

**BIOECOLOGY AND MANAGEMENT OF RICE BLACK BUG,
Scotinophara coarctata (Fabricius)**

*THESIS SUBMITTED IN PART FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE
DEGREE OF DOCTOR OF PHILOSOPHY IN AGRICULTURAL ENTOMOLOGY TO THE
TAMIL NADU AGRICULTURAL UNIVERSITY, COIMBATORE*

BY

G.V. RAMA SUBRAMANIAN

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
CENTRE FOR PLANT PROTECTION STUDIES
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE - 641 003**

1996

CERTIFICATE

This is to certify that the thesis entitled "**BIOECOLOGY AND MANAGEMENT OF RICE BLACK BUG, *Scotinophara coarctata* (Fabricius)**" submitted in part fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURAL ENTOMOLOGY** to the Tamil Nadu Agricultural University, Coimbatore is a record of **BONAFIDE** research work carried out by **Mr. G.V. RAMA SUPRAMANIAN** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Date : 25, September 1996

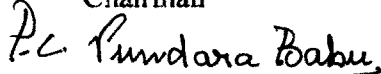
Place : Coimbatore - 3.

APPROVED BY
Chairman

Members

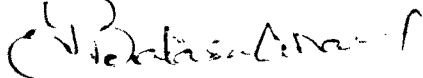

(Dr. P.C. SUNDARA BABU) 25/9/96

Chairman


(Dr. P.C. SUNDARA BABU) 27/11/96


(Dr. S. VAIRAVAN)


(Dr. A. AZEEZ BASHA) 25/11/96


(Dr. G. BALASUBRAMANIAN)


(Dr. S. THAMBU RAJ)


Dr. U.K. KAUSHIK

(External Examiner)

Date : 27th Nov. 1996.

ABSTRACT

ABSTRACT

BIOECOLOGY AND MANAGEMENT OF RICE BLACK BUG, *Scotinophara coarctata* (Fabricius)

BY

G.V. RAMA SUBRAMANIAN

Degree : DOCTOR OF PHILOSOPHY in
Agricultural Entomology

Chairman : Dr.P.C.SUNDARA BABU
Professor of Agricultural Entomology
Tamil Nadu Agricultural University
Coimbatore -641 003.

1996

A preliminary survey was made to find out the occurrence of Rice Black Bug (RBB) *Scotinophara coarctata* (Fabricius) in Chengai-MGR district of Tamil Nadu. Investigations were carried out on the biology of RBB on rice and alternate host, *Echinochloa colona* (L.) Link. Detailed descriptions on the damage of this pest on rice and alternate host were made. Seasonal occurrence and population dynamics were studied to know the incidence of this pest over seasons, influence of weather parameters on the population of bugs and influence of natural enemies on the pest population. Attractability of RBB to different light sources and the dominance of *Scotinophara* spp. at Rice Research Station (RRS), Tirur were established. Life table was constructed to study the intrinsic rate of increase and net reproductive rate of the population. Rice cultivars and accessions were screened under screen house condition to assess their reaction to this pest. Economic Threshold Level (ETL) was worked out by considering the cost of

protective input and varied incremental costs of output. Yield loss and rate of yield loss due to infestation of RBB were estimated individually for nymphs and adults in screen house caged and uncaged situations in the field. Yield loss was also estimated at different damage levels of the bugs. Laboratory evaluations were conducted on the efficacy of botanicals and insecticides. Field trials were also conducted to ascertain their effect on this pest. Cost-benefit ratios were worked out for the botanicals and insecticides. The studies were conducted at RRS, Tirur during 1992 to 1996.

Studies on the biology of *S.coarctata* on two hosts viz., rice and *E.colona* showed significant differences between the host plants. The number of eggs laid was more on rice. Incubation period of eggs, nymphal durations, total development period from egg to adult were shorter on rice. In rice, there was significantly increased mating, pre-oviposition and oviposition periods and a concomitant increase in fecundity and egg hatchability. The adult emergence was higher on rice. In general, production of females was more than males, and in rice, female to male ratio was higher. In both the hosts, females had a longer life than males. However, the longevity of both males and females was significantly higher on rice indicating that rice is the more preferable host.

RBB damaged the plant at all crop growth stages. Its damage resulted in leaf yellowing and in severe cases, it led to 'bug burn' causing total loss of yield. At tillering stage, the damage resulted in dead hearts and in post-flowering stage, white ears were formed.

The population of RBB was uniform throughout the year irrespective of the seasons and years. All the weather parameters were found to exert additive influence ($R^2=0.09$) on *S.coarctata* population, while minimum temperature and radiation exerted a significant positive effect on *S.lurida* (Burmeister) population. RBB population had a positive and significant influence over the leaf damage in all the cultivars.

Significant positive correlation of the predators with leaf damage was established in Co 45. Spiders had a positive and significant association with leaf damage in cultivars White Ponni (Correlation coefficient 0.656) and TKM 9 (0.380).

Telenomus triptus (Nixon) was the commonly encountered egg parasitoid and *Metarhizium anisopliae* (Metschnikoff) Sorokin infected both nymphs and adults. The density of egg masses or eggs showed a positive correlation with per cent egg masses parasitised, while only a few eggs in an egg mass was parasitised and the reason might be due to the egg guarding behaviour of the female.

Light trap is one of the prime tools for monitoring. Among the different light sources tested, Pest-O-Flash was significantly superior to 125 Watts and 40 Watts. Among the two species, *S.coarctata* was found to be more dominant than *S. lurida* in RRS, Tirur.

Life tables indicated that high net reproductive rate (125.17)^{and} the longest generation time (53.41 days) ultimately helped the pest to sustain its population during unfavourable conditions. Prolonged survival ensured continuous damage to the crop.

None of the rice accessions was resistant to RBB. The cultivars ADT 37 and TKM 10 withstood the incidence relatively. Seven accessions were identified to have moderate level of resistance to this pest.

The economic threshold level was worked out by taking into consideration the abatement cost and at varying costs of the output. The ETL was fixed at 4 bugs per hill.

Damage potential of RBB irrespective of the age distribution was high under compelled feeding situations. Under competitive feeding conditions along with other rice pests, the damage potential was additive upto a certain level and beyond which it reduced due to competition among the pests.

Laboratory evaluation indicated that Neem Seed Kernel Extract (NSKE) 5 per cent (50 g/l) accounted for the highest mortality of the bugs. The formulations of Neem Azal were comparable with NSKE. Monocrotophos (2ml/l) was superior among the insecticides with the highest mortality of bugs followed by acephate (1.25 g/l).

Under field conditions Neem Azal - T/S(1%) (0.025 kg a.i./ha) and NSKE 5 per cent were superior among the botanicals. Among the insecticides, acephate (0.469 kg a.i./ha) was superior followed by fenthion (0.413 kg a.i./ha) and monocrotophos (0.360 kg a.i./ha). Cost-benefit ratio was higher in NSKE (1:1.89) among the botanicals and in insecticides it was 1:2.18 in acephate and 1:2.15 in monocrotophos. Taking into consideration the cost-benefit, yield and cost of protection, NSKE, acephate and monocrotophos were the best plant protectants against RBB. The alternatives were fenthion (1:2.06), phosphamidon (1:2.01) and Neem Azal-F(5%) (1:1.80).

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

I express my deep sense of gratitude and indebtedness to **Dr.P.C. Sundara Babu**, Professor of Agricultural Entomology and Chairman of the Advisory Committee for suggesting this problem, constant guidance, untiring advice and lofty inspiration during the period of research and preparation of this thesis.

I am very grateful to the members of the advisory committee, **Dr.S. Vairavan**, Professor and Head, RRS, Tirur, **Dr.A. Azeez Basha**, Professor (Entomology) RRS, Tirur, **Dr.G. Balasubramanian**, Professor (Entomology) Coimbatore, and **Dr.S. Thamburaj**, Professor and Head, Horticultural College and Research Institute, Coimbatore, for their constant encouragement and valuable suggestions.

I am very thankful to the Professor and Head, Department of Agricultural Entomology for having provided all the facilities during the period of study.

I wish to place on record my sincere thanks to **Dr.C. Kailasam**, Associate Professor, (Mathematics) TNAU, Coimbatore for his keen association and guidance in preparation of mathematical modelling.

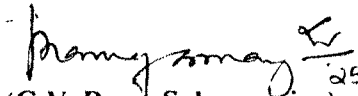
I am much grateful to **Dr.J.Chandrasekaran** and **Dr.A. Subramanian**, Professor of Entomology and **Dr. M. Ganesh Kumar**, Associate Professor (Entomology) for their constant encouragement and valuable comments made during the preparation of thesis.

I also thank **Dr.Usha K. Mehta**, Head Crop Protection and **Dr.P. Sundararajan**, Sugar cane Breeding Institute, Coimbatore for helping me in the arrangement and preparation of photograph plates.

My sincere thanks are due to all the staff members of Agricultural Entomology, Coimbatore and RRS, Tirur for their kind help rendered during the period of investigation.

I am extremely grateful to my beloved parents, wife, son and all my relatives for their tireless support and affectionate encouragement showered during the study.

I gratefully acknowledge the Tamil Nadu Agricultural University for permitting me to undergo this part time Ph.D. Programme.


(G.V. Rama Subramanian) 25.9.96

CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	3
3	MATERIALS AND METHODS	26
4	EXPERIMENTAL RESULTS	48
5	DISCUSSION	145
6	SUMMARY	171
	REFERENCES	
	ANNEXURE	

LIST OF TABLES

Table No.	TITLE	Page No.
1.	Parameters on the eggs of <i>S.coarctata</i> reared on rice	50
2.	Parameters on the nymphs of <i>S.coarctata</i> reared on rice	51
3.	Parameters on the adults of <i>S.coarctata</i> reared on rice	55
4.	Parameters on the eggs of <i>S.coarctata</i> reared on <i>E.colona</i>	56
5.	Parameters on the nymphs of <i>S.coarctata</i> reared on <i>E.colona</i>	58
6.	Parameters on the adults of <i>S.coarctata</i> reared on <i>E.colona</i>	61
7.	Seasonal population of RBB and its natural enemies	65
8.	Seasonal incidence of RBB and the influence of natural enemies (<i>Samba</i>) over years	66
9.	Seasonal incidence of RBB and the influence of natural enemies (<i>Navarai</i>) over years	68
10.	Seasonal incidence of RBB and the influence of natural enemies (<i>Sornavari</i>) over years	71
11.	Inter relationship of weather factors on RBB	73
12.	Correlation of RBB population with other parameters	75
13.	Correlation of leaf damage with predators and weather factors	77
14.	Multiple regression analysis of RBB population with stage of crop and weather parameters	79
15.	Multiple regression analysis of leaf damage with stage of crop and weather parameters	81
16.	Attraction of RBB to light sources	83
17.	Regression analysis on the parasitism of eggmasses and eggs of RBB by <i>T.triptus</i>	85
18.	Species complex of <i>Scotinophara</i>	87
19.	Life table of <i>S.coarctata</i> on rice	88
20.	Reaction of rice cultivars to <i>S.coarctata</i>	90
21.	Reaction of rice accessions to <i>S.coarctata</i> (Initial Yield Trial-1992)	92

Table No.	TITLE	Page No.
22.	Reaction of rice accessions to <i>S.coarctata</i> (Initial Yield Trial-1993)	93
23.	Reaction of rice accessions to <i>S.coarctata</i> (Comparative Yield Trial-1993)	94
24.	Reaction of rice accessions to <i>S.coarctata</i> (Comparative Yield Trial-1994)	95
25.	Reaction of rice accessions to <i>S.coarctata</i> (Advanced Varietal Trial-1994)	97
26.	Reaction of rice accessions to <i>S.coarctata</i> (Multi Locational Trials)	99
27.	Reaction of rice accessions to <i>S.coarctata</i> (Adaptive Research Trial-1994-95)	100
28.	Reaction of BPH and Leaf folder moderately resistance rice accessions to <i>S.coarctata</i>	101
29.	Reaction of rice accessions to <i>S.coarctata</i> (Irrigated Medium Rice Yield Trial)	102
30.	Reaction of rice accessions to <i>S.coarctata</i> (International Irrigated Rice Yield Nursery Trial)	103
31.	Reaction of rice accessions to <i>S.coarctata</i> (Hybrid rices)	104
32.	Economic threshold levels of RBB at incremental cost of rice	107
33.	Predicted yield loss at different levels of <i>S.coarctata</i> nymphs (screen house)	109
34.	Predicted yield loss at different damage levels of <i>S.coarctata</i> nymphs (screen house)	111
35.	Predicted yield loss at different levels of <i>S.coarctata</i> adults (screen house)	113
36.	Predicted yield loss at different damage levels of <i>S.coarctata</i> adults (screen house)	114
37.	Predicted yield loss at different levels of RBB caged in the field	116
38.	Predicted yield loss at different damage levels of RBB caged in the field	117

Table No	TITLE	Page No.
39.	Predicted yield loss at different damage levels of RBB in combination with rice leaf folder and yellow stem borer under uncaged condition in the field	118
40.	Efficacy of botanicals for the management of <i>S.coarctata</i> on rice in the laboratory	120
41.	Efficacy of insecticides for the management of <i>S.coarctata</i> on rice in the laboratory	123
42.	Field efficacy of botanicals for the management of RBB on rice (<i>Samba</i> 1995-96)	125
43.	Yield on hectare basis and Cost-benefit Ratio (Botanicals) (<i>Samba</i> 1995-96)	127
44.	Field efficacy of botanicals for the management of RBB on rice (<i>Navarai</i> 1996)	129
45.	Yield on hectare basis and Cost-benefit Ratio (Botanicals) (<i>Navarai</i> 1996)	131
46.	Yield on hectare basis and Cost-benefit Ratio (Botanicals) (Over two seasons)	133
47.	Field efficacy of insecticides for the management of RBB on rice (<i>Samba</i> 1995-96)	135
48.	Yield on hectare basis and Cost-benefit Ratio (Insecticides) (<i>Samba</i> 1995-96)	137
49.	Field efficacy of insecticides for the management of RBB on rice (<i>Navarai</i> 1996)	139
50.	Yield on hectare basis and Cost-benefit Ratio (Insecticides) (<i>Navarai</i> 1996)	141
51.	Yield on hectare basis and Cost-benefit Ratio (Insecticides) (Over two seasons)	144

LIST OF FIGURES

Figure No.	TITLE	Between Pages.
1.	Occurrence of Rice Black Bug in Chengai-MGR district	26-27
2.	Mass culture of <i>Scotinophara coarctata</i> . (Fabricius)	26-27
3.	Rice Black Bug and damage-Farmer's field (<i>Samba</i> -White Ponni)	81-82
4.	Rice Black Bug and damage-Farmer's field (<i>Navarai</i> -ADT36)	82-83
5.	Rice Black Bug and damage-Farmer's field (<i>Sornavari</i> -IR50)	82-83
6.	Attractability of light sources to <i>Scotinophara</i> spp.	84-85
7.	<i>Scotinophara</i> species dominance at RRS, Tirur	87-88
Predicted yield loss and rate of yield loss with reference to		
8.	Population levels of nymphs - screen house	109-110
9.	Damage levels by nymphs-screen house	111-112
10.	Population levels of adults-screen house	113-114
11.	Damage levels by adults-screen house	113-114
12.	Population levels of RBB in field (caged)	116-117
13.	Damage levels by RBB in field (caged)	117-118
14.	Damage levels by RBB in field (uncaged)	118-119
15.	Field efficacy of botanicals on RBB damage and rice yield (Pooled analysis)	131-132
16.	Field efficacy of insecticides on RBB damage and rice yield (Pooled analysis)	144-145
17.	Flow chart on Rice Black Bug Management	144-145
18.	Economic threshold levels of RBB at incremental cost of rice	158-159

LIST OF PLATES

Plate No	Title	Between pages
1.	Rice black bug and damage on rice	1-2
2.	RBB damage on rice	1-2
3.	Laboratory studies	27-28
4.	Field studies	31-32
5.	Management of RBB	44-45
6.	Life stages of <i>Scotinophara</i>	48-49
7.	Nymphal stages and adults of <i>Scotinophara</i>	51-52
8.	RBB Damage on rice	62-63
9.	RBB Damage on <i>E.colona</i>	63-64
10.	RBB Damage	63-64
11.	Biocontrol agents on RBB	64-65

INTRODUCTION

1. INTRODUCTION

Rice, (*Oryza sativa* L.) the staple diet of over half of the world's population, occupies almost one fifth of total world crop land under cereals (Swaminathan, 1984). Insects are one of the important constraints in rice production and occur in all rice growing environments. A conservative estimate by Cramer (1967) puts the loss due to insect pests to be 31.5 per cent in Asia. Insecticide protection ensures an average of 4.90 tonnes per hectare, while no protection reduced it to 3.0 tonnes per hectare accounting for a loss of 40 per cent (Heinrichs, 1994).

Among more than 100 species of insects causing damage to rice, the Rice Black Bug (RBB), *Scotinophara coarctata* (Fabricius) and *S. lurida* (Burmeister) are the group of economic pests reported occurring in India, besides many other countries. The hardiness of the pest can be understood in the words of Barroga (1988), who wrote "Winds and torrential rains literally ripped asphalt roads, flailing them in rice fields. Houses were levelled, leaving thousands of people homeless. Palawan had seen its worst storm. But a storm that has refused to leave Palawan is the Rice black bug". Though it is reportedly an introduced pest in many countries, its entry into India lacks evidence.

In Tamil Nadu, sporadic but severe outbreaks of this pest was reported by Sundara Babu *et al.* (1984); Uthamasamy and Mariappan (1985) Subramanian *et al.* (1986). RBB, hitherto considered as a minor pest, has become a menace recently. The incidence of RBB is increasing and it has established itself as a major rice pest in Tamil Nadu especially in Chengai MGR, North Arcot Ambedkar, South Arcot Vallalar, Villupuram Ramasamy padayatchiar and Dharmapuri districts as well as in Union Territory of Pondicherry. In Chengai-MGR district, the incidence of this bug is severe causing very heavy loss to rice growers (Saroja *et al.*, 1993). Excessive sucking by large numbers of bugs causes serious damage to rice crop. The damage is very similar to the one caused by

PLATE 1. Rice black bug and damage on rice



RBB



Bug burn

PLATE 2. RBB Damage on rice



Leaf damage



White ear

the brown planthopper, *Nilaparvata lugens* (Stal.) in rice. The black bug affected plants are stunted, with wilting symptoms and are killed outright. This is known as 'bug burn' resulting in very heavy yield loss (Plate 1). During active tillering stage of the crop, besides leaf damage, the central shoots dry up and result in dead hearts and in post-flowering stage, its damage results in white ears (Plate 2). Like Palawan island of Philippines, Chengai-MGR district in Tamil Nadu is found to be an endemic area for RBB. Being capable of existence throughout the year, the pest warranted organised studies from 1990 onwards.

The information on the biology, ecology, yield loss and management aspects were reported else where. Saroja *et al.* (1993) reported the attractability of this pest to light sources, management with insecticides and fixed empirical ETL. From the published literature available, the details of life table, use of botanicals in IPM, dynamic aspects of ETL and independent capability of this pest as a constraint in rice production were in paucity. Therefore, the present study was taken up to elicit information on the following aspects of *S. coarctata* at Rice Research Station (RRS), Tirur.

1. Occurrence of the pest in Chengai-MGR district.
2. Biology on rice and weed host *Echinochloa colona* (L.) Link.
3. Seasonal occurrence.
4. Population dynamics.
5. Life table.
6. Reaction of rice cultivars and accessions.
7. Economic threshold levels.
8. Yield loss.
9. Management tools.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Insect pests are severe constraints in rice production throughout the world. Insect pests attack the rice crop from nursery to harvest. The actual species complex varies in abundance and distribution from locality to locality and year to year. Insect pests that can cause significant yield losses in rice are stem borers; leafhoppers and planthoppers (which cause direct damage by feeding as well as by transmitting viruses); gallmidges, a group of defoliating insects (mainly lepidopterans), and a grain sucking bug complex that feeds on developing grains (Pathak and Khan, 1994). The Rice black bug in Tamil Nadu, even though, recorded as a minor pest on rice, is now assuming greater importance causing severe crop loss in northern parts of rice growing areas. Literature on the rice black bugs with reference to the present studies is reviewed hereunder.

The two most common species of black bugs (Hemiptera : Pentatomidae) attacking rice plants are the Malayan rice black bug (MBB), *Scotinophara coarctata* (Fabricius) and the Japanese rice black bug, *S. lurida* (Burmeister). They are also commonly known as rice pentatomid bugs (Pathak and Khan, 1994). Breddin (1900) reported another species, *S. latiuscula* in South East Asia. It is called as node feeding black bug and was recorded during 1982 in the Philippines but however, this was considered to be of minor importance (Miyamoto *et al.*, 1983).

S. coarctata had been found in India, Pakistan, Sri Lanka, Burma and Vietnam (Heinrichs, 1994); Thailand, Kampuchea, Malaysia and Indonesia (IRRI, 1983). In Malaysia, its occurrence on rice had been recorded as early as 1918 in the district of Pekan Pahang in which nearly every rice field was attacked by this bug (Corbett and Yusope, 1924). However, it had been regarded only as a minor pest of rice (Yunus, 1964). The occurrence of *S. coarctata* on rice was first recorded in Indonesia in 1903. It was first reported as a serious rice pest on the South Western Philippine island of

Palawan in September 1979, since then the swarms of black bugs had caused substantial damage to wetland rice on farms as far as 250 km from the discovery site Bonobono, Batarasa (IRRI, 1983). In West Malaysia, the pest was first recorded on rice in 1918 (Pathak and Khan, 1994).

S.lurida is a major pest of rice in China and Japan. Before 1940, the pest was recorded as an occasional rice pest in Sri Lanka (Fernando, 1961). Since then, it had become economically important, occurred periodically in large numbers and caused extensive damage to rice crops in most parts of the country.

In the year 1979, a severe outbreak of *S.latiuscula* was reported in the month of October in the rice growing areas in Seberangperai, Kedah, Kelantan and Trengganu of Western Malaysia. Severe infestation was reported in BandarBahara in 1979 and 1981 (Barrion *et al.*, 1982). *S.latiuscula* was reported on rice in Luzon, Philippines (Singh, 1988).

Dale (1994) gave the distribution of the three species of black bug as follows.

S.coarctata : Bangladesh, Burma, India, Indonesia, Kampuchea, Malaysia, Pakistan, Philippines (Palawan), Sri Lanka, Thailand and Vietnam.

S.lurida : Bangladesh, China, India, Indonesia, Japan, Kampuchea, Malaysia, Pakistan, Papua Newguinea, Philippines (Mindanao), Sri Lanka, Thailand and Vietnam.

S.latiuscula : Indonesia (Sumatra) and Philippines (Luzon).

2.1. Occurrence in India

Rao (1977) reported the sudden outbreak of *S.coarctata* in Nellore district of Andhra Pradesh. This was the first report of occurrence of this pest from Andhra Pradesh. Singh and Singh (1987) recorded the occurrence of *S.coarctata* for the first time in Manipur.

Sundara Babu *et al.* (1984) reported the occurrence of *S.coarctata* in a severe form on rice TKM 9, Manilla and IET 1444 at Thirunavallur and on TKM 9 at Parvalur in South Arcot district of Tamil Nadu. Uthamasamy and Mariappan (1985) recorded the occurrence in Trichy district of Tamil Nadu. Heavy infestations were reported on the cultivars ADT 36, Co 29 and BCP 1 during April to July, 1984.

Subramanian *et al.* (1986) reported the presence of *S.coarctata* at Paddy Breeding Station, TNAU, Coimbatore. Population density on IR 60, IR 36, Vaigai, ADT 36, PY3, IR50, ADT 31, TKM 9, Rasi and PY 2 ranged from 6-12 bugs per 10 hills. There was no significant difference in numbers on different cultivars at 30 days after transplanting (DAT). Srinivasan and Reddy (1993) reported the occurrence of *S. coarctata* during 1990 wet season at Nellore.

Though reports on the incidence and damage caused by rice black bug was sporadic in India, its damage in rice fields in places like Chengai- MGR, South Arcot Vallalar and North Arcot-Ambedkar districts of Tamil Nadu was considerable and even 100 per cent loss of crop was reported (Saroja *et al.*, 1993).

2.2. Damage

Katsumota (1930) described the damage caused by the black bugs on rice. The bug burn, the most serious symptom was not due to toxic substances produced by the insect. Black bugs were phloem feeders and not recognised as vectors of plant diseases.

Reissig *et al.* (1985) gave a detailed account of damage. Both the nymphs and adults fed at the base of the plant where they sucked plant sap from the nodes. During the tillering stage, their feeding killed the central shoot resulted in dead heart, affected plants were stunted and tiller number was greatly reduced. Feeding during reproductive stage of the crop affected panicle development, exertion of panicles and had empty grains (White heads). When the bugs occurred in high numbers, plants wilted and dried and were "bug-burned" similar to the damage caused by the brown planthopper, *Nilaparvata lugens* (Stal.).

Vanvreden and Abdul Latif (1986) studied the damage made by *S. coarctata*. Adults and nymphs sucked the sap from the mid rib of the leaves and panicles at milky stage but in most cases, they sucked sap from the basal part of the tillers. As a result, the plants became stunted bearing fewer or empty panicles. Heavy damage resulted in overall death of the plants referred to as "bug burn". Adults and nymphs aggregated at the base of the rice plants just above the water level in day time. They moved up at night or on an overcast day.

Ooi (1988) reported that the black bug infested crop gave burnt appearance and adults possessed offensive odour and became a nuisance to man. Further, excessive sucking by large numbers caused severe damage to rice plants. In severe outbreaks, large areas of paddy plants appeared scorched and no yield was recorded. It had been estimated that a black bug feeding on paddy plant could cause the death of the plant in 16 to 20 days. However, if 20 insects were to feed, the plant could perish in two days. Besides direct damage to rice plants in the field, light attracted adults during nights became a nuisance to man when they invaded the eating places and homes especially when they emitted pungent smell.

Barrion and Litsinger (1987) described the symptoms produced by the node feeding black bug *S. latiuscula*. The insect produced three types damage symptoms namely, leaf yellowing, dead hearts and wilting (Bug burn).

2.3. Taxonomy

Ooi (1981) gave the local name of the paddy black bug as "Kutuberuang" in Malaysia and this was the major pest of paddy since 1919. It was earlier known as *Podops coarctata* and now named as *S. coarctata*(F). This insect belongs to the family of sucking bugs or the shield bugs called, Pentatomidae. As with other sucking bugs, the mouth parts have been modified to pierce the plant tissues and suck plant sap. Barrion *et al.* (1982) differentiated the black bug species using following taxonomical characters:

S. coarctata: Backward projection of the tip of the anterolateral spine, head across eyes nearly twice as wide as long; width across prehumeral process 4.0-4.5 mm; antennal segment I as long as II and III combined.

S. lurida : Width across prehumeral process 5.5-6.0 mm; head width across eyes about ¼ wider than long; antennal segment I shorter than II, segments III and IV nearly equal and segment V about one third longer than IV. Tip of the anterolateral spines extended beyond the anterior angle of the pronotum.

Miyomoto *et al.*(1983) gave a detailed account of the taxonomical status of the black bugs. The horizontally projected anterior process of the pronotum separates *S. latiuscula* from the *lurida* subgroup which consists of six species in subfamily Pentatominae. The phylogenetic tree of the oriental *Scotinophara* shows *S. latiuscula* distantly related to *S. coarctata*.

Barrion and Litsinger (1994) gave the detailed taxonomical key for the differentiation of three species of black bugs.

S. coarctata: pronotal disc not excavated anteriorly and transverse depression behind excavation weak; Scutellum without a pair of distinct oblique depressions; tip of the anterolateral spine of pronotum projected posterad but not extended beyond anterior angle of pronotum, clasper with a large tubercle medially.

S. lurida : black species; humeral process of pronotum distinct, as long as or slightly shorter than the apical ones, the latter spinuous and extended beyond outer margin of eye; rostrum reaching midpoint of hind coxae; scutellum twice as long as width at narrowest point; apex of antenniferous tubercle slightly bifid; clasper slightly emarginate apically.

S. latiuscula: Tylus as long as juga; femora without subapical ring; scutellum not reaching abdominal tip with apex subtruncate; hemelytra without distinct pale line; antennae piceous, body beneath widely black.

2.3.1. Species complex

Although there are several black bug species belonging to the genus *Scotinophara*, the following 11 species are very common in rice fields (Reissig *et al.*, 1985).

S. coarctata (Fabricius)

S. lurida (Burmeister)

S. parva Yang

S. tarsalis (Vollenhoven)

S. scotti Horvath

S. horvathi (Distant)

S. inermiceps (Breddin)

S. latiuscula Breddin

S. affinis (Haglund)

S. inermis (Haglund) and

S. ochracea (Distant)

2.4. Habitat

Black bug populations preferred swampy area and particularly were abundant in ill drained rice fields especially those surrounded by poorly drained swamps and abandoned fields with grasses and sedges. Population was low under rainfed conditions but increased with expanded irrigation (IRRI, 1983).

Abdul Latif *et al.* (1982) studied the habitat of black bug, *S. coarctata* and reported that the adults congregated at the base of the rice plants immediately above the water level during day time. At night, they moved up the rice plants and sucked the sap from the tillers. The adults lived longer and passed the winter or dry season in a dormant state in the cracks in soil and grassy areas. With favourable weather conditions, the bugs flew to rice fields and reproduced for several generations. After the rice harvest, these bugs returned to their sites. Adults were capable of migrating to long distances. The black bug crowding was reported to be high during full moon period.

Kawase and Katsumota (1955) studied the ecological conditions and offseason behaviour of *S. lurida* in Japan and observed hibernation. Pathak and Khan (1994) reported the presence of only one generation a year in case of *S. lurida* in Japan. The first generation bugs that developed on the rice crop hibernated in the winter in adult stage and invaded the year's crop in the seedling stage.

Fernando (1961) studied the bioecology of *S.lurida* in Sri Lanka and reported three or four overlapping generations in an year. The first generation and part of the second generation occurred on the first crop, the remainder of the second, the third and part of fourth generations occurred on the second crop. There were two overlapping generations in aestivation at each period between crops. At aestivation sites, fourth and fifth instar nymphs and adults were most commonly found.

In the Philippines, dry season rice crop was damaged more severely than the wet season crop. The population density of *S.latiuscula* varied consistently over two consecutive cropping seasons from June 1982 to January 1983 in nine municipalities of Laguna, Calauan, Kalayaan, Liliw, Mabitac, Pagsanjan, Siniloan, Santa Cruz, Santa Rosa and Victoria. More bugs were collected in the areas of peaty soils in Siniloan and Calauan and hence suggested that the node feeding bug preferred perennially aquatic habitats (Barrion and Litsinger, 1987).

Miyomoto *et al.* (1983) studied the habitat of *S.latiuscula* and reported that shady areas were more preferred and it was rarely attracted to light traps in sharp contrast to other *Scotinophara* spp.

Dale (1994) reported that the black bugs were able to adapt to a wide variety of conditions and were capable of withstanding adverse conditions. They hid in cracks in soil during the periods of water stress and winter. After overwintering, they flew to a rice crop and reproduced over several generations. The black bug aestivated in the adult or late nymphal stage in cracks in bunds, in paddy fields or in adjacent higher grounds to a depth of 30 cm where it remained torpid. It was gregarious during the periods of rice fallow. Heavy damage by the pest was usually observed after the heading stage of the rice crop especially when irrigation had been stopped during the maturation period.

2.4.1. Alternate Hosts

Miyomoto *et al.* (1983) reported that besides rice, wheat, maize, sugar cane, *Echinochloa colona* (L.) Link. *Cyperus rotundus* (L.) and wild rices were also infested by the black bug.

Barrion and Litsinger (1987) gave a detailed account of the host range of *S. latiuscula*. The insect successfully developed on eight weed species in three plant families: *C. difformis* L. *C. iria*, *Fimbristyles miliaceae* (L.) Vahl., (Cyperaceae), *E. colona*, *E. crus-galli* *E. glabrescens*, *Leptochloa chinensis* (L.) Nees (Graminae) and *Commelina benghalensis* (L.) (Commelinaceae). Rice was the most preferred host with greatest survival (82%), body weight (25 mg); fecundity of 72 eggs per female, and egg hatch (93%). The Lowest longevity was observed on *F. miliaceae* (38 days).

Pathak and Khan (1994) listed *Zea mays* (L.), *Alocasia indica* (Roxb.) Schott, *Colocasia esculenta* (L.) Schott, *Leersia hexandra* (L.) Sw., *E. crus-galli*, *Rottboellia cochinchensis* (Lour.) W.D. Clayton, *E. colona*, *F. miliaceae*, *C. rotundus*, *C. iria*, *Sacciolepis myurus* (Lam.) A. Chase, *Scirpus grossus* L.f., *Scleria sumatrensis* Retz., and *Hymenachne acutigluma* (Steud.) Gilliland as alternate hosts of *S. coarctata* besides rice.

2.5. Biology of rice black bugs

2.5.1. Biology of *S. coarctata*

Several authors have studied the biology of *S. coarctata* and the details are tabulated below:

Stage	Number/Duration	Reference
Eggs laid (Number)	29-34	Pathak and Khan (1994)
Eggs laid (Number)	25	Saroja <i>et al.</i> (1993)
Hatching (%)	80	Saroja <i>et al.</i> (1993)
Fecundity (number)	684 eggs in 104 days	Ooi (1981)
Oviposition (days)	7.5	Saroja <i>et al.</i> (1993)
Egg period (days)	4-7	Ooi (1981)
Egg period (days)	5	IRRI (1983)
Egg period (days)	4-7	Pathak and Khan (1994)
I instar (duration in days)	5.0	Saroja <i>et al.</i> (1993)
II instar	6.5	Saroja <i>et al.</i> (1993)
III instar	7.0	Saroja <i>et al.</i> (1993)
IV instar	9.5	Saroja <i>et al.</i> (1993)
V instar	9.0	Saroja <i>et al.</i> (1993)
No. of stadia	6	Ooi (1981)
No. of stadia	5	IRRI (1983)
No. of stadia	5	Pathak and Khan (1994)
Adult longevity (days)		
Male	212	Ooi (1981)
	203	Saroja <i>et al.</i> (1993)
Female	217	Ooi (1981)
	210	Saroja <i>et al.</i> (1993)
	120-210	Pathak and Khan (1994)

2.5.2. Biology of *S. latiuscula* (Barrion and Litsinger, 1987)

Fecundity	72 eggs/female
Number of eggs in a mass	10
Incubation period (days)	3.6
I stadium (days)	4.2
II stadium	8.6
III stadium	7.8
IV stadium	8.8
V stadium	10.4
Nymphal duration (days)	40.0
Total developmental period (days)	43.4
Adult longevity (days)	
Male	97.0
Female	117.0
Pre-oviposition period (days)	4.0

2.5.3. Biology of *S. lurida* (Fernando, 1961)

Pre-oviposition (days)	10
Number of eggs in a mass	8-15
Egg period (days)	6
I instar (days)	5
II instar	9
III instar	7
IV instar	9
V instar	12

2.6. Light trap studies

Ajukwahyu *et al.* (1981) and Abdul Latif *et al.* (1981) observed the highest population of black bug around full moon days and especially during the months of March and October. The incidence ratio of 1:69 during new moon and full moon indicated the influence of lunar cycles on trap catches.

Abdul Latif *et al.* (1982) studied the incidence of *S. coarctata* in Western Malaysia during 1980. From the observations of light trap catches, a strong correlation was observed between the flight aggregation of *S. coarctata* with lunar cycles. On or around full moon days, the light trap catches were high.

Shepard and Arida (1986) studied the sex ratio and productive status of *S. coarctata* collected from light traps and rice fields in Philippines and Malaysia. In both the countries the most eggless females were caught in light traps. Further, they stated that the lower percentage of gravid females in light traps indicated that adults that migrated or dispersed were mainly new ones that might be moving to colonize new habitats or females that had already laid their eggs.

Ferror and Shepard (1987) studied the sampling of *S. coarctata* using fluorescent street light traps, petromax gas lantern traps and visual counts in Palawan. Peak catches were reported around the period of full moon during mid August 1984, mid April to mid May and June 1985. However, there was no relationship between the densities of *S. coarctata* in light traps and in the field. Population sampling revealed that the data fitted a negative binomial distribution with a clumping coefficient of $k=0.50$. The authors had not related the petromax light trap catches with field incidence and gave reason that the rice was not the only host and other hosts also coexisted.

Saroja *et al.* (1993) studied the effect of different intensities of light sources on black bug attraction *Viz.*, 200 Watts incandescent, 125 Watts Mercury Vapour (MV) lamp and 40 Watts incandescent lamp during 1982 at RRS, Tirur. Among the light sources, attraction was significantly highest in 125 Watts MV lamp and significantly least in 40 watts incandescent lamp. In another study instead of 200 watts, 80 watts black light was compared with other two light sources and it was found that attraction was at the highest in 80 Watts black light, moderate in 125 watts and the least in 40 watts.

Kiyomitsu Ito *et al.* (1993) studied the effects of lunar phase on light trap catches of *S. coarctata* and examined the physiological status of the trapped adults. The catch size fluctuated synchronously with lunar phase and catches were large from January to March, July to September, while they were small from May to June and October to November. Most of the females trapped, showed underdeveloped ovaries and some of the females appeared to have oviposited previously.

Srinivasan and Reddy (1993) studied the influence of lunar cycle on light trap catches of *S. coarctata* in Nellore district of Andhra Pradesh. Their study revealed that the catches were the highest during fullmoon weeks. Peak population was observed in 27th Standard Meteorological Week (SMW) (July, 2 to 8) followed by 14th (April, 2 to 8) 36th (Sept, 3 to 9) and 23rd (June, 4 to 10) SMW which constituted 85.4 per cent of the total bugs captured during the calendar year.

2.7. Life table studies

Life table is a concise summary of certain vital statistics of insect population; a useful technique in the study of population dynamics which provides a format for recording and accounting of all population changes in the life cycle of a species in its natural environment (Bilapate and Pawar, 1978).

Deevey (1947) and Morris and Muller (1954) conducted life table studies to determine the distribution of insects and causes of mortality during different developmental stages. Attempts were made earlier to study the net reproductive rate (R_0) of *Heliothis armigera* Hubner on 12 hosts (Pretorius, 1976), the innate capacity of increase (r_m) and finite rate of increase (λ) of *H.armigera* on lucerne, *Medicago sativa* L. (Bilapate *et al.*, 1977). The life tables of *H.armigera* was constructed on pea, *Pisum sativum* L. (Bilapate and Pawar, 1978); on cotton, *Gossypium hirsutum* Linnaeus, sorghum, *Sorghum bicolor* (L) Moench, tomato, *Lycopersicon lycopersicum* (Lin) Karst and redgram, *Cajanus cajan* L. (Dhandapani, 1979).

Nanthagopal (1987) conducted the studies on life table and distribution of cotton bollworms, spotted bollworm, *Earias vitella* (Fabricius), green bollworm, *H.armigera* and pink bollworm, *Pectinophora gossypiella* Saunders on four species of cotton viz., *G.hirsutum*, *G.barbadense*, *G.herbaceum* and *G.arboreum*. Life table of *H.armigera* in the field revealed that the maximum mortality occurred in the earlier part of life cycle. Predation, dispersal, migration and unknown reasons accounted for maximum mortality of early and late instars. Parasitoids were reported to cause perceptible amount of mortality during immature stages. Vertical distribution of larvae of bollworms indicated that spotted and green bollworms were observed at bottom region (61 to 90cm) of the plant; all the three species of bollworms were observed in the middle region (31 to 60cm) and green bollworm and pink bollworm were observed in the top region (0 to 30cm) of the plant.

Balasubramanian *et al.* (1988) constructed the life table and studied the intrinsic rate of increase of *Spodoptera litura* Fabricius on castor, *Ricinus communis* L. and cotton, *G. hirsutum* and reported the net reproductive rate (R_0) of *S. litura* to be 547.18 on castor and 358.76 on cotton. The intrinsic rate (r_m) was 0.1935 and 0.1465 on

castor and cotton respectively. The finite rate of increase (λ) was 1.213 females per day on castor and 1.158 on cotton. The doubling time (DT) of the population was 3.590 days on castor and 4.725 days on cotton and it was able to multiply 3.864 times on castor and 2.725 times on cotton per week. The stage distribution of eggs, larvae, pupae and adults was 54.817, 43.286, 1.639 and 0.258 per cent on castor; 53.325, 45.229, 1.324, and 0.212 per cent on cotton respectively.

Ganesh Kumar (1994) constructed the life table and studied the intrinsic rate of increase of green leafhopper, *Nephotettix virescens* (Distant) on resistant and susceptible rice cultivars viz., Ptb 33 and TN1 respectively. He reported that the adults attained the mean progeny production of 19.2 females per female on the 17th day after oviposition on susceptible cultivar and 9.2 females per female on the 19th day on the resistant cultivar. The adult mortality within the cohort occurred on the 19th and 21st day on the susceptible and resistant cultivars respectively. The innate capacity for increase was 0.262 and 0.175 in susceptible and resistant cultivars respectively.

2.8. Varietal screening

Domingo *et al.* (1985) identified the black bug resistant rice cultivars. Breeding lines (300) from several countries with resistance to various leafhopper and planthopper species were selected and field screened in Palawan during July to December, 1983. The test entries were grown in cages artificially infested @ 5 bugs/hill. Level of resistance was based on the plant damage ratings. Of the 300 accessions screened, 20 were selected for a further evaluation using 35 bugs/hill. The local cultivar 'Tjeremas' was used as a susceptible check. Of the 20 accessions, IR 13149-71-3-2 and IR 10781-75-3-2-2 were the most resistant, while four accessions, IR 18350-175-2-3, BG 379-1,

IR 19661-23-3-2-2 and 2791b-Mr-257-3-2 had low level of resistance. Further they have rated the rice accessions for their reaction to black bug on a 0 to 9 scale indicating the per cent damage and status of reaction.

Heinrichs *et al.* (1987) studied the resistance and yield responses of the rice cultivars to *S. coarctata* and reported that the plant damage ratings and grain yield losses due to feeding by the black bug were the lowest on resistant accessions IR 10781-75-3-2-2 and IR 13149-71-3-2. Plant resistance was primarily attributed to tolerance. Yield losses were due to unfilled grains and decrease in tiller number and filled grains per panicle. Per cent yield loss at 10 bugs/hill ranged from 15 to 18 in the resistant accessions and 23 in susceptible accessions. Based on linear regression of yield on number of bugs per hill, an economic injury level of 3 bugs per hill was recommended.

Nemisio Trillana (1988) developed the black bug tolerant cultivar IR 1314. Saroja *et al.* (1993) screened 213 entries for their reaction to black bug and found none to be resistant. 13 entries were classified as moderately resistant and 56 were graded as moderately susceptible and remaining entries were graded as highly susceptible.

2.9. EIL and ETL

Mochida *et al.* (1986) calculated the gain threshold (= cost of control/ market value of rough rice) for black bug as 6.6 per cent because the price of rice and rice yield per unit area in Japan were 5 and 2.5 times as high as in Philippines respectively. The estimated gain threshold was as low as one per cent of the rice yield. This surprisingly low level of gain threshold ^{was} due to the Government supported rice price.

Saroja *et al.* (1993) conducted a laboratory study to fix up ETL for black bug. The results revealed that the economic yield loss occurred when 8 to 15 per cent leaf damage took place during maximum tillering stage when 4 to 6 bugs per hill were present.

2.10. Yield loss

Rice black bug, *S. coarctata* caused considerable damage when the incidence of this pest was severe. In Palawan it was reported that the rice yield was 4.4 t from two hectare rice field before black bug infestation and after the infestation, the yield was less than 2.2 t (IRRI, 1983).

Heinrichs *et al.* (1987) while evaluating the performance of the rice cultivars to black bug infestation found that for every bug per hill, there was a loss of 6.7g per m² or 67 kg per hectare. They proposed a predictive equation by relating the bug damage and loss in yield. Based on the equation at 40 bugs per hill, yield loss was 95 per cent in 'Tjeremas' the local susceptible cultivar and 59 per cent in IR10781-75-3-2-2, the resistant cultivar.

Mochida *et al.* (1986) reported that the yield loss due to black bug damage was even upto 50 per cent. Heinrichs *et al.* (1987) recorded that the yield loss at 10 bugs per hill ranged from 15 to 23 per cent.

2.11. Management strategies

2.11.1. Cultural practices

Several authors listed out the simple cultural practices for the management of rice black bugs.

Hand picking of egg masses was recommended by Corbett and Yusope (1924). Dammerman (1929) suggested that dense planting increased the population and recommended sufficient rogue space. Continuous cropping throughout the year allowed exponential insect population growth and rice black bug was one of the pests encouraged by a sequential rice cropping. (Krishna Ayyar, 1929). Mochizuki (1957) reported that late planting minimised the black bugs in Japan. Alternate flooding and draining minimised the incidence of black bugs (Fernando, 1961).

Entomologists of the University of Philippines, Los Banos (UPLB) commented that the transformation of upland rainfed farm into irrigated rice lands in the southern portion of Palawan provided the best environment for insect to develop into a full blown pest (IRRI, 1985). IRRI (1987) recommended the use of early maturing cultivars to reduce population build up of the black bug and weeding of the field to allow more sunlight to reach the base of the plants. Use of foliar sprays was recommended instead of granular application and insecticides to be directed to the base of the tillers.

Shepard and Perez (1987) studied the influence of cultivation on survival of *S. coarctata* which remained in the rice stubble after harvest. They ploughed approximately 1/8 ha portion using mould board plough after the harvest and placed 14 one square metre cages at random in the ploughed section and another set of cages in an unploughed section of the same field. Significantly fewer black bug adults and nymphs were found inside the cages in the ploughed field. Many black bugs were killed outright by the ploughing. Shepard *et al.* (1988b) reported that tillage of wetland after harvest directly killed black bugs.

Pathak and Khan (1994) suggested that removal of weeds from the fields which allowed more sunlight to reach the base of the plants which was proved to be effective.

2.11.2. Biological control

2.11.2.1. Parasitoids

The Scelionid, *Telenomus triptus* was reported as an egg parasitoid. The females could easily identify the black bug eggs as the female bug was seen guarding the eggs. However, the female bug prevented the egg parasitisation using their legs and antennae (Corbett and Yusope, 1924). Lever (1955) reported the egg parasitisation by *Microphanorus artabazus* (Nixon). Fernando (1961) observed the egg parasitisation by a scelionid wasp, *T. triptus* on *S. lurida* in Sri Lanka.

