- 172709 -

BIOECOLOGY, POPULATION DYNAMICS AND INTEGRATED MANAGEMENT OF RICE BLUE BEETLE, *Leptispa pygmaea* Baly (Chrysomelidae : Coleoptera)

K. KARTHIKEYAN

Thesis submitted in partial fulfillment of the requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

KERALA AGRICULTURAL UNIVERSITY LIBRARY THRISSUR

2007

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

DECLARATION

I hereby declare that the thesis entitled "**Bioecology, population dynamics and integrated management of rice blue beetle, *Leptispa pygmaea* Baly (Chrysomelidae : Coleoptera)**" is a bona fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma fellowship or other similar title, of any other university or society.

K. Karthikeyan

Place: Vellanikara **K. Karthikeyan**

Date: 01. 03. 2007

CERTIFICATE

Certified that the thesis entitled **"Bioecology, population dynamics and integrated management of rice blue beetle, *Leptispa pygmaea* Baly (Chrysomelidae : Coleoptera)"** is record of research done independently by **Mr.K.Karthikeyan** *under my guidance and supervision and that it has not previously* formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellanikara

Date 01-03-2007

(Dr.Sosamma Jacob)
Major Advisor, Advisory Committee
Associate Professor
Department of Agricultural Entomology
College of Horticulture, Vellanikara

CERTIFICATE

We, the undersigned members of the Advisory Commitee of **Mr. K.Karthikeyan**, a candidate for the degree of Doctor of Philosophy in Agriculture with major in Agricultural Entomology, agree that the thesis entitled **"Bioecology, population dynamics and integrated management of rice blue beetle, *Leptispa pygmaea* Baly (Chrysomelidae : Coleoptera)"** may be submitted by **Mr. K.Karthikeyan** in partial fulfillment of the requirement for the degree.

01/03/2007

Dr.Sosamma Jacob
(Major Advisor, Advisory Committee)
Associate Professor
Department of Agricultural Entomology
College of Horticulture, Vellanikara

01/03/07

Dr.Jim Thomas
(Member, Advisory Commitee)
Associate professor and Head (i/c)
Department of Agricultural Entomology
College of Horticulture, Vellanikara

01-03-'07

Dr.Maicykutty P. Mathew
(Member, Advisory Commitee)
Associate Professor
Banana Research Station
Kannara

Dr.P.V.Balachandran
(Member, Advisory Commitee)
Associate Director of Research (i/c)
Regional Agricultural Research Station
Pattambi – 679 306

01-03-07

Dr.V.K.G.Unnithan
(Member, Advisory Commitee)
Associate professor and Head (i/c)
Department of Agricultural Statistics
College of Horticulture, Vellanikara

M. Bharathi
11/06/07

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

I am immensely thankful to **Dr.Sosamma Jacob**, Associate professor of Agricultural Entomology and Major Advisor of the Advisory Committee, for her tireless support and guidance during the entire course of my study period. She not only acted as advisor but also gave me motherly advice for the improvement of my career. Her meticulous care and untiring encouragement during every point of research work helped in the successful completion of my research work.

I express my sincere thanks to **Dr.Jim thomas**, Associate professor and Head (i/c), Department of Entomology, Member of Advisory Committee whom I could approach any help at any time. He rendered his valuable support and guidance during the entire period of work.

I am also grateful to the Associate Director of Research, **Dr.P.V.Balachandran**, RARS, Pattambi, Member of Advisory Committee who inspite of his busy work as the head of station helped me a lot during the study by permitting me to conduct the field and laboratory experiments at the research station. His continuous support, guidance and valuable suggestions during my research work helped me a lot in the improvement of my thesis work.

It is my immense pleasure to express my heartfelt gratitude to **Dr.V.K.G.Unnithan**, Associate professor and Head (i/c), Department of Agrl. Statistics, Member of Advisory Committee who was behind for all my statistical interpretations of my thesis work. Besides his busy schedule as Head of the Department, he was able to give fatherly advice and suggestion for my improvement and this helped me a lot in successfully completing my research work.

I also extend my thanks to **Dr.Maicykutty P. Mathew**, Associate professor, Department of Entomology, Banana Research, Kannara, and Member of Advisory Committee who helped me in conducting the biocontrol experiments of the research work. Her tireless support and able guidance helped me a lot in the completion of my research work.

My profound thanks to **Dr.S.Krishnan**, Assistant professor, Department of Agrl. Statistics and **Mr.Eldo**, Teaching Assistant, Veterinary College who have helped me voluntarily in the statistical analysis of my thesis data. Their continuous support and suggestions helped me in writing the thesis.

I place my record of thanks to **Dr.Pathummal Beevi**, Associate professor in Entomology, AICRP on BCCP and **Mr.C.R.Biju**, Research Associate, **Dr.K.D.Prathaban**, Asst. Professor, COA, Vellayani, **Dr.A.Joseph Rajkumar**, Head, CRS, Pampadumpara who have helped in taking photoes for the work. Their timely help and guidance cannot be expressed in words.

I am indebted to **Dr.R.Ushakumari**, **Dr.A.M.Ranjith**, Associate professors of Entomology who have extended their help voluntarily in identification of parasitoids and taking photographs of the insect specimens. They also showed personal care and support during the course of my study.

As a personal note, I place my profound thanks to my wife, mother and father for their continuous support, guidance and continuous encouragement during the entire course of my study.

The study leave granted by the Kerala Agricultural University is also thankfully acknowledged.

K. Karthikeyan

CONTENTS

Sl.No.	Chapter	Page Number
1	INTRODUCTION	1 - 4
2	REVIEW OF LITERATURE	5 - 25
3	MATERIALS AND METHODS	26 - 39
4	RESULTS	40 - 100
5	DISCUSSION	101 - 126
6	SUMMARY	127 - 133
	REFRENCES	(i) - (xii)
	ABSTRACT	

LIST OF TABLES

Table No.	Title	Page No.
1	Scoring for the damage by *L. pygmaea* in rice	31
2	Technique of evaluation of rice varieties for resistance	33
3	Treatment details of nursery application with granules	37
4	Details of foliar insecticides against *L.pygmaea*	39
5	Fecundity of *L.pygmaea* on short duration rice variety Jyothi	41
6	Fecundity of *L. pygmaea* on medium duration rice variety Aiswarya	42
7	Duration of developmental stages of *L.pygmaea* on Jyothi and Aiswarya	44
8	Duration of different larval stages of *L. pygmaea* on Jyothi and Aiswarya	45
9	Pre-oviposition and adult longevity of *L. pygmaea* on Jyothi and Aiswarya	46
10	Time of emergence of *L. pygmaea* during different hours of the day	48
11	Sex ratio of *L. pygmaea* in rice fields from June to November'2005	49
12	Measurements of egg of *L. pygmaea*	52
13	Measurements of grub and pupa of *L. pygmaea*	52,53
14	Measurements of male and female beetles of *L. pygmaea*	54
15	Measurements of the reproductive systems of *L. pygmaea*	55
16	Field population dynamics of *L. pygmaea* and weather parameters (Kharif and Rabi, 2005)	57
17	Correlation of rice blue beetle population with weather parameters	59
18	Intensity of feeding by *L. pygmaea* on Jyothi and Aiswarya	60
19	Leaf area consumed by different stages of *L. pygmaea*	60

Table No.	Title	Page No.
20	Extent of damage by *L. pygmaea* during different growth stages of Jyothi	62
21	Effect of methods of cultivation on the incidence of L. *pygmaea* in Jyothi	64
22	Effect of methods of cultivation on the incidence of L.*pygmaea* in Aiswarya during Kharif and Rabi '2005	65
23	Reaction of different rice varieties / entries against the blue beetle	67,69
24	Suitability of weeds as alternative hosts of *L. pygmaea*	71
25	Biology of *L. pygmaea* on the weed *Panicum repens*	72
26	Comparative biology of *L. pygmaea* on Jyothi, Aiswarya and *Panicum repens*	74
27	Effect of plant spacing on the incidence of *L. pygmaea* (Pooled analysis of Kharif and Rabi, 2005)	75
28	Effect of oilcakes on the incidence of *L. pygmaea* ((Pooled analysis of Kharif and Rabi, 2005)	76
29a	Effect of interaction between spacing and oilcakes on per cent leaf damage of *L. pygmaea*	78
29b	Effect of interaction between spacing and oilcakes on beetle population of *L. pygmaea*	79
29c	Effect of interaction between spacing and oilcakes on per cent hill damage and damage scoring of *L. pygmaea*	80
30	Laboratory evaluation of *B. bassiana* against adult beetles of *L. pygmaea*	82
31	Laboratory evaluation of *H. indica* against grubs of *L. pygmaea*	83
32a	Effect of granular insecticides on the leaf damage by blue beetle (Kharif 04& 05)	85
32b	Effect of granular insecticides on the population of blue beetle (Kharif 04& 05)	86
33a	Effect of granular insecticides on damage by rice blue beetle (Rabi 04& 05)	88
33b	Effect of granular insecticides on the populationof blue beetle (Rabi 04& Rabi 05)	89
34a	Persistent toxicity of granular insecticides to *L. pygmaea* (mean of two Kharif seasons)	91
34b	Persistent toxicity of granular insecticides to *L. pygmaea* (mean of two Rabi seasons)	92

Table No.	Title	Page No.
35	Effect of eco-friendly foliar insecticides on the incidence of blue beetle (Kharif 04& Kharif 05)	94
36a	Effect of eco-friendly foliar insecticides on the incidence of blue beetle (Rabi 04& Rabi 05)	95
36b	Effect of eco-friendly foliar insecticides on the population of blue beetle (Rabi 04& Rabi 05)	97
37a	Persistent toxicity of eco-friendly foliar insecticides to *L. pygmaea* (mean of two Kharif seasons)	99
37b	Persistent toxicity of eco-friendly foliar insecticides to *L. pygmaea* (mean of two Rabi seasons)	100

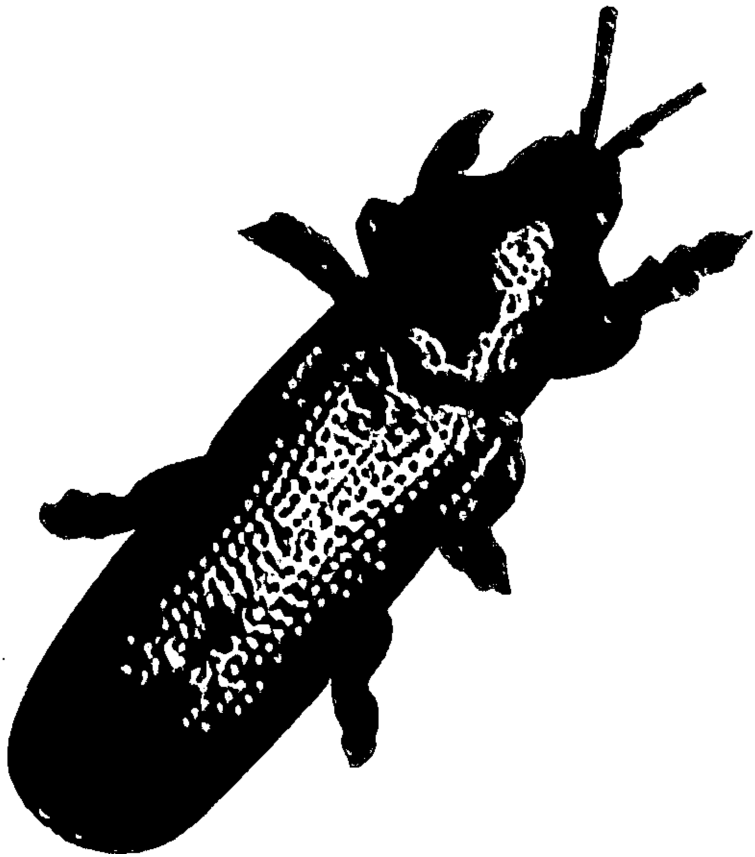
LIST OF FIGURES

Fig. No.	Title	Between pages
1a	Duration of different stages of *L.pygmaea* (Male) in days	104 -105
1b	Duration of different stages of *L.pygmaea* (Female) in days	104 -105
2	Time of emergence of *L.pygmaea*	104 -105
3	Male and Female populations of *L.pygmaea* during different months	105-106
4	Population of *L.pygmaea* during Kharif'05	109 -110
5	Population of *L.pygmaea* during Rabi'05	110 - 111
6	Leaf damage by *L.pygmaea* on Jyothi and Aiswarya	112 - 113
7	Leaf area consumption by different stages of *L.pygmaea* on Jyothi and Aiswarya	112 - 113
8	Leaf damage by *L.pygmaea* during different growth stages of rice	113 - 114
9	Reduction of damage in direct seeded over transplanted (Jyothi)	113 -114
10	Reduction of damage in direct seeded over transplanted (Aiswarya)	114 - 115
11	Comparative biology of *L.pygmaea* in Jyothi, Aiswarya and *P.repens*	117 - 118
12	Reduction of *L.pygmaea* infestation in closer spacing	117 - 118
13	Reduction of incidence of *L.pygmaea* by nursery treatment (2004)	120 -121
14	Reduction of incidence of *L.pygmaea* by nursery treatment (2005)	120 -121
15	Persistent toxicity of granular insecticides	121 -122
16	Bioefficacy of foliar insecticides against *L.pygmaea* (2004)	122 -123
17	Bioefficacy of foliar insecticides against *L.pygmaea* (2005)	122 -123
18	Persistent toxicity of foliar insecticides	124 -125

LIST OF PLATES

Plate No.	Title	Between pages
1	Polyester cage for rearing blue beetle	26 - 27
2	Score '0' showing no leaf damage	30 - 31
3	Score '1' showing 1-10 % leaf damage	30 - 31
4	Score '3' showing 11-25 % leaf damage	30 - 31
5	Score '5' showing 26-50 % leaf damage	30 - 31
6	Score '7' showing 51-75 % leaf damage	30 - 31
7	Score '9' showing > 75 % leaf damage	30 - 31
8	Eggs of blue beetle	52 - 53
9	Head of grub showing spine like projection	52 - 53
10	Grubs with three pairs of legs and posterior abdominal projection	52 - 53
11	Grubs of different instars along with pupa	52 - 53
12	Three pupae seen attached to the same leaf	53 - 54
13	Colour change of beetle after emergence	53 - 54
14	Thorax of adult beetle showing pittings	53 - 54
15	Male and Female adult beetles	53 - 54
16	Scape width difference in Male and Female adult beetles	54 - 55
17	Antennal length difference in Male and Female adult beetles	54 - 55
18	Aedeagus protruding out from male beetle during copulation	54 - 55
19	Lateral view of aedeagus of blue beetle	54 - 55
20	Spermatheca in female Genitalia	56 - 57
21	Coxites in female Genitalia	56 - 57

Plate No.	Title	Between pages
22	Leaf scraping by grubs of blue beetle	59 -60
23	Leaf scraping by adults	59 - 60
24	Comparison of leaf damage by blue beetle and leaf folder	59 -60
25	Plants severly damaged by blue beetle	59 -60
26	Severe damage of national rice entries by blue beetle	71 -72
27	Feeding of blue beetle on *Isachne miliacea*	71 -72
28	Inchipullu, *Panicum repens* – alternative host	71 -72
29	Egg laying in *Panicum repens*	71 -72
30	Grubs feeding on *Panicum repens*	71 -72
31	Pupation and adult beetle feeding on *Panicum repens*	71 -72
32	Parasitised eggs of blue beetle	80 -81
33	*Trichogramma* sp.	80 -81
34	*Telenomus* sp.	80 -81
35	*Tetrastichus* sp.	80 -81
36	Dead beetle covered by white mycelial growth of *Beauveria bassiana*	81 -82
37	Pupa infected by *B. bassiana*	81 -82
38	Entomopathogenic nematode, *Heterorhabditis indica*	82 -83
39	Healthy and infected grub	82 -83



Introduction

1. INTRODUCTION

Insect pests, diseases and weeds are the major biotic bottlenecks in the production of crops inflicting about 40 per cent losses in yield and the monetary value of these losses has been estimated to the tune of rupees 29,000 million (Gupta and Raghuraman, 2003).

Rice is probably the world's most genetically diverse crop, which thrives well under varying ecosystems starting from rain fed upland (dry systems) to rainfed lowland (wet system) and the deep water situations.

More than 90 per cent of the world's rice is grown and consumed in Asia and this crop alone accounts for 35 to 60 per cent of the calories consumed by 2.7 billion Asians. In Asia, rice is planted in about 145 million hectares or in about 11 per cent of the world's cultivated land (Rajehja, 1995). The rice consuming population is increasing at an alarming rate of 100 million per year. By 2020, the rice requirement of Asia would exceed 760 million tonnes (Chandra, 2003).

In India, rice is cultivated in diverse ecologies spread over 44 million hectares with a production of around 90 million tonnes, representing the largest area and the second highest production in the world. This production almost tripled from 30.4 million tonnes (milled rice) in 1966 to a record production of 93.3 million tonnes, with an average productivity of 2.08 tonnes / ha in 2001-2002 (Rai, 2006). For ensuring adequate rice availability, a three pronged strategy of enhancing productivity, profitability and sustainability of rice yields will have to be promoted. This will call for new technological developments including high yielding hybrids, super rices and rice varieties with tolerances to a wide range of biotic and abiotic stresses. Rice remains the most important staple food on the planet since it feeds roughly half the population on a daily basis.

Rice losses in Asia due to pests may vary from 20 to 50 per cent of potential production (Cramer, 1987; Litsinger *et al.,* 1987; Norton and Way, 1990). The field losses in rice due to insect pests account at least 20 per cent in India (Pathak *et al.,* 1982). Damage during vegetative phase (50 per cent) contributed more to yield reduction than the reproductive (30 per cent) or ripening phase (20 per cent) (Gupta and Raghuraman, 2003). Thus, insect pests are one of the major constraints in rice production and it has been reported that protected rice crop yielded 28.8 per cent more than the unprotected. Therefore, insect pests are to be managed effectively to achieve stable higher yields in rice (Kalode and John, 1982). The need to increase rice production has brought about many changes in the technology of rice production. These changes, of course increased yield, but enhanced the susceptibility of the crop to various pests. Intensive usage of insecticides has led to serious ecological consequences resulting in many serious problems. The emergence of minor pests as major ones is one among the important problems.

The scenario of insect pest complex in rice has undergone a tremendous change during the past years. More than 100 insect pests attack rice crop, out of which 20 are major pests (Pathak and Dhaliwal, 1987). There has been a major change in the status of several insect pests in the recent past. Some insect pests of relatively minor importance have started appearing as major problem in rice.

The rice blue beetle, *Leptispa pygmaea* Baly (Coleoptera: Chrysomelidae) hitherto reported as a minor pest (Trehan, 1946; Patel and Patel, 1970; David and Kumaraswami, 1975; Dale, 1994) has recently assumed a serious status as an emerging problem by causing much concern to the rice cultivation in Kerala particularly in Palakkad, Kannur and Kasaragod districts. Severe outbreaks of this pest inflicting extensive damage in the early stages of crop growth have been reported in both Kharif and Rabi seasons. Since the blue beetle has so far been considered as a minor pest, no study on this pest has been carried out in Kerala. Very little information on this pest is available from elsewhere also. As the outbreak of the blue beetle is a recent emerging problem of considerable importance in rice, it is imperative to conduct a systematic detailed investigation on the pest in order to protect the crop by bringing about suitable effective management measures. In this context, an attempt has been made in the present study on "Bioecology, population dynamics and integrated management of rice blue beetle, *Leptispa pygmaea* Baly (Chrysomelidae: Coleoptera)" to generate information regarding its biology, biotic and abiotic factors regulating the population dynamics and different methods of management of the pest. This study will facilitate in formulating an integrated management strategy involving host plant resistance, cultural management, biological management and chemical management for the suppression of population of *L. pygmaea* in rice.

The objectives of the study envisaged are furnished below:

1. To work out the biology of *L.pygmaea* on short and medium duration varieties of rice.
2. To Study the morphology and morphometrics of different stages of rice blue beetle.
3. To Study the population dynamics of *L. pygmaea* as influenced by the abiotic factors in the field.
4. To determine the nature of attack and intensity of feeding by *L. pygmaea*.
5. To assess the extent of damage of blue beetle during different growth stages of rice.
6. To know the influence of different methods of cultivation on the incidence of *L. pygmaea*
7. To develop integrated pest mangement strategy comprising:

7.1. Host plant resistance

7.1.1 Screening of rice varieties / cultures

7.2. Cultural management

7.2.1 Study on alternative weed host plants.

7.2.2 Effect of plant spacing and soil incorporation of non-edible oil cakes.

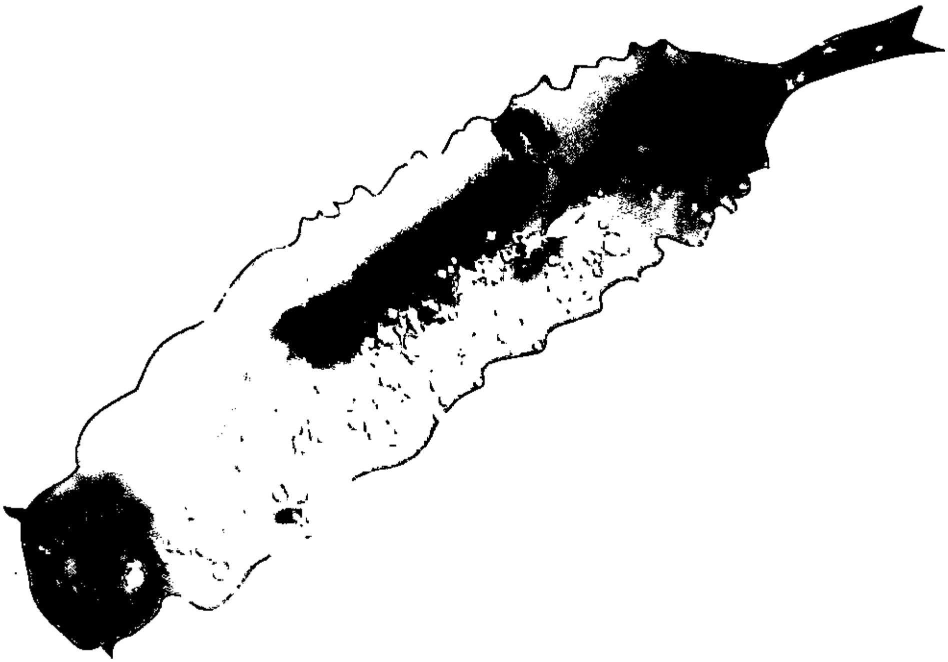
7.3. Biological management

7.3.1 Studying the natural enemies of *L. pygmaea* in the field.

7.4. Chemical management

7.4.1 Granular insecticide application in the nursery and its persistent toxicity

7.4.2 Application of foliar eco-friendly insecticides in the main field and their persistent toxicity.



Review of literature

2. REVIEW OF LITERATURE

A comprehensive review of literature on the investigation entitled 'Bioecology, population dynamics and integrated management of rice blue beetle, *Leptispa pygmaea* Baly (Chrysomelidae: Coleoptera)' is presented in this chapter. *L. pygmaea* has been reported earlier as a minor pest of rice and only recently it has been observed as an emerging problem in Kerala. Hence, not much information is available on *L. pygmaea*. Therefore, literature on other rice pests relevant to the present study is also included here.

Rice blue beetle, *L. pygmaea* has been reported as a pest of rice by Lefroy (1906) and Fletcher (1913). This insect was found near Coloumbo, resting on a small grass just above water (Maulik, 1919). Several other workers (Anonymous, 1931; Trehan, 1946; Usman, 1947; Kadam *et al.*, 1956; Gupta and Chandra, 1957; Ghose *et al.*, 1960; Patel and Patel, 1970; David and Kumaraswami, 1975; Dale, 1994) documented it as a minor pest of rice. However, *L. pygmaea* was considered as a potential pest causing extensive damage to rice varieties in South Gujarat (Patel and Shah, 1985).

The first outbreak of *L. pygmaea* was noticed in Konkan region of Maharashtra (Dalvi *et al.*, 1985) followed by Kanyakumari district of Tamil Nadu in South India (Swamiappan *et al.*, 1990). Dale (1994) observed blue beetle as a minor pest which assumed serious proportions in poorly drained rice fields of Thane and Ratnagiri districts in Central India. In Kerala, an outbreak of *L. pygmaea* was reported to cause much concern to rice cultivation in both Kharif and Rabi seasons (Nadarajan, 1996).

2.1 BIOLOGY OF L. *pygmaea*

2.1.1 Egg

The female rice blue beetle laid smooth pale yellow or pale green elliptical eggs in batches of 2, 3 or 4 in a straight line mostly on lower surface of the leaf with

90.96-98.81 per cent hatching. The mean incubation period was 3.97 to 7.16 days (Patel and Patel, 1970; Dalvi *et al.*, 1985; Patel and Shah, 1985)

2.1.2 Larva

According to Patel and Shah (1985), larva of *L. pygmaea* was a soft bodied campodeiform grub, dorso-ventrally compressed and dirty white having a sclerotized tubular process at the abdominal tip. It had three larval instars. The first instar was completely white except head, which was brownish in colour later changed to dirty white after taking food with an average period of 3.04 days. Second and third instars were dirty white in colour with a duration of 3.33 and 4.97 days respectively. The total larval period was 13.77 days in Kharif season as against 13.22 days in off-season. The larvae arranged themselves in a longitudinal line on the leaf surface, with a maximum of 10-12 and a mean of 7 per leaf. (Dalvi *et al.*, 1985; Patel and Shah, 1985; Swamiappan *et al.*, 1990)

2.1.3 Prepupa

The larva of blue beetle did not spin a cocoon before pupation. Just before completion of prepupal stage, a drop of sticky anal fluid oozed out which helped in sticking the caudal ventrad of the prepupa with the leaf and the pupa was duly formed in prepupal body and came out by splitting epicranial suture of the prepupa. The prepupal skin was completely removed by peristaltic movement within 23 to 27 minutes. The exuviae thus removed were retained folded on the leaf (Patel and Shah, 1985).

2.1.4 Pupa

Freshly formed pupa of *L. pygmaea* was milky white in colour, which changed subsequently to brown colour within a few minutes. The pupa was exarate, brown coloured and attached itself to leaf surface by its posterior end. About three pale brown pupae were seen on each leaf. Appendages *viz.*, head, antennae, mouthparts, wings and legs of developing adult could be seen through the pupal skin. Pupal stage lasted for 4-5 days. The total pupal period was 4.52 days during crop season as against

4.39 days in off-season. A large number of white pupal skin were seen on leaf surfaces after beetle emergence (Patel and Patel 1970; Dalvi *et al.*, 1985; Patel and Shah, 1985; Swamiappan *et al.*, 1990).

2.1.5 Adult

The adult rice blue beetle was narrow, elongate and cylindrical with a slight constriction in the centre. The beetle was deep metallic blue or dark greenish blue or dark bluish green with fine striations or pittings on the elytra or ten regular more or less parallel rows of punctures. Elytra were finely striated at the extreme apex and also slightly reflexed to the dorsal side. The under side of the body was entirely black with minute whitish hairs on it (Kadam *et al.*, 1956; Dalvi *et al.*, 1985; Patel and Shah, 1985; Swamiappan *et al.*, 1990).

Dalvi *et al.* (1985) observed sexual dimorphism in *L. pygmaea.* The male and female beetles were differentiated by the body size and type of antenna. Females were slightly bigger than males.. In female beetle, the antenna was serrate with six uniform sized basal segments and four larger terminal segments while in males, the first basal segment was larger (truncate) than the remaining segments and with a remarkable serrate nature. Six segments in the middle were similar to each other and more or less of the same size. The terminal four segments were similar to each other and larger than the middle six segments (Patel and Shah, 1985). The number of female beetles in the field was less compared to males, with a sex ratio of 1:1.55 (Patel and Shah, 1985).

2.1.6 Adult behaviour

According to Swamiappan *et al.* (1990), the adult beetles of *L. pygmaea* were very weak fliers. They mated immediately after emergence from pupae. Adult being polygamous mated throughout the day. Active mating was observed during morning and evening hours. Mating was also observed at night when adults were exposed to artificial light. Copulation lasted for 8-14 minutes. Average periods for pre-oviposition, oviposition and post-oviposition were 4.91, 13.81 and 0.45 days respectively (Dalvi *et al.*, 1985; Patel and Shah, 1985).

2.1.7 Fecundity

Dalvi *et al.* (1985) observed that in Maharastra, *L. pygmaea* laid 38-66 eggs while the fecundity ranged from 43.00 -58.78 eggs in South Gujarat (Patel and Shah, 1985). August and September months were more congenial for rapid build up of the pest and number of eggs was more during the period (70-120 eggs / 5 hills) than the rest of the year (0-55 eggs / 5 hills). No egg laying was observed from the second week of October in the field of South Gujarat (Patel and Shah, 1985).

2.1.8 Adult longevity

No marked difference was observed in the longevity of male and female beetles of *L. pygmaea* (Dalvi *et al.*, 1985) in Maharashtra. Adults remained alive for 18-35 days. But Patel and Shah (1985) reported that the adults lived longer life in March – April when maximum temperature fluctuated above 30°C. During this period the male and female lived for an average of 19.54 and 19.18 days respectively. During July – September when maximum temperature fluctuated below 30°C the male and the female lived on an average of 15.07 and 16.61 days respectively. During off season, adults survived for 55-70 days in winter months as against 18-35 days during August to October. Its activity retarded remarkably in December and January when the beetles congregated around leaf base. The total life cycle of *L. pygmaea* was completed in 22-24 days in Dapoli, Maharashtra (Dalvi *et al.*, 1985).

2.2 MORPHOMETRICS AND ANATOMY OF REPRODUCTIVE SYSTEM

Dalvi *et al.* (1985) found that the length of the egg of blue beetle varied from 0.86 to 1.14 mm with an average length of 1.00 mm and width from 0.29 to 0.43 mm with an average of 0.38 mm.

The first instar grub measured 1.93 to 2.14 mm in length with an average of 2.07 mm. The breadth of the first instar was 0.43 mm and head width was 0.36 mm. The second instar grub measured from 2.14 to 3.92 mm in length with an average of 2.96 mm and width from 0.64 to 0.71 mm with an average of 0.70 mm. The head measured a width of 0.57 mm. The measurements of third instar grub ranged from 3.75 to 5.35 mm in length with an average of 4.19 mm and 0.93 to 1.07 mm in width with an average of 1.03 mm. Full grown grub was found to be 4.65 mm long and 1.00 mm broad.

The length of prepupa ranged from 4.64 to 5.35 mm with an average of 5.20 mm. The pupa measured 4.00 to 5.00 mm in length with an average of 4.45 mm and width ranged from 1.21 to 1.50 mm with an average of 1.39 mm.

The size of adult female beetle ranged from 4.14 to 4.93 mm in length with an average of 4.47 mm and 1.29 to 1.50 mm in width with an average of 1.37 mm. The male measured 3.50 to 4.21 mm in length with an average of 3.96 mm and 1.14 to 1.36 mm in width with an average of 1.25 mm (Patel and Shah, 1985).

No work has been reported on the anatomy of the reproductive system of *L. pygmaea*. A study conducted on the reproductive system of rice hispa, *Dicladispa armigera* Oliver, another rice pest of the same family Chrysomelidae, indicated that the male reproductive system consisted of bilobed testis, exceedingly long ejaculatory duct and prominent strong aedeagus and female reproductive organs comprised of ovaries with nine filamentous, segmented ovarioles and mango shaped spermatheca equipped with coil-like duct and a spatula like small ovipositor (Deka and Hazarika, 1995).

2.3 NATURE OF DAMAGE

Lefroy (1906) observed that the adults of *L. pygmaea* were feeding on rice leaves either by making holes or completely stripping the plant. Fletcher (1913) reported the beetle to be passing its immature stages on the leaf surface and not as a leaf miner. Maulik (1919) observed that the larvae lived inside the tissues of leaves during the whole period of their development. According to Dalvi *et al.* (1985), both larvae and adult fed on the upper surface by scraping chlorophyll matter of rice leaves by making longitudinal white streaks on them. The streaks made by the larvae were shorter and narrower, as compared to those done by the adults. In the case of severe damage, the rice leaves were folded longitudinally and dried. As a result plants became very weak and dried up. From a distance, the rice field showed severe dried appearance. Symptoms resembled those caused by leaf folder with a difference that there was no webbing and tying of leaf margins. In certain pockets, when the young crop was attacked, it resulted in stunting and severe drying symptoms. Incidence was found to be higher in shaded areas (Patel and Shah, 1985; Swamiappan *et al.,* 1990).

2.4 INFLUENCE OF METHODS OF CULTIVATION

Eiteman and Powar (1997) reported that pest load of green leafhopper per plant was more in transplanted rice than in broadcast rice. Similar studies showed that population of *Nephotettix cincticeps* Uhler and *Cnaphalocrocis medinalis* Guenee were more in machine transplanted rice than in direct seeded rice while *Nilaparvata lugens* Stal. and *Laodelphax striatellus* Fallen were abundant in direct seeded rice than in transplanted rice (Seunchan *et al.,* 1997). Rice root weevils, plant hoppers, rice thrips and aphids were serious in transplanted rice (Liansheng *et al.,* 1999).

2.5 ALTERNATIVE HOSTS

Host plants on which insect pests complete the life cycle in the absence of primary hosts are termed as alternative hosts. Weeds are potent sources of pest infestations. Therefore, the removal of alternative host plants including weeds and grasses has been suggested for the control of a number of insect pests in rice *viz.,* leaf hoppers (*Nephotettix* sp.), leaffolder (*C. medinalis*), gall midge (*Orseolia oryzae* Wood-Mason), hispa (*D. armigera*) etc. (Panda *et al.,* 1983). The blue beetle was reported to feed mainly on plants belonging to family Poaceae (previously known as graminae) including vetiver, volunteer rice plants, ratoon rice and even on sugarcane planted nearby infested area. *Arundinella metzii, Ischaemum travancorence, Paspalum scrobiculatum, Pennisetum purpureotyphoides, Arundinella* sp., *Panicum maximum, Dichanthium aristatum* and *Brachiaria mutica* were the other alternate hosts reported. Although the adult beetles were observed feeding on these host plants during the off-season, no egg laying was observed on such plants. The beetle overwintered on the hosts during off-season. The adults survived on these host plants for 55-70 days during the off-season (Khanvilakar *et al.,* 1983; Dalvi *et al.,* 1985). *Paspalum distichum* was observed as an alternative host for rice hispa (Dhaliwal, 1979) while *P. aristatum* was reported to be an alternative host of *O. oryzae* (Nair, 1978). *P.repens* was observed as an alternative weed host for rice case worm, *Nympula depunctalis* Guen (Pillai, 1977) *Paspalum longifolium* served as an alternative host of brown planthopper (Thomas, 1977).

2.6 POPULATION DYNAMICS

Climatic factors have dominant influence on the survival, development and reproductive capacity of insect pests and were considered to be the most important cause of population fluctuations (Elton, 1927). The seasonal incidence of rice blue beetle in Maharashtra was studied by Dalvi *et al.* (1985). They indicated that blue beetle incidence started during second fortnight of July in the fields. The months of August and September were found to be more congenial for the rapid build up of the pest, since the number of eggs laid during this period was more (70 -120 eggs / 5 hills). No egg laying was observed from the second week of October in the field. Thus, the pest was carried over through off-season as adult and survived for 55 – 70 days during winter months as against 18 – 35 days during August to October. Its activity retarded remarkably in December and January when the beetles congregated around the leaf base. Egg laying and further development resumed in the last week of January and first week of February. The pest activity was low from mid March to mid April. The pest activity again restarted from the second fortnight of April. No other work on the population dynamics of *L. pygmaea* has been reported.

The field incidence of rice hispa, *D. armigera* increased due to negligible rains with ambient temperature and high relative humidity in Palampur, Himachal Pradesh (Thakur *et al.,* 1979). High incidence of rice hispa was observed during excessive wet season from later part of June to August and followed by lesser rainfall in September with relatively low temperature (25°C to 28°C) during growth period of rice in

Jabalpur (Rawat and Singh, 1980). Sunny weather interrupted by quick showers, no summer ploughing and lack of insecticide application increased hispa incidence in Burdwan, West Bengal (Banerjee and Nath, 1986). Damage by blue beetle and hispa were found to be high during the early stage of rice crop (2.2-3.6 beetles per hill) (Kumar, 2003).

2.7 SCREENING OF RICE VARIETIES / LINES

The most successful strategy during the last two decades to manage rice insect pests has been to grow resistant varieties and need based application of insecticides. Resistant varieties are being developed using different donors which could be identified only by screening the available varieties / lines for resistance against the pest (Zaman and Singh, 2000). Not much work has been reported on varietal screening for resistance to *L. pygmaea*.

Shah and Patel (1980) screened 107 rice cultivars for resistance against blue beetle at Navsari, Gujarat. Only 17 cultivars were found to be moderately resistant to the pest and none of the cultivars was completely resistant.

Screening trials conducted in Kerala showed that varieties Ptb.4, Ptb.10, Ptb.28, Ptb.36, H4 and GEB 24 were resistant to blue beetle. Other varieties such as Ptb.2, Ptb.5, Ptb.8, Ptb.9, Ptb.15, Ptb.18, Ptb.20, Ptb.21, Ptb.22, Ptb.23, Ptb.26, Ptb.29, Ptb.30, Ptb.31, Ptb.32, Ptb.33, Ptb.35, Ptb.38, Ptb.40, Ptb.42, Ptb.53 and KAU cultures such as 25331, 25333, 25335, 25336, 25337, 25315, 25316, IR 20 and Co-25 were moderately resistant (Nadarajan and Skaria, 1993). Elsy *et al.* (1995) observed that the Kunjukunju variety was less susceptible to the pest.

The reaction of 334 rice cultivars to hispa was assessed in Punjab and none of the varieties was completely free from attack of *D. armigera* (Dhaliwal, 1980). Among the 64 diverse cultivars tested, OR165-94-1 and KAU 1945 were reported to be moderately resistant to rice hispa at Kanke, Ranchi (Chand and Tomar, 1984). Tests carried out in Bihar to determine the resistance of 10 elite lines to hispa revealed that Type 3, a scented variety from Uttar Pradesh was least preferred by *D.armigera* (Haque *et al.*, 1987).

2.8 PLANT SPACING AND PEST INCIDENCE

Proper plant spacing is one of the important factors to obtain a good yield in rice. Agronomically, the spacing should be wider in wet season than in dry, wider in high tillering than for low tillering, wider for late varieties than for early varieties and wider for normal seedlings than for aged seedlings. Plant spacing influences the incidence of rice pests (Pandey, 2000). Dhaliwal *et al.* (1979) noticed that the widely spaced rice plants were severely damaged by *D. armigera* and there were 9.2, 14.1 and 21.2 hispa damaged leaves per 10 hills in 10x10 cm, 20x15 cm and 30x30 cm spacing respectively. The beetle preferred widely spaced plants probably because it laid eggs on leaf tips, which were better exposed in widely spaced plants. Singh and Dhaliwal (1994) also reported lower incidence of rice hispa, green leafhopper and whorl maggot (*Hydrellia philippina* Ferino) in closer spaced rice seedlings. On the contrary, build up of other rice pests like *N. lugens*, *Sogatella furcifera* (Horvath), *C.medinalis*, *Nephotettix virescens* (Distant) and *Nephotettix nigropictus* (Stal.) was higher in closer spacing of 10x10 cm compared to wider spacing of 30x30 cm (Sain *et al.*, 2001).

2.9 NON-EDIBLE CAKES AND PEST INFESTATION

Krishnaiah and Kalode (1984) reported that the application of non-edible oil cakes in rice showed no acute toxicity to rice BPH and had little effect on toxicity of carbofuran when oil cakes were applied at the recommended rate of 0.1 t / ha. Neem cake did not have a slow toxic effect on the nymphs of *N. lugens*. None of the oil cakes was effective against gall midge in the field. David (1986) observed that neem cake coated urea significantly reduced the population of whorl maggot and leaffolder, but had no significant effect on the stem borer (*Chilo suppressalis* Walker). The green leafhopper population was reduced following the treatment of neem cake coated urea. Rice seedlings grown in soil applied with 25-250 kg / ha of mahua cake (*Madhuca latifolia*) and neem cake (*Azadirachta indica*) were least infected by rice tungro virus. At highest rate of 250 kg / ha, infection was only 20 and 23 per cent respectively as against 70 per cent in control (Gurubasavaraj *et al.*, 1988). Application of neem cake @ 150 kg / ha plus neem seed kernel extract @ 5 per cent reduced the leaf damage caused by hispa by 12.29 per cent (Baitha *et al.*, 1993). Application of neem cake or Hind-O-meal as top dressing significantly reduced the population of gall midge (Samalo *et al.*, 1993). Rezaul-Karim and Hoque (1999) observed that incorporation of neem cake in the seed bed nursery reduced the number of rice hispa and green leaf hopper significantly.

2.10 NATURAL ENEMIES

The importance of natural enemies in regulating the major insect pests of rice has been well documented. About 40 to 60 per cent of rice pests were controlled by their natural enemies (Swaminathan and Siddiq, 1991). About 85 natural enemies against yellow stem borer, 126 against planthoppers, 104 against leafhoppers, 54 against leaffolder, 18 against gall midge, 50 against army worm and 5 against hispa have been reported (Pasalu, 2000). The larvae of *L. pygmaea* were found to be parasitized by *Chrysonotomyia* sp. (Eulophidae) and *Eupteromalus* sp. (Pteromalidae) (Patel and Shah, 1985). Grubs and pupae of hispa were reported to be parasitized by *Microbracon* sp. and *Tetrastichus* sp. (Krishnaiah *et al.*, 1987).

2.10.1 Entomopathogenic Nematodes *(EPN)*

EPN as a biopesticide has received worldwide attention as a safer alternative for the use of insecticides in different crops including rice.

In India, some of the exotic strains of EPN were tested and found to be effective against some of the important insect pests under laboratory conditions. But, in the field, the results were inconsistent due to their poor adaptability under local agro-climatic conditions. Therefore, search for indigenous strains was felt necessary for making biocontrol efforts more effective. Two species of EPN (*Steinernema thermophilum* Ganguly & Singh and *Heterorhabditis indica* Poinar) have been described and seven other species of *Steinernema* have been recorded from this country (Prasad *et al.*, 2006).

Larvae of the blue beetle were observed to be parasitized by nematodes belonging to the family Mermithidae having the characters typical of genus *Hexamermis* (Patel and Shah, 1988).

2.10.2 White muscardine fungus, *Beauveria bassiana* (Bals.) Vuill.

Naturally occurring insect pathogens are important biotic agents, which aid in regulating the abundance of many insect pests. The utilization of pathogenic microorganisms holds a high possibility for the suppression of rice insect pests (Chatterjee *et al.*, 1983).

Rice crop provides a favourable environment for the exploitation of fungi as mycoinsecticides. *B. bassiana* occurs naturally and has been utilized for the control of many insect pests of rice. It was recorded as the most versatile fungus capable of attacking various stages of the host at different stages (Ferron, 1978; Fuxa, 1987; Agarwal, 1990).

The bioefficacy of *B.bassiana* against rice hispa has been reported by several workers (Hazarika and Puzari, 1990; Puzari and Hazarika, 1991, 1992; Puzari *et al.*, 1994). The fungus was found pathogenic to all stages of the beetle *viz.*, egg, larvae, pupae and adults. The infection of egg and adults was 16.95 -45.15 per cent and 1.67 – 40.63 per cent respectively and higher infection was noted in egg than on any other stages of *D. armigera* (Puzari and Hazarika, 1992).

