Polymorphism: The quality or state of being able to assume different forms; proportion of polymorphic loci with the total number of loci controlling the character.

Polyphagous: Feeding on many kinds of plants.

Population density: The number of individuals of one population per unit area or volume.

Population dynamics: The study of changes in population size over time.

Porrect: Extending horizontally forward. Applied especially to antennae.

Posterad: Directed posteriorly.

Posterior ocellar line (=POL): Minimum distance between the two posterior ocelli, abbreviated as POL or POD.

Posterior: Concerning or facing the rear, hind.

Preapical: Before the end or apex.

Precostal area: The area in front of, or to the fore of the costa.

Predaceous: Preying on other animals.

Predation: The killing and eating of an individual of one species by an individual of another species.

Predator control: A predator-prey interaction in which the predator controls population size of the prey The predator population is the limiting factor for the prey population size.

Predator: An animal that attacks and feeds on other animals (the prey) usually smaller and weaker than itself. The prey is killed and usually mostly or entirely eaten.

Prehumeral spine: spine located anterior to the humeral located at the anterior basal portion of the wing.

Preovipositional period: The period between the emergence of an adult female and the start of its egg laying.

Presumptive organization: Arrangement of cells in the embryo into groups which in normal development become a particular organ or tissue.

Pretarsus: The last segment of the insect leg, usually a claw or pair of claws.

Preventive treatment: Treatment designed to prevent a plant becoming infected.

Prey: The food animal of a predator.

principal component axes provides the two-dimensional ordination best summarizing the

Principal components analysis (=PCA): The eigenanalysis of the sample covariance matrix. Principal components (PC's) can be defined as the set of vectors that are orthogonal both with respect to the identity matrix and the sample covariance matrix. They can also be defined sequentially: the first is the linear combination with the largest variance of all those with coefficients summing in square to 1; the second has the largest variance (when normalized that way) of all that are uncorrelated with the first one; etc. One way to compute principal components is to use a singular value decomposition. Relative warps are principal components of partial warp scores. There is a lot to be said about PC's; see any of the colored books.

Proboscis (=Rostrum): Elongated mouthparts often modified into a tube for piercing and sucking.

Procaryota: An organism of the kingdom Prokaryotae, constituting the bacteria and cyanobacteria, characterised by the absence of a nuclear membrane and by DNA that is not organized into chromosomes.

Process: A projection or outgrowth from a larger structure.

Procrustes distance: Approximately, the square root of the sum of squared differences between the positions of the landmarks in two optimally (by least-squares) superimposed configurations at centroid size. This is the distance that defines the metric for Kendall's shape space.

Procrustes mean: The shape that has the least summed squared Procrustes distance to all the configurations of a sample; the best choice of consensus configuration for most subsequent morphometric analyses.

Procrustes methods: A term for least-squares methods for estimating nuisance parameters of the Euclidean similarity transformations. The adjective "Procrustes" refers to the Greek giant who would stretch or shorten victims to fit a bed.

Procrustes residuals: The set of vectors connecting the landmarks of a specimen to

Procrustes scatter: A collection of forms all superimposed by ordinary orthogonal Procrustes fit over one single consensus configuration that is their Procrustes mean; a scatter of all the Procrustes residuals each centered at the corresponding landmark of the Procrustes mean shape.

Procrustes superimposition: The construction of a two-form superimposition by least squares using orthogonal or affine transformations.

Proctiger: The cone-shaped, reduced terminal segment of the abdomen of an insect which contains the anus.

Prognathous: Having forward pointing mouthparts.

Pronotal disc: The central area of the pronotum.

Pronotal: Area of Pronotum which is the upper portion of the prothorax.

Pronotum: The dorsal body plate or sclerite of the first segment of the thorax, which is frequently enlarged and prolonged in many insects.

Proprietary name: Trade name. Name given to a product sold by a company to distinguish it from similar products made by other companies.

Prosternum: Ventral surface of the 1st thoracic segment.

Protective clothing: Clothing protecting spray operator from adverse effects of crop protection chemicals. It includes rubber gloves, rubber boots, apron or overall, respirator, face-mask, etc.