Ooi (1981) observed that the black bug occurred only occasionally in large outbreaks. During other periods, the pest occurred at a very low level and this might be due to the action of small wasps that attacked eggs. Two such wasps namely *M. artabazus* and *T. triptus*, belonging to the family Scelionidae were identified.

Shepard *et al.* (1988a) studied the parasitic behaviour of the scelionid wasp *T. cyrus* on *S. latiuscula* and reported that the parasitisation was upto 30 per cent of eggs. The parasitisation was the highest during December at the end of the monsoon season. They identified one more scelionid, *Psix lacunatus* Jhonson and Masner, which parasitised eggs in the green house condition.

Parducho *et al.* (1988) studied the effect of flooding on unparasitised eggs of black bug and eggs parasitised by *T. triptus*. They found that when unparasitised egg masses were not submerged, 96 per cent hatched; none hatched after the submergence for 24h. When submerged for 6, 12 and 18h only 33, 29, and 3 per cent hatched respectively. However, more than 50 per cent of the parasitoids emerged after 24h of submergence of parasitised eggs.

Shepard *et al.* (1988b) studied the effect of flooding on the eggs of *S. coarctata* and parasitisation by *T. triptus* in screen house. Flooding increased egg parasitisation of 17 per cent in unflooded pots and 54 per cent in flooded pots.

Perez *et al.* (1989) surveyed and assessed the scope of indigenous natural enemies of *S. coarctata* on rice fields on the island of Palawan, the Philippines. Species identified included a scelionid egg parasitoid, *T. triptus* which was the most frequently encountered natural enemy. It parasitised 61.4 per cent egg masses, but only 19.2 per cent of the eggs.

Ooi and Shepard (1994) reported the failure of introduction of parasitoids from a different host to control *S. coarctata*. They have introduced two egg parasitoids *viz.*, *P. lacunatus* and *T. cyrus* from the eggs of an economically unimportant pentatomid *S. latiuscula* on the island of Luzon. A total of 12,840 *P. lacunatus* and 19,300 *T. cyrus* was released during 1985 to 87 and none was recovered.

2.11.2.2. Predators

Ooi (1981) when investigated the outbreak of black bug near Kulin, Kedah noticed the feeding of black bug by the domestic fowls.

Reissig *et al.* (1985) reported the common frog, *Rana* sp; a carabid, *Agonium daimo* (Bates) feeding on black bug nymphs and eggs.

Shepard *et al.* (1988a) listed out two bugs, *Zincrona caerulea* (Linnaeus) and *Stenonabis tagalica* (Stal.) feeding on nymphs and occasionally on eggs.

Barroga (1988) documented that farmers of Palawan were trained to use ducks in the rice fields when the rice plants were one foot high to feed on black bug which resulted in a good check on the bug population.

Perez *et al.* (1989) identified the predators which included crickets, *Metioche vittaticollis* (Stal.) and *Anaxipha* sp; the coccinellid, *Micraspis crocea* (Mulsant) that preyed mainly on eggs; the spiders, *Lycosa pseudoannulata* (Boes. et Str.), *Oxyopes javanus* (Thorell), *Tetragnatha virescens* Okuma and *Camaricus formosus* Thorell. The ant, *Solenopsis geminata* (Fabricius) was also observed attacking the eggs, nymphs and adults.

2.11.2.3. Entomopathogenic fungi

Katsumota (1930) first reported the infection of *S. latiuscula* by *Metarhizium anisopliae* in Japan.

Morimoto (1957) summarised his earlier work (1952 to 1954) on the microbial control of *S. lurida* by *Paecilomyces lilacinus* (Thompson) Samson and *M. anisopliae*. Rice plants with field population of *S. lurida* were sprayed and dusted with *P. lilacinus* and *M. anisopliae*. Sprays were more effective than dusts. Also black bug mortality was higher in *M. anisopliae* treated plots than in *P. lilacinus* where mortality levels of 60 to 100 per cent for upto 46 days were observed. After the application with *M. anisopliae* conidial dust, the fungus spread to untreated adjacent fields and caused high infection levels upto 100 per cent. *M. anisopliae* var *anisopliae* was found to infect planthoppers, leafhoppers and rice black bugs. (Aguda *et al.* 1984; Medrano *et al.*, 1984).

Rombach *et al.* (1986) studied the effects of entomopathogenic fungi namely *Beauveria bassiana* (Balsamo) Vuillemin, *M. anisopliae* and *P. lilacinus* on the population of black bug in caged condition in the main field. Two different fungal materials viz., suspension of conidia and mass produced dry mycelium were used in the experiment. The fungi applied as suspensions of conidia were *M. anisopliae*, *B. bassiana* and *P. lilacinus*. Fungi applied as mass produced dry mycelium were *M. anisopliae* and *P. lilacinus*. The

number of bugs was significantly reduced in all the fungal treatments compared to the control over a period of nine weeks.

Rombach *et al.* (1987) estimated the infections of *M.anisopliae* and *P.lilacinus* on black bug populations and reported 15 to 80 per cent of infection.

Barrion and Litsinger (1987) reported the presence of two fungal pathogens, *B.bassiana* and *M.anisopliae* and an unidentified mermethid which attacked both the nymphs and adults. The combined mortality by the pathogens and nematode was only three per cent.

2.11.3. Insecticidal control

Severity of the black bug damage and drastic yield loss in crops forced the scientists to evaluate suitable insecticides. The black bug was brought under control in the Philippines, an endemic country by massive pesticide spraying with monocrotophos, deltamethrin, permethrin, carbosulfan, dimethoate EC or malathion EC (IRRI, 1983).

Rao (1977) recorded the incidence of black bug in Nellore district and found monocrotophos spray @ 0.04 per cent to be effective.

Abdul Latif *et al.* (1982) evaluated the efficacy of 15 insecticides *viz.*, MIPC, chlorpyrifos, BPMC, endosulfan, propoxur, diazinon, acephate, carbaryl, dieldrin, azinphos-ethyl, dichlorvos, fenthion, malathion, dimethoate and lindane against *S. coarctata* adults in Aborlon, Palawan. Among the insecticides tested, azinphos-ethyl, dichlorvos and malathion produced less than 50 per cent kill even at 24 h after spraying. With respect to residual toxicity, acephate and propoxur had significant effects at four days after spraying.

Sundara Babu *et al.* (1984) recommended the application of phosphamidon, fenthion, methyl demeton at 500 ml/ha for the effective management of the pest. Further,

they advised to drain the water before spraying. Uthamasamy and Mariappan (1985) recorded the occurrence at late flowering stage of the crop and recommended spraying of fenthion at 600 ml/ha.

Heinrichs *et al.* (1985) recommended the foliar spray with dimethoate EC and malathion EC at 0.9 kg a.i./ha. However, this control measure was found to be too expensive for Palawan farmers.

Subramanian *et al.* (1986) evaluated the efficacy of insecticides against black bug on 45 days old IR 50. Of the five insecticides tested, monocrotophos reduced 91 per cent of black bug population over control.

Barrion and Litsinger (1987) evaluated the efficacy of 12 insecticides *viz.*, acephate, azinphos-ethyl, BPMC, carbaryl, carbofuran, carbosulfan, diazinon, endosulfan, fenthion, monocrotophos, permethrin and triazophos for the management of *S. latiuscula* in screen house condition during 1984. The insecticides were tried both on nymphs and adults and mortality per cent per dosage was worked out. Of the 12 insecticides, nine *viz.*, BPMC, carbaryl, carbofuran, carbosulfan, diazinon, endosulfan, fenthion, monocrotophos and triazophos applied as foliar sprays were highly effective ovicides, all producing 100 per cent egg mortality. Permethrin, acephate and azinphos-ethyl were less ovicidal and caused 77 to 79 per cent egg mortality.

Saroja *et al.* (1993) evaluated the efficacy of nine insecticides and two neem derivatives for the control of black bug in screen house condition. The insecticides, acephate and monocrotophos and NSKE (5%) were found significantly superior in controlling the black bug.

Kiritani and Naba (1994) reported the remarkable decrease of *S. lurida* population in Japan due to introduction of organochlorine insecticides.

MATERIALS AND METHODS

2. MATERIALS AND METHODS

A preliminary survey was undertaken in Chengai - MGR district to assess the occurrence of Rice Black Bug (RBB) *Scotinophara coarctata* (Fabricius). Studies conducted on the RBB to investigate the biology on rice and weed host; seasonal occurrence and abundance population dynamics, life table, screening of rice accessions, fixation of economic threshold level, yield loss assessment, and management strategies carried out at Rice Research Station (RRS) Tirur are detailed below.

Survey of RBB

A preliminary survey was undertaken in eight taluks of Chengai - MGR district for the occurrence of RBB. The areas surveyed and the incidence of RBB are indicated in Fig.1.

Mass culture of RBB on rice

The highly susceptible rice cultivar, ADT 36 was chosen for mass culturing the RBB in screen house condition.

Seeds of ADT 36 were sown separately in earthen pots and five to six seedlings of 25 day old were planted in the centre of each pot to produce dense canopy which situation was very ideal for insect multiplication. In addition, five potted plants of the same cultivar were maintained for oviposition. The plants at maximum tillering stage were selected for oviposition. Ten pairs of adult RBB were collected from the field and introduced in the oviposition cage (45 x 45 x 60 cm) having wooden frames, glass top, door and wire mesh side walls. In each oviposition cage, two pairs of adult bugs were released and allowed for mating and oviposition. The eggs laid on the leaf were removed daily along with leaf bit and stapled on potted plants kept separately. Immediately after hatching, the young nymphs were carefully removed by camel hair brush (number six) and

Fig. 1. Occurrence of Rice Black Bug in Chengai-MGR district

Surveyed :

Taluk		Village
Ambattur	*	Paivedu
Chengalpattu	*	Attur
Gummidipoondi	*	Gummidipoondi
Kanchipuram	*	Damal
	●	Magaral
Madurantakam	*	Karunkuzhi
Ponneri	*	Ponneri
Tiruvallur	*	Tirur
	○	Egattur
	▲	Aranvoyal
	□	Pudumavilangai
Uttukkottai	*	Poondi
	●	Thamaraipakkam
Sriperumbudur	*	occurrence not prevalent

Not Surveyed :

Cheyur, Uthiramerur, Tiruttani and Pallipet Taluks.

FIG.1. OCCURRENCE OF RICE BLACK BUG IN CHENGAI MGR DISTRICT

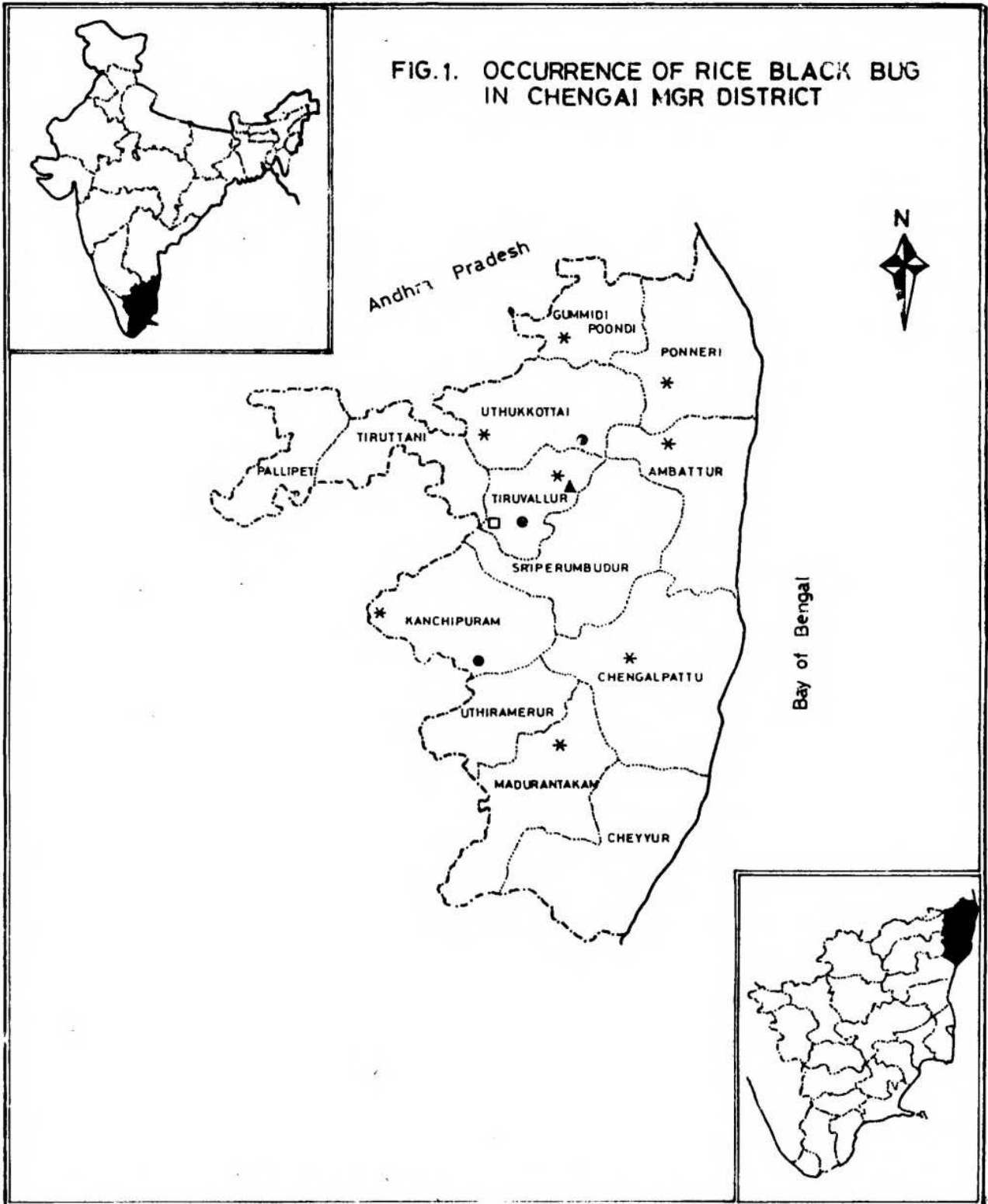
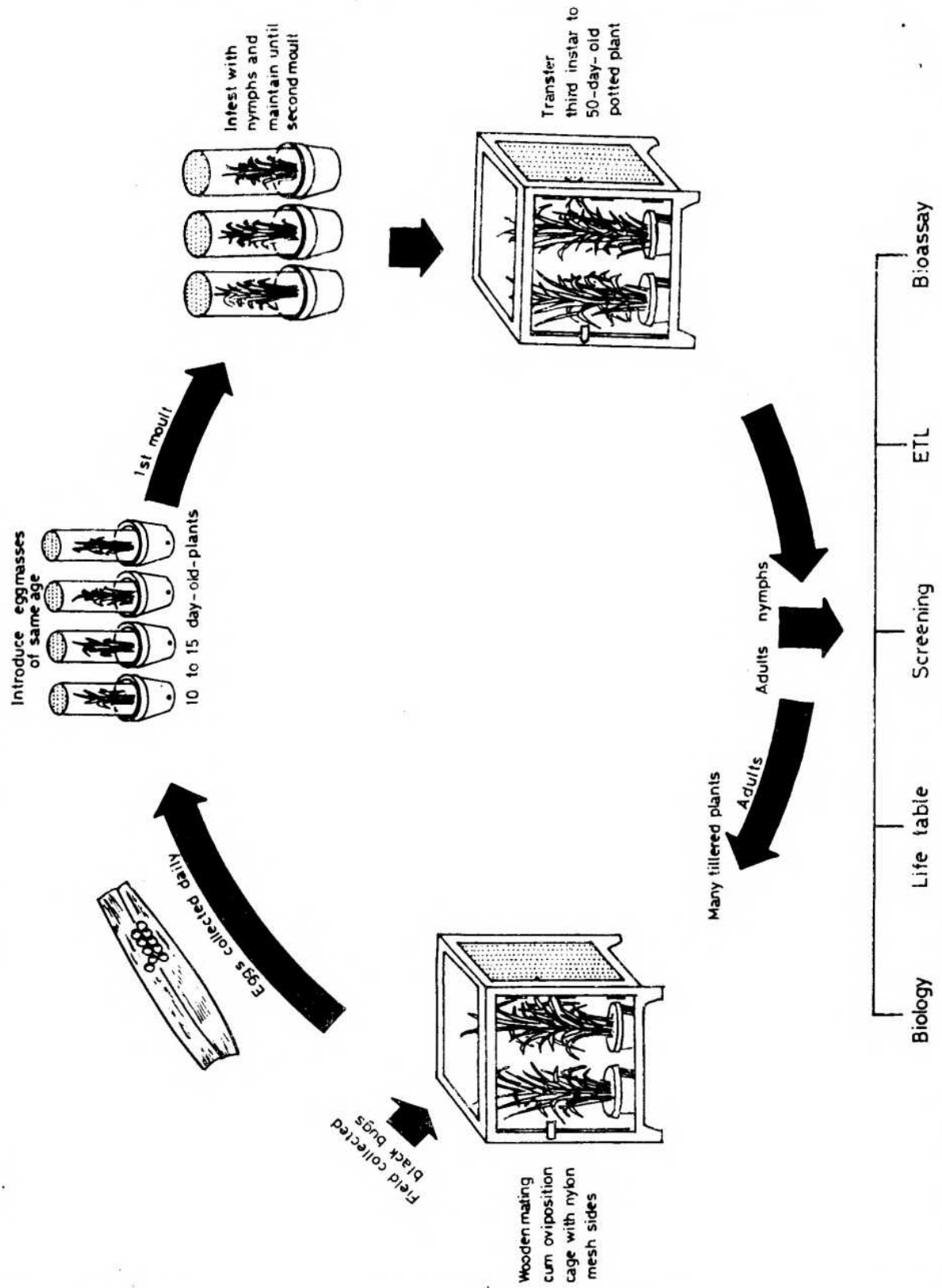


FIG. 2. MASS CULTURE OF *Scotinophara coarctata* (Fabricius)



transferred to the bunch of young rice seedlings in tumbler pots, as the first instar nymphs preferred tender plants. As the instar advanced, older seedlings were provided correspondingly. Individual instars were maintained in the earthen pots having suitable age of the seedlings. Water level was maintained regularly and the insects damaged due to handling were removed. The oviposition and mass rearing cages were inspected periodically and fungal infection, natural enemies and spider webs were removed. The potted plants were also changed as and when the plants dried due to feeding. The mass culture was maintained in the screen house throughout the period of study by adopting routine fortnightly planting of rice seedlings (Fig. 2).

3.1. Biology of RBB on rice

Twenty pairs of adult RBB were drawn from the mass culture and released on 35-day-old ADT 36 rice plants individually. Individual potted plants having a pair of adult bugs were covered with mylar film cages (12x40 cm) with nylon mesh top and side vents. Host plants of same age were provided as soon as the plants were damaged due to "bug burn". After egg laying, egg masses along with a small portion of leaf were removed daily and stapled on the plants kept separately. The number of egg masses and the number of eggs laid by an individual female was recorded daily on 10 plants. Percentage of egg hatch was worked out by taking the total number of eggs laid per female and the number of eggs hatched. The length and breadth of eggs were measured using the stage and ocular micrometer calibrated microscope. A total of 10 eggs was used for the measurements.

Nymphal stages

Nymphs that hatched from eggs were removed carefully and released on young rice plants raised on tumbler pots. The tumbler pots were covered with glass chimney covered at the top with muslin cloth (Plate 3). In each tumbler pot, the nymphs that emerged from the respective egg masses were allowed. The duration of the individual

Plate 3. Laboratory studies

A **Biology**

B **Yield loss assessment**

C **Screening rice accessions**

nymphal stages was worked out by visual observation of moulted skin and the duration from one instar to other was worked out. As the instar advanced, older plants were provided to facilitate proper feeding and growth. Nymphs died due to handling or fungal infections were rejected and nymphs of same age were replaced from mass culture. Periodically, the plants were also changed. The colour of the individual nymphs was observed and descriptions were made. The length and width of the body, antennae and rostrum in each instar were measured using the calibrated microscope by taking 10 insects per instar. The total number of days passed for an egg to become an adult was also recorded on 10 sets which gave the total developmental period.

Adult longevity

The black bugs were sexed and male and females were introduced individually in potted plants having three matured tillers. The plants were covered with mylar film cages. A total of 10 such sets in each sex was maintained till the death of the insects. The date of death of individual bug was recorded and the longevity was worked out for the females and males separately.

Mating, Pre-oviposition and Oviposition period

The bugs kept as individual pairs in the mating cages were utilised to study the mating period. Each pair was observed at hourly intervals. The time between the first mating and last mating gave the mating period. The time between the last mating and first oviposition gave the pre-oviposition period and time between the first and last oviposition gave the oviposition period. A total of 10 sets was used for the study.

Fecundity

After the assessment of pre-oviposition period, the female bugs were individually caged in the oviposition cages and eggs laid were recorded daily till the egg laying stopped. A total of 10 female bugs was studied to find out the fecundity.

Sex ratio

To fix the sex ratio of adult bugs, 10 pairs were separated from the mass culture. They were allowed to mate separately in pairs. The egg masses laid by the individual females were removed and maintained separately and reared upto adult stage. The total number of adults emerged and female to male ratio was worked out.

3.2. Biology of RBB on *E.colona*

The alternate weed host, *E.colona* abundant in and around RRS, Tirur was selected to study the biology. The procedures adopted and observations made on rice were followed on alternate weed host also.

3.3. Seasonal occurrence and abundance of RBB and its natural enemies

Observations were made on the occurrence of RBB and its natural enemies in fixed plots at RRS, Tirur and in farmer's field at Egattur village of Kadambattur block of Chengai - MGR district. The village identified was an endemic area for RBB incidence.

3.3.1. Fixed plot survey

Fixed plot survey was undertaken from *Samba* 1992-'93 to *Navarai* 1996 continuously. One acre plot was selected for fixed plot survey for each season and for each cultivar. Five one square metre microplots were marked out in the four corners and one in the centre of the field. The microplots were laid out by leaving two metres from the bund on all the sides and were demarcated by placing four bamboo stakes painted red. At each observation, four hills were selected at random in each microplot and thus totally 20 hills were taken into account. Observations were commenced 15 days after transplantation (DAT) and completed 15 days before harvest on the number of RBB per hill, total number of leaves present and the number of leaves damaged by RBB and from this, per cent leaf damage was worked out. Total number of tillers and the tillers damaged gave the damage per cent due to dead heart. Likewise at the time of grain

maturation, white ears present were also recorded. The commonly present natural enemies viz., spiders, coccinellids, carabids, staphylinids and mirids were counted. The spiders were counted on the hills and other natural enemies were counted by placing a wide mouthed plastic container having water, just beneath the hills. The hills were gently tapped and the natural enemies falling into the container were counted on hill basis. Corresponding weather parameters viz., maximum temperature (°C), minimum temperature (°C), relative humidity (%), rainfall (mm.) and radiation (cal./cm²/day) were recorded from the weather station situated at RRS, Tirur.

3.3.2. Survey in farmer's field

In farmer's field also, fixed plot survey was undertaken for each season for three years. All the observations recorded at RRS were followed. Weather parameters could not be recorded, as there was no weather station nearby.

The data pertained to seasonal occurrence viz., population of adults and nymphs of RBB, egg masses laid, per cent parasitisation of egg masses and eggs by the parasitoid, *Telenomus triptus* and infection of adults and nymphs by the fungus *Metarhizium anisopliae* over seasons and years were compared using 't' test. The population of RBB were correlated with weather parameters and leaf damage with predators and weather parameters in cultivars viz., Co 45, White Ponni, ADT 37, TKM 9, ADT 36 and PMK 1. Multiple regression analysis of RBB population against stage of the crop and weather parameters was made. Leaf damage was also similarly correlated/regressed with natural enemies

3.4. Population dynamics of RBB

3.4.1. Studies on light trap catches

This study was conducted continuously from the first Standard Meteorological Week (SMW) of 1993 to 17th SMW ending April 28, 1996 at RRS, Tirur. The incidence of adult RBB was monitored using three different light sources namely, Pest-O-Flash (M/s. Pest Control India, Pvt. Ltd.), 125 Watts incandescent lamp and 40 Watts incandescent lamp, installed in fourth, eighth and second blocks of RRS, Tirur, respectively covering a total area of 7.05 ha (Plate 4). Light traps were operated daily between 6 to 11 PM. The number of adults attracted was individually collected on the next morning and counted. The weekly mean of RBB attracted to each of ^{the} light sources during an year was compared with each other using paired 't'test.

3.4.2. *In situ* Counts

In situ counts were taken starting from *Samba* 1992 to *Sornavari* 1995 covering nine seasons. In each season, one bulk crop was selected. Observations were recorded at weekly intervals starting from 15 DAT and completed 15 days before harvest. In each week, a total of 50 hills was selected at random. The RBB damaged hills were identified by the presence of orange yellow leaves at the basal portion of the plant. Such hills was examined and number of adults and nymphs present on the hills were counted. On the same hill, number of adults and nymphs infected by the fungus, *M. anisopliae* was also recorded. While taking observations, some of the infected adults and nymphs were seen floating on the water. Hence, the adults and nymphs died due to fungal infection and that had fallen very close to the sampling hill alone were recorded and removed. The infected adults and nymphs found inbetween the walking space or irrigation channels were, however, rejected. While inspecting the individual hills, the number of egg masses and number of eggs present in the egg masses were counted using a hand lens (10x). The egg masses parasitised by *T. triptus* were clipped off from the plant along with



A



B



C

PLATE 4. Field studies



Light trap



Yield loss assessment and FTI

the leaf bit and observed for parasitoid emergence in the laboratory by placing the egg masses in test tubes covered with cotton wool. Parasitoids that emerged from the eggs were counted and per cent parasitisation of the egg masses and per cent parasitisation of the eggs within the egg masses were worked out. The data obtained in respect to the parasitisation of egg masses and eggs were subjected to simple regressions for the individual seasons in an year and pooled over the seasons. The adult population versus nymphal population and density of egg masses with the eggs were also regressed.

3.4.3. Species Composition

The species of RBB present at RRS, Tirur was recorded for seven seasons starting from *Navarai* 1993-'94 to *Navarai* 1996. The observations were taken on bulk crops by randomly selecting 100 hills in each SMW starting from January 1994. On the individual hills, RBB adults were hand picked and collected in polythene bags. The species was identified in the laboratory using the taxonomical key raised by Barrion *et al.* (1982). Observations on the species complex was recorded corresponding to that SMW. The data obtained from this study were subjected to paired 't' test and the dominance of the species was worked out within the seasons and over seasons. The influence of RBB species was correlated with weather parameters and population of both *S.coarctata* and *S.lurida* were individually regressed with weather parameters.

3.5. Life table studies on *S. coarctata* on rice

Adult pairs were released into the ovipositional cages having 35-day-old ADT 36 potted plants and allowed for egg laying. Eggs laid on the plants were separated using camel hair brush and 100 eggs were kept for hatching. The nymphs and adults were reared in sub-groups as per the methodology given by Evans and Smith (1952). Immediately after hatching, the nymphs were released @ 10 per tumbler pot having young seedlings. As the instar advanced, older plants were provided and they were changed

periodically. The tumbler pots were kept in wooden cages. The sex ratio was worked out based on the nymphs reaching adult stage. The adults that emerged on a particular day were paired and released in separate rearing cages @ five pairs per cage. Fecundity of the females was recorded till their death. The number of eggs laid on each day was recorded. In each succeeding day, daily mean number of eggs laid per female was worked out based on the total number of eggs laid and the total number of females survived on the previous day. Then the number of eggs laid per female was divided by 1:0.406 in order to get the number of females (mx). Observations from hatching of eggs till emergence and death of adults were recorded daily which gave values for life table (lx). Life tables were constructed as per the method of Birch (1948) and Atwal and Bains (1974). The innate capacity for increase (rm), net reproductive rate (Ro) and mean generation time (Tc) are the basic parameters required to assess the population growth. Life table studies were undertaken at RRS, Tirur at a maximum temperature of 32 to 35.5°C and minimum temperature of 18 to 26.5°C.

i. Innate capacity for increase (rm) :

It is the maximal rate of increase attained by a population of a particular organism at any particular combinations of environmental factors. This is infinitesimal rate of increase of population of stable age distribution. It was expressed as number of females per day. It was calculated using the formula:

$$\sum e^{-rm} l_x \cdot m_x = 1$$

Where

x = Age of individual in days.

lx = Number of individuals alive at age x.

mx = Number of female offsprings produced per female in the age interval x.

The value for x, lx and mx were taken from the data on fecundity.

ii. Net reproductive rate (Ro) :

It is the rate of multiplication of population in each generation measured in terms of females produced per generation. The sum of products of l_x and m_x is the net reproductive rate.

iii. Mean duration of a generation : (Tc) :

This is the mean time from birth of parents to birth of offsprings. The precise value of mean length of generation (Tc) was calculated by using the formula:

$$T_c = \frac{\sum l_x m_x x}{R_o}$$

The arbitrary values of innate capacity for increase was calculated from the formula:

$$r_c = \frac{\log_e R_o}{T_c}$$

This is the arbitrary value of r_m . The value of the negative exponent of $e^{-r_m x}$ ascertained from this experiment, often lay outside the range given in the tables found in most mathematical hand books. For this reason, both sides of the above equation were multiplied by the factor e^7 to give:

$$\sum e^{7-r_m x} \cdot l_x m_x = 1096.6$$

The arbitrary value of r_m up to two decimal places were substituted until the two values of the equation ($\sum e^{7-r_m x} \cdot l_x m_x$) were found which lay in between 1096.6. Therefore two arbitrary r_m 's were needed for computation, one giving a value slightly less than 1096.6 and the next lower r_m which would give a higher value than 1096.6 (Watson, 1964). The two values were then plotted on horizontal axis against their respective arbitrary r_m 's on the vertical axis. The two points were joined to give a line which intersected a vertical

line drawn from the desired value of $\sum e^{7-rm} \cdot l_x m_x = 1096.6$. The point of intersection gave a value of rm accurate to two decimal places.

iv. Finite rate of natural increase (λ) :

It is the multiplication per female in unit time of population of stable age distribution. This was calculated from the formula:

$$e^{rm}$$

v. Corrected generation time (T) :

This was calculated from the formula:

$$T = \frac{\log_e R_0}{rm}$$

vi. Weekly multiplication of the population (WM) :

This was calculated by using the formula

$$WM = (e^{rm})^7$$

vii. Doubling time (DT) :

It gives the time in days that is required by a population to double in numbers (Campbell and Mackauer, 1975).

$$DT = \frac{\log_2}{\log \lambda}$$

viii. Stable age distribution : (Dhandapani and Balasubramanian, 1979)

The per cent distribution of various stages (egg, nymph and adult) was also worked out by observing the population schedule of birth rate, death rate and from the formula:

$$e^{rm}$$

3.6. Screening of rice accessions to RBB

The popular cultivars grown in Chengai-MGR district, rice accessions in Adaptive Research Trials (ART), Multi Locational Trials (MLT), Comparative Yield Trials (CYT), Initial Yield Trial (IYT) and Advance Varietal Trial (AVT), moderately resistant accessions of BPH and leaf folder, accessions of Irrigated Medium Rice Yield Trial, International Irrigated Rice Yield Nursery Trial and Hybrid rices (368 entries) were screened for their reaction to RBB in the screen house (Plate 3). The entries were screened season wise. The test entries were sown in clay pots and 25-day-old seedlings were transplanted by adopting 15x15 cm spacing @ four seedlings per hill per entry per replication in a permanently erected rectangular cement tub (1.5x0.5x0.4 m). Before planting, the cement tubs were filled with field collected soil and puddled condition was created artificially. Suitable standard checks were included in each group of accessions for comparison. Each accession was replicated thrice. A fortnight after planting, laboratory reared, pre-starved adult bugs on of the same age were released on the test accessions @ five per hill. The accessions accommodated in the cement tubs were covered with rectangular iron cages lined with nylon mesh. Each cage could accommodate 10 test accessions. The water level was maintained regularly. Each accession was monitored constantly and dead insects if any were replaced by fresh ones. The leaf damage was rated at 40 days after infestation. The leaf damage was rated on a 0 to 9 scale as per the methodology standardised by Domingo *et al.* (1985).

Leaf damage (%)	Grade	Reaction
0	0	Highly resistant
1-10	1	Resistant
11-20	3	Moderately resistant
21-35	5	Moderately susceptible
36-50	7	Susceptible
Above 50	9	Highly susceptible

3.7. Economic threshold level for RBB

The experiment was conducted during *Navarai* 1996 on ADT 36 rice (Plate 4). By surveying the field randomly, the hills having the RBB nymphs and adults were selected and marked. In each sample category, three caged hills were chosen and these constituted the replications. The other pests and their damages in the chosen hills were mechanically eliminated in the early stage of the crop itself and only RBB were retained. These identified hills were caged using circular iron frames covered with polyester netted cloth. Sufficient care was taken to prevent the migration of either RBB or other pests into the cages or escape of RBB from the cages to the adjoining hills by firmly fixing the cage frame and their sides were sealed with wet mud. The caged hills had RBB numbers ranging from one to 15 per hill. At the time of observation, the individual cages were lifted carefully. Damage on the tillers were recorded at maximum tillering stage. Length of the tillers and panicles were recorded. At the time of harvest, individual caged hills was harvested and observations on number and weight of the filled grains and chaff was worked out. The data obtained from the above experiment was subjected to mathematical equations to work out the ETL. (Suyambulingom and Kailasam, 1988). To show that ETL is dynamic, output value was varied between Rs.9/= to Rs.11/= per kg of rice at constant cost of plant protection with insecticides and plant products. Though variation is possible, with cost of protection and value of output, only the latter was used for variation. The procedure adopted for ETL calculation involved the following equation:

$$\text{Where } \frac{d_{y_L} \cdot P_I}{d_I \cdot P_Y}$$

d_{y_L} = Abated loss in yield

d_I = Level of RBB equal to d_{y_L}

P_I = Price of protectants

P_Y = Value of output.

3.8. Yield loss assessment for RBB

3.8.1. Assessment of yield loss (screen house)

Yield loss was assessed for RBB in screen house. The highly susceptible cultivar, ADT 36 was chosen for the study. Seeds were sown in pots and 25-day-old seedlings were transplanted in earthen pots (20x12cm). Four seedlings were transplanted and allowed for establishment (Plate 3). The experiment was conducted in two sets *viz*; first set with nymphs and second with adults. There were eight treatments replicated thrice with one pot per replication. Laboratory reared uniform aged, second instar nymphs were released^e 1,2,3,4,5,6 and 9 adults for the first and second sets. The pots were labelled and covered individually with circular iron cages with mylar film netted at the top with side vents. Each pot was examined on alternate days and dead insects were replaced. First observation on the leaf damage was recorded 15 days after initiating the experiment by counting the total number of leaves and leaves damaged by RBB which gave the per cent leaf damage. The insects were allowed in the treatments till the death of the plants or grain maturation whichever occurred earlier. The individual pot were harvested and number and weight of filled grains^{and} unfilled grains ~~were~~ calculated using (Anamed^R) electronic seed counter cum balance. The reduction in grain weight per panicle was worked out. The damage caused by a single insect was calculated by comparing the observations with the yields from plants in which RBB was not introduced and the same were regressed against RBB numbers.

3.8.2. Assessment of yield loss in field (caged)

The experiment was conducted during *Navarai* 1996 on ADT 36 rice. The experimental data from section 3.7. were utilised for working out the yield loss also in caged condition in the field (Plate 4). The population of RBB and corresponding weight of filled grains was also used in regression analysis.

3.8.3. Assessment of yield loss in field (uncaged)

The experiment was conducted during *Samba* 1995-96 on ADT 36 rice. Initially (25 DAT), the field was surveyed to grade the RBB damage which resulted into 18 class intervals of leaf damage, each class varying at five per cent intervals. Fully protected plants were maintained for the comparison of observations. Thus, there were 19 treatments with five replications. Therefore, n was fixed at 95 (19x5). The plants representing different classes were marked with bamboo stakes for further observations. In each treatment, leaf damage by bugs and number of RBB per hill were recorded. The damage due to leaf folder and stem borer was also assessed on the marked hills of each sample. The yield related components *viz.*, number of productive tillers, length of the tillers and panicle were recorded. At the time of harvest, each marked hill was separately harvested and number and weight of filled grains and chaff were counted. The reduction in grain weight per panicle was worked out. The per cent damage and corresponding weight of filled grains alone were used in the regression analysis. The damage caused by the group of pests including the RBB was worked out by comparing the observations with fully protected hills.

3.8.4. Prediction of yield loss using mathematical models

Using the data collected as per sections 3.8.1. to 3.8.3. attempts were made to fix a suitable mathematical model for assessing the trend of loss and the rate of loss for unit increment in pest number/leaf damage.

Various mathematical models *Viz.*, Mitscherlich's curve (Briggs , 1925; Balmukand, 1928; Hexem *et al.*, 1976). Logistic curve (Meek *et al.*, 1991), Hill curve , Gombertz curve, Richards curve, Polynomial curve, Cubic polynomial curve and Gauss curve (Ramachandra Prasad *et al.*, 1992) were tried to establish the functional form between the population of RBB (number /hill) and yield loss (g/hill) and/or leaf damage

(%). Based on the predicting ability of the model and correlation coefficient, the Mitscherlich's curve was found to be the best form between the population of RBB and yield loss. The Logistic curve was found to be the best between the leaf damage (%) and yield loss (g/hill).

Mitscherlich's Curve

The exponential form of Mitscherlich's Model is of the form

$$y_L = A (1 - B e^{-CI_i}) \quad 1$$

Where,

- Y_L = Yield loss (g/hill)
- I_i = Population of RBB (number /hill)
- A = Maximum crop yield loss when I is increased to the maximum limit
- B and C = Parameters to be estimated

Logistic curve

The Logistic curve is of the form:

$$y_L = A (1 + B e^{-CD_j})^{-1} \quad 2$$

Where,

- Y_L = Yield loss (g/hill)
- D_j = Leaf damage (%)
- A = Maximum crop yield loss when D is increased to the maximum limit
- B and C = Parameters to be estimated

The Mitscherlich's Curve (equation 1) and Logistic curve (equation 2) were estimated by the method of Ordinary Least Squares (OLS).

The rate of yield loss (g/hill) in respect to different population levels of RBB was estimated from equating the equation 1 using the formula:

$$R_{yL_i} = \alpha e^{-CI_i}$$

Where,

R_{yL_i} = Rate of yield loss at i th level of RBB population

I_i = i th level of RBB

α = Parameters to be estimated

The rate of yield loss due to leaf damage (%) was estimated from the Logistic curve. The rate of yield loss due to per cent leaf damage was worked out by the formula:

$$R_{yL_j} = \beta e^{-CD_j} (1 + B e^{-CD_j})^{-2}$$

Where,

R_{yL_j} = Rate of yield loss at j th level of leaf damage per cent

D_j = j th level of leaf damage per cent

β = Parameters to be estimated

3.9. Management of RBB

3.9.1. Laboratory evaluation of botanicals

Trial I :

Treatment	Concentration	Dosage
		(ml/l) (g/l)
Neem oil	3 per cent	30.00
Neem Seed Kernel Extract (NSKE)	5 per cent	50.00g
<i>Vitex negundo</i> leaf Extract (LE)	10 per cent	100.00g
<i>Ipomoea carnea</i> (LE)	10 per cent	100.00g
<i>Prosopis juliflora</i> (LE)	10 per cent	100.00g
Neem Azal-T/S	1 per cent	5.00 ml
Neem Azal-F	5 per cent	1.00 ml
Untreated control	-	-

Preparation of botanicals

Leaf/seed powder

The botanicals viz., *Vitex negundo* Linn. *Ipomoea carnea* Linn. and *Prosopis juliflora* Linn. were collected in large quantities and the leaves alone were separated and shade dried for three days. The dried leaves were powdered individually by a blender (Sumeet^R) and sieved using a flour sieve. The leaf powder was stored in airtight containers. Neem seeds were broken and the kernels were powdered. These botanicals were used, whenever necessary. For laboratory experiments the requirement of the botanicals was arrived for one litre of spray fluid. To treat one hectare main field, 50 kg of leaf powders and 25 kg of neem seed kernel powder were required. The spray fluid required was 500 litres per hectare.

Leaf extract

A day prior to the commencement of experiment, the botanical leaf powders (50 kg) were taken individually in a thin muslin cloth bag and soaked overnight in the container having 50 litres of water. On the day of treatment, the muslin cloth bag was squeezed to get maximum extract. To the extract, 450 litres of water was added to treat one hectare. Similarly 25 kg neem seed kernel powder was also prepared. To this, water was added and made up with required quantity of water (Total spray fluid - Water taken initially for soaking = water added before spray). The wetting agent viz., teepol was added @ 0.5 ml/l of suspension to all the treatments except for the neem based commercial formulations.

3.9.2. Laboratory evaluation of insecticides

Trial-II

Treatment	Formulation	Dosage
		(ml/l) (g/l)
Monocrotophos	36 WSC	2.00
Acephate	75 SP	1.25g
Chlorpyrifos	20 EC	2.00
Phosphamidon	85 WSC	1.00
Triazophos	40 EC	1.00
Carbaryl	50 WP	2.50g
Endosulfan	35 EC	3.00
Fenthion	82.5 EC	1.00
Untreated control	-	-

Evaluation procedure

ADT 36 rice seedlings (25-day-old) from the nursery were planted in earthen pots (20x12cm) @ three seedlings per pot. Before planting, the seedlings were checked for the presence of any insect eggs, damage symptoms and natural enemies and these were removed. After planting, the pots were kept in glass cages for establishment. The RBB adults of the same age were drawn from the mass culture and released on the individual pots @ 20 bugs per pot. The botanical/insecticide spray fluid was prepared individually in small plastic container. The treatments were replicated thrice. The treatments were imposed with the help of a kitchen garden plastic sprayer (Sujatha^R) covering the entire plant. After the completion of each treatment, the sprayer was cleaned thoroughly. The untreated control pot was given a water spray. The pots were then covered individually with mylar film cages having a netted top and side vents.

The mortality of adult bugs in each treatment was recorded on 1,2 and 3 days after treatment by removing the dead insect(s) at each time of observation. Per cent mortality was worked out at each period. The data were analysed by Completely Randomised block Design (CRD).

3.9.3. Field evaluation of botanicals and insecticides against RBB

Field trials were conducted in two seasons *viz.*, *Samba* 1995-1996 and *Navarai* 1996 to evaluate the efficacy of botanicals and insecticides for the management of RBB, *S. coarctata* (Plate 5).