Hazarika and Puzari (1995) tested the pathogenicity of *B.bassiana* in Assam and it caused more than 90 per cent mortality of *D. armigera*. From the adults of hispa they isolated six entomogenous fungi *viz.*, *B.bassiana*, *Aspergillus flavus* Link and *Fusarium heterosporum* Nees which were pathogenic, while *Penicillium cyclopium* Westling, *Geotrichum* sp. and *Mucor* sp. were opportunistic fungi. These opportunistic fungi could be isolated only from the insects initially parasitized or weakened by primary mycoparasitic invaders (Machrowicz *et al.*, 1990). *B. bassiana* was highly pathogenic to *D. armigera*, the LC 50 value being 90.16 conidia / ml and it caused death potentiality of 91.83 per cent when the conidial density was maintained at 10^7 conidia / ml of water (Mazumder *et al.*, 1995). Leite *et al.* (1995) found that fipronil spray in combination with *B. bassiana* effectively controlled rice water weevil, *Oryzophagus oryzae*. Hazarika and Puzari (1997) while assessing the field efficacy of *B. bassiana*, found that *B. bassiana* (10 million spores / ml) was superior to 1 per cent neem seed oil, but at par with monocrotophos @ 0.072 per cent in controlling rice hispa leading to an increase in yield.

Hazarika *et al.* (1998) in a survey conducted in rice ecosystem in Assam revealed the virulence of *B. bassiana* on eggs, pupae and adults of *D. armigera*. Infection was more prevalent in the egg stage and fluctuated during different months. Susceptibility of the insect to fungal attack was influenced by host plant.

2.11 CHEMICAL MANAGEMENT

2.11.1 Neem based insecticides

Neem (*Azadirachta indica* A.Juss) has emerged as the strong alternative to synthetic insecticides and as an important component in IPM programmes. All the parts of the tree possess insecticidal activity. Neem has diverse biological effects on insects. No synthetic chemical or plant origin material is known to occur which has such a diverse biological effect on insects as neem. Among the different plants evaluated, neem has shown promise against a number of insect pests of rice (Singh, 2000). No information on the effect of neem products against *L. pygmaea* is available. Hence, works on other rice pests are reviewed. Neem oil and aqueous extract of seed kernel are the most widely used.

Spraying with neem products *viz.*, neem seed kernel extract (2 %), neem cake extract (5 %) and neem leaf extract (5 %) effectively controlled green leafhopper, gall midge and grasshoppers but was ineffective against stem borer (*Scirpophaga incertulas* Walker) (Saroja, 1986). Saxena and Greenhalgh (1987) observed that neem seed oil acted as an antifeedant against rice pests *viz., C. medinalis, Mythimna seperata* (Walker), *Spodoptera mauritia* (Boisd.), *Nephotettix lugens* and *Nephotettix virescens.* It was also found that neem oil application decreased transmission of rice ragged stunt and rice tungo virus. Neem @ 2 per cent and their oils @ 10 per cent effectively reduced green leafhopper and its transmission of rice tungro virus (Gurubasavaraj *et al.,* 1988). But David (1986) reported that foliar application of 2 per cent neem seed extract did not control major rice pests. Neem seed bitters @ 5000 ppm acted as an ovipositional deterrent against both *N. lugens* and *N. virescens.* Neem seed bitters @ 2500 ppm completely affected the development of both these pests (Kareem *et al.,* 1989).

The efficiency of neem oil spray was found to be poor against rice hispa (Krishnaiah and Kalode, 1991) but its concentration of 12 per cent or greater acted as an ovipositional deterrent to BPH (*N. lugens*) while its spray @ 1 per cent affected the growth of first instar nymphs of *N. virescens* and a concentration of 25 per cent a.i. or more adversely affected egg production. Baitha *et al.,* (1993) noticed that application of neem based products *viz.,* neem cake (150 kg / ha) plus neem seed kernel extract (5 per cent) and neem oil (3 per cent) reduced the leaf damage caused by hispa by 14.11, 14.57 and 14.84 per cent respectively. Spray of 3 per cent neem oil at 10, 25, 40 and 55 days after transplanting significantly reduced the population of gall midge (Samalo *et al.,* 1993). Neem seed oil (NSO) acted as a potential antifeedant against adults of rice hispa and rice leaves treated with 6.46 per cent NSO reduced the daily adult consumption by 50 per cent (Deka and Hazarika, 1997). The efficacy of neem oil at a lower concentration of 1 per cent against rice hispa was also reported (Dutta *et al.,* 1997).

Application of neem based insecticides *viz.,* Nimbecidine (300 ppm azadirachtin) at 4.0 and 2.0 per centand Rakshak (1500 ppm azadirachtin) at 1.0 per cent recorded lower rice leaf damage in no-choice test with *D. armigera,* while in multiple choice test Nimbecidine at 4.0 and 2.0 per cent, Neem azal (10,000 ppm) at 1 per cent and Rakshak showed considerable antifeedant effects (Lingaiah *et al.,* 1999).

Spray of neem oil @ 3 per cent reduced green leafhopper and neem seed kernel extract @ 5 per cent reduced the number of grasshoppers with no effect on rice bug and spiders in rice (Rezaul-karim and Hoque, 1999). Foliar sprays of azadirachtin resulted in lower population of green leafhopper in rice (Patel *et al.*, 2004). But neem derivatives failed to give adequate protection against rice stem borer, leaffolder and grasshopper in rice (Samalo *et al.*, 1993).

2.11.2 Granular insecticides

The effectiveness of granular insecticides for the management of pests in rice has been well documented by several workers. Granular insecticides are less deleterious to natural enemies. No work on granular insecticides against *L. pygmaea* has been reported and hence, information available on other rice pests is included below.

Cartap hydrochloride: (S,S-[2-(dimethylamino)- trimethylene] –bis (thiocarbamate)

Cartap hydrochloride, a neristoxin based insecticide, is found effective for the control of pests in rice and vegetables. It is moderately toxic to honey bees and is non-persistent. Its acute LD_{50} is 325 mg/kg for male mice.

Kulshreshtha *et al.* (1971) observed that cartap (Padan) was most effective against borers in rice. Cartap applied @ 1.25 kg a.i. /ha was effective against the rice hispa, but slow acting from 10 to 30 days after application (Zafar, 1984). The application of cartap as a spray @ 500 litres / ha at 20, 40 and 60 days after transplanting of rice was found to reduce the incidence of white stemborer (*S. innotata*). It also reduced the incidence of yellow stemborer, leaffolder and whorl maggot in rice (Kandaswamy and Ravikumar, 1986). Cartap @ 1.5 kg a.i. / ha was found most effective against major pests of rice like green leafhopper, brown planthopper and gall midge (Uthamaswamy and Karuppuchamy, 1988). Broadcasting of cartap @ 1.0 kg a.i. /ha in standing water (2.5 to 5.0 cm) only once at 20 days after transplanting significantly reduced live hispa adults / 20 hills by 7.2 – 7.7 per cent (Sain *et al.*, 1994).

Cartap was reported to be effective @ 1.5 kg a.i./ha against rice stem borer and rice hispa, but inferior to carbofuran in its efficacy (Kaul and Bhagat, 1997). Application of cartap @ 1 kg a.i. / ha resulted in low population of rice white backed planthopper and brown planthopper at 35 days after application (Lal and Lal, 2000). Cartap @ 22-23 kg a.i./ ha was effective against rice stemborer with increased grain yield (Salioqi *et al.*, 2002). Afzal *et al.* (2003) reported that the dead hearts and white heads caused by *S.incertulas* and *S.innotata* were lowest in cartap treated rice plots but inferior to carbofuran. The green leafhopper population was also low in cartap treated plots (Patel *et al.*, 2004).

Carbosulfan: (2,2.dihydro, 2,2 dimethyl-7-benzo furanyl (dibutylamino) thio methyl carbamate).

Carbosulfan is a systemic broad spectrum carbamate insecticide. Its acute oral LD_{50} value for rats is 87 mg/kg.

Carbosulfan as a spray was found effective against rice stem borer and leaffolder (Rao *et al.*, 1982; Razvi *et al.*, 1983). Carbosulfan @ 0.24 per cent proved effective against *N. lugens* and *N. virescens* giving 79.34 and 87.25 per cent control for 30 days after treatment and the plots treated with carbosulfan also maintained a low population of rice bug at a significantly low level up to 23 days after application. (Pillai *et al.*, 1983). Application of carbosulfan was found to reduce the termite damage in upland rice ecosystem (Ferreira *et al.*, 1996). Carbosulfan applied as root zone placement reduced rice stem borer, gall midge, whorl maggot and case worm (*Paraponyx stagnalis* Zeller) but inferior to carbofuran in its efficacy (Krishnaiah *et al.*, 1988). At 1000 g a.i./ha carbosulfan was found effective against *S.incertulas* on rice giving a higher yield in Kerala (Karthikeyan and Purushothaman, 2000). Nursery application of carbosulfan granules reduced the incidence of gall midge (*O.oryzae*) (Sonatakke, 1993; Sonatakke and Dash, 2000). The dead hearts and white heads caused by *S.incertulas* and *S.innotata* were lowest in carbosulfan treated plots but inferior to carbofuran (Afzal *et al.*, 2003). Carbosulfan @ 1000 g a.i./ha was at par with carbofuran against insect pest complex of rice (Krishnaiah *et al.*, 2003).

Fipronil : (5 amino-1-[2,6 dichloro –4- (trifluoromethyl) phenyl]-4-[(1 R, S-(trifluoromethyl) sulfinyl]-1H- pyrazol-3-carbonitrile).

Fipronil is a broad spectrum pyrazole insecticide. Its acute oral LD_{50} for rats is 97 mg/kg.

Leite *et al.* (1995) found that fipronil spray in combination with *B.bassiana* or mineral oil effectively controlled rice water weevil, *Oryzophagus oryzae* (Costa lima). Fipronil spray @ 600 ml / ha was found effective against white backed planthopper, striped borer, *Chilo suppressalis* (Walker), leaffolder and rice skipper (*Pelopidas mathias* Fabricius) (Yongbao *et al.,* 2001). Application of fipronil as spray at 50 days after transplanting reduced the incidence of stemborer and leaffolder in rice (Sonatakke and Dash, 2000). Fipronil granules were also found effective against rice stemborer but persistent toxicity of fipronil was found lowest in rice (PT: 1126) (Lakshmi *et al.*, 2001). Fipronil 5 per cent SC @ 0.30 and 0.75 litre / m^2 was effective in controlling WBPH, leaffolder and brown planthopper (Huifang *et al.,* 2001). Fipronil spray 197.6 ml / ha was effective against rice stem borer with increased grain yield (Salioqi *et al.,* 2002), but inferior to cartap.

Wenda *et al.* (2002) reported that the application of fipronil 5 per cent as spray @ 30 g a.i. / ha reduced the incidence of rice stemborer (*S. incertulas)* and rice leaf folder. The efficacy of fipronil spray @ 500 ml /ha against rice leaffolder was also reported by Panda and Rath (2004). Fipronil granular application @ 0.075 kg a.i. / ha in rice gave maximum protection against gall midge, stemborer and mixed population of both species of planthoppers with increased grain yield (Rath, 2001; Dash and Mukherjee, 2003).

Jena (2004) found that root dip of rice seedlings with fipronil @ 0.01 per cent effectively controlled rice yellow stemborer. Fipronil application @ 25 kg / ha was effective in controlling rice gall midge, but inferior to carbofuran (Srinivas and Madhumathi, 2004).

Phosphamidon: (O, O -dimethyl-O-(2-chloro-diethyl carbomoyl-1-methyl-vinyl phosphate)

Phosphamidon is a systemic organophosphorus insecticide having low contact action. It is very much effective for sucking pests. Its acute oral LD_{50} for rats is 17-30 mg/kg.

Mookerjee and Chatterjee (1973) found that phosphamidon was effective against major pests of paddy. Kabir and Mia (1971; 1976) noticed that phosphamidon as spray @ 0.05 – 0.10 % or 1.12 kg a.i. / ha offered protection against hispa up to one week and not effective beyond 10 days after application in the soil. Application of phosphamidon as spray @ 0.04 % at 450 l / ha reduced the population of grubs, pupae and adults of *D. armigera* (Singh and Rawat, 1979; 1980). Similar studies on the efficacy of phosphamidon were also reported by Budhraja *et al.* (1979; 1980). Krishnaiah and Kalode (1983) found that phosphamidon was effective against yellow stem borer, leaf folder and whorl maggot. Zafar (1984) observed that phosphamidon @ 0.688 kg a.i./ha was effective against rice hispa. According to Biswas and Mandal (1992), phosphamidon @ 0.05 per cent effectively controlled larvae and adults of rice hispa upto 15 days and also showed reduction in the number of damaged leaves. Phosphamidon @ 0.128 per cent was found effective against larva of rice hispa (Dutta *et al.*, 1997).

Carbofuran: (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methyl carbamate).

Carbofuran is a systemic broad spectrum and long residual carbamate insecticide, miticide and nematicide. Its acute oral LD_{50} value for rats is 8-14 mg/kg.

Kulshreshtha *et al.* (1971) observed that carbofuran was most effective against borers and *N. virescens* in rice for atleast 21 days. Carbofuran application in root zone @ 2.06 kg a.i. / ha controlled major rice insect pests and rice dwarf virus disease (Choi, 1976). Shukla *et al.* (1979) observed that application of carbofuran @ 1 kg a.i. /ha reduced the gall midge incidence by 36.7 per cent with increased yield (1.8 t/ha).

Carbofuran applied @ 1.5 kg a.i. / ha applied at 38 days after transplanting controlled hispa with increased grain yield from 0.4 t / ha to 2.3 t / ha (Budhraja *et al.,* 1979; 1980).

Among 12 granular insecticides tested, carbofuran @ 1.0 kg a.i. / ha applied as broadcast in standing water at 42 and 63 days after rice transplanting as well as by applying them near the root zone (a week after transplanting), recorded 97 per cent mortality within 5 hours after treatment (Krishnaiah and Kalode, (1983); Krishnaiah *et al.* (1987). Carbofuran applied @ 1.125 kg a.i./ha was effective against rice hispa, but slow acting from 10 to 30 days after application (Zafar, 1984). Application of carbofuran in two doses *viz.,* 0.75 and 1.0 kg a.i./ha caused 77.29 and 86.26 per cent mortality of hispa grubs and mortality increased to 90 and 98 per cent on seventh day in both doses, probably due to translocation of more quantities of toxicant into the plant tissues (Lakshminarayana *et al.,*1985). Carbofuran application reduced the incidence of yellow stemborer, leaffolder and whorl maggot in rice (Kandaswamy and Ravikumar, 1986).

Dhaliwal and Singh (1988) noticed that chlorpyriphos @ 0.02 per cent root dip coupled with broadcast of carbofuran @ 0.75 kg a.i./ha or at 0.70 kg a.i. /ha applied in the root zone four days after transplanting reduced the leaf damage due to rice hispa. The application of carbofuran @ 1.0 kg a.i./ ha was most effective for major pests like *N. virescens, N. lugens* and *O. oryzae* (Uthamaswamy and Karuppuchamy, 1988). Root zone placement of carbofuran reduced rice stem borer, gall midge, whorl maggot and case worm (Krishnaiah *et al.,* 1988). Application of carbofuran @ 1.0 kg a.i./ha as broadcast in standing water (2.5 to 5.0 cm) only once at 20 DAT significantly reduced live adults / 20 hills by 3 per cent (Sain *et al.,* 1994). The effectiveness of carbofuran @ 1 kg a.i. /ha against rice stem borer and hispa was reported by several workers (Kaul and Bhagat, 1997; Tripathy *et al.,* 1999; Rath, 2001; Vardhani and Rao, 2002; Afzal *et al.,* 2003).

Incorporation of neem cake and carbofuran in seed bed nursery reduced the numbers of rice hispa and green leafhopper significantly (Rezaul-Karim and Hoque, 1999). Application of carbofuran @ 1 kg a.i. /ha resulted in low population of rice white backed planthopper and brown planthopper at 35 days after application (Lal and Lal, 2000). Nursery application of carbofuran granules reduced the incidence of gall midge (Sonatakke and Dash, 2000). The efficacy of carbofuran application @ 25 kg a.i. /ha against rice leaf hopper and gall midge was also reported (Patel *et al.*, 2004; Srinivas and Madhumathi, 2004).

2.11.3 Synthetic foliar insecticides

Only few insecticides have been reported to be effective in managing the blue beetle population. Thontadarya and Devaiah (1975) reported that aerial spraying with fenthion and fenitrothion controlled blue beetle (100 per cent) within 24 hours. Foliar insecticides *viz.*, orthene (0.05%), dimethoate (0.04%), lannate (0.05%), monocrotophos (0.05%), BHC (0.2%), carbaryl (0.01%), permethrin (0.01%), phosalone (0.05%) and endosulfan (0.05%) were found effective in controlling blue beetle (Dalvi *et al.*, 1985). According to Nair (1978), rice blue beetle could be controlled by spraying contact insecticides. The foliar insecticides included in this review were tested for the first time against *L. pygmaea*.

Chlorpyriphos: (0, 0-diethyl 0-(3, 5, 6-trichloro-2-pyridyl) phosphorothioate)

Chlorpyriphos is a non-systemic contact organophosphorus insecticide. It is an effective insecticide against household insects and crop pests. Its acute oral LD_{50} for rats is 135-163 mg/kg.

Chlorpyriphos showed better contact toxicity under laboratory conditions against rice hispa (Dhaliwal *et al.*, 1977). Chlorpyriphos alone or mixed with dichlorvos, thiodicarb were found effective against rice thrips (*Baliothrips biformis* Bagnell). It was also found effective against *C medinalis* (Rao *et al.*, 1982). Among 21 spray chemicals tested by Krishnaiah and Kalode (1983) against rice hispa, chlorpyriphos showed high degree of knock down effect at concentrations of 0.025 and 0.05 per cent. The chemical completely suppressed the emergence of adults from the pupae. The effectiveness of chlorpyriphos against yellow stem borer; leaffolder and whorl maggot was also observed by Kandaswamy and Ravikumar (1986).

Spray of chlorpyriphos @ 0.5 kg a.i. /ha or seedling root dip @ 0.02 per cent was effective against rice hispa (Krishnaiah *et al.*, 1987). Rice root dip with chlorpyriphos @ 0.02 per cent coupled with broadcast of carbofuran @ 0.75 kg a.i./ ha or at 0.70 kg a.i. /ha applied in the root zone four days after transplanting reduced the leaf damage due to rice hispa (Dhaliwal and Singh, 1988). Chlorpyriphos @ 0.75 kg a.i. / ha was most effective for rice major pests like green leafhopper, the brown planthopper and the gall midge (Uthamaswamy and Karuppuchamy, 1988).

Biswas and Mandal (1992) observed that chlorpyriphos @ 0.05 per cent effectively controlled larvae and adults of hispa upto 15 days and also reduced the number of damaged leaves. Application of chlorpyriphos @ 1.0 kg a.i. /ha as broadcast in standing water once at 20 days after transplanting significantly reduced live hispa adults / 20 hills by 7.2 – 7.7 per cent(Sain *et al.*, 1994). Kaul and Bhagat (1997) reported the effectiveness of chlorpyriphos @ 1.0 kg a.i. / ha against rice stem borer and rice hispa. Srinivas and Madhumathi (2004) found that chlorpyriphos granular application @ 10 kg / ha was effective in controlling rice gall midge.

Carbaryl: (1-naphthyl N-methyl carbamate)

Carbary is a moderately residual, contact and stomach carbamate insecticide. Its acute oral LD_{50} value for rats is 500 mg/kg. It results in minimum hazard to most non target organisms with the exception of honeybees

Carbaryl was found to be ineffective against rice hispa (Dhaliwal *et al.*, 1977). A mixture of carbaryl and molasses gave good control of rice gall midge (Shukla *et al.*, 1979). Carbaryl @ 0.2 per cent proved effective against *N. lugens* and *N. virescens* causing mortality of 76.17 and 51.73 per cent respectively (Pillai *et al.,* 1983). Carbaryl was found effective @ 1 kg a.i.ha against rice gundhi bug, *Leptocorisa acuta* Thunberg (Pangtey, 1990; Mishra, 2003). Carbaryl spray @ 0.1 per cent effectively controlled rice cut worm (Patil *et al.,* 1991). Carbaryl 10 D had little control over white backed planthopper (Ismail *et al.,* 1995).

Mineral oil:

Work on mineral oil is very scanty. Mineral oil @ 5 per cent significantly reduced the production and germination of *B. bassiana* conidia (Batista *et al.,* 1995). Fipronil spray with mineral oil effectively controlled rice water weevil, *O. oryzae* (Leite *et al.,* 1995). Sprays with mineral oil (Oleostac) controlled the population of citrus leaf miner, *Phyllocnistis citrella* Stainton in Northern Tunisia (Boulahia *et al.,* 1996). Mineral oil (KZ oil 95 %) was found effective against California red scale, *Aonidiella aurantii* (Maskell) and cottony cushion scale, *Icerya purchasi* (Maskell) under laboratory conditions (Hassan, 1999).

Materials and Methods

KERALA AGRICULTURAL UNIVERSITY LIBRARY THRISSUR
172709

3. MATERIALS AND METHODS

The present investigation on "Bioecology, population dynamics and integrated management of rice blue beetle, *Leptispa pygmaea* Baly (Chrysomelidae: Coleoptera)" was undertaken at the Regional Agricultural Research Station, Pattambi, Kerala Agricultural University during 2004-2006. The materials and methods used in the different experiments of this study are elaborated hereunder. The studies conducted on *L. pygmaea* are listed below:

3.1. Biology of rice blue beetle, *L. pygmaea*
3.2. Morphology, morphometrics and anatomy
3.3. Field population dynamics
3.4. Nature of attack and intensity of feeding
3.5. Extent of damage during different growth stages of rice
3.6. Influence of methods of rice cultivation on the pest incidence
3.7. Integrated management of *L. pygmaea*

3.1 BIOLOGY OF RICE BLUE BEETLE, *L. pygmaea*

Biological studies on *Leptispa pygmaea* were carried out in the net house at the prevailing conditions of maximum temperature (30.1°C ±1.40°C), minimum temperature (23.1°C ± 0.69°C) and relative humidity (94.33 % ± 2.11%) during June to October, 2004-05. The biology of blue beetle was studied on two rice varieties *viz.*, Jyothi (short duration) and Aiswarya (medium duration) by raising them in mud pots in the net house.

3.1.1 Maintenance of culture of *L. pygmaea* in net house

Adult beetles of *L. pygmaea* were collected from unsprayed rice fields of the Regional Agricultural Research Station, Pattambi and reared on potted rice seedlings (variety Jyothi) covered with polyester cages of size 49 x 18 cm (Plate 1) in the net

Plate 1. Polyester cage for rearing Blue beetle

house. This served as a stock culture for the steady supply of beetles required for conducting various net house studies.

3.1.2 Raising of seedlings of Jyothi and Aiswarya

Seeds of Jyothi and Aiswarya were sown in separate mud pots and seedlings were maintained in the net house. This provided sufficient rice seedlings as host plants for conducting the biological studies of the test insect in the net house.

3.1.3 Life cycle

A pair of freshly mated beetles of *L. pygmaea* collected from the stock culture was released on 15 days old potted rice seedlings and covered with a polyester cage of size 49 x 18 cm closed by muslin cloth at one end which served as a replication. Ten such replications were maintained for the study on the life cycle of *L. pygmaea* . Observations on the site of oviposition, pre-oviposition period, oviposition period, fecundity, incubation period and hatchability of eggs were recorded. The number of eggs laid per female was recorded daily, until the cessation of egg laying and the fecundity was worked out based on the total number of laid eggs. Number of larval instars, duration of each larval instar, total larval period, pupal period and total period of life cycle from egg to adult were also observed and the mean and standard deviation values were worked out. The life cycle was studied on both Jyothi and Aiswarya varieties of rice.

3.1.4 Adult longevity

Ten freshly emerged adult beetles of both sexes were released separately on 15 days old potted rice seedlings and covered with polyester cages. The longevity of the beetles was recorded until death of the beetles and their mean and standard deviation values were worked out. Adult longevity was also studied on both Jyothi and Aiswarya varieties.

3.1.5 Time of adult emergence

Rice seedlings with 10 freshly pupated pupae were collected from the field and kept in polyester cage in the nethouse. Three replications of fresh pupae were kept for each hour of the study. The adult emergence was observed at one hour interval starting from 0800 to 1800 hours. The number of adults emerged was recorded and the mean and per cent emergence were calculated.

3.1.6 Sex ratio

Adult beetles were collected randomly by 10 net sweeps from the rice fields at monthly interval during the peak period of beetle activity from June to November'05 and their sex ratio was worked out.

3.2 MORPHOLOGY, MORPHOMETRICS AND ANATOMY OF REPRODUCTIVE SYSTEM

Shape, colour and size of different stages of *L. pygmaea* were examined and measurements on the length and width of eggs, larvae, pupae and adults (males and females) were taken using an image anlayser (Model 2 EISS STEMI 2000-C) for describing the different stages of the insect.

3.2.1 Egg

Eggs were collected from the insect culture reared on potted seedlings under nethouse conditions and measurements of ten eggs were taken and their maximum, minimum and standard deviation values were worked out.

3.2.2 Larva

Grubs of different larval instars were collected and the length and width of head capsule, body and tail were measured. Measurements were recorded in 10 larvae to work out the maximum, minimum and standard deviation values.

3.2.3 Pupa

Length and width of freshly formed 10 pupae were measured and the maximum, minimum and standard deviation values were worked out.

3.2.4 Adult male and female beetles

Length and width of head, thorax, abdomen, length of antenna and scape of 10 male and 10 female beetles were measured and maximum, minimum and standard deviation values were calculated.

3.2.5 Anatomy of the reproductive system

The reproductive systems of 10 male and 10 female beetles were dissected out to study their anatomy. The length and width of aedeagus in male and coxites in female were measured using an image anlayser and maximum and minimum values were recorded.

3.3 MONITORING OF FIELD POPULATION DYNAMICS

The seasonal changes in the field population of *L. pygmaea* in relation to abiotic factors were studied. A survey on the field population of blue beetle was conducted in the rice fields of Regional Agricultural Research Station, Pattambi at weekly intervals from 10 days after transplanting of rice (variety Jyothi) during Kharif and Rabi'05. Observations on beetle population counts from 20 randomly selected hills walking diagonally covering the entire field of the station were recorded. Data on the prevailing meteorological parameters *viz.*, maximum temperature, minimum temperature, relative humidity, rainfall and sunshine hours during the study period were collected from the meteorological observatory of the station. Correlation coefficient between population dynamics and leaf damage with weather parameters was done.

3.4 NATURE OF ATTACK AND INTENSITY OF FEEDING

Freshly emerged single male, female adults and larva were released separately on 15 days old potted rice seedlings (Jyothi and Aiswarya) covered with polyester cages in the net house for studying the nature of attack and intensity of feeding by different stages of *L. pygmaea*. Four replications were maintained for each stage of the beetle. Observations on the nature of feeding and number of damaged leaves per hill at 3, 6, 9 and 12 days after release were recorded and mean per cent damage was calculated. The leaf area consumed by each stage of the beetle was worked out by graphical method also.

3.5 EXTENT OF DAMAGE DURING DIFFERENT GROWTH STAGES OF RICE

The extent of damage caused by *L. pygmaea* during different growth stages of rice crop (variety Jyothi) was assessed in order to identify the most susceptible stage of attack. This was studied by taking observations from rice fields of the Regional Agricultural Research Station, Pattambi during Kharif and Rabi seasons, 2005. Number of damaged leaves and damage rating by score were recorded from 20 randomly selected hills walking diagonally covering the entire field. Damage rating was done based on 0 to 9 score (Plate 2, 3, 4, 5, 6, 7) as described in the standard evaluation system of rice (Anonymous, 1975). The details of scoring method are given in Table 1. These observations on the leaf damage of *L. pygmaea* during the different stages of crop growth *viz.,* seedling (3-21 days), early tillering (22-32 days), maximum tillering (33-48 days), panicle intiation (49-60 days), booting (61-70 days) and flowering (71-80 days) were recorded at weekly intervals starting from 10 days after sowing. The mean values of per cent damage per hill were worked out.

Plate 2. Score '0' showing no leaf damage

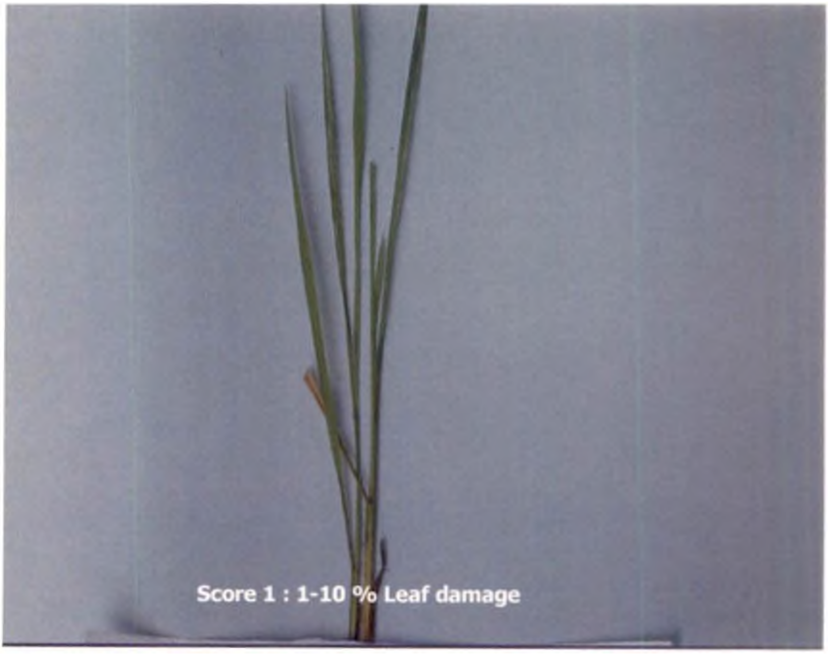


Plate 3. Score '1' showing 1-10 % leaf damage

Plate 4. Score '3' showing 11-25 % leaf damage

Plate 5. Score '5' showing 26-50 % leaf damage

Plate 6. Score '7' showing 51-75 % leaf damage

Plate 7. Score '9' showing >75 % leaf damage

Table 1. Scoring for the damage by *L. pygmaea* in rice

Sl. No.	Damaged leaves / hill (%)	Score
1	No damage	0
2	1-10	1
3	11-25	3
4	26-50	5
5	51-75	7
6	More than 75	9

3.6 INFLUENCE OF METHODS OF CULTIVATION ON THE PEST INCIDENCE

The effect of two methods of rice cultivation *viz.,* direct seeding and transplanting on the incidence of *L. pygmaea* was studied by assessing the damage occurred in the direct seeded and transplanted rice fields of the Regional Agricultural Research Station, Pattambi during Kharif and Rabi, 2005. Observations on the number of leaves damaged and damage score were recorded at different crop growth stages on 20 randomly selected hills by walking diagonally across the entire direct seeded and transplanted fields of both Jyothi and Aiswarya. The mean per cent leaf damage was worked out.

3.7 INTEGRATED PEST MANAGEMENT METHODS

Different components of integrated pest management taken for the study are as follows:

3.7.1 Host plant resistance

3.7.1.1 Screening of varieties / cultures to identify resistance source

3.7.2 Cultural management methods

3.7.2.1 Study of alternative weed hosts

3.7.2.2 Effect of plant spacing and non-edible oil cakes on the incidence of *L. pygmaea*

3.7.3 Biological methods

3.7.3.1 Studying the natural enemies in the field

3.7.3.2 Pathogenicity of white muscardine fungus, *Beauveria bassiana*

3.7.3.3 Efficacy of entomopathogenic nematode, *Heterorhabditis indica*

3.7.4 Chemical management methods

3.7.4.1 Granular insecticide application in the nursery

3.7.4.2 Persistent toxicity of granular insecticides

3.7.4.3 Foliar application of eco-friendly insecticides in the main field

3.7.4.4 Persistent toxicity of foliar insecticides

3.7.1 Host plant resistance

3.7.1.1 Screening of varieties / cultures to identify resistant sources against blue beetle

Cultures / varieties released by the Kerala Agricultural University (KAU) and a few entries from the Directorate of Rice Research (DRR), Hyderabad were screened for resistance against *L. pygmaea* during Kharif and Rabi, 2005. Seeds of KAU varieties were collected from the different research stations *viz.*, Agricultural Research Station, Mannuthy, Regional Agricultural Research Station, Pattambi, Rice Research Station, Moncompu and Onattukara Regional Agricultural Research Station, Kayamkulam. Seedlings were raised in the nursery at the Regional Agricultural Research Station, Pattambi for the field screening.

Twenty two days old seedlings of different varieties / cultures / entries were transplanted in the main field with a spacing of 20 x 15 cm in rows of 20 hills per variety at the rate of one seedling per hill. Observations on total damaged hills per entry and number of damaged leaves and damage score per hill from ten randomly selected hills were made at 10 and 20 days after transplanting. The maximum and minimum mean values of these observations during Kharif and Rabi seasons were recorded. Based on the intensity of damage by scoring technique, the reaction of the tested varieties was evaluated as per the method in Table 2.

3.7.2 Cultural methods

3.7.2.1 Identification and study of the alternative weed hosts of L. pygmaea

A survey on the weed flora in the rice fields of Regional Agricultural Research Station, Pattambi was conducted to identify the weeds that served as alternative host plants for *L. pygmaea*. Major weed plants commonly seen in the rice fields and on the bunds were collected and grown in separate pots in the nethouse.

Table 2. Technique of evaluation of rice varieties for resistance

Sl. No.	Damaged leaves / hill (%)	Score	Reaction
1	No damage	0	Immune (I -Highly Resistant)
2	1-10	1	Resistant (R)
3	11-25	3	Moderately Resistant (MR)
4	26-50	5	Moderately Susceptible (MS)
5	51-75	7	Susceptible (S)
6	More than 75	9	Highly Susceptible (HS)

Freshly emerged five pairs of adult beetles were released on them and covered with mylar cages and observed for their feeding and oviposition. The biology of blue beetle on the preferred weed plant was studied in the same method as described earlier in rice. A comparative biology of *L. pygmaea* on Jyothi, Aiswarya and the most preferred weed was studied.

3.7.2.2 Effect of plant spacing and soil application of oil cakes on the pest incidence

The effects of three spacings *viz.,* 20x15cm, 10x15cm and 10x10cm and the application of three types of plant oil cakes *viz.*, neem cake, castor cake and pungam cake @ 150 kg / ha on the incidence of *L. pygmaea* were studied by conducting field experiments during Kharif and Rabi, 2005. The experiments were laid out in a randomized block design with nine treatments and three replications using the rice variety 'Jyothi'. The factorial combinations of treatments are given below.

Oil cakes	Spacing
C1 : Neem cake	S1 : 20x15 cm
C2 : Castor cake	S2 : 10x15 cm
C3 : Pungam cake	S3 : 10x10 cm

Treatment details

T1 - C1S1: Neem cake @ 150 kg/ha and 20X15 cm spacing

T2 - C2S1: Castor cake @ 150 kg/ha and 20X15 cm spacing

T3 - C3S1: Pungam cake @150 kg/ha and 20X15 cm spacing

T4 - C1S2: Neem cake @ 150 kg/ha and 10X1 5 cm spacing

T5 - C2S2: Castor cake @ 150 kg/ha and 10X15 cm spacing

T6 - C3S2: Pungam cake @15 0 kg/ha and 10X15 cm spacing

T7 - C1S3: Neem cake @ 150 kg/ha and 10X10 cm spacing

T8 - C2S3: Castor cake @ 150 kg/ha and 10X10 cm spacing

T9 - C3S3: Pungam cake @150 kg/ha and 10X10 cm spacing

Twenty two days old seedlings were transplanted at the rate of two per hill in plots of size of 21 m^2 with different spacings as mentioned above. Different non-edible oil cakes were applied in the plots at seven days after transplanting and each plot was provided with bunds to restrict the movement of water from one plot to the other. Observations on total damaged hills per plot, damaged leaves per hill in ten randomly selected hills per plot, intensity of damage by scoring and counts of beetle population were taken at 10, 20 and 30 days after transplanting. The data were pooled and analysed statistically and the treatments were compared by Duncan Multiple Range Test (DMRT) (Duncan, 1951).

3.7.3 BIOLOGICAL METHODS

3.7.3.1 Studying the natural enemies of L. pygmaea

The rice fields of Regional Agricultural Research Station, Pattambi were surveyed to identify predators and parasitoids of *L. pygmaea*. The different stages *viz.,* egg, larva and pupa of the pest were collected from the field and reared in polybags and observed for the emergence of parasitoids.

3.7.3.2 Pathogenicity of white muscardine fungus, Beauveria bassiana (Bals.) Vuill. on L.pygmaea

A survey was conducted in the rice fields to observe dead insects due *to B. bassiana*. Based on the field observations, a laboratory study was carried out to understand the pathogenicity of *B. bassiana* against *L. pygmaea.* The culture of *B. bassiana* was obtained from the College of Horticulture, Vellanikara. The pathogenicity of white muscardine fungus was intially tested on adult blue beetles. The fungus was grown in a culture medium of 200 gm boiled sorghum grains mixed with 12.5 gm lime.

Different treatment concentrations of *B. bassiana* prepared with 1 per cent teepol (spreading agent) along with an untreated control (water and teepol) were used solutions of different concentrations and air dried for 15 minutes and kept in petridish. The adult beetles @ 5 beetles / treatment were released on the treated seedlings and each treatment was replicated four times. Observations on per cent mortality of beetles were taken at 24, 48 and 72 hours after treatment. Mortality data were corrected by Abbott's formula and LC $_{50}$ values were worked out by probit analysis (Finney, 1977).

3.7.3.3 Efficacy of entomopathogenic nematode (EPN), Heterorhabditis indica (Poinar)

A laboratory study was conducted to evaluate the bioefficacy of the entomopathogenic nematode, *H. indica* against *L. pygmaea.* The EPN culture was obtained from the Cardamom Research Station, Pampadumpara. Intially, an experiment was carried out to test the pathogenicity of the EPN against the grub of *L. pygmaea.* After confirmation of the pathogenicity, an experiment was carried out to evaluate *H. indica* with different infective juveniles at concentrations *viz.,* 3, 5, 6, 7 and 8 per ml along with an untreated control. These concentrations of IJ's were sprayed on 15 days old Jyothi seedlings kept in petridishes. Five grubs of *L. pygmaea* were released in each treatment with four replications. An untreated control sprayed with 1 per cent teepol was also maintained. The various concentrations of IJ's were prepared with 1 per cent teepol which served as spreading agent. Mortality of grubs was recorded at 24, 48 and 72 hours after treatment. Cumulative mortality was also calculated. Mortality data were corrected by Abbot's formula and LC_{50} values were worked out by probit analysis.

3.7.4 Chemical management

3.7.4.1 Efficiency of granular insecticides in nursery against L. pygmaea

The efficacy of application of granular insecticides in the nursery against the conducted using the variety Jyothi during Kharif and Rabi 2004, 2005. The experiments were laid out in randomized block design with four replications and six treatments whose details are given in Table 3.

The granular insecticides were applied in the nursery five days before pulling the seedlings for transplantation. Twenty days old seedlings were transplanted at the rate of two seedlings per hill in plots of size 24 m^2 at a spacing of 20x15 cm. Observations on total damaged hills per plot, beetle population and damaged leaves per hill were taken at 10, 20 and 30 days after transplanting from ten randomly selected hills per plot. The data were statistically analysed and the DMRT (Duncan, 1951) was used for comparing the treatments.

Table 3. Treatment details of nursery application with granules

Treatment	Common name	Trade name	Dosage (g a.i./ha)
T1	cartap hydrochloride	Caldan 4 G	1000
T2	carbosulfan	Marshall 6 G	1000
T3	fipronil	Regent 0.3 G	100
T4	phosphamidon	Sumidon 10 G	1000
T5	carbofuran	Furadan 3 G	1000
T6	Control		

3.7.4.2 Persistent toxicity of granular insecticides against blue beetle

Insecticide treated rice seedlings from the nursery of the above experiment were used to study the persistent toxicity of granular insecticides against *L. pygmaea*. Twenty days old treated seedlings were planted in mud pots in the nethouse. Ten newly emerged beetles were released in each pot and covered with polyester cage of beetles were taken at different intervals of treatment of insecticides in nursery. The experiment was carried out during Kharif and Rabi 2004 and 2005. Persistent toxicity was calculated in terms of PT indices based on the criterion elaborated by Sarup *et al.* (1970), where 'P' is the period upto, which the toxicity persisted, and 'T' is the average toxicity.

$$\text{Average toxicity (T)} = \frac{\text{Sum of per cent mortality}}{\text{Number of observations}}$$

3.7.4.3 Bioefficacy of eco-friendly foliar insecticides against rice blue beetle

Four field experiments were conducted during Kharif and Rabi seasons, 2004 and 2005 using rice variety Jyothi, to find out the efficacy of eco-friendly foliar insecticides against *L. pygmaea*. The treatment details of the experiment are given in Table 4.

Experiments were laid out in a randomized block design with four replications. Twenty two days old rice seedlings were transplanted in plot size of 20 m^2 at a spacing of 20 x 15 cm at two seedlings per hill. Treatment was applied as sprays at 8, 15 and 25 days after transplanting. Observations were recorded at 10, 20 and 30 days after transplanting. Number of damaged leaves per hill on randomly selected ten hills per plot, total number of beetles, total damaged hills per plot and intensity of damage were recorded and analysed statistically by DMRT.

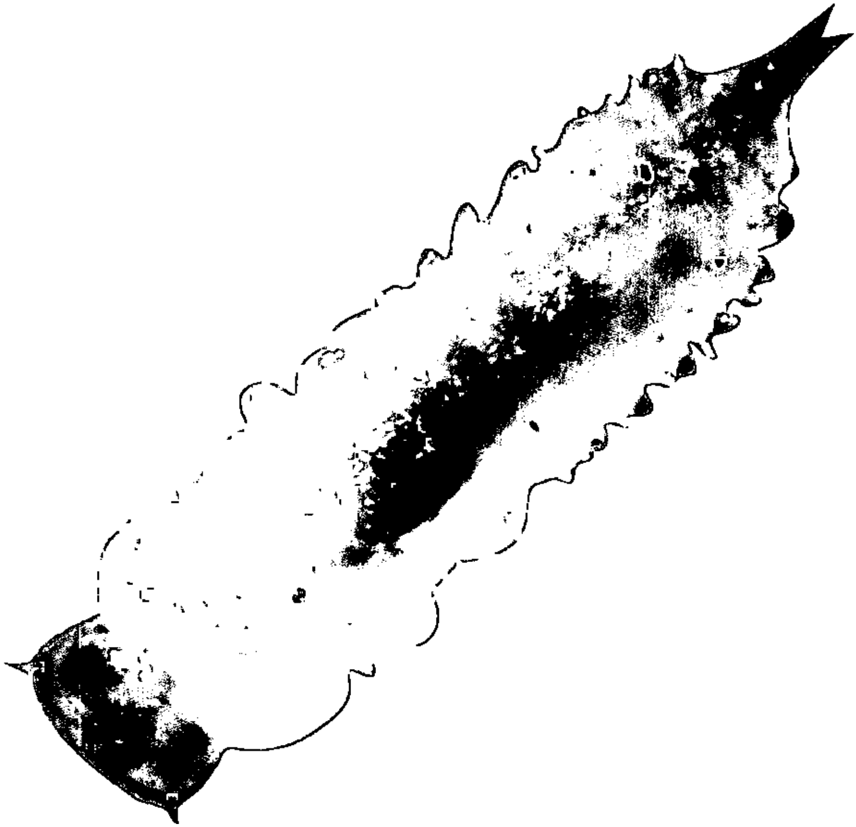
3.7.4.4 Study on persistent toxicity of foliar insecticides against blue beetle

Persistent toxicity of the foliar insecticides was studied under net house condition by using insecticide treated seedlings from the field. They were planted in pots covered by polyester cages of size 49 x 18 cm closed with muslin cloth at the distal end. The experiment was conducted at different intervals of insecticide treatment by releasing 10 freshly emerged beetles. Three replications were maintained for each treatment. Observations on the mortality of beetles were recorded after 48 hours of release of the beetles on the treated plants. The study was conducted during

Kharif and Rabi' 2004, 2005. Persistence of the toxicity of foliar insecticide was calculated based on the PT indices as described in 3.7.4.2.