Prothoracic gland: One of a pair of endocrine glands located in the prothorax near the prothoracic spiracles.

Prothorax: The 1st or anterior thoracic segment. This is the segment never bears wings.

Protruded: Extended or projected outward.

Proximal: Concerning the basal part of an appendage - the part nearest to the body.

Pseudo pulvillus: The slender hairs on the tip of the legs between the claws.

Pseudoarolia (=Pseudoarolium): A pad at the apex of the tarsus, resembling an arolium.

Pubescent: Covered with short, downy/soft hairs.

Punctate: Punctured or deep seated points/spots on the body.

Punjab: A Province of Pakistan having five rivers i.e., Indus, Jhelum, Chanab, Ravi & Satluj (Punj: five & ab: water/river).

Pygophore: The large upper piece of the genitalia in Homoptera.

Q

Quadrate: Square or nearly so.

Quarantine: Free movement imposed to prevent the spread of pests.

R

R+M+CuA triangle: The area formed by the merging of three veins in the hind wings.

Rabi: Rabi or dry winter season crop of rice is grown usually from November/December to April/ May in Bangladesh and India. Non-rice crops grown in the winter is collectively called as rabi crops. Rabi crops include variety of minor cereals, species and condiments, pulses, oilseeds, tuber crops etc. It is mainly irrigated crop and short duration varieties of approximately four months are cultivated during this season.

Race: A variety of a species; a subspecies.

Rachna Doab: Rachna derived from the names of two rivers Ravi and Chanab (Ra from Ravi & Chna from Chanab) flowing in the Punjab province, Pakistan. Whereas Doab is a local word, do means two and ab means water, the Rachna Doab is a specific land in between two rivers.

Radius (R): Third longitudinal vein of wing.

Rainfed lowlands: It is an ecosystem of rice cultivation in which rice is sown when there is low or no water stagnation in the fields. Subsequently water level will rise with the onset of monsoon. This ecosystem is confined only during the rainy season and the duration of varieties may vary from 4 – 5 months. The water level may vary from 15 cm up to 50 cm. In some cases the water level may go up to 1 to 3 m where it is termed as deep water rice.

Rate: The amount of active ingredient of a pesticide applied to a unit area.

Ratoon: New tillers that grow from the stubble of harvested plants. These new tillers constitute the ratoon crop.

Rebordered: Hardened margins of the lateral pronotum.

Rectum: In insects, the posterior expanded part of the hindgut, typically pear shaped.

Reference configuration: In the context of superimposition methods, this is the configuration to which data are fit. It may be another specimen in the sample but usually it will be the average (consensus) configuration for a sample. The construction of two-point shape coordinates does not involve a reference specimen, though the intelligent choice of baseline for the construction usually does. The reference configuration corresponds to the point of tangency of the linear tangent space used to approximate Kendall's shape space. The mean configuration is usually used as the reference in order to minimize distortions caused by this approximation. When splines and warps are part of the analysis, the bending energy that goes with them is computed using the geometry of the grand mean shape, and the orthogonality that characterizes the partial warps is with respect to this particular formula for bending energy.

Relative Length: A means of measuring Pachytene chromosomes; calculated using the formula:

rl = <u>Actual Length of Each Chromosome</u>
Total Length of All the Chromosomes

Repellent: A chemical which has the property of inducing avoidance by a particular pest due to unpleasant odor, color, taste or mechanical effect. Some plants have repellent properties. When interplanted in a crop their smell will cause certain pest insects to avoid the crop.

Reproductive diapause: A short stop in the reproduction.

Reproductive stage: From panicle initiation to flowering; a stage when the plant matures sexually.

Residual insecticide: An insecticide with properties that make it suitable for application to surfaces which will later be visited by insects. It remains effective after application.

Residue tolerance: The amount of chemical pesticide residue which may legally remain in or on a food crop.

Residue: Trace of a pesticide and its metabolites remaining on or in crop tissues or in the environment (soil, water, etc.) after a certain time.