There were two sets of trials in each season. Trial I had botanicals and neem based formulations. Trial II had commercial formulations of insecticides. Details of the trials and treatments identified for each set are detailed below:

	Season I (<i>Samba</i> 1995-'96) Co 43		Season II (<i>Navarai</i> 1996) IR 64	
	Trial I	Trial II	Trial I	Trial II
Plot size	4x2.5 m	4x2.5 m	4x2.5 m	3x2.4 m
Spacing	15x10 cm	15x10 cm	15x10 cm	15x10 cm
Sown on	30/08/'95	30/08/'95	07/01/'96	07/01/'96
Planted on	26/09/'95	26/09/'95	07/02/'96	07/02/'96
Treatments	8	9	8	9
Replications	3	3	3	3

Plate 5. Management of RBB

A Botanicals

1 *Ipomoea carnea*

2 *Prosopis juliflora*

3 *Vitex negundo*

B Neem and neem based formulations

C Field trial



A



B



C

3.9.3.1. Treatment details of botanicals

Trial I

Treatment	Concentration	Dosage (kg a.i./ha)
Neem oil	3 per cent	-
Neem Seed Kernel Extract(NSKE)	5 per cent	-
<i>Vitex negundo</i> Leaf extract (L E)	10 per cent	-
<i>Ipomoea caenea</i> (L E)	10 per cent	-
<i>Prosopis juliflora</i> (L E)	10 per cent	-
* Neem Azal-T/S	1 per cent	0 025
* Neem Azal-F	5 per cent	0 025
Untreated control	-	-

* Active ingredient known, hence a 1 /ha could be worked out

3.9.3.2. Treatment details of insecticides

Trial II

Treatment	Formulation	Dosage (kg a.i./ha)
Monocrotophos	36 WSC	0 360
Acephate	75 SP	0 469
Chlorpyrifos	20 EC	0 200
Phosphamidon	85 WSC	0 425
Triazophos	40 EC	0 200
Carbaryl	50 WP	0 625
Endosulfan	35 EC	0.525
Fenthion	82 5EC	0 413
Untreated Control	-	-

The treatments were imposed as and when the RBB reached ETL (10 % leaf damage) Pretreatment counts were taken on 20 hills selected at random per plot a day before treatment Treatments were imposed using the hand operated knapsack sprayer (Aspee^R) Five hundred litres of spray fluid was used to treat one hectare Water spray was given to untreated control Post treatment counts were recorded on 1,3,5 and 7 days after treatment The per cent reduction in the leaf damage caused by RBB at each period of observation was worked out with reference to damage before treatment At the time of harvest, individual plot was harvested, thrashed and yield (dry weight) was recorded The yield obtained per plot was converted to hectare basis The data were analysed by Factorial Randomised Block Design (FRBD) The experiments conducted in two seasons were pooled for botanicals and insecticides separately to find out the overall efficacy

3.10. Cost-benefit analysis

Cost-benefit ratios were worked out for individual seasons and pooled analysis for the botanicals and insecticides excluding the plant products viz , *V negundo*, *P juliflora* and *I carnea* Two methods were used for analysis The details are indicated below Method I (Akila Selvaraj and Sundara Babu, 1994)

$$\frac{\text{Treatment yield (kg/ha) x Value of paddy (Rs /kg)}}{\text{Basic cost of cultivation } \pm \text{ cost of protection }^*}$$

* For control yields, cost of protection was excluded and for treatment, it was included

Method II (Heinrichs *et al* , 1981)

$$\frac{\text{Value of treated crop - Value of untreated crop}}{\text{Cost of protection to treated crop}}$$

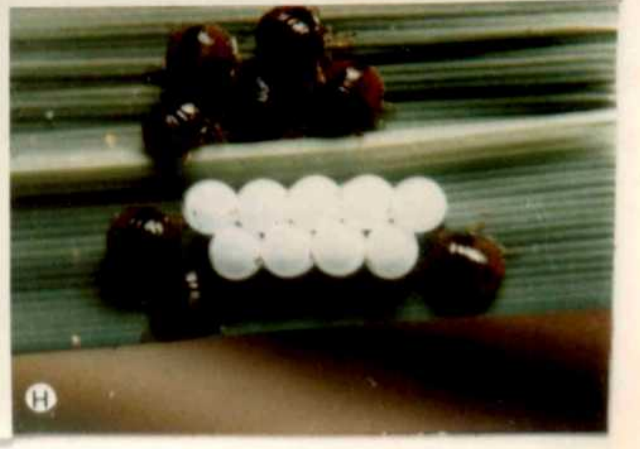
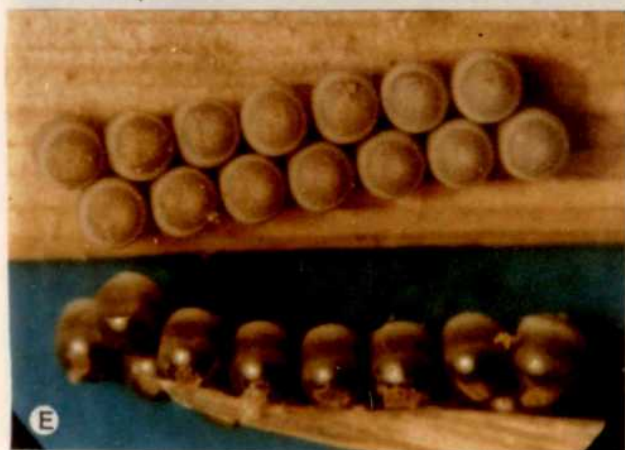
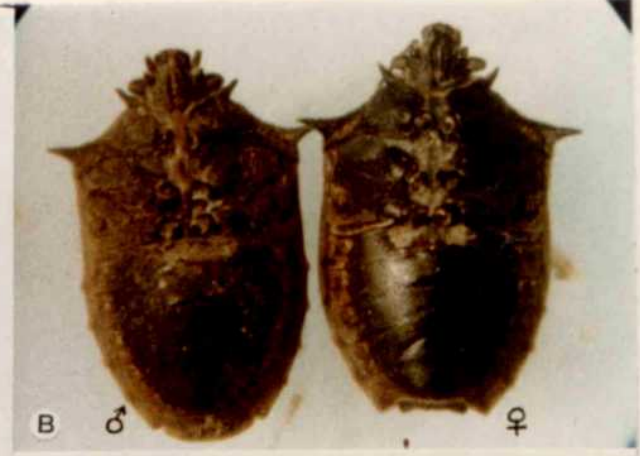
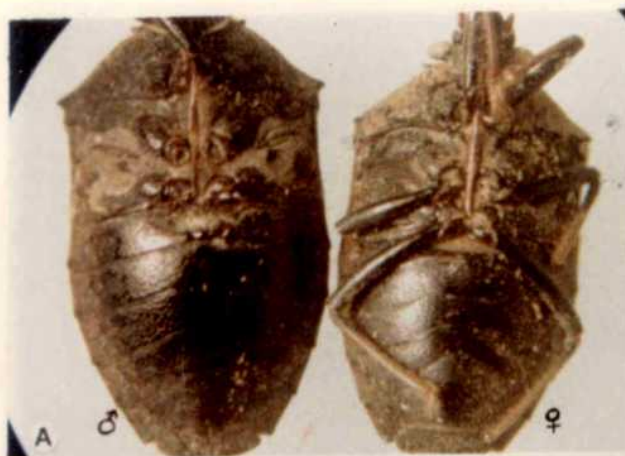
3.11. Statistical Analysis

The data collected on biology were analysed by the procedures described by Panse and Sukhatme (1967) Multiple correlation and regression analyses were performed as per Gomez and Gomez (1984) Life table analysis was carried out as per the methodology given by Birch (1948) and Atwal and Bains (1974) Pooled analysis was used in management trials pertained to field experiments The transformation of original values followed in the various experiments are indicated in the concerned table itself

EXPERIMENTAL RESULTS

Plate 6 Life stage of *Scotinophara*

A	Male and female of <i>S coarctata</i>	(6 x)
B	Male and female of <i>S lurida</i>	(5.25 x)
C	Mating	(1 5 x)
D	Freshly laid eggs	(1 x)
E	Eggs-Magnified	(10 x)
F	Empty egg shells	(12 x)
G	Congregation of nymphs after hatching	(5 x)
H	Dispersal of nymphs	(8 x)



that the female bug was often seen guarding the eggs till they hatched out. The percentage of egg hatch ranged from 68.42 to 95.23 with a mean of 81.82. The incubation period ranged between three and six days with a mean of 4.7 days. The length of the egg was from 0.97 to 0.99 mm with a mean of 0.98 mm while the width ranged from 0.71 to 0.73 mm with a mean of 0.72 mm (Table 1). The newly hatched nymphs congregated on the dorsal surface of the empty egg shells and dispersed in the advanced stage of the first instar. The just hatched nymphs were seen feeding the empty egg shells.

Nymphal stages (Plate 7)

First instar

Body globular in outline, head and thorax reddish brown, antennae reddish brown and posterior flagellar segment was dark brown in colour. Eyes orange red in colour, abdomen, pale yellow with prominent brown markings in the middle and six to seven median scent glands. Legs light yellowish brown in colour. The duration of the first instar ranged from four to seven days with a mean of 5.7 days. The mean length and width of the body was 2.05 and 1.26 mm respectively. The length of antennae and the rostrum was 0.75 and 1.06 mm respectively (Table 2). The first instar nymphs were very active and seen near the base of the young plants and preferred tender plants for feeding.

Second instar

Body subglobular, head and thorax brown, abdomen greenish brown with dark brown bands on the notal region. The duration ranged from six to eight days with a mean of 7.1 days. The length and width of the body was 3.41 and 2.25 mm respectively. The antennal and rostral lengths were 1.22 and 1.88 mm respectively.

Table 1. Parameters on the eggs of *S. coarctata* reared on rice

Particulars	Range	Mean of ten	± SD
Egg rows in a mass (Number)	2-4	2.90	0.70
Eggs in a mass (Number)	14-46	31.40	8.49
Egg hatch (Percentage)	68.42-95.23	81.82	8.47
Egg period (Days)	3-6	4.70	0.78
Length (mm)	0.97-0.99	0.98	0.01
Width (mm)	0.71-0.73	0.72	0.0007

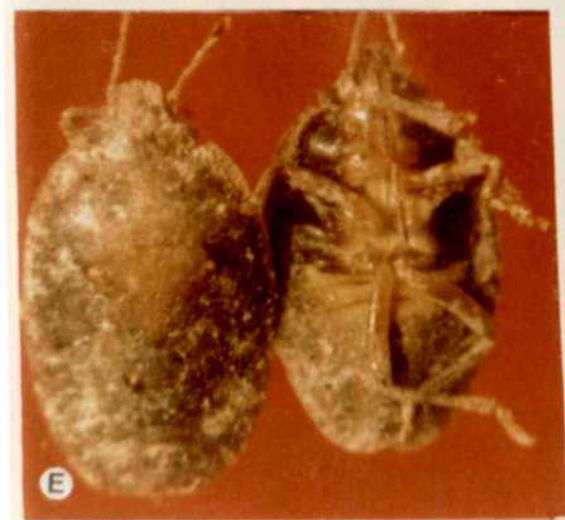
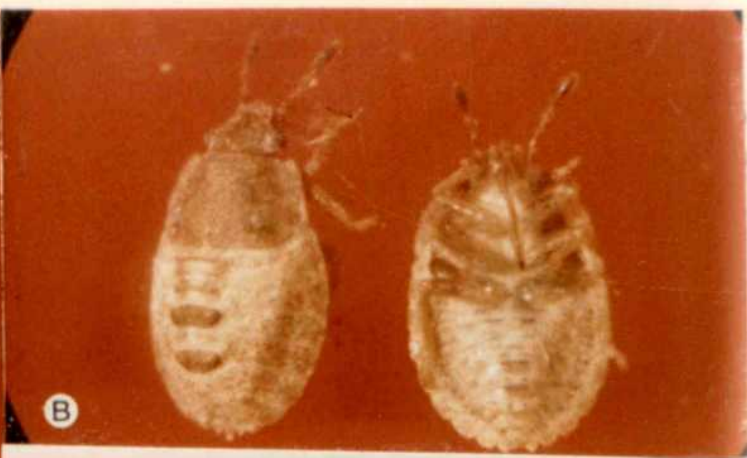
Table 2. Parameters on the nymphs of *S. coractata* reared on rice (Mean of ten \pm SD)

Nymphal instars	Duration (Days)			Body		Antennal		Rostrum	
	Range	Mean	\pm SD	Length (mm)	Width (mm)	Length (mm)	Length (mm)	Length (mm)	Length (mm)
First	4-7	5.70	0.90	2.05 \pm 0.067	1.26 \pm 0.066	0.75 \pm 0.067	1.06 \pm 0.049		
Second	6-8	7.10	0.70	3.41 \pm 0.070	2.25 \pm 0.050	1.22 \pm 0.040	1.88 \pm 0.060		
Third	6-8	6.80	0.87	4.13 \pm 0.078	2.71 \pm 0.104	2.15 \pm 0.050	2.30 \pm 0.077		
Fourth	7-10	8.30	1.05	5.22 \pm 0.060	2.85 \pm 0.050	2.50 \pm 0.077	2.72 \pm 0.098		
Fifth	7-10	8.60	0.80	7.18 \pm 0.098	3.91 \pm 0.054	2.86 \pm 0.049	3.07 \pm 0.078		
Total	33-40	36.20	2.31	--	--	--	--		

Plate 7 Nymphal stage and adults of *Scotinophara*

S coarctata nymphs

A	First instar	(20 x)
B	Second instar	(13 x)
C	Third instar	(12 x)
D	Fourth instar	(10 x)
E	Fifth instar	(8 x)
F	<i>S coarctata</i> adult	(9 x)
G	<i>S lurida</i> adult	(8 x)



Third instar

The third instar resembled the second instar except for the larger body size. Body was dark brown in colour. The duration ranged from six to eight days with a mean of 6.8 days. The length and width of the body was 4.13 and 2.71 mm respectively. The antennal and rostral regions measured 2.15 and 2.30 mm respectively.

Fourth instar

Head, thorax and abdomen were dark brown. Formation of the scutellum was clearly seen. The duration of the nymphs ranged from seven to 10 days with a mean of 8.30 days. The length and width of the body was 5.22 and 2.85 mm respectively. The antennal and rostral regions measured 2.50 and 2.72 mm respectively.

Fifth instar

Body was dark brown and sclerotisation of the scutellar region was more prominent. Nymphs were more active and they preferred grown up tillers for feeding. The duration of the fifth instar ranged from seven to 10 days with a mean of 8.60 days. The length and width of the body was 7.18 and 3.91 mm respectively. The antennal and rostral regions measured 2.86 and 3.07 mm respectively.

Total nymphal period

The RBB passed through five nymphal stadia to become an adult. The nymphs prior to moulting remained motionless by directing their heads downwards. Newly moulted nymphs were white with pale brown dots over the dorsum of the abdomen and preferred to stay in between the clumps of the tillers. The total nymphal period ranged from 33 to 40 days with a mean of 36.2 days.

Adult

Adults were dark brown, with a black head, yellowish brown antennae, reddish to dark brown thorax, dark brown abdomen, reddish brown legs with yellowish tibiae. *S. coarctata* adult was brownish black whereas *S. lurida* was slightly lighter in colour. The per cent emergence of adults ranged from 58.62 to 90.47 with a mean of 74.58. The adult male was 9.57 mm long and 4.65 mm wide. The female bug was slightly larger in size. The length and width was recorded as 9.79 and 5.02 mm respectively. The lengths of the antennae and rostrum were 3.26 and 3.29 mm in male and 3.32 and 3.30 mm in the female respectively (Table 3).

S. coarctata was easily distinguished from *S. lurida* by observing the following characters

S. coarctata backward projection of the tip of the anterolateral spine

S. lurida tip of the anterolateral spine extended beyond the anterior angle of the pronotum (Plate)

The sex of the rice black bug was determined by observing the ventral abdominal segments. In female, the fifth abdominal segment showed a slight bulging in the middle, whereas in the male it was flat.

Sex ratio

Studies on the sex ratio of the adults showed that the production of the females was more than males. The ratio of females to males was 1.0571.

Longevity

The females lived longer than the males. The longevity of the male ranged from 138 to 205 days with a mean of 174.90 days, while in the female it ranged from 183 to 217 days with a mean of 201.8 days.

Mating period

Mating was normally noticed during the morning hours. Repeated mating was observed at an interval of 12 to 14 h. Prior to copulation, the male tapped the abdominal tip of the female with the antennae and forelegs and pushed its genitalia into the female. Both the sexes faced the opposite directions during copulation. To separate, the male jerked its body forward dragging the female. Mating period ranged from two to four days with a mean of 2.5 days.

Pre - oviposition period

Pre - oviposition period of the female ranged from four to six days with a mean of 5.10 days.

Oviposition period

Oviposition began four to six days after copulation. The female bug glued its egg singly forming the first row and at the end of the first row, it turned and laid the eggs by gluing along the sides of the first row. The females rarely laid the eggs in a circular manner by gluing the first egg and keeping this egg as a support. The hind legs were used for guiding the deposition of the eggs. The oviposition period ranged from six to nine days with a mean of 7.80 days.

Table 3. Parameters on the adults of *S. coarctata* reared on rice (Mean of ten \pm SD)

Particulars	Range	Mean	\pm SD	
Adult emergence (Percentage)	58 62-90 47	74 58	10 19	
Longevity (Days)				
Male	138-205	174 90	23 18	
Female	183-217	201 80	10 85	
Sex ratio ($\varphi : \sigma$)		1 0 571		
Mating period (Days)	2-4	2 50	0 67	
Pre-oviposition period (Days)	4-6	5 10	0 70	
Oviposition period (Days)	6-9	7 80	1 07	
Fecundity/female (Number)	127-392	246 90	84 84	
Total (egg-adult days)	37-45	41 30	2 45	
	Body		Antennal	
	Rostrum			
	Length (mm)	Width (mm)	Length (mm)	
	Adult			
Male	9 57 \pm 0 36	4 65 \pm 0 15	3 26 \pm 0 08	3 29 \pm 0 09
Female	9 79 \pm 0 15	5 02 \pm 0 13	3 32 \pm 0 08	3 30 \pm 0 06

Table 4. Parameters on the eggs of *S. coarctata* reared on *E. colona*

Particulars	Range	Mean of ten	± SD
Egg rows in a mass (Number)	1-3	1.90	0.54
Eggs in a mass (Number)	9-33	20.80	6.50
Egg hatch (Percentage)	56.35-73.68	67.61	8.30
Egg period (Days)	4-6	5.10	0.83
Length (mm)	0.95-0.98	0.97	0.01
Width (mm)	0.71-0.73	0.71	0.0009

Fecundity

The fecundity of the female ranged from 127 to 392 with a mean of 246.9 eggs. Egg laying was maximum during her early period of life and ceased after 90 to 100 days (Table 3).

The total duration from egg to adult ranged from 37 to 45 days with a mean of 41.3 days.

4.1.2. Biology on *E. colona*

The biology of *S. coarctata* was also studied on an alternate host, *E. colona*.

Egg

The eggs were laid in masses arranged in longitudinal rows similar to that of rice. Stems were more preferred for egg laying by the females. The number of rows ranged from one to three with a mean of 1.90. In an individual egg mass, the number of eggs ranged from nine to 33 with a mean of 20.80 eggs per mass. The per cent of egg hatch ranged from 56.35 to 73.68 with a mean of 67.61. The incubation period ranged from four to six days with a mean of 5.10 days. The length of the eggs ranged from 0.95 to 0.98 mm with a mean of 0.97 mm while the width ranged from 0.71 to 0.73 mm with a mean of 0.71 mm (Table 4).

Nymphal stages

The descriptions on the individual instar were similar to that of rice.

First instar

The duration of the first instar nymphs ranged from six to eight days with a mean of 7.50 days. The length and width of the body was 1.90 and 1.13 mm respectively. The mean length of the antennae and rostrum was 0.69 and 1.01 mm respectively (Table 5).

Table 5. Parameters on the nymphs of *S. coarctata* reared on *E. colona* (Mean of ten \pm SD)

Nymphal instars	Duration (Days)			Body		Antennal		Rostrum	
	Range	Mean	\pm SD	Length (mm)	Width (mm)	Length (mm)	Length (mm)	Length (mm)	Length (mm)
First	6-8	7.50	0.50	1.90 \pm 0.12	1.13 \pm 0.06	0.69 \pm 0.05	1.01 \pm 0.07		
Second	7-9	8.20	0.98	3.24 \pm 0.14	2.05 \pm 0.07	0.99 \pm 0.05	1.75 \pm 0.06		
Third	7-10	8.80	0.87	4.01 \pm 0.07	2.54 \pm 0.08	1.93 \pm 0.08	2.20 \pm 0.09		
Fourth	9-10	9.50	0.50	5.09 \pm 0.07	2.90 \pm 0.06	2.54 \pm 0.08	2.73 \pm 0.05		
Fifth	7-10	8.00	1.00	6.98 \pm 0.07	3.77 \pm 0.06	2.73 \pm 0.09	2.97 \pm 0.06		
Total	37-44	42.00	1.09	--	--	--	--		

Second instar

The duration ranged from seven to nine days with a mean of 8.20 days. The length and width of the body was 3.24 and 2.05 mm respectively. The mean length of the antennae and rostrum was 0.99 and 1.75 mm respectively.

Third instar

Significant differences were not observed between the second and third instars except for the body size. The duration ranged from seven to 10 days with a mean of 8.80 days. The length and width of the body was 4.01 and 2.54 mm respectively. The mean length of the antennae and rostrum was 1.93 and 2.20 mm respectively.

Fourth instar

The duration required to pass from the fourth to the fifth instar ranged from nine to 10 days with a mean of 9.50 days. The mean length and width of the body was 5.09 and 2.90 mm respectively. The mean length of the antennae and rostrum was 2.54 and 2.73 mm respectively.

Fifth instar

Fifth instar nymphs were very active and they preferred the base of the grown up tillers. It took seven to nine days with an average of eight days to become an adult. The length and width of the body was 6.98 and 3.77 mm respectively. The mean length of the antennae and rostrum was 2.73 and 2.97 mm respectively.

Total nymphal period

As in rice, *S. coarctata* passed five nymphal stadia which were completed in 37 to 44 days with a mean of 42 days.

Adult

There were no differences observed in the morphology of the adults reared on two hosts namely rice and *E colona*. The per cent adult emergence ranged from 40.00 to 71.42 with a mean of 53.58. The adult male was 8.99 mm long and 4.56 mm wide while the female was 9.58 mm long and 4.84 mm wide. Generally the females were larger in size. The mean length of the antennae and rostrum was 3.10 and 2.98 mm respectively in the male while it was 3.2 and 3.14 in the female (Table 6).

Sex ratio

The black bugs reared on *E colona* showed the production of more females than males. The sex ratio was 1.0418.

Longevity

Females had a longer life which ranged from 139 to 203 days with a mean of 165.8 days, while the male longevity ranged from 127 to 201 days with a mean of 160.7 days.

Mating period

Mating was observed during day time and repeated as in rice. The duration ranged from one to three days with a mean of 1.7 days.

Pre oviposition period

The pre oviposition period ranged from three to five days with a mean of 3.8 days.

Oviposition period

The females started to lay eggs three to five days after mating and continued for four to six days with a mean of 4.9 days. No difference was observed in the egg laying pattern on rice and *E colona*.

Table 6. Parameters on the adults of *S. coarctata* reared on *E. colona* (Mean of ten \pm SD)

Particulars	Range	Mean	\pm SD
Adult emergence (Percentage)	40 00-71 42	53 58	8 69
Longevity (Days)			
Male	127-201	160 70	23 83
Female	139-203	165 80	17 36
Sex ratio (♀ : ♂)		1 0 418	
Mating period (Days)	1-3	1 70	0 64
Pre-oviposition period (Days)	3-5	3 80	0 75
Oviposition period (Days)	4-6	4 90	0 54
Fecundity/female (Number)	119-212	163 50	32 56
Total (egg-adult days)	42-49	46 80	1 93
	Body	Antennal	Rostrum
	Length (mm)	Width (mm)	Length (mm)
Adult			
Male	8 99 \pm 0 07	4 56 \pm 0 17	3 10 \pm 0 09
Female	9 58 \pm 0 06	4 84 \pm 0 09	3 20 \pm 0 09

Fecundity

The fecundity ranged from 119 to 212 eggs with a mean of 163.5 eggs per female during her life time

The total duration from egg to adult ranged from 42 to 49 days with a mean of 46.80 days

4.1.3. Comparative biology of *S. coarctata* on two host plants

Observations on the comparative biology of *S. coarctata* on two hosts viz, rice and *E. colona* showed significant variations. Significant differences were noticed in the egg rows and the eggs per egg mass. Incubation period of the eggs was shorter on rice compared to *E. colona*. The duration of the nymphal stadia was shorter on rice compared to the weed host except for the fifth instar in which the duration was slightly longer. Total nymphal period and developmental period from egg to adult were longer on *E. colona*. In rice, there was significantly increased mating, pre oviposition and oviposition periods and a concomitant increase in fecundity and egg hatchability. The per cent adult emergence was also higher on rice than on *E. colona*. However, on both the hosts, more females were produced than males, and the sex ratio was more than 1:1 in favour of females. Females also tended to live longer than the males on both the hosts though the longevity of both the sexes were significantly higher on rice than on *E. colona*. There was only a slight increase in the biometrics of the life stages from egg to adult reared on rice.

4.2. Damage

4.2.1. Damage on rice

Both the nymphs and adults remained at the base of the plant just above the water level and sucked the sap. It caused three types of damage on rice and *E. colona*. The lower most leaves just above the water level turned orange-yellow in colour.

Plate 8. RBB Damage on rice

- A RBB at the base of hill
- B RBB at the top of hill
- C RBB on earheads
- D Initial leaf damage
- E Complete leaf damage
- F "Bug burn" symptom
- G Dead heart (✓)
- H White ears
- I RBB on milky grains



When the infestation was high, the infested plants became stunted, showed wilting symptoms and the plants were killed outright. This symptom was called 'bug burn'. Rice blackbug infested fields had a characteristic buggy odour and the presence of the pest could be easily identified by this nature, besides the bug burn symptom. During active tillering stage, besides leaf damage, the central shoot dried up resulting in the production of deadhearts which could not be pulled out easily as in the case of stem borer infestation. The central shoot had not shown any decay but had minute feeding punctures due to insertion of stylets. The damaged tillers became stunted, wilted and finally dried up. When the crop was in the post-flowering stage, the affected plants produced 'white ear' similar to that of the rice yellow stem borer but which could not be pulled out easily. During evening hours, it was also observed that RBB sucked the sap from milky grains. In all the cases, the first expression was leaf yellowing. It was difficult to collect the nymphs and adults from the infested crop. Once we entered the field, the nymphs and adults moved very deep into the tillers or into the mud. Insects present in the fields where the water level was low tended to migrate to fields having excess irrigation or to swampy and ill drained fields. Wherever the crops were submerged more, the bugs were seen. During day time, the adults remained at the base of the plants and during evening hours and night, they were seen on the leaves and migrated to adjacent fields. The RBB nymphs and adults had not spared even the nursery. Whenever the seed rate was higher and the plant stand was denser, the infestation was also higher in those nurseries. The affected plants in the nursery dried up (Plate 8).

4.2.2. Damage on *E.colona*

The symptoms were similar to that on rice (Plate 9). The nymphs and adults were seen congregating in large numbers on the weed plants near the irrigation channels and on the sides of the bunds where the water availability was plenty. During harvest, nymphs and adults migrated to the weed host, found along the field bunds. Apart from *E.colona*,

PLATE 9. RBB Damage on E. colona



Damaged leaves and earheads



PLATE 10. RBB Damage

C. rotundus



Leaf damage and white ears

C. difformis



White ear

RBB also infested the other weed hosts namely *Cyperus rotundus* and *C difformis*. The damage symptoms were similar to that on *E colona*. The leaf damage and white ears in *C.rotundus* and white ear in *C difformis* are presented in Plate 10

4.3. Seasonal occurrence and abundance of *S. coarctata* and its natural enemies

The mean incidence of the nymphs and adults of the *S coarctata*, mean number of egg masses laid, per cent parasitisation of egg masses by *Telenomus triptus* and infection of nymphs and adults by *Metarhizium anisopliae* over *Samba, Navari and Sornavari* seasons for the years 1993 to 1995 are summarised in Table 7. The various bio control agents observed in the field are depicted in Plate 11

4.3.1. Seasonal incidence of *S. coarctata* and influence on its natural enemies

4.3.1.1. *Samba*

The mean incidence of *S coarctata* adults was maximum during 1995 (139.90) and minimum during 1994 (122.67) (Table 7). The mean differences observed in the population between 1993 and 1994, 1993 and 1995 and 1994 and 1995 were 3.42, -13.81 and -17.23 respectively. The differences in the incidence between 1993 and 1995 and 1994 and 1995 were statistically significant while between 1993 and 1994 was not significant.

The mean nymphal population over the years varied from 120.58 (1994) to 189.00 (1993). The population was significantly more during 1993 compared to 1994 and 1995 and that in 1995 was significantly more compared to 1994, the corresponding mean differences being 68.42 (1993 and 1994), 51.5 (1993 and 1995) and -16.92 (1995 and 1994). However, the difference of 16.92 nymphs in favour of the 1995 population was non-significant compared to the population in 1994.

Plate 11. Biocontrol agents on RBB

- A Egg parasitoid, *Telenomus triptus*
- B Parasitoid emerged egg shells (10 x)
- C Water scorpion preying on RBB
- D Spider preying on RBB

M.anisopliae infection

- E Fifth instar - initial symptom (2 x)
- F Fifth instar advanced symptom (Ventral view) (11 x)
- G Fifth instar advanced symptom (Dorsal view) (12 x)



Table 7. Seasonal population of RBB and its natural enemies*

Season and cultivar	Mean incidence (Number) \pm SD		Egg masses collected		<i>T. triptus</i> parasitisation (%) \pm SD		<i>M. anisopliae</i> infection (%) \pm SD	
	Adults	Nymphs	Number \pm SD	Egg masses	paratitisation (%) \pm SD	Eggs	Adults	Nymphs
Cu 43								
Samba								
1993	126.09 \pm 11.96	189.00 \pm 25.36	18.09 \pm 3.31	21.36 \pm 3.03	15.52 \pm 3.45	12.24 \pm 1.97	14.63 \pm 2.76	
1994	122.67 \pm 24.23	120.58 \pm 23.84	34.83 \pm 6.78	43.85 \pm 6.79	9.71 \pm 2.14	7.48 \pm 1.49	7.44 \pm 2.12	
1995	139.90 \pm 19.08	137.50 \pm 12.01	23.70 \pm 4.38	15.35 \pm 2.82	7.58 \pm 1.28	11.03 \pm 2.59	10.40 \pm 2.92	
TKM 9								
Navarai								
1993	120.78 \pm 18.68	113.89 \pm 15.52	28.89 \pm 6.40	47.19 \pm 5.96	18.98 \pm 4.27	1.45 \pm 0.72	4.73 \pm 1.99	
1994	125.56 \pm 12.99	118.22 \pm 20.54	26.56 \pm 6.40	28.20 \pm 8.08	11.02 \pm 3.68	4.64 \pm 1.53	7.01 \pm 2.97	
1995	138.00 \pm 19.11	134.90 \pm 12.45	16.20 \pm 2.72	17.11 \pm 4.33	6.52 \pm 2.08	3.00 \pm 1.30	7.16 \pm 2.20	
ADT 36								
Sornavari								
1993	199.20 \pm 25.31	228.01 \pm 25.63	45.30 \pm 9.11	42.92 \pm 8.32	12.04 \pm 3.07	2.48 \pm 1.01	3.13 \pm 1.02	
1994	166.22 \pm 21.28	172.56 \pm 20.19	24.56 \pm 2.63	17.47 \pm 3.89	7.38 \pm 1.25	2.79 \pm 0.96	5.75 \pm 1.23	
1995	104.78 \pm 11.67	153.56 \pm 9.83	18.78 \pm 1.81	22.67 \pm 5.01	8.77 \pm 1.72	6.86 \pm 2.63	6.55 \pm 2.07	

* Mean of 50 observations

Regression on adult Vs nymphal population :

$$y = 24.22 + 0.92x$$

(t = 18.40; correlation coefficient 0.71)

Regression egg masses Vs total number of eggs :

$$y = 16.03x - 55.67$$

(Correlation and regression coefficients 0.99)

Table 8. Seasonal incidence of RBB and the influence of natural enemies (*Samba*) over years

Parameters [@]	Mean difference between		
	1993-1994	1994-1995	1993-1995
Population of adults (Number)	3.42	-17.23	-13.81
t	0.28 ^{NS}	2.31*	2.62**
Population of nymphs (Number)	68.42	-16.92	51.50
t	3.21*	1.09 ^{NS}	3.29*
Egg masses laid (Number)	-16.74	11.13	-5.61
t	2.71*	2.34*	0.90 ^{NS}
Parasitisation of egg masses by <i>T. triptus</i> (%)	-22.49	28.50	6.01
t	2.67*	3.19*	0.88 ^{NS}
Infection of adults by <i>M. anisopliae</i> (%)	4.76	-3.55	1.21
t	1.95 ^{NS}	0.89 ^{NS}	0.71 ^{NS}
Infection of nymphs by <i>M. anisopliae</i> (%)	7.19	-2.96	4.23
t	2.17 ^{NS}	1.19 ^{NS}	1.23 ^{NS}

@ Mean of 50 observations

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

The number of egg masses laid was 18.09, 34.83 and 23.70 respectively for the years 1993 through 1995. The differences were -16.74, 11.13 and -5.61 respectively between 1993 and 1994, 1994 and 1995 and 1993 and 1995. The egg mass density observed during 1994 was significantly more compared to 1993 and 1995. The mean difference in the egg masses during 1993 and 1995 was not significant.

The per cent parasitisation of the egg masses by the parasitoid *T. triptus* was 21.36 during 1993, 43.85 during 1994 and 15.35 during 1995. The parasitisation was significantly higher during 1994 and 1993 than during 1995. The difference in parasitization was the highest in 1994.

The infection of adult bugs by the fungus *M. anisopliae* ranged from 7.48 per cent during 1994 to 12.24 during 1993. The differences observed in the infection of adults during the years 1993 to 1995 were not significant. Similarly the infection of nymphal population, though ranged from 7.44 per cent in 1994 to 14.63 per cent in 1993, the differences were not significant. The mean differences in nymphal infection by the fungus ranged from -2.96 to 7.19 per cent (Table 8).

4.3.1.2. *Navarai*

The mean incidence of adult bugs during *Navarai* season showed an increment over 1993 through 1995. The mean number of adults recorded for the years was 120.78 (1993), 125.56 (1994) and 138.00 (1995) (Table 7). The difference in the population between years of comparison was, however not significant. The differences ranged between 4.78 and 17.22 bugs.

The maximum nymphal population was recorded during 1995 (134.90) compared to 1993 (113.89) and 1994 (118.22). The mean difference in the nymphal population between the years of comparison was not significant.

Table 9. Seasonal incidence of RBB and the influence of natural enemies (*Navarai*) over years

Parameters [@]	Mean difference between		
	1993-1994	1994-1995	1993-1995
Population of adults (Number)	-4.78	-12.44	-17.22
t	0.19 ^{NS}	0.94 ^{NS}	1.16 ^{NS}
Population of nymphs (Number)	-4.33	-16.68	-21.01
t	0.18 ^{NS}	0.85 ^{NS}	1.00 ^{NS}
Egg masses laid (Number)	2.33	10.36	12.69
t	0.16 ^{NS}	1.57 ^{NS}	1.96 ^{NS}
Parasitisation of egg masses by <i>T. triptus</i> (%)	18.99	11.09	30.08
t	2.48*	1.30 ^{NS}	3.31*
Infection of adults by <i>M. anisopliae</i> (%)	-3.19	1.64	-1.55
t	2.22 ^{NS}	0.75 ^{NS}	1.50 ^{NS}
Infection of nymphs by <i>M. anisopliae</i> (%)	-2.28	-0.15	-2.43
t	0.50 ^{NS}	0.43 ^{NS}	1.00 ^{NS}

@ Mean of 50 observations

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

The mean number of egg masses laid was in decrement from the value recorded for 1993 (28.89). Egg masses observed during 1994 were 26.56 and in 1995 it was 16.20. However, the differences noticed between the years of observation were not significant.

The per cent parasitisation of egg masses was the highest (47.19) during 1993 and showed a trend similar to the number of egg masses laid. The differences in the parasitisation of egg masses of 18.99 per cent observed between 1993 and 1994 and the one between 1993 and 1995 (30.08%) were significant, while the difference observed between the years 1994 and 1995 (11.09) was not significant.

The infection of *M.anisopliae* on the adult bugs was more (4.64%) during 1994, followed by 1995 (3.00%) and 1993 (1.45%). The differences observed over the years were not significant. The infection on the nymphal population ranged from 4.73 per cent in 1993 to 7.16 per cent in 1995. The marginal differences showed statistical parity (Table 9).

4.3.1.3. *Sornavari*

The incidence of nymphs and adults and the number of egg masses observed was in decrement over the years 1993 to 1995. The mean adult population was 199.20 during 1993; 166.22 during 1994 and 104.78 during 1995. The mean population of nymphs was 228.01, 172.56 and 153.56 for the years 1993, 1994 and 1995 respectively. The mean number of egg masses laid during the corresponding years was 45.30, 24.56 and 18.78 respectively (Table 7). A difference of 32.98 adult bugs was observed between 1993 and 1994 and the same between the years 1994 and 1995, was 61.44. Between the years 1993 and 1995, the difference in adult population recorded was 94.42. The population observed during 1993 and 1994 was significantly more compared to 1995 while in 1993 the

population had not significantly varied from the 1994 population. The nymphal population observed during 1993 was significantly more than the population observed during 1994 and 1995. Similarly the population recorded during 1994 was significantly more than that in 1995.

With regard to the differences in the number of egg masses laid, a difference of 20.74 between 1993 and 1994 and 26.52 between 1993 and 1995 were observed significant, while the difference of 5.78 egg masses between 1994 and 1995 was not significant over the one observed during 1994.

The per cent parasitisation of the egg masses was highest in 1993 (42.92) and lowest in 1994 (17.47). The difference in parasitisation during 1993 compared to 1994 was 25.45 per cent and it was 20.25 per cent between 1993 and 1995. These differences were highly significant. A difference of -5.20 per cent parasitisation observed during 1994 over 1995 was not, however, significant.

The fungal infection on the adult bugs was more or less similar during 1993 and 1994 (2.48 and 2.79%). The infection of 6.86 per cent observed during 1995 was significantly more compared to those recorded during the earlier years. The mean differences in the infection observed between 1994 and 1995 and between 1993 and 1995 were significant, while the difference observed between 1993 and 1994 was not significant.

The trend of infection on the RBB nymphs was increasing from 1993 through 1995. The per cent infection observed during these three years was 3.13, 5.75 and 6.55 respectively. While the highest infection during 1995 was significantly more compared to 1993, the difference over 1994 was not significant (Table 10).

Table 10. Seasonal incidence of RBB and the influence of natural enemies (Sornavari) over years

Parameters [@]	Mean difference between		
	1993-1994	1994-1995	1993-1995
Population of adults (Number)	32.98	61.44	94.42
t	2.05 ^{NS}	5.27**	5.14**
Population of nymphs (Number)	55.45	19.00	74.45
t	2.70*	2.92*	3.47*
Egg masses laid (Number)	20.74	5.78	26.52
t	2.36*	1.39 ^{NS}	2.93*
Parasitisation of egg masses by <i>T. triptus</i> (%)	25.45	-5.20	20.25
t	4.28**	2.05 ^{NS}	3.51*
Infection of adults by <i>M. anisopliae</i> (%)	-0.31	-4.07	-4.38
t	0.06 ^{NS}	3.50*	2.85*
Infection of nymphs by <i>M. anisopliae</i> (%)	-2.62	-0.80	-3.42
t	1.48 ^{NS}	1.15 ^{NS}	2.84*

@ Mean of 50 observations

NS - Not significant

* - Significant at 5% level

** - Significant at 1% level

The adult bug population was regressed against the nymphal population (n=180) and the regression equation was:

$$y=24.22+0.92x$$

The regression coefficient was highly significant (t=18.40). The corresponding correlation coefficient was 0.71. Similarly the density of egg masses and the total number of eggs were analysed. The regression equation was:

$$y=16.03x-55.57$$

The regression and correlation coefficients (0.99) were highly significant (Table 7).

4.3.2. Influence of weather factors on *S. coarctata*

The influence of weather factors *viz.*, relative humidity (x_1), maximum temperature (x_2), minimum temperature (x_3), rainfall (x_4) and radiation (x_5) computed for respective Standard Meteorological Weeks (SMW) were regressed over the incidence of *S. coarctata* for the years 1993 to 1996 (upto 17 SMW in 1996). The regression equation was as follows:

$$y=-566.577 + 0.178 x_1 + 6.809 x_2 + 9.482 x_3 + 0.580 x_4 + 0.609 x_5$$

The R^2 value of 0.0924 was highly significant. However, the individual regression coefficients of the variants were not significant which explained the additive effects of the variants. The correlation matrix of the weather factors are given in table 11.

4.3.2.1. Influence of weather factors on *S. lurida*

The multiple regression analysis of weather factors *viz.*, relative humidity (x_1), maximum temperature (x_2), minimum temperature (x_3), rain fall (x_4) and radiation (x_5) was worked out using the mean data of the SMW of the years 1993 through 1996 (upto 17 SMW for 1996) against *S. lurida*. The study indicated that the combined effect of relative

Table 11. Interrelationship of weather factors on RBB

	RH (%) x ₁	Temperature (°C)		Rainfall (mm) x ₄	Radiation (cal/cm ² /day) x ₅
		Maximum x ₂	Minimum x ₃		
x ₁	1.000	-0.768	-0.607	0.302	-0.559
x ₂		1.000	0.760	-0.190	0.618
x ₃			1.000	0.150	0.095
x ₄				1.000	-0.485
x ₅					1.000

Regression equation :

S. coarctata

$$y = -566.577 + 0.178x_1 + 6.809x_2 + 9.482x_3 + 0.580x_4 + 0.609x_5$$

$$R^2 = 0.0924^{**}$$

S. lurida

$$y = -33.405 + 0.172x_1 - 0.316x_2 + 0.934x_3 - 0.002x_4 + 0.025x_5$$

$$R^2 = 0.1713^{**}$$

* - Significant at 5% level

** - Significant at 1% level

humidity, minimum temperature, maximum temperature, rainfall and radiation had significant influence over the insect ($R^2=0.1713$). However, among the weather parameters, minimum temperature and radiation alone had a positive and significant effect on *S. lurida* while the influence of other factors was not significant. The regression equation is given below:

$$y = -33.405 + 0.172x_1 - 0.316x_2 + 0.934^*x_3 - 0.002x_4 + 0.025^*x_5$$

The correlation matrix of the weather factors are given in table 11.

4.3.3. Correlation of RBB with predators and weather factors

The population of RBB was correlated with a number of independent factors like leaf damage, spiders, coccinellids, carabids, staphylinids, mirids and weather parameters namely relative humidity, maximum temperature, minimum temperature, rainfall and radiation. Leaf damage had a positive and significant relationship to RBB population in all the cultivars tested. In rice cultivar Co 45, the correlation coefficients for leaf damage, staphylinids and mirids alone were significant showing a positive relationship. In White Ponni, RBB population was found to significantly influence leaf damage, spider population and mirid populations. Among the predators, positive and significant relationship was observed with spiders in White Ponni and TKM 9 while the coccinellids showed a similar relationship. Only in ADT 36, carabids established a positive and significant relationship with RBB population in TKM 9. Significant, positive relationship of staphylinid was observed only in Co 45, while mirids showed that relationship in Co 45, White Ponni and TKM 9. In short, the leaf damage was directly correlated to RBB population in all the cultivars tested. Among the weather factors except maximum temperature in ADT 37 and TKM 9, and the minimum temperature in ADT 37, none of the correlation coefficients was significant. Both maximum and minimum temperatures had

Table 12. Correlation of RBB population with other parameters

Parameters	Cultivar					
	Co 45	W.Ponni	ADT 37	TKM 9	ADT 36	PMK 1
Leaf damage	0.773**	0.983*	0.810**	0.875**	0.787**	0.821*
Spiders	-0.149	0.618*	-0.041	0.457*	0.155	-0.146
Coccinellids	0.231	0.321	0.230	0.166	0.309*	0.150
Carabids	0.230	0.137	0.262	0.513**	0.292	0.255
Staphylinids	0.327*	0.483	0.060	0.069	0.102	-0.435
Mirids	0.298*	0.605*	-0.056	0.317*	-0.073	NC
Maximum temperature	0.009	-0.522	0.438*	0.266*	-0.094	0.694
Minimum temperature	-0.182	-0.371	0.589*	0.119	-0.020	0.200
Relative humidity	-0.005	0.477	-0.356	-0.047	0.084	0.239
Rainfall	-0.177	-0.005	-0.028	-0.016	0.213	0.267
Radiation	0.078	-0.404	0.099	0.208	-0.119	0.369

NC - Not correlated

* - Significant at 5% level

** - Significant at 1% level

positive influence on RBB population in ADT 37. In TKM 9, only the maximum temperature had a positive influence, In short, RBB population failed to have any significant relationship with the weather factors tested (Table 12).

4.3.3.1. Correlation of leaf damage with predators and weather factors

Correlations were made between leaf damage due to RBB and predator population as well as leaf damage with weather factors. A positive correlation was observed with coccinellids, carabids, staphylinids and mirids in Co 45 in which maximum and minimum temperatures had significant negative associations with leaf damage. Maximum temperature had significant but negative relationship with leaf damage in both Co 45 and White Ponni. Minimum temperature had a positive correlation in PMK 1 and ADT 37 but a negative correlation in Co 45. The correlation coefficients obtained for other weather factors were not significant. Spider population and carabids had significant positive correlations in TKM 9. In ADT 36 none of the variants had shown significant correlation (Table 13).

4.3.4. Multiple regression analysis of RBB population with stage of the crop and weather parameters

The weather factors and stage of the crop were regressed against populations of RBB in the rice cultivars *viz.*, Co 45, ADT 37, PMK 1, TKM 9 and White Ponni. In Co 45, White Ponni and PMK 1, the dependent variable, RBB population per hill had not regressed significantly against the independent variables *viz.*, stage of the crop (x_1), maximum temperature (x_2), minimum temperature (x_3), relative humidity (x_4), rainfall (x_5) and radiation (x_6). The regression was significant in ADT 37 and TKM 9. However, they gave a low R^2 value of 0.420 and 0.290 respectively. The regression equation for these two cultivars were as follows:

Table 13. Correlation of leaf damage with predators and weather factors

Parameters	Cultivar					
	Co 45	W.Ponni	ADT 37	TKM 9	ADT 36	PMK 1
Spiders	0.061	0.656*	-0.132	0.380*	0.247	-0.032
Coccinellids	0.421*	0.390	-0.025	0.147	0.206	-0.071
Carabids	0.379*	0.116	0.186	0.443*	0.138	-0.050
Staphylinids	0.496*	0.395	0.250	0.076	0.123	-0.287
Mirids	0.513*	0.609*	-0.020	0.380*	-0.024	NC
Maximum temperature	-0.298*	-0.583*	0.324	0.223	-0.252	0.373
Minimum temperature	-0.403*	-0.375	0.565*	0.054	-0.149	0.770*
Relative humidity	0.177	0.541	-0.226	-0.034	0.093	-0.070
Rainfall	0.013	0.012	0.086	-0.003	0.222	-0.454
Radiation	-0.119	-0.467	-0.051	0.259	-0.192	0.049

NC - Not correlated

* - Significant at 5% level

** - Significant at 1% level

ADT 37:

$$y = -0.197 - 0.169 x_1 - 0.223 x_2 + 0.542 x_3 - 0.221 x_4 - 0.004 x_5 - 0.0007x_6$$

TKM 9:

$$y = -13.809 + 0.029 x_1 + 0.259 x_2 - 0.049 x_3 + 0.067 x_4 + 0.0007 x_5 + 0.002 x_6$$

In ADT 37, among the independent variables, the contribution of minimum temperature alone was significant which had positively influenced the population of RBB per hill, while in TKM 9 none of the weather parameters influenced the number of bugs per hill significantly but the stage of the crop alone showed significant positive influence over the population of RBB (Table 14).

4.3.4.1. Multiple regression analysis of leaf damage with stage of the crop and weather parameters

The leaf damage was regressed against stage of the crop (x_1), maximum temperature (x_2), minimum temperature (x_3), relative humidity (x_4), rainfall (x_5) and radiation (x_6). The multiple regression analysis in respect of White Ponni, ADT 37 and PMK 1 was not significant. In TKM 9 and Co 45, the regression analysis was significant. The R^2 values of 0.284 for TKM 9 and 0.355 for Co 45 were recorded. The regression equations were as follows:

Co 45:

$$y = 64.937 + 0.084 x_1 + 0.390 x_2 - 1.830 x_3 - 0.262 x_4 - 0.011 x_5 - 0.206x_6$$

TKM 9:

$$y = -47.911 + 0.138 x_1 + 0.759 x_2 - 0.250 x_3 + 0.196 x_4 + 0.031 x_5 + 0.024x_6$$

Table 14. Multiple regression analysis of RBB population with stage of crop and weather parameters

Variable (x)	Partial regression coefficients 'b'				
	Cultivars				
	Co 45	ADT 37	PMK 1	TKM 9	White ponni
Stage of crop	0.1850*	-0.1690	0.1210	0.0290*	0.9890
Maximum temperature	0.2420	-0.2230	3.8170	0.2590	0.2070
Minimum temperature	-0.3620	0.5420*	-1.3690	-0.0490	1.0470
Relative humidity	0.0050	-0.2210	0.2780	0.0670	-0.3100
Rainfall	-0.0050	-0.0040	-0.0550	0.0007	-0.0170
Radiation	-0.0050	-0.0007	-0.2470	0.0020	-0.2700
Constant 'a'	3.2050	-0.1970	-113.3700	-13.8090	4.9490
R ²	0.2440	0.4200	0.6810	0.2880	0.5930

* - Significant at P=0.05 based on 't' values

Regression equation :

ADT 37:

$$y = -0.197 - 0.169x_1 - 0.223x_2 + 0.542x_3 - 0.221x_4 - 0.004x_5 - 0.0007x_6$$

TKM 9 :

$$y = -13.809 + 0.029x_1 + 0.259x_2 - 0.049x_3 + 0.067x_4 + 0.0007x_5 + 0.002x_6$$

In Co 45, the stage of the crop positively and significantly influenced the leaf damage but minimum temperature had a significant negative coefficient. All other independent variables had not influenced the leaf damage significantly. In TKM 9, only the stage of the crop showed significant positive influence while the influence of others was not significant (Table 15).