Table 4. Details of foliar insecticides against *L. pygmaea*

Treatment	Common name	Trade name	Dosage (%)
T1	White muscardine fungus	*Beauveria bassiana*	10^{7} spores / ml
T2	Paraffin oil	Servo Agrospray S	2 .000
T3	Neem oil	Neem oil	2.000
T4	1 % Azadirachtin	Econeem 1 %	0.004
T5	chlorpyriphos	Pyriban 20 % EC	0.050
T6	carbaryl	Sevin 50 % WP	0.200
T7	Control		



Results

4. RESULTS

Field and net house investigations were undertaken at the Regional Agricultural Research Station, Pattambi, Kerala Agricultural University during 2004-2006 to study the bioecology, population dynamics and integrated management of rice blue beetle, *Leptispa pygmaea*. The results of the studies are presented in this chapter.

4.1 BIOLOGY OF RICE BLUE BEETLE, *L. pygmaea*

The biology of *L. pygmaea* was studied on two rice varieties *viz.*, Jyothi (short duration) and Aiswarya (medium duration) under net house conditions of maximum temperature (30.1°C ±1.40°C), minimum temperature (23.1°C ± 0.69°C) and relative humidity (94.33% ± 2.11%).

4.1.1 Site of ovipostion, fecundity and oviposition period

The female beetle of *L. pygmaea* laid either single egg or in groups of 2, 3, 4 or 5 in a straight line on the upper or lower surface of mature or tender leaves of young rice plant. In the short duration variety Jyothi, it laid 15 to 19 eggs (mean = 16.8) during an oviposition period of six days (Table 5).

Maximum number of eggs (mean = 4.3) were laid on second and third days and thereafter it was reduced. The number of eggs laid was very low (mean =0.4) on the sixth day of oviposition.

In the medium duration variety, Aiswarya (Table 6), the number of eggs laid ranged from 12 to 19 eggs with an average of 14.3 eggs. Egg laying was observed to be highest on the first day (4.6) and thereafter it was reduced to 0.9 and 0.1 (mean values) during fifth and sixth day, respectively.

Table 5. Fecundity of *L. pygmaea* on Jyothi

Hill No.	Number of eggs laid per female beetle						
	1st day	2nd day	3rd day	4th day	5th day	6th day	Total eggs
1	3	4	5	2	2	0	16
2	2	4	4	2	2	1	15
3	4	3	3	2	3	0	15
4	3	5	4	3	2	1	18
5	4	6	4	2	1	0	17
6	5	4	4	3	1	0	17
7	4	4	3	3	2	1	17
8	3	4	5	4	1	0	17
9	2	5	5	4	1	0	17
10	3	4	6	3	2	1	19
Mean ± SD	3.3 ± 0.95	4.3 ± 0.82	4.3 ± 0.95	2.8 ± 0.79	1.7 ± 0.67	0.4 ± 0.52	16.8 ± 1.23

Table 6. Fecundity of *L. pygmaea* on Aiswarya

Hill No.	Number of eggs laid per female beetle						
	1st day	2nd day	3rd day	4th day	5th day	6th day	Total eggs
1	4	4	5	2	1	0	16
2	5	4	3	2	1	0	15
3	6	3	2	1	0	0	12
4	4	5	4	3	2	1	19
5	4	3	2	1	0	0	10
6	3	4	3	2	1	0	13
7	5	4	2	1	0	0	12
8	6	4	3	2	1	0	16
9	4	3	2	2	1	0	12
10	5	4	4	3	2	0	18
Mean ± SD	4.6 ± 0.97	3.8 ± 0.63	3.0 ± 0.33	1.9 ± 0.23	0.9 ± 0.23	0.1 ± 0.32	14.3 ± 2.95

4.1.2 Developmental stages

Eggs of *L. pygmaea* hatched into grubs within 3 to 4 days (mean =3.4 days) in both Jyothi and Aiswarya (Table 7). The larval duration varied from 6 to 11 days in Jyothi and 7 to 10 days in Aiswarya. The mean larval period was 8.2 days in both the varieties. The grubs pupated in a period of 3.2 and 2.9 days on Jyothi and Aiswarya respectively and the adult beetles emerged out. The total life cycle of rice blue beetle from egg to adult was completed within a period of 12 to 19 days (mean =14.8) in Jyothi, while it was 12 to 15 days (mean = 13.8 days) in Aiswarya.

4.1.3 Duration of different larval instars of *L. pygmaea*

In both Jyothi and Aiswarya, five instars were observed during the grub stage of rice blue beetle. The mean duration of 1st, 2nd, 3rd, 4th and 5th instars were found to be 2.2, 1.6, 1.3, 1.3 and 1.8 days respectively on Jyothi and the corresponding values on Aiswarya were 1.8, 1.9, 1.2, 1.4 and 1.9 days (Table 8).

4.1.4 Pre-oviposition and adult longevity

Pre-ovipostion period of rice blue beetle ranged from 14 to 26 hours in Jyothi, whereas in Aiswarya it was 15 to 24 hours. The mean pre-oviposition period was observed to be 21.0 and 20.3 hours on Jyothi and Aiswarya respectively (Table 9).

Adult male beetle lived for 22 to 60 days on Jyothi and 20 to 55 days on Aiswarya (Table 9). The male beetle had an average life span of 40.9 and 36.7 days in Jyothi and Aiswarya respectively.

The longevity of female beetle varied from 20 to 35 days in Jyothi and 20 to 30 days in Aiswarya. The mean longevity of female beetle was 24.9 and 24.7 days in Jyothi and Aiswarya.

Table 7. Duration of developmental stages of *L. pygmaea* on Jyothi and Aiswarya

Repl. No.	Egg period (days)		Larval period (days)		Pupal period (days)		Total life cycle (days)	
	J	A	J	A	J	A	J	A
1	3	3	6	7	3	3	12	13
2	4	4	11	10	4	2	19	14
3	3	3	7	9	3	4	13	15
4	3	3	9	9	3	3	15	15
5	4	4	6	7	3	3	13	13
6	3	3	9	8	3	3	15	14
7	4	4	9	7	4	3	17	12
8	3	3	7	8	3	2	13	13
9	4	4	9	8	3	3	16	14
10	3	3	9	9	3	3	15	15
Mean ± S.D	3.4 ± 0.52	3.4 ± 0.52	8.2 ± 1.62	8.2 ± 1.00	3.2 ± 0.4	2.9 ± 0.57	14.8 ± 2.15	13.8 ± 1.03

J = Jyothi , A = Aiswarya

Table 8. Duration of different larval stages of *L. pygmaea* on Jyothi and Aiswarya

Repl. No.	Grub instars period (days)									
	I		II		III		IV		V	
	J	A	J	A	J	A	J	A	J	A
1	2	1	1	2	1	1	1	1	1	2
2	3	2	2	2	2	1	2	2	2	3
3	2	2	1	2	1	1	1	2	2	2
4	2	2	2	2	2	2	1	1	2	2
5	2	2	1	2	1	1	1	1	1	1
6	3	1	2	2	1	2	1	2	2	1
7	2	2	2	1	1	1	2	1	2	2
8	2	2	1	2	1	1	1	2	2	1
9	2	2	2	2	2	1	1	1	2	2
10	2	2	2	2	1	1	2	1	2	3
Mean ± SD	2.2 ± 0.13	1.8 ± 0.42	1.6 ± 0.52	1.9 ± 0.32	1.3 ± 0.48	1.2 ± 0.42	1.3 ± 0.48	1.4 ± 0.52	1.8 ± 0.42	1.9 ± 0.74

J: Jyothi, A: Aiswarya

Table 9. Pre-oviposition and adult longevity of L. *pygmaea* on Jyothi and Aiswarya

Repl. No.	Pre-oviposition period (hours)		Adult longevity (days)			
			Male		Female	
	J	A	J	A	J	A
1	26	22	25	25	25	20
2	22	23	22	20	20	22
3	14	24	33	30	22	20
4	25	20	45	40	30	24
5	18	15	60	45	22	30
6	24	21	35	50	25	25
7	22	20	40	55	35	24
8	20	18	47	40	25	28
9	25	19	52	32	22	29
10	16	21	50	30	23	25
Mean ± SD	21.00 ± 4.10	20.30 ± 2.58	40.9 ± 12.17	36.7 ± 11.21	24.9 ± 4.48	24.7 ± 3.50

J = Jyothi , A = Aiswarya

4.1.5 Time of adult emergence

Emergence of adult beetles was found to be higher during morning than evening (Table 10). Highest emergence (83.3 per cent) occurred between 0800 and 1100 hours and thereafter, it was gradually reduced and reached 3.3 per cent between 1200 and 1300 hours. There was no emergence during 1300 to 1500 hours. The adults started emerging again from 1500 hours (36.7 per cent). Between 1600 and 1700 hours, 76.7 per cent adults emerged and thereafter again the emergence was reduced to 33.3 per cent between 1700 and 1800 hours.

4.1.6 Sex ratio

Sweep net collection of adult beetles from the field during the peak period of activity from June'05 to November'05 showed highest population (220) during July and lowest (90) during November'05 (Table 11). Male beetles were found to be more than females in the field during June, September, October and November'05. Females predominated the field population during July and August. Female to male ratio was highest (2.6:1) during July while male to female ratio was highest (2:1) during September'05 and November'05 . When the field population was high (July and August), female beetles were more in number and males became more, when the field population was low (June, September, October and November'05). There was a predominance of female population during July and August'05. The average sex ratio of male to female was 1.5 to 1.3.

4.2 MORPHOLOGY, MORPHOMETRICS AND ANATOMY

The measurements of different stages of beetle *viz.*, egg, larva, pupa and adult beetles (male and female) were recorded using image analyzer and presented in Tables 12 and 13.

Table 10. Time of emergence of *L. pygmaea* during different hours of the day

Time (Hours)	Number of pupae in each replication	Number of adult beetles emerged				
		R1	R2	R3	Mean ±SD	Per cent emerged in each interval
0800-0900	10	9	10	6	**8.33±2.08**	83.3
0900-1000	10	8	7	8	**7.67±0.58**	76.7
1000-1100	10	5	8	9	**7.33±1.73**	73.3
1100-1200	10	1	2	2	**1.67±0.58**	16.7
1200-1300	10	0	1	0	**0.33±0.58**	3.3
1300-1400	10	0	0	0	**0.00±0.00**	0.0
1400-1500	10	0	0	0	**0.00±0.00**	0.0
1500-1600	10	2	4	5	**3.67±1.53**	36.7
1600-1700	10	7	8	8	**7.67±0.58**	76.7
1700-1800	10	2	3	5	**3.33±1.53**	33.3

R1, R2, R3 = Replications

Table 11. Sex ratio *L. pygmaea* in rice fields from June to November'2005

Month	Number of beetles per 10 net sweeps			Male to Female ratio
	Male	Female	Total	
June'05	108	77	185	1.4 : 1.0
July'05	61	159	220	1.0 : 2.6
August'05	88	123	211	1.0 : 1.4
September'05	88	44	132	2.0 : 1.0
October'05	114	88	202	1.3 : 1.0
November'05	60	30	90	2.0 : 1.0
			Mean	**1.50 : 1.30**

4.2.1 Egg

Fresh laid eggs laid on the upper or lower surface of the leaves of *L. pygmaea* were smooth and oval in shape with light green colour (Plate 8). They turned yellowish towards hatching.

Eggs measured 0.38 to 0.39 mm in length (mean =0.39 mm) in length and 0.13 to 0.24 mm in width (mean = 0.19 mm) (Table 12).

4.2.2 Larva

The grub of the beetle was creamish green in colour with a brown head showing two spine like projections on the head (Plate 9). It has three pairs of thoracic legs and two tubular projections (tail) were seen at the posterior end of the body (Plate 10). The blue beetle grub had five larval instars (Plate 11). The last instar of the grub turned dirty white before pupation. The measurements of head capsule, body and tail of the grub are given in Table 13. The mean width of head capsule of 1st, 2nd, 3rd, 4th and 5th instars ranged from 0.17 to 0.26 mm.

The mean body length of 1st, 2nd, 3rd, 4th and 5th instars ranged from 2.53 mm to 4.56 mm, while mean body width ranged from 0.74 to 1.09 mm with maximum body width in both 2nd and 3rd instars. The mean tail length of 1st, 2nd, 3rd, 4th and 5th instars ranged from 0.50 to 0.56 mm while mean tail width ranged from 0.10 to 0.15mm.

4.2.3 Pupa

The newly formed pupa of *L. pygmaea* was white in colour and later turned brown in colour. They were seen glued to the leaf surface by its distal end. Even 3 - 4 pupa could be seen on a single leaf (Plate 12).

Table 12. Measurements of egg of *L. pygmaea*

Serial No.	Stage of the insect	Maximum (mm)	Minimum (mm)	Mean (mm)	± S.D
1	**Egg**				
	Length	0.39	0.38	**0.39**	**0.01**
	Width	0.24	0.13	**0.19**	**0.08**

Table 13. Measurements of grub and pupa of *L. pygmaea*

Serial No.	Stage of the insect	Maximum (mm)	Minimum (mm)	Mean (mm)	± S.D
1	I instar grub				
	A.Head Capsule				
	Width	0.18	0.15	**0.17**	**0.02**
	B.Body				
	a.Length	2.60	2.46	**2.53**	**0.10**
	b.Width	0.86	0.62	**0.74**	**0.17**
	C.Tail				
	a.Length	0.61	0.39	**0.50**	**0.16**
	b.Width	0.13	0.07	**0.10**	**0.04**
2	II instar grub				
	A.Head Capsule				
	Width	0.22	0.18	**0.20**	**0.03**
	B.Body				
	a.Length	4.05	3.75	**3.90**	**0.21**
	b.Width	1.14	1.04	**1.09**	**0.07**
	C.Tail				
	a.Length	0.58	0.46	**0.52**	**0.08**
	b.Width	0.16	0.08	**0.12**	**0.06**
3	III instar grub				
	A.Head Capsule				
	Width	0.24	0.21	**0.23**	**0.02**
	B.Body				
	a.Length	4.16	3.84	**4.00**	**0.23**
	b.Width	1.15	1.03	**1.09**	**0.08**
	C.Tail				
	a.Length	0.55	0.49	**0.52**	**0.04**
	b.Width	0.18	0.10	**0.14**	**0.06**

Contd.

Table 13. continued

Serial No.	Stage of the insect	Maximum (mm)	Minimum (mm)	Mean (mm)	± S.D
4	IV instar grub				
	A.Head Capsule				
	Width	0.28	0.23	**0.26**	**0.04**
	B.Body				
	a.Length	4.49	4.23	**4.36**	**0.18**
	b.Width	1.04	0.82	**0.93**	**0.16**
	C.Tail				
	a.Length	0.62	0.48	**0.55**	**0.10**
	b.Width	0.19	0.09	**0.14**	**0.07**
5	V instar grub				
	A.Head Capsule				
	b.Width	0.29	0.23	**0.26**	**0.04**
	B.Body				
	a.Length	4.65	4.47	**4.56**	**0.13**
	b.Width	0.98	0.82	**0.90**	**0.11**
	C.Tail				
	a.Length	0.63	0.49	**0.56**	**0.10**
	b.Width	0.18	0.12	**0.15**	**0.04**
6	**Pupa**				
	a.Length	3.89	3.73	**3.81**	**0.11**
	b.Width	1.32	1.12	**1.22**	**0.14**

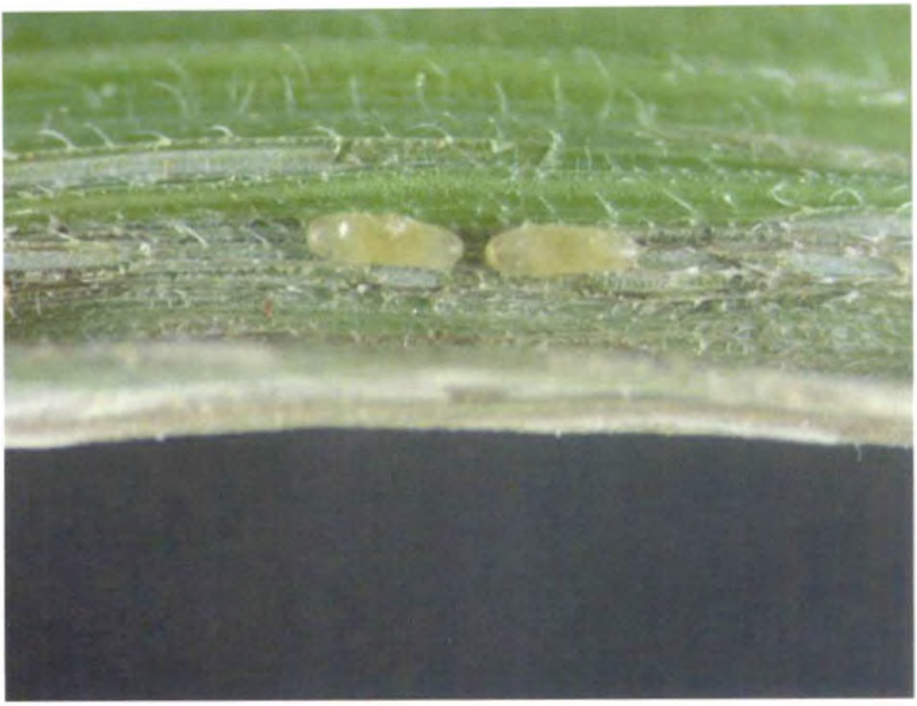


Plate 8. Eggs of blue beetle

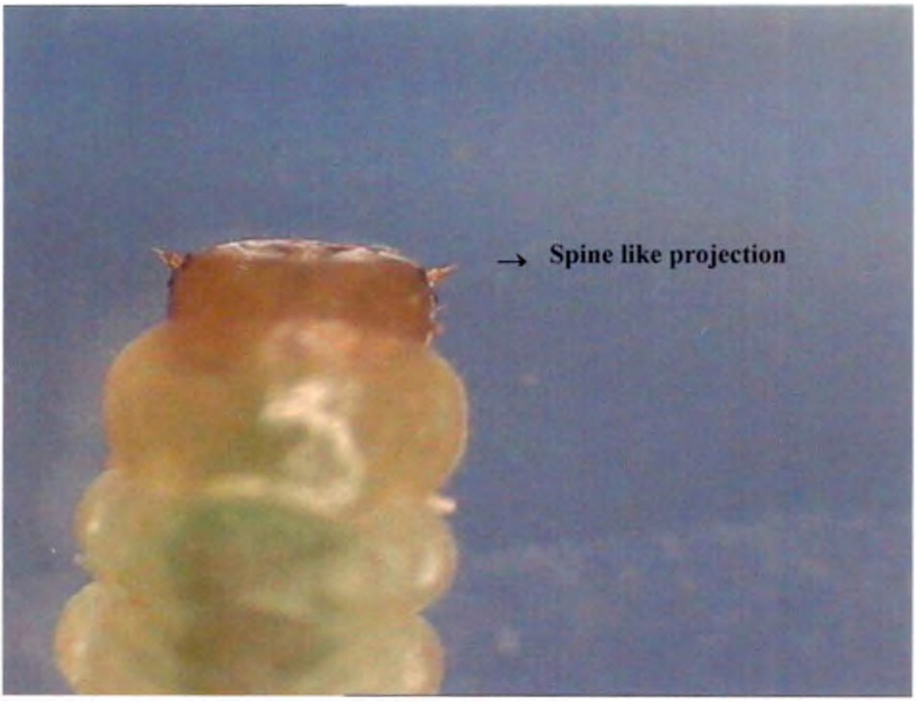


Plate 9. Head of grub showing spine like projection

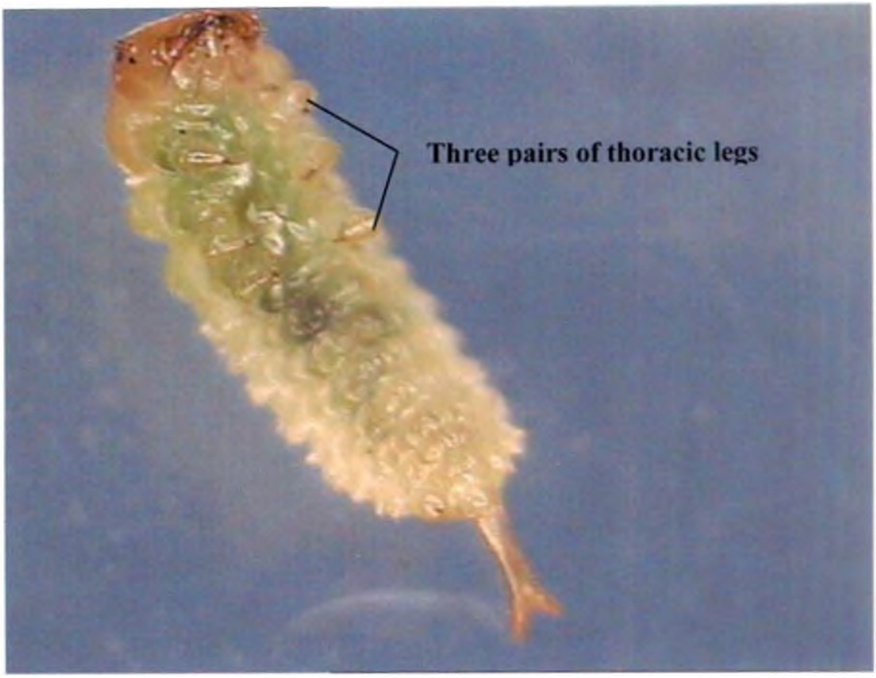


Plate 10. Grubs with three pairs of legs and posterior abdominal projection

Plate 11. Grubs of different instars along with pupa

The pupa had a maximum length of 3.89 mm and minimum length of 3.73 mm with a mean value of 3.81 mm and a width from 1.12 to 1.32 mm with a mean value of 1.22 mm (Table 13).

4.2.4 Adult

Freshly emerged adult beetle was white coloured (Plate 13) and later its colour changed to metallic blue. The body of adult beetle was narrow, elongated, cylindrical and very slightly constricted in the middle with shining metallic bluish green or yellowish green colour dorsally and black colour on the underside with short hairs. The head was covered above with irregular punctures. The upper surface of the thorax showed pittings (Plate 14). Elytra showed rows of punctures. Male beetles were metallic bluish green and larger in size (7.05 mm), while female showed metallic yellowish colour with 6.05 mm length (Plate 15) (Table 14). The body width in male was 2.10 mm while that of female was 1.89 mm. The head of both male and female beetles measured length and width of 0.27 and 0.22 mm respectively. Thoracic length and width in male was 0.65 mm and 0.75 mm and corresponding values were 0.66 mm and 0.77 mm in female beetle. The male and female beetles could be differentiated also by the length of antennae. Males had longer antenna measuring 1.01mm, while in females it was 0.79 mm (Plate 16). Antennal scape was wider (truncate) (Plate 17) with 0.15 mm in females and narrower in males with 0.12 mm.

4.2.5 Anatomy of the reproductive system

Dissection of the reproductive system of the male beetle showed that it was comprised of aedeagus seen protruding out during copulation (Plate 18). The aedeagus had two parts tegmen and sipho (Plate 19). The aedeagus measured length of 1.06 to 1.67 mm (mean = 1.36) (Table 15). Its width ranged from 0.04 to 0.10 mm (mean =0.07) and posterior width from 0.08 to 0.12 mm (mean = 0.10)

Plate 12. Three pupae seen attached to the same leaf

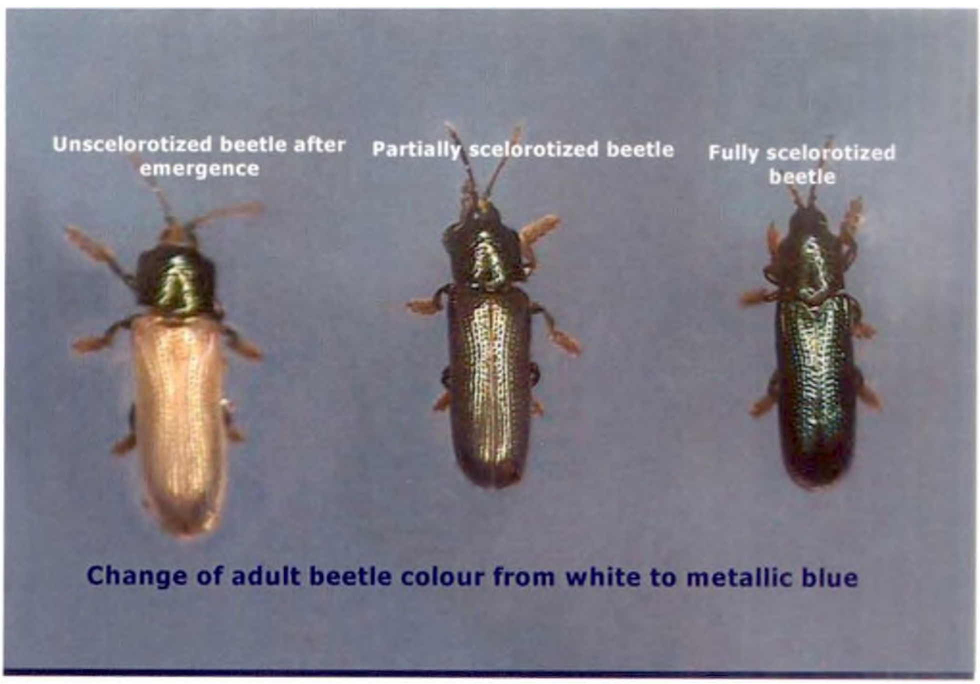


Plate 13. Colour change of beetle after emergence

Plate 14. Thorax of adult beetle showing pittings

Plate 15. Male and Female adult beetles

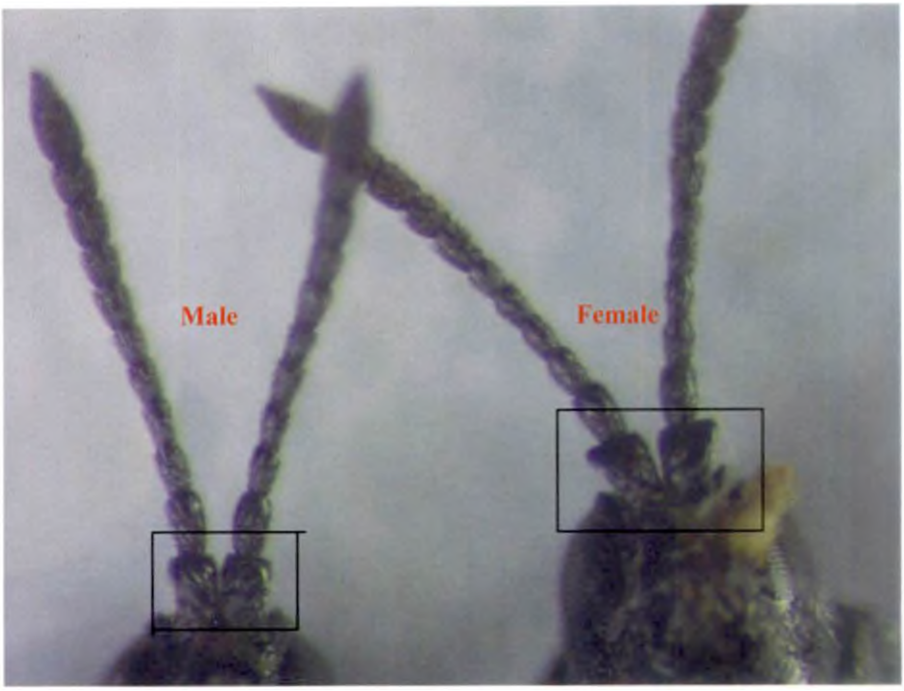


Plate 16. Scape width difference in Male and Female beetles

Plate 17. Antennal length difference in Male and Female beetles

Table 14. Measurements of male and female beetles of *L. pygmaea*

Serial No.	Part of the insect body	Maximum (mm)	Minimum (mm)	Mean (mm)	± S.D
1	**Male Beetle**				
	A.Body				
	a. Length	7.30	6.80	**7.05**	**0.35**
	b.Width	2.20	2.00	**2.10**	**0.14**
	B.Head				
	a.Length	0.27	0.27	**0.27**	**0.00**
	b.Width	0.23	0.20	**0.22**	**0.02**
	C.Thorax				
	a.Length	0.68	0.62	**0.65**	**0.04**
	b.Width	0.78	0.72	**0.75**	**0.04**
	D.Antenna				
	Length	1.03	1.00	**1.01**	**0.02**
	E.Antennal scape	0.12	0.12	**0.12**	**0.00**
2	**Female Beetle**				
	A.Body				
	a. Length	6.50	5.60	**6.05**	**0.64**
	b.Width	2.00	1.77	**1.89**	**0.16**
	B.Head				
	a.Length	0.27	0.27	**0.27**	**0.00**
	b.Width	0.23	0.21	**0.22**	**0.02**
	B.Thorax				
	a.Length	0.69	0.62	**0.66**	**0.05**
	b.Width	0.83	0.71	**0.77**	**0.08**
	C.Antenna				
	Length	0.84	0.73	**0.79**	**0.08**
	D.Antennal scape	0.16	0.14	**0.15**	**0.01**

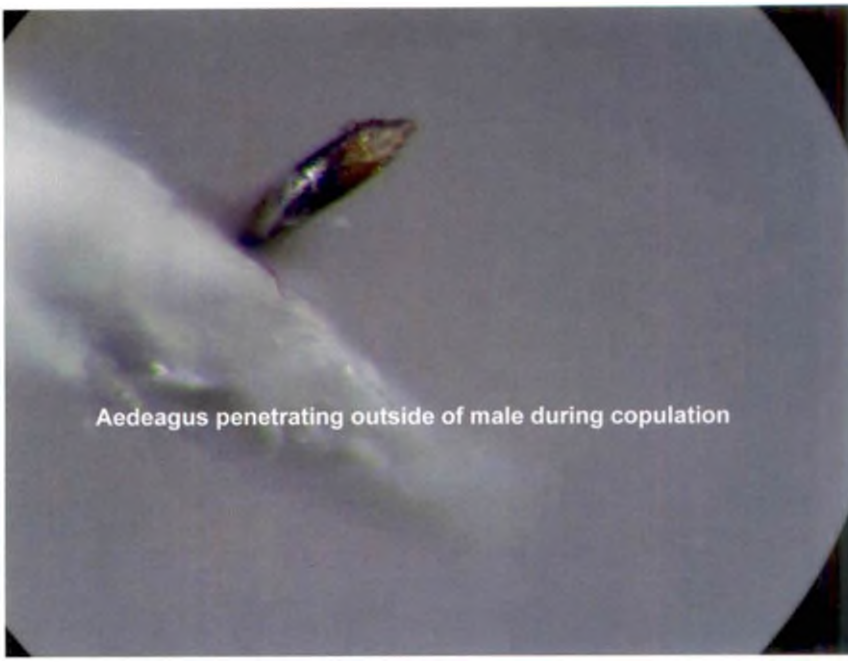


Plate 18. Aedaegus protruding out from male beetle during copulation

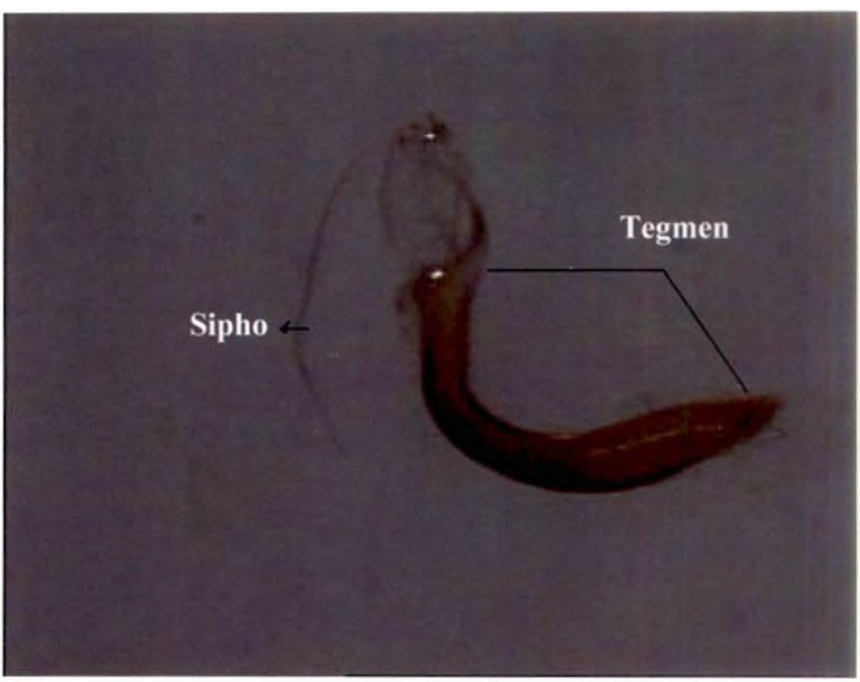


Plate 19. Lateral view of aedeagus of blue beetle

Table 15. Measurements of the reproductive systems of *L. pygmaea*

Sl. No.	Part of the reproductive system	Maximum (mm)	Minimum (mm)	Mean (mm)
1	**Male beetle**			
	Aedeagus			
	a.Length	1.67	1.06	**1.36**
	b.Width (anterior)	0.10	0.04	**0.07**
	c.Width (posterior)	0.12	0.08	**0.10**
2	**Female Beetle**			
	Coxites			
	a. Length	1.75	1.45	**1.60**
	b.Width	0.82	0.22	**0.52**

The female reproductive system consisted of spermatheca and two lateral coxites forming the opening of female genitalia (Plate 20 and 21). The coxites had a mean length of 1.60 mm and a width of 0.52 mm.

4.3 MONITORING OF FIELD POPULATION DYNAMICS

The survey conducted in the rice fields of Regional Agricultural Research Station, Pattambi to study the seasonal fluctuation of the field population of *L. pygmaea* indicated that during Kharif'05 the population of rice blue beetle was 232 beetles per 20 plants during fourth week of June (at 10 DAT) and reached a peak (664 beetles / 20 plants) during second week of July'05 (at 24 DAT) (Table 16).

The abiotic factors of maximum temperature, minimum temperature, relative humidity, rainfall and sunshine during the peak period were 29.8 °C, 23.7 °C, 95 per cent, 50.9 mm and 2.9 hours respectively. Thereafter, the population started declining and a lowest population of 26 beetles / 20 plants was observed during third week of September at 87 DAT. A maximum temperature of 30.9°C, minimum temperature of 23.7°C and relative humidity of 94 per cent were observed during this period. The rainfall and sunshine were 21.1 mm and 1.6 hours respectively during this lean period of third week of September.

In Rabi'05, the beetle population showed an increasing trend from 220 beetles / 20 plants during third week of October (at 10 DAT) and reached a peak of 550 beetles / 20 plants during first week of November'05 (at 24 DAT). The population indicated a decreasing trend from second week of November onwards. The lowest populations of 5 beetles / 20 plants were observed during first week of November and fourth week of December'05 respectively. The weather parameters recorded at peak population were maximum temperature 31.8°C, minimum temperature 23.2°C, relative humidity 95 per cent, rainfall 70.2mm and sunshine 4.2 hours. Population was lowest during the fourth week of December'05 (73 DAT) when the maximum temperature

Plate 20. Spermatheca in Female Genitalia

Plate 21. Coxites in Female Genitalia

Table 16. Field population dynamics of *L. pygmaea* and weather parameters (Kharif and Rabi, 2005)

Season, Month & Week	DAT	Mean population per 20 plants	Weather parameters					
Kharif'05			Temp. (°C)		RH (%)	RF (mm)	SS (hrs)
			Max.	Min.			
(June'05) IV	10	232	29.9	23.2	95	176.6	0.8
(July'05) I	17	604	27.4	23.0	96	262.2	0.5
II	24	664	29.8	23.7	95	050.9	2.9
III	31	567	29.4	23.8	95	108.0	2.3
IV	38	370	28.1	22.5	95	268.6	2.1
(August'05) I	45	350	29.7	23.0	95	012.9	5.3
II	52	322	30.0	22.9	95	103.3	5.3
III	59	207	30.9	23.5	95	003.8	7.7
IV	66	117	31.1	24.2	95	002.3	6.1
(September'05)I	73	68	28.5	23.6	86	208.7	1.3
II	80	50	28.4	23.3	96	182.8	6.3
III	87	26	30.9	23.7	94	021.1	1.6
Rabi,05 (October'05) III	10	220	30.9	23.7	94	021.1	3.5
IV	17	368	30.8	24.0	94	015.5	4.1
(November'05)I	24	550	31.8	23.2	95	070.2	4.2
II	31	430	31.3	21.8	95	053.6	5.0
III	38	320	30.9	21.8	91	000.3	4.7
IV	45	250	32.8	22.3	87	000.0	7.8
(December'05)I	52	150	32.2	21.7	93	112.6	6.8
II	59	50	31.5	22.4	89	000.3	6.2
III	66	22	33.0	20.7	94	000.0	8.8
IV	73	5	32.0	18.5	91	000.0	9.4

DAT : Days after transplanting , Max. Temp: Maximum temperature, Min. Temp: Minimum temperature, RH: Relative humidity, RF: Rainfall, SS: Sunshine hours was 32.0°C with 91 per cent relative humidity. There was no rainfall and sunshine was 9.4 hours during the lean period of field population of *L. pygmaea*. A minimum temperature of 22.5°C to 23.2°C and relative humidity 95 per cent were observed during the peak population in both Kharif and Rabi seasons.

Correlation analysis (Table 17) of beetle population and per cent damaged leaves with the weather parameters showed that there was a negative correlation with regard to maximum temperature and sunshine hours (respective correlation values -0.281 and -0.400). A positive correlation of blue beetle population and percent damaged leaves with minimum temperature and relative humidity was observed.There was no significant correlation between the average rainfall received and the beetle population and their damage.

4.4 NATURE OF ATTACK AND INTENSITY OF DAMAGE

Both grubs and adults of *L. pygmaea* fed on rice leaves by scraping the green tissues from the upper surface leading to longitudinal white streaks on them (Plate 22 and 23). The feeding of grub resulted in inward rolling of leaf and even 6-7 grubs were seen feeding on a single leaf. In adult feeding rolling of leaf was not observed. The damage of blue beetle resembled the attack of leaf folder except the absence of any webbing of leaves (Plate 24).

Regarding the intensity of damage by *L. pygmaea*, the grub stage caused highest damage followed by adult female and male beetles (Table 18). The grub caused damage from 35.72 to 67.09 per cent with a mean of 39.54 per cent in Jyothi and 29.76 to 57.55 per cent with a mean of 30.70 per cent in Aiswarya respectively. Highest damage due to grub was observed at 9 days after release in both Jyothi and Aiswarya. Adult females produced highest damage at 12 days after release in both the varieties (30.95 and 28.27 per cent). Male beetles incurred 15.58 and 11.23 per cent

Table 17. Correlation of rice blue beetle population with weather parameters

Serial No.	Particulars	Correlation coefficient
1	Beetle population and average maximum temperature	-0.281
2	Beetle population and average minimum temperature	0.244
3	Beetle population and average relative humidity	0.388
4	Beetle population and average rainfall	0.155*
5	Beetle population and average sunshine hours	-0.400
6	Per cent damaged leaves and average maximum temperature	-0.271
7	Per cent damaged leaves and average minimum temperature	0.211
8	Per cent damaged leaves and average relative humidity	0.323
9	Per cent damaged leaves and average rainfall	0.119*
10	Per cent damaged leaves and average sunshine hours	-0.369

* Not-significant

Plate 22. Leaf scrapping by grubs of blue beetle

Plate 23. Leaf scrapping by adults

Plate 24. Comparison of leaf damage by blue beetle and leaf folder

Plate 25. Plants severly damaged by blue beetle

Table 18. Intensity of feeding by *L. pygmaea* on Jyothi and Aiswarya

Variety	Stage of the beetle	Per cent damaged leaves per hill				Mean (Per cent)
		Days after release				
		3	6	9	12	
Jyothi	Grub	35.72	55.35	67.09	0.00	39.54
	Adult female	14.58	20.47	28.27	30.95	23.57
	Adult male	8.73	11.05	13.65	15.58	12.25
Aiswarya	Grub	29.76	35.49	57.55	0.00	30.70
	Adult female	7.95	17.27	25.17	28.27	19.67
	Adult male	3.84	6.76	10.47	11.23	8.08

Table 19. Leaf area consumed by different stages of *L. pygmaea*

Serial No.	**Stages of the beetle**	**Mean leaf area fed by different stages (mm^2)**	
		Jyothi	**Aiswarya**
1	Grub	3.82	2.58
2	Adult (Female)	1.04	0.60
3	Adult (Male)	0.70	0.34

leaf damage in Jyothi and Aiswarya respectively. The mean percent damage by grub, female and male beetles were 23.57 and 12.25 in Jyothi while in Aiswarya the values were 19.67 and 8.08 resectively.

Leaf area consumption studies by graphical method also indicated similar results. Leaf area consumption by *L. pygmaea* was more in Jyothi than in Aiswarya (Table 19). The grub consumed highest leaf area of 3.82 mm^2 in Jyothi and 2.58 mm^2 in Aiswarya. Adult female beetle consumed leaf area of 0.6 mm^2 to 1.04 mm^2, while the male feeding ranged from 0.34 to 0.70mm^2 of the leaf. The cumulative consumption due to grub and male, female beetle was 5.56 mm^2 leaf area in Jyothi and 3.52 mm^2 in Aiswarya.

4.5 EXTENT OF DAMAGE DURING DIFFERENT GROWTH STAGES OF RICE

Early tillering stage of rice was found to be the most susceptible stage for the infestation of blue beetle resulting in maximum damage in both Kharif and Rabi seasons (Table 20). High damage scores of '7' and '9' were observed in the Kharif and Rabi, 2005 seasons respectively. The maximum damage during this stage was 68.54 and 75.32 per cent in Kharif and Rabi'05 respectively and thereafter the damage was found to be reduced.