Resistance: With respect to plants: All properties enabling them to fight and overcome, partially or completely, the pathogenic effects of a disease or pest attack. This also includes 'tolerance', the ability of a plant to grow and develop in spite of pest or disease attack. With respect to pests and diseases: The ability of a pest population or disease to survive the poisonous effect of a pesticide.

Resistant variety: A variety that produces a larger amount of a good quality crop than other varieties when grown under the same conditions and exposed to similar population of insects and diseases.

Resolution: This is the ability to discern the fine structure of an object, or the ability to identify two points or two lines at a very short distance from each other.

Resurgence (=Pest resurgence=Flare-up): The rapid reappearance of a pest population in injurious numbers, usually brought about after the application of a broad-spectrum pesticide has killed the natural enemies which normally keep a pest in check.

Reticulate: Covered with a network pattern.

Rf value: Rate of mobility pf protein determined through the quotient of the distance (mm) traveled by the electrophoretic band over the distance (mm) traveled by tracking dye.

Rhythm: The course of events.

Ribosome: Is a cell organelle that serves as the site for protein production or synthesis.

Rice paddies: Rice is also known as paddy in many rice growing countries. The term paddy actually refers to slushy state of the soil condition in which rice crop is normally and most suitable grown. That particular water stagnated slushy soil condition is called rice paddies.

Ridge: Elevated structures.

Ripening stage: From flowering to reproductive maturity.

Robust: Tough or strong.

Roguing: To remove diseased or abnormal specimens from a group of plants of the same variety. To remove deviant plants.

Rostrum (= Proboscis): Elongated mouthparts often modified into a tube for piercing and sucking.

Rough: Irregular; uneven; coarse.

Rudimentary: Poorly or imperfectly developed.

S

S3-S7: A shorthand way of writing "ventral abdominal segment." and then the number of that segment. The abdomen of bugs has 2 surfaces, the dorsal surface and the ventral surface, divided by the lateral margin. The plates of the ventral surface are called sternites and are numbered from the base of the abdomen to the apex. The first abdominal sternite (S1) is not visible and S2 usually occurs as a very thin band between the thorax and the first completely visible sternite (S3). The sternites are then numbered out to the apex of the abdomen.

SADIE: It is the spatial analysis by distance indices developed by Perry (1998). It provides methods to measure overall spatial pattern for a single set of data and to test spatial association between two sets of data.

Salivary glands: Glands that open into the mouth and secrete a fluid with digestive, irritant, or anticoagulatory properties.

Sampling techniques: The methods used in drawing samples from a population usually in manner that the sample will facilitate determination of some hypothesis concerning the population.

Sampling: A process of obtaining small representative samples from a give population.

Sanitation: The act or process of making healthy environmental conditions.

Saprophytic: Living on dead or decaying organic matter.

Scape: The 1st antennal segment, especially if it is longer than the other segment.

Scar: Imprints in the body.

Scent glands: Glandular structures, sometimes eversible, sometimes in the form of hair tufts or pencils for diffusing odors that may be repellant or attractive; most frequently found in males as a secondary sexual character.

Sclerite: A hardened body wall plate of an insect's exoskeleton, usually separated from other sclerites by a suture or membranous area.

Sclerotization: The hardening and darkening processes in the cuticle (involves the epicuticle and exocuticle with a substance called sclerotin).

Sclerotized: hardened or toughened tissue, like the elytra of a beetles forewing.

Score: A linear combination of an observed set of measured variables. The coefficients for the linear combination are usually determined by some matrix computation. Multivariate statistical findings in the form of coefficient vectors can usually be more easily interpreted if scores are also shown case by case, their scatters, their loadings (correlations with the original variables), etc.

scores are an orthogonal rotation of the full set of these residuals.

Scutellar arm: The basolateral extension of the Scutellum.

Scutellar pits: The groove where the scutellar arm is located.

Scutellum ratio (WAB: WNP: L): The proportion of the basal width of the scutellum versus width at the narrowest point versus the length.

Scutellum: In Heteroptera, the triangular part of the mesothorax, generally placed between the bases of the hemelytra, but in some groups overlapping them to a greater or less extent.