4.3.5. Rice black bug and its damage in farmers' field

The RBB incidence and the related leaf damage, dead heart and white ear symptoms were observed over three years on three cultivars viz., White Ponni (*Samba*), ADT 36 (*Navarai*) and IR 50 (*Sornavari*).

4.3.5.1. White Ponni (*Samba*)

This variety showed higher population during 52, 66, 73 and 87 DAT and the population level during these observations was on par. Minimum population of 1.53 per hill was observed at 17 DAT. The population increased with the age of the crop. Leaf damage was maximum (16.39 %) at 66 DAT and minimum during 17 DAT (1.85 %). Dead hearts were seen from 38 DAT upto 80 DAT. The per cent dead heart ranged from 3.02 (13 DAT) to 7.45 (80 DAT). White ear damage was observed between 73 and 87 DAT which ranged from 6.92 to 8.61 per cent (Fig.3).

4.3.5.2. ADT 36 (*Navarai*)

The mean RBB incidence on this cultivar was minimum on 17 DAT (0.78/hill) and maximum at 66 DAT (2.72/hill) beyond which the observed difference in the levels was not significant. The leaf damage suffered by this cultivar was maximum at 59 DAT (7.43%). Thereafter, it showed a decline and it was 5.00 per cent at 87 DAT. The dead heart symptom was observed between 38 and 80 DAT. The trend was increasing from

Table 15. Multiple regression analysis of leaf damage with stage of crop and weather parameters

Variable (x)	Partial regression coefficients 'b'				
	Cultivars				
	Co 45	ADT 37	PMK 1	TKM 9	White ponni
Stage of crop	0.084*	0.160	0.128	0.138*	0.348
Maximum temperature	0.390	-1.468	2.923	0.759	-0.730
Minimum temperature	-1.830*	2.358*	0.325	-0.250	4.958
Relative humidity	-0.262	0.129	0.068	0.196	-1.268
Rainfall	-0.011	-0.023	0.020	0.031	-0.069
Radiation	-0.206	0.004	-0.032	0.024	-0.902
Constant 'a'	64.937	-10.627	-103.963	-47.911	46.770
R ²	0.355	0.393	0.852	0.284	0.641

* - Significant at P=0.05 based on 't' values

Regression equation :

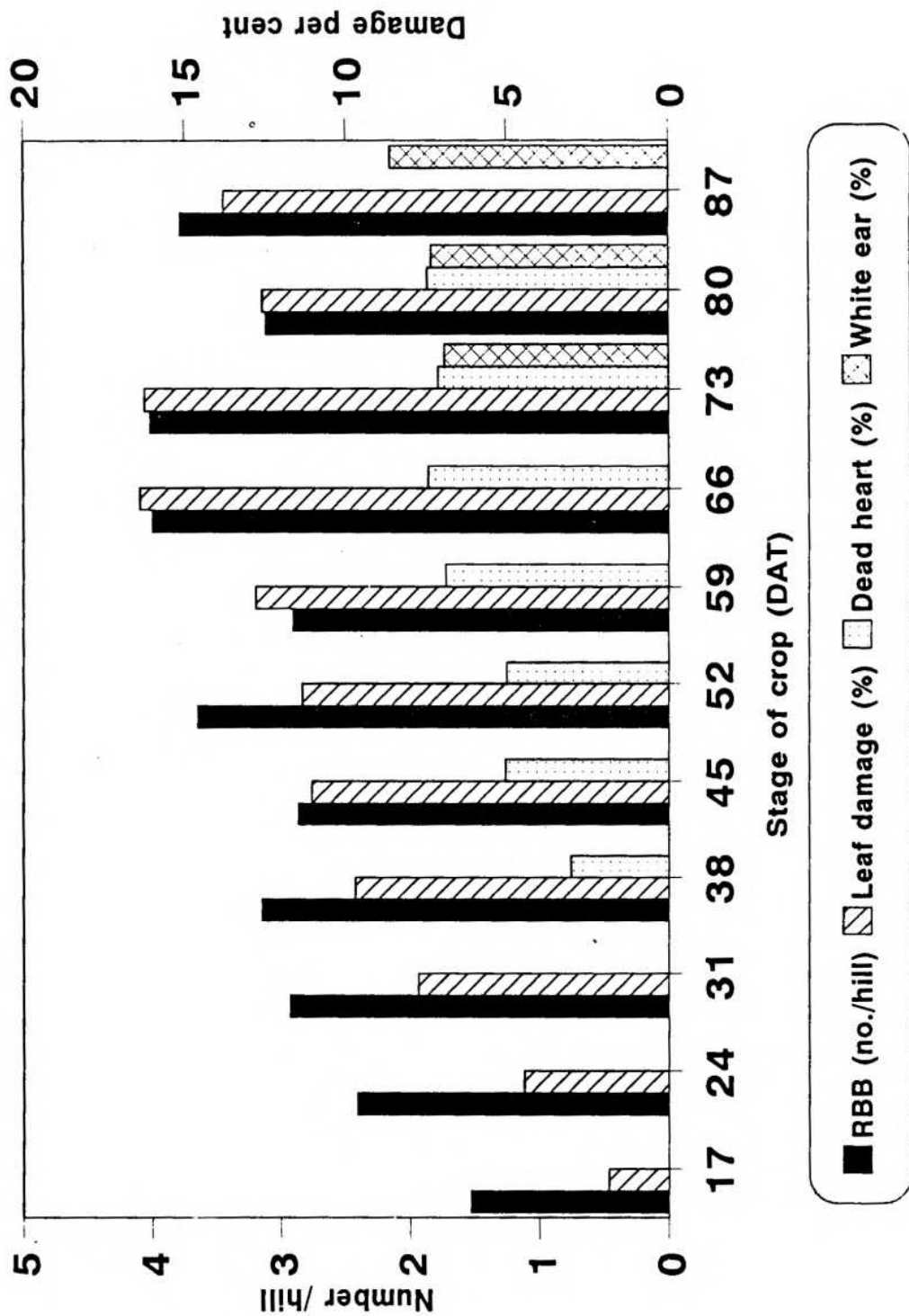
Co 45 :

$$y = 64.937 + 0.084x_1 + 0.0390x_2 - 1.830x_3 - 0.262x_4 - 0.011x_5 - 0.206x_6$$

TKM 9 :

$$y = -47.911 + 0.138x_1 + 0.759x_2 - 0.250x_3 + 0.196x_4 + 0.031x_5 + 0.024x_6$$

**Fig.3. Rice Black Bug and damage
Farmer's field (Samba-White Ponni)**



2.16 per cent at 38 DAT to 3.18 per cent at 73 DAT. White ears were observed from 73 to 87 DAT, the percentage of which varied from 3.50 (80 DAT) to 3.95 (87 DAT) (Fig.4).

4.3.5.3. IR 50 (*Sornavari*)

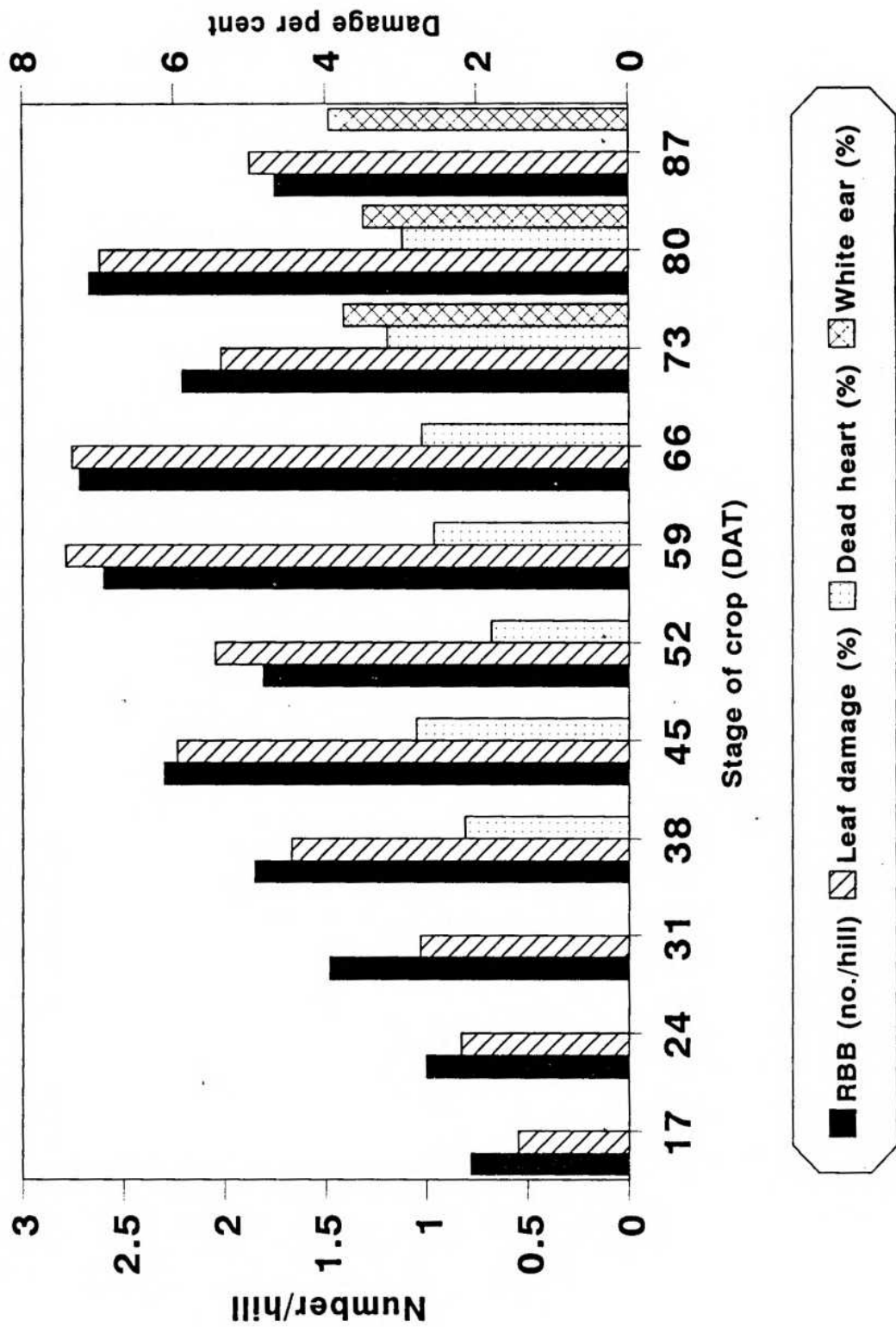
The number of bugs per hill showed an increasing trend upto 52 DAT and decreased at 59 and 66 DAT. However, the trend was again increased from 73 DAT onwards. The maximum bug population was 4.07/hill and minimum was 1.43. The leaf damage increased as the age progressed during the entire period of observations. The per cent leaf damage was minimum on 17 DAT (1.17) and maximum on 87 DAT (11.10). Dead hearts were observed from 38 DAT and continued upto 80 DAT. Dead hearts were minimum (1.88%) on 38 DAT and maximum on 66 DAT (9.62%). White ear symptom was seen from 73 DAT. It was evident that the crop suffered damage in all its growth phases (Fig.5).

4.4. Population dynamics of RBB

4.4.1. Attraction of *Scotinophara* spp to light sources

Among the light sources used, Pest-O-Flash was superior to both 125 Watts and 40 Watts with mean catches recorded per SMW being 154.40, 92.15, 116.09 and 13.88 for 1993, 1994, 1995 and 1996 respectively. The differences between the mean catches in Pest-O-Flash and 125 Watts were 110.35, 68.19, 52.09 and 17.29 for the four years respectively. This was highly significant as shown by the respective 't' values of 5.99, 3.89, 3.88 and 3.85. Similarly the difference between Pest-O-Flash and 40 Watts was also highly significant in all the four years. The 't' values ranged between 3.68 during 1995 and 6.29 during 1993. The mean differences of catches ranged between 25.11 and 135.15. The difference between 125 Watts and 40 Watts was also highly significant in all the years. The range of difference was 7.94 during 1996 to 37.25 during 1995.

**Fig.4. Rice Black Bug and damage
Farmer's field (Navarai -ADT 36)**



**Fig.5. Rice Black Bug and damage
Farmer's field (*Sornavari-IR 50*)**

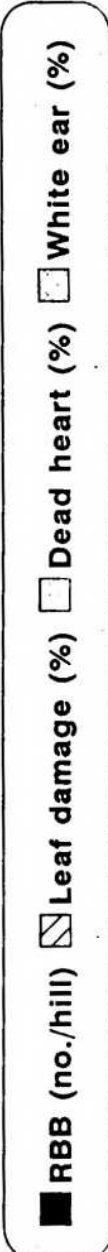
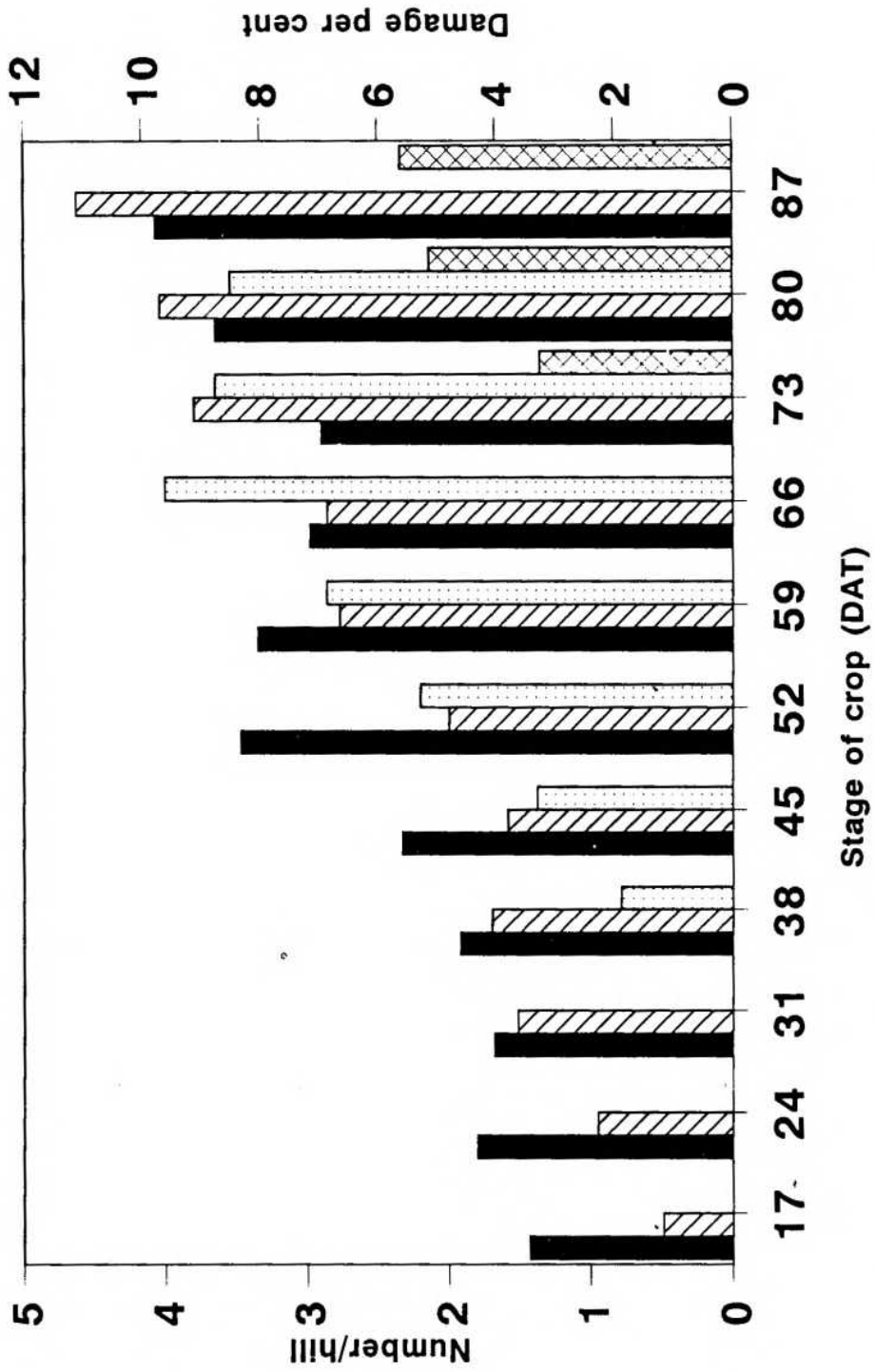


Table 16. Attraction of RBB to light sources

Light source	Mean catches (Number)			
	1993	1994	1995	1996 [@]
125 Watts (A)	44.05	23.96	64.00	13.58
Pest-O-Flash (B)	154.40	92.15	116.09	30.88
40 Watts (C)	19.25	12.50	28.59	5.65
d (B-A)	110.35	68.19	52.09	17.29
t (P=0.05)	5.99**	3.89**	3.88**	3.85**
d (A-C)	24.81	10.69	37.25	7.94
t (P=0.05)	5.24**	2.55**	3.26**	5.42**
d (B-C)	135.15	79.65	87.50	25.11
t (P=0.05)	6.26**	3.94**	3.68**	4.51**

@ Mean of observations taken upto 17 SMW

** Significant at 1% level

d - Difference between

In conclusion, the attraction of light sources is Pest-O-Flash > 125 Watts > 40Watts (Table 16 and Fig.6).

4.4.2. Influence of egg parasitoid, *T.triptus* on RBB egg masses and eggs

The parasitisation by *T.triptus* showed positive correlation with both the number of egg masses and number of eggs. The regression coefficients obtained for the three cultivars and three seasons were significant ($P=0.05$) except for the eggs versus parasitisation during *Navarai* and *Sornavari* 1995. The R^2 values, defining the degree of association between egg masses and parasitisation as well as for the eggs and per cent parasitisation were significant. The simple regression coefficients obtained suggested a marginal increase in parasitisation for every unit increase in egg mass or egg of host. The positive correlation explained the host dependence of the parasitoid. Further, the regression coefficients, being less than one, indicated the parasitisation of few egg masses and few eggs within an egg mass. The regression coefficient was near unity in *Navarai* 1993 and 0.69 during *Sornavari* 1993 (Table 17).

The analysis of the data collected during the three successive years ($n=180$) irrespective of the season and cultivar using the egg masses and the per cent parasitisation gave the equation:

$$Y=0.27+1.07x$$

The regression as well as the correlation coefficients (0.77) was highly significant ($t=5.63$). Similar analyses using the pooled data for the three years using the per cent parasitisation and the number of eggs in an egg mass was not significant ($r=0.28$; $t=0.91$)

Fig.6. Attractability of light sources to *Scotinophara* spp.

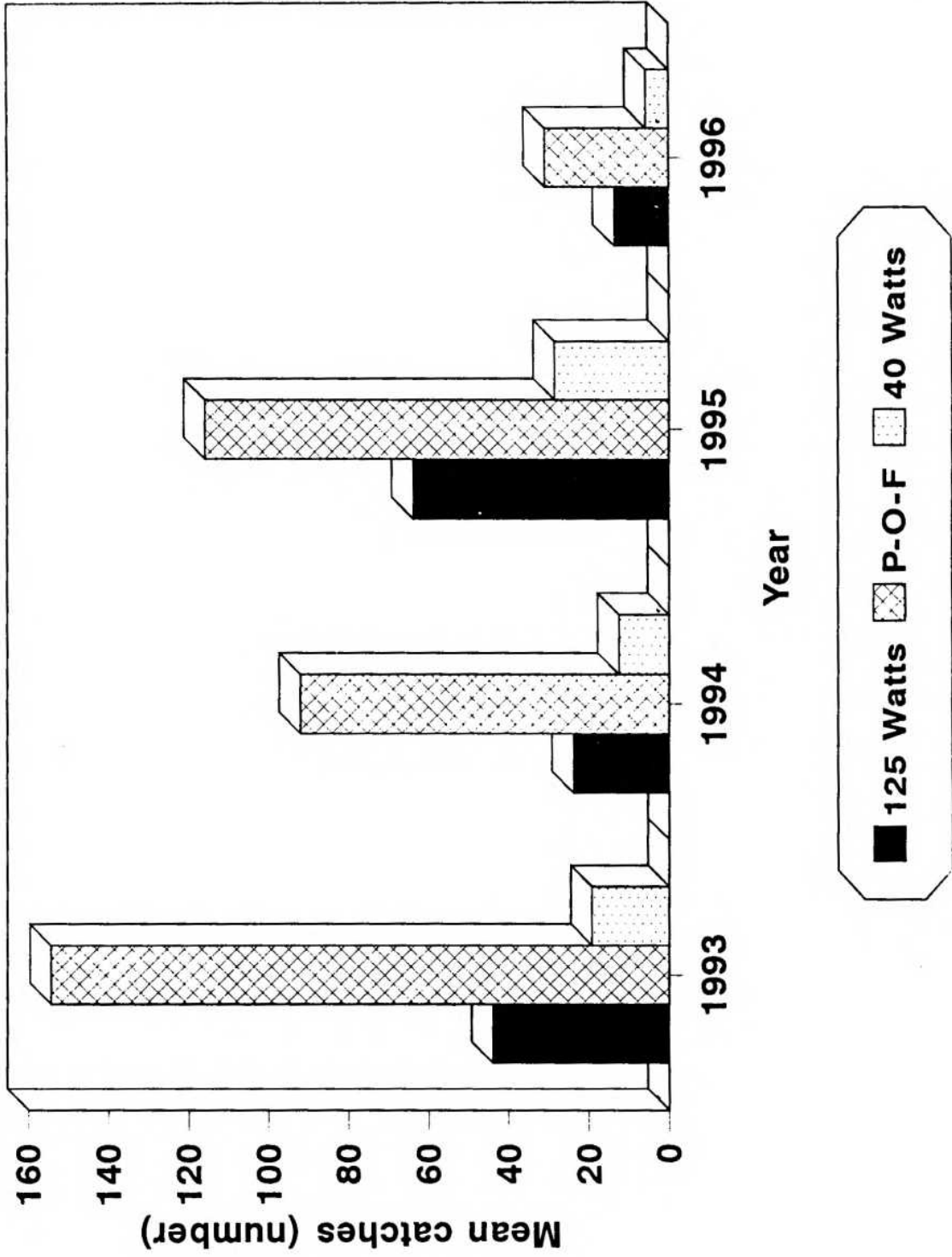


Table 17. Regression analysis on the parasitism of egg masses and eggs of RBB by *T. triptus*

Cultivar/Season	Year	n	Regression equation	R ²
Egg masses				
Co 43 Samba	1993	55	$y = 0.28x - 0.58$	0.84
	1994	55	$y = 0.49x - 0.97$	0.76
	1995	55	$y = 0.20x - 0.58$	0.51
TKM 9 Navarai	1993	45	$y = 0.97x - 9.37$	0.73
	1994	45	$y = 0.48x - 3.15$	0.68
	1995	45	$y = 0.37x - 2.01$	0.70
ADT 36 Sornavari	1993	45	$y = 0.69x - 7.71$	0.84
	1994	45	$y = 0.41x - 4.83$	0.76
	1995	45	$y = 1.63 + 0.14x$	0.55
Eggs				
Co 43	1993	55	$y = 10.33 + 0.09x$	0.68
	1994	55	$y = 12.68 + 0.08x$	0.69
	1995	55	$y = 3.22 + 0.69x$	0.53
TKM 9 Navarai	1993	45	$y = 24.67 + 0.10x$	0.55
	1994	45	$y = 0.16x - 12.15$	0.74
	1995	45	$y = 5.45 + 0.04x$	0.15 ^{NS}
ADT 36 Sornavari	1993	45	$y = 1.94 + 0.10x$	0.79
	1994	45	$y = 0.09x - 0.56$	0.48
	1995	45	$y = 18.19 + 13.31x$	0.008 ^{NS}

NS - Not significant

4.4.3. Species complex of *Scotinophara*

The *in situ* counts recorded to ascertain the species prevalent in RRS, Tirur, during 1994, 1995 and 1996 indicated that the mean collection of *S. coarctata* ^{was} 246.84, 167.71 and 62.80 during the three years respectively. The collection of *S. lurida* for these years was respectively 4.52, 5.63 and 3.33 only. The mean difference between the two species was 242.33, 162.08 and 59.47 respectively for these three years. The 't' values denoted that *S. coarctata* was the dominant species and *S. lurida*, though coexisting with *S. coarctata* was incapable of competing with it. Of the three years in comparison, the prevalence of *S. coarctata* was significantly more in 1994 over 1995 and 1996. The prevalence was comparatively more in 1995 than in 1996. The difference among the less dominant species *viz.*, *S. lurida* over the three years was, however, not significant (Table 18 and Fig.7).

4.5. Life table studies of *S. coarctata* on rice

Life table studies of *S. coarctata* on rice indicated that the length of time spent in immature stages was 32 days. The first female mortality within the cohort occurred on the 146th day after emergence of adults and the mortality increased thereafter. The relevant information pertaining to the life table of *S. coarctata* are given in Table 19 and annexure 1 and 2. The results indicated that the net reproductive rate (R_0) was 125.17 which meant that there was 125.17 fold increase in the population per generation. The mean length of the generation lasted for 53.41 days. The population increased at an infinitesimal rate (rm) of 0.0904 and finite rate (λ) of 1.09 per female per day and could double in numbers every 8.04 days. The weekly multiplication rate of the population was 1.83 times. It was estimated that on reaching the stable age distribution, the population of *S. coarctata* would comprise 37.3777 per cent as eggs, 57.1679 per cent as nymphs and 5.7719 per cent as adults.

Table 18. Species complex of *Scotinophara*

Species	Mean collection (Number)* \pm SD		
	1994	1995	1996 [@]
<i>S. coarctata</i>	246.84 \pm 28.85	167.71 \pm 14.60	62.80 \pm 8.65
<i>S. lurida</i>	4.52 \pm 0.50	5.63 \pm 0.73	3.33 \pm 0.73
Mean difference	242.33	162.08	59.47
t (P=0.05)	18.34**	20.41**	7.23**

* Mean of 100 observations

@ Observations upto 17 SMW

** Significant at 1% level

Fig.7. *Scotinophara* species dominance at RRS, Tirur

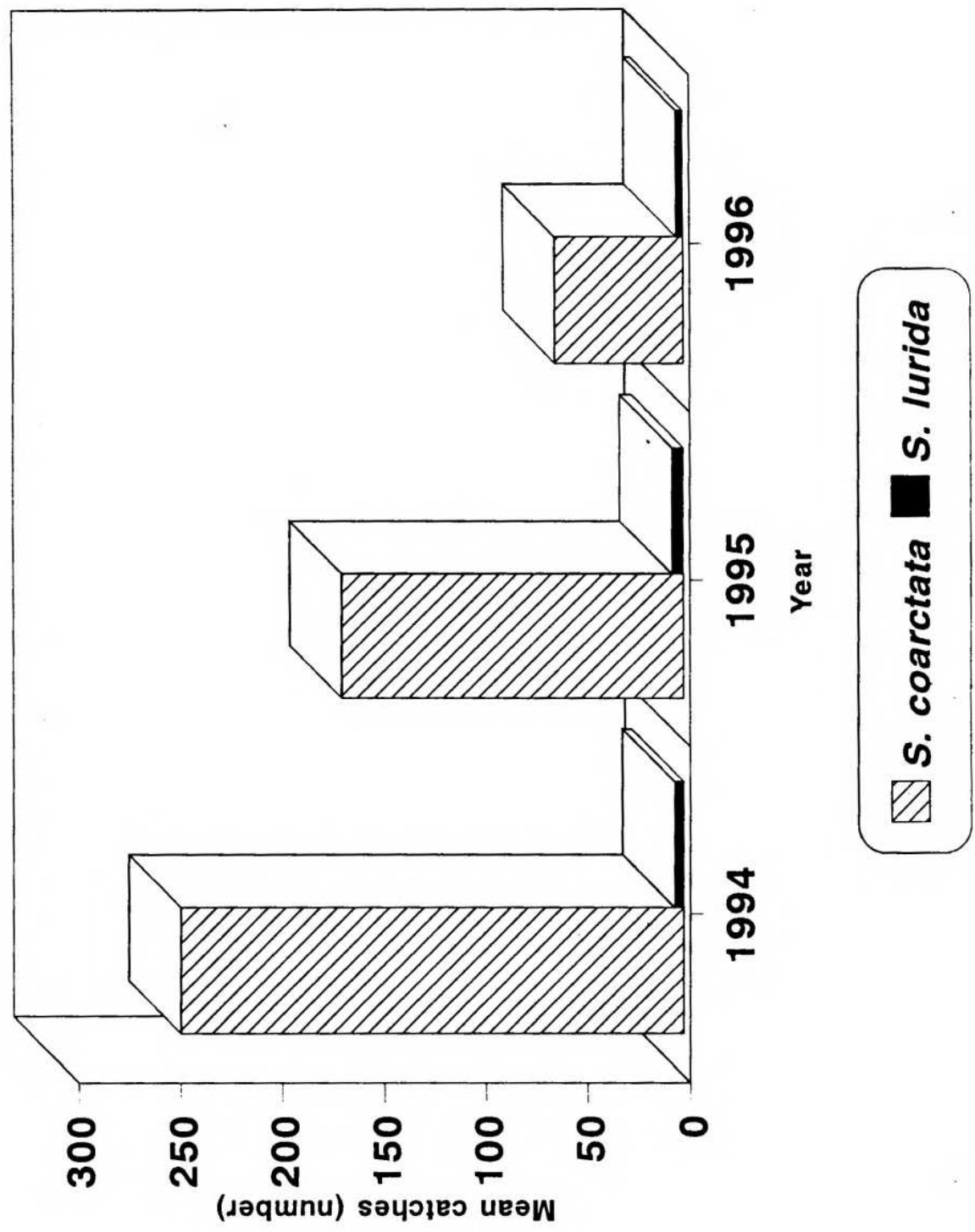


Table 19. Life table of *S. coarctata* on rice

Parameters	Values
Net reproductive rate (Ro)	125.17
Mean length of generation (TC-Days)	61.48
Arbitrary values of innate capacity for increase (rc-Numbers)	0.08
Innate capacity for increase (rm-Numbers)	0.09
Finite rate of natural increase (λ)	1.09
Corrected generation time (T-Days)	53.41
Weekly multiplication of the population (WM)	1.83
Doubling time (DT-Days)	8.04
Stable age distribution (%)	
Eggs	37.37
Nymphs	57.17
Adults	5.77

4.6. Reaction of rice accessions to RBB

The popular rice cultivars grown in Chengai-MGR district, rice accessions in Adaptive Research Trials (ART), Multi Locational Trials (MLT), Comparative Yield Trials (CYT), Advance Varietal Trails (AVT), Initial Yield Trials (IYT), and hybrid rices (368 entries) were screened for their varietal reaction to RBB in screen house conditions. Besides these, BPH and leaffolder moderately resistant rice accessions and accessions from Irrigated Medium Rice Yield Trial and International Irrigated Rice Yield Nursery Trial were also screened.

4.6.1. Popular rice cultivars

A total of 18 cultivars recommended for Chengai-MGR district was screened for their reaction. Of them, ADT 37 and TKM 10 were rated as moderately susceptible (grade 5) where the per cent of leaf damage was in the range of 33.30 to 34.80. Eight cultivars recorded the leaf damage of 42.10 to 49.10 per cent and they were rated as susceptible (grade 7). Another eight cultivars were rated as highly susceptible (grade 9) wherein the leaf damage ranged from 66.30 to 82.40 per cent. None of the cultivars was resistant (Table 20).

4.6.2. Initial Yield Trial

1992

Seventy three accessions were screened for their reaction. Two accessions *viz.*, IET 12029 and IET 13989 which recorded the leaf damage in the range of 16.75 to 19.75 per cent were classified as moderately resistant (grade 3). 10 accessions which recorded 38.10 to 47.70 per cent leaf damage were rated as grade 5 (moderately susceptible); 19 accessions were rated as susceptible (38.10 to 47.70%) and 42 were highly susceptible (51.10 to 80.50 %). The standard checks *viz.*, ADT 37 (28.80 %) and ADT 36 (44.30 %) were moderately susceptible and susceptible respectively, while

Table 20. Reaction of rice cultivars to *S. coarctata**

Cultivars	No.	Leaf damage range (%)	Grade
ADT 37, TKM 10	2	33.30-34.80	5 (MS)
ASD 16, ASD 17, ASD 18, IR 20, White Ponni, ADT 39, ADT 40, Co 45	8	42.10-49.10	7 (S)
TKM 9, ADT 36, IR 36, IR 50, IR 64, ADT 41, Co 43, PMK 1	8	66.30-82.40	9 (HS)

* Mean of three replications

Ratna, Vikas and TKM 9 were highly susceptible and they recorded 60.90, 57.20 and 64.90 per cent leaf damage respectively (Table 21).

1993

Out of 34 accessions screened, IET 12901 recorded 18.40 per cent leaf damage and was moderately resistant (grade 3). Two accessions *viz.*, IET 12891 and IET 12893 which had leaf damages of 32.20 and 32.80 per cent were graded as moderately susceptible (grade 5). Nine accessions were classified as susceptible (36.90 to 49.46 %) and 23 were identified highly susceptible (51.60 to 99.80 %). Among the standard checks, ADT 37 recorded a leaf damage of 44.80 while Vikas and Rasi recorded 61.70 and 67.20 per cent respectively (Table 22).

4.6.3.Comparative Yield Trial

1993

A total of 26 accessions was screened of which TM 5514 and TNAU 841434 recorded the damage range of 31.20 to 34.30 per cent and categorised as moderately susceptible. Eight entries were grouped as susceptible (37.10 to 48.10 %) and 16 entries as highly susceptible (58.70 to 92.20%). Of the standard checks, Co 37 (grade 5) recorded 29.80 per cent damage and was graded moderately susceptible. ASD 18 and IR 64 recorded 37.50 and 43.30 per cent respectively and were grouped as susceptible, while TKM 9 (52.00%) and ADT 36 (69.70%) were highly susceptible (Table 23).

1994

Nine accessions were screened and none was resistant. The accession TM 6481 (47.90%) was rated as susceptible (grade 7) and eight were grouped as highly susceptible (grade 9), wherein the leaf damage was in the range of 59.10 to 95.00 per cent. Both the standard checks IR 50 and TKM 6 were highly susceptible which recorded 77.10 and 92.80 per cent respectively (Table 24).

Table 21. Reaction of rice accessions to *S. coarctata* (Initial Yield Trial - 1992)*

Accessions	No.	Leaf damage range (%)	Grade
IET 120129, IET 13989	2	16.75-19.75	3 (MR)
IET 12395, IET 12398, IET 12402, IET 12403, IET 12419, IET 12421, IET 12035, IET 13442, IET 13452, IET 13991	10	22.00-29.00	5 (MS)
IET 10486, IET 10773, IET 11766, IET 11768, IET 11771, IET 11825, IET 12351, IET 12364, IET 12394, IET 12424, IET 12425, IET 12426, IET 12435, IET 12481, IET 9219, IET 13432, IET 12036, IET 13981, IET 14272	19	38.10-47.70	7 (S)
IET 11009, IET 11074, IET 11747, IET 11748, IET 11749, IET 11750, IET 11751, IET 11752, IET 11753, IET 11758, IET 11759, IET 11769, IET 11781, IET 11791, IET 11813, IET 11819, IET 11828, IET 11831, IET 12354, IET 12355, IET 12360, IET 12397, IET 12428, IET 12486, IET 12488, IET 13434, IET 12703, IET 13431, IET 13443, IET 12691, IET 13983, IET 13990, IET 13985, IET 13987, IET 13993, IET 14267, IET 14274, IET 14282, IET 14297, IET 14298, IET 14306, IET 10494	42	51.10-80.50	9 (HS)
Standard check			
ADT 37		28.80	5 (MS)
ADT 36		44.30	7 (S)
Ratna		60.90	9 (HS)
Vikas		57.20	9 (HS)
TKM 9		64.90	9 (HS)

* Mean of three replications

Table 22. Reaction of rice accessions to *S. coarctata* (Initial Yield Trial - 1993)*

Accessions	No.	Leaf damage range (%)	Grade
IET 12901	1	18.40	3 (MR)
IET 12891, IET 12893	2	32.20-32.80	5 (MS)
IET 12892 IET 12902 IET 12908 IET 12914 IET 12918 IET 12921 IET 12928 IET 13236 IET 13239	9	36.90-49.46	7 (S)
IET 12514 IET 12517 IET 12889 IET 12890 IET 12906 IET 12911 IET 12915 IET 12929 IET 13131 IET 13232 IET 13233 IET 13234 IET 13235 IET 13237 IET 13238 IET 13240 IET 13241 IET 13242 IET 13243 IET 13244 IET 13245 IET 13246	22	51.60-99.80	9 (HS)
Standard check			
IR 50		44.80	7 (S)
Vikas		61.70	9 (HS)
Rasi		67.20	9 (HS)

* Mean of three replications

Table 23. Reaction of rice accessions to *S. coarctata* (Comparative Yield Trial - 1993)*

Accessions	No.	Leaf damage range (%)	Grade
TM 5514 TNAU 841434	2	31.20-34.30	5 (MS)
ACM 41 ACM 53 ACM 46 ACM 145 IET 10410 IET 11752 TNAU 89069 TPAS 42673	8	37.10-48.10	7 (S)
ACM 20 ACM 24 ACM 27 ACM 46 ACM 51 ACM 60 ACM 38 IR 39357 IET 10889 IET 11869 IET 11766 IET 9819 MS 210 TNAU 880714 P 2409 AS 89090	16	58.70-92.20	9 (HS)
Standard check			
Co 37		29.80	5 (MS)
ASD 18		37.50	7 (S)
IR 64		43.30	7 (S)
TKM 9		52.00	9 (HS)
ADT 36		69.70	9 (HS)

* Mean of three replications

Table 24. Reaction of rice accessions to *S. coarctata* (Comparative Yield Trial - 1994)*

Accessions	No.	Leaf damage range (%)	Grade
TM 6481	1	47.90	7 (S)
TM 4438 TM 5655 TM 8089 TM 8785 TM 5906 TM 8786 TM 8708/2/2 TM 8626	8	59.10-95.00	9 (HS)
Standard check			
IR 50		77.10	9 (HS)
TKM 6		92.80	9 (HS)

* Mean of three replications

4.6.4. Advanced Varietal Trial

1994

The accession TM 5514 was moderately susceptible (30.00%). Three accessions were grouped as susceptible (32.75 to 44.90%) and 11 were highly susceptible (53.20 to 76.10%). ADT 36 (71.10%), IR 50 (78.40%) and TKM 6 (94.10%) used as standard checks were highly susceptible (Table 25).

4.6.5. Multi Locational Trials

1992

Two accessions were susceptible (38.60 to 47.77%) and five were highly susceptible (69.50 to 90.00%). The standards IR 50 (46.90%), ADT 36 (69.70%) and TKM 9(50.00%) were all rated as susceptible.

1993

Two accessions were graded as moderately susceptible (27.13 to 27.90%) and six were highly susceptible (60.90 to 95.27%). IR 64, ASD 16 and ADT 36 which were used as standard checks recorded the damage of 41.70, 62.90 and 68.80 per cent respectively.

1994

The accession TM 6044 (34.82%) was moderately susceptible (grade 5), while six entries (37.11 to 46.23%) were graded as susceptible and nine as highly susceptible (84.40 to 94.49%). The standard checks, ASD 18 and ADT 42 with 36.42 and 53.27 per cent damage respectively were grouped as susceptible and IR 50 (64.35%) was identified as highly susceptible.

Table 25. Reaction of rice accessions to *S. coarctata* (Advanced Varietal Trial - 1994)*

Accessions	No.	Leaf damage range (%)	Grade
TM 5514	1	30.00	5 (MS)
TM 5516 TM 5737 TM 5906	3	32.75-44.90	7 (S)
TM 5738 TM 5656 TM 8643/2 TM 8683 TM 8682 TM 8643/1 TM 8828 TM 8864 TM 9423 TM 9428 TM 9429	11	53.20-76.10	9 (HS)
Standard check			
ADT 36		71.10	9 (HS)
IR 50		78.40	9 (HS)
TKM 6		94.10	9 (HS)

* Mean of three replications

1995

Of the seven entries, three accessions were graded as susceptible (48.30 to 49.60%) and remaining four were highly susceptible (55.50 to 73.10%). PMK 2 and PMK 1 which were used as standard checks recorded the damage of 53.90 per cent and 69.10 per cent highly susceptible (Table 26).

4.6.6. Adaptive Research Trials

A total of 11 accessions was screened of which AD 93001 recorded 29.30 per cent damage and was categorised as moderately susceptible. Two entries were grouped as susceptible (39.30 to 40.68%) and eight entries as highly susceptible (51.20 to 98.80%). In the standard checks, the damage ranged from 43.20 per cent in Co 45 to 81.30 per cent in ADT 36 (Table 27).

4.6.7. BPH and Leaffolder moderately resistant accessions

Fifteen accessions which showed moderate level of resistance to BPH and leaffolder were screened for their reaction to RBB and all of them were highly susceptible (53.20 to 99.80%). The standard checks ADT 36 (70.90%), TKM 6 (90.40%) and IR 50 (91.30%) also fell into the same category (Table 28).

4.6.8. Irrigated Medium Rice Yield Trial

A total of 21 accessions was screened of which IET 12872 recorded the damage of 18.80 per cent and was categorised as moderately resistant. Four entries were grouped as moderately susceptible (25.10 to 32.60%) and eight susceptible (37.20 to 49.70%) and highly eight susceptible (51.60 to 83.70%). Of the standard checks, Rasi (41.70%) was moderately susceptible, TKM 9 (53.90%) and Vikas (60.90%) were highly susceptible (Table 29).

Table 26. Reaction of rice accessions to *S. coarctata* (Multi Locational Trials)*

Year and Accessions	No.	Leaf damage range (%)	Grade
1992			
TNAU 88011 TNAU 88022	2	38.60-47.77	7 (S)
ACM 56 TNAU 88013 AS 89044 AD 85065 AD 85 446	5	69.50-90.00	9 (HS)
Standard check			
IR 50		46.90	7 (S)
ADT 36		69.70	7 (S)
TKM 9		50.00	7 (S)
1993			
TM 5514 ACM 60	2	27.13-27.90	5 (MS)
TNAU 841434 TNAU 851979 AS 90043 IET 9976 TM 1307 TM 6012	6	60.90-95.27	9 (HS)
Standard check			
IR 64		41.70	7 (S)
ADT 16		62.90	7 (S)
ADT 36		68.80	7 (S)
1994			
TM 6044	1	34.82	5 (MS)
TNAU 89093 TNAU 90013 TNAU 91045 AD 90180 AS 88014 ACK 258	6	37.11-46.23	7 (S)
IR 10198/6 IR 58025 B IR 62829/B Pusa 150 R	4	84.40-94.49	9 (HS)
Standard check			
ASD 18		36.42	7 (S)
ADT 42		53.27	7 (S)
IR 50		64.35	9 (HS)
1995			
TNAU 90094 TNAU 90627 PM 9106	3	48.30-49.60	7 (S)
RMAS 90033 BR 4290-3-3-5 ACK 198 ACM 95	4	55.50-73.10	9 (HS)
Standard check			
PMK 2		53.90	7 (S)
PMK 1		69.10	9 (HS)

* Mean of three replications

Table 27. Reaction of rice accessions to *S. coarctata* (Adaptive Research Trial - 1994-1995)*

Accessions	No.	Leaf damage range (%)	Grade
AD 93001	1	29.60	5 (MS)
AS 89030 AD 90140	2	39.30-40.68	7 (S)
BG 1165-2 BG 915 ACM 44 BR 20 SSRC 91216 TM 9423 BR153-2B-10-1-3 ACM 10	8	51.20-98.80	9 (HS)
Standard check			
Co 45		43.20	7 (S)
IR 20		48.80	7 (S)
IR 50		64.17	9 (HS)
TKM 9		65.06	9 (HS)
ADT 36		81.30	9 (HS)

* Mean of three replications

**Table 28. Reaction of BPH and Leaffolder moderately resistant rice accessions to
S. coarctata ***

Accessions	No.	Leaf damage range (%)	Grade
TNAULFR 832042	15	53.20-99.80	9 (HS)
TNAULFR 831324			
TNAUBPHR 831305			
TNAUBPHR 83116			
TNAU 831293			
TNAU 842745			
TNAU 831307			
TNAU 871390			
TNAULFR 832039			
TNAULFR 842735			
TNAUBPHR 842718	70.90	9 (HS)	
TNAUBPHR 83742			
TNAU 831521			
TNAU 831311	90.40	9 (HS)	
TNAU 831520			
Standard check	91.30	9 (HS)	
ADT 36			
TKM 6			
IR 50			

* Mean of three replications

Table 29. Reaction of rice accessions to *S. coarctata* (Irrigated Medium Rice Yield Trial) *

Accessions	No.	Leaf damage range (%)	Grade
IET 12872	1	18.80	3 (MR)
IET 12873 IET 12875 IET 12887 IET 13381	4	25.10-32.60	5 (MS)
IET 12867 IET 16868 IET 12870 IET 12871 IET 12876 IET 12879 IET 12880 IET 13378	8	37.20-49.70	7 (S)
IET 12874 IET 12884 IET 12886 IET 12888 IET 13379 IET 13380 IET 13382 IET 13383	8	51.60-83.70	9 (HS)
Standard check			
Rasi		41.70	7 (S)
TKM 9		53.90	9 (HS)
Vikas		60.90	9 (HS)

* Mean of three replications

Table 30. Reaction of rice accessions to *S. coarctata* (International Irrigated Rice Yield Nursery Trial)*

Accessions	No.	Leaf damage range (%)	Grade
IR58099-41-2-3 IR53970-2-1 IR52341-60-1-2-1	3	17.90-19.80	3 (MR)
IR59606-119-3	1	31.30	5 (MS)
IR39357 IR 57301-195-3-3 IR 57311-95-2-3	3	34.63-47.10	7 (S)
BR1067-84-1-3-2-1, BR1067-96-6-2-1, E7034, FARO 36, IET11755, IR 29725-117-2-3-3, IR 53292-159-1-2-3, IR 53970-100-3-3-2, IR 5683-17-3-2, IR 56446-94-3-1-2, IR 56450-4-2-2, IR 58082-126-1-2, Kalyani II, NJ70507, RP 1451-92-21-9, RP2199-16-2-2-1, RP2434-22-3-3, RP51765-15H-PM1, TAI-SEN-YU-724, ZHONG 83-49, IR 60832	23	51.87-98.70	9 (HS)
Standard check			
IR 36		63.90	9 (HS)
ADT 36		81.30	9 (HS)
IR 50		82.20	9 (HS)
TKM 9		88.80	9 (HS)

* Mean of three replications

Table 31. Reaction of rice accessions to *S. coarctata* (Hybrid rices) *

Accessions	No.	Leaf damage range (%)	Grade
TNRH8, TNRH 9, TNRH 15, ASRH1, ADRH 4	5	29.90-34.14	5 (MS)
TNRH 1, TNRH 6, TNRH 7, TNRH 10, TNRH 14 TNRH 16	6	41.33-49.60	7 (S)
CORH 1, ASRH 2, ASRH 8, ADRH 1, ADRH 2 TNRH 13, TNRH 17	7	52.42-95.80	9 (HS)
Standard check			
ADT 39		54.00	9 (HS)
IR 64		69.30	9 (HS)
Co 43		77.45	9 (HS)

* Mean of three replications

4.6.9. International Irrigated Rice Yield Nursery Trial

Out of 30 accessions screened, IR 58099-41-2-3, IR 53970-21 and IR 52341-60-1-2 showed leaf damage rating of grade three (17.90 to 19.80%) and were moderately resistant. The accession IR 59606-119-3 which had leaf damages of 31.30 per cent was graded as moderately susceptible (grade 5). Three accessions were identified as susceptible (34.63 to 47.10 %), while the remaining 23 were found to be highly susceptible (51.87 to 98.70 %). Among the standard checks, the damage ranged from 63.90 per cent in IR 36 to 88.80 per cent in TKM 9 indicating that all were highly susceptible (Table 30).