Seedling stage recorded the mean damage of 60.40 (score '7') and 35.24 per cent (score '5') in Kharif and Rabi seasons respectively. Higher damage occurred during vegetative growth stages. Infestation during reproductive stages of panicle intiation, booting and flowering stages was less ranging from 10.55 to 20.93 and 1.62 to 16.42 per cent in Kharif and Rabi seasons respectively

Table 20. Extent of damage by *L. pygmaea* during different growth stages of rice

Growth stage	DAS	Kharif 2005		Rabi 2005	
		Mean damaged leaves per hill (Per cent)	Damage rating (score)	Mean damaged leaves per hill (Per cent)	Score
Seedling	3-21	60.40	7	35.24	5
Early tillering	22-32	68.54	7	75.32	9
Maximum tillering	33-48	40.70	5	59.94	7
Panicle intiation	49-60	20.93	3	16.40	3
Booting	61-70	17.70	3	8.25	1
Flowering	71-80	10.55	3	1.62	1

DAS : Days after sowing
Score 0 = 0, 1 = 1-10%, 3= 11-25%, 5=26-50%, 7=51-75%, 9= 75%
*** Each value is the mean of 20 hills**

4.6 INFLUENCE OF METHODS OF CULTIVATION ON THE INCIDENCE OF *L.pygmaea*

4.6.1 Incidence of *L.pygmaea* in direct and transplanted rice (variety Jyothi)

Results of the study on the influence of methods of rice cultivation *viz.,* direct seeding and transplanting on the incidence of *L. pygmaea* revealed that transplanted rice suffered more damage than direct seeded in both the seasons of Kharif and Rabi, 2005 (Plate 25).

The leaf damage in Jyothi (Table 21) was observed to be lower in direct seeded method than in transplanted method during different stages of crop growth in both Kharif and Rabi seasons. In Jyothi, during seedling stage (10-17 DAT), transplanted rice suffered 60.40 per cent leaf damage in Kharif, while direct seeded rice suffered only 10.18 per cent, while it was respectively 35.24 and 20.30 per cent in Rabi seasons. Highest leaf damage was observed in early tillering stage in both direct and transplanted rice with scores of '5' and '9' in both Kharif and Rabi seasons. The leaf damage at this stage was 68.54 per cent in transplanted while it was 45.07 per cent in direct seeded rice in Kharif. The corresponding values in transplanted and direct seeded methods were 75.32 per cent and 31.51 per cent respectively during Rabi season. The leaf damage gradually declined towards maximum tillering stage and lowest leaf damage was observed at booting stage (66-73 DAT) with 15.16 per cent in transplanted while it was 6.86 in direct seeded rice (71-80 DAS) in Kharif season. In Rabi season, damage was 5.74 in transplanted while it was 'nil' damage in direct seeded rice.

4.6.2 Incidence of *L. pygmaea* in direct and transplanted rice (variety Aiswarya)

A trend similar to Jyothi was observed in Aiswarya also, where transplanted rice suffered more leaf damage than direct seeded rice in both Kharif and Rabi seasons (Table 22). During seedling stage (10-17 DAT) the per cent leaf damage was 37.60 in

Table 21. Effect of methods of cultivation on the incidence of *L. pygmaea* in rice (Variety Jyothi) during Kharif and Rabi '2005

DAS	Direct seeded rice				DAT	Transplanted rice			
	Mean damaged leaves per hill (Per cent)		Damage rating (score)			Mean damaged leaves per hill (Per cent)		Damage rating (score)	
	Kharif	Rabi	Kharif	Rabi		Kharif	Rabi	Kharif	Rabi
15	10.18	20.30	1	3	10-17	60.40	35.24	7	5
22-36	45.07	31.51	5	5	24-31	68.54	75.32	7	9
43-50	31.13	6.99	5	1	38-45	40.70	59.94	5	7
57-64	13.81	1.90	3	1	52-59	20.93	16.40	3	3
71-80	6.86	0	1	0	66-73	15.16	5.74	3	1
80-87	0	0	0		80-87	6.00	0	1	0

DAS = Days after sowing, DAT = Days after transplanting
Score 0 = 0, 1 = 1-10%, 3= 10-25%, 5=25-50%, 7=50-75%, 9= >75%

Table 22. Effect of methods of cultivation on the incidence of *L. pygmaea* in rice (Variety Aiswarya) during Kharif and Rabi '2005

DAS	Direct seeded rice				DAT	Transplanted rice			
	Mean damaged leaves per hill (Per cent)		Damage rating (score)			Mean damaged leaves per hill (Per cent)		Damage rating (score)	
	Kharif	Rabi	Kharif	Rabi		Kharif	Rabi	Kharif	Rabi
15	13.44	12.50	3	1	10-17	37.60	24.41	5	3
22-36	29.57	19.57	5	5	24-31	46.44	36.15	5	5
43-50	14.98	5.50	3	1	38-45	23.54	17.24	5	3
57-64	6.22	0	1	0	52-59	12.90	2.67	3	1
71-80	0	0	0	0	66-73	11.58	0	3	0

DAS = Days after sowing, DAT = Days after transplanting,
Score 0 = 0, 1 = 1-10%, 3= 10-25%, 5=25-50%, 7=50-75%, 9= >75%

transplanted and 13.44 in direct seeded rice (15 DAS) in Kharif season, while in Rabi the leaf damage was 24.41 and 12.50 per cent in transplanted and direct seeding respectively. The highest leaf damage (Score of '5') was observed during early tillering stage (46.44 per cent in transplanted and 29.57 per cent in direct seeded rice) in Kharif season, while in Rabi, the respective values were 36.15 and 19.57 per cent. The leaf damage gradually declined thereafter during maximum tillering stage and reached minimum during booting stage with 12.90 per cent in transplanted (52-59 DAT) and 6.22 per cent in direct seeeded rice (59-64 DAS) in Kharif season and it was 2.67 and '0' in transplanted and direct seeded rice respectively in Rabi seasons. Damage was less in direct seeded method compared to transplanted at all stages of crop growth.

4.7 INTEGRATED PEST MANAGEMENT METHODS

4.7.1 Host Plant Resistance

4.7.1.1 Screening of varieties / cultures to identify resistant sources against blue beetle

A total of 106 rice varieties / entries were tested for field resistance to *L. pygmaea* and none of them was found to be resistant (Table 23). Moderate resistance was observed in nine Pattambi traditional varieties *viz.*, Ptb.3, Ptb.4, Ptb.7, Ptb.9, Ptb.8, Ptb.19, Ptb.20, Ptb.25, Ptb.26 and a short duration high yielding variety of Mannuthy (Hraswa) with a damage score of '3. Seven Moncompu varieties (MO 4, MO 5, MO 7, MO 8, MO 9, MO 10, MO 20), 19 Pattambi traditional varieties (Ptb.2, Ptb.6, Ptb.8, Ptb.10, Ptb.12, Ptb.13, Ptb.14, Ptb.16, Ptb.21, Ptb.22, Ptb.23, Ptb.24, Ptb.27, Ptb.28, Ptb.30, Ptb.31, Ptb.32, Ptb.33, Ptb.34), 11 Pattambi high yielding varieties (Ptb.35, Ptb.37, Ptb. 38, Ptb.43, Ptb.44, Ptb.47, Ptb.48, Ptb.49, Ptb.51, Ptb.52, Ptb.54), 10 DRR cultures (IET 18206, IET 18716, IET 18717, IET 18784, IET 18746, IET 18892, IET 18917, IET 18924, IET 18946, IET 18948) and four Kayamkulam varieties (KYLM 2, KYLM 4, KYLM 5, KYLM 6) were moderately

Table 23. Reaction of different rice varieties / entries against the blue beetle

Sl. No.	Varieties/ Cultures	Damaged hills (%)	Damaged leaves per hill (%)	Damage Score	Reaction
		Min. – Max.	Min. – Max.		
1	Ahalya (Cul 10-15)	55 - 80	31.33 - 57.50	7	S
2	Hraswa (Cul24-20)	40 - 60	12.50 - 24.36	3	MR
3	Bhadra (MO 4)	50 - 85	10.75 - 31.40	5	MS
4	Asha (MO 5)	50 - 85	10.00 - 39.13	5	MS
5.	Pavizham (MO 6)	50 - 80	15.60 - 52.27	7	S
6	Karthika (MO 7)	45 - 70	23.40 - 45.12	5	MS
7	Aruna (MO 8)	40 - 80	4.88 - 45.21	5	MS
8	Makom (MO 9)	65 - 75	23.53 - 35.60	5	MS
9	Remya (MO 10)	50 - 75	10.22 - 46.84	5	MS
10	Kanakom (MO 11)	55 - 80	16.95 - 56.98	7	S
11	Ranjini (MO 12)	65 - 90	37.63 - 80.21	9	HS
12	Pavithra (MO 13)	70 - 90	31.52 - 52.08	7	S
13	Panchami (MO 14)	65 - 80	42.11 - 69.41	7	S
14	Ramanika (MO 15)	75 - 100	31.76 - 61.84	7	S
15	Uma (MO 16)	65 - 85	40.28 - 61.68	7	S
16	Revathy (MO 17)	45 - 85	18.75 - 62.80	7	S
17	Karishma (MO 18)	45 - 70	11.71 - 62.07	7	S
18	Krishnanjana(MO 19)	65 - 95	41.30 - 69.81	7	S
19	Gowri (MO 20)	45 - 85	10.00 - 40.82	5	MS
20	Aryan (Ptb.1)	30 - 65	18.07 - 59.26	7	S
21	Ponnaryan (Ptb.2)	50 - 75	4.13 - 46.43	5	MS
22	Eravanpandy (Ptb.3)	35 - 60	6.20 - 20.29	3	MR
23	Vellari (Ptb.4)	10 - 45	4.17 - 23.08	3	MR
24	Velutharikayama (Ptb.5)	20 - 45	0.86 - 69.38	7	S
25	Athikkiraya (Ptb.6)	20 - 65	4.62 - 35.15	5	MS
26	Parambuvattan (Ptb.7)	25 - 55	10.98 - 16.56	3	MR
27	Chuvannari (Ptb.8)	35 - 75	10.61 - 36.52	5	MS
28	Thavalakannan (Ptb.9)	30-60	6.76-23.01	3	MR
29	Thekkancheera (Ptb.10)	10 - 40	14.96 - 36.30	5	MS
30	Halliga (Ptb.11)	Seeds not available			
31	Chitteni (Ptb.12)	50 - 70	6.82 - 37.50	5	MS
32	Kayama (Ptb.13)	60 - 75	26.61 - 41.38	5	MS
33	Maskathi (Ptb.14)	30 - 65	11.54 - 33.25	5	MS
34	Kavunginpoothala Ptb.15)	25 - 85	25.85 - 61.39	7	S
35	Kavunginpoothala (Ptb.16)	40 - 70	5.47 - 37.61	5	MS
36	Jedduhalliga (Ptb.17)	25 - 50	3.03 - 53.01	7	S
37	Eravapandy (Ptb.18)	20 - 45	2.82 - 21.48	3	MR

Sl. No.	Varieties/ Cultures	Damaged hills (%)	Damaged leaves per hill (%)	Damage Score	Reaction
		Min. – Max.	Min. – Max.		
38	Athikraya (Ptb.19)	15 - 40	0.66 - 16.79	3	MR
39	Vadakkanchitteni (Ptb.20)	15 - 50	3.48 - 22.05	3	MR
40	Thekkan (Ptb.21)	40 - 70	17.36 - 39.34	5	MS
41	Veluthavattan (Ptb.22)	45 - 80	17.32 - 38.89	5	MS
42	Cheriya Aryan (Ptb.23)	45 - 60	12.82 -48.89	5	MS
43	Chuvannavattan (Ptb.24)	15 - 75	3.26 - 30.77	5	MS
44	Thonnuran (Ptb.25)	25 - 60	16.20 - 24.81	3	MR
45	Chenkayamma (Ptb.26)	15 - 45	4.83 - 15.38	3	MR
46	Kodiyan (Ptb.27)	35 - 70	4.84 - 34.83	5	MS
47	Kattamodan (Ptb.28)	35 - 70	14.29 - 29.57	5	MS
48	Karuthamodan (Ptb.29)	50 - 85	30.93 - 63.16	7	S
49	Chuvannamodan (Ptb.30)	40 - 65	24.11 - 39.62	5	MS
50	Elappapoochampan (Ptb.31)	50 - 70	28.38 - 36.56	5	MS
51	Aruvakkari (Ptb.32)	40 - 70	19.17 - 42.67	5	MS
52	Arikrayi (Ptb.33)	20 - 70	9.01 - 29.67	5	MS
53	Valliyachampan (Ptb.34)	25 - 65	3.15 - 31.51	5	MS
54	Annapoorna (Ptb.35)	35 - 65	11.58 - 37.04	5	MS
55	Rohini (Ptb.36)	45 - 60	18.95 - 57.33	7	S
56	Aswathy (Ptb.37)	45 - 70	24.80 - 49.32	5	MS
57	Triveni (Ptb.38)	40 - 80	10.08 - 50.00	5	MS
58	Jyothi (Ptb.39)	45 - 80	8.70 - 81.93	9	HS
59	Sabari (Ptb.40)	55 - 75	29.84 - 64.13	7	S
60.	Bharathy (Ptb.41)	60 - 85	47.11 - 79.31	9	HS
61	Suvarna Modan (Ptb.42)	20 -70	9.80 - 57.80	7	S
62	Swarnaprabha (Ptb.43)	35 - 75	8.28 - 33.16	5	MS
63	Reshmi (Ptb.44)	35 - 70	4.14 - 39.25	5	MS
64	Matta Triveni (Ptb.45)	30 - 45	6.00 - 55.84	7	S
65	Jayathy (Ptb.46)	50 - 75	11.45 - 58.24	7	S
66	Neeraja (Ptb.47)	25 - 60	4.97 - 40.60	5	MS
67	Nila (Ptb.48)	50 - 85	7.14 - 37.74	5	MS
68	Kairali (Ptb.49)	55 - 75	28.13 - 46.51	5	MS
69	Kanchana (Ptb.50)	60 - 70	17.99 - 57.73	7	S
70	Aathira (Ptb.51)	50 - 70	19.54 - 38.10	5	MS
71	Aishwarya (Ptb.52)	35 - 65	8.28 - 37.86	5	MS
72	Mangalamashuri (Ptb.53)	35 - 60	9.32 - 65.12	7	S
73	Karuna (Ptb.54)	35 - 50	5.53 - 25.15	5	MS
74	Harsha (Ptb.55)	60 - 70	15.63 - 55.14	7	S
75	Varsha (Ptb.56)	35 - 60	10.10 - 61.11	7	S
76	Swetha (Ptb.57)	60 - 80	17.21 - 58.11	7	S

-Contd.-

Sl. No.	Varieties/ Cultures	Damaged hills (%)	Damaged leaves per hill (%)	Damage Score	Reaction
		Min. – Max.	Min. – Max.		
77	Ptb-2005-1 (F5-11-3)	35 - 55	9.01 - 49.23	5	MS
78	Ptb-2005-2 (F5-17-1-1)	30 - 70	9.92 - 49.33	5	MS
79	Ptb-2005-3(F5-23-1)	60 - 95	17.22 - 61.45	7	S
80	Ptb-2005-4 (F5-23-2)	75 - 90	25.17 - 64.79	7	S
81.	Ptb-2005-5 (F6-11-1-1)	80 - 85	26.36 - 63.64	7	S
82	Ptb-2005-14 (C3-2-(KM)	60 - 80	37.23 - 60.42	7	S
83	Ptb-2005-15(C3-2-49-H-11)	30 - 60	10.47 - 34.91	5	MS
84	WR-3-2-1 (IET18206)	65 - 75	19.70 - 50.00	5	MS
85	NDR-1091-5 (IET18716)	60 - 70	20.18 - 34.78	5	MS
86	RR 363-1 (IET18717)	55 - 70	14.29 - 34.91	5	MS
87	NDR 9830109 (IET18784)	60 - 65	7.75 - 32.31	5	MS
88	IR 72014-11-NDR-35 (IET18476)	45 - 60	7.14 - 37.50	5	MS
89	CSAR 442 (IET18892)	60 - 75	23.53 - 41.24	5	MS
90	RGL 11694 (IET18895)	60 - 85	24.68 - 54.67	7	S
91	DBS 13-1-AR (IET18904)	55 - 70	21.01 - 54.26	7	S
92	HKR 01-62 (IET18917)	50 - 60	30.95 – 50.00	5	MS
93	RAU 1415-9 (IET18924)	50 - 60	7.43 - 48.50	5	MS
94	UTR 57(IET17895)	45 - 85	17.36 - 81.01	9	HS
95	CR 749-20-2-18-15 IET18946)	55 - 90	16.28 - 43.88	5	MS
96	NDR-2069 (IET18948)	55 - 70	14.55 - 44.68	5	MS
97	CN1163-7-9-1 (IET18183)	30 - 70	14.55 - 61.54	7	S
98	Kayamkulam-1 (Lakshmi)	50 - 75	5.51 - 58.46	7	S
99	Kayamkulam-2 (Bhagya)	65 - 70	26.04 - 46.30	5	MS
100	Kayamkulam-3 (Onam)	55 - 70	14.01 - 51.09	7	S
101	Kayamkulam-4 (Dhanya)	20 - 55	6.16 - 42.17	5	MS
102	Kayamkulam-5 (Dhanu)	35 - 60	3.39 - 41.49	5	MS
103	Kayamkulam-6 (Sagara)	35 - 60	2.90 - 36.45	5	MS
104	Kayamkulam-7 (Chingam)	20 - 75	2.94 - 61.54	7	S
105	Kunjukunju (Priya)	20-50	13.33-53.66	7	S
106	Kunjukunju (Varna)	50-80	52.67-78.30	9	HS

* Each value is from the observations recorded during Kharif and Rabi'05

* Score value is based on the highest value of leaf damage recorded during Kharif and Rabi'05

* MR : Moderately resistant, MS : Moderately Susceptible, S : Susceptible, HS : Highly susceptible

susceptible to blue beetle (Score 5). Susceptible varieties (Score 7) included nine varieties of Moncompu (MO 6, MO 11, MO 13, MO 14, MO 15, MO 16, MO 17, MO 18, MO 19), five Pattambi traditional varieties (Ptb.1, Ptb.5, Ptb.15, Ptb.17, Ptb.29), 10 Pattambi high yielding varieties (Ptb.36, Ptb.40, Ptb.42, Ptb.45, Ptb.46, Ptb.50, Ptb.53, Ptb.55, Ptb.56, Ptb.57), three DRR cultures (IET 18895, IET 18904, IET 18183) and two Kayamkulam varieties (KYLM 3, KYLM 7) and a variety of Mannuthy (Ahalya) and Kunjukunju variety (Priya).

A Moncompu variety (MO 12), a DRR culture (IET 17895), two Pattambi high yielding varieties (Ptb.39 (Jyothi), Ptb.41 (Bharathy) and Kunjukunju variety (Varna) were found to be highly susceptible to the blue beetle with a score of '9'. Jyothi, the most popular variety used in Kerala was thus found to be highly susceptible to *L. pygmaea*. Almost all national rice entries were severly attacked by blue beetle (Plate 26).

4.7.2 Cultural methods

4.7.2.1 Study of alternative weed hosts

Ten weed plants commonly seen growing in the rice fields and bunds were studied in order to test whether they served as alternative hosts of *L. pygmaea*. These plants were identified by their local names, common names, botanical names and families (Table 24). Among these weeds, five plants belonged to the family Poaceae, two from the family Limnocharitaceae, one each from Cyperaceae, Pontederiaceae and Lythraceae. Rice blue beetles were observed on all these plants. But feeding and oviposition were observed only on *Panicum repens* and *Isachne miliacea* (Plate 27 and 28). The beetle laid 12-15 eggs on *P. repens* and 5-8 eggs on *I. miliacea*. All the eggs laid on *P. repens* hatched out while there was no hatchability of eggs on *I. miliacea*.

The beetle completed its full cycle on *P. repens* (Plate 29, 30 and 31). Biology study of *L. pygmaea* on *P. repens* showed that eggs hatched into grubs within 2-3 days (Table 25). Grubs had five larval instars with 1-2 days for each instar. Adult beetles

Table 24. Suitability of weeds as alternative hosts of *L. pygmaea*

Local name	Common name	Botanical name	Family	No. of eggs laid	Egg hatchability (Per cent)
Inchipullu	Torpedo grass	*Panicum repens*	Poaceae	12-15	100
Varinellu	Wild rice	*Oryza rufipogon*	Poaceae	-	-
Naringa	Not known	*Isachne miliacea*	Poaceae	5-8	Nil
Polla	-do-	*Sacciolepis interrupta*	Poaceae	-	-
Kavada	Jungle rice /Awnless barnyard grass	*Echinochloa colona*	Poaceae	-	-
Mungu	Globe finger rush	*Fimbristylis miliacea*	Cyperceae	-	-
Neelolppalam	Pickerel weed	*Monochoria vaginalis*	Pontederiaceae	-	-
Nagappola	not known	*Limnocharis flava*	Limnocharitaceae	-	-
Kulavazha	Water hyacinth/ Lilac devil	*Eicchornia crassipes*	Limnocharitaceae	-	-
Nellicheera	Blistering ammania	*Ammania baccifera*	Lythraceae	-	-

Plate 26. Severe damage of national rice entries by blue beetle

Plate 27. Feeding of blue beetle on *Isachne miliacea*

Plate 28. Inchipullu, *Panicum repens* – alternative host

Plate 29. Egg laying in *Panicum repens*

Plate 30. Grubs feeding on *Panicum repens*

Plate 31. Pupation and adult beetle feeding on *Panicum repens*

Table 25. Biology of *L. pygmaea* on the weed *Panicum repens*

Replication No.	Duration of different stages of beetle in days									
	Egg	Larval instars					Pupa	Total life cycle	Longevity of Adults	
		I	II	III	IV	V			M	F
1	3	1	1	1	1	2	3	12	22	20
2	2	1	1	1	1	2	3	11	25	20
3	2	1	1	2	1	2	2	11	30	25
4	2	2	2	1	1	1	3	12	45	22
5	2	1	2	1	1	2	2	11	45	23
6	3	1	1	2	2	2	2	13	60	21
7	3	1	1	1	1	2	3	12	50	28
8	2	1	1	1	1	1	3	10	45	27
9	2	1	1	1	1	2	3	11	32	29
10	2	1	1	1	1	2	4	12	30	22
Mean ± SD	**2.3 ± 0.48**	**1.1 ± 0.32**	**1.2 ± 0.42**	**1.2 ± 0.42**	**1.1 ± 0.32**	**1.8 ± 0.42**	**2.8 ± 0.63**	**11.5 ± 0.85**	**38.4 ± 12.30**	**23.7 ± 3.34**

* M = Male, F = Female

emerged out after a pupal period of 2-4 days and the full life cycle was completed in 10-13 days (mean = 11.5 days). On *P. repens* males lived longer (38.4 days) than females with a longevity of 23.7 days.

4.7.2.1.1 Comparative biology of L. pygmaea on rice and weed plant, P. repens

A comparative study of the biology of *L. pygmaea* on Jyothi, Aiswarya and *Panicum repens* indicated that the life cycle of rice blue beetle was shortest with 11.5 days on *P. repens* followed by Aiswarya and Jyothi (Table 26). Fecundity was also lowest on the weed as compared to rice. The longevity of female beetle was 23.7 days on *P. repens* while it was 24.9 days on rice Jyothi. Male life span was highest (40.9 days) on Jyothi followed by *P. repens* (38.4) and Aiswarya (36.7). Males lived longer than females on both rice and *P. repens.*

4.7.2.2 Effect of plant spacing and soil application of oil cakes on the pest incidence

Pooled analysis of two seasons results (Table 27) on the effect of plant spacing indicated that incidence of *L. pygmaea* was significantly reduced in closer spacing of 10x15 cm and 10x10 cm. Infestation was significantly higher in wide spacing (20x15 cm). Spacing of 10x10 cm was significantly superior over the other two spacings of 10x15cm and 20x15 cm in reducing the leaf damage, damaged hills and beetle population. Damage score was rated as '1' in 10x15 cm and 10x10 cm spacings, while it was '3' in wider spacing of 20x15 cm.

Data (Table 28) on the effect of application of neem cake, castor cake and pungam cake in the field against *L. pygmaea* showed that there was no significant difference between these cakes on the leaf damage, damaged hills and beetle population at 10, 20 and 30 days after transplanting. However, the beetle population in the treatment with pungam cake was significantly lower than the other treatments of castor and neem cake at 20 days after transplanting. Neem cake treated plots recorded

Table 26. Comparative biology of *L. pygmaea* on Jyothi, Aiswarya and *Panicum repens*

Host	Fecundity	Egg period (days)	Larva period (days)	Pupa period (days)	Total life cycle (days)	Longevity (days)	
						Male	Female
Jyothi	16.8	3.4	8.2	3.2	14.8	40.9	24.9
Aiswarya	14.3	3.4	8.2	2.9	13.8	36.7	24.7
Panicum repens	13.5	2.3	6.4	2.8	11.5	38.4	23.7

* Each value is a mean of 10 replications

Table 27. Effect of plant spacing on the incidence of *L. pygmaea* (Pooled analysis of Kharif and Rabi, 2005)

Treatment Spacing (cm)	Mean damaged leaves per 10 hills (Per cent)			Average number of beetles per 10 hills			Damaged hills per plot (Per cent)		Score
	Days after Transplanting			Days after Transplanting			Days after Transplanting		
	10	20	30	10	20	30	20	30	
20 X 15	13.08 (0.37^{b})	13.91 (0.38^{b})	9.22 (0.31^{a})	15.06 (1.11^{b})	10.11 (0.98^{b})	17.17 (1.21^{b})	6.52 (0.26^{b})	6.54 (0.26^{b})	3
10 X 15	9.15 (0.30^{ab})	7.46* (0.27^{a})	9.46 (0.31^{a})	9.61 (0.93^{ab})	4.11* (0.60^{a})	12.72 (1.08^{ab})	5.09 (0.23^{b})	2.70* (0.16^{a})	1
10 X 10	5.36* (0.23^{a})	6.12* (0.24^{a})	8.16 (0.29^{a})	6.11* (0.66^{a})	3.28* (0.50^{a})	10.06* (0.98^{a})	2.97* (0.17^{a})	1.66* (0.13^{a})	1

* Figures in parentheses are arscine and logarithmic transformed values
* Figures followed by different letters are significantly different at p=0.05

Table 28. Effect of oilcakes on the incidence of *L. pygmaea* ((Pooled analysis of Kharif and Rabi, 2005)

Treatment (Cakes @ 150 kg/ha)	Mean damaged leaves per 10 hills (Per cent)			Average number of beetles per 10 hills			Damaged hills per plot (Per cent)		Score
	Days after Transplanting			Days after Transplanting			Days after Transplanting		
	10	20	30	10	20	30	20	30	
Neem cake	10.70 (0.32[a])	10.13 (0.31[a])	9.20 (0.31[a])	10.61 (0.97[a])	5.61 (0.71[ab])	11.56 (1.03[a])	5.70 (0.24[a])	3.86 (0.19[a])	3
Castor cake	8.30 (0.28[a])	9.60 (0.31[a])	8.87 (0.30[a])	10.72 (0.81[a])	7.39 (0.77[b])	14.11 (1.11[a])	4.40 (0.20[a])	3.71 (0.19[a])	1
Pungam cake	8.60 (0.29[a])	7.77 (0.28[a])	8.78 (0.30[a])	9.44 (0.92[a])	4.50 (0.60[a])	14.28 (1.14[a])	4.48 (0.21[a])	3.32 (0.18[a])	1

* Figures in parentheses are arscine and logarithmic transformed values

* Figures followed by different letters are significantly different at p=0.05

highest damage (Score '3'), while castor cake and pungam cake treatments showed lowest damage score of '1'.

The results of interaction effect of spacings and oilcakes (Table 29a) indicated that the treatments 10 x10 cm spacing with neem cake (20 DAT), castor cake (10 and 20 DAT), pungam cake (10 and 20 DAT) were significantly superior in reducing leaf damage by *L. pygmaea*. Lowest leaf damage (3.9 per cent) was observed in 10 x 10 cm spacing with castor cake at 10 DAT.

Interaction effect of spacing with cakes on beetle population reduction was found to be significant in 10 x 10 cm with castor cake (3.00 per cent) at 20 DAT (Table 29b). At 30 days after transplanting neem cake and 10x10 cm^2recorded significant lowest population (8.00) and pungam cake 20x15 cm showed highest population (18.67).

The interaction effect of spacing 10 x 10 cm with neem cake, castor cake and pungam cake was significant in reducing hill damage at 10 and 20 days after transplanting (Table 29c). Significantly lower hill damage was also observed in the treatment of 10 x 15 cm spacing with neem cake (2.60 per cent), castor cake (2.95 per cent) and pungam cake (2.54 per cent) at 20 days after transplanting. Highest damage was found in the treatment of 20 x 15 cm spacing with all the three oil cakes of neem cake, castor cake and pungam cake.

4.7.3 BIOLOGICAL MANAGEMENT

4.7.3.1 Identification and study of the natural enemies of *L. pygmaea*

Blue beetle eggs were found to be parasitized in the field and such eggs were black in colour (Plate 32). The egg parasitoids emerged were identified as *Trichogramma* sp. (Trichogrammatidae) (Plate 33), *Telenomus* sp. (Scelionidae) (Plate 34) and *Tetrastichus* sp. (Eulophidae) (Plate 35). The eggs were found to be heavily parasitized towards the end of tillering stage of the crop, when the pest population was low (August-September) in the field. No parasitization was observed during the early

Table 29a. Effect of interaction between spacing and oilcakes on per cent leaf damage of *L. pygmaea*

Treatments	Neem cake			Castor cake			Pungam cake		
	Mean damaged leaves per 10 hills (Per cent)								
	Days after Transplanting								
	10	20	30	10	20	30	10	20	30
20 x 15 cm	14.80 (0.40^{g})	15.91 (0.41^{d})	10.13 (0.32^{a})	11.99 (0.35^{def})	14.89 (0.40^{d})	8.62 (0.30^{a})	12.47 (0.36^{f})	10.94 (0.34^{cd})	8.93 (0.30^{a})
10x15 cm	9.92 (0.31^{cde})	6.50 (0.26^{abc})	9.05 (0.30^{a})	8.99 (0.30^{cde})	8.87* (0.30^{ab})	9.94 (0.32^{a})	8.55 (0.29^{cde})	7.01* (0.26^{ab})	9.40 (0.31^{a})
10x10 cm	7.40 (0.26^{abc})	7.98* (0.27^{ab})	8.41 (0.29^{a})	3.90* (0.20^{a})	5.02* (0.23^{a})	8.06 (0.29^{a})	4.78* (0.22^{ab})	5.37* (0.23^{a})	8.01 (0.29^{a})

* Figures in parentheses are arscine transformed mean values
* Figures followed by different letters are significantly different at p=0.05

Table 29b. Effect of interaction between spacing and oilcakes on beetle population of *L. pygmaea*

Treatments	Neem cake			Castor cake			Pungam cake		
	Average number of beetles per 10 hills								
	Days after Transplanting								
	10	20	30	10	20	30	10	20	30
20 x 15 cm	16.67 (0.40^{g})	8.83 (0.93^{e})	14.83* (1.14^{ab})	17.83 (1.12^{b})	14.17 (1.15^{f})	18.00 (1.23^{b})	10.67 (0.91^{b})	7.33 (0.84^{cd})	18.67 (1.25^{b})
10x15 cm	8.17 (0.91^{b})	4.00* (0.60^{ab})	11.83* (1.05^{ab})	10.50* (0.88^{ab})	5.00 (0.68^{bc})	15.33* (1.17^{ab})	10.17 (1.00^{b})	3.33* (0.52^{ab})	11.00* (1.03^{ab})
10x10 cm	7.00* (0.78^{ab})	4.00* (0.60^{ab})	8.00* (0.89^{a})	3.83* (0.34^{a})	3.00* (0.47^{a})	9.00* (0.93^{ab})	7.50* (0.85^{ab})	2.83* (0.45^{a})	13.17* (1.12^{ab})

*Figures in parentheses are logarithmic transformed mean values
*Figures followed by different letters are significantly different at p=0.05

Table 29c.Effect of interaction between spacing and oilcakes on per cent hill damage of *L. pygmaea*

Treatments	Neem cake		Castor cake		Pungam cake	
	Damaged hills per plot (Per cent)					
	Days after Transplanting					
	10	20	10	20	10	20
20 x 15 cm	7.22 (0.27^{f})	7.44 (0.28^{b})	6.51 (0.26^{de})	6.39 (0.26^{b})	5.83 (0.24^{de})	5.80 (0.24^{b})
10x15 cm	5.70 (0.24^{de})	2.60* (0.16^{a})	4.88 (0.22^{cd})	2.95* (0.17^{a})	4.69 (0.22^{cd})	2.54* (0.16^{a})
10x10 cm	4.16 (0.20^{abc})	1.56* (0.12^{a})	1.82* (0.14^{a})	1.81* (0.13^{a})	2.92* (0.17^{ab})	1.63* (0.13^{a})

*Figures in parentheses are arscine transformed mean values,
*Figures followed by different letters are significantly different at $p = 0.05$

Plate 32. Parasitised eggs of blue beetle

Plate 33. *Trichogramma* Sp.

Plate 34.*Telenomus* sp.

Plate35. *Tetrastichus* Sp.

tillering stage of the crop, when the pest load was high. No predators were found in the field during the study period.

***4.7.3.2 Pathogenicity of Beauveria bassiana to** L. pygmaea*

Survey for the search of diseased blue beetles in rice fields resulted in the identification of *L. pygmaea* infected with *B. bassiana.* The body of adult beetle was found to be covered with white mycelial growth (Plate 36). In field conditions *B. bassiana* infected pupa turned black in colour (Plate 37). Bioassay studies conducted in the laboratory showed that the mortality of adults of *L. pygmaea* was dependent on spore concentration of *B. bassiana*. The different concentrations of blue beetle from 10^5 to 10^9 spores / ml resulted in 45 to 60 per cent mortality at 24 hours after treatment (Table 30).

The same concentration caused 55 to 80 per cent mortality at 48 hours after treatment, while the mortality was from 70 to 100 per cent at 72 hours after treatment. The cumulative mortality of rice blue beetle ranged from 56.67 to 80.00 per cent. The LC_{50} values for *B. bassiana* were found to be 9.97×10^6, 4.44×10^4, 8.84×10^3 spores / ml at of 24, 48 and 72 hours respectively. The LC_{50} value for cumulative mortality was 2.26×10^4 spores / ml.

4.7.3.3 Bioefficacy of entomopathogenic nematode, Heterorhabditis indica

Infection of rice blue beetle grub with the EPN, *Heterorhabditis indica* (Plate 38) indicated a change in colour to pink (Plate 39). Concentrations of 5 IJ's, 6 IJ's, 7 IJ's, 8 I J's and 9 IJ's per ml of *H. indica* tested against the grubs of rice blue beetle in the laboratory resulted in 40 to 85 per cent mortality at 24 hours after treatment (Table 31). The mortality was increased to 65-90 per cent when the exposure period was increased to 48 hours and 90-100 per cent mortality was observed at 72 hours after treatment. A concentration of 9 IJ's produced 85 per cent mortality at 24 hours after treament. The LC_{50} values at 24, 48 and 72 hours after treatment were 5.45, 3.74 and

Plate 36. Dead beetle covered by white mycelial growth of *Beauveria bas*

Plate 37. Pupa infected by *B.bassiana*

Table 30. Laboratory evaluation of *B. bassiana* against adult beetles of *L. pygmaea*

Treatments	Mortality (per cent)			Cumulative mortality
	Hours after treatment			
	24	48	72	
B. bassiana @10^5 spores / ml	45	55 (52.63)	70 (66.67)	56.67 (54.39)
B. bassiana @10^6 spores / ml	45	65 (63.16)	80 (77.78)	63.33 (61.40)
B. bassiana @10^7 spores / ml	50	60 (57.90)	90 (88.89)	66.67 (64.92)
B. bassiana @10^8 spores / ml	50	70 (68.42)	90 (88.89)	70 (68.42)
B. bassiana @10^9 spores / ml	60	80 (78.98)	100 (100)	80 (78.95)
Control	0	5	10	5.00
LC_{50}	9.97×10^6	4.44×10^4	8.84×10^3	2.26×10^4

* Figures in parentheses are corrected mortality by Abbott's formula

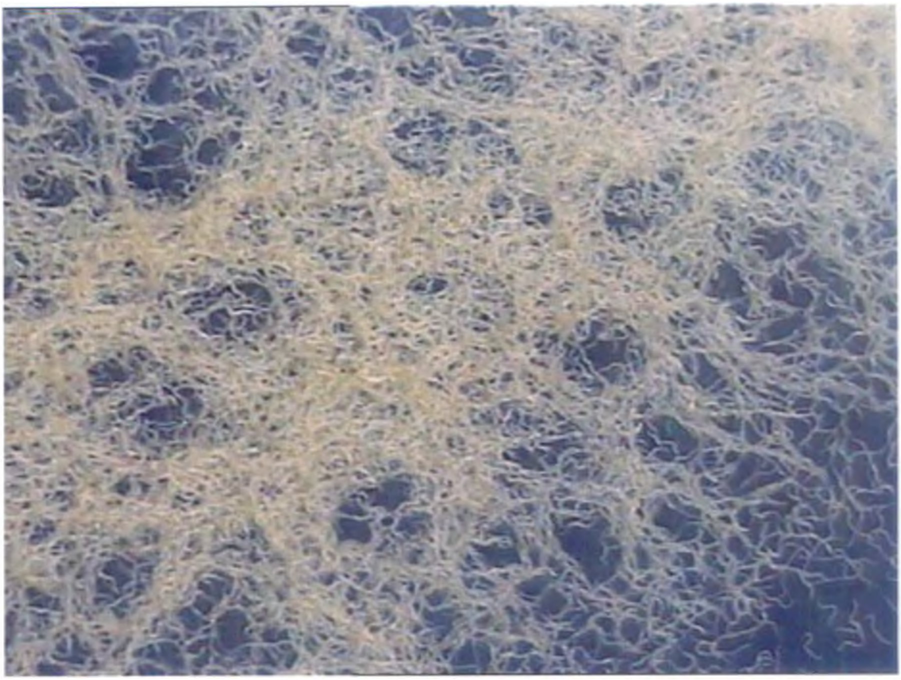


Plate 38. Entomopathogenic nematode, *Heterorhabditis indica*

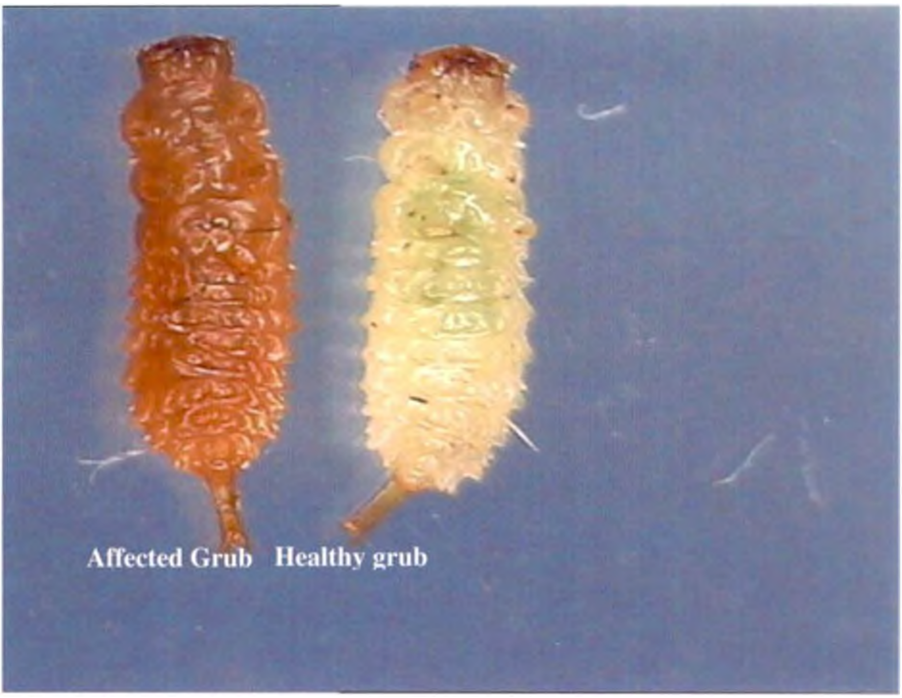


Plate 39. Healthy and infected grub

Table 31. Laboratory evaluation of *H. indica* against grubs of *L. pygmaea*

Treatments per ml	Mortality (%)			Cumulative mortality
	Hours after treatment			
	24	48	72	
H. indica @ 5 IJ's	40	65 (63.16)	90 (88.89)	66.67 (64.92)
H. indica @ 6 IJ's	65	80 (78.95)	95 (94.44)	80.00 (78.95)
H. indica @ 7 IJ's	65	85 (84.21)	100 (100)	83.33 (82.45)
H. indica @ 8 IJ's	80	85 (84.21)	100 (100)	88.33 (87.72)
H. indica @ 9 IJ's	85	90 (89.47)	100 (100)	91.67 (91.23)
Control	0	5	10	5.00
LD_{50}	5.45 IJ's	3.74 IJ's	3.72 IJ's	3.83 IJ's

IJ's : Infective juveniles

* Figures in parentheses are corrected mortality by Abbott's formula

3.72 IJ's respectively. The various tested concentration caused cumulative mortality of 66.67 to 91.67 per cent with a LC_{50} value of 3.83 IJ's.

4.7.4 CHEMICAL MANAGEMENT

4.7.4.1 Management of blue beetle by nursery treatment with granular insecticides

Effect of nursery treatment with granular insecticides against the infestation of *L. pygmaea* in the main field was studied during four seasons (Kharif and Rabi in 2004 & 2005).

Kharif seasons (2004 and 2005)

Leaf damage: Results of two Kharif seasons (Table 32a and 32b) indicated no significant differences among the treatments in reducing leaf damage at 10 days after transplanting. The leaf damage ranged from 6.36 to 12.65 per cent during 2004 and 2005. At 20 days after transplanting, cartap hydrochloride recorded significantly lowest damage of 8.15 and 7.60 per cent during 2004 and 2005 respectively and it was significantly superior over control in reducing leaf damage. Carbosulfan and cartap hydrochloride treatments were found to be on par. At 30 days after transplanting the leaf damage ranged from 6.90 to 13.12 per cent and there was no significant difference between treatments in both years.

Beetle population: There were no significant differences in blue beetle population among treatments at 10 days after transplanting during 2004 (Table 32b). However, in 2005, T1 (cartap hydrochloride) and T3 (fipronil) showed significantly lower beetle population. At 20 days after transplanting, all the insecticide treatments were on par during 2004 and 2005. At 30 days after transplanting, carbofuran showed significantly lower beetle population compared to other treatments in 2004. However in 2005, there were no significant differences among treatments in the reduction of beetle population.