Scutum: The middle of the three main divisions of the dorsal surface of a thoracic segment.

Secondary electron detector: The most widely used type of secondary detector consists of a combination of a scintillator, and a photomultiplier tube. A positive potential of 10 kV is applied to the scintillator, accelerating low-energy secondary electrons and causing them to collide. As a result, light is emitted. This light passes through a light pipe to the photomultiplier tube, and is converted into an electrical signal which becomes an image signal.

Secondary parasite: A parasite on another parasite.

Seedbed: The bed on which rice seeds are sown consisting of soil or banana leaves and plastic sheets.

Seedling stage: From rice seed germination to tillering during which the plant grows to the five-leaf stage.

Segment: A subdivision of the body or of an appendage, between joints.

Segmentation: The embryological process by which the insect body becomes divided into a series of parts or segments.

SEI: The abbreviation of Secondary Electron Image. This refers to an image formed with a signal by secondary electrons emitted from the specimen surface by a SEM or EPMA. The depth from the specimen surface at which secondary electrons release is only about 10 nm; hence, there is little scattering of the incident electrons at the specimen surface, and the best image resolution is obtained among other images obtained by SEM or EPMA. The contrast of a secondary electron image depends upon the surface roughness and profile of the sample, as well as upon differences in the composition of the sample.

Selective insecticide: An insecticide which kills selected insects, but does not kill most other organisms, including beneficial species.

Semiglobular: Incompletely or partly rounded

Sequential sampling: A sampling plan in which an undetermined number of samples are tested one by one, accumulating the results until a decision can be made.

Serrate: Saw like; with notched edges like the teeth of a saw.

Sessile: Attached to one place and unable to move, like many female scale insects.

Seta (=Setae): A sclerotized bristle-shape hair-like structure of the insect cuticle, arising from single cells, and surrounded at base by thin cuticular

Setaceous: Bristle-like, applied especially to antennae.

Sex ratio: The relative proportion of males and females in a population.

Shape coordinates: In the past, any system of distance-ratios and perpendicular projections permitting the exact reconstruction of a system of landmarks by a rigid trusswork. Now, more generally, coordinates with respect to any basis for the tangent space to Kendall's shape space in the vicinity of a mean form.

Shape variable: Any measure of the geometry of a biological form, or the image of a form, that does not change under similarity transformations: translations, rotations, and changes of geometric scale (enlargements or reductions). Useful shape variables include angles, ratios of distances, and any of the sets of shape coordinates that arise in geometric morphometrics.

Shape: The geometric properties of a configuration of points that are invariant to changes in translation, rotation, and scale. In morphometrics, we represent the shape of an object by a point in a space of shape variables, which are measurements of a geometric object that are unchanged under similarity transformations. For data that are configurations of landmarks, there is also a representation of shapes per se, without any nuisance parameters (position, rotation, scale), as single points in a space, Kendall's shape space, with a geometry given by Procrustes distance. Other sorts of shapes (e.g., those of outlines, surfaces, or functions) correspond to quite different statistical spaces.

Simple eye: An Ocellus. A simple eye is a single lens that tells the difference between light and dark.

Sindh: A province of Pakistan.

Sinuate: S-shaped.

Size measure: In general, some measure of a form (i. e., an invariant under the group of isometries) that scales as a positive power of the geometric scale of the form. Interlandmark lengths are size measures of dimension one, areas are size measures of dimension two, etc. small padlike lobe projection

Solitary: Occurring singly or in pairs, not in colonies/ groups.

Somewhat confusing now as any morphometric technique must be multivariate in nature.

SP: Soluble powder.

Spatial distribution: The observed geographic dispersion or patterning of individuals.

Species evenness: Number of individuals of one species in a given area or distribution of a species.

Species richness: Number of various species in a given area.

Species: The basic unit of living things, consisting of a group of individuals which all look more or less alike and which can all breed with each other to produce another generation of similar creatures.

Spermatheca: A small sac-like branch of the female reproductive tract of arthropods in which sperm may be stored.

Spermathecal bulb: The swollen structure in the spermathecal duct.

Spermatophore: A packet of sperm.