4.6.10. Hybrid Rices

Hybrid rice accessions (18 entries) developed by Tamil Nadu Agricultural University were screened for their reaction to RBB. None was found to be resistant. Out of the 18 entries, five *viz.*, TNRH 8, TNRH 9, TNRH 15, ASRH 1 and ADRH 4 recorded 29.90 to 34.14 per cent leaf damage and were moderately susceptible. Six accessions which had leaf damage ranging from 41.33 to 49.60 per cent were graded as susceptible while the remaining seven accessions were classified as highly susceptible (52.42 to 95.80 %). Among the standard checks, ADT 39 recorded a leaf damage of 54.00 per cent and was graded as susceptible; while IR 64 and Co 43 recorded 69.30 and 77.45 per cent respectively and were graded as highly susceptible (Table 31).

4.6.11. Moderately resistant rice accessions

Out of 368 accessions screened under various categories, against RBB, only seven accessions possessed moderate level of resistance and recorded grade 3. Parentages of these entries are indicated below:

Moderately resistant rice accessions to RBB

Entry	Parentage	Resistance rating
IET 12029	M63-83/Sarya//IRAT 8/63-88	3
IET 13989	P743-1-1-1/Pusa 150	3
IET 12901	PR 106/OB 5528	3
IET 12872	Manasarovar/IET 6187	3
IR 58099-41-2-3	IR35366-90-3-2-1-2/IR 24632-34-2	3
IR 53970-2-1	IR31906-67/IR31802//41985	3
IR 52341-60-1-2-1	IR33021-39/IR32429-47/IR31802-48	3

4.7. Economic Threshold level of RBB

The cost analysis involved many factors among which the resultant return cost is of paramount importance. The break even cost in terms of numbers of bugs per hill to the cost of protective inputs are summarised in Table 32. Monocrotophos, acephate, chlorpyrifos and phosphamidon which were equally effective recorded the ETL values varying from 3.23 in chlorpyrifos to 5.30 in phosphamidon at a value of Rs.9/kg of rice. The trend was true for all the treatments compared except Neem Azal-T/S (1%). In Neem Azal-T/S (1%), the cost of abatement was high. Therefore, the trend was reversed until the break even was achieved. Within the incremental cost of return from Rs. 9 to 11/kg of rice, the break even did not materialise and therefore, the negative decreasing trend. Another factor to reckon with is the efficacy of insecticide. On comparing phosphamidon and chlorpyrifos whose cost was approximately equal, the differences in their break even points was evident. For chlorpyrifos, the break even varied from 3.23 to 4.50 and for phosphamidon the same varied from 5.30 to 6.59.

Table 32. Economic threshold level of RBB at incremental cost of rice

Treatments	ETL at different cost of rice (Rs./kg)				
	9.00	9.50	10.00	10.50	11.00
Monocrotophos	4.10	4.49	4.80	5.10	5.40
Acephate	3.81	4.16	4.49	4.80	5.09
Chlorpyrifos	3.23	3.57	3.90	4.21	4.50
Phosphomidon	5.30	5.65	5.98	6.29	6.59
Triazophos	4.21	4.56	4.88	5.19	5.50
Carbaryl	0.06	0.28	0.61	0.92	1.22
Endosulfan	0.70	1.04	1.37	1.68	1.98
Fenthion	2.90	3.25	3.57	3.89	4.19
Neem oil 3%	2.15	2.50	2.83	3.14	3.43
Neem seed kernel extract 5%	4.23	4.57	4.90	5.21	5.51
Neem Azal-T/S 1%	-3.04	-2.69	-2.37	-2.06	-1.76
Neem Azal-F-5%	0.67	1.01	1.34	1.65	1.95

When both the cost of protective input and its efficacy were almost similar the ETL also remained almost constant. This can be seen in the trend expressed for monocrotophos, triazophos and NSKE, where the ETL under varying costs of rice, the resultant output was almost similar.

4.8. Studies on yield loss assessment in rice due to RBB

An attempt was made to estimate the yield loss in rice cultivar ADT 36 due to the infestation of RBB, *S. coarctata* in four situations viz., using nymphal and adult populations separately under screen house conditions, mixed populations of both adults and nymphs caged under field conditions and the same under uncaged conditions coexisted with infestations of leaffolder and rice stem borer.

Mitscherlich's and logistic models were used for the estimation. Estimation of yield loss and the rate of yield loss were also compared to the situation such as population versus damage level.

4.8.1. Predicted yield loss and rate of yield loss at different levels of RBB nymphs (Screen house)

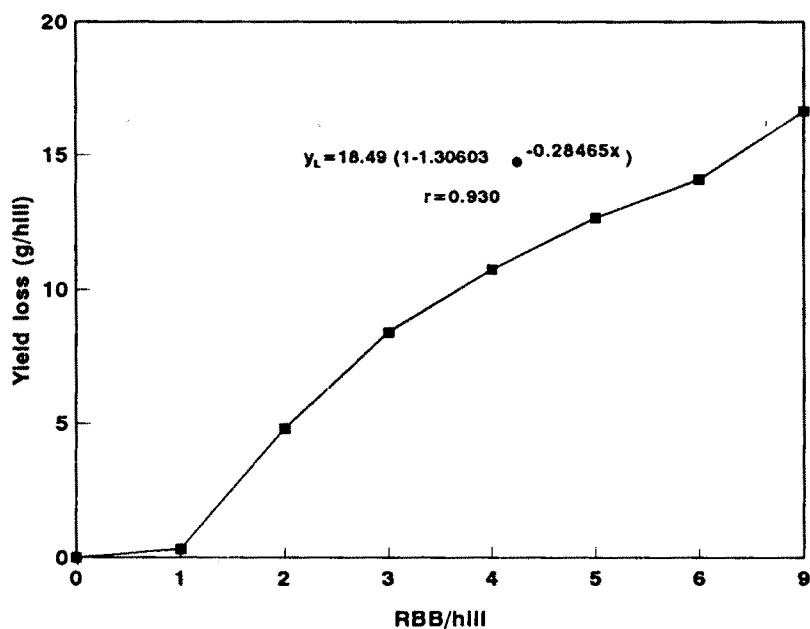
When the nymphal population was one per hill, the estimated yield loss was minimum (0.32g/hill, 1.66% damage). As the population increased, the yield obtained showed a decline and yield loss correspondingly increased. In the population level between one and two, an yield loss of 4.82g/hill was recorded (25.03%) and at four per hill, the yield loss was 10.76g (55.84%). When the nymphal population was maximum (9/hill), the estimated yield loss was 16.63g/hill (86.28%). At this stage the plant was almost killed. While the yield was expected to decline with an increase in the number of nymphs per hill, the rate of loss for every unit increase in black bug also declined. It was maximum (5.20g/hill) when only one bug existed per hill but declined to 0.53g when the bug population was nine per hill. The difference in the decline for

Table 33. Predicted yield loss at different levels of *S. coarctata* nymphs

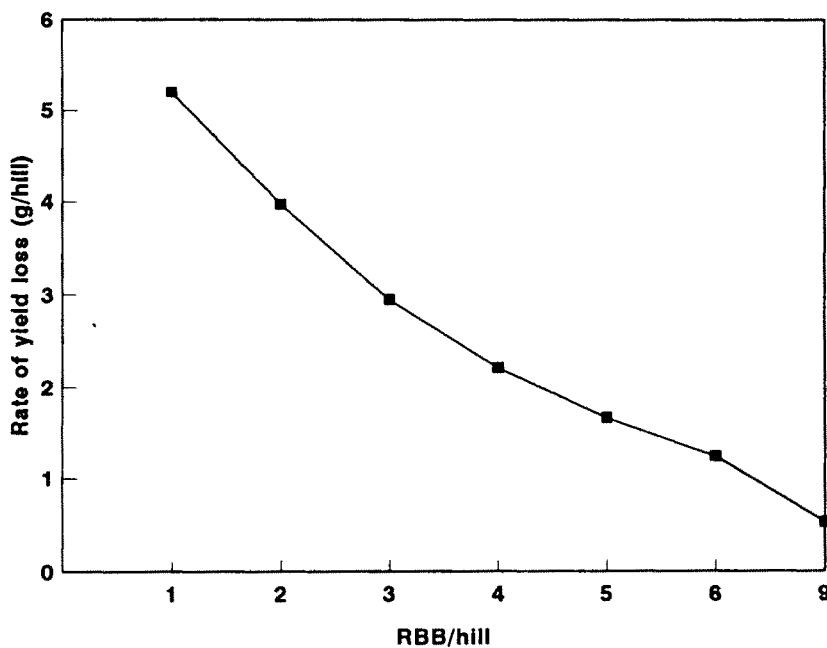
(Screen house)		Cultivar : ADT 36			
RBB No./hill	Yield obtained (g/hill)	Yield loss (g/hill)	Percentage		Rate of Yield loss (g/hill)
			Yield obtained	Yield loss	
1	18.95	0.32	98.34	1.66	5.20
2	14.45	4.82	74.97	25.03	3.98
3	10.86	8.41	56.36	43.64	2.95
4	8.51	10.76	44.16	55.84	2.22
5	6.60	12.67	34.24	65.76	1.67
6	5.16	14.11	26.76	73.24	1.25
9	2.64	16.63	13.72	86.28	0.53

Fig.8. Population levels of nymphs -Screen house

a. Predicted yield loss



b. Predicted rate of yield loss



every additional bug was more than one until there was three bugs per hill. Further increment in the bug population showed the decline to be less than one. Beyond four bugs per hill, the difference in the rate of decline was almost constant at 0.5g/hill (Table 33 Fig.8).

4.8.1.1. Predicted yield loss and rate of yield loss at different damage levels of RBB nymphs

Computing the yield loss based on leaf damage per cent, an yield loss of 8.59g/hill was recorded (48.62%) at 10 per cent leaf damage. The number of nymphs recorded at 10 per cent damage was three. As the damage level increased, the yield loss also simultaneously increased. The yield loss was 99.43 per cent, when the leaf damage was 50 per cent, beyond which every addition in leaf damage caused very little yield loss occurred indicated the damage to be almost total. The rate of yield loss at five per cent damage was 0.5197g/hill. As the damage increased, the rate of loss also increased upto 10 per cent leaf damage (0.6039g/hill) and thereafter, the rate of loss declined. Beyond 45 per cent of leaf damage, the rate of yield loss was reduced by half for every additional five per cent damage (Table 34 Fig.9).

4.8.2. Predicted yield loss and rate of yield loss at different levels of RBB adults (Screen house)

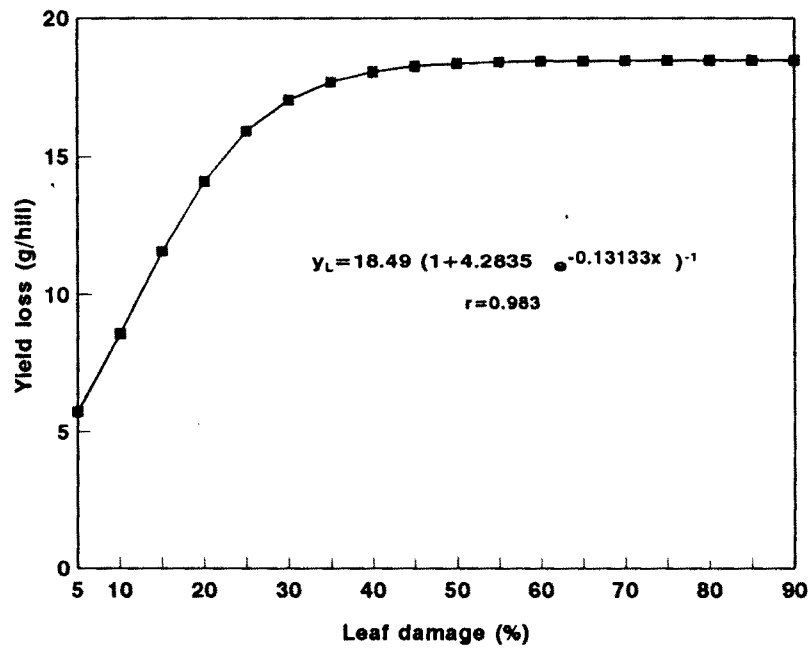
The study indicated that as the number of RBB adults per hill increased, the yield obtained got correspondingly reduced and yield loss (g/hill) got increased. When the adult population was one per hill, the yield loss was minimum (0.45g/hill). When the population increased from one to two per hill, 4.53 g of yield was lost which was 21.93 on per cent basis. At a population of three and four per hill, the yield loss estimated was 21.93 and 49.79 per cent respectively. At the maximum population level(9/hill), there was an yield loss of 81.40 per cent. Considering the rate of yield loss when the adult

Table 34. Predicted yield loss at different damage levels of *S. coarctata* nymphs

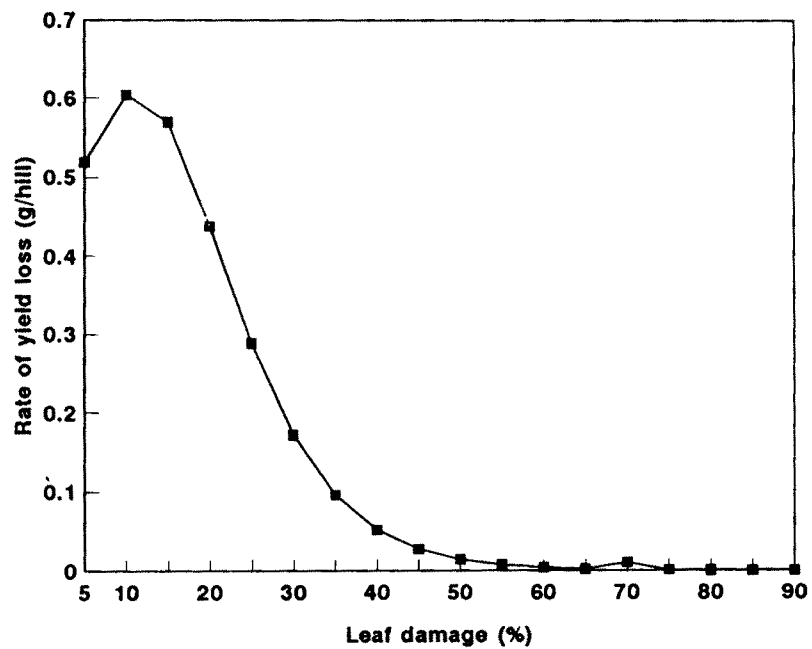
(Screen house)		Cultivar : ADT 36			
Leaf damage (%)	Yield obtained (g/hill)	Yield loss (g/hill)	Percentage		Rate of Yield loss (g/hill)
			Yield obtained	Yield loss	
5	12.75	5.74	66.16	33.84	0.519700
10	9.90	8.59	51.38	48.62	0.603900
15	6.92	11.57	35.91	64.09	0.568000
20	4.37	14.12	22.67	77.33	0.438000
25	2.56	15.93	13.28	86.72	0.289000
30	1.43	17.06	7.42	92.58	0.172000
35	0.77	17.72	3.99	96.01	0.096300
40	0.41	18.08	2.13	97.87	0.052000
45	0.21	18.28	1.08	98.92	0.027500
50	0.11	18.38	0.57	99.43	0.014500
55	0.06	18.43	0.31	99.69	0.007500
60	0.03	18.46	0.16	99.84	0.003900
65	0.02	18.47	0.10	99.90	0.002000
70	0.01	18.48	0.05	99.95	0.001060
75	0.00	18.49	0.00	100.00	0.000550
80	0.00	18.49	0.00	100.00	0.000280
85	0.00	18.49	0.00	100.00	0.000148
90	0.00	18.49	0.00	100.00	0.000077

Fig.9. Damage levels by nymphs- Screen house

a. Predicted yield loss



b. Predicted rate of yield loss



population was one per hill, the estimated rate of yield loss was 4.61g/hill and it gradually declined, as the population increased. At the maximum population level, the rate of yield loss was only 0.68g/hill (Table 35. Fig. 10).

4.8.2.1. Predicted yield loss and rate of yield loss at different damage levels of RBB adults

Considering the per cent leaf damage, an yield loss of 6.72g/hill was recorded (37.52%) when the leaf damage was at 10 per cent, which corresponded to three adults per hill. When the per cent leaf damage increased, the yield loss also increased. Though this statement is generally true, the actual loss suffered was on increment upto 40 per cent leaf damage level. Thereupon, though the same trend continued, the loss expressed was almost constant (19.23 to 19.63 g/hill) and the rate of loss suffered fell below five per cent level (0.05 to 0.000153 g/hill). When the leaf damage was five per cent, the rate of yield loss was 0.4279 g/hill and as the damage increased, the rate also increased upto a certain level (0.6360 g/hill at 15% leaf damage) and thereafter declined (Table 36 Fig. 11).

4.8.3. Predicted yield loss and rate of yield loss at different levels of RBB in field (caged)

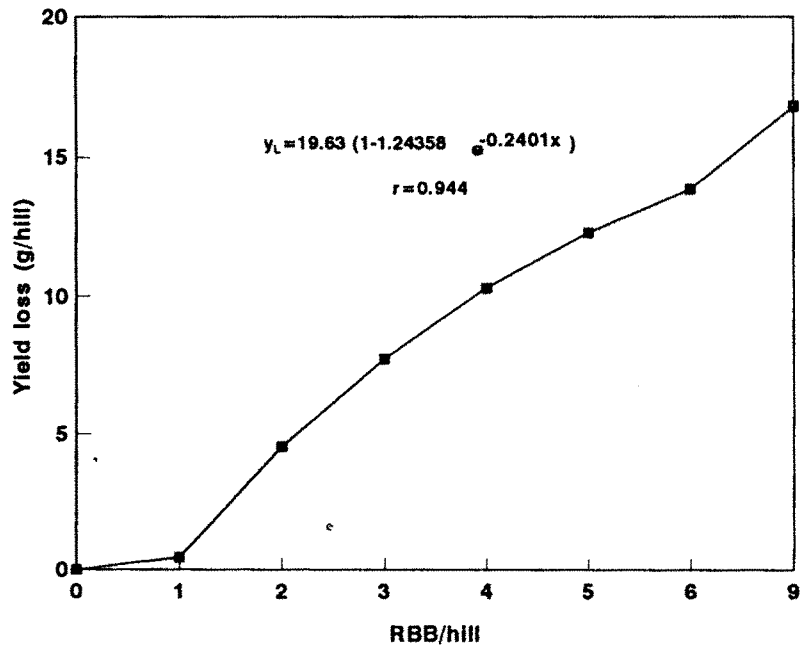
Prediction ability of the mathematical model was tested for the naturally occurring combined populations of both nymphs and adults caged under field conditions by estimating the differential yield loss and the corresponding rate of loss. The computation was extended to correlate the per cent leaf damage also. When the population was one per hill, the estimated yield loss was 0.92 g/hill (4.25%). As the population increased, the yield loss also showed an increasing trend. The population between two and three per hill resulted in the yield loss ^{which} _λ ranged from 3.14 to 5.00 g/hill (15.62 to 25.10%). At a maximum population (15/hill), the yield loss

Table 35. Predicted yield loss at different levels of *S. coarctata* adults

(Screen house)		Cultivar : ADT 36			
RBB No./hill	Yield obtained (g/hill)	Yield loss (g/hill)	Percentage		Rate of Yield loss (g/hill)
			Yield obtained	Yield loss	
1	20.23	0.45	97.92	2.08	4.61
2	16.13	4.53	78.07	21.93	3.63
3	12.91	7.75	62.48	37.52	2.85
4	10.37	10.29	50.21	49.79	2.24
5	8.38	12.28	40.56	59.44	1.76
6	6.81	13.85	32.96	67.04	1.39
9	3.84	16.82	18.60	81.40	0.68

Fig.10. Population levels of adults -Screen house

a. Predicted yield loss



b. Predicted rate of yield loss

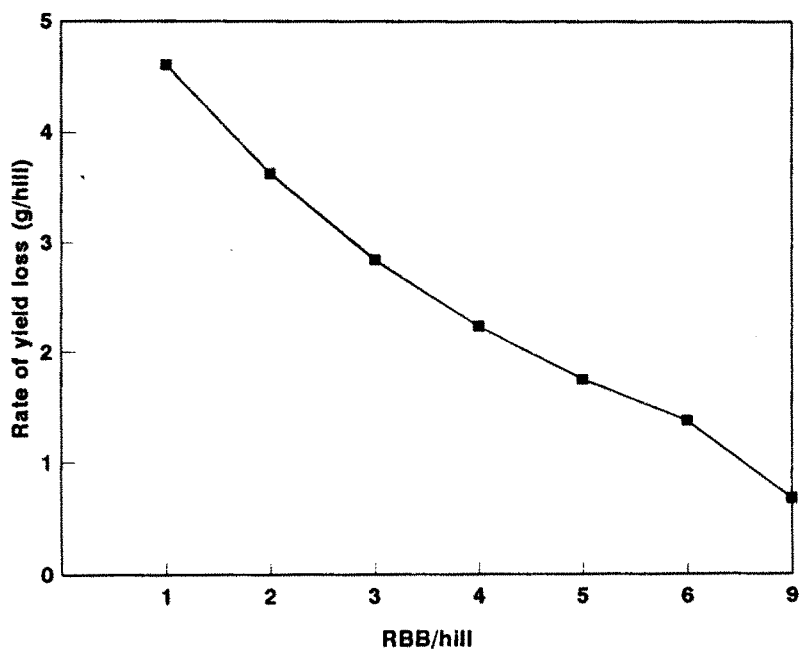
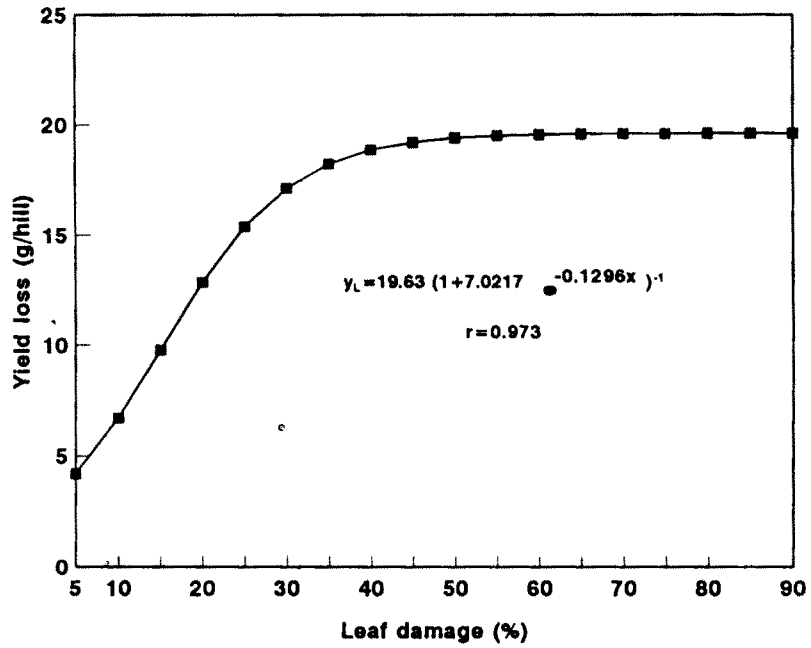


Fig.11. Damage levels by adults-Screen house

a. Predicted yield loss



b. Predicted rate of yield loss

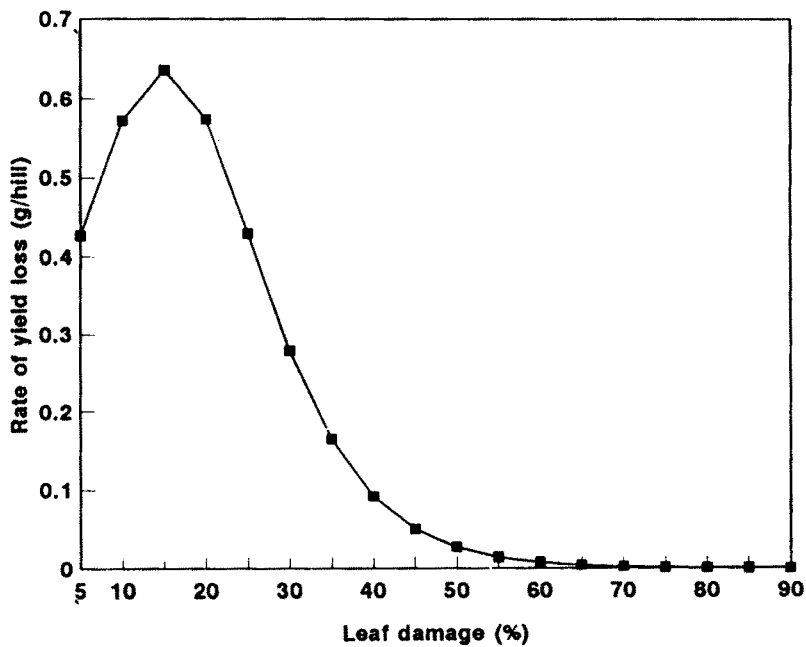


Table 36. Predicted yield loss at different damage levels of *S. coarctata* adults

(Screen house)		Cultivar : ADT 36			
Leaf damage (%)	Yield obtained (g/hill)	Yield loss (g/hill)	Percentage		Rate of Yield loss (g/hill)
			Yield obtained	Yield loss	
5	15.43	4.20	74.68	25.32	0.427900
10	12.91	6.72	62.48	37.52	0.572700
15	9.84	9.79	47.62	52.38	0.636000
20	6.76	12.87	32.72	67.28	0.574500
25	4.24	15.39	20.52	79.48	0.430300
30	2.47	17.16	11.95	88.05	0.279600
35	1.37	18.26	6.63	93.37	0.165500
40	0.74	18.89	3.58	96.42	0.092700
45	0.40	19.23	1.94	98.06	0.050280
50	0.21	19.42	1.02	98.98	0.026800
55	0.11	19.52	0.53	99.47	0.014170
60	0.06	19.57	0.29	99.71	0.007450
65	0.03	19.60	0.15	99.85	0.003900
70	0.02	19.61	0.09	99.91	0.002050
75	0.01	19.62	0.04	99.96	0.001070
80	0.00	19.63	0.00	100.00	0.000561
85	0.00	19.63	0.00	100.00	0.000293
90	0.00	19.63	0.00	100.00	0.000153

estimated was 14.50 g/hill (72.27%). When the population was one per hill, the rate of yield loss was 2.40g. At maximum population level, the rate of loss was very minimum (0.27 g/hill). The rate of loss was more than two upto two bugs per hill and it was more than one for every addition of one bug upto a total of six. Thereafter the rate of loss fell below one. The minimal rate of loss corresponded to a loss of 72.27 per cent (Table 37. Fig. 12).

4.8.3.1. Predicted yield loss and rate of yield loss at different damage levels of RBB in field (caged)

The yield loss correlated with per cent leaf damage ranged from 5.92 to 15.79 g/hill corresponding to five and 90 per cent leaf damage respectively showing an increasing trend. When the rate of loss was considered, the range observed was 0.1847 to 0.0201 g/hill. The trend was in decrement (Table 38 Fig.13).

4.8.4. Predicted yield loss and rate of yield loss of RBB in mixed population situation of rice pests in field (uncaged)

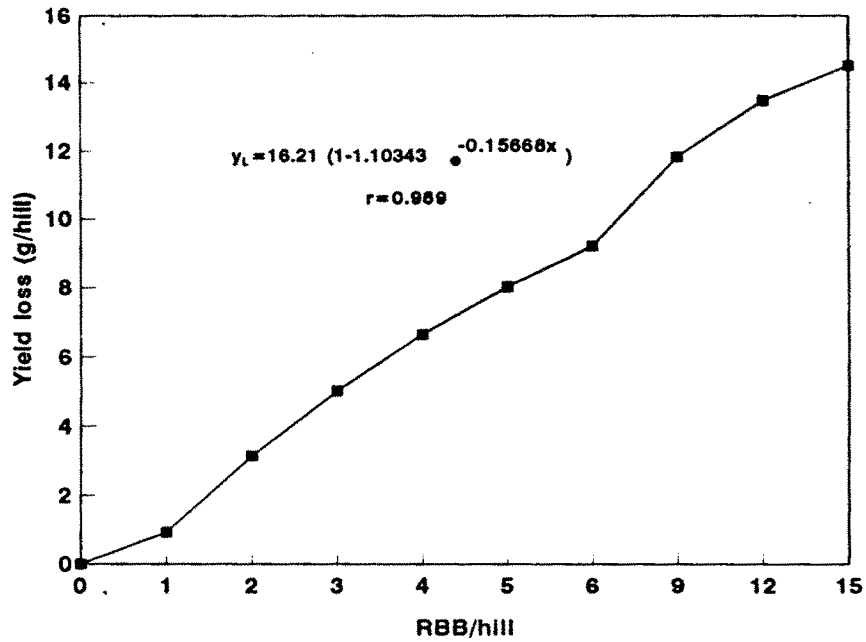
An attempt was made to estimate the yield loss and rate of yield loss in the mixed population situation of rice pests. At the time of conducting the experiment, the rice pests *viz.*, leaffolder and yellow stem borer were noticed, besides RBB. Logistic model was used to estimate the yield loss. When the damage of the plant was at five per cent level, the estimated yield loss was 2.17 g/hill (11.19%). As the damage level went up, the yield loss also increased. An yield loss of 10.05 g/hill (51.83%) was recorded at 30 per cent damage. While the damage suffered increased, the loss in yield also increased correspondingly. The rate of loss suffered showed an increasing trend upto 30 per cent

Table 37. Predicted yield loss at different levels of RBB caged in the field

<i>Samba 1995-96</i>			<i>Cultivar : ADT 36</i>		
RBB No./hill	Yield obtained (g/hill)	Yield loss (g/hill)	Percentage		Rate of Yield loss (g/hill)
			Yield obtained	Yield loss	
1	19.15	0.92	95.75	4.25	2.40
2	16.93	3.14	84.38	15.62	2.05
3	15.04	5.03	74.90	25.10	1.75
4	13.42	6.65	66.87	33.13	1.50
5	12.03	8.04	59.94	40.06	1.28
6	10.85	9.22	54.06	45.94	1.10
9	8.23	11.84	40.99	59.01	0.69
12	6.59	13.48	32.83	67.17	0.43
15	5.57	14.50	27.73	72.27	0.27

Fig.12. Population levels of RBB in field (Caged)

a. Predicted yield loss



b. Predicted rate of yield loss

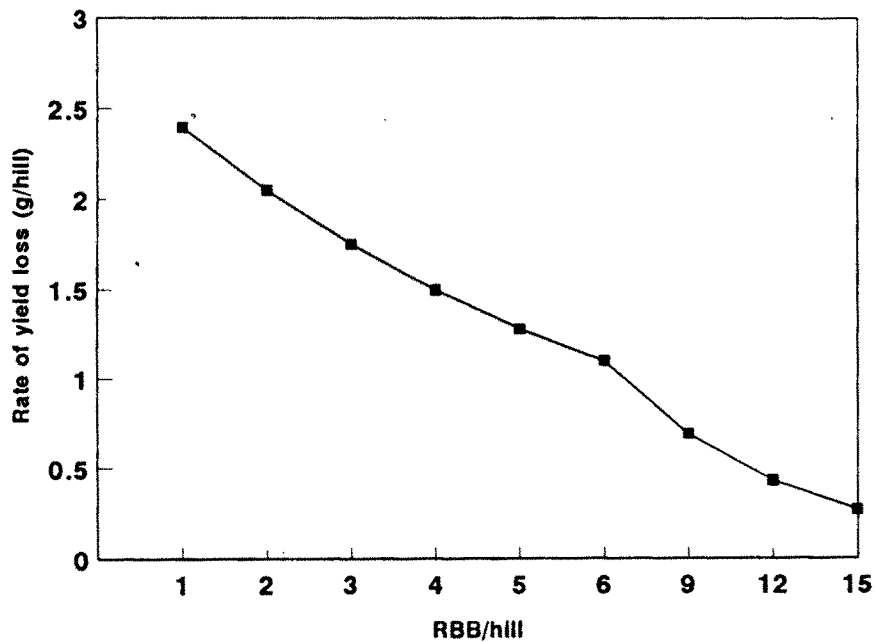
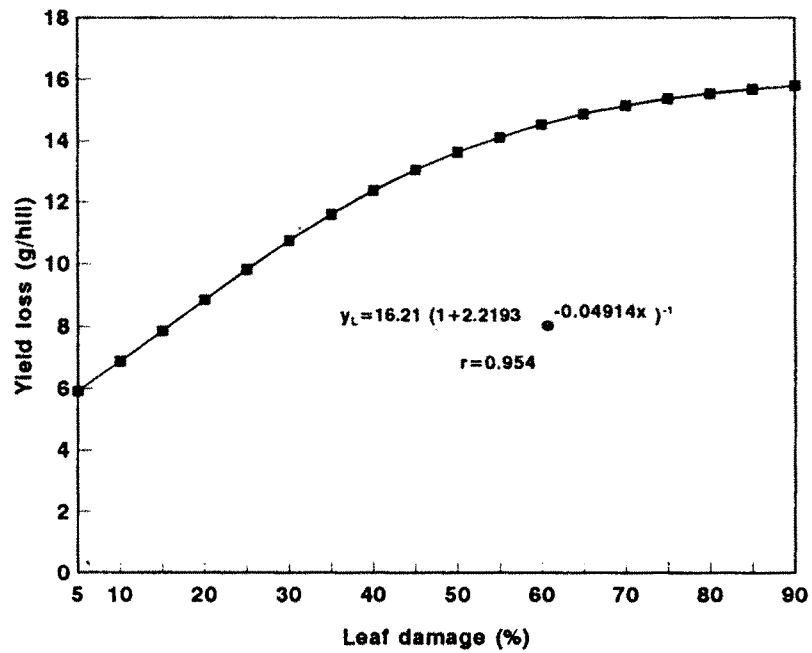


Table 38. Predicted yield loss at different damage levels of RBB caged in the field

<i>Samba 1995-96</i>			Cultivar : ADT 36		
Damage (%)	Yield obtained (g/hill)	Yield loss (g/hill)	Percentage		Rate of Yield loss (g/hill)
			Yield obtained	Yield loss	
5	10.29	5.92	51.27	48.73	0.18470
10	9.33	6.88	46.48	53.52	0.19460
15	8.35	7.86	41.60	58.40	0.19890
20	7.35	8.86	36.62	63.38	0.19740
25	6.38	9.83	31.79	68.21	0.19010
30	5.46	10.75	27.20	72.80	0.17790
35	4.61	11.60	22.97	77.03	0.16211
40	3.84	12.37	19.13	80.87	0.14410
45	3.17	13.04	15.79	84.21	0.12530
50	2.59	13.62	12.90	87.10	0.10690
55	2.10	14.11	10.46	89.54	0.08970
60	1.69	14.52	8.42	91.58	0.07435
65	1.35	14.86	4.73	93.27	0.06089
70	1.08	15.13	5.38	94.62	0.04940
75	0.85	15.36	4.23	95.77	0.03978
80	0.68	15.53	3.39	96.61	0.03185
85	0.53	15.68	2.64	97.36	0.02537
90	0.42	15.79	2.09	97.91	0.02013

Fig.13. Damage levels by RBB in field (Caged)

a. Predicted yield loss



b. Predicted rate of yield loss

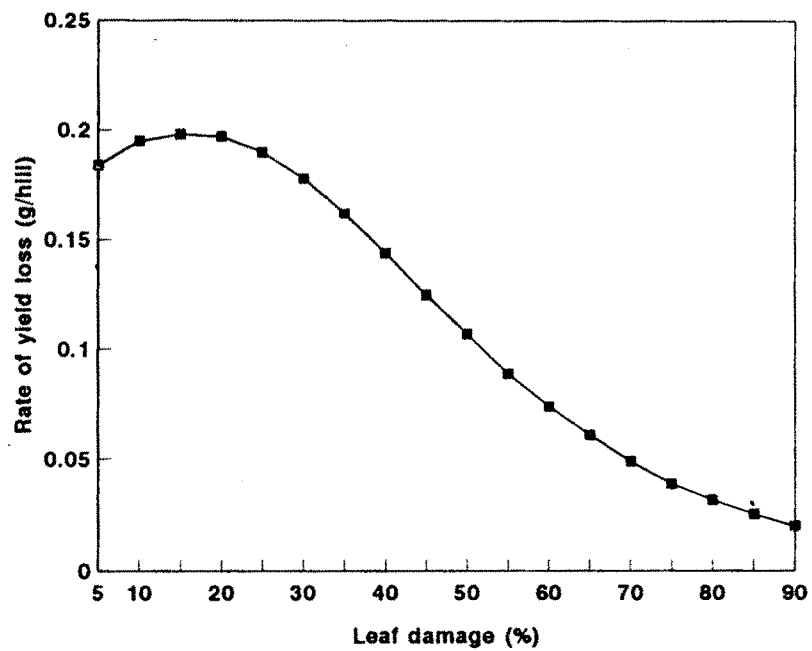


Table 39. Predicted yield loss at different damage levels of RBB in combination with rice leaffolder and yellow stem borer under uncaged conditions in the field

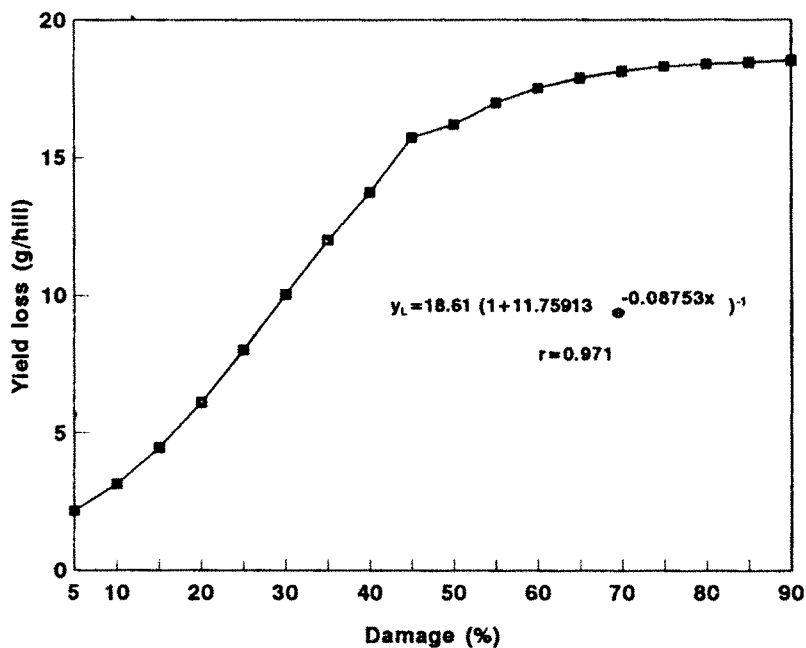
Samba 1995-96

Cultivar : ADT 36

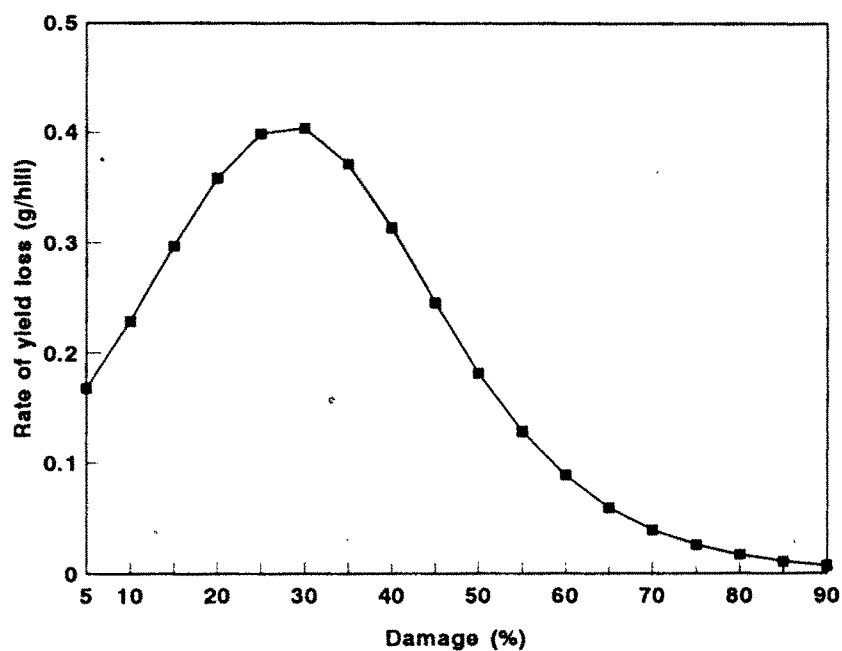
Damage (%)	Yield obtained (g/hill)	Yield loss (g/hill)	Percentage		Rate of Yield loss (g/hill)
			Yield obtained	Yield loss	
5	17.22	2.17	88.80	11.19	0.1680
10	16.24	3.15	83.75	16.25	0.2290
15	14.92	4.47	76.94	23.06	0.2970
20	13.28	6.11	68.49	31.51	0.3590
25	11.37	8.02	58.64	41.36	0.3990
30	9.34	10.05	48.17	51.83	0.4040
35	7.38	12.01	38.06	61.94	0.3720
40	5.65	13.74	29.14	70.86	0.3140
45	4.25	15.14	21.92	78.08	0.2460
50	3.18	16.21	16.40	83.60	0.1820
55	2.40	16.99	12.37	87.63	0.1290
60	1.86	17.53	9.59	90.41	0.0890
65	1.50	17.89	7.73	92.27	0.0590
70	1.25	18.14	6.44	93.56	0.0390
75	1.08	18.31	5.57	94.43	0.0260
80	0.98	18.41	5.05	94.95	0.0170
85	0.93	18.46	4.79	95.21	0.0110
90	0.86	18.53	4.43	95.57	0.0071

Fig.14. Damage levels of RBB in field (Uncaged)

a. Predicted yield loss



b. Predicted rate of yield loss



damage level. Beyond this point, the rate of loss due to the pest complex started to decline. The rate of loss at 30 per cent damage level was 0.404 g/hill and at 90 per cent it was 0.0071g and corresponding to the yield loss of 10.05 g to 18.53 g/hill (Table 39 Fig.14).

4.9. Management of RBB

4.9.1. Laboratory evaluation of botanicals

Laboratory experiments were conducted to evaluate the efficacy of botanicals against RBB. Leaf extracts of commonly available botanicals and neem based commercial formulations were evaluated against RBB. The overall efficacy of botanicals revealed that Neem Seed Kernel Extract (NSKE) 5 per cent was superior (82.78 % mortality) followed by *Vitex negundo* ten per cent extract (82.22%) and these two were on par in increasing the mortality. The next in merit were Neem Azal-F five per cent. Neem Azal-T/S one per cent and leaf extract of *Prosopis juliflora* which gave 74.33, 73.33 and 71.11 per cent mortality respectively and were statistically not different. Neem oil three per cent had resulted in 68.33 per cent kill and was on par with *Ipomoea carnea* leaf extract (61.67%). While considering the overall efficacy, NSKE ranked first and *I.carnea* extract ranked last. However, all the treatments were superior to untreated check.

At 24 h after treatment, the overall knockdown of the adult bugs varied between 45 in neem oil and *I.carnea* and 70 per cent in *V.negundo* leaf extract. The highest kill was recorded with *V.negundo* treatment at 24h. Among the neem based formulations, Neem Azal-F 5 per cent showed 68.33 per cent mortality and this was on par with *V.negundo* leaf extract. *P.juliflora* extract gave 50 per cent kill and this was on par with Neem Azal-T/S 1 per cent (58.33%).

Table 40. Efficacy of botanicals for the management of *S. coarctata* on rice in the laboratory

Treatments	Dosage ml/l g/l	Mortality (%) after treatment (days)			
		1	2	3	Mean
Neem oil 3%	30.00	45.00 C (42.12) c	71.66 B (57.98) bc	88.33 A (70.11) b	68.33 (56.73) b
NSKE 5%	50.00g	63.33 C (52.79) ab	88.33 B (70.11) a	96.66 A (83.85) a	82.77 (68.92) a
<i>Vitex negundo</i> LE 10%	100.00g	70.00 B (56.99)a	81.66 B (64.69)ab	95.00 A (79.54)a	82.22 (67.07)a
<i>Ipomea carnea</i> LE 10%	100.00g	45.00C (42.12)c	61.66B (51.75)c	78.33A (62.47)b	61.66 (52.11)b
<i>Prosopis juliflora</i> LE 10%	100.00g	50.00C (44.99)bc	75.00B (60.07)bc	88.33A (70.11)b	71.11 (58.39)ab
Neem Azal-T/S 1%	5.00	58.33B (49.83)abc	78.33A (62.28)ab	83.33A (65.94)b	73.33 (59.35)ab
Neem Azal-F 5%	1.00	68.33A (55.85)a	73.00A (58.76)bc	81.67A (64.66)b	74.33 (59.75)ab
Untreated control	--	0.06B (1.20)d	6.66A (12.28)d	6.66A (12.28)c	4.46 (8.59)c
Mean		50.00C (43.23)	67.04B (54.74)	77.29A (63.62)	

* Mean of three replications

Figures in parentheses are angular transformed values.