Table 32 (a). Effect of granular insecticides on the leaf damage by blue beetle (Kharif 04& 05)

Treatments	Granular Insecticide (g a.i. / ha)	Mean damaged leaves / 10 hills (Per cent)					
		Days after transplanting					
		10		20		30	
		2004	2005	2004	2005	2004	2005
T1	Cartap hydrochloride (1000)	8.48 (0.29[a])	7.02 (0.26[a])	8.15 (0.28[a])	7.60 (0.27[a])	6.90 (0.26[a])	12.81 (0.36[a])
T2	Carbosulfan (1000)	9.10 (0.30[a])	6.96 (0.27[a])	8.65 (0.29[a])	12.01 (0.35[ab])	8.91 (0.29[a])	16.56 (0.41[a])
T3	Fipronil (100)	7.26 (0.27[a])	12.65 (0.36[a])	10.94 (0.33[ab])	16.85 (0.42[b])	8.67 (0.30[a])	19.44 (0.47[a])
T4	Phosphamidon (1000)	9.67 (0.31[a])	10.53 (0.33[a])	9.44 (0.31[ab])	12.15 (0.36[ab])	7.82 (0.28[a])	15.31 (0.40[a])
T5	Carbofuran (1000)	6.36 (0.24[a])	11.08 (0.34[a])	12.58 (0.36[ab])	10.78 (0.33[ab])	8.93 (0.30[a])	12.51 (0.36[a])
T6	Control	12.52 (0.36[a])	12.60 (0.36[a])	16.76 (0.42[b])	12.86 (0.36[ab])	13.04 (0.37[a])	13.12 (0.37[a])

* Figures in parentheses are angular transformed transformed values

* Figures followed by different letters are significantly different at p=0.05

Table 32 (b).Effect of granular insecticides on the population of blue beetle (Kharif 04& 05)

Treatments	Granular Insecticide (gm a.i. / ha)	Average beetle population/ 10 hills					
		Days after transplanting					
		10		20		30	
		2004	2005	2004	2005	2004	2005
T1	Cartap hydrochloride (1000)	40.00 (1.61^{a})	4.75 (0.60^{a})	36.75 (1.56^{a})	4.00 (0.60^{a})	23.00 (1.36^{ab})	4.45 (0.52^{a})
T2	Carbosulfan (1000)	51.00 (1.69^{a})	5.25 (0.70^{ab})	50.25 (1.64^{a})	4.50 (0.63^{a})	27.25 (1.34^{ab})	4.75 (0.56^{a})
T3	Fipronil (100)	48.75 (1.65^{a})	4.75 (0.65^{a})	68.25 (1.83^{a})	3.50 (0.46^{a})	23.25 (1.33^{ab})	4.00 (0.44^{a})
T4	Phospamidon (1000)	49.50 (1.68^{a})	8.50 (0.92^{b})	61.25 (1.77^{a})	7.00 (0.82^{a})	21.00 (1.24^{ab})	5.75 (0.67^{a})
T5	Carbofuran (1000)	47.00 (1.66^{a})	6.50 (0.81^{ab})	49.75 (1.63^{a})	5.50 (0.66^{a})	12.50 (0.99^{a})	2.75 (0.38^{a})
T6	Control	57.75 (1.76^{a})	8.75 (0.89^{b})	61.25 (1.78^{a})	5.25 (0.70^{a})	31.75 (1.50^{b})	3.00 (0.38^{a})

* Figures in parentheses are logarithmic transformed values

* Figures followed by different letters are significantly different at p=0.05

It is revealed from the results of two Kharif seasons that among the treatments, cartap hydrochloride was significantly effective in bringing about the reduction of leaf damage at 20 days after transplanting in 2004 and 2005 and beetle population at 10 days after transplanting in 2005.

Rabi seasons (2004 and 2005)

Leaf damage: Results of two Rabi seasons (Table 33 a and 33 b) revealed that cartap hydrochloride (10.82 per cent) and phosphamidon (11.54 per cent) were significantly superior to other treatments in reducing leaf damage at 10 days after transplanting during 2004. But in 2005, the leaf damage ranged from 15.00 to 17.11 per cent and all the treatments were on par. At 20 days after transplanting, there were no significant differences among treatments with leaf damage ranging from 3.22 to 7.74 per cent in 2004 whereas in 2005, cartap hydrochloride revealed significantly low damage (9.25 per cent) compared to 27.53 per cent damage in control. However, no significant differences were observed among cartap hydrochloride (9.25 per cent), carbofuran (13.00 per cent) and phosphamidon (13.48 per cent) in reducing leaf damage.

Hill damage: carbofuran (2.49 per cent) and cartap hydrochloride (2.52 per cent) were significantly effective over other treatments in showing low number of damaged hills (Table 33a). These two treatments were found to be on par during 2004, but in 2005 cartap hydrochloride showed lowest hill damage (3.54 per cent) and was significantly superior to rest of the treatments.

Beetle population: There were no significant difference in the beetle population among the treatments at 10 days after transplanting with population ranging from 29.00 to 38.00 beetles / 10 hills in 2004 (Table 33b). However, in 2005, beetle population was significantly lower in all the insecticide treatments (7.00- 11.00 beetles / 10 hills) showing their equal effectiveness compared to untreated control treatment (16.00 beetles / 10 hills). At 30 days after transplanting in 2004, cartap hydrochloride

Table 33 (a). Effect of granular insecticides on damage by rice blue beetle (Rabi 04& 05)

Treatments	Granular Insecticide (g a.i. / ha)	Mean damaged leaves/ 10 hills (Per cent)				Mean Damaged hills/plot (Per cent)	
		Days after transplanting					
		10		20		35	
		2004	2005	2004	2005	2004	2005
T1	Cartap hydrochloride (1000)	10.82 (0.33^{a})	15.00 (0.39^{a})	5.47 (0.22^{a})	9.25 (0.31^{a})	2.52 (0.16^{a})	3.54 (0.19^{a})
T2	Carbosulfan(1000)	13.14 (0.37^{ab})	15.87 (0.41^{a})	3.36 (0.18^{a})	17.72 (0.43^{ab})	3.73 (0.19^{ab})	5.22 (0.23^{b})
T3	Fipronil(100)	13.84 (0.38^{ab})	14.80 (0.39^{a})	3.94 (0.20^{a})	16.46 (0.42^{ab})	4.82 (0.22^{bc})	4.94 (0.22^{ab})
T4	Phospamidon (1000)	11.54 (0.34^{a})	14.66 (0.39^{a})	4.17 (0.20^{a})	13.48 (0.37^{a})	4.10 (0.20^{b})	5.15 (0.23^{b})
T5	Carbofuran (1000)	15.46 (0.40^{ab})	16.20 (0.41^{a})	3.22 (0.19^{a})	13.00 (0.36^{a})	2.49 (0.16^{a})	4.80 (0.22^{ab})
T6	Control	16.60 (0.42^{b})	17.11 (0.42^{a})	7.74 (0.28^{a})	27.53 (0.55^{b})	5.62 (0.24^{c})	5.34 (0.23^{b})

- Figures in parentheses are angular transformed values
- Figures followed by different letters are significantly different at p=0.05

Table 33 (b). Effect of granular insecticides on the populationof blue beetle (Rabi 04& Rabi 05)

Treatments	Granular Insecticide (g a.i. / ha)	Average beetle population/10 hills			
		Days after transplanting			
		10		30	
		2004	2005	2004	2005
T1	Cartap hydrochloride (1000)	34.25 (1.51 ^{a})	7.25 (0.81 ^{a})	1.25 (0.08 ^{a})	3.50 (0.52 ^{a})
T2	Carbosulfan (1000)	29.00 (1.41 ^{a})	7.00 (0.79 ^{a})	3.25 (0.44 ^{abc})	10.25 (1.00 ^{b})
T3	Fipronil (100)	29.75 (1.46 ^{a})	7.25 (0.82 ^{a})	3.75 (0.50 ^{cd})	11.50 (1.05 ^{b})
T4	Phospamidon (1000)	32.00 (1.50 ^{a})	11.00 (0.99 ^{a})	3.00 (0.45 ^{abc})	4.25 (0.60 ^{a})
T5	Carbofuran (1000)	34.50 (1.53 ^{a})	10.75 (0.99 ^{a})	2.50 (0.35 ^{ab})	2.50 (0.35 ^{a})
T6	Control	38.00 (1.57 ^{a})	16.00 (1.19 ^{b})	6.50 (0.81 ^{e})	28.75 (1.43 ^{c})

* Figures in parentheses are logarithmic transformed values
* Figures followed by different letters are significantly different at p=0.05

resulted in lowest population (1.25 beetles / 10 hills) as against other treatments (2.50 to 3.75 beetles / 10 hills) and control (6.5 beetles / 10 hills) indicating its significant superiority over other treatments. In 2005, though carbofuran recorded lowest population (2.5 beetles / 10 hills), cartap hydrochloride (3.50 beetles / 10 hills) and phosphamidon (4.25 beetles / 10 hills) were on par.

It is indicated from the results of two Rabi seasons that cartap hydrochloride was significantly effective in reducing leaf damage at 10 days after transplanting in 2004, 20 days after transplanting in 2005, hill damage at 35 days after transplanting in 2004 and 2005. Beetle population was also significantly reduced by cartap hydrochloride at 10 days after transplanting (2005) and 30 days after transplanting (2004, 2005). Overall results showed that cartap hydrochloride and carbofuran were effective in reducing the incidence of *L. pygmaea.*

4.7.4.2 Persistent toxicity of granular insecticides against blue beetle

It is clear from the results of two Kharif seasons (Table 34a) that at 10 days after treatment, carbofuran resulted in 100 per cent mortality of *L. pygmaea* followed by carbosulfan (66.7 per cent), phosphamidon (63.3 per cent) and cartap hydrochloride (60 per cent). Fipronil brought about lowest mortality (53.3 per cent). Carbofuran was the most persistent insecticide causing 100 per cent mortality in *L. pygmaea* upto 20 days after treatment. Cartap hydrochloride, which was proved to be most effective in the bioefficacy study, showed only 60 per cent mortality at 10 days after treatment. Even after 50 days of treatment, carbofuran treatment showed 50 per cent mortality whereas other insecticides caused mortality from 13 to 27 per cent in *L. pygmaea.* Carbofuran was the most persistent insecticide with the highest PT value (4368) followed by carbosulfan (2436), phosphamidon (2232), cartap hydrochloride (1800) and fipronil (1556.5).

Results of the two Rabi seasons (Table 34b) also indicated similar order of persistence (i.e) carbofuran > carbosulfan > phosphamidon > cartap hydrochloride > fipronil.

Table 34 (a). Persistent toxicity of granular insecticides to *L. pygmaea* (mean of two Kharif seasons)

Treatment	Granular Insecticide @ g a.i ./ ha	Per cent mortality							P	T	PT	ORE
		Days after treatment										
		10	20	30	40	50	60	70				
T1	Cartap hydrochloride (1000)	60.0	43.4	36.7	26.7	13.4	0	0	50	36.0	1800.0	4
T2	Carbosulfan (1000)	66.7	63.3	46.7	30.0	26.7	10.0	0	60	40.6	2436.0	2
T3	Fipronil (100)	53.3	43.4	26.7	20.0	13.3	0	0	50	31.3	1556.5	5
T4	Phospamidon (1000)	63.3	56.7	36.7	26.7	26.7	13.3	0	60	37.2	2232.0	3
T5	Carbofuran (1000)	100	100	93.3	73.4	50.0	20.0	0	60	72.8	4368.0	1

* P = Period, T = Toxicity, PT = Index based on persistent toxicity
ORE = Order of relative effectiveness based on PT indices

Table 34 (b). Persistent toxicity of granular insecticides to *L. pygmaea* (Mean of two Rabi seasons)

Treatment	Granular Insecticide @ g a.i. / ha	Per cent mortality							P	T	PT	ORE
		Days after treatment										
		7	15	25	35	45	60	75				
T1	Cartap hydrochloride (1000)	60.0	43.2	33.3	23.4	13.3	0	0	50	34.6	1730.0	4
T2	Carbosulfan (1000)	63.4	53.3	40.0	33.3	26.7	6.7	0	60	37.2	2333.8	2
T3	Fipronil (100)	70.0	36.7	26.7	20.0	20.0	0	0	50	34.7	1735.0	5
T4	Phospamidon (1000)	66.7	56.7	33.3	30.0	23.4	6.7	0	60	36.1	2166.0	3
T5	Carbofuran (1000)	100	100	93.3	70.0	46.7	16.7	0	60	71.1	4266.0	1

* P = Period, T = Toxicity, PT = Index based on persistent toxicity
ORE = Order of relative effectiveness on PT indices

4.7.4.3 Evaluation of eco-friendly insecticides for the management of rice blue beetle

Bioefficacy of foliar insecticides against *L. pygmaea* in the main field was studied during four seasons (two Kharif and Rabi in 2004 & 2005) and the results are presented as follows:

Kharif seasons (2004 and 2005)

Results of the experiment in Kharif, 2004 (Table 35) indicated that at 10 days after transplanting, white muscardine fungus, *B. bassiana* @ 10^7 spores/ml significantly reduced leaf damage (7.04 per cent) as compared to the untreated control (18 per cent). However, neem oil @ 2 per cent (7.11 per cent) and chlorpyriphos @ 0.05 per cent (8.47 per cent) were found to be on par with *B. bassiana.* In Kharif 2005, all the treatments were on par with leaf damage ranging from 9.94 to 14.72 per cent at 10 days after transplanting.

At 10 days after transplanting during Kharif'2004 and 2005, there was no significant difference in beetle population ranging from 47.50 to 95.25 beetles / 10 hills and 2.50 to 6.00 beetles / 10 hills. At 30 days after transplanting, there was no significant difference among treatments during Kharif'2004 with beetles population ranging from 7.00 to 11.00 beetles / 10 hills while during Kharif'2005, chlorpyriphos was significantly superior to all other treatments with lowest beetle population of 23.50 / 10 hills as compared to 36.25 beetles / 10 hills in untreated plot.

Rabi seasons (2004 and 2005)

At 10 days after transplanting in Rabi 2004 (Table 36a), *B. bassiana* @ 10^7 spores/ml(T1) was significantly superior (2.01 per cent) to all other treatments in reducing leaf damage and highest damage (7.53 per cent) in untreated control (Table 36a). *B. bassiana* showed its superiority over control in reducing leaf damage at 20 days after transplanting also. All the treatments were significantly superior to control. At 30 days after transplanting, *B. bassiana* (T1), econeem (T4) and chlorpyriphos (T5)

Table 35. Effect of eco-friendly foliar insecticides on the incidence of blue beetle (Kharif 04& Kharif 05)

Treatments	Foliar Insecticides (%)	Mean damaged leaves/10 hills (%)		Average beetle population/10 hills			
		Days after Transplanting					
		10		10		30	
		2004	2005	2004	2005	2004	2005
T1	*B. bassiana*@ 10^7 spores/ml	7.04 (0.27[a])	13.75 (0.38[a])	47.50 (1.66[a])	3.25 (0.52[a])	9.75 (1.00[a])	25.00 (1.11[ab])
T2	Paraffin oil @ 2	10.00 (0.31[ab])	10.47 (0.32[a])	87.75 (1.86[a])	3.50 (0.61[a])	7.00 (0.97[a])	25.25 (1.33[cde])
T3	Neem oil @ 2	7.11 (0.27[a])	15.93 (0.41[a])	83.50 (1.88[a])	6.00 (0.79[b])	7.00 (0.90[a])	34.50 (1.47[de])
T4	Econeem @ 0.004	10.70 (0.33[ab])	12.13 (0.35[a])	82.25 (1.92[a])	3.75 (0.63[a])	9.50 (1.02[a])	28.75 (1.20[ab])
T5	Chlorpyriphos @ 0.05	8.47 (0.28[a])	9.94 (0.31[a])	67.25 (1.81[a])	3.50 (0.61[a])	7.75 (0.91[a])	23.50 (0.87[a])
T6	Carbaryl @ 0.2	10.24 (0.32[ab])	11.31 (0.34[a])	70.75 (1.82[a])	2.50 (0.54[a])	11.00 (1.05[a])	27.25 (1.18[ab])
T7	Control	18.00 (0.43[b])	14.72 (0.39[a])	95.25 (1.93[a])	3.00 (0.56[a])	10.50 (1.17[a])	36.25 (1.76[e])

* Figures in parentheses are angular transformed and logarithmic transformed values
* Figures followed by different letters are significantly different at p=0.05

Table 36a. Effect of eco-friendly foliar insecticides on the incidence of blue beetle (Rabi 04& Rabi 05)

Treatments	Foliar Insecticides (%)	Mean damaged leaves/10 hills (Per cent)						Total damaged hills/ plot (Per cent)	
		Days after Transplanting							
		10		20		30		35	
		2004	2005	2004	2005	2004	2005	2004	2005
T1	*B. bassiana*@ 10^7 spores/ml	2.10 (0.13^{a})	9.22 (0.31^{ab})	1.61 (0.12^{a})	9.48 (0.31^{b})	3.10 (0.18^{a})	5.50 (0.23^{a})	3.10 (0.18^{a})	5.50 (0.23^{a})
T2	Paraffin oil @ 2	4.40 (0.21^{abc})	9.95 (0.31^{ab})	2.64 (0.16^{a})	9.25 (0.31^{b})	4.03 (0.20^{ab})	8.34 (0.29^{cd})	4.03 (0.20^{a})	8.34 (0.29^{c})
T3	Neem oil @ 2	2.92 (0.17^{abc})	11.33 (0.34^{ab})	2.62 (0.16^{a})	9.45 (0.31^{b})	4.87 (0.22^{b})	6.72 (0.26^{abc})	4.87 (0.22^{a})	6.72 (0.26^{abc})
T4	Econeem @ 0.004	2.16 (0.15^{ab})	8.83 (0.30^{ab})	2.60 (0.16^{a})	8.95 (0.30^{b})	3.21 (0.18^{a})	6.92 (0.27^{abc})	3.21 (0.18^{a})	6.92 (0.27^{abc})
T5	Chlorpyriphos @ 0.05	4.10 (0.20^{abc})	7.85 (0.28^{a})	2.20 (0.15^{a})	6.56 (0.25^{a})	3.10 (0.18^{a})	5.90 (0.24^{a})	3.10 (0.18^{a})	5.90 (0.24^{a})
T6	Carbaryl @ 0.2	7.28 (0.27^{cd})	8.24 (0.28^{a})	1.66 (0.13^{a})	8.85 (0.30^{b})	3.51 (0.18^{a})	6.00 (0.25^{ab})	3.51 (0.18^{a})	6.00 (0.25^{ab})
T7	Control	7.53 (0.28^{d})	15.87 (0.41^{b})	4.37 (0.21^{b})	15.81 (0.41^{c})	6.67 (0.26^{c})	8.90 (0.30^{d})	6.67 (0.26^{a})	8.90 (0.30^{d})

* Figures in parentheses are angular transformed transformed values
* Figures followed by different letters are significantly different at p=0.05

were found to be significantly effective in reducing leaf damage. The leaf damage was 3.10 to 3.21 per cent in these treatments as against 6.67 per cent in untreated control.

In Rabi 2005, all the insecticide treatments were significantly effective. Chlorpyriphos was significantly superior with rest of the treatments in reducing leaf damage at 10, 20 and 30 days after transplanting compared to control.

Hill damage: Treatments showed no significant effect in reducing damaged hills ranging from 3.10 per cent to 6.67 per cent in Rabi, 2004 (Table 36a). In 2005, *B. bassiana* (T1) and chlorpyriphos (T5) were significantly effective in the reduction of hill damage. *B. bassiana* (T1) recorded 5.5 per cent damaged hills compared to 8.9 per cent in control.

Beetle population: Results of Rabi, 2004 (Table 36b) indicated that the treatments had no significant effect on the incidence of beetle population ranging from 35.25 to 48.75 beetles / 10 hills at 10 days after transplanting. However, at 20 days after transplanting chlorpyriphos showed significant effect (1.25 beetles / 10 hills) in reducing the beetle population compared to 10.75 beetles per 10 hills in control. The significant superiority of chlorpyriphos was again observed at 30 days after transplanting with a lowest population (2.25 beetles per 10 hills) followed by *B. bassiana* (2.75 / 10 hills), carbaryl (2.75 / 10 hills), azadirachtin (3.50/ 10 hills) as against the highest population (22.75 beetles / 10 hills) in control.

In Rabi, 2005 (Table 36b), *B. bassiana* was significantly superior in reducing beetle population (15.25 beetles / 10 hills) at 10 days after transplanting while the highest population (39 beetles / 10 hills) was observed in control. At 20 days after transplanting, though all insecticide treatments were equally effective in reducing the beetle population. Lowest population of of 4.00 beetles / 10 hills was observed in chlorpyriphos (T5) as compared to control (19.50/ 10 hills). At 30 days after transplanting also chlorpyriphos recorded significantly lower population (1.75 / 10 hills) and at par with carbaryl (2.75 beetles / 10 hills). Foliar insecticides were found more effective during Rabi than Kharif season.

Table 36b. Effect of eco-friendly foliar insecticides on the populationof blue beetle (Rabi 04& Rabi 05)

Treatments	Foliar Insecticides (%)	Average beetle population/10 hills					
		Days after transplanting					
		10		20		30	
		2004	2005	2004	2005	2004	2005
T1	*B. bassiana*@ 10^7 spores/ml	39.00 (1.59^{a})	15.25 (1.20^{a})	2.00 (0.46^{ab})	7.00 (0.79^{a})	2.75 (0.52^{ab})	3.50 (0.62^{ab})
T2	Paraffin oil @ 2	43.25 (1.65^{a})	31.75 (1.47^{cd})	4.50 (0.74^{c})	5.75 (0.81^{a})	5.50 (0.78^{cd})	3.75 (0.66^{ab})
T3	Neem oil @ 2	44.00 (1.65^{a})	23.00 (1.35^{abc})	4.75 (0.71^{c})	5.75 (0.80^{a})	5.50 (0.97^{d})	4.00 (0.69^{ab})
T4	Econeem @ 0.004	50.25 (1.70^{a})	25.25 (1.40^{abc})	2.50 (0.51^{ab})	6.25 (0.81^{a})	3.50 (0.62^{ab})	4.00 (0.65^{ab})
T5	Chlorpyriphos @ 0.05	44.75 (1.66^{a})	21.00 (1.31^{ab})	1.25 (0.35^{a})	4.00 (0.65^{a})	2.25 (0.46^{a})	1.75 (0.44^{a})
T6	Carbaryl @ 0.2	35.25 (1.48^{a})	28.75 (1.47^{cd})	3.00 (0.56^{ab})	6.50 (0.84^{a})	2.75 (0.50^{ab})	2.25 (0.51^{a})
T7	Control	48.75 (1.70^{a})	39.00 (1.55^{d})	10.75 (1.06^{d})	19.50 (1.28^{b})	22.75 (1.37^{e})	8.50 (0.92^{c})

* Figures in parentheses are logarithmic transformed values
* Figures followed by different letters are significantly different at p=0.05

4.7.4.4 Persistent toxicity of eco-friendly foliar insecticides against blue beetle

The study on persistent toxicity of foliar insecticides applied in the main field during Kharif seasons (Table 37a) indicated that Carbaryl @ 0.2 per cent exhibited highest persistence with a PT value of 3500. Chlorpyriphos @ 0.05 per cent was second best in persistence with a PT value of 3035. All the non chemical eco-friendly treatments showed less persistence in the field. Neem based treatments *viz.*, neem oil @ 2 per cent and 1 per cent econeem @ 0.004 % with PT values of 600 and 1132 respectively . Paraffin oil @ 2 per cent exhibited a PT value of 900. *B. bassiana* @ 10^7 spores/ml resulted in 20 per cent mortality of *L. pygmaea* at 10 days after treatment. Its average toxicity lasted for 20 days thus revealing its lowest persistence in the field with a PT value of 300. Based on the PT indices the order of relative efficacy of different treatments were carbaryl @ 0.2 per cent > chlorpyriphos @ 0.05 per cent > azadirachtin @ 0.004 per cent > paraffin oil @ 2 per cent > neem oil @ 2 per cent > *B. bassiana*@ 10^7 spores/ml.

In Rabi seasons (Table 37b) also, lowest persistence was observed in *B. bassiana* with PT value was found to be higher in Rabi (533.4) as compared to that of Kharif season (300). A similar trend of increased PT value was seen in all other treatments also except carbaryl. Carbaryl @ 0.2 per cent ranked first in the order of persistence in the field with the same PT value (3500) in both Kharif and Rabi seasons.The average toxicity of neem oil was found to be increased from 20.0 to 29.2 and the PT value increased from 600 to 1168 during Kharif to Rabi. The relative efficacy of different treatments based on PT indices was found to be in the same order as that of Kharif except a change in the position of paraffin oil and neem oil.

Table 37a. Persistent toxicity of eco-friendly foliar insecticides against *L. pygmaea* (mean of two Kharif seasons)

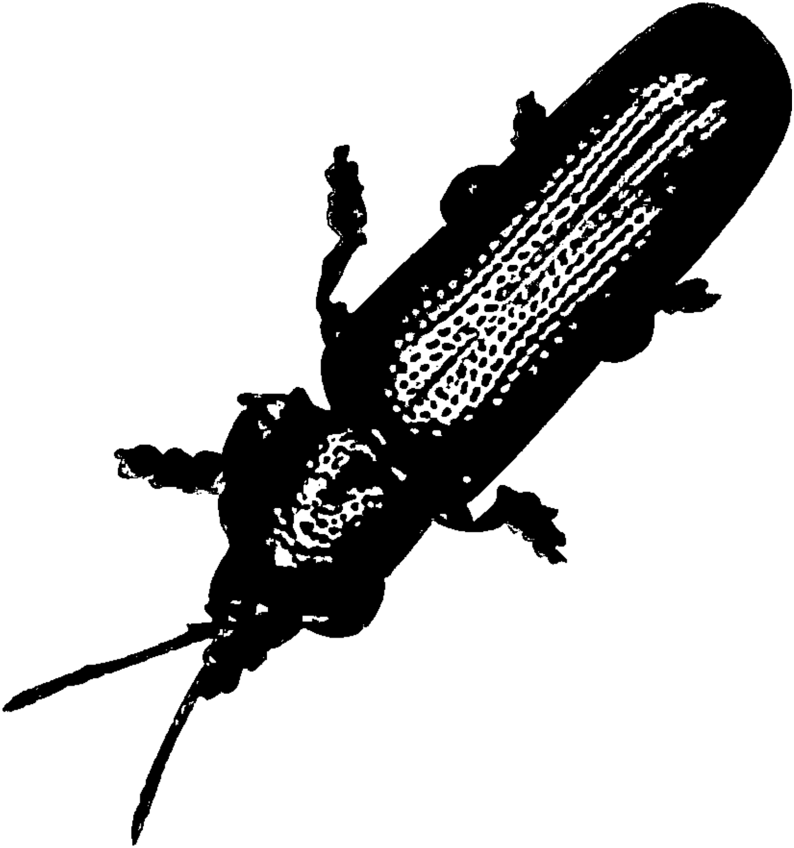
Treatments	Foliar Insecticides (%)	Per cent mortality						P	T	PT	ORE
		Days after treatment									
		10	20	30	40	50	60				
T1	*B. bassiana*@ 10^7 spores/ml	20.0	10.0	0	0	0	0	20	15.0	300.0	6
T2	Paraffin oil @ 2	33.3	30.0	23.4	3.4	0	0	40	22.5	900.0	4
T3	Neem oil @ 2	26.7	30.0	20.0	3.4	0	0	40	20.0	600.0	5
T4	1 % Econeem@ 0.004	40.0	36.7	30.0	6.7	0	0	40	28.3	1132.0	3
T5	Chlorpyriphos @ 0.05	100	86.7	66.7	33.4	16.7	0	50	60.7	3035.0	2
T6	Carbaryl @ 0.2	100	93.3	76.7	53.3	26.7	0	50	70.0	3500.0	1

* P = Period, T = Toxicity, PT = Index based on persistent toxicity
ORE = Order of relative effectiveness based on PT indices

Table 37b. Persistent toxicity of eco-friendly foliar insecticides on beetle survival (mean of two Rabi seasons)

Treatment	Foliar Insecticides (%)	Per cent mortality						P	T	PT	ORE
		Days after treatment									
		10	20	30	40	50	60				
T1	*B. bassiana*@ 10^7 spores/ml	26.7	16.7	10.0	0	0	0	30	17.8	533.4	6
T2	Paraffin oil @ 2	53.4	30.0	20.0	10.0	0	0	40	28.3	1132.0	5
T3	Neem oil @ 2	50.0	33.3	23.4	10.0	0	0	40	29.2	1168.0	4
T4	1 % Econeem@ 0.004	63.4	53.4	30.0	13.3	0	0	40	40.0	1600.0	3
T5	Chlorpyriphos @ 0.05	100	93.3	63.4	23.4	13.4	0	50	58.7	2935.0	2
T6	Carbaryl @ 0.2	100	93.4	83.3	53.4	20.0	0	50	70.0	3500.0	1

* P=Period, T= Toxicity, PT= Index based on persistent toxicity
ORE= Order of relative effectiveness ased on PT indices



Discussion

KERALA AGRICULTURAL UNIVERSITY LIBRARY THRISSUR
2709-

5. DISCUSSION

The results of the investigation on the bioecology, population dynamics and integrated management of rice blue beetle *Leptispa pygmaea* are discussed based on the earlier literature and with relevant conclusions are presented in this chapter.

5.1 BIOLOGY OF RICE BLUE BEETLE, *L. pygmaea*

The study of life cycle of a pest helps to understand the weak points in its life stage and thereby provides important clues for intervention and management. The biology of *L. pygmaea* was studied on two rice varieties of short duration (Jyothi) and medium duration (Aiswarya) under nethouse conditions during June to October 2004 and 2005.

5.1.1 Site of oviposition, fecundity and oviposition period

Results of fecundity studies showed that the female blue beetle laid eggs either singly or in groups in a straight line either on the dorsal or ventral surface of mature or tender rice leaves of Jyothi and Aiswarya, thus indicating no preference of surface and age of rice leaf for oviposition. No difference on the site of oviposition was observed between varieties. Eggs were seen glued to the leaf surface and turned yellowish towards hatching. The fecundity ranged from 15 to 19 eggs (mean = 16.8) on short duration variety Jyothi and 10 to 19 eggs (mean = 14.3) on medium duration rice variety Aiswarya thus showing a higher fecundity on Jyothi. In Maharastra, Dalvi *et al.* (1985) observed that female blue beetle laid 38-66 eggs singly or in batches of 2, 3 or 4 in a straight line mostly on the lower surface. Very rarely eggs were observed on the upper surface of the leaves. Biological studies conducted in Gujarat (Patel and Shah, 1985) indicated that *L. pygmaea* laid an average of 43 and 58.78 eggs when temperature was above 30°C and below 30°C respectively showing a lower fecundity when temperature was above 30°C. Dalvi *et al.* (1985) reported a higher fecundity of 43-58.78 eggs at a temperature range of 28-29°C. The present study showed a lower fecundity for *L. pygmaea* which might be due to the higher temperature conditions prevailing in Kerala. An ovipostion period of six days was observed in the present study, whereas in Maharashtra and Gujarat it was found to be 14 days (Patel and Shah, 1985; Dalvi *et al.* 1985).

5.1.2 Duration of developmental stages

The incubation period of *L. pygmaea* was found to be same, ranging from 3 to 4 days (mean= 3.4 days) in both Jyothi and Aiswarya. According to Patel and Shah (1985), the incubation period varied from 3.79 to 7.16 days depending upon the temperature and the incubation period increased with decrease in temperature. They observed a constant level of 35°C was lethal for hatching of eggs. The present result is in agreement with the findings of Patel and Patel (1970) who reported an incubation period of 4 to 5 days in *L. pygmaea.*

5.1.3 Larval Period

The average grub period of *L. pygmaea* (8.2 days) was found to be same in both varieties with a range of 6-11 days. Dalvi *et al.* (1985) observed that larva of *L. pygmaea* was fully developed in 12-14 days in Maharastra. Patel and Shah (1985) also reported a higher larval period of 11.3 days for blue beetle in Gujarat.

Five instars each with duration of 1-2 days were found to be completed during the larval stage in both Jyothi and Aiswarya. Patel and Shah (1985) observed only three instars for *L. pygmaea* in Gujarat. This might be due to difference in the prevailing rearing conditions.

5.1.4 Pupal Period

The pupal period lasted for 3-4 (mean 3.2) and 2-4 (mean =2.9) days in Jyothi and Aiswarya respectively. Patel and Patel (1970) also reported that pupal period of *L. pygmaea* was about 4 days which is in agreement with the present finding. Patel and

Shah (1985) observed that the pupal period was 4.14 days (at 25° C to 28°C) and 3.64 days (at 29°C to 30°C) indicating that pupal period was more in lower temperature. In Maharastra, Dalvi *et al.* (1985) observed that the pupal period lasted for 4-5 days.

5.1.5 Total life cycle

L. pygmaea completed its life cycle within 12-19 days (mean 14.8) in Jyothi while it was 12-15 (mean 13.8) days in Aiswarya. There was a difference of only one day in the mean duration of total life cycle of *L. pygmaea* on Jyothi and Aiswarya thus indicating no marked difference in the duration of life cycle on short and medium duration rice varieties. In Maharashtra, Dalvi *et al.* (1985) reported that rice blue beetle completed its life cycle in 22 to 24 days. The shorter duration of life cycle in the present study might be due to the difference in weather conditions in the two regions.

5.1.6 Pre-oviposition period

The pre-oviposition of *L. pygmaea* varied from 14 to 26 hours (mean = 21 hours) in Jyothi and 15 to 24 hours (mean = 20.3 hours) in Aiswarya, thus showing no marked difference in the pre-oviposition period between varieties of rice. The mean pre-oviposition period in *L. pygmaea* was reported to be 4.9 days in Gujarat (Patel and Shah, 1985) and 2.6 days in Maharastra (Dalvi *et al.*, 1985). The difference in the present finding might be due to the difference in the temperature and other rearing conditions.

5.1.7 Adult longevity

Longevity is important not only because of its influence on demographics but also it determines how long the pest is active and exerts a negative influence on the crop. The longevity of adult varied with the sex of blue beetle. Males lived longer than females. Adult male of *L. pygmaea* lived for 22 to 60 days (mean 40.9 days) on Jyothi and from 20 to 55 days (mean 36.7 days) on Aiswarya. The male life span was longer in Jyothi (41 days) than Aiswarya (37 days). The females lived for an average period of 25 days in both varieties, thus indicating a shorter life for females than males. This result is contrary to the earlier findings of Patel and Shah (1985) in Gujarat, where there was no marked difference in the longevity of male and female rice blue beetles. They found the adults lived a longer life of 19 days in March / April when maximum temperature fluctuated above 30°C. During July – September, when maximum temperature was below 30°C the adult beetles lived for 15 to 16 days. In Maharastra, the adult beetles were found to have longevity of 18 to 35 days during kharif season (Dalvi *et al.,* 1985). The difference in the present results might be due to temperature and other prevailing rearing conditions.

Among the duration (Fig.1a and 1b) of different stages *viz.,* egg, larva, pupa and adult of *L. pygmaea*, the period of adult stage (male = 40.9 days; female = 24.9 days) was found to be longest (39 days) followed by larva (8.2 days), egg (3.4 days) and pupa (3.2 days). The longer duration of adult and grub stages would result in a higher degree of damage to the crop. Hence, this finding is of considerable importance from the angle of management of the pest.

5.1.8 Time of adult emergence

Highest emergence (83.3 per cent) of adult blue beetle (Fig.2) was observed in the morning period between 0800 and 0900 hours and then it was reduced as the day temperature increased. No emergence was observed between 1300 and 1500 hours when the temperature was high. There was 76.7 per cent emergence in the evening during 1600 and 1700 hours and thereafter again it was reduced. It is evident from the study that the emergence of rice blue beetle is influenced by the day temperature. The pattern of adult emergence has got much significance in chemical management of the pest. This will help in adjusting the timing of insecticide application preferably in the morning hours coinciding with the peak emergence of the beetle. No earlier work has been reported on the time of emergence of *L. pygmaea*. Swamiappan *et al.* (1990)

Fig.1a. Duration of different stages of of *L.pygmaea* (Male) in days

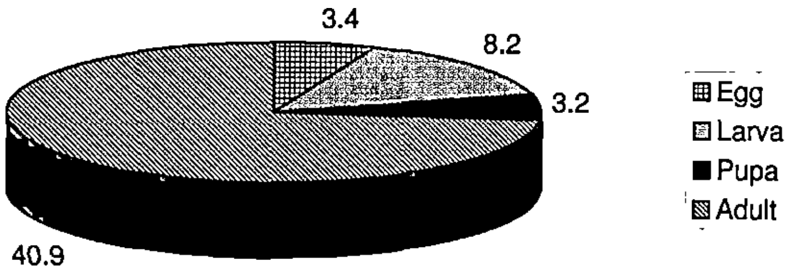


Fig.1b. Duration of different stages of L.pygmaea (Female) in days

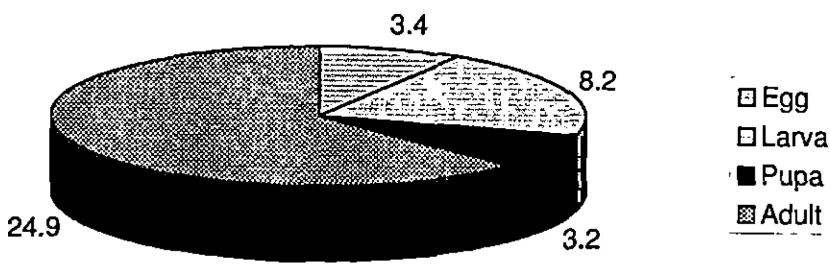
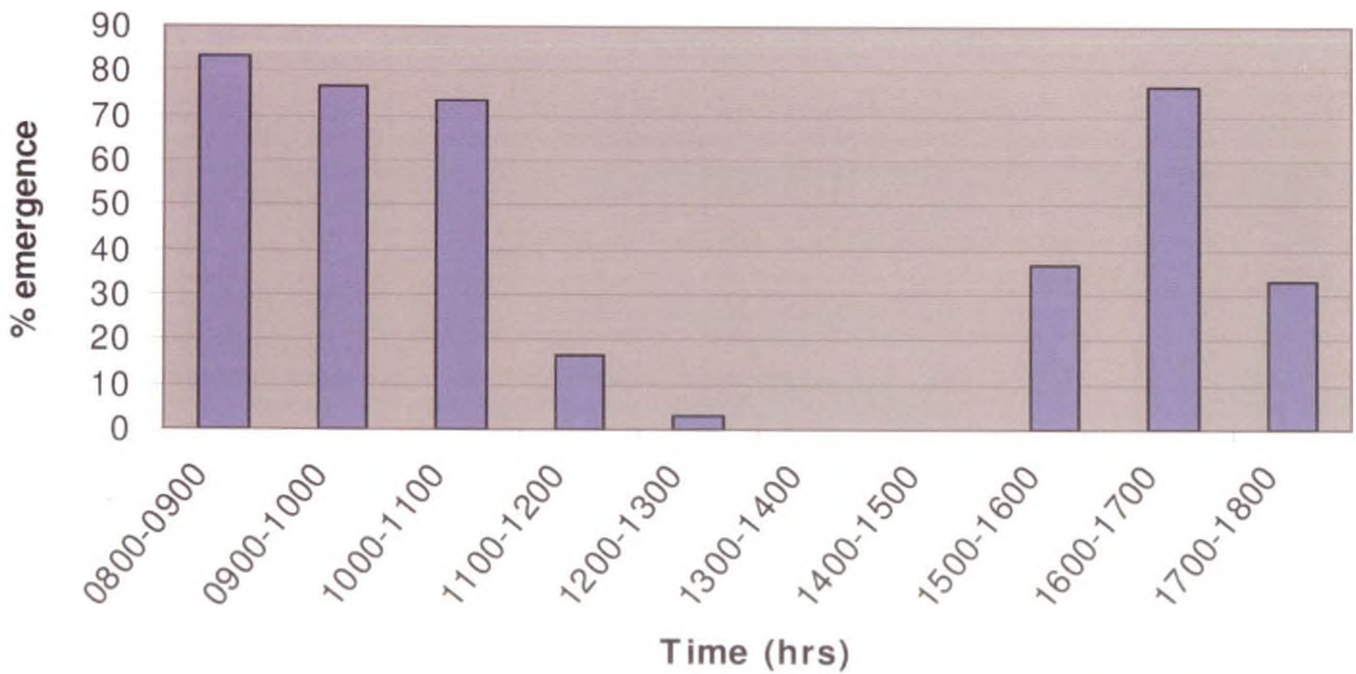


Fig 2. Time of emergence of *L. pygmaea*



observed active mating of *L. pygmaea* during morning and evening hours which probably might have coincided with the high emergence of adults.

5.1.9 Sex ratio

The male and female beetles collected from rice fields during the peak period from June-November (Fig.3) indicated that the number of males was more compared to females (mean sex ratio = 1.5:1.3). This is in close agreement with the results of Dalvi *et al.* (1985) who reported a similar sex ratio of 1.5: 1 in Gujarat. Highest population was observed during July followed by August, wherein, the females predominated the population. The field population was lowest during November with more number of male beetles. Males were more during September and November. It is thus indicated that as the field population increased females out numbered the males and when the population was reduced males predominated the population.

5.2 MORPHOLOGY AND MORPHOMETRICS

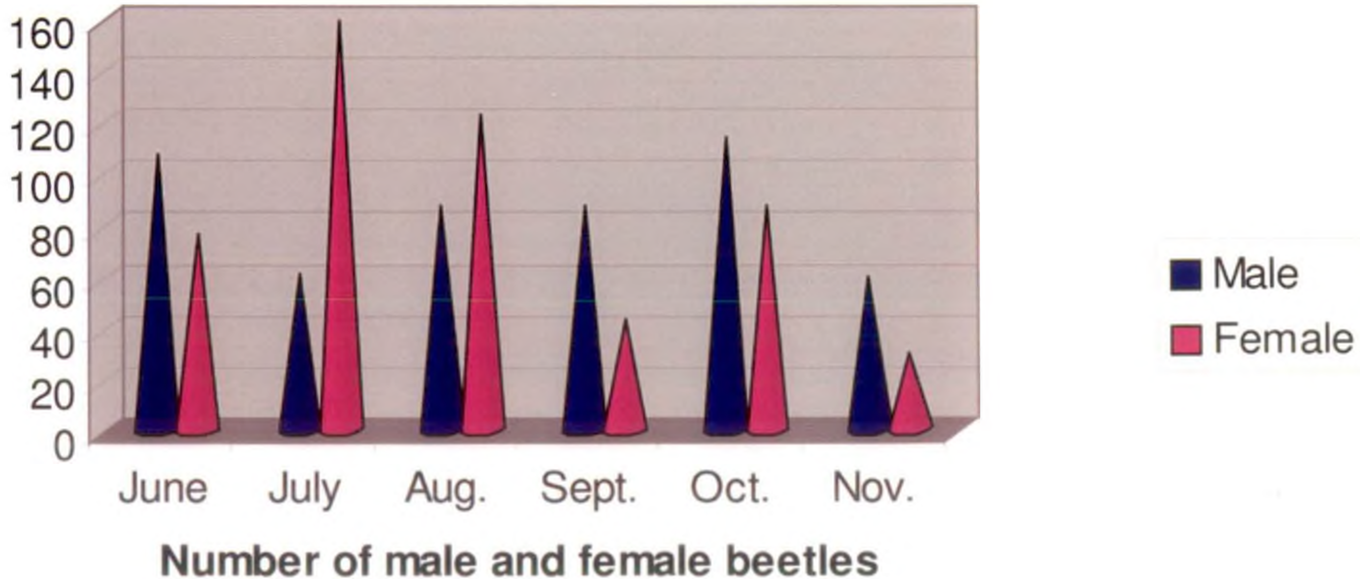
5.2.1 Egg

L. pygmaea laid light green coloured smooth oval shaped eggs on rice leaves. They turned yellowish towards hatching. The size of egg was 0.39 mm in length and 0.19 mm in width. Dalvi *et al.* (1985) and Patel and Shah (1985) reported a bigger size for the egg of blue beetle with an average length of 1.00 mm and width of 0.38 mm.

5.2.2 Larva

The grub of *L. pygmaea* was light green in colour with brown head. It showed a small head capsule, long body and a tail like projection (urogomphi) at the posterior end of the body. Similar observations were reported by Patel and Shah (1985) who observed a sclerotized tubular process at the tip of the abdomen of *L. pygmaea*.