Spider: The common name for arachnids comprising the order Araneida.

Spikelet: A unit on the rice panicle consisting of one or more flowers and their bracts.

Spine: A multicellular, thorn like process or outgrowth of the integument not separated from it by a joint.

Spine: needle-like structure

Spinnerets: small tubular appendages from which silk threads are secreted by spiders and by the larvae of many insects.

Spinose: Spiny.

Spiracle: Breathing pore. External opening of the tracheal respiratory system.

Spiracular plate: A plate like sclerite next to or surrounding a spiracle.

Spray: To apply minute particles or liquids containing a pesticide.

Spur: A large and usually movable spine, normally found on the legs.

Spurious Vein: A false vein formed by a thickening of the wing membrane and usually unconnected with any of the true veins.

Stadium (=Stadia): The time interval between molts in a developing insect.

Stage: A distinct, sharply differentiated period in the development of an insect, e.g., egg stage, larval/nymphal stage, pupal stage, adult stage.

Starch gel electrophoresis: A technique on determining the gene and genotypic frequencies based on the movement of suspended protein through starch-gel under the action of an electromotive force applied to electrodes in contact with the suspension.

Stem: The base of the clasper in the male reproductive organ.

Stemma (=Stemmata): The simple eye in holometabolous larvae. Also called lateral ocellus.

Sternal plates: The external insect body is composed of sclerotized plates, the sternal plates are on the underside of the body.

Sternite (=Sterna): The plate or sclerite on the underside of a body segment of an arthropod thorax or abdomen.

Sternum: Ventral sclerite of a segment.

Stigma: A small colored area near the wing-tip of dragonflies, bees, and various other clear-winged insects: also called the pterostigma.

Straw: Stalk of grains after threshing.

Striae: Grooves running across or along the body: applied especially to the grooves on beetle elytra.

Stubble: The lower portion of the stem remaining in the field after rice has been harvested.

Subacute: Moderately pointed.

Subanteriorly: Before the anterior tip.

Subapical spines: Spines before the apex.

Sub-apical: Situated just before the tip or apex.

Subcosta: Usually the first of the longitudinal veins behind the front edge of the wing, although it is often missing or very faint: abbreviated to Sc.

Subdistal: Situated just before the free end of an appendage.

Subequal: Almost equal in length.

Subglobose: Roughly spherical in shape

Sub-marginal Cells: Cells lying just behind the stigma in the hymenopteran forewing: important in the identification of bees and sphecid wasps.

Submarginal Cells: Cells lying just behind the stigma in the hymenopteran forewing: important in the identification of bees and sphecid wasps.

Subproximal: Situated near to body, or to the base of an appendage.

Subrectangular: Roughly rectangular in shape.

Subspecies: A sub-division of a species, usually inhabiting a particular area: visibly different from other populations of the same species but still able to interbreed with them.

Subterminal: Situated before the terminal area.

Subtriangular: Roughly triangular in shape.

Subtruncate: Moderately straight margin.

Sulaiman Piedmont: Plains of the Sulaiman Range.

Sulcate: With a deep groove or furrow.

Sulcus (=Sulci): A deep, narrow furrow or groove, as in an organ or tissue.

Superfamily: A group of closely related families; super-family names end in -oidea.

Superimposition: The transformation of one or more figures to achieve some geometric relationship to another figure. The transformations are usually affine trans-formations or similarities. They can be computed by matching two or three landmarks, by least-squares optimization of squared residuals at all landmarks, or in other ways. Sometimes informally referred to as a "fit" or "fitting," e.g., a resistant fit.

Susceptibility: The inability of a plant to resist the effect of a harmful organism.

Sustainable development: Development that meets the needs and aspirations of the current generation without compromising the ability to meet those of future generations.

Suture: A groove on the body surface which usually divides one plate or sclerite from the next: also the junction between the elytra of a beetle.

Swarm: A large number of insects or other small organisms in motion.

Synchronous planting: Is planting rice in a large contiguous area (barangay or village level) within a month of the regular planting time.

Synonym: One of two or more names which have been given to a single species. The earliest name usually (should) take precedence.