In a column, means followed by a common letter (lower case) and in a row means followed by the same letter (upper case) are not significantly different at the 5% (P=0.05) level by DMRT.

The mortality of adult bugs increased as the days progressed in all the treatments. NSKE was found superior at 48h and had recorded 88.33 per cent mortality. The next ranking treatment was *V.negundo* with 81.67 per cent and this was on par with Neem Azal-T/S 1 per cent (78.33%).

While considering the efficacy of neem based formulations, Neem Azal-F 5 per cent which was found superior to Neem Azal-T/S 1 per cent at 24h showed the reverse trend after 48h. Neem Azal-F 5 per cent recorded 73 per cent kill while it was higher in Neem Azal-T/S 1 per cent (78.33%). The per cent kill in *P.juliflora* and neem oil were 75.00 and 71.67 per cent respectively and were on par with Neem Azal-F 5 per cent (73%). Among the botanicals, *I.carnea* recorded lower mortality of 61.67 per cent compared to other treatments. However, all the treatments were highly superior to untreated check.

NSKE continued to express its efficacy even after 72h. It recorded the highest mortality of 96.67 per cent and was on par with *V.negundo* (95%). Neem Azal-T/S 1 per cent, resulted in 83.33 per cent mortality compared to Neem Azal-F 5 per cent (81.67%) and these were on par with *P.juliflora*, neem oil and *I.carnea* which recorded 88.33, 88.33 and 78.33 per cent mortality respectively. While analysing the overall efficacy of both the neem formulations, significant differences were not observed between them. Regarding the period of observation, the peak expression of mortality was observed at 72h. All the treatments were highly superior to untreated check at all the periods of observation (Table 40).

4.9.2. Laboratory evaluation of insecticides

The experiments conducted to evaluate the efficacy of insecticides against RBB indicated that the overall efficacy in the descending order was monocrotophos, acephate, phosphamidon, fenthion, triazophos, chlorpyriphos, endosulfan and carbaryl.

When the overall efficacy was analysed, monocrotophos (84.44%) and acephate (81.11%) were superior to the other treatments. Phosphamidon and fenthion, endosulfan and carbaryl were on par. However, all the treatments were superior to untreated check.

The overall knockdown effect of the adult bugs varied among the insecticides at 24, 48 and 72 h after treatment. The mortality was highest in monocrotophos (60%). Acephate, phosphamidon and fenthion which recorded 56.67, 53.33 and 50 per cent mortality respectively 24 h after treatment were on par. Triazophos which gave 40.0 per cent kill at 24h was on par with chlorpyrifos (36.67%). The lowest kill was obtained in carbaryl and endosulfan each with 26.67 per cent and both were on par. The per cent kill was significantly more at 48 and 72h than at 24h irrespective of the insecticides.

The per cent mortality ranged between 33.33 in carbaryl and 93.33 in monocrotophos at 48h. The insecticides monocrotophos, acephate, phosphamidon and fenthion were on par. Chlorpyrifos which gave 60 per cent kill at 48h was on par with triazophos (73.33%). Among the insecticides, endosulfan and carbaryl recorded significantly lower mortalities (36.67 and 33.33% respectively) compared to all the other insecticides except untreated control and were on par. Monocrotophos showed its peak expression at 72h and resulted in 100 per cent mortality followed by acephate and fenthion (96.67%) and these were on par. Phosphamidon gave 93.33 per cent kill at 72h and was on par with acephate and fenthion. Carbaryl and endosulfan which brought 33.33 and 36.67 per cent kill respectively at 48h gave comparatively higher mortality (70.0%) at 72h and these were on par with chlorpyrifos (80.0%) and triazophos (83.33%). Considering the statistical significance between the periods, the insecticide, acephate, phosphamidon and triazophos expressed peak mortality at 48h as the mortalities obtained with these insecticides had not differed significantly from that of the mortalities recorded at 72h. The mortality recorded in carbaryl and endosulfan at

Table 41. Efficacy of insecticides for the management of *S. coarctata* on rice in the laboratory

Treatments	Dosage ml/l g/l	Mortality (%) after treatment (days)			
		1	2	3	Mean
Monocrotophos	2.00	60.00C (50.78)a	93.33B (77.70)a	100.00A (90.00)a	84.44 (72.83)a
Acephate	1.25g	56.66B (48.84) ab	90.00A (74.99) a	96.66 A (83.85) ab	81.11 (69.23) ab
Chlorpyriphos	2.00	36.66C (37.22)bc	60.00B (50.85)c	80.00A (63.92)c	58.88 (50.66)d
Phosphamidon	1.00	53.33B (46.92)ab	86.66A (68.85)ab	93.33A (77.70)b	77.77 (64.49)b
Triazophos	1.00	40.00B (39.14)abc	73.33B (59.00)bc	83.33A (66.14)c	65.55 (54.76)c
Carbaryl	2.50	26.66B (30.99)c	33.33B (35.21)d	70.00A (56.99)c	43.33 (41.07)e
Endosulfan	3.00	26.66B (30.99)c	36.66B (37.22)d	70.00A (56.99)c	44.44 (41.73)e
Fenthion	1.00	50.00C (44.99)ab	83.33B (66.14)ab	96.66A (83.85)ab	76.66 (64.99)b
Untreated control	--	0.10A (1.45)d	0.03A (0.60)e	6.66A (12.28)d	2.26 (4.78)f
Mean		38.90C (36.81)	61.85B (52.29)	77.40A (65.75)	

* Mean of three replications

Figures in parentheses are angular transformed values.

In a column, means followed by a common letter (lower case) and in a row means followed by the same letter (upper case) are not significantly different at the 5% (P=0.05) level by DMRT.

48h increased to twice at 72h. All the others showed their peak expression at 72h and among them, monocrotophos ranked superior giving 100 per cent kill. All the insecticides were superior to untreated check and within the period, differences in the untreated check were not significant (Table 41).

4.9.3. Field evaluation of botanicals for the management of *S. coarctata*

4.9.3.1. Samba 1995-1996

The field trial was laid out to study the effect of commonly available botanicals and neem formulations during *Samba* 1995-1996 on Co 43 rice. As far as the overall efficacy was concerned, Neem Azal-T/S (1%) was the best (61.54%) followed by NSKE (55.64%) and there was no statistical difference between them. NSKE was, however on par with Neem Azal-F (5%) (54.75%). The other botanicals viz., *V.negundo*, *P.juliflora* and neem oil recorded 47.34, 46.66 and 46.41 per cent reduction respectively and were on par. *I. carnea* leaf extract was least effective (28.92%).

As the period advanced, the reduction in leaf damage was considerably increased except in *I.carnea* and Neem Azal-F (5%) wherein the leaf damage reduction gradually increased upto five days and thereafter at seven days, a drastic decline was recorded. At one day, Neem Azal-F (5%) recorded the highest reduction (51.99%) of leaf damage followed by Neem Azal-T/S (1%) (49.55%) which were on par with NSKE (47.83%), neem oil (37.57%), *V.negundo* (37.29%) and *P.juliflora* (37.16%). The reduction was the least in *I.carnea* (32.39%). Neem Azal-F (5%) recorded the reduction of 64.47 per cent at three days and declined at five days to 63.56 per cent and to 38.96 per cent after seven days. *P.juliflora* (44.02%) was on par with *V.negundo* (44.25%) at three days. The efficacy of Neem Azal-T/S (1%) was the best throughout the period of observation and was superior to all the other treatments irrespective of the period.

Table 42. Field efficacy of botanicals for the management of RBB on rice*

<i>Samba 1995-96</i>		<i>Cultivar : Co 43</i>					
Treatments	Dose kg a.i./ha	Mortality (%) after treatment (days)					Yield (kg/ha)
		1	3	5	7	Mean	
Neem oil 3%		37.57C	43.19C	50.12A	54.76A	46.41	4316 a
		(37.80)ab	(41.09)c	(45.07)ab	(47.37)ab	(42.92)b	
NSKE 5%		47.83C	52.86B	58.23A	63.65A	55.64	4416 a
		(43.76)ab	(46.64)abc	(49.74)ab	(52.92)a	(48.27)a	
<i>Vitex negundo</i> LE 10%		37.29C	44.25B	51.48A	56.33A	47.34	3883 a
		(37.64)ab °	41.70)bc	(45.85)ab	(48.64)ab	(43.46)b	
<i>Ipomea carnea</i> LE 10%		32.39B	35.25B	47.94A	0.10C	28.92	3750 a
		(34.69)b	(36.42)c	(43.82)b	(1.81)c	(29.18)c	
<i>Prosopis juliflora</i> LE 10%		37.16C	44.02B	52.48A	52.97A	46.66	3830 a
		(37.56)ab	(41.57)bc	(46.42)ab	(46.70)ab	(43.06)b	
Neem Azal-T/S 1%	0.025	49.55C	61.67B	67.10A	67.85A	61.54	4383 a
		(44.74)ab	(51.75)ab	(55.00)a	(55.46)a	(51.74)a	
Neem Azal-F 5%	0.025	51.99B	64.47A	63.56A	38.96C	54.75	4333 a
		(46.14)a	(53.41)a	(52.87)ab	(38.62)b	(47.76)ab	
Untreated control	--	0.10A	0.10A	0.10A	0.10A	0.10	2175 b
		(1.81)c	(1.81)d	(1.81)c	(1.81)c	(1.81)d	
Mean		36.74C	43.23 AB	48.88A	41.84 BC		
		(35.52)	(39.30)	(42.57)	(36.71)		

* Mean of three replications

Figures in parentheses are angular transformed values.

In a column, means followed by a common letter (lower case) and in a row means followed by the same letter (upper case) are not significantly different at the 5% (P=0.05) level by DMRT.

At five days after treatment, Neem Azal-F (5%) (63.56%) was on par with NSKE (58.23%), *P.juliflora* (52.48%), *V.negundo* (51.48%) and neem oil (50.12%). Among the botanicals, *I.carnea* recorded the lowest reduction in one, three and five days after treatment and lost its total efficacy at seven days, whereas *P.juliflora* showed the positive trend in the same period and thereafter, there was a significant change. At seven days, Neem Azal-T/S (1%) recorded the highest reduction (67.85%) followed by NSKE (63.65%) and were on par. There were no significant differences observed in *V.negundo* (56.33%), *P.juliflora* (52.97%) and neem oil (54.76%) in causing the reduction in leaf damage. The highest yield of 4416 kg/ha was recorded in NSKE. Neem Azal-T/S, which was found superior throughout the period had recorded the yield of 4383 kg/ha. However, there were no significant differences observed among these treatments. The grain yield was the lowest (2175kg/ha) in the untreated control (Table 42).

4.9.3.1.1. Cost-benefit analysis for Botanicals

The Cost-benefit ratio was worked out using the values of total return and values of total input (Method I) as discussed in section 3.10. of Materials and Methods. The cost benefit ratio was also worked by the method (II) suggested by Henrichs *et al.* (1981).

In method I, when the total return was considered against the total inputs, the Cost-benefit ratio ranged from 1: 1.87 in NSKE 5 per cent as against only 1: 0.96 in an untreated control. The total return ranged from Rs.22,500^{ha}/in *I.carnea* leaf extract to Rs.26,052 in NSKE. The value of the return from the untreated control was Rs.13,050. High returns were realised from NSKE (Rs.26,502), Neem Azal-T/S (1%) (Rs.26,298), Neem Azal-F (5%) (Rs.25,998) and neem oil (3%) (Rs.25,902). The leaf extracts of *V.negundo* and *P.juliflora* accounted for a return of Rs.23,298 and Rs.22,980 respectively.

Table 43. Yield on hectare basis and Cost-benefit Ratio (Botanicals)

Samba 1995-96

Treatment	Paddy yield (kg/ha)	Returns* (Rs.)	Cost of treatment (Rs.)	Cost-benefit Ratio Method	
				I	II
Neem oil 3%	4317	25,902	737	1:1.82	1:17.43
NSKE 5%	4417	26,502	637	1:1.87	1:21.09
Neem Azal-T/S 1%	4383	26,298	1,787	1:1.72	1: 7.41
Neem Azal-F 5%	4333	25,998	1,012	1:1.79	1:12.79
Untreated control	2175	13,050	--	1:0.96	--

Cost of botanicals :

Neem oil	Rs. 30/l
Neem seed kernel	Rs. 14/kg
Neem Azal-T/S 1%	Rs.600/l
Neem Azal-F 5%	Rs.1450/l
Spraying charges	Rs. 287/ha/round

* Price of paddy : Rs.6/kg (Current market rate)

Method I

$$\frac{\text{Treatment yield (kg/ha) X value of paddy (Rs./kg)}}{\text{Basic cost of cultivation } \pm \text{ Cost of protection**}}$$

** for control yields, cost of protection was excluded and for treatment it was included

Method II

$$\frac{\text{Value of treated crop - Value of untreated crop}}{\text{Cost of protection to treated crop}}$$

Method II assumes the difference in value of treated crop and the value of untreated crop to be wholly due to the treatment. In this, the extra return though was due to many factors that might have contributed for the yield, cost of plant protection only was assumed to be responsible for the output. As such the Cost-benefit was exaggerated. The results showed a cost benefit ranged from 7.41 in Neem Azal-T/S 1 per cent to 21.09 in NSKE (5%). Neem oil and Neem Azal-F (5%) gave a Cost-benefit of 17.43 and 12.79 respectively (Table 43).

4.9.3.2. Evaluation of botanicals *Navarai* 1996

The efficiency of botanicals and neem formulations tried during *Navarai* 1996 against RBB indicated that the NSKE was superior (54.83%) followed by Neem Azal-T/S (1%) (54.57%). Neem Azal-F(5%), *V.negundo*, *P.juliflora* and neem oil recorded the reduction in leaf damage of 50.15, 51.56, 49.01 and 46.48 per cent respectively and were on par and also on par with NSKE and Neem Azal-T/S(1%). *I.carnea* was the least effective (23.72%).

Considering the per cent reduction, at each period after treatment, increasing trend was observed except in *I.carnea* and Neem Azal-F(5%). At all the periods observed, Neem Azal-F(5%) recorded significantly the highest reduction upto five days and thereafter the reduction was found to decline. At one day after treatment, the highest reduction was recorded in Neem Azal-F(5%) (50.94%) followed by Neem Azal-T/S (1%) (44.36%) and NSKE (44.34%) which were on par. Similarly, *V.negundo* (37.99%), *P.juliflora* (37.80%) and neem oil (36.57%) were on par. Among the botanicals, *I.carnea* registered the lowest reduction (26.68%), compared to all other treatments but superior to untreated control. Neem Azal-F(5%) continued to rank first (53.73%) at three days followed by NSKE (52.02%) and *V.negundo* (50.65%) and these were on par. There was no significant difference between *P.juliflora* and neem oil which

Table 44. Field efficacy of botanicals for the management of RBB on rice*

Navarai 1996		Cultivar : IR 64					
Treatments	Conc.	Reduction (%) after treatment (days)					Yield (kg/ha)
	Dose (kga.i./ha)	1	3	5	7	Mean	
Neem oil 3%		36.57B	43.89A	52.65A	52.83A	46.48	3975 bc
		(37.21)ab	(41.49)ab	(46.52)a	(46.62)a	(42.96)a	
NSKE 5%		44.34B	52.02A	61.99A	60.99A	54.83	4530 a
		(41.75)a	(46.16)a	(51.94)a	(51.35)a	(47.80)a	
<i>Vitex negundo</i> LE 10%		37.99B	50.65A	56.28A	61.33A	51.65	4496 ab
		(38.05)ab	(45.37)a	(48.61)a	(51.55)a	(45.90)a	
<i>Ipomea carnea</i> LE 10%		26.68A	31.77A	36.32A	0.10B	23.72	3333 c
		(31.10)b	(34.31)b	(37.06)b	(1.81)c	(26.07)b	
<i>Prosopis juliflora</i> LE 10%		37.80B	46.34 A	54.98A	56.94A	49.01	4462 ab
		(37.94)ab	(42.90)ab	(47.86)a	(48.99)a	(44.42)a	
Neem Azal-T/S 1%	0.025	44.36B	48.97A	62.43A	62.50A	54.57	4722 a
		(41.76)a	(44.41)a	(52.20)a	(52.24)a	(47.65)a	
Neem Azal-F 5%	0.025	50.94A	53.73A	62.23A	33.71B	50.15	4375 ab
		(45.54)a	(47.14)a	(52.08)a	(35.49)b	(45.06)a	
Untreated control	--	0.10A	0.10A	0.10A	0.10A	0.10	2152 d
		(1.81)c	(1.81)c	(1.81)c	(1.81)c	(1.81)d	
Mean		34.85C	40.93B	48.37A	41.06BC		
		(34.39)	(37.95)	(42.26)	(36.23)		

* Mean of three replications

Figures in parentheses are angular transformed values.

In a column, means followed by a common letter (lower case) and in a row means followed by the same letter (upper case) are not significantly different at the 5% (P=0.05) level by DMRT.

brought 46.34 and 43.89 per cent respectively. At five days, Neem Azal-T/S(1%) was found superior (62.43%) followed Neem Azal-F(5%) (62.23%) and all the botanicals excepting *I.carnea* were on par. *I.carnea* ranked last and it had lost its efficacy and the reduction was almost nil at seven days after treatment.

The maximum yield of 4722 kg/ha was recorded in Neem Azal-T/S (1%) followed by NSKE (4530 kg/ha). However, significant differences were not observed between them. *V.negundo* *P.juliflora* and Neem Azal-F(5%) were inturn on par with the above two treatments. Neem oil 3 per cent gave an yield of 3975 kg/ha and was on par with *I.carnea* (3333 kg/ha). All the treatments, however were superior to untreated control (2152 kg/ha) (Table 44).

4.9.3.2.1. Cost-benefit analysis

Maximum return of Rs.28332 was received in Neem Azal -T/S(1%) follwed by NSKE (Rs.27,180). In other botanicals, it was in the range of Rs.19,998 in *I.carnea* to Rs.26,972 in *V.negundo*. The cost of treatment was worked out for all the treatments except the three leaf extracts viz., *V.negundo*, *P.juliflora*, and *I.carnea*. The cost of treatment ranged from Rs.637 in NSKE (5%) to Rs.1,787 in Neem Azal-T/S(1%). The cost of treatment in neem oil was Rs.787 while for Neem Azal-F(5%) it was Rs.1,012. The Cost-benefit ratio worked as per method I ranged from 1:0.96 in an untreated control to 1:1.92 in NSKE. The ratio for Neem Azal formulations was 1:1.85 in 1 per cent and 1:1.81 in 5 per cent. In neem oil, Cost-benefit ratio was 1:1.68.

The Cost-benefit as per method II ranged from 8.62 in Neem Azal-T/S (1%) to 22.38 in NSKE. The Cost-benefit for Neem Azal-F(5%) and neem oil was 13.17 and 14.83 respectively (Table 45).

Table 45. Yield on hectare basis and Cost-benefit Ratio (Botanicals)

Navarai 1996

Treatment	Paddy yield (kg/ha)	Returns* (Rs.)	Cost of treatment (Rs.)	Cost-benefit Ratio Method	
				I	II
Neem oil 3%	3975	23,850	737	1:1.68	1:14.83
NSKE 5%	4530	27,180	637	1:1.92	1:22.38
Neem Azal-T/S 1%	4722	28,332	1,787	1:1.85	1: 8.62
Neem Azal-F 5%	4375	26,250	1,012	1:1.81	1:13.17
Untreated control	2152	12,912	--	1:0.96	--

Cost of botanicals :

Neem oil	Rs. 30/l
Neem seed kernel	Rs. 14/kg
Neem Azal-T/S 1%	Rs.600/l
Neem Azal-F 5%	Rs.1450/l
Spraying charges	Rs. 287/ha/round

* Price of paddy : Rs.6/kg (Current market rate)

Method I

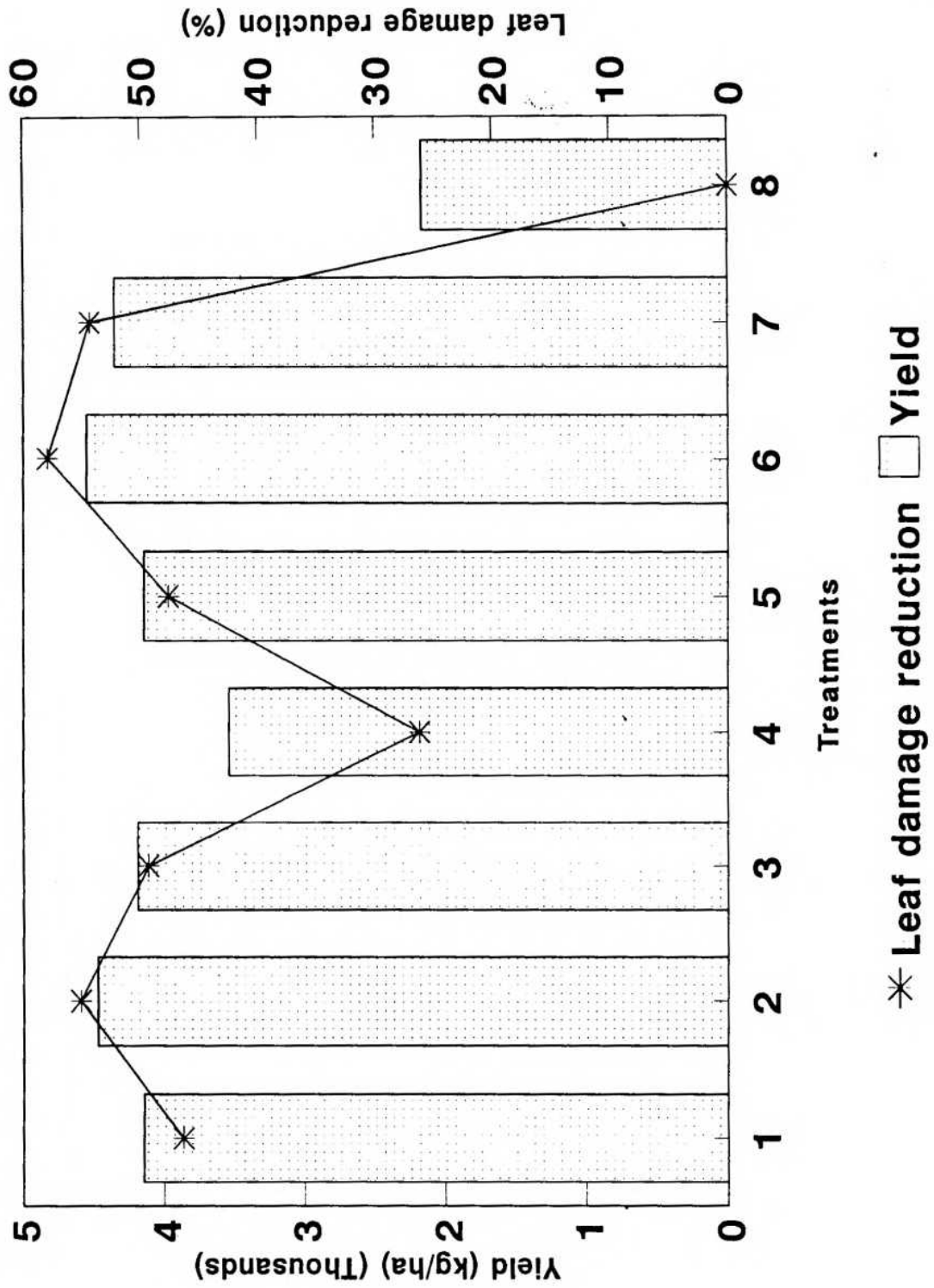
$$\frac{\text{Treatment yield (kg/ha) X value of paddy (Rs./kg)}}{\text{Basic cost of cultivation } \pm \text{ Cost of protection**}}$$

** for control yields, cost of protection was excluded and for treatment it was included

Method II

$$\frac{\text{Value of treated crop - Value of untreated crop}}{\text{Cost of protection to treated crop}}$$

Fig.15. Field evaluation of botanicals on RBB damage and rice yield (Pooled analysis)



4.9.4. Field efficacy of botanicals for the management of *S. coarctata* over seasons

The pooled analysis indicated that the seasonal differences observed were not significant. Of the botanicals tried, Neem Azal-T/S(1%) was significantly superior to other treatments but was on par with NSKE. This was followed by Neem Azal-F(5%). *I.carnea* leaf extract had given the lowest reduction in leaf damage but it was superior to untreated control. The rate of reduction in leaf damage was found to increase from one day after treatment to seven days after treatment excepting Neem Azal-F(5%), where the highest reduction was observed during five days after treatment. As regards the yield, all the treatments except *I.carnea* leaf extract were on par. The yield ranged from 4146 kg/ha in neem oil to 4552kg/ha in Neem Azal-T/S(1%). In *I.carnea* leaf extract (3541kg/ha), the yield was significantly superior to untreated check (2164kg/ha) but was significantly inferior to all the other botanicals tested (Fig.15).

4.9.4.1. Cost-benefit analysis (Pooled analysis)

Pooled analysis of both the seasons had shown that the return per hectare was maximum in Neem Azal-T/S (1%) (Rs.21,312) followed by NSKE (Rs.26,844) and Neem Azal-F(5%) (Rs.26,124). In other botanicals, excluding *I.carnea*, the returns ranged from Rs.24,876 in neem oil and *P.juliflora* to Rs.25,140 in *V.negundo*. leaf extract. Among the botanicals, the return was lowest in *I.carnea* leaf extract (Rs.21,246). In untreated control, the return was the lowest (Rs.12,984). In method I, the Cost-benefit ratio was the highest in NSKE (1:1.89) followed by Neem Azal -F(5%) (1:1.80), Neem Azal-T/S(1%)(1:1.78) and neem oil (1:1.74). In the untreated control, the ratio was only 1:0.96. In method II, Cost-benefit realised ranged from, 8.02 in Neem Azal-T/S (1%) to 21.74 in NSKE. Neem Azal-F(5%) and neem oil (3%) gave the Cost-benefit of 12.98 and 16.12 respectively (Table 46).

Table 46. Yield on hectare basis and Cost-benefit Ratio (Botanicals)

Treatment	Paddy yield (kg/ha)	Returns* (Rs.)	Cost of treatment (Rs.)	Cost-benefit Ratio Method	
				I	II
				Neem oil 3%	4146
NSKE 5%	4474	26,844	637	1:1.89	1:21.74
Neem Azal-T/S 1%	4552	27,312	1,787	1:1.78	1: 8.02
Neem Azal-F 5%	4354	26,124	1,012	1:1.80	1:12.98
Untreated control	2164	12,984	--	1:0.96	--

Cost of botanicals :

Neem oil	Rs. 30/l
Neem seed kernel	Rs. 14/kg
Neem Azal-T/S 1%	Rs.600/l
Neem Azal-F 5%	Rs.1450/l
Spraying charges	Rs. 287/ha/round

* Price of paddy : Rs.6/kg (Current market rate)

Method I

$$\frac{\text{Treatment yield (kg/ha) X value of paddy (Rs./kg)}}{\text{Basic cost of cultivation } \pm \text{ Cost of protection**}}$$

** for control yields, cost of protection was excluded and for treatment it was included

Method II

$$\frac{\text{Value of treated crop - Value of untreated crop}}{\text{Cost of protection to treated crop}}$$

4.9.5. Field evaluation of insecticides for the management of *S. coarctata*

4.9.5.1. *Samba* 1995-1996

The field trial was laid out to evaluate the efficacy of insecticides during *samba* 1996 on Co 43 rice. Data gathered in the field experiment on the per cent reduction in leaf damage by RBB after treatment indicated that application of fenthion at 0.5 kg a.i./ha was superior followed by acephate (0.469 kg a.i./ha) and these two were on par. Monocrotophos was next in order of merit. Phosphamidon, triazophos and chlorpyrifos recorded the reduction in leaf damage of 63.60, 62.39 and 61.97 per cent respectively and these were on par and superior to endosulfan (55.52%) and carbaryl (48.09%). All the treatments were highly superior to untreated control at all the periods of observation.

Considering the reduction in leaf damage, at each period of observation, an increasing trend was noticed as the days progressed. At one day after treatment, fenthion recorded the highest reduction in leaf damage (56.51%) and was superior among all. acephate (51.26%), phosphamidon (51.08%), monocrotophos (50.75%) and triazophos (49.32%) were on par. The per cent reduction of leaf damage was considerably lower in chlorpyrifos (47.91%) and endosulfan (47.77%) and were on par. The lowest among all was carbaryl (36.03%).

The reduction in leaf damage at three days showed that fenthion was significantly superior to other treatments with 73.81 per cent. The next in rank was monocrotophos (67.15%). The treatments phosphamidon (65.53%) and acephate (65.23%) were on par. The next in order were triazophos (59.86%), chlorpyrifos (57.49%) and endosulfan (53.60%).

Table 47. Field efficacy of insecticides for the management of RBB on rice*

<i>Samba 1995-96</i>		<i>Cultivar : Co 43</i>					
Treatments	Dosage (kga.i./ha)	Reduction (%) of leaf damage after treatment (days)					Yield (kg/ha)
		1	3	5	7	Mean	
Monocrotophos	0.360	50.75D	67.15C	73.18B	87.93A	69.75	4847 a
		(45.43)ab	(55.03)b	(58.81)bc	(69.67)b	(57.24)b	
Acephate	0.469	51.26D	65.23C	86.29B	93.98A	74.19	4853 a
		(45.72)ab	(53.87)bc	(68.27)a	(75.80)a	(60.92)a	
Chlorpyriphos	0.200	47.91D	57.49C	66.71B	75.77A	61.97	4033 c
		(43.80)b	(49.31)de	(54.76)cd	(60.51)c	(52.10)c	
Phosphamidon	0.425	51.08C	(65.53B	64.62B	73.18A	63.60	4286 b
		(45.62)ab	(54.05)bc	(53.50)d	(58.81)c	(53.00)c	
Triazophos	0.200	49.32C	59.86B	69.68A	70.69A	62.39	4023 c
		(44.61)ab	(50.69)cd	(56.59)cd	(57.22)c	(52.28)c	
Carbaryl	0.625	36.03B	50.54A	54.18A	51.64A	48.09	3672 d
		(36.89)c	(45.31)e	(47.40)e	(45.94)e	(43.89)e	
Endosulfan	0.525	47.77C	53.60B	56.96A	63.75A	55.52	3805 cd
		(43.72)b	(47.07)de	(49.00)e	(52.98)d	(48.19)d	
Fenthion	0.413	56.51D	73.86C	77.81B	89.75A	74.48	4135 b
		(48.74)a	(59.25)a	(61.90)b	(71.33)b	(60.31)a	
Untreated control	--	0.10A	0.10A	0.10A	0.10A	0.10	1921 e
		(1.81)d	(1.81)f	(1.81)f	(1.81)f	(1.81)f	
Mean		43.41D	54.82C	61.06B	67.42A		
		(39.59)	(42.26)	(50.23)	(54.90)		

* Mean of three replications

Figures in parentheses are angular transformed values.

In a column, means followed by a common letter (lower case) and in a row means followed by the same letter (upper case) are not significantly different at the 5% (P=0.05) level by DMRT.

Considering the efficacy of insecticide at five days, phosphamidon showed a slight decrease in the reduction while increasing trend was noticed in all the others. Acephate had recorded the highest reduction (86.29%) and was found independently superior to all others even after seven days. Fenthion which ranked first in one day became second efficacy-wise on the second day. Chlorpyrifos (66.71%) and triazophos (69.68%) were on par. The leaf damage reduction was lower in endosulfan (56.96%) and carbaryl (54.18%) and these two were on par. All the insecticides showed increased reduction at seven days except carbaryl.

The highest yield of 4853 kg/ha was recorded in acephate followed by monocrotophos (4847 kg/ha) and these were on par. There were no significant differences noticed in phosphamidon and fenthion which gave the yield of 4286 and 4135 kg/ha respectively. Chlorpyrifos and triazophos recorded 4033 and 4023 kg/ha respectively and were on par. The lowest yield of 1921kg/ha was recorded in untreated control (Table 47).

4.9.5.1.1. Cost-benefit analysis

Acephate ranked first in fetching the highest return of Rs.29,118/ha followed by monocrotophos (Rs.29,082). Returns of Rs.24,810, Rs.24,198 and Rs.24,138 were realised in fenthion, chlorpyrifos and triazophos respectively. Phosphamidon, endosulfan and carbaryl recorded the return of Rs.25,716, 22,830 and 22,032 respectively. In untreated control, the return was only Rs.11,526. Cost of treatment in acephate was Rs.675/ha and it was Rs. 512 in phosphamidon and triazophos and Rs.687 in fenthion. The cost of treatment per ha/round for acephate, monocrotophos, endosulfan, carbaryl and chlorpyrifos worked out to be Rs.675, Rs.667, 632, 637 and 537 respectively. In method I, the Cost-benefit ratio was higher in monocrotophos and acephate (1:2.05). The ratio had not varied significantly in phosphamidon (1:1.79),

Table 48. Yield on hectare basis and Cost-benefit Ratio (Insecticides)

Samba 1995-96

Treatment	Paddy yield (kg/ha)	Returns* (Rs.)	Cost of treatment (Rs.)	Cost-benefit Ratio Method	
				I	II
Monocrotophos	4847	29,082	667	1:2.05	1:26.30
Acephate	4853	29,118	675	1:2.05	1:26.06
Chlorpyriphos	4033	24,198	537	1:1.72	1:23.58
Phosphamidon	4286	25,716	512	1:1.79	1:26.63
Triazophos	4023	24,138	512	1:1.72	1:24.61
Carbaryl	3672	22,032	637	1:1.56	1:16.48
Endosulfan	3805	22,830	632	1:1.61	1:17.87
Fenthion	4135	24,810	687	1:1.75	1:19.32
Untreated control	1921	11,526	--	1:0.85	--

Cost of insecticides :

Monocrotophos	Rs.380/l	Triazophos	Rs.450/l
Acephate	Rs.620/kg	Carbaryl	Rs.280/kg
Chlorpyriphos	Rs.250/l	Endosulfan	Rs.230/l
Phosphamidon	Rs.450/l	Fenthion	Rs.800/l
Spraying charges	Rs.287/ha/round		

* Price of paddy : Rs.6/kg (Current market rate)

Method I

$$\frac{\text{Treatment yield (kg/ha)} \times \text{value of paddy (Rs./kg)}}{\text{Basic cost of cultivation} \pm \text{Cost of protection**}}$$

** for control yields, cost of protection was excluded and for treatment it was included

Method II

$$\frac{\text{Value of treated crop} - \text{Value of untreated crop}}{\text{Cost of protection to treated crop}}$$

fenthion (1:1.75), chlorpyrifos and triazophos (1:1.72). Among the insecticides, carbaryl recorded the lowest ratio of 1:1.56. However, it was superior to untreated control (1:0.85). In method II the Cost-benefit ranged from 16.48 in carbaryl to 26.63 in phosphamidon. Monocrotophos recorded the Cost-benefit of 26.30 and in acephate the Cost-benefit ratio was 26.06. This was followed by triazophos (24.61), chlorpyrifos (23.58), fenthion (19.32) and endosulfan (17.87) (Table 48).

4.9.5.2. Navarai 1995-1996

The results revealed that acephate was superior in reducing the leaf damage (74.06%). Fenthion ranked next (70.23%) and this was on par with monocrotophos (68.98%) which was in turn on par with phosphamidon (66.67%), chlorpyrifos and triazophos with 63.84 and 61.44 per cent respectively. The per cent reduction in leaf damage was lower in endosulfan (52.02%) and among the insecticides, carbaryl recorded the lowest reduction (23.45%). However, all the treatments were significantly superior to untreated control.

At one day after treatment, acephate recorded the highest reduction in leaf damage (61.99%). Fenthion (60.00%), monocrotophos (56.23%), phosphamidon (51.36%), triazophos (49.45%) and chlorpyrifos (48.03%) showed varied degree of reduction and all were on par. Endosulfan had registered 44.27 per cent reduction and in carbaryl, it was still lower (28.13%).

As the days progressed, the reduction in leaf damage considerably increased. However, in carbaryl, though the per cent reduction at three days after treatment was 37.13 per cent the same trend was not maintained at five and seven days after treatment. At three days after treatment, the reduction was maximum (66.62%) in fenthion and the efficacy in the descending order was acephate (66.16%), phosphamidon (63.21%), monocrotophos (62.86%), chlorpyrifos (59.35%) and triazophos (55.76%)

Table 49. Field efficacy of insecticides for the management of RBB on rice*

<i>Navarai 1996</i>		Cultivar : IR 64					
Treatments	Dosage (kga.i./ha)	Reduction (%) of leaf damage after treatment (days)					Yield (kg/ha)
		1	3	5	7	Mean	
Monocrotophos	0.360	56.23C	62.86B	77.16A	79.68A	68.98	5322 ab
		(48.58)ab	(52.45)a	(61.45)a	(63.21)ab	(56.42)b	
Acephate	0.469	61.99C	66.16C	79.27B	88.81A	74.06	5472 ab
		(51.94)a	(54.43)a	(62.92)a	(70.46)a	(59.94)a	
Chlorpyriphos	0.200	48.03C	59.35B	68.68B	79.29A	63.84	5208 ab
		(43.87)ab	(50.39)a	(55.97)ab	(62.93)ab	(53.29)c	
Phosphamidon	0.425	51.36C	63.21B	72.46B	79.64B	66.67	5420 ab
		(45.78)ab	(52.66)a	(58.35)a	(63.18)ab	(54.99)bc	
Triazophos	0.200	49.45B	55.76B	65.13A	75.41A	61.44	4340 c
		(44.69)ab	(48.31)a	(53.81)ab	(60.27)b	(51.77)c	
Carbaryl	0.625	28.13A	37.13A	21.91B	6.64C	23.45	4208 c
		(32.03)c	(37.54)b	(27.91)c	(14.93)d	(28.10)e	
Endosulfan	0.525	44.27B	51.01A	55.43A	57.39A	52.02	4930 bc
		(41.71)b	(45.58)ab	(48.12)b	(49.25)c	(46.16)d	
Fenthion	0.413	60.00B	66.62B	73.62A	80.70A	70.23	5624 a
		(50.77)ab	(54.71)a	(59.10)a	(63.94)ab	(57.13)ab	
Untreated control	--	0.10A	0.10A	0.10A	0.10A	0.10	2257 d
		(1.81)d	(1.81)c	(1.81)d	(1.81)e	(1.81)f	
Mean		44.39C	51.36B	57.08A	60.85A		
		(40.13)	(44.21)	(47.71)	(50.00)		

* Mean of three replications

Figures in parentheses are angular transformed values.

In a column, means followed by a common letter (lower case) and in a row means followed by the same letter (upper case) are not significantly different at the 5% (P=0.05) level by DMRT.

and all were on par. carbaryl showed an increase in leaf damage reduction (37.13%) at three days. Thereafter, decline was noticed as 21.91 per cent at five days and further steep reduction to 6.64 per cent at seven days.

At five days after treatment, acephate recorded the highest leaf damage reduction of 79.27 per cent and this was on par with monocrotophos (77.16%), fenthion (73.62%) and phosphamidon (72.46%). Chlorpyriphos and triazophos brought 68.68 and 65.13 per cent respectively and were on par and were also significantly superior to endosulfan (55.43%). Acephate continued to express its efficacy at seven days with 88.81 per cent, followed by fenthion (80.70%), monocrotophos (79.68%), phosphamidon (79.64%) and chlorpyriphos (79.29%) and these were on par. Triazophos and endosulfan resulted 75.41 and 57.39 per cent reduction in leaf damage and were independently superior. Among the insecticides, carbaryl was the least effective at seven days after treatment.

The highest yield of 5624 kg/ha was recorded in fenthion. Acephate (5472 kg/ha), phosphamidon (5420 kg/ha), monocrotophos (5322 kg/ha) and chlorpyriphos (5208 kg/ha) were on par. These four treatments were inturn on par with fenthion. Triazophos and carbaryl were on par. Untreated control recorded significantly the lowest yield (2257 kg/ha) (Table 49).

4.9.5.2.1. Cost-benefit analysis

In *Navaraj*, gross return was maximum in fenthion (Rs.33,744) followed by acephate (Rs.32,832), phosphamidon (Rs.32,520) and monocrotophos (Rs.31,938). Gross return of Rs.31,248, 29,580 and 26,040 were received from chlorpyriphos, endosulfan and triazophos respectively. Carbaryl recorded the lowest return among the treatments (Rs.25,248) and in the untreated control, the return was only Rs.13,542.

Table 50. Yield on hectare basis and Cost-benefit Ratio (Insecticides)

Navarai 1996

Treatment	Paddy yield (kg/ha)	Returns* (Rs.)	Cost of treatment (Rs.)	Cost-benefit Ratio Method	
				I	II
Monocrotophos	5323	31,938	667	1:2.25	1:27.55
Acephate	5472	32,832	675	1:2.31	1:28.57
Chlorpyriphos	5208	31,248	537	1:2.23	1:32.94
Phosphamidon	5420	32,520	512	1:2.32	1:37.03
Triazophos	4340	26,040	512	1:1.85	1:24.39
Carbaryl	4208	25,248	637	1:1.78	1:18.36
Endosulfan	4930	29,580	632	1:2.09	1:25.36
Fenthion	5624	33,744	687	1:2.38	1:29.39
Untreated control	2257	13,542	--	1:1.00	--

Cost of insecticides :

Monocrotophos	Rs.380/l	Triazophos	Rs.450/l
Acephate	Rs.620/kg	Carbaryl	Rs.280/kg
Chlorpyriphos	Rs.250/l	Endosulfan	Rs.230/l
Phosphamidon	Rs.450/l	Fenthion	Rs.800/l
Spraying charges	Rs.287/ha/round		

* Price of paddy : Rs.6/kg (Current market rate)

Method I

$$\frac{\text{Treatment yield (kg/ha)} \times \text{value of paddy (Rs./kg)}}{\text{Basic cost of cultivation} \pm \text{Cost of protection}^{**}}$$

** for control yields, cost of protection was excluded and for treatment it was included

Method II

$$\frac{\text{Value of treated crop} - \text{Value of untreated crop}}{\text{Cost of protection to treated crop}}$$

In method I, the Cost-benefit ratio was the highest in fenthion (1:2.38) followed by phosphamidon (1:2.32) and acephate (1:2.31). The variation among the treatments in monocrotophos, endosulfan, and chlorpyrifos was meager. Cost-benefit ratio was much lower in triazophos (1:1.85) but was superior to carbaryl (1:1.78). Untreated control gave a ratio of 1:1 indicating that the cost of production and return realised was the same. In method II, phosphamidon recorded a Cost-benefit of 37.03 which was the highest among the treatments followed by chlorpyrifos (32.94), fenthion (29.39) acephate (28.57) and monocrotophos (27.55). Carbaryl recorded the lowest Cost-benefit of 18.36 (Table 50).

4.9.6. Field efficacy of insecticides for the management of RBB (pooled analysis)

The overall efficacy of insecticides against RBB indicated that acephate was significantly superior to other treatments in bringing down the leaf damage (75.65%). This was followed by fenthion (72.13%) and monocrotophos (69.25%) and both were on par. Significant differences were not observed among phosphamidon (65.01%), chlorpyrifos (62.79%) and triazophos (61.81%). Endosulfan was independent in action and brought 53.67 per cent reduction. The reduction in leaf damage increased as the days after treatment progressed in all the treatments except carbaryl wherein the highest reduction was observed at three days after treatment. Thereafter a decline was noticed. The pooled analysis also revealed that the influence of the season in reducing the leaf damage was also significant. *Samba* 1995 recorded a higher reduction than *Navarai* 1996. Regarding the yield, all the treatments except carbaryl gave higher yield. The yield was maximum in acephate (5162kg/ha) followed by monocrotophos (5085 kg/ha) and were on par. The next in order was fenthion which gave 4880 kg/ha and was in turn on

par with monocrotophos. The yield ranged from 3940 kg/ha in carbaryl to 5162 kg/ha in acephate. Untreated control recorded the lowest yield of 2089 kg/ha. When the two seasons were compared, *Navarai* 1996 recorded a significantly higher yield than *Samba* 1995-1996 (Fig. 16).

4.9.6.1. Cost-benefit analysis

Maximum return of Rs.30,972 was obtained from acephate followed by monocrotophos (Rs.30,510). Fenthion, phosphamidon, chlorpyrifos, endosulfan and triazophos recorded the returns of Rs.29,280, Rs. 29,116, Rs.27,720, Rs.26,202 and Rs.25,086 respectively. Carbaryl yielded the lowest return of Rs.23,640 which was significantly higher than untreated control (Rs.12,534). In method I, Cost-benefit ratio was maximum in acephate (1:2.18) followed by monocrotophos (1:2.15) and fenthion (1:2.06). In other treatments, the ratio varied between 1:2.01 in phosphamidon to 1:1.67 in carbaryl. The untreated control recorded the Cost-benefit of 1:0.93. In method II, the Cost-benefit varied from 17.42 in carbaryl to 30.40 in phosphamidon. Chlorpyrifos recorded the Cost-benefit of 28.25 followed by acephate (27.31), monocrotophos (26.93) triazophos (24.49) and fenthion (24.36). Endosulfan recorded a Cost-benefit of 21.60 (Table 51).