Fig 3. Male and female populations of L. pygmaea during different months



5.2.3 First instar

Newly emerged first instar grub was light green coloured with a brown head. The head capsule measured an average width of 0.17 mm. Patel and Shah (1985) observed a slightly higher head width of 0.36 mm. The average length and width of body of first instar grub was found to be 2.53 and 0.74 mm respectively, while Patel and Shah (1985) observed lower body length and higher body width of 2.14 mm. The tail of first instar grub measured an average length and width of 0.50 and 0.10 mm respectively.

5.2.4 Second instar

The second instar grub showed the same colour of light green with a brown head measuring an average body length of 3.9 mm and 1.09 mm width. The head capsule measured an average width of 0.20 mm. The tail had an average length of 0.52 mm and width of 0.12 mm.

Patel and Shah (1985) indicated a lower body length of 2.14 mm and higher body width of 3.92 mm. They also observed a higher width of head capsule of 0.57 mm.

5.2.5 Third instar

No change in colour was observed in third instar also. It measured an average length of 4.00 and 1.09 mm width for the body and 0.23 mm for head width. The tail had a mean length of 0.52 mm and width of 0.14 mm.

A higher head width (0.71mm) for third instar grub of *L. pygmaea* was observed by Patel and Shah (1985). The other morphometrics observations made by them were in agreement with the present findings.

5.2.6 Fourth instar

Fourth instar grub also showed no colour change. It had an average length of 4.36 and width 0.93 mm for the body. The head width measured an average of 0.26 mm. The tail measured an average mean length of 0.55 mm and width of 0.14 mm.

5.2.7 Fifth instar

The colour of fifth (last) instar grub was changed to dirty white and showed an average length of 4.56 and width of 0.90 mm for the body. The head width measured an average of 0.26 mm. The mean length and width of tail was 0.56 mm and 0.15 mm respectively. This finding of fourth and fifth instar stage in the grub of *L. pygmaea* is contrary to the earlier report of Patel and Shah (1985) who observed only three larval instars. Dalvi *et al.* (1985) did not mention about the number of larval instars of *L. pygmaea*. They observed that the full grown larva was 4.65 mm long and 1 mm broad which developed in 12-14 days. They found a prepupal stage of 4.75 mm length and 1.1 mm breadth with a head width of 0.81 mm which lasted for one day. The fifth instar observed in the present study might have been the prepupal stage reported by Patel and Shah (1985).

5.2.7.1 Head capsule of larval instars

The overall results of the morphometrics studies on the grubs of rice blue beetle indicated that width of head capsule increased from 0.17 to 0.26 mm from 1st to 4th instar and width of head capsule of 4th and 5th instars remained the same of 0.26 mm and the last instar may be the prepupa as observed by Patel and Shah (1985).

5.2.7.2 Body of larval instars

The length of the body of grub was found to increase from 2.5 mm in the first instar to 4.6 mm in the fifth instar. The body width of 0.70 mm in the first instar increased to 1.1 mm in second and third instar. It was 0.9 mm in fourth and fifth instar.

5.2.7.3 Tail of larval instars

There was not much difference in the tail width from first to fifth instar. The tail length increased from 0.1 to 0.2 mm from first to fifth instar.

5.2.7.4 Total length of larva

The total length of grub increased from 3.7 mm in the first instar to 5.9 mm in the fifth instar. The width also increased from 1.1 in the first instar to 1.6 mm in the fifth instar.

5.2.8 Pupa

Freshly formed pupa was white in colour, later changed to brown and was seen loosely attached to the leaf by its distal end. It measured a maximum length of 3.89 mm and minimum length of 3.73 mm with a mean value of 3.81 mm. Its width varied from 1.12 to 1.32 mm with a mean value of 1.22 mm. Patel and Shah (1985) reported slightly bigger size for pupa with 4.00 to 5.00 mm in length (average of 4.45 mm) and 1.21 mm to 1.50 mm in width (1.39 mm). Dalvi *et al.* (1985) observed that blue beetle pupa was obtect brown and measured 4.35 mm in length and 1.06 mm in breadth. The anterior end of the pupa turned dark blue colour before emergence of adult.

5.2.9 Adult

Newly emerged adult beetle was metallic bluish green in colour dorsally and white coloured on the ventral side of the body. The male and female beeles could be differentiated based on the body size. The males were bigger in size than the females. The body length (7.1mm) and width (2.1mm) of males was larger than that of females (length 6.1 mm and width 1.9 mm). But, there was no difference in the length and width of head and thorax in both sexes.

Besides the body size, the sex differentiation in *L. pygmaea* could be done by the antennae also. The male had a longer antenna (1.1 mm) than the female (0.08 mm).

The basal two segments of the antenna were larger than the rest in both males and females. Out of these two segments, the basal segment (scape) was larger (truncated) in female antennae (0.15 mm) as compared to that of male (0.12 mm). In both sexes the 3rd, 4th, 5th and 6th antennal segments were small and uniform, while the terminal 7th to 11th segments were larger than the middle four segments. The finding of larger scape in female is in confirmation with that of Patel and Shah (1985).

The present finding of the larger size for male beetle is against the report by Patel and Shah (1985) who mentioned that female beetle was slightly bigger than male. Dalvi *et al.* (1985) noticed sexual dimorphism in *L. pygmaea*, wherein; the basal antennal segments were larger than the rest and with a remarkable serrate nature in male ,while the remarkable serrate nature was absent in female beetle.

5.2.10 Anatomy of the reproductive system

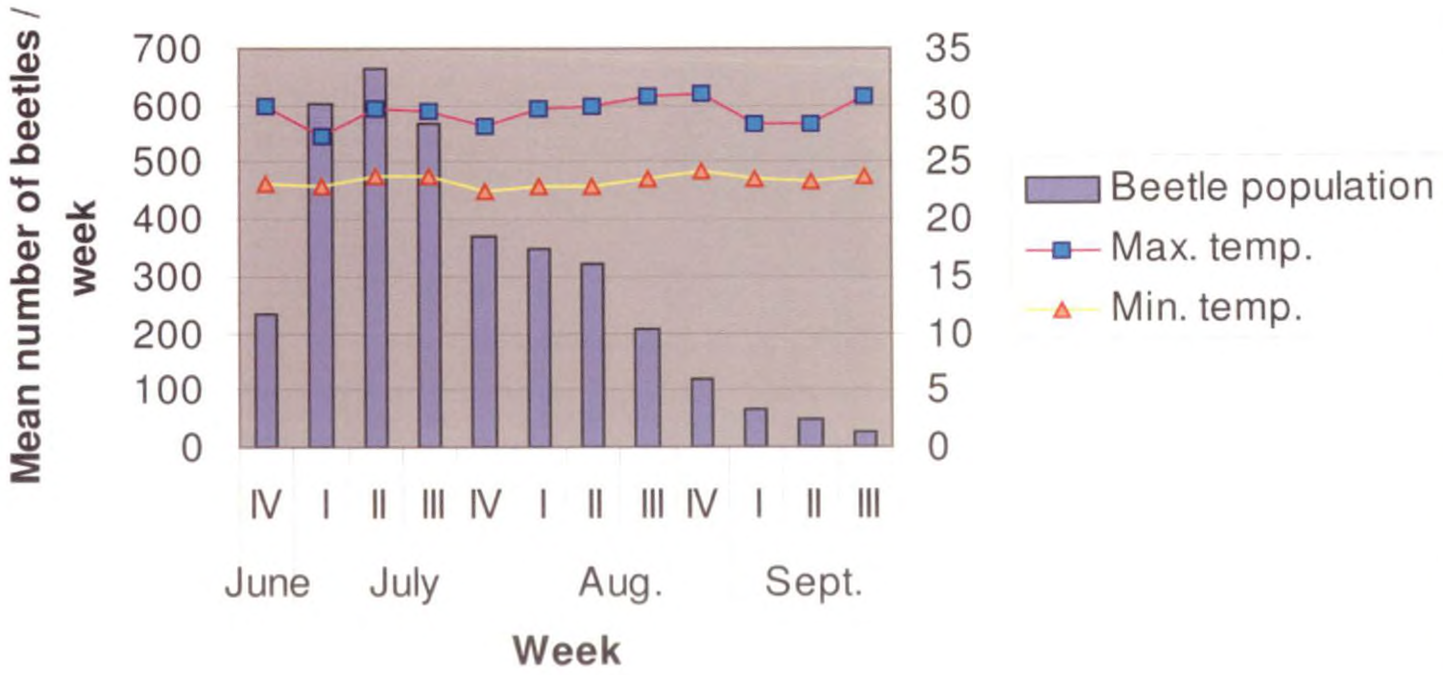
The male reproductive system comprised of aedeagus with two parts *viz.*, tegmen and sipho. The aedeagus showed an average length of 1.36 mm and width 0.07 mm (anterior) and 0.10 mm (posterior).

The female reproductive system showed spermatheca and two lateral coxites with an average length of 1.60 mm and width 0.52 mm. No earlier work on the reproductive system of *L. pygmaea* has been reported. Deka and Hazarika (1995) described the anatomy of reproductive system in rice hispa, wherein no measurements of the organs were reported.

5.3 SEASONAL INCIDENCE OF *L. pygmaea* AS INFLUENCED BY ABIOTIC FACTORS

The field population dynamics of *L. pygmaea* was estimated by monitoring the population in different seasons in order to understand the seasonal distribution in the field as influenced by the meterological parameters. In Kharif'05, the field incidence of *L. pygmaea* started from fourth week of June at 10 days after transplanting and there was an increasing trend in the population which reached a peak (664 beetles / 20 plants) during second week of July'05 (Fig.4). The peak population coincided with the

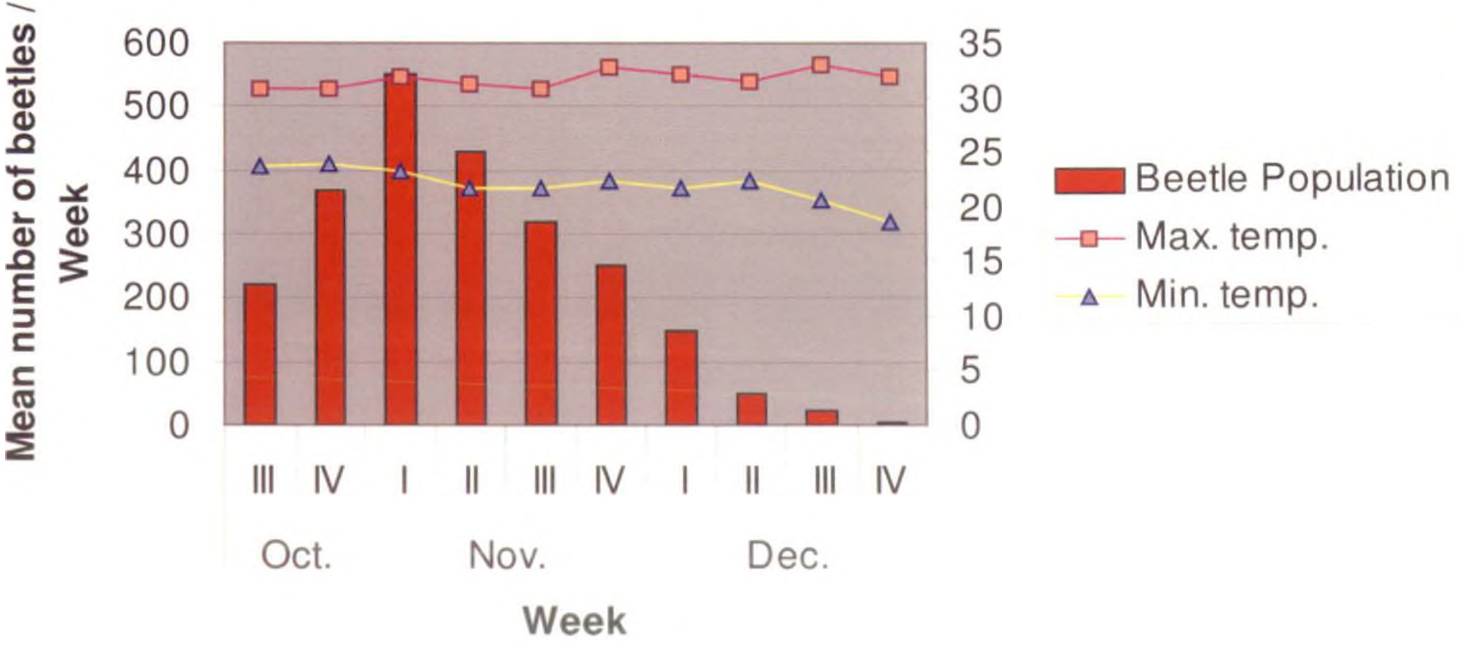
Fig.4. Population of *L. pygmaea* during Kharif'05



early tillering stage of the crop. After the second week of July'05 there was a declining trend in the population and it reached the lowest during the third week of September'05. Thus, the field population of rice blue beetle was higher during the month of July during Kharif season. The abiotic factors of maximum temperature, minimum temperature, relative humidity, rainfall and sunshine during the peak period were 29.8°C, 23.7°C, 95 %, 050.9 mm and 2.9 hours respectively. Dalvi *et al.* (1985) reported that in Maharastra the blue beetle incidence started in the field during second fortnight of July and the months of August and September were more congenial for the rapid build up of the pest.

In Rabi'05, the beetle population showed an increasing trend from third week of October (Fig 5) at 10 days after transplanting and reached a peak during first week of November'05 when the crop was in the tillering stage. The population indicated a decreasing trend from second week of November onwards. A highest population of 550 and lowest population of 5 beetles / 20 plants were observed during first week of November and fourth week of December'05 respectively. During Rabi'05 the period from fourth week of October to fourth week of November was conducive for higher population. It is also indicated from this study that highest population occurred at 24 DAT, when the crop was in the early tillering stage during both seasons (Kharif and Rabi). The peak population period was characterized by a lower maximum temperature (29.8 - 31.8°C), higher minimum temperature (23.2 - 23.7°C), higher relative humidity (95 %) and higher rainfall (50.9 - 70.2 mm) coinciding with early tillering growth stage of the crop. The beetle population was higher in Kharif than in Rabi seasons. Lower maximum temperature, higher minimum temperature, relative humidity and rainfall found to influence the higher population in Kharif than in Rabi season. The higher maximum temperature (30.9-32°C), lower minimum temperature (18.5-23.7°C), lower relative humidity (91-94 %) and low rainfall (0-21.1 mm) coupled with later growth period of rice resulted in lean population of rice blue beetle. Two abiotic factors *viz.,* minimum temperature of 23°C and relative humidity of 95 % were found to influence the peak population in both Kharif and Rabi seasons. Dalvi *et*

Fig.5 .Population of *L.pygmaea* during Rabi'05



al. (1985) reported that in Maharashtra no multiplication of rice blue beetle was observed from the second week of October to mid January in the field, and the pest activity was low up to mid March to mid April. This difference might have been due to the difference in the weather conditions prevailed in that area.

Correlation analysis of beetle population and per cent leaf damage with the weather parameters revealed a negative correlation with regard to maximum temperature and sunshine hours (respective correlation values -0.281 and -0.400). A positive correlation of blue beetle population and leaf damage with minimum temperature and relative humidity was observed. Rainfall showed no significant effect on beetle population. Negligible rains with relatively low temperature and high relative humidity were reported to cause increased hispa incidence (Thakur *et al.*, 1979; Rawat and Singh, 1980). Sunny weather interrupted by quick showers increased hispa incidence (Banerjee and Nath, 1986).

It is indicated in the present study that minimum temperature and relative humidity were the two important abiotic factors that showed positive influence on the damage by *L. pygmaea.*

5.4 NATURE AND INTENSITY OF DAMAGE

Both stages of larva and adult of *L. pygmaea* feed on the upper surface of rice leaves by scraping chlorophyll matter leading to longitudinal white streaks on them. The streaks made by the larvae were shorter and narrower than those by the adults. Similar findings were reported by Patel and Shah (1985). But the present finding is not in agreement with Lefroy (1906) who reported that the adults of *L. pygmaea* feed on rice leaves either making holes or completely stripping the plant.

In case of severe damage by *L. pygmaea* the rice leaves were seen folded longitudinally and ultimately dried up. The plants were very weak or dried up. From a distance, the damaged rice patch showed severe drying. Symptoms of damage by rice blue beetle resembled those caused by leaf folder except that there was no webbing and tying of leaf margins.Swamiappan *et al.*, (1990) also observed that in certain pockets, when the young rice plants were attacked by rice blue beetle, it resulted in stunting and severe drying symptoms and the incidence was higher in shaded areas.

Study on the feeding intensity of different stages of the blue beetle (Fig.6) revealed that grub feeding caused highest mean damage in Jyothi (39.54 and 30.70 per cent) and Aiswarya followed by adult female (23.57 and 19.67 per cent). Male beetle inflicted lowest leaf damage of 12.25 and 8.08 per cent in Jyothi and Aiswarya respectively. It is thus revealed that Jyothi suffered 28.9 per cent increase in damage over Aiswarya. In Jyothi, grub caused 69 per cent more damage than adult male while female beetle resulted in 48 per cent more damage than the male. But, in Aiswarya, grub feeding was 73.7 per cent more than that of adult male beetle whereas the female beetle produced 59 per cent more damage than the male.

The study on leaf area consumption by different stages in graphical method also indicated similar results. Leaf area consumption by *L. pygmaea* was more in Jyothi than in Aiswarya (Fig. 7). A grub consumed 3.82 mm^2 in Jyothi and 2.58 mm^2 in Aiswarya. Adult female beetle consumed higher leaf area (0.6 mm^2-1.04 $mm^{2)}$. while the males feeding ranged from 0.34 to 0.70 mm^2 of the leaf in both Aiswarya and Jyothi. A single grub, male and female beetle alltogether consumed 5.56 mm^2 leaf area in Jyothi, while it was 3.52 mm^2 in Aiswarya. It is thus inferred that grub of *L. pygmaea* caused the maximum damage followed by male and female adults irrespective of varieties in rice. A grub consumed 3.82 mm^2 leaf area which is 82 per cent more than that consumed by a male beetle (0.70 mm^2), while the female beetle consumed 32.6 per cent more leaf area than that by a male. In rice hispa, similar observations were reported by Deka and Hazarika (1997) who indicated that significantly more leaf area was consumed by females than males. Budharaja *et al.* (1979) observed that a single adult beetle of *D.armigera* consumed 25.3 mm^2 leaf area.

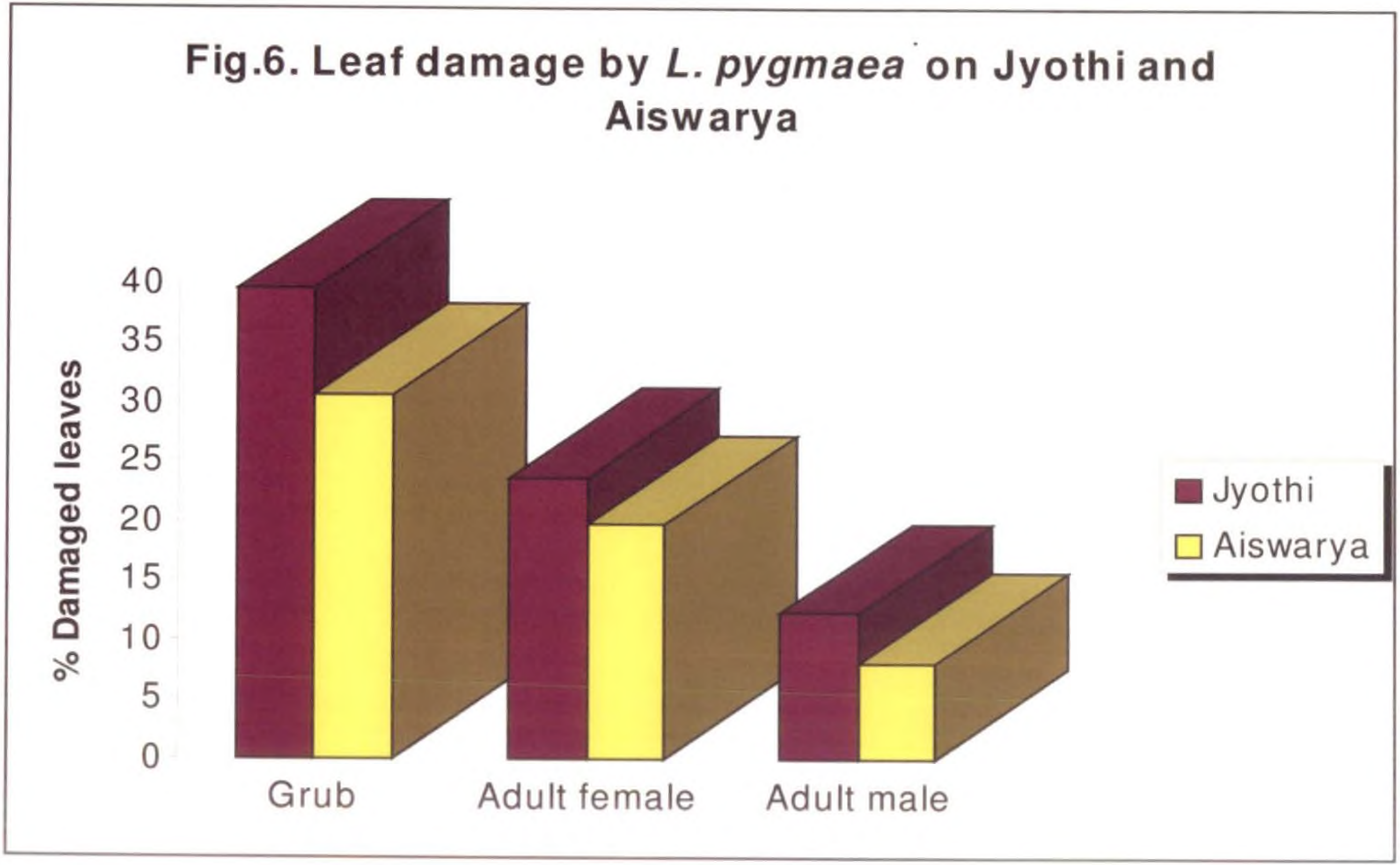
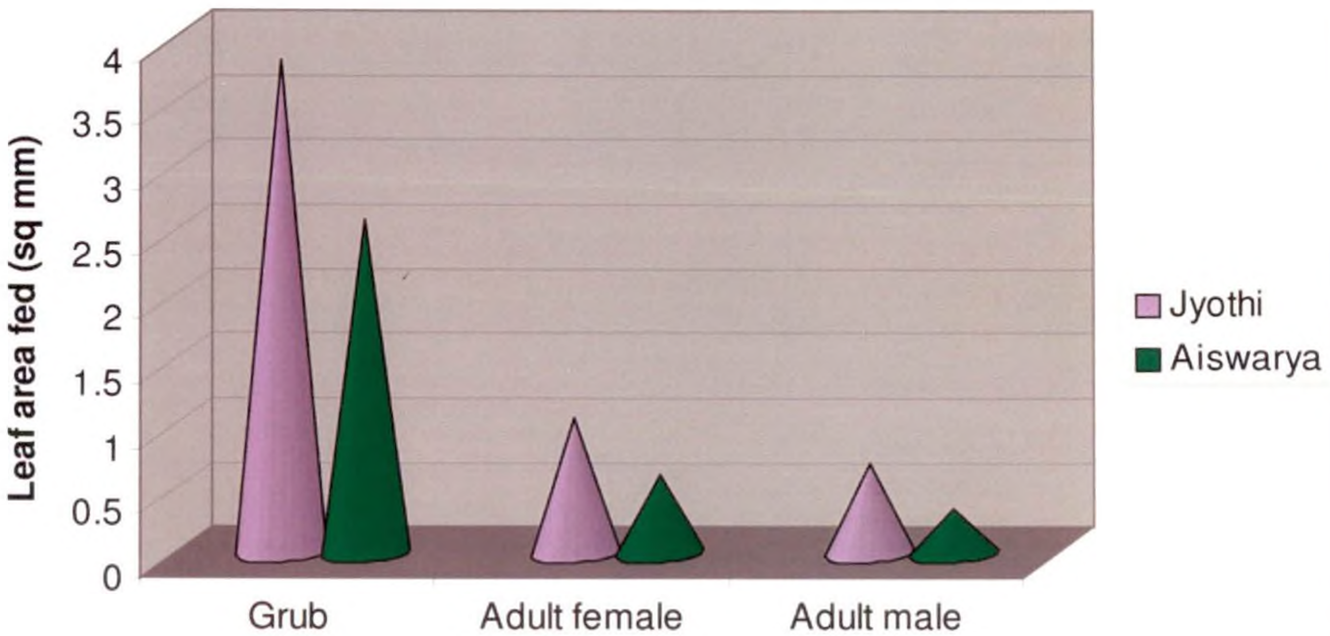


Fig.6. Leaf damage by L. pygmaea on Jyothi and Aiswarya
% Damaged leaves
40
35
30
25
20
15
10
5
0
Grub
Adult female
Adult male
Jyothi
Aiswarya

Fig 7. Leaf area consumption by different stages of *L. pygmaea* on Jyothi and Aiswarya



5.5 EXTENT OF DAMAGE DURING DIFFERENT GROWTH STAGES OF RICE

Among the different growth stages in rice, early tillering stage was found to be the most susceptible stage for the infestation of blue beetle (Fig. 8) with a maximum damage score of '7' and '9' during Kharif and Rabi respectively. The extent of mean damage during this stage was 68.54 and 75.32 per cent in Kharif and Rabi'05 respectively and thus confirming the earlier finding by Kumar (2003) who reported that the damage by blue beetle was high during early stage of the rice crop. In both seasons of Kharif and Rabi, the damage was found to increase from seedling stage and reached peak at early tillering and thereafter it was gradually declined. It is thus revealed that blue beetle caused higher damage in the early stages of crop growth (vegetative period), and less in the reproductive growth period (panicle intiation, booting and flowering) of crop.

The descending order of susceptibility of growth stages to rice blue beetle damage was early tillering > seedling > maximum tillering > panicle initiation > booting > flowering.

5.6 INFLUENCE OF METHODS OF CULTIVATION ON THE INCIDENCE OF BLUE BEETLE

The method of direct seeding in rice was found to reduce the damage of *L. pygmaea* as compared to transplanting method during Kharif and Rabi seasons in both Jyothi and Aiswarya. In Jyothi (Fig.9) during seedling stage, there was 83.15 per cent reduction of damage in direct seeded over transplanted method during Kharif and Rabi season. The reduction of damage in direct seeded over transplanted was more in Rabi than Kharif in early tillering (Rabi = 58.17 per cent, Kharif = 34.24 per cent), maximum tillering (Rabi = 88.34 per cent, Kharif = 23.51 per cent), panicle intiation (Rabi = 88.41 per cent, Kharif = 34 per cent) and booting (Rabi = 100 per cent, Kharif = 54.75 per cent)

Fig.8. Leaf damage of *L.pygmaea* during different growth stages of rice

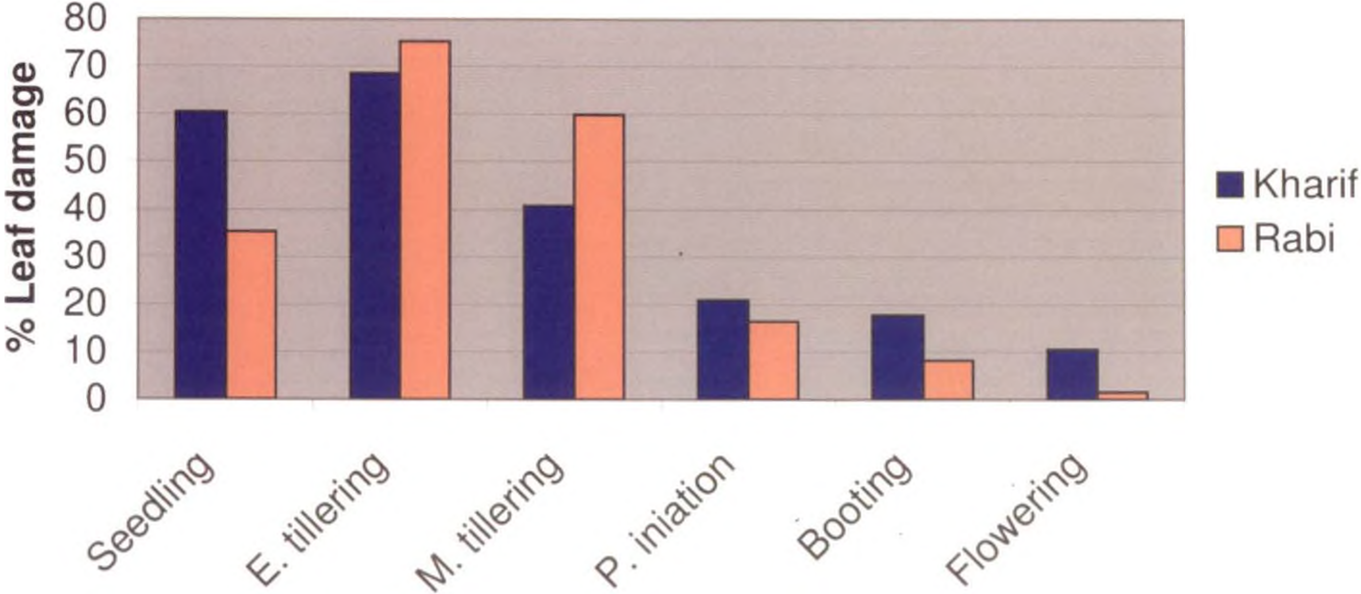
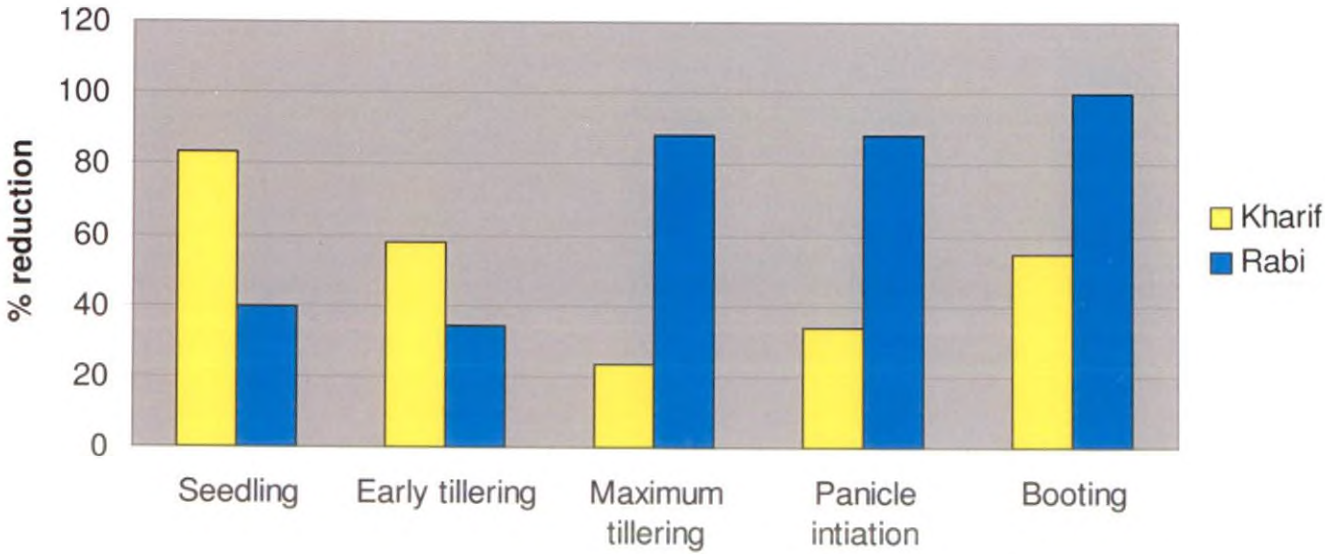


Fig.9. Reduction of damage in direct seeded over transplanted (Jyothi)



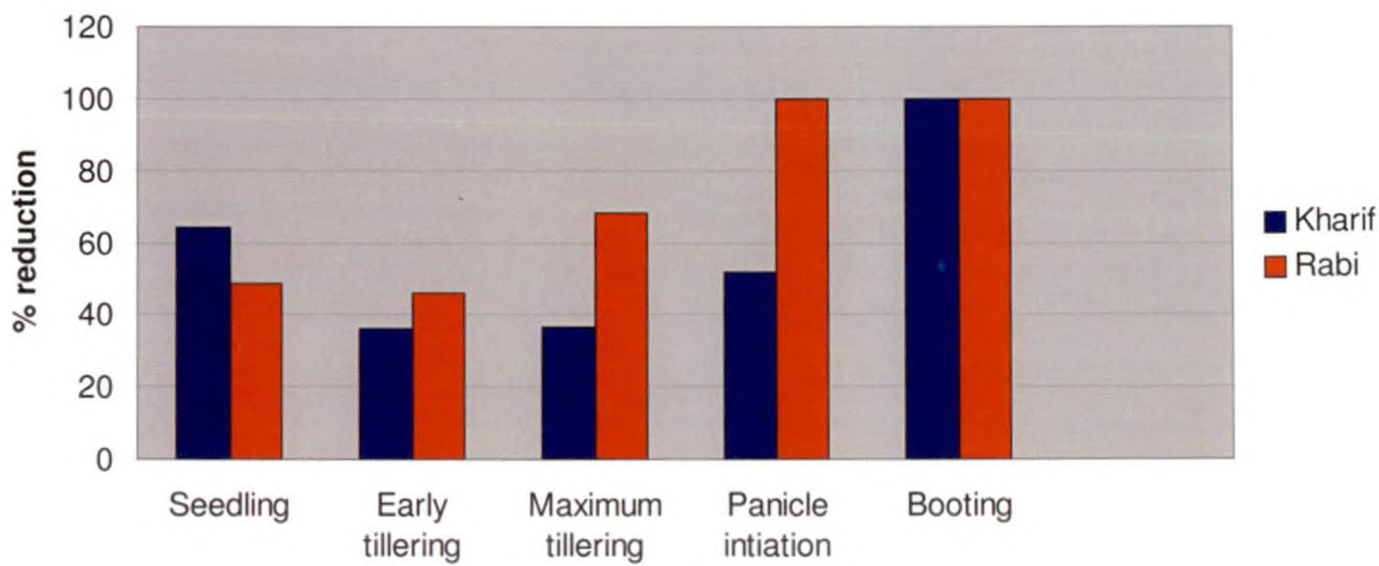
The same trend was noticed in Aiswarya (Fig. 10) also where direct seeding reduced the infestation of *L. pygmaea*. Seedling stage of direct seeded Aiswarya showed 64.26 per cent reduction of damage over transplanted during kharif whereas in rabi season it was 48.79 per cent. The per cent reduction in direct seeded over transplanted in all other stages was more in Rabi over Kharif *viz.,* early tillering (Rabi = 45.86 per cent, Kharif = 36.33 per cent), maximum tillering (Rabi = 68.1 per cent, Kharif = 36.36 per cent), panicle initiation (Rabi = 100 per cent, Kharif = 51.78 per cent, booting (Kharif = 100 per cent).

It is thus revealed that direct seeding resulted in 49.4 per cent reduction of damage over transplanting system during Kharif, while in Rabi there was 68.4 per cent reduction in direct seeding in Jyothi. The lower infestation in direct seeding might be due to closer spacing leading to high plant density which might not have provided conducive conditions for the development and multiplication of the pest. This finding is in accordance with the earlier reports on *D. armigera* (Dhaliwal and Singh, 1979), *N. cincticeps* and *C. medinalis* (Seungchan *et al.,* 1997), rice root weevil, planthoppers and rice thrips and aphids (Liansheng *et al.,* 1999).

5.7 INTEGRATED PEST MANAGEMENT METHODS

Integrated pest management methods involving host plant resistance by screening varieties, cultural management by studying alternative weed hosts and effect of plant spacing with oil cakes, biological management by identifying biological agents and chemical management by nursery treatment with granular insecticides and main field treatment with eco-friendly foliar insecticides were studied in order to develop an integrated management strategy against *L. pygmaea*.

Fig. 10.Reduction of damage in direct seeded over transplanted (Aiswarya)



5.7.1 Host Plant Resistance

5.7.1.1 Screening of varieties / cultures to identify resistant source against blue beetle

Varietal resistance is a dominant component in IPM and the varieties provide the information on which a good pest management system can be built up. Instead of a high level of resistance, use of moderately resistant varieties with need based insecticide application produced good yield in rice (Singh and Dhaliwal, 1994).

Among 106 varieties / entries screened for their field reaction against *L. pygmaea*, none of them was found to be completely resistant. Earlier Nadarajan and Skaria (1993) reported that varieties Ptb.4, Ptb.10, Ptb.28, Ptb.36, H4, GEB 24 were resistant to blue beetle. But in the present study Ptb.4 was found moderately resistant, Ptb.10 and Ptb.28 were moderately susceptible and Ptb.36 was susceptible to rice blue beetle. Moderate resistance was observed in nine traditional Pattambi varieties *viz.*, Ptb.3, Ptb.4, Ptb.7, Ptb.9, Ptb.18, Ptb.19, Ptb.20, Ptb.25, Ptb.26 and a short duration high yielding variety of Mannuthy (Hraswa) with a damage score of '3'. These varieties could be utilized in future breeding programmes for varietal resistance against *L. pygmaea*.

Jyothi, the most popular high yielding variety in Kerala, was found highly susceptible to *L. pygmaea*. This was confirmed by different studies conducted during the present investigation. In the variety Jyothi, fecundity of *L. pygmaea* was higher (16.8 eggs) with a total life cycle of 14.8 days and shorter period of different instars (1.2-2.2 days) and longer adult longevity (40.9 days for male and 24.9 days for female). The other KAU varieties *viz.*, Rangini (MO-10) and Bharathy (Ptb.4) were also found to be highly susceptible for the pest. The Kunjukunju varieties Priya and Varna screened for resistance were also susceptible to the pest, however, Elsy *et al.* (1995) observed that Kunjukunju variety Vilayam chatanur was less susceptible to *L. pygmaea*.

5.7.2 Cultural Management

5.7.2.1 Alternative weed hosts

Alternative hosts are the plants on which the pest survives and carries out the full life cycle in the absence of primary host. During the present study, on the alternative hosts, *L. pygmaea* was observed for the first time on 10 new weed plants *viz., Fimbristylis miliacea, Panicum repens, Isachne miliacea, Oryza rufipogon, Monochoria vaginalis, Sacciolepis interrupta, Limnocharis flava, Eicchornia crassipes, Echinochloa colona* and *Ammania baccifera* seen in the rice fields. Among these weed plants, the beetle was found to oviposit only on two grassy weeds *viz., Panicum repens.* and *Isachne miliacea.* Both of them belong to the family Poaceae earlier known as Graminae. Though 5-8 eggs were laid on *I. miliacea,* there was no hatching of eggs. But, on *P. repens* the beetle laid 12-15 eggs with cent per cent hatchability and the beetle was able to carry out its normal life cycle on the weed host in 10-13 days. The identification of *P. repens* as the alternative host of *L. pygmaea* on which it could complete its full life cycle is reported for the first time and thus adds to the list of earlier reported alternative hosts for the beetle.

The other recorded alternative food plants of *L. pygmaea* reported were *Arundinella metzii, Ischaemum travancorence, Paspalum scropiculatum, Pennisetum purpureotyphoides, Arundinella sp., Panicum maximum, Dichanthium aristatum* and *Brachiaria mutica* (Dalvi *et al.,* 1985). Although the adult beetles were observed feeding on these host plants during the off season, no egg laying was observed on such plants. Khanvilakar *et al.* (1983) observed the beetle to feed mainly on similar host plants belonging to family Poaceae (Graminae) including vetiver, volunteer rice plants, ratoon rice and even on sugarcane planted near by infested area. They found that the adult survived on these host plants for 55-70 days during the off-season. In the present study, adults survived for 24-38 days on *P.repens*. *Oryza rufipogon* and *P.repens* were earlier reported as alternative hosts of *Dicladispa armigera* (Dutta and Hazarika, 1995). These plants were capable of sustaining population of rice hispa when rice was not grown. *E. colonum* was earlier reported as an alternate graminaceous food plant for rice hispa.

5.7.2.1.1 *Comparative biology on rice and weed*

A comparative study on the biology of *L. pygmaea* on Jyothi, Aiswarya and *Panicum repens* (Fig. 11) indicated that the life cycle of rice blue beetle was shortest (11.5 days) on *P. repens* followed by Aiswarya (14 days) and Jyothi (15 days). Fecundity, duration of larval and pupal periods of *L. pygmaea* were less on *P.repens* when compared to rice. Male life span was highest on Jyothi (40.9 days) followed by *P.repens* (38.4 days) and Aiswarya (36.7 days). On both rice and weed, the male beetles lived a longer life than females. This is in line with the observations of Dutta and Hazarika (1995) who observed that hispa feeding on suitable alternate host plants had shorter larval and pupal periods and the pest took less time to complete its life cycle on suitable host plant. More over adults lived longer on more preferred hosts.

5.7.2.2 Effect of plant spacing and soil application of oil cakes on the pest incidence

Closer plant spacing (10x15 cm and 10 x 10 cm) significantly reduced the incidence of *L. pygmaea*. Infestation was significantly higher in the recommended wider spacing (20x15 cm) as compared to closer spacing. Damage score was rated as '1' in 10x15 cm and 10x10 cm spacings, while it was '3' in wider spacing of 20x15 cm indicating a lower incidence of the pest in the closer spacing.