Systemic insecticide: An insecticide capable of absorption into plant sap or animal blood and lethal to insects feeding on or within the treated host.

Systemic: A pesticide absorbed through the plant surfaces (usually roots) and translocated through the plant vascular system. For example, some pesticides are systemic.

Systems analysis: The use of mathematics to determine how a set of interconnected components whose individual characteristics are known will behave in response to a given input or set of inputs.

T

t/ha: tones per hectare.

Tarsal claw: A curved pointed appendage found at the end of the tarsus

Tarsal formula: The number of tarsal segments on the front, middle, and hind tarsi, respectively.

Tarsi (=Tarsal): The fifth segment of the leg. Itself usually consisting of 1-5 segments and usually bearing claws pretarsus. Located at the end of the tibia.

Taxonomy: A study aimed at producing a hierarchical sys-tem of classification of organisms which best reflects the totality of similarities and differences.

TCd: Depth of the tarsal claw.

TCh: Height of the tarsal claw.

TCl: Length of the tarsal claw.

***Telenomus triptus*:** Is a small egg parasitoid of the rice black bug that has generally black coloration with yellowish brown legs and scape.

Tergite (=Tergum): The primary plate or sclerite forming the dorsal surface of any body segment.

Terminal: At the end or tip. The last of a series.

Theca: A case or covering; specifically applied to the lower piece of the male genitalia.

There are many kinds of ordinations depending upon the goals of the ordination and

Thin-plate spline: In continuum mechanics, a thin-plate spline models the form taken by a metal plate that is constrained at some combination of points and lines and otherwise free to adopt the form that minimizes bending energy. (The extent of bending is taken as so small that elastic energy - stretches and shrinks in the plane of the original plate – can be neglected.) One particular version of this problem - an infinite, uniform plate constrained only by displacements at a set of discrete points - can be solved algebraically by a simple matrix inversion. In that form, the technique is a convenient general approach to the problem of surface interpolation for computer graphics and computer-aided design. In morphometrics, the same interpolation (applied once for each Cartesian coor-dinate) provides a unique solution to the construction of D'Arcy Thompson-type deformation grids for data in the form of two landmark configurations.

Thorax: The middle of the three major divisions of the in-sect body. The legs and wings (if present) are always attached to the thorax.

Tibia (=Tibiae): The forth leg segment between the femur and the tarsus.

Tillage: The operation or practice of cultivating soil in order to improve it for agricultural purposes.

Tiller: A stem and its leaves.

Tillering stage: Growth stage of grain crops when a plant produces additional shoots.

total variability of the objects in the original sample space. Biplots combine an ordination

Toxicity: The quality of being toxic. The kind and amount of poison or toxin produced by a microorganism, or possessed by a chemical substance not of biological origin.

Trademark name (=Trade name=brand name=proprietary name): Name given to a product sold by a company to distinguish it from similar products made by other companies.

Traditional morphometrics: Application of multivariate statistical methods to arbitrary collections of size or shape variables such as distances and angles. "Tra-ditional morphometrics" differs from the geometric

morphometrics discussed here in that even though the distances or measurements are defined to record biologically meaningful aspects of the organism, but the geometrical relationships between these measurements are not taken into account. Traditional morphometrics makes no reference to Procrustes distance or any other aspect of Kendall's shape space.

Transplant: To remove seedlings from the nursery (seedbed) and plant in the field either by hand or mechanically.

Transverse Suture: A suture running across the thorax of many flies and dividing the mesonotum into a scutum and a prescutum.

Trichobothria: Minute sensory hairs on the tarsi and side of abdomen.

Trifurcate: Splitting from one branch and divide into three.

Trochanter: The second segment of the insect leg, situated between the coxa (which is attached to the insect body) and the femur: often very small and easily overlooked.

Truncate: Cut off squarely at tip.

Tubercle: A small knob like or rounded protuberance.

Two-parameter cumulative Weibull function: This function describes the cumulative Weibull distribution, which is named after Waloddi Weibull, and is frequently used to describe the cumulative distribution of biological data.