Table 51. Yield on hectare basis and Cost-benefit Ratio (Insecticides)

Over two seasons

Treatment	Paddy yield (kg/ha)	Returns* (Rs.)	Cost of treatment (Rs.)	Cost-benefit Ratio Method	
				I	II
Monocrotophos	5085	30,510	667	1:2.15	1:26.93
Acephate	5162	30,972	675	1:2.18	1:27.31
Chlorpyrifos	4620	27,720	537	1:1.97	1:28.25
Phosphamidon	4686	28,116	512	1:2.01	1:30.40
Triazophos	4181	25,086	512	1:1.79	1:24.49
Carbaryl	3940	23,640	637	1:1.67	1:17.42
Endosulfan	4367	26,202	632	1:1.85	1:21.60
Fenthion	4880	29,280	687	1:2.06	1:24.36
Untreated control	2089	12,534	--	1:0.93	--

Cost of insecticides :

Monocrotophos	Rs.380/l	Triazophos	Rs.450/l
Acephate	Rs.620/kg	Carbaryl	Rs.280/kg
Chlorpyrifos	Rs.250/l	Endosulfan	Rs.230/l
Phosphamidon	Rs.450/l	Fenthion	Rs.800/l
Spraying charges	Rs.287/ha/round		

* Price of paddy : Rs.6/kg (Current market rate)

Method I

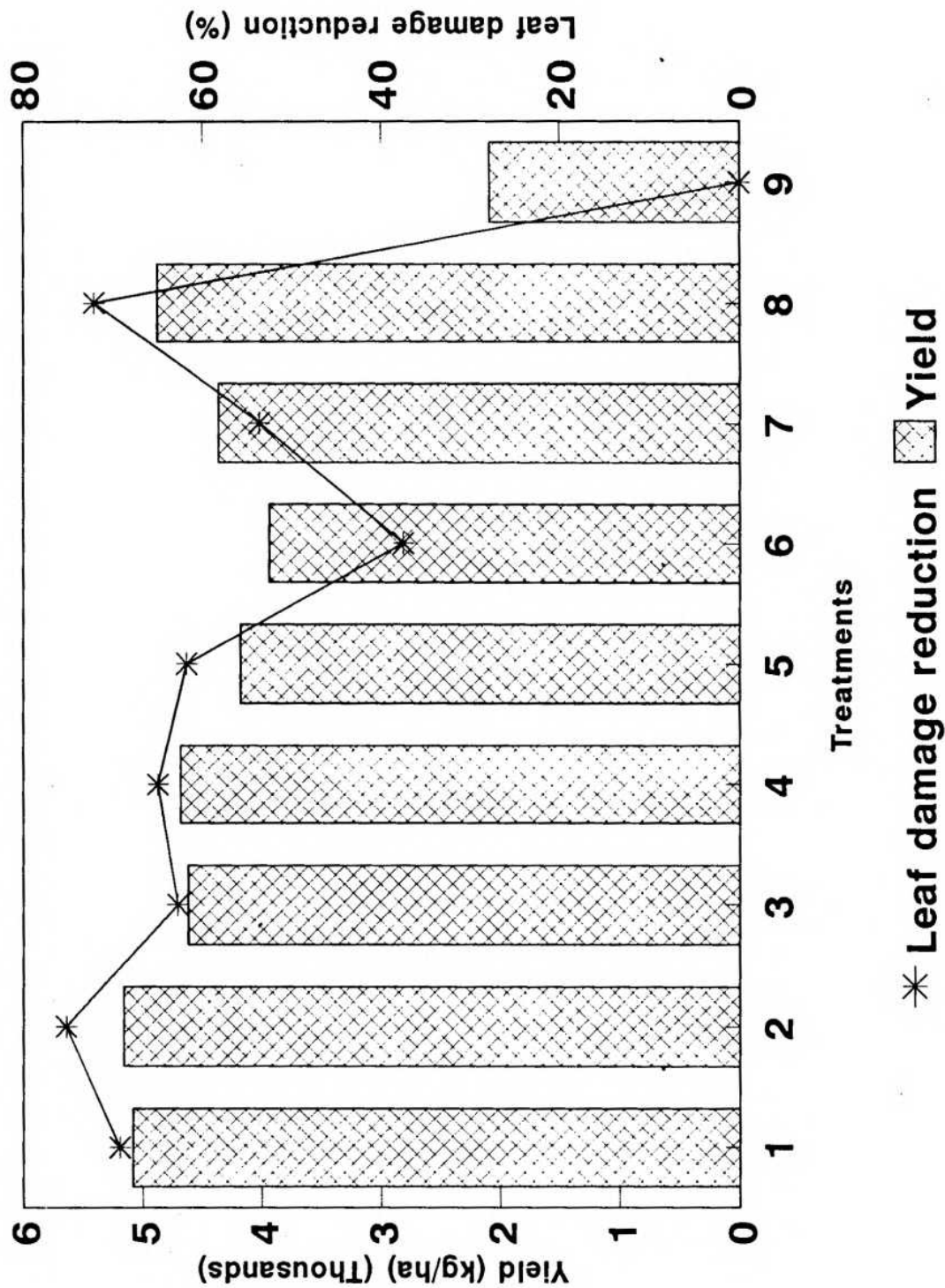
$$\frac{\text{Treatment yield (kg/ha)} \times \text{value of paddy (Rs./kg)}}{\text{Basic cost of cultivation} \pm \text{Cost of protection**}}$$

** for control yields, cost of protection was excluded and for treatment it was included

Method II

$$\frac{\text{Value of treated crop} - \text{Value of untreated crop}}{\text{Cost of protection to treated crop}}$$

Fig.16. Field evaluation of insecticides on RBB damage and rice yield (Pooled analysis)



DISCUSSION

5. DISCUSSION

Among the different insect pests infesting rice, the Rice Black Bug (RBB), *Scotinophara coarctata* is now assuming greater importance in Tamil Nadu by causing severe crop loss especially in northern parts of rice growing areas, particularly in Chengai-MGR district. Although the biology of this pest on rice and chemical control aspects have been studied by several workers, information on the biology of this insect on alternate weed hosts, seasonal occurrence and abundance, population dynamics, species composition, damage potential, reaction of the rice accessions, economic threshold levels, life table studies, yield loss assessment and management strategies are very meager. Therefore, in order to add more information on this insect, detailed investigations were carried out on the above aspects and the findings are presented in the Flow chart (Fig. 17) and are discussed in this chapter.

5.1. Biology of *S. coarctata* on rice and alternate host, *Echinochloa colona*

Biology of *S. coarctata* was studied on rice (Cultivar ADT 36) and on predominant weed host *E. colona* in screen house. Pathak and Khan (1994) reported that adult females laid their eggs in clusters with 29 to 34 eggs on the basal portion of the rice plants near the water surface. Saroja *et al.*, (1993) reported that the female bug laid 25 to 50 eggs in three to four longitudinal rows on the leaves. Barrion and Litsinger (1987) reported that the females of *S. latiuscula* laid the eggs in masses of two to 14 eggs each arranged longitudinally in two to three rows. In the present study, it was observed that the female bug laid eggs in rows with 14 to 46 eggs on rice. The number of rows varied between two and four but predominantly in two rows with seven to nine eggs per row. More than four rows were not recorded. The eggs in the mass were contiguous. The eggs were laid preferably on the older leaf sheaths or on the stem just above the water level.

This observation was in conformity with earlier reports. Fernando (1961) reported the Japanese black bug, *S. lurida* laid eggs in two to four rows having eight eggs per row. The average number of eggs was only eight to 15. But in the present study, it was observed that the total eggs per mass was more. The reason may be that when the insects were confined on the cages, marked difference in the total number of eggs might be possible. This phenomenon was observed by Fernando (1961) when he reared *S. lurida* in screen house condition and reported 31 eggs per row. In case of *E. colona*, the number of egg rows and number of eggs per row were comparatively less. This clearly indicated that rice is the most suitable and primary host for the bugs and only in the absence of rice, it might prefer the alternate host to sustain its population level. Similar observation was given by Barrion and Litsinger (1987), where they have reported that rice was the most preferred host in which survival was 82 per cent and in *E. colona*, it was only 48 per cent.

The incubation period of eggs was reported as four to seven days (Ooi 1981); five days (IRRI, 1983) and four days (Saroja *et al.*, 1993) for *S. coarctata*. Fernando (1961) reported six days for *S. lurida*. The closely related species, *S. latiuscula* had the egg period of two to seven days (Barrion and Litsinger, 1987). In the present study it was observed that eggs hatched in three to six days on rice and on *E. colona* they hatched in four to six days. The present findings in respect of the incubation period are in accordance with the earlier reports. The colour variations observed in eggs from laying till hatch in both the hosts were similar and this agrees with the findings of Fernando (1961).

The per cent egg hatch ranged from 68.42 to 95.23 on rice and in *E. colona*, it was 56.35 to 73.68. Similar observation was made by Saroja *et al.* (1993). Barrion and Litsinger (1987) reported the egg hatch of 92 per cent under controlled humidity conditions. The wide variation in egg hatch observed in the present study might be due to the variation in weather factors.

S. coarctata passed through five nymphal instars to become adult. But Ooi (1981) reported six nymphal instars, while Saroja *et al.* (1993); IRRI (1983) and Pathak and Khan (1994) reported only five nymphal instars. Regarding the duration of the individual instars, it was observed that the average of 5.70, 7.10, 6.80, 8.30 and 8.60 days were recorded respectively for the first to fifth instars on rice. On *E.colona*, the duration of the individual instars was longer. The variation in duration might be possible because when the host was most favourable, the growth and development would be faster compared to the alternate host. The insect required some alternate host for its survival and hence increased duration in each stage was noticed. The duration of the individual instars coincided with the findings of Saroja *et al.* (1993). The total developmental period from egg to adult was 36.20 days on rice and on *E.colona*, it was longer (42 days). The early instar preferred young crop of 10 to 15 days. The first instar nymphs remained gregariously near the egg mass for about one to two days and then gradually dispersed towards the lower regions of the plant. Older instars always preferred profusely tillered and matured plants for feeding. Similar observations were made by Fernando (1961).

The descriptions on the adult bugs made in this study agreed with earlier reports. Longevity of adult bugs was more compared to other rice insects. Longevity varied with sex. The females lived longer both on rice as well as on *E.colona*. In the present study it was observed that the female lived longer (201.80 days) when compared to male (174.90 days). On *E.colona*, there was not much variation in the longevity. The female bug lived for 165.80 days and the male for 160.70 days. Ooi (1981) reported a longevity of 217 days for females and 212 days for males. As per IRRI (1983) report, the longevity was only two months. This was contrary to the present finding. However, Saroja *et al.* (1993) reported the longevity as 203 days for males and 210 days for females. Pathak and Khan (1994) reported 120 to 210 days as longevity.

Barrion and Litsinger (1987) reported 117 days for females and 138 days for males of *S. latiuscula*. The highest longevity of the adult bugs might be the reason for the continuous damage at all the stages of crop growth and also the pest maintained its population even in the absence of the host.

The sex ratio had shown that the production of females was always more than males in respect of rice and *E.colona*. In *E.colona*, the sex ratio was slightly low.

Mating period was longer on rice compared to *E.colona*. It was two to four days on rice and one to three days on *E.colona*. Barrion and Litsinger (1987) reported a mating period of three days in *S. latiuscula* and three to four days in *S. lurida* (Fernando, 1961).

Pre-oviposition period was four to six days for those reared on rice and on *E.colona*, it was three to five days. Fernando (1961) reported five days in *S. lurida*, while Barrion and Litsinger (1987) reported four days for *S. latiuscula*. The present study agreed with their findings and it indicated that there was no variation at the species level.

Oviposition period lasted for six to nine days on rice whereas it was much lower on *E.colona* (4-6 days). Saroja *et al.* (1993) reported similar findings. When the rice crop was in the early tillering stage, oviposition was chiefly on the rice plants and the eggs were frequently deposited on the leaves and less frequently on the stem. On the rice seedlings, oviposition was predominantly on the apical three inches of the leaves. In *E.colona*, oviposition was mainly on the stems.

The fecundity of the females ranged from 127 to 392 eggs on rice and on *E.colona*, it was 119 to 212. Ooi (1981) reported that 684 eggs were laid in 104 days. Peak period of egg laying was observed in the early life period of the adults. After egg laying, the eggs were guarded by the females till they hatched. It was also observed that whenever the parasitoids were encountered, the females were seen protecting their eggs

with their antennae and legs. Similar phenomenon was reported by Corbett and Yusope (1924) and Fernando (1961).

Considering the comparative biology of the insect on two hosts, it was observed that the number of eggs laid, egg hatch and adult emergence were high on rice. In addition, a favourable sex ratio with more of females was obtained when reared on rice. Mating, pre-oviposition and oviposition periods were considerably longer on rice. Lower values were recorded on *E.colona* suggested that *S. coarctata* is oligophagous and it highly preferred rice over *E.colona*. The shorter nymphal duration on rice reared black bugs indicated that rice is more preferable than other hosts. Similar trend was observed by Barrjon and Litsinger (1987) where they have reported rice as the most preferred host compared to *Cyperus* spp. for *S. latiuscula*.

5.2. Damage

Unlike in other rice insects, the black bug was capable of damaging the crop at all the stages of crop growth. Its damage in the early stage resulted in leaf yellowing and dead heart formation while the damage in post-flowering stage resulted in the formation of white ears, thus no specific critical stage could be fixed for the crop damage. The pest required abundant water in the field and if the water supply was short, it migrated either to the alternate host seen along the field bunds or moved to adjacent fields having young crop. Fernando (1961) observed aestivation of nymphs and adults. In the present study, aestivation or hibernation was not observed. The reason might be that Chengai-MGR district is endemic for black bugs. In this district, rice is grown throughout the year and hence the crop will be available throughout the lifecycle for the pest. Saroja *et al.* (1993) also reported the absence of aestivation in black bugs.

Several alternate hosts were reported for RBB (Fernando, 1961; Miyamoto *et al.*, 1983; Barrion and Litsinger 1987; Pathak and Khan, 1994). *E.colona* is the most predominant weed in RRS, Tirur. Besides rice, the bugs were also found on *E.crus-galli*, *Cyperus rotundus* and *C.difformis*. The damage symptoms expressed on the alternate hosts were similar to that of rice.

5.3. Seasonal occurrence and abundance of RBB

The yield reduction due to RBB depended upon the number of bugs present on hills, the period of infestation, cultivar and crop development stage (Mohd. Norowi Hamid and Shuhaimen Ismail, 1994). Heinrichs *et al.* (1987) found that 40 bugs/hill at reproductive stage of the crop resulted in 54 to 83 per cent yield loss. Yield loss is influenced by the pest behaviour, environment, and status of the crop. The damage potential of RBB spreads over all important stages of the crop. Early infestation results in wilting of leaves due to blockage of phloem vessels and at active tillering stage, the damage results in the formation of dead hearts. At post-flowering, the damage results in white ears. Therefore, the damage to the crop largely is not influenced by the crop stage. IRRI (1983) and Saroja *et al.* (1993) have reported that both nymphs and adults feed at the base of the plants, where they suck plant sap from the culms during tillering to flowering stages. The bugs are also found to desap leaf sheaths, leaves and panicles. Fernando (1961) reported that the leaves lost their turgidity and tissues appeared collapsed due to desapping by the Japanese black bug, *S. lurida*. He further stated that due to feeding on the leaves, lesions were formed on the leaves and these turned brown with necrosis and wilting of leaves was reported within 24 h after feeding. The feeding by RBB on the culms resulted in the wilting of central shoots and subsequently rolling of the shoots. Mohd. Norowi Hamid and Shuhaimen Ismail (1994) opined that RBB damage by sucking of assimilates of the crop resulted in a reduction of daily total gross assimilation of the crop available for growth and continuous removal of assimilates was responsible for

"bug burn". Therefore it might be desirable to develop a model considering the span of the RBB'S desapping activity, the resulting loss to yield contributing plant components. Considering the pest's ability to cause damage to plant parts that would contribute for yield and its continuous presence until the crop maturity might warrant constant monitoring of the crop to direct management efforts at the appropriate time. The present study also indicated that the damage causing ability of the pest was not confined to a brief period of plant growth but continued until the crop became unsuitable for feeding.

Influence of weather factors

Literature on the effect of weather factors is wanting. Though workers have reported the effect of lunar phases and the abundance of bugs related to seasons, no particular information is available to explain the influence of weather factors on this pest. Goel (1976) generalised the effect of relative humidity to be more positive than temperatures on hemipterans. The present study showed that none of the weather factors had a significant effect on the bug population. Multiple regression equation developed with R^2 showing high significance explained only the additive effect. However, in the case of *S. lurida*, a positive significant effect with minimum temperature and radiation was observed. The correlation of weather factors with RBB incidence and leaf damage on different cultivars of rice also indicated non-correlation except the influence of maximum and minimum temperatures on cultivars Co 45 and either of them in White Ponni, ADT 37 and PMK 1.

In Co 45, both these variables contributed negatively while the effect of minimum temperature was positive on varieties ADT 37 and PMK1. This opposing response might be due to microclimatic effects rather than on macroclimatic effects. The population of RBB was initially seen on the base of the tillers in the day time and subsequently during night they came up to the apical portions. This might be due to the change in microclimate

prevalent at night. The contiguous stand of the crop made it possible to have variations of microclimate parameters at its bottom, middle and top areas. Therefore, further studies to evaluate the microclimatic parameters related with macroclimate might be necessary to conclusively define the effect of weather parameters on this insect.

The correlation of predator population with RBB incidence and the extent of leaf damage had shown that not all the predators were influenced by the abundance of RBB in a cultivar. The trend was that there was an increment in the predator population ^{which} resulted in an increase in RBB population. Most of the predators reported like the spiders (Perez *et al.*, 1989), carabids (Reissig *et al.*, 1985) and other predaceous bugs (Shepard, *et al.*, 1988a) were found to feed more on the eggs and nymphal population. Therefore, fluctuation mostly in their density depended on the host. This density dependence might be the reason for most of the positive correlations observed in the present studies. However, when the leaf damage was correlated with the predator, the response was variable. For example, in rice cultivar PMK 1, the predators barring mirids associated negatively with the extent of leaf damage while the same was positive in Co 45 and other cultivars. The reason might be due to the differences in duration. PMK 1 was shorter by 25 days compared to Co 45. Therefore, the peak damage level in PMK 1 might have been reached earlier resulting in the migration of the pest as well as its predators.

Also the tritrophic relationship between the cultivar, RBB and predator might have a significant role. Further studies on this aspect is needed. The role of semiochemicals, if any, has to be investigated.

5.4. Population dynamics

The attractability of three light sources namely, 125 Watts, Pest-O-Flash and 40 Watts had been evaluated from 1993 to 1996. Among these sources, the highest collections were consistently recorded in Pest-O-Flash during all the years of observation.

The attractability of 125 Watts was significantly higher compared to 40 Watts, but it was inferior to Pest-O-Flash. Ferrer and Shepard (1987) compared the attractability of fluorescent street lights and Petromax gas lantern light traps and reported that both sources were attracting large numbers of RBB during full moon period. Similar phenomenon were also observed by the researchers of Malaysian Agriculture Research and Development Institute (1982). Saroja *et al.* (1993) compared 200 Watts incandescent, 125 Watts Mercury Vapour and 40 Watts incandescent light sources and reported that the 125 Watts Mercury Vapour lamp attracted significantly more RBB and the catches were significantly the least in 40 Watts incandescent lamp. The present findings are in conformity with those findings in that 125 Watts Mercury Vapour lamp attracted more RBB than 40 Watts lamp. In another study, the same workers replaced the 200 Watts incandescent light source with 80 Watts black light and compared the attractability. Their results showed that the highest attraction was in 80 Watts black light while the collection in 125 Watts was only moderate. The present finding was in conformity with that of Saroja *et al.* (1993), where the highest collection of RBB was recorded in Pest-O-Flash and moderate in 125 Watts and the least in 40 Watts. Thus the information on the efficiency of Pest-O-Flash as an effective monitoring tool will be very useful in the management of RBB. Additionally it can be used to monitor other rice pests too. With the availability of electricity in all rice fields to energise the motors in pumpsets for drawing water from wells, there may not be any difficulty in operating light traps.

Influence of natural enemies

Biological control of RBB using natural enemies might prove to be useful in the future. Before an effective biological control programme for RBB can be developed, it is important to document the impact of indigenous natural enemies so that suitable programmes can be developed to conserve them.

Perez *et al.* (1989) reported that *Telenomus triptus* was the most frequently encountered parasitoid on *S. coarctata*. They have further reported that the per cent parasitisation on egg masses was more compared to eggs. Corbett and Yusope (1924) reasoned that the egg guarding behaviour of females to be the cause of less percentage of parasitisation of eggs. Perez *et al.* (1989) have endorsed the view that the egg guarding behaviour caused inadequate biological control of RBB by *T. triptus*, inspite of the olfactory cues provided by the guarding female. The results from the present study were also similar. It was observed that after egg laying, the females guarded the eggs from enemies. Sometimes the females fed at the base of the plants. As soon as the females noticed the parasitoid, they rushed to the eggs and protected them with their antennae and legs. IRRI (1986.) report stated that in mylar cages with egg masses guarded by the female RBB, egg masses and egg parasitisation were higher than in unguarded egg masses. The reason given was the olfactory cue given by the female RBB to be of help in locating the egg masses by the parasitoids. However, the contrary results of the IRRI (1986) was based on the study conducted in confinement. Therefore, the reason for the low parasitisation of eggs compared to egg masses might be due to the egg guarding behaviour of the RBB females.

Species complex of *Scotinophara*

The abundance of the two commonly occurring species, *S. coarctata* and *S. lurida* was studied from 1994 to 1996. In all the three years, *S. coarctata* was the dominant one. Prevalence of *S. lurida* was very meager. While the mean number of *S. coarctata* varied from 62.80 to 246.84, that of *S. lurida* was between 3.33 and 5.63. The abundance of these two species has been discussed by Saroja *et al.* (1993), and reported that *S. coarctata* accounted for 97 per cent of incidence. The present study also showed the predominance of *S. coarctata* as compared to *S. lurida*. The possible reason could be that *S. lurida* was a poor competitor between the two species.

5.5. Life table studies of *S. coarctata*

Host plant significantly influenced vital features such as rate of development, survival and reproductive potential insects which ultimately determined the rate of population build up (Painter 1951; Kennedy 1995). In that respect, life table is a condensed tabulation of certain vital statistics of insect population which provides a format for recording and accounting of all population changes in the life cycle of a species. An understanding of factors regulating the population density of pests is obligatory for a sound planning of pest management. *S. coarctata* is one of the important pests capable of damaging the crop at all the stages of crop growth irrespective of varieties and seasons. Economic pest control would ultimately depend on a thorough understanding of the biology of pest and its population dynamics. Identification of weak links in the biology of the insect will enable the pest managers to plan effectively for managing the pest. Keeping these views, life table was constructed on *S. coarctata* on rice (Cultivar ADT 36). **Life table studies on this pest are reported for the first time.**

The overall fraction of the new born individuals reaching the adulthood is determined by two factors namely *viz.*; fertility of eggs and survival rate of nymphs. In this study, the total fertility was observed on rice and hence, higher survival. The maximum net reproductive rate (R_0) was observed as 125.17. In spite of higher net reproductive rate (R_0), the innate capacity for increase (r_m) was found to be low. Actually r_m value was influenced by T value and it had been demonstrated in cotton that shorter generation time (T) favoured high reproduction fitness (r_m) (Trichilo and Leigh, 1985). Ganesh Kumar (1994) reported a low r_m value (0.26) on rice cultivar TN 1 and precise generation time as 18.51 for the green leafhopper, *Nephotettix virescens* (Distant).

In the present study, the generation time was found to be longer because of the prolonged oviposition which helped to sustain in unfavorable condition. Since prolonged survival was noticed, it is evident that the damage will be continued for a longer time. For rapid population growth, two factors are involved: first the age of oviposition and second fecundity in prime youth (Birch, 1948; Cole 1954; Dobzhansky, 1968). In the present study, prolonged oviposition was observed. The oviposition was maximum in the early part of the life i.e., youth stage when oviposition was observed upto 95 days. Actually the eggs laid during the youth stage helped to increase the population and the senescence stage helped to maintain the population in an unfavorable condition. The longevity of the adults was more in both sexes and it was capable of maintaining the population at all times.

Stable age distribution is the age distribution which can be approached by a population of stable age-schedule of birth rate and death rate when growing in unlimited space (Andrewartha and Birch, 1954). In the present study, it was observed that the population had 37.06 per cent as eggs, 57.17 per cent as nymphs and 5.78 per cent only as adults and it clearly indicated that adult alone couldnot be taken as the true index of the degree of infestation.

5.6. Screening of rice accessions

The development of insect resistant, high yielding rice varieties is considered as breakthrough in the modern rice production technology. Their large scale rapid adoption by farmers has minimised insect pest problems and considerably augmented the rice yield (Saxena, 1982). In an IPM programme, resistant varieties form the pivot on which the other technologies are superimposed. The use of resistant plants as a tool to control the ravages of insects is not new, but had been known and advocated since 1792 (Bigger, 1943). The work done so far in Philippines and Malaysia has brought out only a

few varieties resistant to RBB. Domingo *et al.* (1985) screened 300 breeding lines and identified 20 entries for further evaluation and finally selected two accessions possessing high level of resistance and four cultivars possessing moderate level of resistance. Further evaluation of these six entries was done by Heinrichs *et al.* (1987) and they reported that the accessions IR10781-75-3-2-2 and IR13149-71-3-2 to be highly resistant. They have attributed tolerance mechanism in these entries. Because of tolerance, there was a low level of plant damage even under high population load. These tolerant entries were reported to be good yielders to the tune of 7.1 tonnes/ha.

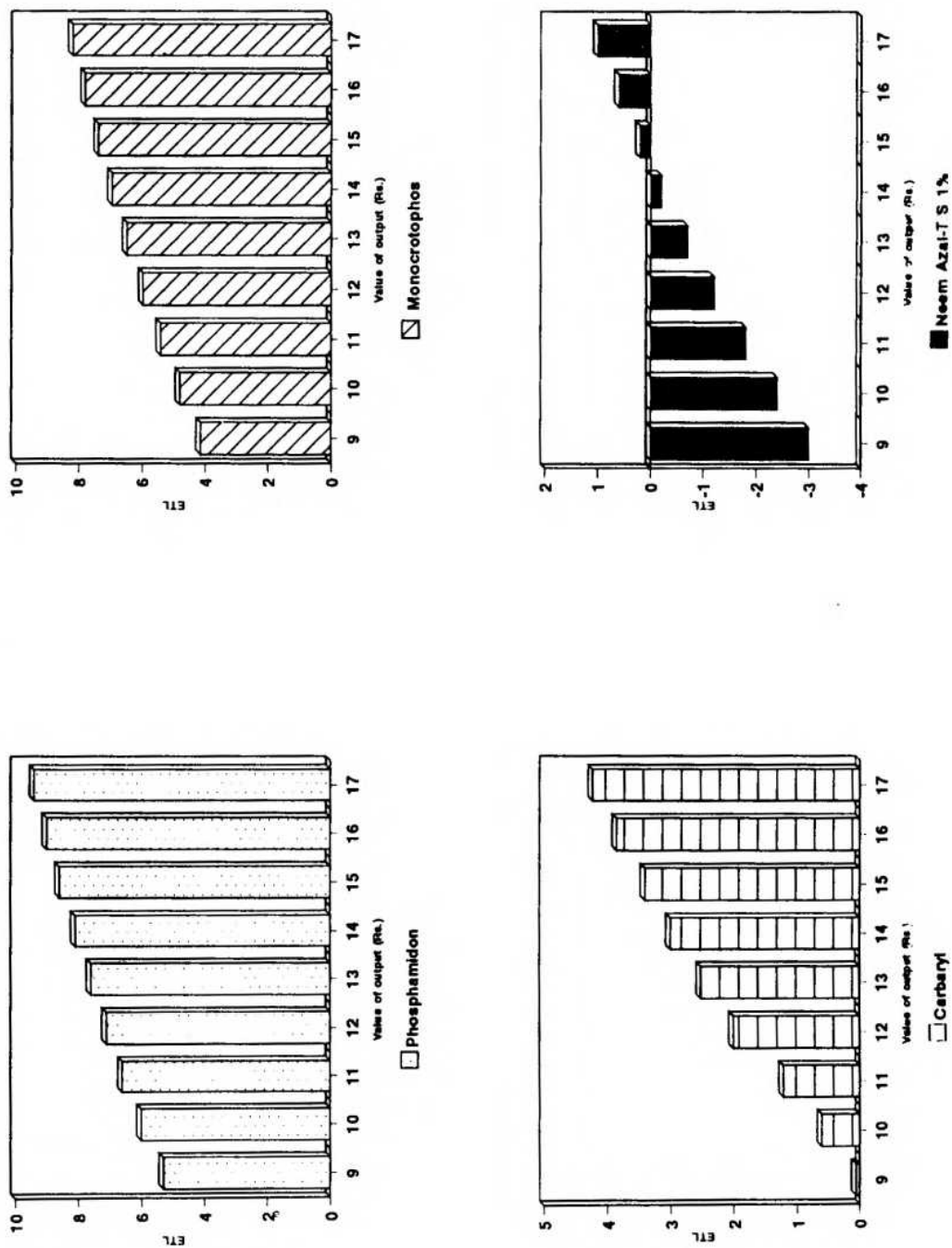
In order to find out the resistance sources from the germplasm collections of RRS, Tirur, a total of 368 entries in different categories of breeding programme was screened. None of the entries showed high level resistance. Among the popular varieties, ADT 37 and TKM 10 alone were grouped as moderately susceptible. Saroja *et al.* (1993) screened 213 entries of which, only 13 entries possessed moderate level of resistance. In the present study, only seven accessions *viz.*, IET12029, IET13989, IET12901, IET12872, IR58099-41-2-3, IR53970-2-1 and IR52341-60-1-2-1 had moderate levels of resistance by recording the leaf damage ranged from 16.75 to 19.75 per cent. The accessions already identified with moderate level of resistance to BPH and leaffolder were highly susceptible to RBB. None of the hybrid rices screened was found resistant. Nemisio Trillana (1988) developed the RBB tolerant variety IRI314 under rigorous screening programme for more than five years. Evolving resistant variety to RBB is not an easy task because RBB is capable of causing severe damage in all the cultivars resulting in maximum yield loss. The moderately resistant accessions brought out in this study should be analysed for the mechanism of resistance. These entries might be utilised for further breeding programmes through hybridisation after ascertaining its consistency to evolve suitable cultivars which would control the spread of the bug in the coming years.

5.7. Economic threshold levels

Agriculture is a system of biological production to increase and channel the biological yield of an ecosystem. That is, to produce food and fiber^{7E} which is in excess of what could be produced by the use of same resources devoted to natural production (Headley, 1972). The implication of this statement is true when the additional energy or value of the damage prevented exceeds the cost of resources required to control the pests (Headly, 1971).

Production function is related to the technology of the moment. Loss is, therefore, measured from the point of optimal production without pest and not from the maximum of the output function. Therefore, the decision to adopt control will depend upon the cost of the method. The economically efficient level of output is that level of output which maximises the difference between total benefit and total cost. Unless optimal control methods are cent per cent effective, that is to reduce the damage from the pest to zero, there will always be some loss due to pests (Headley, 1972). Therefore, pest control is a means of protecting investment. The usual way to conceptualise pest control benefits is in terms of damages abated; that is the difference in output with and without control measures. The quantitative measure of insect density determines if an insect component of an agroecosystem is to be classified as pest or not. The present study attempted to work out the economic threshold of RBB using the variants of cost of protection and the value of output. Profits are maximised when the profit function with respect to vector of pest management inputs is set equal to zero (Norgaard, 1976). Like the vectors of pest management inputs, the profit function is also variable at different points of time. The level of output and input prices affects the optimum intensity of pest management. More intensive pest management is profitable only when the incremental returns match with the cost of protection. Therefore, in the present study, envisaging the above points, both the variants were considered.

Fig.18. Economic Threshold Levels of RBB at incremental cost of rice



The study brought out the following points:

- a. ETL is subject to not only the cost of the plant protection but also to the accrued value of returns ruling at a point of time. Norgaard (1976) stated that the level of product and input prices affected the optimum intensity of pest management that is, when farm prices rise, the return to pest management rises including the incremental returns from additional action. By this it is evident that more intensive pest management is profitable, because the incremental returns match incremental cost at a higher intensity level. Similarly an increase or decrease in pest management cost would decrease or increase the optimum level of management intensity respectively. The present study reflected this observation. At increasing cost of return, the ETL showed increasing trend, as per example, the ETL of monocrotophos, at constant protective cost, increased from 4.10 to 5.40 when the return cost varied from Rs.9 to Rs.11 per kg of rice. This trend was reflected in all the insecticides except in Neem Azal-T/S (1%). It is evident from the foregoing, the ETL is not constant but dynamic with variations both in the abatement cost and the increased value of return. A decrease in ETL is envisaged when the abatement cost increases and it increases when the return value increases. As exemplified by the use of Neem Azal-T/S (1%), a high abatement cost compared to its efficacy and the quantum of abatement will result in the negative ETLs. The ETL will be neutralised only when the value of output increases to a certain level. In the present example, a value of Rs.15/kg is needed for the neutralisation. Thereafter, the ETL will be increasing and positive (Fig. 18).
- b. The extra efficacy expressed by an insecticide over its comparable counterpart has no bearing on the ETL, while the same was not reflected on the output. In the present study fenthion had given the control of leaf damage of 72.13 per cent and recorded an yield of 4880 kg/ha, while phosphamidon gave 65.01 per cent reduction in leaf damage

and yielded 4686 kg/ha. On considering the abated loss (differences in yields), there was very little difference between them (194 kg/ha). This difference was to be equated against Rs.175 being the extra cost of abatement i.e. the cost of treatment with fenthion minus the cost of treatment with phosphamidon. The extra control of 7.12 per cent achieved with fenthion was not reflected in the extra yield. Geir, (1966) and Smith and van den Bosch (1967) have analysed many of the biological factors involved in pest control and generally concluded that economic control need not rely on the killing of organisms but may be achieved in other ways. Munakata and Okamoto (1966) found that heavy tillering rice cultivars could tolerate moderate level of rice stem borer during the early stages of crop growth without loss in yield because lost tillers were rapidly replaced. Many plants can suffer moderate loss of leaves, stems, fruits or roots before the crop yield is affected, as the damage more often tends to be compensated (Greene, 1971). The extra efficacy recorded by certain insecticides like fenthion has not reflected in yield gain. The reason might be that the level of damage abated by them is within the compensating ability of the plant. It is obvious, therefore, the choice of insecticide depends more on their ability to reduce yield losses beyond this compensating ability at reasonable cost. In the example, phosphamidon is preferable to fenthion as well as monocrotophos on considering the cost of protection. Not necessarily a low cost input is always desirable, unless its expressive efficacy is high. Similarly a high cost input, with high efficacy need not be considered as an alternative to a marginally inferior input such as phosphamidon as the resultant output might not reflect the marginal variation in their efficacy.

- c. An approximately equal ETL would be possible for both most effective but costlier insecticides and cheaper but less efficacious insecticide. The study showed under certain varying values of returns the ETL recorded was less than one for carbaryl.

If the cost of insecticide which was superior both in efficacy and yield was doubled to that of an inferior insecticide, an approximately equal ETL will result for both the insecticides. In this situation, an inferior protection is matched with the superior protection, in respect of ETL, because of the increased abatement cost. The fundamental principle in determining the ETL of a pest species is to distinguish between its mere presence in a crop, as opposed to a higher density that will cause a reasonable loss in the quality and/ or quantity of the harvest crop (Stern, 1973). Ideally the decision to apply a pesticide should be determined by cost-benefit ratio (that is the control measures balanced against the increased value of crop that can be recovered or protected) which can be affected by market conditions, local grower economics and investment in the crop but not by personal values of the people concerned (Ordish, 1952). Determination of economic thresholds in conjunction with agronomic variables will establish more precise treatment time to avoid damage. Heinrichs *et al.* (1987) fixed EIL of three bugs per hill at 30 DAT. Ferrer and Shepard (1987) fixed EIL as 2.5 to 3.2 bugs per hill as EIL. Saroja *et al.* (1993) fixed four to six bugs per hill or eight to 15 per cent leaf damage as the threshold levels for black bugs.

The present study has shown that the ETL is variable with the chosen insecticides and value of output. However, at the existing cost price of the output and cost of protective input it is variable between 0.06 to 5.30. Predictive equations for two varieties MR 84 and MR 106 using the duration of infestation in days by the Malayan black bug and the time of infestation (DAT) were proposed by Mohd. Norowi Hamid and Shuhaimen Ismail (1994). Probably the suggested equations might be useful when expertise is available for consultation in decision making. In our situation, an empirical ETL is more practical than others. In conclusion an empirical ETL arrived at taking into account the quantum of abatement beyond the compensatory ability of the crops and

optimal cost of abatement is useful in the present situations. The same for RBB was 4 per hill in the present study. The profit maximising farmer should choose to loose some of his crop to pests rather than forego the even higher costs of stricter pest management. A pest residue of 4 bugs/hill and its damage can be tolerated. This will lead to a rational resource allocation for pest management.

5.8. Yield loss assessment

The results of the yield loss assessment with nymphs and adult populations showed that the yield declined with every unit increase of either population. The quantum of loss increased with an increase in the pest population. The rate of loss, quantified for every unit increment, was, however, not equal at each stage of increment. The general trend observed was decrement. The documented cases of yield loss were very few for RBB. A 50 per cent yield reduction was reported due to RBB infestation (IRRI, 1983). Heinrichs *et al.* (1987) reported that for every addition in RBB infestation, a loss of 6.70 g/m² or 67kg/ha was resulted. Based on this, they proposed a predictive equation by relating the bug damage and loss in yield. Using this, they have shown that 95 per cent yield loss in "Tjeremas", a susceptible cultivar can be equated with 40 bugs per hill while in a resistant line, IR1078-75-3-2-2, the same level of infestation could account for 59 per cent damage only. They have further reported that the yield loss at 10 bugs/ hill ranged from 15 to 23 per cent. None of the reports, however, indicated the potential of the bugs to cause yield loss under controlled conditions. In the present study, the yield loss assessment was made by varying the RBB population from one to nine and the assessment showed that the yield loss was 0.32 to 16.63 g/hill when the nymphs were used. The estimated potential yield when the bugs were excluded was 19.27g/hill. Unlike other insects infesting rice crop, RBB could cause damage in all the crop growth phases. It is noteworthy that the damage caused by this pest during the latter stages of crop growth directly translates into yield loss. The disproportion in the rate of loss caused

by every additional bug might be due to two factors namely, the competitive sharing of food by the bugs and the limited source of food availability. At a stage when the maximum damage was inflicted, the bugs were also observed to migrate to new sources. Under controlled conditions, infestation might account for the total loss of the plant as observed in the present study. The yield loss reported elsewhere was mainly based on field study where the bugs could have migrated to new sources after inflicting some damage. Therefore, the low loss estimates. Similar trend was observed when the adults were used instead of nymphs. It is evident that at the low populations, the pests's ability to cause damage is enormous compared to high populations; where the plant may be totally damaged and unsuitable for feeding, particularly under controlled conditions. In confinement the ability of the pest to cause such high level of damage might be due to prolonged longevity of the adults that compel continuous feeding on already damaged plants.

When the differential population of nymphs and adults was trapped under field conditions, the yield loss observed was comparatively less. Similar results in respect of yield loss was reported earlier (IRRI, 1986). In their report, an approximately 10 per cent damage was accounted for two bugs per hill. Thereafter, the increase in number of bugs accounted for more or less 10 per cent increment in damage. Therefore, the present study was in agreement with IRRI (1986) report. As expressed, the rate of yield loss for every addition in bug population was not constant, but was in decrement for every unit increment of the pest. Ooi (1988) reported that a single bug could cause the death of the plant in 16 to 20 days and 20 bugs could kill the plant in two days. The present study showed that with one bug, the plant suffered very little loss but with 15 bugs, the loss was 72.27 per cent. As discussed earlier, the rate of loss was not proportional to each additional bug because of the competitive sharing of limited food. This is true under a condition where the mostly damaged plant offered a very limited portion for feeding.

The yield loss assessment was rated against varying leaf damage levels with five per cent addition at each stage. The loss suffered was positive for each addition of damage. It was reported that 30 per cent damage accounted for 32 per cent loss in yield in the cultivar TKM 9. (Saroja *et al.*, 1993). However, in the present study it was observed that at five per cent damage level, the loss suffered was 33.84 per cent which was not in agreement with the earlier report. The present study was carried out under screen house condition, whereas the reported study was under field conditions. Considering the ability of the pest to cause the death of the plant over a period of time, as reported by Vanvreden and Abdul Latif (1986) and Ooi (1988), the enhanced damage observed in the present study might be a possibility under confinement.

Comparison of the damage levels and yield loss caused by adult bugs was in agreement with results reported for nymphs. It can, therefore, be inferred that the damage causing potential was almost the same for adults and nymphs.

Under caged situations in the field, the severity of damage suffered was more compared to screen house conditions. Being a phloem feeder, the damage already done could block normal uptake of nutrients and therefore, result in poor yields (Katsumota, 1930; Reissig *et al.*, 1985). However, the rate of yield loss for every additional five per cent damage was higher under screen house condition than in field condition.

In the uncaged situations, in the field, the rate for every additional damage unit fell by half. Under field situations, when other key pests were are not excluded, the yield loss observed was very nominal and the trend was increasing for every increment of five per cent damage.

As against the high loss estimate under caged conditions both in the field and screen house, the loss suffered in the field under caged condition was less. Saroja *et al.* (1993) reported that the yield loss was approximately equal to the damage levels. The present estimate showed that yield loss doubled to that of damage levels. The rate of loss calculated for every unit increase of damage showed an increasing trend upto 30 per cent damage level beyond which it was decreasing. This is contrary to the trend observed under caged conditions. This might be due to the additive effect of the combined damage caused by the pests consisting of RBB, leaffolder and stem borer and the decline in the trend could be due to the inadequacy of the food source shared by the pest complex over a point of time.

5.9. Management of RBB

The trials conducted to evaluate the efficacy of botanicals against RBB indicated that Neem Azal-T/S (1%) recorded the maximum reduction of leaf damage followed by NSKE (5%) and these two were on par. The formulation Neem Azal-F(5%) containing the same insecticide principle of NSKE is on par with NSKE. Among the other botanicals *I. carnea* was the least effective. The efficacy of neem oil in controlling RBB and establishing higher yields was reported by IRRI (1986.). Saroja *et al.* (1993) have reported about the efficacy of neem oil and NSKE against this pest. However, in the present study, it was observed that the neem oil was less effective than NSKE against this pest. This finding is in conformity with the findings of Attri (1975) who reported that neem oil was less effective than the aqueous extract of neem seed kernels. It was concluded that the active material was hydrophilic in nature and neem seed kernel contained more azadirachtin than neem oil. Ganesh Kumar *et al.* (1994) evaluated the azadirachtin content of neem in different ecotypes and found that in neem seed kernel, the azadirachtin content varied from 2895 to 7525 ppm. Because of the high azadirachtin content in neem seed kernels, it gave better results than neem oil. Among the other plant

products, *V.negundo* also gave better results and *I.carnea* was ineffective. Durairaj and Venugopal (1993) reported the efficacy of *V.negundo* extracts on the rice earhead bug *Leptocorisa acuta* (Fabricius). Patil *et al.* (1990) reported that *I.carnea* was inferior in efficacy and they have reasoned out that *I.carnea* extract was easily degradable and this might be the reason for its poor performance.

Among the insecticides, acephate was superior to the rest of the treatments. Monocrotophos and fenthion were on par and were next to acephate in their efficacy. The laboratory assay also showed more or less similar trends. Monocrotophos was largely used against this pest (IRRI, 1983). Rao (1977) reported the effectiveness of monocrotophos against this insect in Nellore, Andhra Pradesh. In the present study, monocrotophos stands second to acephate. Abdul Latif *et al.* (1982), while evaluating 15 insecticides against this pest, reported that acephate had significant effect even four days after spraying. Sundara Babu *et al.* (1984) recommended the application of phosphamidon, fenthion and methyl demeton for the management of RBB. Uthamasamy and Mariappan (1985) recommended fenthion against this pest. Subramanian *et al.* (1986) reported the efficacy of monocrotophos. In the present study monocrotophos has also given good results though acephate was superior to this. Barrion and Litsinger (1987) reported that carbaryl, endosulfan, fenthion, monocrotophos and triazophos as foliar sprays had high ovicidal action with 100 per cent efficacy while acephate was reported to be less efficacious as an ovicidal. In the present study, efficacy of the insecticides for their ovicidal action was not studied. Saroja *et al.* (1993) reported the effectiveness of monocrotophos and acephate against this pest. The present study is in conformity with the results in respect to acephate and monocrotophos but endosulfan's relative efficacy was far below than that of the other insecticides except carbaryl.

As for as the yield was concerned, acephate, monocrotophos and fenthion recorded higher yields. The parity in the yield levels for these treatments signified that the difference between their efficacies was not sufficient to reflect on yield.

The insecticidal efficacy alone should not be considered for their choice in protective programmes. A benefit-cost of more than two was recorded by monocrotophos, acephate, phosphamidon, and fenthion in the present study. At yield levels showing parity, the differences in the benefit-cost might not show the real differences. Likewise, the ETL which is a reflection on the cost of pest control and the value of avoided loss should be a major criterion in the choice of insecticides. The present study an ETL range of four to seven bugs was seen with monocrotophos, acephate, phosphamidon, triazophos and NSKE while carbaryl gave the ETL of just above one. Monocrotophos and acephate which gave almost equal ETL and yield would be the best choice as their cost of protection matches well with their returns. Though phosphamidon has given similar ETL, it was inferior in its efficacy against the pest and yield levels compared to monocrotophos and acephate and as the input cost in this insecticide was less, and this insecticide might be the choice for small and marginal farmers. Similarly NSKE though inferior to monocrotophos in yield levels warrants consideration as the product is indigenous, ecofriendly and farm preparable. Among the botanicals, both the formulations of Neem Azal though effective in checking the insects and yielding on par with NSKE, needs higher investment. The high cost of this candidate insecticide might come down in the long run when this user-friendly botanical is demanded more and more in due course. As such, their choice in the management of RBB cannot be brushed aside at this stage.

5.10. Cost-benefit analysis

The cost of pest management includes

- a. cost of acquiring information and making decisions,
- b. cost of carrying out cultural practices and applying inputs and
- c. cost of pest control inputs. The resultant profit (yields), therefore, is a function of these efforts plus the other inputs of cultivation (Norgaard, 1976).

In the present study, two methods were used for working out the Cost-benefit ratio. In method I (Akila Selvaraj and Sundara Babu, 1994), the yield was assumed to be due to all functions involved in crop production efforts including the one for crop protection. The Cost-benefit arrived in this method precisely gave information on how much money a farmer can expect for every rupee invested. This simple method works out the proportion of total value of returns to total cost investment. Therefore, results of protection efforts without the efforts of production will also be available in this method. In case of insecticides the present study (Pooled analysis) gave the highest return of 1: 2.18 in acephate followed by 1: 2.15 in monocrotophos, 1: 2.06 in fenthion and 1: 2.01 in phosphamidon. The return from the untreated plots was only 1: 0.93. Using botanicals a high return of 1: 1.89 was obtained in NSKE 5 per cent followed by Neem Azal -F 5 per cent which gave 1: 1.80. These returns were almost doubled considering the return of 1: 0.96 in an untreated check.