Leaf damage was lowered by 45.73 and 28 per cent in 10x10 cm and 10x15 cm spacing respectively over 20x15 cmspacing (Fig.12). Beetle population was lowered by 37.56 and 54.1 per cent in closer spacings of 10x10 cmand 10x15 cm respectively over the wider spacing of 20x15 cm which is being recommended for Jyothi. Hill damage also was reduced by 64.47 and 40.27 per cent in 10x10 cm and 10x15 cmrespectively over wider spacing of 20x15 cm. It is indicated that closer spacing with 10x10 cm could bring about reduction of 64.47 per cent hill damage, 54.1 per

Fig.11. Comparative biology of *L. pygmaea* on Jyothi, Aiswarya and P. repens

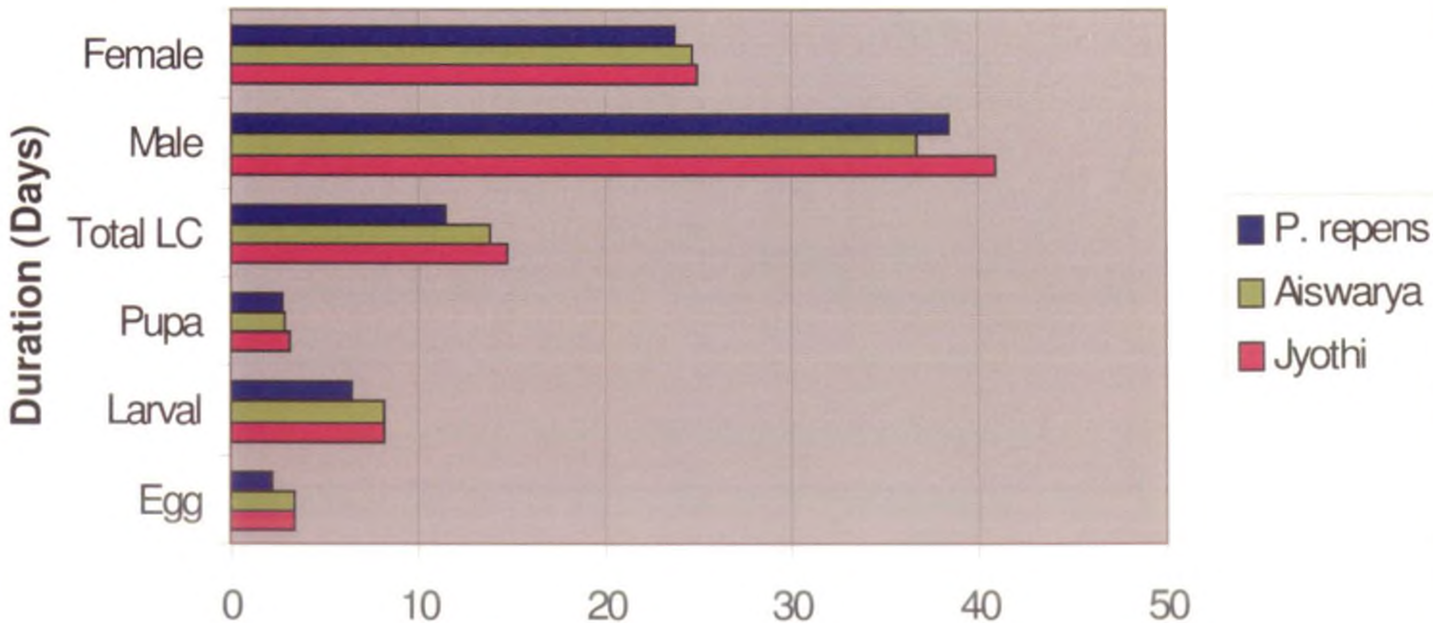
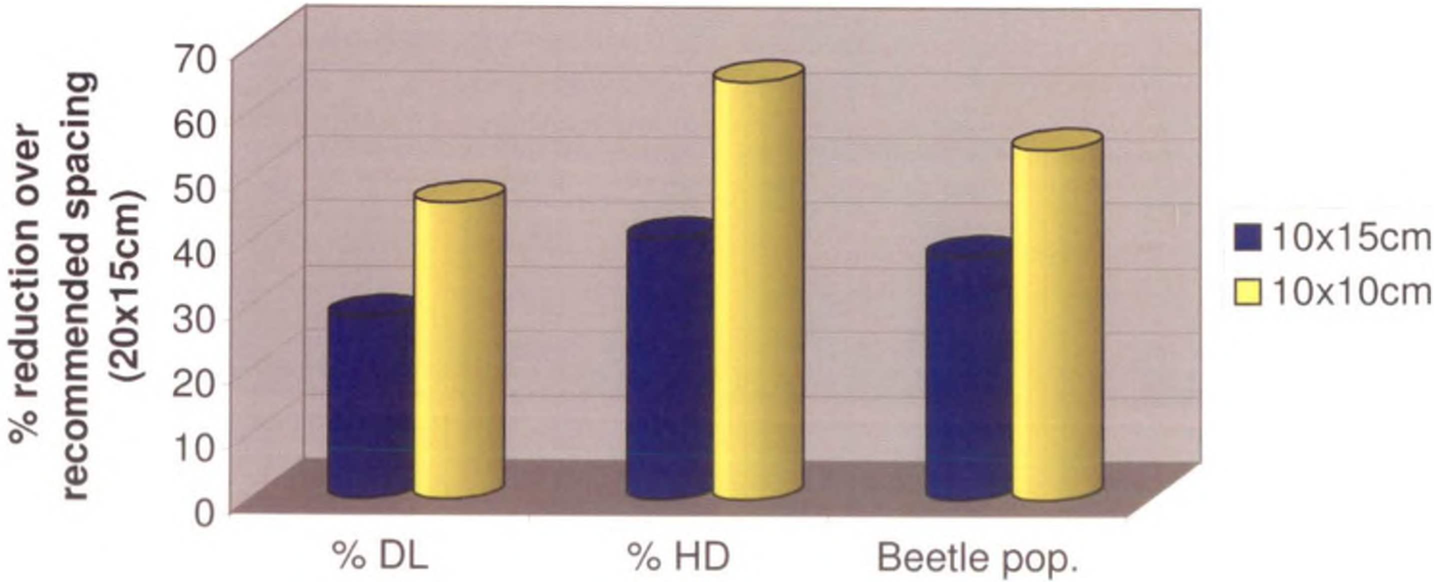


Fig.12. Reduction of *L.pygmaea* infestation in closer spacing



cent beetle population and 45.73 per cent leaf damage over the recommended spacing of 20x15 cm. Therefore, in endemic areas of blue beetle infestation, a closer spacing with 10x10 cm is useful.

The above findings corroborate the results of Dhaliwal *et al.* (1979) who reported that widely spaced rice plants were damaged severely than closely planted rice plants by hispa because of the ovipositional site on the leaves were better exposed in widely spaced plantings. Similar findings on closer spacing resulting in lower incidence of the stem borer, green leafhopper and whorl maggot (Kalode and John, 1982; Singh and Dhaliwal, 1994) were also reported earlier. In contrary, the build up of *N. lugens*, *Sogatella furcifera*, *N.virescens* and *N. nigropictus* was found higher in closer spacing of 10 x 10 cm as compared to wider spacing of 30x30 cm (Sain *et al.*, 2001).

The effect of application of neem cake, castor cake and pungam cake in the field against *L. pygmaea* showed that there was no significant difference between these cakes on the leaf damage, damaged hills and beetle population at 10, 20 and 30 days after transplanting. This corroborates the findings of Krishnaiah and Kalode (1984) who reported that non-edible cakes showed no acute toxicity to *N. lugens* in rice and oil cakes were not effective against gall midge in the field. However, the beetle population in the treatment with pungam cake was significantly lower than that in the other treatments of castor and neem cake at 20 days after transplanting. The ineffectiveness of neem cake against *L. pygmaea* is revealed in the present study. Baitha *et al.* (1993) reported that the application of neem cake @ 150 kg / ha plus neem seed kernel extract @ 5 per cent reduced the leaf damage caused by hispa by 12.29 per cent.

The interaction effect of plant spacing and oil cakes showed similar results. Closer plant spacing of 10x10cm with castor cake suffered lowest leaf damage, low beetle population and low hills damage per plot and similarly the other oil cakes like neem cake and castor treated plots with a closer spacing of 10 x 10 cm suffered low leaf damage, beetle population and hills damage. The plants with higher plant spacing of 20 x 15 cm with all three oil cakes suffered high leaf damage, high beetle population and high hills damage per plot. No such work on the interaction effects of plant spacing and oil cakes on the incidence of rice insects are available.

5.7.3 Biological management

5.7.3.1 Identification and study of the natural enemies of L. pygmaea

The present study showed that blue beetle eggs were parasitized by *Trichogramma* sp., *Telenomus* sp. and *Tetrastichus* sp. These parasitoids are reported for the first time on *L. pygmaea*, thus adding to the earlier reported ones *viz.*, *Chrysonotomyia* sp. (Eulophidae) and *Eupteromalus* sp. (Pteromalidae) by Patel and Shah (1985). Since the parasitoids were observed in the field , cvwhen the pest population was low, natural biocontrol by these parasitoids could not be effected in the field. But there is good scope for artificial release of these egg parasitoids by inundation of the field and thereby the population of the pest could be suppressed. Further studies on this line are required to be initiated.

5.7.3.2 Pathogenicity of Beauveria bassiana on L. pygmaea

The results of laboratory studies of the pathogenicity clearly indicated the effective role of *B. bassiana* in causing mortality of *L. pygmaea* adults. It caused a cumulative mortality of 56.67 to 80.00 per cent at 10^5 to 10^9 spores / ml and the LC_{50} value was 2.26 x 10^4 spores / ml. The dose and time of exposure were found to be inversely proportional for *B. bassiana*, as also reported by Agarwal (1990). The factors that contribute to the efficacy of a fungus include fungal strain, test insect species, its behaviour, method of application and abiotic conditions (Ferron, 1978). Beetles were more susceptible to fungal pathogens than other insect groups (Carruthers and Soper, 1987). The field efficacy of *B. bassiana* in controlling *D. armigera* was earlier reported by Hazarika and Puzari, (1995; 1997)

5.7.3.3 *Efficacy of entomopathogenic nematode, Heterorhabditis indica against L. pygmaea*

Laboratory evaluation of *H.indica* against grubs of *L.pygmaea* indicated the efficacy of EPN in bringing out mortality of *L. pygmaea*. This is the first report of the effectiveness of *H.indica* to infect the grubs of *L.pygmaea*. It produced a cumulative mortality of 66.67 to 91.67 per cent at concentrations of 5IJ's to 9 IJ's in the grubs of *L. pygmaea*. The cumulative LC_{50} value was 3.83 IJ's. The mortality was found to increase with reducing dose and increasing exposure period thus indicating an inverse proportion for the dose and period of exposure. Rice blue beetle was earlier reported to be parasitized by *Hexamermis* (Patel and Shah, 1988). *H. indica* caused 100 per cent of *C. medinalis* mortality within 18-20 hours of exposure (Prasad *et al.*2006)

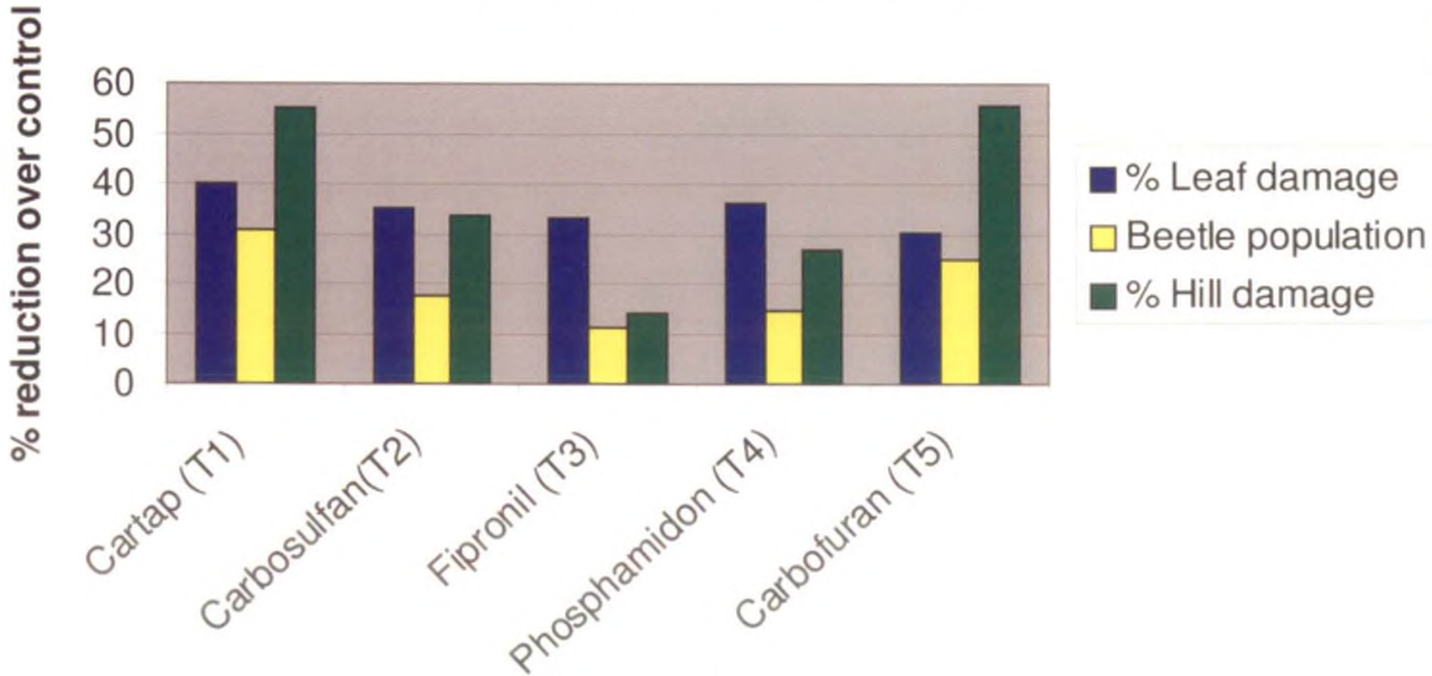
5.7.4 CHEMICAL MANAGEMENT

5.7.4.1 Management of blue beetle by nursery treatment with granular insecticides

Effect of nursery treatment with granular insecticides against the incidence of *L. pygmaea* in the main field was studied during four seasons (two Kharif and Rabi in 2004 & 2005).

The results of two crop seasons, 2004 and 2005 (Fig. 13 and 14) revealed that among the treatments, cartap hydrochloride was most effective against *L. pygmaea*. It reduced the leaf damage by 40.29 and 37.86 per cent (mean = 39.21 per cent) over control during 2004 and 2005 respectively while the beetle population was reduced by 30.73 to 61.13 per cent (mean = 45.9 per cent) over control. Hill damage was reduced by 55.16 and 33.71 per cent (mean = 44.4 per cent) over control during the two years. The present finding on the effectiveness of cartap hydrochloride is in confirmity with earlier studies of Zafar, 1984; Sain *et al.,* 1994; Kaul and Bhagat, 1997 who reported that cartap hydrochloride was found to be effective against rice hispa, another chrysomelid beetle, attacking rice crop. Cartap was also found effective against other rice pests like yellow stem borer, leaffolder, whorl maggot, brown planthopper and

Fig.13. Reduction of incidence by *L. pygmaea* by nursery treatment (2004)



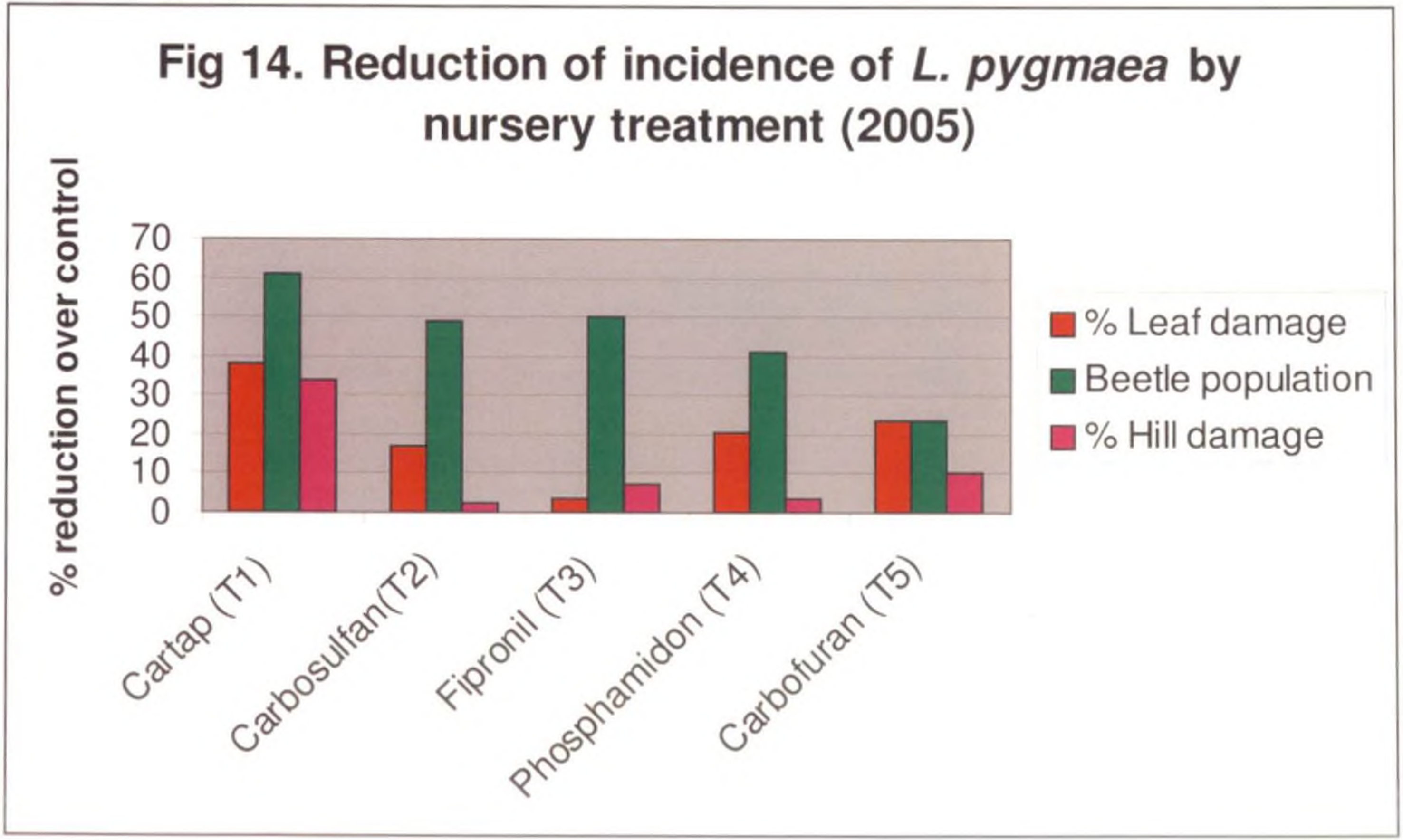


Fig 14. Reduction of incidence of L. pygmaea by nursery treatment (2005)
% reduction over control
70
60
50
40
30
20
10
0
Cartap (T1)
Carbosulfan(T2)
Fipronil (T3)
Phosphamidon (T4)
Carbofuran (T5)
% Leaf damage
Beetle population
% Hill damage

gall midge (Kandaswamy and Ravikumar, 1986; Uthamaswamy and Karuppuchamy, 1988).

Carbofuran, was the next best effective insecticide against *L. pygmaea*. It produced significant reduction of leaf damage by 30.16 and 23.62 per cent (mean = 26.9 per cent) over control. Beetle population was reduced by 25.10 and 54.66 per cent (mean = 39.9 per cent) and hill damage by 55.70 and 10.11 per cent (mean = 32.9 per cent) over control during 2005 and 2005 respectively. This corroborates with the earlier results of Budhraja *et al.,* 1980; Krishnaiah and Kalode, 1983; Zafar, 1984; Lakshminarayana *et al.,*1985; Dhaliwal and Singh, 1988; Kaul and Bhagat, 1997 who reported the effectiveness of carbofuran granules against rice hispa. Carbofuran was also effective against other rice pests like *S.incertulas*, *C. medinalis*, *H. philippina*, *N. virescens*, *N. lugens*, *Paraponyx stagnalis* Zeller and *O. oryzae* (Kandaswamy and Ravikumar, 1986; Krishnaiah *et al.,* 1988; Uthamaswamy and Karuppuchamy, 1988).

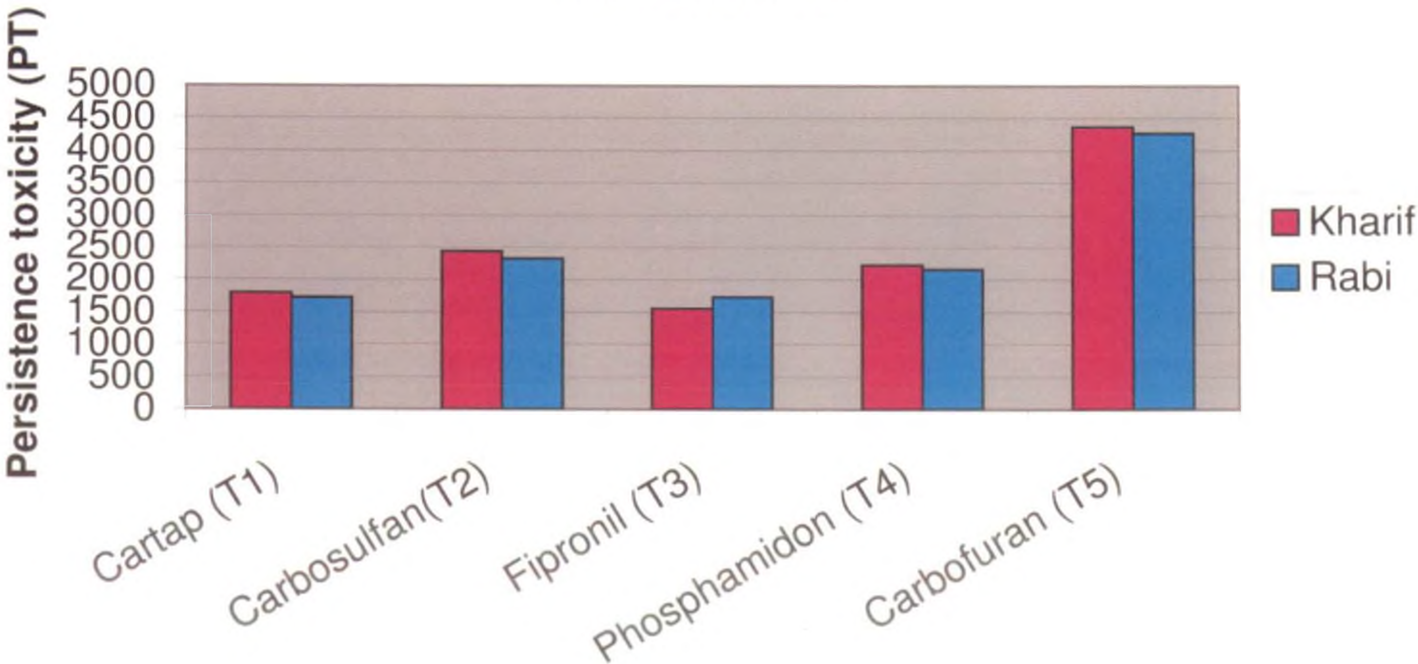
Fipronil was found least effective against *L. pygmaea*. But, it has been reported to be effective against other rice pests *viz., Oryzophagus oryzae. S.furcifera*, *N.lugens*, *Chilo suppressalis*, *S. incertulas*, *C. medinalis* and *Pelopidas mathias*. (Leite *et al.,* 1995; Sonatakke and Dash, 2000; Huifang *et al.,* 2001; Wenda *et al.,* 2002; Salioqi *et al.,* 2002; Dash and Mukherjee, 2003; Panda and Rath, 2004; Srinivas and Madhumathi, 2004). Root dip of rice seedlings with fipronil @0.01 % effectively controlled rice yellow stemborer (Jena, 2004).

The decreasing order of efficacy of the tested granular insecticide against *L. pygmaea* was cartap hydrochloride > carbofuran > carbosulfan > phosphamidon > fipronil.

5.7.4.2 Persistent toxicity of granular insecticides against blue beetle

Results of persistent toxicity studies conducted in the net house for four seasons (two Kharif and two Rabi seasons) indicated the same order of residual toxicity on *L. pygmaea* in all four seasons (Fig.15). Carbofuran was the most

Fig.15. Persistence toxicity of granular insecticides



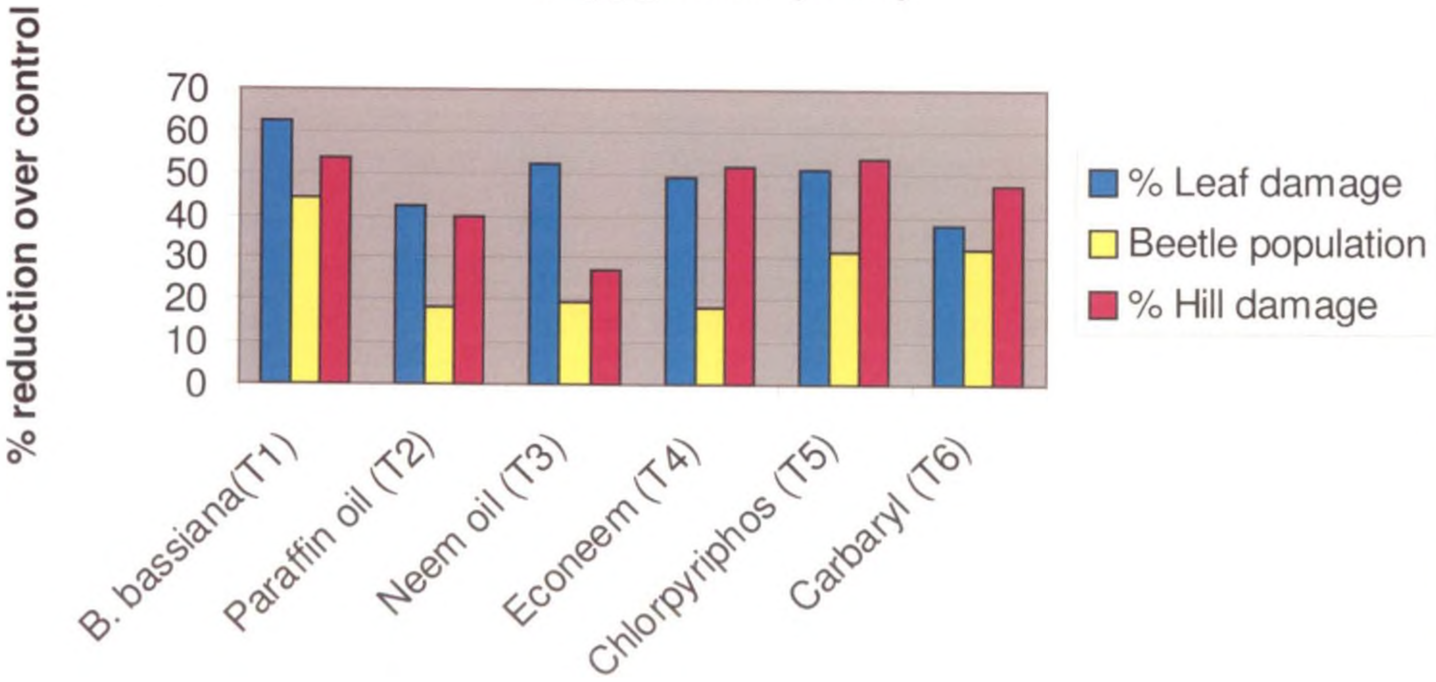
persistent insecticide with highest PT value followed by carbosulfan, phosphamidon, cartap hydrochloride and fipronil. Higher persistence of carbamate insecticide followed by organophosphate is thus indicated in the present findings. Cartap hydrochloride, an animal origin insecticide based on nereistoxin, showed high bioefficacy against *L.pygmaea*, but showed low residual toxicity. The present finding of high degree of persistent toxicity of carbofuran corroborates with the report of Krishnaiah and Kalode, (1983). Fipronil showed lowest persistent toxicity and bioefficacy and hence it was least effective against *L. pygmaea*. These findings are in confirmation with the study of Lakshmi *et al.* (2001) who reported lowest persistent toxicity in fipronil against *Tytthus parviceps* (Reut), a potential predator of brown plant hopper.

5.7.4.3 Evaluation of eco-friendly insecticides for the management of rice blue beetle

The field toxicity of foliar insecticides evaluated for their bioefficacy against *L. pygmaea* was in the decreasing order of *B. bassiana* > chlorpyriphos > carbaryl > econeem > paraffin oil > neem oil (Fig 16 and 17). White muscardine fungus, *B. bassiana* @ 10^7spores/ml significantly reduced leaf damage, population of blue beetle and hill damage by 62.14 and 31.18 per cent (mean = 46.7 per cent), 46.28 and 49.18 per cent (mean = 47.7 per cent) and 53.52 and 38.20 per cent (mean = 45.9 per cent) during 2004 and 2005 respectively over control. This confirms to the findings of Hazarika and Puzari, 1990; Puzari and Hazarika,1991, 1992 and Puzari *et al.*,1994 who reported that white muscardine fungus, *B. bassiana* was an effective biocontrol agent against another chrysomelid, rice hispa. Hazarika and Puzari (1995) indicated the effectiveness of *B. bassiana* @ 10 million spores / ml as on par with 1 per cent neem oil and monocrotophos against hispa.

The insecticide, chlorpyriphos @ 0.05 per cent was equally effective in reducing leaf damage, population of rice blue beetle and hill damage during 2004 and 2005 by 51.1 and 45.34 per cent (mean = 48.2 per cent), 34.44 and 49.41 per cent

Fig.16. Bioefficacy of foliar insecticides against *L. pygmaea* (2004)



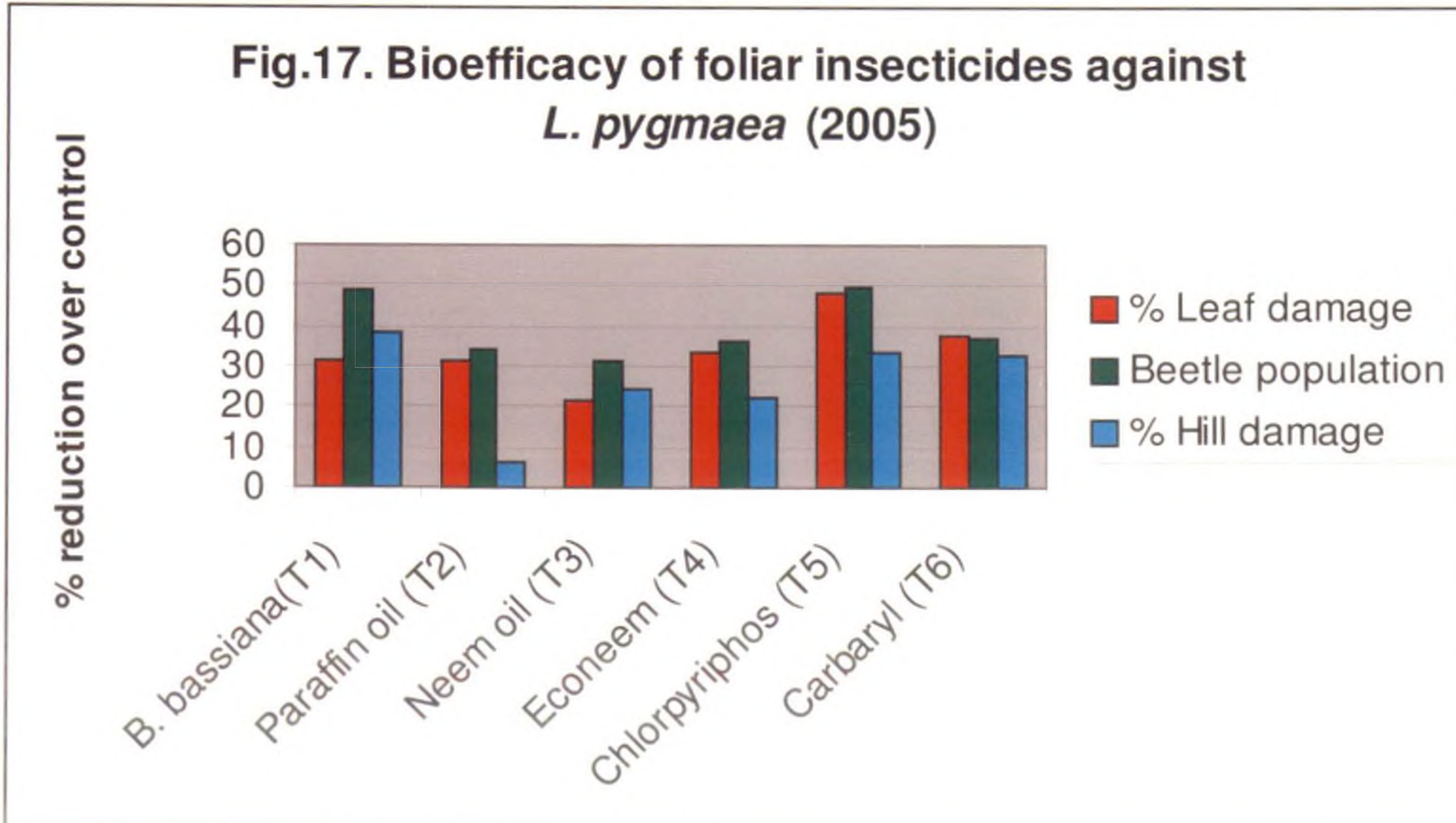


Fig.17. Bioefficacy of foliar insecticides against
L. pygmaea (2005)
% reduction over control
60
50
40
30
20
10
0
B. bassiana(T1)
Paraffin oil (T2)
Neem oil (T3)
Econeem (T4)
Chlorpyriphos (T5)
Carbaryl (T6)
% Leaf damage
Beetle population
% Hill damage

(mean = 41.9 per cent), 53.52 and 33.51 per cent (mean = 43.4 per cent) respectively over control. This result is in confirmation with earlier study on the efficacy of chlorpyriphos against hispa (Dhaliwal *et al.,* 1977; Biswas and Mandal, 1992). Chlorpyriphos both as sprays @ 0.05 % as well as seedling root dip @ 0.02 per cent was found effective against rice hispa (Krishnaiah *et al.*, 1987; Dhaliwal and Singh, 1988). Chlorpyriphos was also reported to be effective against other rice pests like *S. incertulas*, *C. medinalis*, *H. philippina*, *B. biformis* (Kandaswamy and Ravikumar, 1986), *N. virescens*, *N. lugens* and *O.oryzae* (Uthamaswamy and Karuppuchamy, 1988).

Carbaryl @ 0.02 per cent was found to reduce leaf damage, population of rice blue beetle and hill damage by 37.96 and 37.82 per cent, 34.71 and 36.71 per cent and 47.38 and 32.58 per cent respectively over control during 2004 and 2005 thus confirming the earlier study of Dalvi *et al.* (1985) and Dhaliwal and Singh (1988) who reported that carbaryl @ 500 g a.i. /ha or @ 0.01 % was effective against both rice blue beetle and hispa.

In 2004 and 2005, leaf damage, beetle population and hill damage were reduced in neem oil treatment by 40.48 and 21.43 per cent, 23.01 and 31.06 per cent and 26.99 and 24.50 per cent respectively over control. Similar observations were made by Krishnaiah and Kalode (1991) who reported that efficiency of neem oil spray was poor against rice hispa. On the contrary, Baitha *et al.* (1993) noticed that application of neem based products, NSKE @ 5 % and neem oil @ 3 per cent reduced the per cent leaf damage of rice hispa by 14.11 and 14.84 per cent respectively.

Econeem 1 per cent spray @ 0.004 per cent reduced the leaf damage, beetle population and hills damage by 48.91 and 33.41 per cent, 21.28 and 36 per cent and 51.87 and 22.25 per cent in 2004 and 2005 respectively over control. Lingaiah *et al.* (1999) observed that NG 4 (300 ppm azdirachtin), Nimbecidine (300 ppm azadirachtin), Rakshak (1500 ppm azdirachtin) and Neem azal T/S (10,000 ppm) exhibited feeding deterrency against rice hispa. Patel *et al.* (2004) observed that foliar sprays of azadirachtin resulted in lower population of green leafhopper in rice.

The application of paraffin oil @ 2 per cent during 2004 and 2005 reduced the leaf damage, beetle population and hill damage by 42.34 and 31.31 per cent, 21.28 and 34.12 per cent and 39.58 and 6.30 per cent respectively over control. No work on mineral oil in rice insect pests has been reported. Mineral oil @ 5 per cent significantly reduced the production and germination of *B. bassiana* conidia (Batista *et al.,* 1995). Boulahia *et al.* (1996) observed that the sprays with mineral oil (Oleostac) controlled the population of citrus leaf miner, *Phyllocnistis citrella* in Northern Tunisia. Mineral oil (KZ oil 95 % e.c) was found effective against California red scale, *Aonidiella aurantii* and cottony cushion scale, *Icerya purchasi* under laboratory conditions (Hassan, 1999).

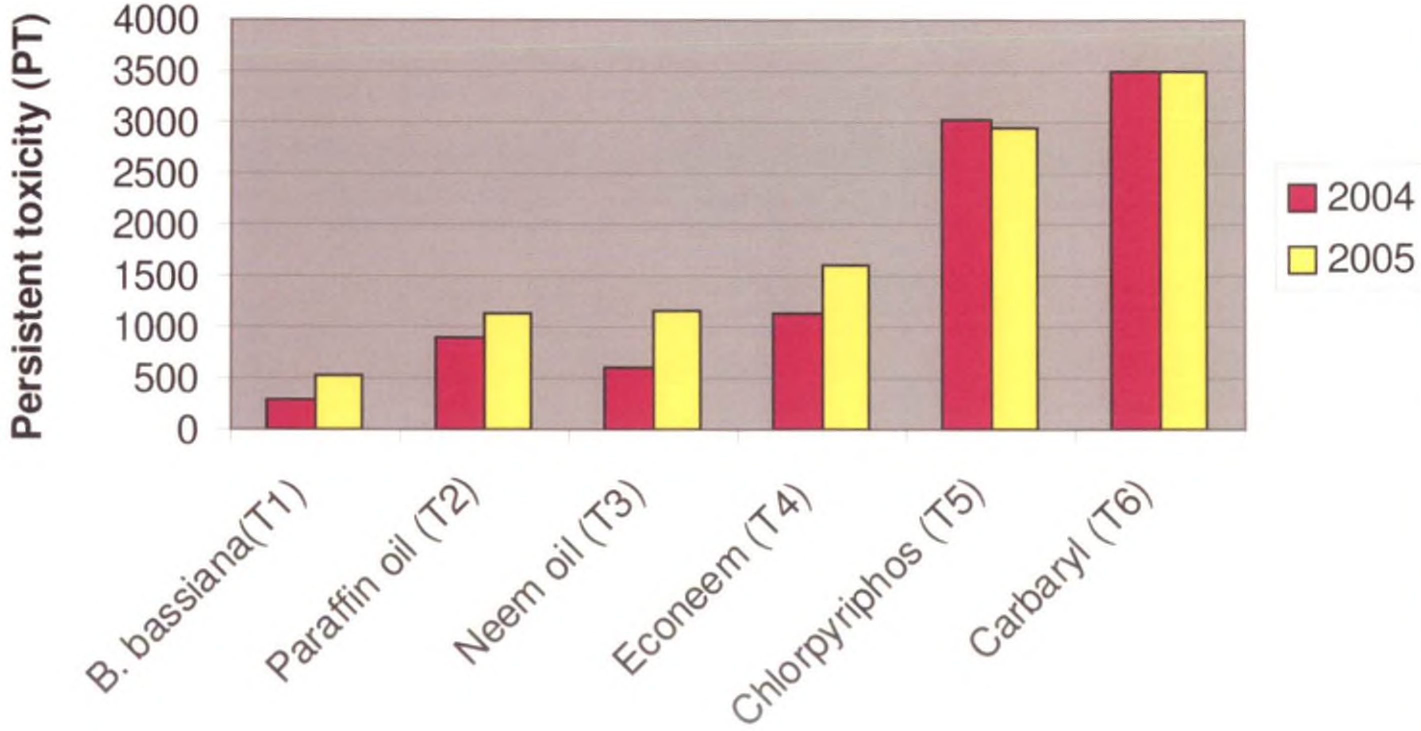
The higher efficacy of *B. bassiana* @ 10 million spores / ml and chlorpyriphos @ 0.05 % against *L. pygmaea* is thus revealed in the present study and adds to the list of earlier promising chemicals viz., fenthion, fenitrothion, orthene (0.05%), dimethoate (0.04%), lannate (0.05%), monocrotophos (0.05%), BHC (0.2%), carbaryl (0.01%), permethrin (0.01%), phosalone (0.05%), Bassa (0.05%) and endosulfan (0.05%) (Thontadarya and Devaiah 1975; Dalvi *et al.,* 1985).

Among the eco-friendly insecticides, *B. bassiana* followed by econeem and synthetic insecticides - chlorpyriphos followed by carbaryl were found effective for the management of *L. pygmaea*.

5.7.4.4 Persistent toxicity of foliar insecticides against blue beetle

Among the tested foliar insecticides, carbaryl (0.2 %) showed highest persistent toxicity (PT value = 3500) followed by chlorpyriphos (PT value = 3035) (Fig.18). Both resulted in 100 per cent mortality of *L. pygmaea* at 10 days after treatment. Similar results were reported by Krishnaiah and Kalode (1983) who

Fig. 18. Persistent toxicity of foliar insecticides



observed moderate to high degree of persistent toxicity for chlorpyriphos against rice hispa. Persistent toxicity of insecticides was found to be lesser in Kharif than Rabi seasons, because the rains occurring in Kharif season might have reduced the residual effectiveness. *B.bassiana* recorded lowest persistent toxicity (PT value = 533) producing only 26.7 per cent mortality of *L. pygmaea* at 10 days after treatment. The decreasing order of persistent toxicity of different treatments was carbaryl > chlorpyriphos > econeem > neem oil > paraffin oil > *B. bassiana.*

The results also confirm the general observation that chemical insecticides persist for a longer period, when compared to non chemical ones. *B. bassiana* being fungal in origin, showed the lowest persistence, since it is effective and eco-friendly, it is of great importance in the management of the pest. It is also indicated that persistent toxicity of carbamate insecticide (carbaryl) is more than that of organophosphate (chlorpyriphos). This was found true in the case of granular insecticides also tested in the earlier experiment. Chlorpyriphos was very effective in toxicity as well as persistence to *L. pygmaea*. Krishnaiah and Kalode (1984) indicated low acute and persistent toxicity of neem oil against *N. lugens* and *N. virescens*. But econeem, a neem based commercial formulation showed higher persistence and toxicity than neem oil.

5.8 IPM PACKAGE AGAINST *L. pygmaea*

Based on the salient findings of the present investigation, an IPM package can be recommended against *L.pygmaea.* The various tactics evolved in the present study are summarised below:

- At present no rice varieties are found to be resistant against *L.pygmaea*. There are no moderately resistant high yielding varieties except Hraswa which is a short duration KAU variety with 70 to 75 days duration. Jyothi, the most popular variety from Kerala is a highly susceptible and hence avoid its cultivation in rice blue beetle endemic areas.
- Removal of alternate weed hosts from rice fields and bunds. *Panicum repens* and *Isachne miliaceae* are the important weed hosts of *L.pygmaea.*

- Infestation is higher in transplanted than direct seeded rice. Closer spacing reduces the attack of *L. pygmaea*. Therefore, direct seeding is more useful in rice blue beetle prone areas to suppress the population. If transplanting is to be done, adoption of closer spacing (10x10cm) is better.
- Nursery application of cartap hydrochloride granules @ 1000 g a.i./ha five days prior to pulling out of rice seedlings affords good protection against rice blue beetle.
- Foliar application with eco-friendly insecticides such as white muscardine fungus, *B. bassiana* @ 10^7 spores / ml or azadirachtin 10,000 ppm (econeem) @ 0.004 % are effective in reducing the rice blue beetle population.
- Alternating chemical insecticides *viz.*, chlorpyriphos @ 0.05 % or carbaryl @ 0.2 % can be recommended for the effective management of *L. pygmaea*.

Summary

6. SUMMARY

In recent years, there has been a tremendous change in the insect pest scenario of rice. Insect pests of relatively minor importance attaining major status and leading to pest out breaks, is one of the serious problems in rice cultivation.

The rice blue beetle, *Leptispa pygmaea* Baly hitherto considered as a minor pest of rice has been recently reported to have emerged as a major pest and caused severe damage to rice cultivation in Kerala particularly in the Palakkad, Kannur and Kasaragod districts. Hence, the present study entitled "Bioecology, population dynamics and integrated management of rice blue beetle, *Leptispa pygmaea* Baly" was been undertaken at the Regional Agricultural Research Station, Pattambi, Kerala Agricultural University during 2004-2006. The results of the study are summarised hereunder.