Tylus: The distal part of the clypeus in Hemiptera.

Type I landmark: A mathematical point whose claimed homology from case to case is supported by the strongest evidence, such as a local pattern of juxtaposition of tissue types or a small patch of some unusual histology.

Type II landmark: A mathematical point whose claimed homology from case to case is supported only by geometric, not histological, evidence: for instance, the sharpest curvature of a tooth.

Type III landmark: A landmark having at least one deficient coordinate, for instance, either end of a longest diameter, or the bottom of a concavity. Type III landmarks characterize more than one region of the form. The multivariate machinery of geometric

Type: The type specimen of a species is the actual insect from which the original description of that species was produced. If several specimens were used for this purpose, one of them should have been designated as the type. Because the type can be of only one sex, it is usual to designate a certain individual of the opposite sex as the allotype. The original type specimen is then called the holotype. These type specimens' are very important in taxonomy and classification.

Type-locality: The place or source where a holotype or type specimen was found.

U

Univoltine: One generation per year.

Upland rice: It is the rice crop grown in unleveled and unbunded fields directly dependent on rainfall. Upland rice is usually of short duration (90 – 100 days) with low productivity.

Uric acid: The chief nitrogenous waste of insects; chemically, C,H,N,O,.

V

Vegetative stage: From germination to panicle initiation.

Veins: In insects, the rib like tubes that strengthen the wings.

Venation: The arrangement of veins in the wings of insects. Ventral. Concerning the lower side of the body.

Venter of body: The lower side of the body

Ventrad: Towards the lower portion or underside of the body; downward.

Ventral: Lower or underneath. Referring to the underside of the body.

Vesica: A terminal membranous part of the aedeagus.

Volunteer: Crop plant growing accidentally from shed seeds; not deliberately cultivated.

W

Weed: A plant that is not valued where it is growing and is usually of rank growth.

Weeding: The act of removing unwanted plants (weeds).

Weekly multiplication rate: The ability of an insect species to increase in numbers in a period of one week. It is usually expressed as numbers per week per insect.

White ears (White heads): It is the symptom of expression in flowering phase of rice crop where the ear heads completely turn white and contain chaffy and unfilled grains. In many cases the flag leaf may still be green. This symptom is caused mainly due to feeding by stem borer larvae at heading phase. Similar symptom can also be found due to feeding by black bugs at times when there is very severe infestation usually more or less 200 bugs per hill. The white ears caused by stem borers can be easily pulled out but white ears caused by black bugs cannot be easily separated from the main plant.

Whorl: An arrangement of three or more leaves radiating from a single node.

WSC: Water Soluble Concentrate.

X

Xylem: A complex lignified plant tissue, comprising the woody portion of the vascular system in higher plants. Xylem acts as a support, conveys water and minerals, and often stores food.