The second method proposed by Heinrichs *et al* (1981) assumed the extra yield over control to be solely due to plant protection. In this method, the proportion of the value of the difference in the treatment and control yield to the cost of plant protection was worked out. Hence, a very high benefit was projected. The cost-benefit in present study thus was arrived at 17.42 to 30.40 among the insecticides and it varied between

8.00 and 21.74 for the botanicals. As the yield is the function of many factors assumption of the benefit realised to be due only to protective inputs may not be correct.

To conclude pest management inputs do not contribute for extra yield but mitigate possible loss due to pests. As such, any extra yield realised through pest management is the resultant output due to husbandry efforts. Therefore, a realistic Cost-benefit estimate should be based on all inputs on cultivation rather than working out the ratio using the additional yield value and cost of protection.

Thus in the present investigations, it has been clearly brought out that rice is the most preferred host where the number of eggs laid, hatchability and adult emergence were higher compared to the alternate weed host, *E. colona*. Shorter duration of nymphal instars, the higher longevity in both male and female, longer duration of mating, pre - oviposition and oviposition on rice indicated that the oligophagous *S. coarctata* showed high preference to rice.

RBB's damage on rice and on alternate host manifest in leaf yellowing and dead hearts during early tillering stage and white ears at post-flowering stage.

Light trap (Pest-O-Flash) is one of the prime sources for monitoring of RBB. Among the species, *S. coarctata* is predominant in Chengai-MGR district.

Weather factors had very little influence on the RBB population. Individual weather factors, generally showed collective effect on the pest, as their individual correlation mostly was non significant.

T. triptus is the commonly available egg parasitoid. However, per cent parasitisation of eggs was lower compared to egg masses due to the egg guarding behaviour of females.

None of the rice accessions and popular cultivars were free from RBB infestation. The cultivars ADT 37 and TKM 10 alone withstood the pest incidence to some extent. In the screening programme, seven accessions were found to have moderate level of resistance. The accessions might be useful for the further breeding programmes, which information will be passed on to the rice breeders.

The economic threshold level worked out taking into consideration of abatement cost and at varying costs of out put the ETL 4 bugs/ hill.

The damage potential of the RBB irrespective of age distribution, was heavy under compelled feeding situations. Under competitive feeding condition along with other rice pest *viz.*, leaffolder and stem borer, the combined potential was additive upto certain level, beyond which it reduced due to more competition among the pests.

The net reproductive rate of RBB was high. The longest generation time indicated prolonged oviposition that helps to sustain the pest during unfavourable conditions. Prolonged survival ensures continuous damage to the crop.

In the management trials NSKE (5%) is the best botanical against this pest. Among the insecticides acephate, monocrotophos and phosphamidon were effective. Cost-benefit ratios were highest in acephate, monocrotophos, and fenthion and in botanicals it was high in NSKE and Neem Azal-F (5%). The current study envisaged that the pest is capable of damaging the crop at all crop stages irrespective of cultivars and season and thus no specific vulnerable stage could be fixed and a close monitoring is needed for plant protection decision.

SUMMARY

6. SUMMARY

Investigations were carried on the biology of Rice Black Bug (RBB), *Scotinophara coarctata* on rice and alternate weed host *Echinochloa colona*; occurrence of this pest in Chengai-MGR district; seasonal occurrence and abundance; population dynamics and life table studies. Popular rice cultivars and accessions were screened for their reaction to this pest. Detailed experiments were conducted to estimate the yield loss and economic threshold levels. Studies were also carried out to evaluate the efficacy of botanicals and insecticides for RBB. The studies were conducted at Rice Research Station, Tirur during 1992 to 1996 and the results of these experiments are summarised below.

Biology of RBB, *S. coarctata* on rice and on alternate host, *E. colona*

Biology of *S. coarctata* on *E. colona* is reported for the first time

The number of eggs laid by the female bug was 31.40 on rice and 20.80 on *E. colona*. The incubation period of eggs was shorter on rice (4.70 days) as compared to *E. colona* (5.10 days). Per cent egg hatch was significantly more on rice (81.82%) than on *E. colona* (67.61%).

The RBB passed through five nymphal instars on both the hosts. The total nymphal period was shorter on rice (36.20 days) when compared to *E. colona* (42.00 days). Similarly the duration from egg to adult was also shorter on rice (41.30 days) and longer on *E. colona* (46.80 days).

Production of females was always more than males in both the hosts studied.

Females lived longer than males. Longevity was higher on rice compared to *E. colona*. The females lived for 201.80 days on rice while on *E. colona* they lived for 165.80 days. The males lived for 174.90 days on rice and 160.70 days on *E. colona*.

Mating period (2.50 days), pre-oviposition period (5.10 days) and oviposition period (7.80 days) were longer on rice. The same were recorded as 1.70, 3.80 and 4.90 days respectively on *E.colona*. Fecundity was significantly higher on rice (246.90) than on *E.colona* (163.50). Per cent adult emergence was also higher on rice (74.58%) compared to *E.colona* (53.58%). There was a slight increase observed in the biometrics of the life stages from egg to adult reared on rice. The comparative biology of RBB on two hosts indicated that rice was the more preferred host.

Damage

The RBB caused damage in all the stage of the crop. feeding on shoots resulted in leaf yellowing that progressed into 'bug burn'. Damage at tillering stages resulted in dead heart formation while in post - flowering stage, damage resulted in the formation of white ears. The symptoms of damage were similar on rice as well as on *E.colona*.

Seasonal occurrence and abundance of RBB

The population of RBB was noticed throughout the year irrespective of seasons and cultivars. The weather parameters viz., relative humidity, maximum temperature, minimum temperature, rainfall and radiation were found to exert additive effect ($R^2=0.09$) on *S.coarctata* population, but failed to show significant effect individually. Minimum temperature and radiation exerted a significant positive effect ($R^2=0.17$) on *S.lurida* population. RBB population had a positive and significant influence over leaf damage in the rice cultivars (correlation coefficient of 0.773 in Co 45 to 0.983 in White Ponni). Significant positive correlation of the predators except spiders with leaf damage was established only in Co 45 (Correlation coefficient of 0.379 for carabids to 0.513 for mirids), while spiders had a similar association in White Ponni. (Correlation coefficient 0.656) and TKM 9(0.380). The multiple regression analysis showed that the leaf damage was significantly influenced by the stage of the crop in Co 45 and TKM 9 alone

in which the partial regression coefficients were 0.084 and 0.138 respectively. The contribution of weather parameters were also additive in general ($R^2=0.284$ in TKM 9 to 0.852 in PMK 1).

Telenomus triptus is the commonly encountered egg parasitoid of RBB. The parasitisation by *T.triptus* and infection by the fungal pathogen *Metarhizium anisopliae* were found to be independent of RBB population. However, the density of the egg masses or eggs showed positive correlation with per cent egg masses parasitised, while only few eggs in an egg mass were parasitised and it might be due to egg guarding behaviour of the female.

Population dynamics

Among the different light sources tested, Pest-O-Flash was significantly superior to 125 Watts and 40 Watts. The Pest-O-Flash had trapped 17.29 to 110.35 bugs more than that of 125 Watts while 40 Watts attracted 25.11 to 135.15 less bugs than Pest-O-Flash. Between the two species, *S.coarctata* was the most dominant species found in RRS, Tirur.

Life table

Life table studies on RBB, *S.coarctata* is reported for the first time. The net reproductive rate was high (125.17) and the longest generation time (53.44 days) indicated prolonged oviposition. The stable age distribution of the population would comprise of 37.0654 per cent as eggs, 57.1679 per cent as nymphs and 5.7719 per cent as adults.

Screening of accessions

Screening of cultivars and accessions of rice (368) to *S.coarctata* showed that none of the cultivars or accessions was resistant to RBB. The cultivars ADT 37 and

TKM 10 alone withstood the incidence to some extent. Among the rice accessions only seven accessions viz., IET 12029, IET 13989, IET 12901, IET 12872, IR58099-41-2-3, IR 53970-2-1 and IR52341-60-1-2-1 were found to have moderate level of resistance.

Economic Threshold Levels

The Economic Threshold level was four bugs per hill at the present market value of Rs 9/kg of rice. However, the ETL is variable with variation in plant protection cost and the value of output. Negative ETL resulted with very high cost of protective input. For example, with optimum cost as in acephate, phosphamidon or monocrotophos, the ETL varied from 4.10 to 6.59, while Neem Azal - T/S (1%) being costliest protective input recorded the negative ETL.

Yield loss

The damage potential of RBB irrespective of age distribution, was heavy under compelled feeding situations. Under competitive feeding condition along with other rice pests, the combined potential was additive upto certain level, beyond with it reduced due to more competition among the pests.

The yield loss accrued with increment in RBB population. When the nymphal population was one per hill, the yield loss was 0.32g/hill and with nine bugs/hill, the loss was 16.63g. The nymph's capability of causing damage was marginally less than that of adults. The yield loss estimated was 0.45g per hill at one adult and it was 16.82g when the adult population was nine per hill. An yield loss of 92.58 per cent was observed when the per cent leaf damage exceeded 30 in nymphs and in adults 88.05 per cent yield loss was estimated at the same leaf damage level. However, the rate of yield loss for every addition of insect or per cent leaf damage declined gradually.

Under caged condition in the field, the maximum loss of 72.27 per cent was recorded at 15 bugs/hill and a loss of more than 90 per cent resulted when the damage level reached 60 per cent. Similar trend was observed when the damage was estimated in the uncaged condition in the field.

Management of RBB

Laboratory evaluation indicated that among the botanicals NSKE 5 per cent accounted for the highest mortality of the bugs (82.78%). *I. carnea* leaf extract was inferior (61.67%) to others. Both the formulations of Neem Azal were comparable with NSKE in their superiority. Monocrotophos was superior to other insecticides to cause the highest mortality of bugs (84.44%). However, acephate was comparable with monocrotophos. Carbaryl was the least effective.

Under field conditions, Neem Azal - T/S (1%) (0.025 kg a.i./ha) and NSKE (5%) were superior in the reduction^{of} the leaf damage by 57.95 per cent and 55.14 per cent respectively. Among the insecticides, acephate (0.469 kg a.i./ha) was superior in its efficacy which resulted in the reduction of leaf damage by 75.65 per cent followed by fenthion (72.13%) and monocrotophos (69.25%). Cost-benefit ratio was the highest (1:1.89) in NSKE and among insecticides acephate and monocrotophos recorded the highest ratio of 1:2.18 and 1:2.15 respectively. However, with due consideration for the Cost - benefit, parity in yield and cost of protection, **acephate, monocrotophos among the insecticides and NSKE among the botanicals were the best against RBB. The alternatives were phosphamidon, fenthion and Neem Azal - T/S.**

REFERENCES

REFERENCES

- Abdul Latif, A.Z., P.M.Chang and N.S.Nik Mohammed Noor.1981. The Malayan black bug, *Scotinophara coarctata* distribution and occurrence in Malaysia. **Paper presented at the Symposium on Pest Ecology and Pest Management, Bogor, Indonesia. 8p.**
- Abdul Latif, A.Z., P.M.Chang and N.S.Nik Mohammed Noor.1982. The incidence and chemical control of the Malayan black rice bug, *Scotinophara coarctata* in West Malaysia. **Proc. Padi. Workshop, Bumbong, Lima. pp276-289.**
- Aguda, R.M., J.A.Litsinger and D.W.Roberts.1984. Pathogenicity of *Beauveria bassiana* on brown planthopper (BPH), white backed planthopper (WBPH) and green leafhopper (GLH). **IRRN., 9 (6):20.**
- Ajukwahyu, Denan Keratosa putro and Hendarish suharto.1981. Seasonal occurrence of the rice black bug, *Scotinophara coarctata* (Heteroptera:Pentatomidae).**Paper presented at the Symposium on Pest Ecology and Pest Management, Bogor, Indonesia. 8p.**
- Akila Selvaraj and P.C.Sundara Babu.1994. Release of different doses of *Trichogramma* and its effect on internode borer, yield and quality of sugarcane. **Sugarcane (London)2:22-23.**
- Andrewartha, H.G. and L.C.Birch.1954. **The Distribution and Abundance of Animals.** The University of Chicago Press, Chicago. 782p.
- Attri, B.S.1975.Utility of neem oil extractive as feeding deterrent to locust. **Indian. J.Ent., 37:417-419.**
- Atwal, A.S. and S.S.Bains.1974.**Applied Animal Ecology.** Kalyani Publishers, Ludhiana. 245p.

- Balasubramanian, G., S.Chelliah, M.Balasubramanian and M.Gopalan. 1988. Life table and intrinsic rate of increase of *Spodoptera litura* Fabricius on castor and cotton. **Entomon** 13:141-145.
- Balmukand, B.H. 1928 Studies in crop variation: The relation between yield and soil nutrients. **J.Agr. Sci.**, 18:602-627.
- Barrion, A.T. and J.A.Litsinger. 1987. The bionomics, karyology and chemical control of the node feeding black bug, *cotinophara latiuscula* Breddin (Hemiptera:Pentatomidae) in the Philippines. **J.Pl.Prot. Tropics** 4:37-54.
- Barrion, A.T. and J.A.Litsinger. 1994. Taxonomy of rice insect pests and their arthropod parasites and predators. In: **Biology and Management of Rice Insects** Heinrichs, E.A. (ed.) Wiley Eastern limited, New Delhi. pp 13- 362.
- Barrion, A.T., O. Mochida, J.A. Litsinger and N. de la cruz. 1982. The Malayan black bug, *Scotinophara coarctata* (F.) (Hemiptera: Pentatomidae) : a new rice pest in the Philippines. **IRRN.**, 7(6): 6- 7.
- Barroga, R.F. 1988. Recapturing Palawan from the rice black bug. **Phil. Rice. Newsl.**, 1 (3): 4- 5.
- Bigger, J.H. 1943. Insect resistance in corn. **J. Amer. Soc. Agron.**, 35: 689- 694.
- Bilapate, C.G. and V.M. Pawar. 1978. Life table for gram pod borer, *Heliothis armigera* Hubner (Lepidoptera: Noctuidae) **J. Bombay. nat. History. Soc.**, 44: 275- 288.
- Bilapate, C.G., V.M. Pawar and A.K. Raodeo. 1977. Growth of population of *Heliothis armigera* Hbn. on lucerne. **Indian. J. agric. Sci.**, 47: 540- 542.
- Birch, L.C. 1948. The intrinsic rate of natural increase of an insect population. **J. Anim. Ecol.**, 17: 15- 26.
- * Breddin, G. 1900. Hemiptera Sumatrana. **Stettiner Entomologische Zeitung.** 61: 281- 285. Cf. Barrion, A.T. and J.A. Litsinger, 1987. **J. Pl. Prot. Tropics** 4: 37- 54.

- Briggs, G.E. 1925. Plant yield and the intensity of external factors Mitscherlich's 'Wirkungsgesetz'. **Ann. Bot.**, **39**: 475- 502.
- Campbell, A. and M. Mackauer. 1975. Effect of parasitism by *Aphidius smithi* (Hymenoptera: Aphididae) on reproduction and population growth of pea aphid (Homoptera: Aphididae). **Can. Ent.**, **107**: 919- 926.
- Cole, L.C. 1954. The population consequences in life history phenomena. **Q. Rev. Biol.**, **29**: 103- 137.
- Corbett, G.H. and M.Yusope. 1924. *Scotinophara coarctata* (F.) The black bug of padi. **Malays. Agric. J.**, **12**: 91- 106.
- Cramer, H.H. 1967. Plant protection and World crop protection. *Pflanzenschutz Nachr.*
Cf: Heinrichs, E.A. (ed.) 1995. **Biology and Management of Rice Insects.** Wiley Eastern Limited. New Delhi. pp.3-11.
- Dale, D. 1994. Insect pests of the rice plant- Their biology and ecology. In: **Biology and Management of Rice Insects** Heinrichs, E.A. (ed.). Wiley Eastern Limited. New Delhi. pp. 363- 486.
- * Dammerman, K.W. 1929. The Agricultural zoology of the Malay Archipelago. J.H. de Bussy, Amsterdam, Netherlands. Cf: Heinrichs, E.A.(ed.) 1994. **Biology and Management of Rice Insects.** Wiley Eastern Limited. New Delhi. pp 549- 584.
- Deevey, E.S. 1947. Life tables for natural population of animal. **Rev. Biol.**, **22**: 283- 314.
- Dhandapani, N. 1979., **Food utilization and life -table studies of Heliothis armigera (Hubner) (Notuidae: Lepidopetera) on eight different food plants.** M.Sc (Ag.) Thesis. Tamil Nadu. Agricultural University. 97p.
- Dhandapani, M and M. Balasubramanian. 1979. Life table for gram pod borer, *Heliothis armigera* Hubner (Noctuidae: Lepidoptera) on cotton. **J.Ent.Res.**, **3(2)**:186-190.
- Dobzhansky, T. 1968. Adaptedness and fitness. In: **Population Biology and Evolution.** Lewontin, R.C. (ed.) Syracuse university Press, New york. pp. 109- 121.

- Domingo, I.T., E.A. Heinrichs, G.S. Kush, T.Masago, D.M Wood, R.Aseron and R. Vigonte. 1985. Field screening for resistance to the black bug *Scotinophara coarctata*. **IRRN.**,10 (3): 8-9.
- Durairaj,C. and M.S. Venugopal. 1993. Effects of neem and nochi on rice bug *Leptocorisa acuta* **IRRN.**, 18(3):34.
- Evans, F.C. and F.E. Smith. 1952. The intrinsic rate of natural increase for human louse *Pediculus humanus* L. **Am. Nat.**, 136 :299- 310.
- Fernando, H.E. 1961. A biological and ecological study of the rice pentatomid bug, *Scotinophara lurida* (Burm.) in Ceylon. **Bull. Entmol. Res.**, 51: 559- 576.
- Ferror, E.R and B.M Shepard. 1987. sampling Malayan black bugs (Heteroptera: Pentatomidae) in rice. **Environ. Entomol.**, 16: 259- 263.
- Ganesh Kumar, M. 1994. **Prey- Predator interactions in the rice ecosystem with special reference to the spiders.** Ph.D. Thesis. Tamil Nadu Agricultural University. Coimbatore. 210p.
- Ganesh Kumar, M., R. Jaya Kumar, A. Regupathy and B. Rajasekaran. 1994. Liquid chromatographic determination and monitoring of Azadirachtin in Neem ecotypes. **Pestology** 18 (11): 26- 28.
- Geier, P.W. 1966. Management of insect pests. **Annu. Rev. Entomol.**, 11: 471- 490.
- Goel, S.C. 1976. Lunar periodicity in phototropic Hemiptera. **Oriental Insects** 10: 307- 316.
- Gomez, K.A and A.A. Gomez. 1984. **Statistical Procedures for Agricultural Research.** A Wiley- Interscience Publication, John Wiley and Sons, New York. 680 p.
- Greene, G.L. 1971. Economic damage levels of bean leaf roller populations on snap beans. **J. Econ. Entmol.**, 64: 673- 674.

- Headley, J.C. 1971. Defining the economic threshold. In: *Pest Control Strategies for the Future*. 100- 108. Washington DC: **Nat. Acad. Sci. Res. Counc.**376 p.
- Headley, J.C. 1972. Economics of Agricultural Pest Control. **Annu. Rev. Entomol.**, 17: 273- 286.
- Heinrichs, E.A. (ed.)1994. **Biology and Management of Rice Insects**. Wiley Eastern Limited. New Delhi. 779p.
- Heinrichs, E.A., S.Chelliah, S.L.Valencia, M.B.Arceo, L.T.Fabellar, G.B.Aquino and S.Pickin.1981.**Manual for Testing Insecticides on Rice**. International Rice Research Institute, Los Banos, Laguna, Philippines. 134p.
- Heinrichs,E.A., I.T.Domingo and E.H.Castillo.1987. Resistance and yield responses of rice cultivars to the black bug *Scotinophara coarctata* (F.) (Hemiptera:Pentatomidae).**J.Pl.Prot. Tropics** 4:55-64.
- Heinrichs, E.A., P.L.Pathak, V.Z.Dyck, S.Chelliah, R.C.Saxena and J.A.Litsinger.1985. **Guide to Management of Insect Pests of Lowland rice in Tropical Asia**. IPC/SP/65. p.13.
- Hexem, R.W.,V.A.Sposito and E.A.Heady.1976.Application of two variable Mitscherlich function analysis of yield, water and fertilizer relationship for corn. **Water resource Research** 12:6-10.
- International Rice Research Institute (IRRI).1983.Black bugs threaten rice in Palawan. **IRRI.Reporter** 1:2.
- International Rice Research Institute (IRRI).1985. **Annual report for 1984** Los Banos, Laguna, Philippines. p.116.
- International Rice Research Institute (IRRI).1986. **Annual report for 1985** Los Banos, Laguna, Philippines. p.161.
- International Rice Research Institute (IRRI).1987. Rice black bug under control in the Philippines. **IRRI. reporter** 2:3.

- * Katsumota, K. 1930. Results of the studies on *Scotinophara* (=Podops) *lurida* (Burmeister) (in Japanese). **Ishikava** 1:240. Cf: Heinrichs, E.A. (ed.) 1994. **Biology and Management of Rice Insects**. Wiley Eastern Limited. New Delhi. 779p.
- * Kawase, E. and H. Katsumoto. 1955. On some observations on hibernation of black rice bug, *Scotinophara lurida* (Burm.). **Oyo-Kotnyu** 11:32-35. Cf: Barrion, A.T. and J.A. Litsinger. 1987. The bionomics, Karyology and chemical control of the node feeding black bug, *Scotinophara latiuscula* Breddin (Hemiptera: Pentatomidae) in the Philippines. **J.Pl.Prot. Tropics** 4:37-54.
- Kennedy, J.S. 1995. **Functional Ecology of the False Spider Mite, *Brevipalpus phoenicis* (Geijsker)** D.Sc. Thesis. Universite Catholique De Louvain, Louvain-la-Neuve. 406p.
- Kiritani, K. and K. Naba. 1994. Development and implementation of Rice IPM in Japan. In: **Biology and Management of Rice Insects** Heinrichs, E.A. (ed.). Wiley Eastern Limited. New Delhi. pp.712-731.
- Kiyomitsu Ito, Hachiro Sugiyama, N.S. Nik Mohammed Noor, Nik Salleh and P.M. Chang. 1993. Effects of lunar phase on light trap catches of the Malayan black rice bug, *Scotinophara coarctata* (Heteroptera: Pentatomidae). **Bull. Entomol. Res.**, 83:59-66.
- Krishna Ayyar, P.N. 1929. A new pest of rice in South India. **Bull. Entomol. Res.**, 20:173-178.
- Lever, R.J.A.W. 1955. Insect pests of the rice plant in Malaysia. **Int. rice. comm. Newsl.**, 16:12-21.
- Malaysian Agricultural Research and Development Institute. 1982. **Rice Branch Annual Report for 1981** Malaysian Agricultural Research and Development Institute, Malaysia. p.9.
- Medrano, F., E.A. Heinrichs and R.M. Aguda. 1984. Control of *Metarhizium anisopliae* in brown plantopper (BPH) rearing. **IRRN.**, 9:15-16.

- Meek, D.W., R.B. Hutmacher, B.E. Mackey and K.R. Davis. 1991. Heteroscedasticity in whole plant growth curves developed from non-replicated data. **Agron. J.**, 93:417-424.
- Miyamoto, S., N.A. Torres, B.H. Habibuddin, R. Montri, T. Fujimura, P. Thieng and O. Mochida. 1983. Emerging problems of pests and diseases- The black bug in South east Asia. **Paper presented at the International Rice Research Conference**, April, 1983. International Rice Research Institute, Los Banos, Laguna, Philippines. 33p.
- Mochida, O., S. de Sagun, M. Parducho, D. Gapasin and N.P. Orolaza. 1986. General information on black bugs, insecticide evaluation, economic injury levels and principle of chemical control. **Paper presented at the PC ARRD/MAF/IRRI Workshop on Black bug**, October, 1986. Palawan, Philippines. pp.1-17.
- * Mochizuki, M. 1957. Control of insect damage for early planting of rice plant in Toyama Prefecture. **Agric. Hort.**, 32:61-622. Cf: Heinrichs, E.A. (ed.) 1994. **Biology and Management of Rice Insects**. Wiley Eastern Limited. New Delhi. 779p.
- Mohd Norowi Hamid and Shuhaimen Ismail. 1994. Predicting a dynamic economic threshold level for Malayan black bug infestation on rice in Malaysia. In: **Analysis of Damage Mechanisms by Pests and Diseases and their Effects on Rice Yield** Elings, A. and E.G. Rubia (eds.) SARP. Research Proceedings - III. DLO Research Inst. for Agrobiolgy and Soil Fertility, Wageningen pp.171-180.
- * Morimoto, T. 1957. Studies on the *Oospora destructor* as a control agent against black rice bug. **Mem. Fac. Agric. Kochi. Univ. (Kochi Daigaku Noga Kubu Kiyo)** 2:1-14. Cf: Rombach, R.M. Aguda, B.M. Shepard and D.W. Roberts. 1986. **J. Invertebr. Pathol.**, 43: 174-179.
- Morris, R.F. and C.A. Muller. 1954. The development of life tables for the spruce bud worm. **Can. J. Zool.**, 32:283-301.

- Munakata, K. and D.Okamoto.1966.Symposium on the major insect pests of rice. Baltimore, Md: John Hopkins Press. 468 p.
- Nanthagopal,R.1987.**Studies on Life tables and Distribution of Cotton Bollworms.** M.Sc.(Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore. 106p.
- Nemisio Trillana.1988.Black bug tolerant variety developed in Palawan, Widespread planting urged. **Phil. Rice Newsl., (Anniversary Issue):5p.**
- Norgaard, R.B.1976.The economics of improving pesticide use. **Annu.Rev. Entomol., 21:45-60.**
- Ooi., P.A.C.1981. The padi black bug. **Nature Malaysiana 6:32-35.**
- Ooi., P.A.C.1988. **Insects in Malaysian Agriculture.** Kualalumpur, Tropical Press, p.106.
- Ooi., P.A.C. and B.M. Shepard. 1994. Predators and Parasitoids of Rice Insect Pests. In: **Biology and Management of Rice Insects..** Heinrichs E.A. (ed.) Wiley Eastern Limited. pp 584- 612.
- * Ordish, G. 1952. Untaken Harvest, chap 3. Cf: Stern, V.M. 1973. **Annu. Rev. Entmol., 18: 259- 280.**
- Painter, R.H. 1951. **Insect Resistance in Crop Plants.** The Macmillon Co., New york. 520 p.
- Panse, V.G. and P.V. Sukhatme. 1967. **Statistical Methods for Agricultural Workers.** 2nd ed. I.C.A.R. New Delhi. 328 p.
- Parducho, M.A., G.S. Arida and B.M. Shepard. 1988. Effect of flooding on Malayan black bug (MBB) egg hatching and parasitoid emergence. **IRRN., 13(6): 39.**
- Pathak, M.D. and Z.R. Khan. 1994. Rice black bugs. In: **Insect pests of Rice** Pathak M.D. and Z.R. Khan. (eds.) **IRRI., and ICIPE** , pp 63- 64.

- Patil, K.J., M.M. Deshkar, A.E. Rane and S.A. Nimbalkar. 1990. Some indigenous plant materials against *Aphis gossypii* G. and *Dactynotus carthami* HRL. In **Proc. Symp. Botanical. Pesticides in IPM**. Rajahmundry, pp 238- 344.
- Perez, V.A., B.M. Shepard and G.S. Arida. 1989. Indigenous natural enemies of the Malayan black bug *Scotinophara coarctata*(Fab.) on Palawan Island, Philippines. **Philipp. Entmol.**, 7: 185- 490.
- Pretorius, L.M. 1976. Laboratory studies on the developmental and reproductive performance of *Heliothis armigera* on various food plants. **J. ent. soc. South. Afric.**, 39: 3317- 3343.
- Ramachandra Prasad, T.V., K.Krishnamurthy and C. Kailasam. 1992. Functional crop and cob growth models of maize (*Zea mays* L.) cultivars **J. Agron. crop. Sci.**, 168: 208- 212.
- Rao, V.G. 1977. Out break of Malayan black rice bug in Nellore district. **IRRN.**, 2(6): 16.
- Reissig, W.H., and E.A. Heinrichs, J.A. Litsinger, K.M. Moody, L. Fielder, T.W. Mew and A.A. Barrion. 1985. **Illustrated Guide to Integrated Pest Management in Rice in Tropical Asia**. International Rice Research Institute, Los Banos, Philippines. 411 p.
- Rombach, M.C., R.M. Aguda, B.M. Shepard and D.W. Roberts. 1986. Entomopathogenic Fungi (Deutero mycotina) in the control of the black bug of rice, *Scotinophara coarctata* (Hemiptera: Pentatomidae). **J. Invertebr. Pathol.**, 43: 174- 179.
- Rombach, M.C., G.M. Rombach and D.W. Roberts. 1987. Pathogens of Insect pests of rice. A bibliography. **Insect. Sci. Applic.**, 8: 197- 210.
- Saroja, R., M. Subramanian and A. Abdul Kareem. 1993 **Rice Black Bug** Rice Research Station, Tirur. Publication. 29p.
- Saxena, R.C. 1982. Rice insect pest management Paper presented at the 1982 **ICIPE/UNEP Group Training Course at the International Centre of Insect Physiology and Ecology**, Nairobi, Kenya, 27 p.

- Shepard, B.M. and G.S. Arida. 1986. Sex ratio and productive status of *Scotinophara coarctata* collected from light traps and rice fields. **IRRN.**, 11(3): 23- 24.
- Shepard, B.M., E.R. Ferrer and P.E. Kenmore. 1988a. Sequential sampling of plant hoppers and predators in rice. **J. Plant. Prot. Tropics** 5:39- 44.
- Shepard, B.M., M.A. Pardocho and G.S. Arida. 1988b. Effect of flooding on black bug *Scotinophara coarctata* (F). egg parasitization **IRRN.**, 13(2):22.
- Shepard, B.M. and V.A. Perez. 1987. Influence of cultivation on survival of the Malayan Black Bug in rice fields. **IRRN.**, 12(3):35.
- Singh, K.G. 1988. New pest threats and pest quarantine development in the South East Asian region. **Planti. News** 7: 3- 7.
- Singh, M.P. and N.I. Singh. 1987. First recorded incidence of rice bugs in Manipur- India. **IRRN.**, 12(2):31.
- Smith, R.F. and R. van den Bosch. 1967. Integrated control. In: **Pest Control Biological, Physical and Selected Methods**. Kilgore, W.W. and R.L. Doutt (eds.). New York: Academic. 477 p.
- Srinivasan, S. and A.S. Reddy. 1993. Influence of lunar cycle on light trap catches of Malayan rice black bug. **Oryza** 30: 174- 175.
- Stern, V.M. 1973. Economic Thresholds. **Annu. Rev. Entomol.**, 18: 259- 280.
- Subramanian, A., S. Murugesan, R. Rajendran and P.C. Sundara Babu 1986. Occurrence and control of rice black bug at Coimbatore. **IRRN.**, 11(3): 24.
- Sundara Babu, P.C., M. Muthusamy and R. Sadasivam. 1984. Occurrence of black bugs on rice. **Tamil Nadu. Agric. Univ. Newsl.**, 14(5): 3-4.

Suyambalingom, C and C. Kailasam. 1988. **Mathematics for Plant Sciences**. Sakthi publications. 200 p.

* Swaminathan, M.S. 1984. **Rice Sci. Am.** 250 (1) : 81-93. Cf: Heinrichs, E.A. (ed.) 1994. **Biology and Management of Rice Insects**. Wiley Eastern Limited. pp.5-11.

Tricholo, P.G. and T.F. Leigh. 1985. The use of life tables to assess varietal resistance of cotton spider mites. **Entomol. exp. appl.**, 39: 27- 33.

Uthamasamy, S and V. Mariappan. 1985. Occurrence of black bug in Tamil Nadu. **IRRN.**, 10(2):15.

van vreden, G. and A. Abdul Latif. 1986. **Pests of Rice and their Natural Enemies in Peninsular Malaysia**. Wageningen, Pudok. 230 p.

Watson, T.F. 1964. Influence of Host plant condition on population increase of *Tetranychus telarius* (Linnaeus) (Acarina: Tetranychidae). **Hilgardia** 35: 273-322.

Yunus, A. 1964. The major pests of the rice plant. In : **Insect Pests of Rice in Malaysia**. John Hopkins press, Baltimore, Maryland. 726 p.

* Not seen in original.

ANNEXURE

ANNEXURE 1

Life table and specific fecundity for *Scotinophara coarctata* on rice

Pivotal age (days) X	Proportional survival of females at age X lx	No. of female progenies/♀ mx	lxmx	lxmx.X
0 - 32	0.900	Immature stages		
33	0.900	0.000	0.000	0.000
34	0.900	0.000	0.000	0.000
35	0.900	0.000	0.000	0.000
36	0.900	0.000	0.000	0.000
37	0.900	2.133	1.920	71.029
38	0.900	2.190	1.971	74.898
39	0.900	1.955	1.760	68.621
40	0.900	2.368	2.131	85.248
41	0.900	3.435	3.092	126.752
42	0.900	3.968	3.571	149.990
43	0.900	2.667	2.400	103.213
44	0.900	2.900	2.610	114.840
45	0.900	3.556	3.200	144.018
46	0.900	2.254	2.029	93.316
47	0.900	3.079	2.771	130.242
48	0.900	3.022	2.720	130.550
49	0.900	4.324	3.892	190.688
50	0.900	2.667	2.400	120.015
51	0.900	2.724	2.452	125.032
52	0.900	3.200	2.880	149.760
53	0.900	2.489	2.240	118.725
54	0.900	2.724	2.452	132.386
55	0.900	4.502	4.052	222.849
56	0.900	1.834	1.651	92.434

Pivotal age (days) X	Proportional survival of femals at age X lx	No. of female progenies/♀ mx	lxmx	lxmx.X
57	0.900	4.089	3.680	209.766
58	0.900	3.321	2.989	173.356
59	0.900	3.200	2.880	169.920
60	0.900	1.422	1.280	76.788
61	0.900	3.079	2.771	169.037
62	0.900	4.210	3.789	234.918
63	0.900	2.190	1.971	124.173
64	0.900	2.965	2.669	170.784
65	0.900	3.790	3.411	221.715
66	0.900	3.200	2.880	190.080
67	0.900	2.425	2.183	146.228
68	0.900	3.911	3.520	239.353
69	0.900	2.546	2.291	158.107
70	0.900	2.133	1.920	134.379
71	0.900	1.650	1.485	105.435
72	0.900	0.590	0.531	38.232
73	0.900	1.244	1.120	81.731
74	0.900	2.901	2.611	193.207
75	0.900	1.834	1.651	123.795
76	0.900	2.610	2.349	178.524
77	0.900	1.301	1.171	90.159
78	0.900	1.187	1.068	83.327
79	0.900	1.543	1.389	109.707
80	0.900	2.311	2.080	166.392
81	0.900	1.066	0.959	77.711

Pivotal age (days) X	Proportional survival of femals at age X l_x	No. of female progenies/ ϕ m_x	$l_x m_x$	$l_x m_x \cdot X$
82	0.900	1.657	1.491	122.287
83	0.900	0.654	0.589	48.854
84	0.900	1.714	1.543	129.578
85	0.900	1.543	1.389	118.040
86	0.900	0.590	0.531	45.666
87	0.900	1.187	1.068	92.942
88	0.900	1.657	1.491	131.234
89	0.900	1.899	1.709	152.110
90	0.900	1.301	1.171	105.381
91	0.900	1.066	0.959	87.305
92	0.900	1.301	1.171	107.723
93	0.900	0.832	0.749	69.638
94	0.900	1.543	1.389	130.538
95	0.900	1.422	1.280	121.581
96-145	0.900	0.000	0.000	0.000
146-153	0.825	0.000	0.000	0.000
154-181	0.750	0.000	0.000	0.000
182-183	0.675	0.000	0.000	0.000
184	0.525	0.000	0.000	0.000
185-186	0.450	0.000	0.000	0.000
187-188	0.375	0.000	0.000	0.000
189-191	0.300	0.000	0.000	0.000
192-193	0.225	0.000	0.000	0.000
194	0.150	0.000	0.000	0.000
195-200	0.075	0.000	0.000	0.000
201	0.000	0.000	0.000	0.000

ANNEXURE 2

Stable age distribution of *S. coarctata* on rice

rm=0.0904

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$	
0	0.95	0.9135651338	8.8842665338	
1	0.95	0.8346012537	8.1163561449	
2	0.95	0.7624626061	7.4148199876	
3	0.95	0.6965592527	6.7739210142	
4	0.95	0.6363522469	6.1884180578	37.3777817
5	0.95	0.5813492256	5.6535229711	
6	0.95	0.5311003831	5.1648614697	
7	0.95	0.4851947926	4.7184373597	
8	0.95	0.4432570456	4.3105998579	
9	0.95	0.4049441822	3.9380137360	
10	0.95	0.369942886	3.5976320458	
11	0.95	0.3379669221	3.2866712013	
12	0.95	0.3087547964	3.0025882158	
13	0.95	0.2820676169	2.7430599052	
14	0.95	0.2576871402	2.5059638894	
15	0.95	0.2354139867	2.2893612359	
16	0.95	0.2150660103	2.0914806039	
17	0.95	0.1964768085	1.9107037577	
18	9.05	0.1794943618	1.7455523341	
19	0.95	0.1639797907	1.5946757518	
20	0.95	0.1498062194	1.4568401666	
21	0.95	0.1368577389	1.3309183817	

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$
22	0.95	0.1250284585	1.2158806295
23	0.95	0.1142216405	1.1107861500
24	0.95	0.1043489082	1.0147754978
25	0.95	0.0953295243	0.9270635134
26	0.95	0.0870897297	0.8469329027
27	0.95	0.0795621405	0.7737283706
28	0.95	0.0726851976	0.7068512624
29	0.95	0.0664026622	0.6457546681
30	0.95	0.0606631570	0.5899389498
31	0.95	0.0554197451	0.5389476556
32	0.95	0.0506295469	0.4923637871
			57.1679
33	0.95	0.0462533888	0.449806381
34	0.95	0.0422554833	0.4109274340
35	0.95	0.0386031363	0.3754089763
36	0.95	0.0352664793	0.3429605516
37	0.95	0.0322182259	0.3133168022
38	0.95	0.0294334479	0.2862353064
39	0.95	0.0268893718	0.2614945960
40	0.95	0.0245651925	0.2388923456
41	0.95	0.0224419034	0.2182437176
42	0.95	0.0205021405	0.1993798511
43	0.95	0.0187300407	0.1821464804
44	0.95	0.0171111121	0.1664026737
45	0.95	0.0156321154	0.1520196809

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$
46	0.95	0.0142809556	0.1388798801
47	0.95	0.0130465831	0.1268758162
48	0.95	0.0119189035	0.1159093220
49	0.95	0.0108886947	0.1058907153
50	0.95	0.0099475318	0.0967380655
51	0.95	0.0090877182	0.0883765238
52	0.95	0.0083022225	0.0807377108
53	0.95	0.0075846210	0.0737591575
54	0.95	0.0069290453	0.0673837946
55	0.95	0.0063301342	0.0615594853
56	0.95	0.0057829899	0.0562385995
57	0.95	0.0052831379	0.0513776236
58	0.95	0.0048264906	0.0469368056
59	0.95	0.0044093136	0.0428798291
60	0.95	0.0040281951	0.0391735168
61	0.95	0.0036800186	0.0357875591
62	0.95	0.0033619367	0.0326942663
63	0.95	0.0030713482	0.0298683417
64	0.95	0.0028058766	0.0272866756
65	0.95	0.0025633510	0.0249281554
66	0.95	0.0023417881	0.0227734937
67	0.95	0.0021393760	0.0208050698
68	0.95	0.0019544593	0.0190067864
69	0.95	0.0017855259	0.0173639373
70	0.95	0.0016311942	0.0158630877

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$
71	0.95	0.0014902021	0.0144919639
72	0.95	0.0013613967	0.0132393529
73	0.95	0.0012437246	0.0120950112
74	0.95	0.0011362234	0.0110495805
75	0.95	0.0010380141	0.0100945115
76	0.95	0.0009482935	0.0092219938
77	0.95	0.0008663279	0.0084248920
78	0.95	0.0007914469	0.0076966876
79	0.95	0.0007230383	0.0070314254
80	0.95	0.0006605426	0.0064236651
81	0.95	0.0006034487	0.0058684365
82	0.95	0.0005512897	0.0053611989
83	0.95	0.0005036390	0.0048978044
84	0.95	0.0004601071	0.0044744634
85	0.95	0.0004203378	0.0040877137
86	0.95	0.0003840059	0.0037343927
87	0.95	0.0003508144	0.0034116110
88	0.95	0.0003204918	0.0031167288
89	0.95	0.0002927902	0.0028473348
90	0.95	0.002674829	0.0026012258
91	0.95	0.0002443630	0.0023763892
92	0.95	0.0002232415	0.0021709863
93	0.95	0.0002039457	0.0019833374
94	0.95	0.001863177	0.0018119079
95	0.95	0.0001702133	0.0016552959

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$
96	0.95	0.0001555010	0.0015122206
97	0.95	0.0001420603	0.0013815120
98	0.95	0.0001297813	0.0012621012
99	0.95	0.0001185637	0.0011530117
100	0.95	0.0001083156	0.0010533513
101	0.95	0.0000989534	0.0009623050
102	0.95	0.0000904004	0.0008791283
103	0.95	0.0000825866	0.0008031409
104	0.95	0.0000754483	0.0007337216
105	0.95	0.0000689269	0.0006703024
106	0.95	0.0000629692	0.0006123649
107	0.95	0.0000575265	0.0005594353
108	0.95	0.0000525542	0.0005110805
109	0.95	0.0000480117	0.0004669054
110	0.95	0.0000438618	0.0004265485
111	0.95	0.0000400706	0.0003896798
112	0.95	0.0000366071	0.0003559979
113	0.95	0.0000334430	0.0003252273
114	0.95	0.0000305523	0.0002971163
115	0.95	0.0000279115	0.0002714351
116	0.95	0.0000254990	0.0002479736
117	0.95	0.0000232950	0.0002265401
118	0.95	0.0000212815	0.0002069591
119	0.95	0.0000194420	0.0001890706
120	0.95	0.0000177616	0.0001727283

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$
121	0.95	0.0000162264	0.0001577986
122	0.95	0.0000148238	0.0001441593
123	0.95	0.0000135425	0.0001316989
124	0.95	0.0000123720	0.0001203155
125	0.95	0.0000113026	0.0001099161
126	0.95	0.0000103257	0.0001004155
127	0.95	0.0000094332	0.000917361
128	0.95	0.0000086178	0.000838069
129	0.95	0.0000078729	0.000765630
130	0.95	0.0000071924	0.000699453
131	0.95	0.0000065708	0.000638996
132	0.95	0.0000060028	0.000583765
133	0.95	0.0000054840	0.000533307
134	0.95	0.0000050100	0.000487211
135	0.95	0.0000045769	0.000445099
1.36	0.95	0.0000041813	0.000406627
137	0.95	0.0000038199	0.000371480
138	0.95	0.0000034897	0.000339371
139	0.95	0.0000031881	0.000310038
140	0.95	0.0000029125	0.000283240
141	0.95	0.0000026608	0.000258758
142	0.95	0.0000024308	0.000236392
143	0.95	0.0000022207	0.000215960
144	0.95	0.0000020288	0.000197293
145	0.8625	0.0000018534	0.000180240

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$
146	0.8625	0.0000016932	0.000164661
147	0.8625	0.0000015469	0.000150429
148	0.8625	0.0000014131	0.000137426
149	0.8625	0.0000012910	0.000125548
150	0.8625	0.0000011794	0.000114696
151	0.8625	0.0000010770	0.000104782
152	0.8625	0.0000009843	0.000095726
153	0.7875	0.0000008993	0.000087452
154	0.7875	0.0000008215	0.000079893
155	0.7875	0.0000007505	0.000072987
156	0.7875	0.0000006857	0.000066679
157	0.7875	0.0000006264	0.000060915
158	0.7875	0.0000005722	0.000055650
159	0.7875	0.0000005228	0.000050840
160	0.7875	0.0000004776	0.000046446
161	0.7875	0.0000004363	0.000042431
162	0.7875	0.0000003986	0.000038764
163	0.7875	0.0000003642	0.000035413
164	0.7875	0.0000003327	0.000032352
165	0.7875	0.0000003039	0.000029556
166	0.7875	0.0000002777	0.000027001
167	0.7875	0.0000002537	0.000024667
168	0.7875	0.0000002317	0.000022535
169	0.7875	0.0000002117	0.000020587
170	0.7875	0.0000001934	0.000018808

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$
171	0.7875	0.0000001767	0.000017182
172	0.7875	0.0000001614	0.000015697
173	0.7875	0.0000001475	0.000014340
174	0.7875	0.0000001347	0.000013101
175	0.7875	0.0000001231	0.000011968
176	0.7875	0.0000001124	0.000010934
177	0.7875	0.0000001027	0.000009989
178	0.7875	0.0000000938	0.000009125
179	0.7875	0.0000000857	0.000008337
180	0.7875	0.0000000783	0.000007616
181	0.7125	0.0000000715	0.000006958
182	0.7125	0.0000000654	0.000006356
183	0.6600	0.0000000597	0.000005807
184	0.4875	0.0000000546	0.000005305
185	0.4875	0.0000000498	0.000004847
186	0.4125	0.0000000455	0.000004428
187	0.4125	0.0000000416	0.000004045
188	0.3375	0.000000038	0.000003695
189	0.3375	0.0000000347	0.000003376
190	0.3375	0.0000000317	0.000003084
191	0.2625	0.000000029	0.000002818
192	0.2625	0.0000000265	0.000002574
193	0.1875	0.0000000242	0.000002352
194	0.1125	0.0000000221	0.000002148
195	0.1125	0.0000000202	0.000001963

x	Lx	$Lx(e^{-m(x+1)})$	Distribution % $100 \beta Lx(e^{-m(x+1)})$
196	0.1125	0.0000000184	0.000001793
197	0.1125	0.0000000168	0.000001638
198	0.1125	0.0000000154	0.000001496
199	0.1125	0.0000000141	0.000001367
200	0.0375	0.0000000128	0.000001249
			5.7719