Abbreviations

ADB: Asian Development Bank, Philippines

AIT: Asian Institute of Technology, Thailand

ANIC: Australian National Insect Collection, Australia

ARMM: Autonomous Region in Muslim Mindanao, Philippines

AVRDC: Asian Vegetable Research and Development Center, Taiwan

BCCU: Bioengineering College of Chongqing University, China

BIOTECH: National Institute of Molecular Biology and Biotechnology, Philippines

BOLD: Barcoding of Life Database, Canada

BOLI: Barcoding of Life Initiative

BOLNET: Canadian Barcode of Life Network, Canada

BPBM: Bernice P Bishop Museum, Hawaii

BPI: Bureau of Plant Industry, Philippines

BRRI: Bangladesh Rice Research Institute, Bangladesh

CABI: Commonwealth Agricultural Bureau International, UK

CARDI: Cambodian Agricultural and Development Institute, Cambodia

CAS: College of Arts and Sciences, Philippines

CBOL: Consortium for the Barcode of Life, UK

COPR: Center for Overseas Pest Research, UK

CPC: Crop Protection Compendium, UK

CRRI: Central Rice Research Institute, India

CSIRO: Commonwealth Scientific and Industrial Research Organisation, Australia

DA: Department of Agriculture, Philippines

DAA: Days after application

DAI: Days after infestation

DAR: Department of Agricultural Research, Myanmar

DAS: Days after sowing/seeding

DAT: Days after transplanting

DPPQS: Directorate of Plant Protection, Quarantine and Surveillance, India

DRR: Directorate of Rice Research, India

DSR: Direct-seeded rice

EIL: Economic/Ecological/Environmental injury level

EMSL: Electron Microscopy Service Laboratory, Philippines

EPA: Environment Protection Agency, USA

EWC: East West Center, Hawaii, USA

FAO, Food and Agriculture Organization, Rome

FFS: Farmer field school

FPA: Fertilizer and Pesticide Authority, Philippines

HORDI: Horticultural Crop Research and Development Institute, Sri Lanka

IABGR: Indonesian Agricultural Biotechnology and Genetic Resources, Indonesia

IBS: Institute of Biological Sciences, Philippines

ICRR: Indonesian Center for Rice Research, Indonesia

IITA: International Institute of Tropical Agriculture, Nigeria

INBIPS: International Network for Barcoding Invasive and Pest Species, USA

IPM: Integrated Pest Management

IPP: Institute of Plant Protection, China

IRCSPPEP: Interagency Rice-Based Cropping Systems Pre-Production Evaluation Program, Philippines

IRRI: International Rice Research Institute, Philippines

ISL-NIAES: Insect Systematics Laboratory-National Institute for Agro-Environmental Sciences, Japan

IUNS: Islamic University of North Sumatra, Indonesia

JIRCAS: Japan International Research Center for Agricultural Sciences, Japan

LC: Lethal concentration

LD: lethal dose

LGU: Local Government Unit, Philippines
LIBRIS: Libungan River Irrigation System, Philippines
LSD: Least Significant Difference
LSU: Leyte State University, Philippines
MARDI: Malaysian Agricultural Research Development Institute, Malaysia
MBB: Malayan Black Bug
MDL: Molecular Diagnostics Laboratory, New Zealand
MLT: Mercury light trap
MNHN: Muséum National d'Histoire Naturelle, France
MOA: Ministry of Agriculture, China
MRRTC: Maligaya Rice Research Training Center, Philippines
NARC: National Agricultural Research Center, Japan
NBCRC: National Biological Control Research Center, Thailand
NBPGR: National Bureau of Plant Genetic Resources, India
NCPC: National Crop Protection Center, Philippines
NIAST: National Institute of Agricultural Science and Technology, Korea
NMNH: National Museum of Natural History, USA
NMNS: National Musuem of Natural Science, Taiwan
OISAT: Online Information Service for Non-chemical Pest Management in the Tropics, Germany
OUMNH; Oxford University Museum of Natural History, UK
PAN: Pesticide Action Network, Germany
PCARRD: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, Philippines

PhilRice: Philippine Rice Research Institute, Philippines
PPAI: Plant Protection Association of India, India
PPD: Plant Protection Department, Vietnam
PPRI: Plant Protection Research Institute, Vietnam
PRA: Pest risk analysis
RCBD: Randomized complete block design
RCPC: Regional Crop Protection Center, Philippines
RDA: Rural Development Administration, Korea
RFU: Regional Field Unit, Philippines
RRDI: Rice Research and Development Institute, Sri Lanka
RVIG: Rice Varietal Improvement Group, Philippines
SEM: Scanning electron microscope
SMNH: Swedish Museum of Natural History, Sweden
TARC: Tropical Agriculture Research Center, Japan
TARI: Taiwan Agricultural Research Institute, Taiwan
TEM: Transmission electron microscope
TNAU: Tamil Nadu Agricultural University, India
TNRRI: Tamil Nadu Rice Research Institute, India
TPR: Transplanted rice
ULV: Ultra-low volume
UPLB: University of the Philippines Los Baños, Philippines
UPLBMNH: University of the Philippines at Los Baños Museum of Natural History, Philippines
USM: University of Southern Mindanao, Philippines
VAAS: Vietnam Academy Science Institute, Vietnam
WAT: Week(s) after transplanting
ZAAS: Zhejiang Academy of Agricultural Sciences, China

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