1. BIOLOGY OF *Leptispa pygmaea*

The biology of *L. pygmaea* was worked out on two rice varieties *viz.,* Jyothi (short duration) and Aiswarya (medium duration) under net house condition. There was no marked difference in the biology of *L. pygmaea* on short and medium duration varieties. Eggs are laid singly or groups of 2, 3, 4 or 5 in a straight line on the upper or lower surface of tender or mature leaves of young rice plants. The fecundity ranged from 10 to 19 eggs during an oviposition period of six days. Eggs hatched into grubs within 3 to 4 days and the grubs by feeding on the rice leaves completed development with five larval instars in 6 to 11 days. Grubs pupated on the leaves for 2 to 4 days and the adult beetles emerged out and lived for a period of 25 to 41 days. Males had a longer longevity of 25 to 41 days. Adult emergence was higher in morning hours at 800-900 hours. The total life cycle of *L. pygmaea* from egg to adult stage was completed within a period of 12 to 19 days.

In the field, generally male blue beetles were found to be more than females with mean sex ratio of 1.5: 1.3. The peak population period was observed during July to November. Highest population was observed during July, when females predominated whereas, males outnumbered when the field population was lowest in November.

2. MORPHOLOGY, MORPHOMETRICS AND ANATOMY OF REPRODUCTIVE SYSTEM

Freshly laid eggs were oval in shape and light green coloured. They turned yellowish towards hatching. The eggs measured an average length and width of 0.39 mm and 0.19 mm respectively.

The grub of *L. pygmaea* was creamish green coloured with a brown head having two spiny projections on the head. The last instar grub turned to dirty white before pupation. The total length of grub increased from 3.7 to 5.9 mm from the 1st instar to 5th instar. The width was increased from 1.1 to 1.6 mm during these instars.

Freshly formed pupa was white in colour which later changed to brown and seen loosely attached to the leaf by its posterior end. It measured an average length of 3.81mm and width of 1.22 mm. The freshly emerged beetle was bluish dorsally and white coloured on ventral side and later changed to black in colour.

Adult female was elongated metallic bluish green beetle with 7.05 mm length and 2.10 mm width. Male beetle was metallic yellowish green with 6.05 mm length and 1.89 mm width.

Male and female beetles could be differentiated by the size of the body. Male beetles showed larger body size, smaller thorax, longer antennae with short scape while females had small body size, wider thorax, short antenna with broad (truncate) scape.

The dissection of male and female sex organs showed that male reproductive organ comprised of aedeagus with two parts of tegmen and sipho. The aedeagus measured a length of 1.36 mm and the anterior and posterior width measured 0.07 and 0.10 mm respectively. The female reproductive organs comprised of spermatheca and two lateral coxites. The coxites had a mean length of 1.60 mm and a width of 0.52 mm.

3. MONITORING OF FIELD POPULATION DYNAMICS

Seasonal incidence of *L. pygmaea* in the field during Kharif and Rabi seasons were monitored. During Kharif'05, the population of rice blue beetle was found to increase from fourth week of June at 10 days after transplanting and reached a peak during the second week of July'05 at early tillering stage. Thereafter, the population started declining and lowest population was observed during third week of September.

In Rabi'05, the beetle population showed an increasing trend from third week of October at 10 days after transplanting and reached a peak during first week of November'05 at 24 days after transplanting. The population indicated a decreasing trend from second week of November. Highest population of 550 and lowest population of 5 beetles / 20 plants were observed during first week of November and fourth week of December'05 respectively. It is indicated that highest blue beetle population occurred at early tillering stage of rice in both Kharif and Rabi seasons revealing the importance of crop stage in the population buildup of *L. pygmaea*. Incidence of *L. pygmaea* was higher in Kharif than in the Rabi season.

There was a negative correlation of beetle population and per cent damaged leaves with regard to maximum temperature and sunshine hours and a positive correlation with minimum temperature and relative humidity. Rainfall showed no significant effect on beetle population.

4. NATURE OF ATTACK AND INTENSITY OF DAMAGE

Both grubs and adults scrape the chlorophyll matter from the upper surface of leaves resulting in white longitudinal streaks. Highest damage was caused by grub followed by female and male beetles irrespective of varieties in rice. A single grub consumed 82 per cent more leaf area than by a single male beetle, while the female fed 32.6 per cent more leaf area than that of a male.

Between the two varieties of rice, Jyothi suffered more (29 per cent) damage than Aiswarya.

5. EXTENT OF DAMAGE DURING DIFFERENT GROWTH STAGES OF RICE

Higher damage occurred from seedling to tillering and thereafter the infestation was less in the other stages of crop growth. Early tillering stage of rice was found to be the most susceptible stage for the infestation of blue beetle resulting in highest damage (68.54-75.32 per cent) in both Kharif and Rabi seasons. The damage of the beetle declined in later growth stages and lowest damage was observed in booting, while and there was no damage during flowering stage.

6. INFLUENCE OF METHODS OF CULTIVATION ON THE INCIDENCE OF *L. pygmaea*

Direct seeding method of rice cultivation reduced the damage by *L. pygmaea* compared to transplanted rice in both Kharif and Rabi seasons. Direct seeding resulted in 49.4 to 68.4 per cent reduction of damage over transplanting during Kharif and Rabi seasons respectively.

In early tillering stage, damage was lowered by 34.24 to 36.33 per cent and 45.86 to 58.17 per cent during Kharif and Rabi seasons respectively in direct seeding.

7 INTEGRATED MANAGEMENT METHODS

7.1 HOST PLANT RESISTANCE

7.1.1 Screening of varieties / cultures to identify resistant source

A total of 106 rice varieties / cultures were screened for resistance against *L.pygmaea*. None of the entries showed complete resistance to the pest. The varieties *viz.,* Ptb.3, Ptb.4, Ptb.7, Ptb.9, Ptb.18, Ptb.19, Ptb.20, Ptb.25, Ptb.26 and Hraswa showed moderate resistance to the pest. The high yielding varieties, Jyothi (Ptb.39), Bharathy (Ptb.41), Ranjini (MO 12) and Kunjukunju variety (Varna) were highly susceptible to the pest.

7.2 CULTURAL METHOD

7.2.1 Alternative weed hosts

L. pygmaea was observed on ten weed plants growing in the rice field. But, feeding and oviposition were seen only on two weed plants *viz., Panicum repens* and *Isachne miliacea.* There was no egg hatchability on *I. miliacea,* but on *P. repens* there was cent per cent egg hatching and the beetle carried out its normal life cycle on the weed. The life cycle was shorter on *P. repens* as compared to Jyothi and Aiswarya.

7.2.3 Effect of plant spacing and soil application of oil cakes on the pest incidence

Closer plant spacing of 10x10 cm and 10x15 cm significantly reduced the incidence of beetle with low per cent leaf damage, beetle population and per cent hill damage compared to the recommended spacing of 20x15 cm. The damage score was '3' in the recommended plant spacing (20x15 cm), while it was '1' in closer spacings (10x15 cm and 10x10 cm). Closer spacing with 10x10 cm could result in a reduction of 64.47 per cent hill damage, 54 per cent beetle population and 45.73 per cent leaf damage over the recommended spacing of 20x15 cm in Jyothi. But the application of non-edible oil cakes *viz.,* neem cake, castor cake and pungam cake did not have any significant effect on the incidence of the pest.

7.3 BIOLOGICAL METHODS

7.3.1 Identification and study of the natural enemies of *L.pygmaea* in the field

Eggs of rice blue beetle were found to be parasitized by *Trichogramma* sp. (Trichogrammatidae), *Telenomus* sp. (Scelionidae) and *Tetrastichus* sp. (Eulophidae) in the field. These parasitoids are reported for the first time on *L. pygmaea*.

7.3.2 Pathogenicity of *Beauveria bassiana* on *L.pygmaea*

The effectiveness of white muscardine fungus, *Beauveria bassiana* against *L. pygmaea* revealed that *B. bassiana* @ 10^5 to 10^9 spores / ml caused highest mortality of 60, 80 and 100 per cent within 24, 48 and 72 hours after treatment. The LC_{50} values were $9.97x10^6$, $4.44x10^4$, $8.84x10^3$ spores / ml at 24, 48, 72 hours after treatment respectively.

7.3.3 Entomopathogenic nematode, *Heterorhabditis indica*

The efficacy of entomopathogenic nematode, *H. indica* against the grubs of *L. pygmaea* indicated that *H. indica* at concentrations of 5 IJ's, 6 IJ's, 7 IJ's, 8 IJ's and 9 IJ's per ml resulted in 40 to 85 per cent mortality at 24 hours after treatment. Concentration of 9 IJ's per ml produced 85 per cent mortality at 24 hours after treament. The LC_{50} values at 24, 48 and 72 hours after treatment were 5.45, 3.74 and 3.72 IJ's per ml respectively.

7.4 CHEMICAL MANAGEMENT

7.4.1 Management of blue beetle by nursery treatment with granular insecticides

Nursery treatment with cartap hydrochloride @ 1000 g a.i./ha was most effective in reducing leaf damage, beetle population and hill damage caused by *L. pygmaea* in the main field followed by carbofuran treatment @ 1000 g a.i./ha. Fipronil was least effective.

7.4.2 Persistent toxicity of granular insecticides against blue beetle

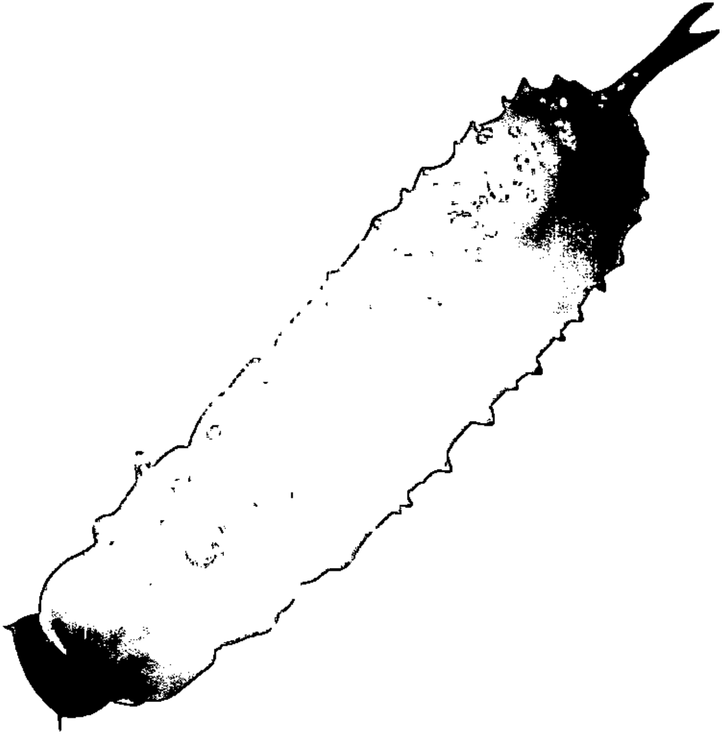
Carbofuran was the most persistent insecticide with the highest PT value followed by carbosulfan, phosphamidon, cartap hydrochloride and fipronil in both the Kharif and Rabi seasons. Carbofuran caused 100 per cent mortality of *L. pygmaea* upto 20 days after treatment. The residual toxicity of cartap was less as it caused only 60 per cent mortality at 10 days after treatment.

7.4.3 Evaluation of eco friendly foliar insecticides for the management of rice blue beetle

Among the eco-friendly foliar insecticides, white muscardine fungus, *B. bassiana* @ 10^7 spores / ml was the most effective one against *L. pygmaea*. Econeem (1 % azadirachtin) @ 0.004 per cent was the next best one. Among the chemical insecticides, chlorpyriphos @ 0.05 per cent followed by carbaryl @ 0.2 per cent also showed effective management of the blue beetle. Neem oil @ 2 per cent indicated very low effectiveness.

7.4.4 Persistent toxicity of foliar insecticides against blue beetle

Carbaryl was the most persistent insecticide with the highest PT value followed by chlorpyriphos, econeem, paraffin oil, neem oil and *B. bassiana* in both Kharif and Rabi seasons.



References

REFERENCES

Afzal, M., Hussain, S.S. and Sherawat, S.M. 2003. Toxicity of different insecticides against rice stem borers (*Scirpophaga incertulas* Walker and *Scirpophaga innotata* Walker). *Pakist. Entomologist* 25 (2) : 207-210

Agarwal, S.D. 1955. On the control of paddy hispa (*Hispa armigera* Oliv.) at Pusa (Bihar-India). *Indian J. Ent.* 17 (1) : 11-16

Agarwal. G. 1990. Entomogenous fungi in India and management of insect pests. *Indian Phytopatho.* 43 : 131-142

Anonymous, 1931. The paddy *Leptispa* leaflet no:42, Department of Agriculture, Madras, pp : 3-4

Anonymous, 1975. Standard Evaluation System for Rice. 2nd edition. International Rice Testing Programme. International Rice Research Institute, Manila, Philippines. 54p

Banarjee, D.K. and Nath, D.K. 1986. Rice hispa in Burdwan, West Bengal. *IRRI Newsl.* 11 (1) : 14-15

Baitha, A., Hameed, S.F. and Singh, R. 1993. Effectiveness of neem (*Azadirachta indica* A.Juss) products against rice hispa, *Dicladispa armigera* Oliv. and *Hieroglyphus nigropletus* Bol. *J. Ent. Res.* 17 (2) : 149-152

*Batista, F.A., Leite, L.G., Raga, A., Sato, M.E. and Rossi, M.N. 1995. Effect of mineral oil on the entomogenous fungus, *Beauveria bassiana* (Bals.) Vuill. *Revista-de-Agricultura-Piracicaba.* 70 (3) : 315-324

Biswas, A.K. and Mandal, S.K. 1992. Field efficacy of several insecticides against rice hispa. *J. Maharashtra agric. Univ.* 17 (1) : 169

*Boulahia, S.K., Jerraya, A. and Zaidi, H. 1996. Chemical control trials against citrus leaf miner, *Phyllocnistis citrella*. *Fruits-Paris.* 51 (4) : 223-228

Budhraja, K., Rawat, R.R. and Singh, O.P. 1979. Field efficacy and economics of some insecticides against *Dicladispa armigera* on paddy. *Indian J. Pl. prot.* 7 (2) : 119-123

Budhraja, K., Rawat, R.R .and Singh, O.P. 1980. Effectiveness and economics of granular insecticides for control of hispa. *IRRI Newsl.* 5 (5) : 20

*Carruthers, R.J. and Soper, R.S. 1987. Fungal diseases. *Epizootiology of Insect Diseases* (eds. Fuxa, J.R. and Tanada. Y). John Wiley and Sons, New York. pp. 357-416.

Chand, P. and Tomar, J.B. 1984. Screening for resistance to rice hispa. *IRRI Newsl.* 9 (2) : 6

Chandra, D. 2003. Sarla rice suitable for shallow submergence for Eastern India. *Indian Fmg.* 53 (6) : 4-6

Chatterjee, P.B., Sen, S.C., Sarkar, D. and Hikimindran, 1983. On the implementation of IPM in rice. *Pest Mgmt in Rice*, TNAU, Coimbatore. pp. 270-279

*Choi, S.Y. 1976. Application of insecticides in the root zone of rice plants. *Korean J. Pl. Prot.* 15 (2) : 60

*Cramer, H.H. 1987. Plant Protection and World food protection. *Pflanzenschrutz-Nachrichten*, Bayer. 20 (1) : 1-524

Dale.D. 1994. Insect pests of rice plant – their biology and ecology. *Biology and Management of Rice Insects* (ed. Heinrichs, E.A). Wiley Eastern Limited and New Age International Limited. p .779

Dalvi, C.S., Dumbre, R.B. and Khanvilakr, V.C. 1985. Bionomics, seasonal incidence and off season biology of rice blue beetle. *J. Maharashtra agric. Univ.* 10 (2) : 185-187

Dalvi, C.S., Dumbre, R.B. and Khanvilakr, V.C. 1985. Efficacy of some insecticides for the control of rice blue beetle. *Leptispa pygmaea* Baly. *Pesticides* 19 (7) : 11-12

Dash, A.N. and Mukherjee, S.K. 2003. Insecticidal control of major pests of rice. *Pest Mgmt. Econ. Ecol.* 11 (2) : 147-151

David, B.V. and Kumaraswami, T. 1975. *Elements of Economic Entomology*. Popular Book Depot, Madras. p.514

David, P.M.M. 1986. Effect of slow release nitrogen fertilizer and foliar application of neem products. *Madras agric. J.* 73 (5) : 274-277

Deka, M. and Hazarika, L.K. 1995. Anatomy of the reproductive system of *Dicladispa armigera* (Coleoptera : Chrysomelidae). *Pl. Health.* 1 : 48-55

Deka, M. and Hazarika, L.K. 1997. Mating and oviposition behaviour as affected by differences in sex ratio of rice hispa, *Crop Res. Hisar.* 13 (1) : 163-167

Deka, M. and Hazarika, L.K. 1997. Effects of neem seed oil on food consumption and utility by rice hispa. *Pesticides Res. J.* 9 (1) : 113-116

Dhaliwal, G.S. 1979. Some weed hosts of rice hispa recorded in India. *IRRI Newsl.* 4 (2) : 19

Dhaliwal, G.S. 1980. Field reaction of rice cultivars to hispa and leaf folder. *IRRI Newsl.* 5 (1) : 7

Dhaliwal, G.S., Chawla, R.P. and Kalra, R.L. 1977. Toxicity of commercial formulations of some insecticides to adults of rice hispa. *Int. Rice Commn. Newsl.* 26 (1) : 31-32

Dhaliwal, G.S. and Singh, J. 1988. Effect of dosage and method of application of insecticides on the incidence of rice hispa. *J. Insect Sci.* 1 (1) : 79-82

Dhaliwal, G.S., Singh, J. and Jaswant, S. 1979. Effect of spacing on rice hispa incidence. . *IRRI Newsl.* 4 (2) : 19

Dhingra, M.R. Singh, S.B. and Bhagat, D.V. 2003. Field efficacy of some insecticides against *Leptocorisa varicornis* Fabr. (Coreidae : Hemiptera) in rice. *J. Soils Crops.* 13 (1) : 29-32

Duncan, D.B. 1951. A significance test for differences between ranked treatment means in an analysis of variance. *Va. J. Sci.* 2 : 171-189

Dutta, B.C., Bairagi, P.P. and Bhattacharya, B. 1997. Bioefficacy of certain insecticides against rice hispa, *Dicladispa armigera. J. agric. Sci. Soc. North East India.* 10 (2) : 202-205

Dutta, B.C. and Hazarika, L.K. 1995. Feeding and ovipositional preference of rice hispa, *Dicladispa armigera* (Oliver) (Coleoptera : Chrysomelidae) on some host plants. *J. agric. Sci. Soc. North East India.* 8 (2) : 14-19

Eiteman, I.M.J. and Powar, A.G. 1997. Response of green leaf hoppers to rice growing practices of northern Ireland. *Ecol. Applications* 7 (1) : 194-208

Elsy, C.R., Dev, V.P.S., Rosamma, C.A., Rajan, K.M. and Nadarajan. 1995. Adaptability and Acceptability components of rice cultivar Kunjukunju. *J. trop. Agric.* 33 (1) : 72-74

Elton, C.S. 1927. *Animal Ecology*. Sidgwick and Jackson, London.

*Ferreira, E., Kluthcouski, J., Silveira, P.M.D. and Santos, A.D. 1996. Effects of cultural practices on upland rice insect pests. *Anais-da-Sociedade-Entomologica-da-Brasil* 25 (1) : 131-135

Ferron, D. 1978. Biological control of insect pests by entomogenous fungi. *Ann. Rev. Ent.* 23: 409-421

Finney, D.J. 1977. *Probit Analysis*. Cambridge University press, Cambridge. p. 333

Fletcher, T.B. 1913. *Note on Insects Attacking the Paddy Plant in Southern India*. Popular Book Depot. p. 53

*Franco, G.V. 1999. Chemical control of *Aphis gossypii* Glover. (Homoptera : Aphididae) on a cultivar susceptible to viruses. *Anais II congresso Brasileiro de Algodao: O algodao no seculo XX, perpectivar para a seculo XXI, Ribeirao Preto, SP, Brasil, Setembro 5-10,* 1999. pp.195-197

Fuxa, J.R. 1987. Ecological considertation for the use of entomopathogens in IPM. *Ann. Rev. Ent.* 32 : 225-251

Ghose, R.L.M., Ghatge, M.B. and Subramanyam, V. 1960. *Rice in India,* ICAR, New Delhi. pp. 253-254

*Guozhong, M., Guankang, X., Anpin, Y., Zhaokang, Z., Youlong, L. and Huiquan, Z. 2002. Screening of insecticides for control of *Cnaphalocrocis medinalis* Guenee. *Plant Prot.* 28 (1) : 51

Gupta,S. and Chandra, G. 1957. Annotated list of crop pests in the state of Orissa. *Mem. Ent. Soc. India.* No.5, p.7

Gupta, G.P. and Raghuraman, M. 2003. Plant protection in suppressing for food security. *Indian Fmg.* 53 (7) : 31-34

*Gurubasavaraj, T.M., Mariappan, V. and Jayaraj, S. 1988. Final workshop of IRRI-ADB-EWC project on Botanical Pest Control in Rice- Based cropping system. IRRI, Manila Philippines

Haque, M.E., Durbey, S.C. and Singh, B.N. 1987. Varietal resistance to rice hispa. *IRRI Newsl.* 12 (6) : 13

Hassan, T.A. 1999. Evaluation of some insecticides for the control of scale insects and mealy bugs in Yemen. *J. Natural appl. Sci.* 33 : 50

Hazarika, L.K. and Puzari, K.C. 1990. *Beauveria bassiana* for biological control of rice hispa in Assam, India. *IRRI Newsl.* 11 (1) : 31

Hazarika, L.K. and Puzari, K.C. 1995. White muscardine fungus, *Beauveria bassiana* pathogenic to different stages to rice hispa, *Dicladispa armigera. Indian J. agric. Sci.* 65 (1) : 368-372

Hazarika, L.K. and Puzari, K.C. 1997. Field efficacy of White muscardine fungus, *Beauveria bassiana* on rice hispa, *Dicladispa armigera. Indian J. agric. Sci.*, 67 (10) : 463-465

Hazarika, L.K., Puzari, K.C. and Saikia, D.K. 1998. Seasonal and host correlated variation in the susceptablility of rice hispa to *Beauveria bassiana* in the field. *Indian J. agric. Sci.* 67 (7) : 361-363

*Huifang, G., Jiehao, F., Zhaolin, S., Huaxin,F. and Lingui, W. 2001. Laboratory tests and field evaluation of fipronil against rice insect pests. *Acta Phytophylacia.* 28 (3) : 259-264

Ismail, M., Ahmad, M., Riaz, M. and Ramzan, M. 1995. Efficacy of some insecticides for the control of white backed plant hopper, *Sogatella furcifera* (Horv.). *Pakist. Entomologist* 17 (1/2) : 78-80

Jena, M. 2004. Efficacy of new insecticides as seedling root dip treatment against yellow stem borer in rabi rice. *Indian J. Pl. Prot.* 32 (2) : 37-39

Kabir, S.M.H. and Mia, M.D. 1971. Residual toxicity of three organophosphorus insecticides applied to rice hispa, *Hispa armigera*. *Indian J. agric. Sci.* 41 (1) : 25-29

Kabir, S.M.H. and Mia, M.D. 1976. Persistence toxicity of monocrotophos and phosphamidon in soil against *Dicladispa armigera* in rice. *Indian J. Ent.* 38 (3) : 297-298

*Kadam, M.V., Bhatt, M.V. and Patel, G.A. 1956. *Pests of Paddy and Their Control. Crop Pests and How to Fight Them.* Directorate of Pubilicity, Govt. of Bombay. pp.54-55

Kalode, M.B. and John, V.T. 1982. Strategy for increased production-plant protection. Paper presented at the Annual Workshop of the All India Co-ordinated Rice Improvement Project. 12-14 April, 1982

Kandaswamy, C. and Ravikumar, S. 1986. Efficacy of four insecticides against major pests in Tamil Nadu. *IRRI Newsl.* 11 (3) : 21

Kareem, A.A., Saxena, R.C., Boncodin, M.E.M. and Malayba, M.T. 1989. Effect of neem seed and leaf bitters on oviposition and development of green leaf hopper (GLH) and brown plant hopper (BPH). *IRRI Newsl.* 14 (6) : 26-27

Karthikeyan, K. and Purushothaman, S.M. 2000. Efficacy of carbosulfan against rice stem borer, *Scirphophaga incertulas* Walker (Pyralidae : Lepidoptera). *Indian J. Pl. Prot.* 28 (2) : 212-214

Kaul, B.K. and Bhagat, R.M. 1997. Bioefficacy of four granular insecticides against *Tryporyza incertulas* Wald and *Dicladispa armigera* Oliv. *Pl. Protec. Bull.* 49 (1-4) : 8-9

Khanvilakar, V.G., Dalvi, C.S. and Bhole, S.R. 1983. Record of alternate hosts of rice blue beetle, *Leptispa pygmaea* Baly.(Coleoptera : Chrysomelidae). *Indian J. Ent.* 45 (2) : 199

Krishnaiah, N.V. and Kalode, M.B. 1983. Effectiveness of some granular and spray formulations against rice hispa. *Pesticides* 17 (7) : 25-28

Krishnaiah, N.V. and Kalode, M.B. 1984. Evaluation of neem oil, neem cake and other non-edible cakes against rice pests. *Indian J. Pl. Prot.* 12 (2) : 101-107

Krishnaiah, N.V. and Kalode, M.B. 1991.Efficacy of neem oil against rice insect pests under green house conditions. *Indian J. Pl. Prot.* 19 (1) : 11-16

Krishnaiah, N.V., Kalode, M.B and Reddy, A. A. 1988. Recent approaches in root-zone placement for effective rice pest control. *Trop. Pest Mgmt.* 34 (1) : 116-121

Krishnaiah, N.V., Pasalu, I.C., Lingaiah, T., Prasad, A.S.R. and Varma. 2003. Evaluation of selected insecticides, spray formulations and combination products against insect pest of rice under field conditions. *Indian J. Pl. Prot.* 31 (2) : 34-37

Krishnaiah, N.V., Rao, P.S., Rao, N.H.P., Rao, P.S. and Narasimham, V. 1987. Control of rice hispa. *Indian Fmg.* 37 (7) : 37-39

Kulshreshtha, J.P., Prakasharao, P.S., Rajamani, S. and Rao, P.S.P. 1971. Recent developments in control of insect pests of rice crop in India. *Oryza.* 8 : 329-336

Kumar, P. 2003. Survey on the incidence of pests under rainfed low land ecosystem. *Karnataka J. agric. Sci.* 16 (3) : 460

Lakshmi, V.J., Krishnaiah, N.V., Pasalu, I.C., Lingaiah, T. and Krishnaiah, K. 2001. Safety of some insecticides to brown mirid bug, *Tytthus parviceps* (Reut.) (Hemiptera : Miridae) a predator of brown plant hopper, *Nilaparvata lugens* (Stal.) (Homoptera : Delphacidae) in rice. *J. Biological Control.* 15 (1) : 43-48

Laksminarayana, K., Subbaratnam, G.V., Raju-Thammi, N.B., Murthy, K.S.R.K. and Thammi-Raju, N.B. 1985. Control of rice hispa with carbofuran granules. *Pesticides* 19 (4) : 53

Lal, R and, Lal, R. 2000. Evaluation of some granular insecticides against white backed and brown plant hopper in rice. *Pesticides Res. J.* 12 (1) : 96-98

*Lefroy, H.M. 1906. Beetle pests, *Indian Insect Pests*. Govt. Printing, India, pp. 200-201

*Leite, L.G., Takada, H.M., Cardoso, C.L., Vielella, O.V., Batista-Filho, A. and Aguiar, J.C. 1995. Control of rice water weevil, *Oryzophagus oryzae* with fipronil and mineral oil with *Beauveria bassiana*. *Anais-da-Sociedade. Entomologica-do-Brasil.* 24 (2) : 339-344

*Liansheng.W., Chaokun, D., Zhilong, D., Xintian, D., Ruiquiang, S., Huoming, H., Wang, L.S., Deng, C.R., Dui, Z.L., Ding, X.T., Shi, R.H. and Huang, H.M. 1999. Occurance of major pests in rice field with new cultivation pattern, direct seeding or ridge plot without ploughing and optimum control technique of rice pests in south west mountain area of Zhejiang province. *Korean J. appl. Ent.* 11 (6) : 356-359

Lingaiah, T., Krishnaiah, N.V., Kumar, K.M., Katti, G., Krishnaiah, K. and Pasalu, I.C. 1999. Antifeedant effect of neem formulations against rice leaf folder, *Cnaphalocrocis medinalis* and hispa, *Dicladispa armigera*. *Pesitcide Res. J.* 11 (1) : 93-96

Litsinger, J.A., Canapi, B.L., Bandong, J.P., Delta-cruz, C.G., Apostol, R.F., Pantua, P.C., Lumaban, M.D. and Alvioa, A.L. 1987. Rice crop losses from insect pests in wetland and dry land environments of Asia with emphasis on Philippines. *Insect Sci. Applic.* 8 : 677-692

Machrowicz, I., Poprawski, T.J., Robert, P. and Maniania, N.K. 1990. Effect of entomopthogenic and oppurtunistic fungi on *Delia antiqua* (Diptera : Anthomyiidae) at low relative humidity. *Environmental Ento.* 19 : 1163-1167

*Maulik, S. 1919. *The Fauna of British India including Ceylon and Burma.* Coleoptera : Chrysomelidae (Hispinae and Cassidinae). Today and Tomorrows printer and publishers, New Delhi, India. pp. 76-78

Mazumdar, D., Puzari, K.C. and Hazarika, L.K. 1995. Mass production of *Beauveria bassiana* and its potentiality of rice hispa. *Indian Phytopath.*. 48 (3) : 275-278

Mishra, H.P. 2003. Evaluation of new insecticides against rice gundhi bug. *Indian J. Pl. Prot.* 31 (2) : 107-108

Mookerjee, A.L. and Chatterjee, D.K. 1973. Efficacy of new insecticides on major rice pests and their effect on yield. *Agric. Agro-Indian J.* 6(2) : 34-36

Nadarajan, L. and Skaria, B.P. 1993. Insect resistance levels in traditional and new rice varieties cultivated in Kerala. *Indian J. Pl. Prot.* 21 (2) : 161-162

Nadarajan, L. 1996. Changing status of rice pests in Kerala. 'National symposium on Technical Advancement, 17-19 June, 1996, KAU, Vellanikara. *Abstract* :149.

Nair.M.R.G.K. 1978. *A Monograph on crop pests of Kerala and Their Control.* Kerala Agricultural University, Thrissur. p. 227

Norton, G.A. and Way, M.J. 1990. Rice pest management system. *Pest Management in Rice* (eds. Grayson, B.T.,Green, M.B. and Copping, L.G.). Society of chemical Industry, Elsevier Applied science, New York. pp.1-14

Panda, B.M. and Rath, L.K. 2004. Efficacy of some new insecticides on the incidence of leaf folder, *Cnaphalocrocis medinalis* Guenee infesting rice. *Ann. Pl. Protec. Sci.* 12 (1) : 59-62

Panda, N., Sahoo, B.C. and Jena, B.C. 1983. Rice pest management in India. *Pest Management in Rice* (eds. Chelliah, S and Balasubramanian, M.). Tamil Nadu Agric. Univ., Coimbatore. pp. 326-342

Pandey, J. 2000. *Role of improved agricultural practices and integrated nutrient management in rice IPM*, Training Manual of Rice IPM, NCIPM, New Delhi, pp. 25-29

Pangtey, V.S. 1990. A note on the efficacy of selected insecticides against gundhi bug, *Leptocorisa acuta* (Thunberg). *Indian J. Ent.* 52 (4) : 715-717

Pasalu, I.C. 2000. Recent advances in integrated pest management in rice. Training Manual of Rice IPM, NCIPM, New Delhi, pp. 66-67

Patel, G.A. and Patel, H.K. 1970. *Krishikit vidya part II*, Govt. of Gujarat, pp. 57

Patel, C.B. and Shah, A.H. 1985. Biology of rice blue beetle, *Leptispa pygmaea* Baly. (Coleoptera : Hispinae).*Bull. Ent.* 26 (2) : 120-128

Patel, C.B. and Shah, A.H. 1988. Nematodes (Mermithids) as a parasite of larvae of *Leptispa pygmaea* Baly. *Indian J. Ent.* 14 (3) : 354

Patel, M.L., Patel, K.G. and Pandya, H.V. 2004. Effect of insecticides commonly used for the control of insect pests of paddy on spiders. *Insect Environ.* 10 (4) : 171-174

Pathak, M.D. and Dhaliwal, G.S. 1987. Trends and strategies for rice insect problems in Tropical Asia. IRRI Research Paper Series No. 64, IRRI, Los Banos, Philippines.

Pathak, M.D., Khelsa, M.S. and Varma, S.K. 1982. Controlling major pests of rice plant. *Indian Fmrs' Digest* 15 (10) : 6-9

Patil, R.S., Bhole, S.D. and Patil, S.P. 1991. Studies on biology and chemical control of rice cutworm. *J. Maharashtra agric. Univ.* 16 (1) : 66-68

*Pillai, K.S. 1977. Studies on the biology of rice caseworm, *Nympula depunctalis* (Unpublished)

Pillai, K.S., Saradamma, K. and Das, N.M. 1983. Field evaluation of two newer insecticides against some pests in Kerala. . *Pesticides* 17 (27) : 15-18

Prasad, J.S., Katti, G., Padmakumari, A.P. and Shankar, M. 2006. Bioefficacy of indigenous entomopathogenic nematodes against leaf folder, *Cnaphalocrocis medinalis* Guenee *in rice*. Paper presented in 'Second International Conference held at National Academy of Agricultural Sciences, New Delhi, 9-13 October, 2006 pp. 418

Puzari, K.C. and Hazarika, L.K. 1991. Efficacy of *Beauveria bassiana* combined with various stickers or spreaders against rice hispa. . *IRRI Newsl.* 16 (6) : 21

Puzari, K.C. and Hazarika, L.K. 1992. Entomogenous fungi from North East India. *Indian Phytopath.* 45 (1) : 35-35

Puzari, K.C., Hazarika, L.K. and Deka, N. 1994. Pathogenicity of *Beauveria bassiana* on rice hispa, *Dicladispa armigera*. *Indian J. agric. Sci.* 64 (2) : 123-125

*Rajehja, A.K. 1995. Practice of IPM in South Asia. *Integrated pest management in the Tropics, Status and Future Prospects.* (eds. Mengech, A.N., Saxena K.S and Gopalan, H.N.B). pp. 69-111

Rai, M. 2006. Rice culture in agriculture: An Indian perspective. 'Second International Conference held at National Academy of Agricultural Sciences, NewDelhi, 9-13October, 2006 .pp. 2

Rao, N.V., Rao, V.L.V.P. and Reddy, P.S. 1982. Evaluation of new chemical formulations for the control of rice insect pests. *Indian J. Pl. Prot.* 10 (1/2) : 29-32

Rath, P.C. 2001. Efficacy of insecticides, neem and Bt formulations against stemborer on rice yield in West Bengal. *J. appl. Zool. Res.* 12 (2/3) : 191-193

Rawat, R.R. and Singh, O.P. 1980. Incidence of rice hispa, *Dicladispa armigera* in rice in Madhyapradesh and the associated factors. *Oryza* 17 (1) : 65-67

Razvi, S.A., Rao, C.S., Rao, N.V., Subbarao, C. and Venugopalrao, N. 1983. Efficacies of new granular insecticides and spray insecticides on rice pests. *IRRI Newsl.* 8 (1) : 15-16

*Rezaul-karim, A.N.M. and Hoque, N.M.M. 1999. Evaluation of certain neem products against some rice insect pests of Bangladesh. *Bangladesh J. Ent.* 9 (2) : 1-7

Sain.M ., Bentur, J.S., Kalode, M.S. and Sain, M. 2001. Influence of agronomic and cultural practices of rice hopper pests and their natural enemies. *J. appli. Zool. Res.* 12 (1) : 8-13

Sain.M ., Kalode, M.S. and Sain, M. 1994. Influence of agronomic and cultural practices of rice hopper pests and their natural enemies. *J. appl. Zool. Res.* 12 (1) : 8-13

Sain.M ., Krishnaiah, N.V., Kalode, M.B. and Sain, M. 1994. Relative toxicity of new formulations against rice hispa, *Dicladispa armigera* Oliv. *Entomon* 19 (1-2) : 73-75

*Salioqi, A.V.R., Khan, M., Abdullah, K. and Latif, A. 2002. Evaluation of fipronil for the management of rice stem borer (*Tryporhyza incertulas*) (Lepidoptera : Pyralidae). *Sarhad J Agric.* 18 (1) : 59-61

Samalo, A.P., Senapathi, B., Satpathy, C.R. and Jacob, T.J. 1993. Effect of neem derivatives on incidence of some major insect pests in wet season rice. *Botanical pesticides in Integrated pest management.* p. 197-202

Saroja, R. 1986. Effect of neem product foliar sprays on rice pests. *IRRI Newsl.* 11 (4) : 33-34

Sarup, P., Singh, D.S., Amarpur, S. and Lal, R. 1970. Persistent and relative residual toxicity of some important pesticides to the adults of sugarcane leafhopper, *Pyrilla perpusilla* Walker (Lophopidae : Homoptera). *Indian J. Ent.* 32 (3) : 256-267

*Saxena, R.C. and Greenhalgh, R 1987. Neem seed oil a potential antifeedant against insect pests of rice. Pesticides Science and Biotechnology (eds. Roberts, T.R.). Proceedings of the 6^{th} International congress of Pesticide Chemistry held at Ottawa, Canada, Aug.10-15, 1986, 1987. pp. 139-144

*Seungchan,L., Kyoung, M., Lee, S.C. and Ma, K.C. 1997. Occurrence of major pests of machine transplanted and direct seeded paddy field. *Korean J. Appl. Ent.* 36 (2) : 141-144

Shah, A.H. and Patel, C.B. 1980. Screening breeding materials against rice blue beetle. *Int. Rice Commn. Newl.* 29 (1) : 62

Shukla, B.C., Shrivtasava, S.K, Deshmukh, P.D., Pophali., Kaushik, U.K., Gangrade, G.A. and Patidar, G.L. 1979. Evaluation of new insecticides for gall midge control. *IRRI Newsl.* 11 (3) : 21

Singh, R.P. 2000. *Evaluation of insect pests with neem.* In rice training manual in IPM, NCIPM. pp. 42-48

Singh, J. and Dhaliwal, G.S. 1994. Insect pest management in rice; A perspective. *Trends in Agricultural Insect Pest Management.* perspective (eds. Dhaliwal,G.S. and Arora, R) Commonwealth Publishers, New Delhi, India. pp. 56-112

Singh, O.P. and Rawat, R.R. 1979. Toxicity of some insecticides against pupae and adults of *Dicladispa armigera* (Coleoptera : Chrysomelidae) on rice. *Indian J. agric. Sci.* 50 (3) : 271-272

Singh, O.P. and Rawat, R.R. 1980.Efficacy of some insecticides against grubs and pupae of rice hispa. *Oryza* 17 (1) : 68-69

Sonatakke, B.K. 1993. Field efficacy of insecticides alone and in combination with neem oil against insect pests and their predators in rice. *Indian J. Ent.* 55 (3) : 260-266

Sonatakke, B.K. and Dash, A.N. 2000. Field efficacy of some granular insecticides against major pests of rice. *Indian J. Ent.* 62 (4) : 353-357

*Srinivas, K. and Madhumathi, T. 2004. Efficacy of certain selected insecticides against gall midge, *Orseolia oryzae* (Wood-Mason). *Pest Mgmt. Econ. Zool.* 12 (2) : 187-191

Swamiappan, M., Rajaram, K.S. and Nair, V.C. 1990. Outbreak of blue beetle in India. . *IRRI Newsl.* 15 (2) : 16-17

Swaminathan, M.S. and Siddiq, F.A. 1991. Rice pest management in India. *Shell Agric.* 10 : 30-33

Thakur, A.K., Kashyap, N.P., Hameed, S.F. and Suri, S.M. 1979. Unusual occurrence of rice hispa in Himachal Pradesh, India. *IRRI Newsl.* 4 (6) : 7

Thontadarya, T.S. and Devaiah, M.C. 1975. Effect of aerial spraying of fenthion and fenitrothion on some insect pests of paddy. *Curr. Res.* 4 (6) : 107

Thomas, M.J. 1977. Biology, ecology and host plant realtions of brown plant hopper, *Nilaparvata lugens.* PhD thesis, Kerala Agricultural University, Thrissur. p. 206

Trehan, K.N. 1946. Annotated list of crop pests in Bombay province. *J. Bombay nat. Hist. Soc.* 46 : 139-153

Tripathy, M.K., Setpathi, B., Acarya, S. and Pathak, H.P. 1999. Evaluation of certain insecticides against rice gall midge and yellow stem borer. *J. appl. Zool. Res.* 10 (2) : 123-125

Usman,S. 1947. The green beetle pest (*Leptispa pygmaea*) of paddy and its control in 1946. *Mysore agric. J.* 25 : 54-55

Uthamaswamy, S. and Karuppuchamy, P. 1988. A note on the efficacy of new insecticides against rice pests. *Indian J. Pl. Prot.* 16 (2) : 265-267

Vardhani, B.P. and Rao, K.T. 2002. Effect of normal and sub-normal application of insecticides on brown planthopper and its predators. *J. Appl. Zoological Res.* 13 (1) : 74-75

*Yongbao,W., Quiang, C., Yanwen, X. and Mingxi, L. 2001. Applied studies of fipronil (Regent) in the control of rice insects pest. *Entomological Knowledge* 38 (5) : 345-347

*Wenda,Z., Zhongyi, W. and Sibin, Q. 2002. Efficacy of fipronil (Regent) against rice pests and its effect on rice yield. *Acta-phytophylacica-Sinica.* 29 (3) : 265-271

Zafar, M.A. 1984. Chemical control of rice hispa. *IRRI Newsl.* 9 (5) : 18-19

Zaman, F.U. and Singh, A.K. 2000. Role of improved varieties in rice IPM. Training Manual of Rice IPM . NCIPM, pp. 20-24

*** Originals not seen**

BIOECOLOGY, POPULATION DYNAMICS AND INTEGRATED MANAGEMENT OF RICE BLUE BEETLE, *Leptispa pygmaea* Baly (Chrysomelidae : Coleoptera)

K. KARTHIKEYAN

Abstract of the thesis submitted in partial fulfillment of the requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture

Kerala Agricultural University, Thrissur

2007

Department of Agricultural Entomology

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

ABSTRACT

The Rice Blue Beetle *Leptispa pygmaea* Baly (Chrysomelidae : Coleoptera), hitherto reported as a minor pest of rice, has recently assumed a serious status by causing severe outbreaks in different northern districts *viz.,* Palakkad, Kannur and Kasaragod of Kerala.This pest is reported to inflict extensive damage to rice in both kharif and rabi seasons. Since the rice blue beetle has been considered as a pest of minor importance, very scanty information is available on the pest. In this context, the present investigation on the "Bioecology, population dynamics and integrated management of Rice Blue Beetle *Leptispa pygmaea* Baly" was carried out at the Regional Agricultural Research Station, Pattambi, Kerala Agricultural University during 2004-06. The study has helped to generate information on the biology, population dynamics and management methods of rice blue beetle by which an IPM strategy could be formulated against this pest.

The biology of rice blue beetle, *L. pygmaea* was worked out on a short duration (Jyothi) and a medium duration (Aiswarya) variety of rice under nethouse conditions. The female beetle laid eggs either singly or in groups in a straight line either on the dorsal or ventral surface of mature or tender rice leaves of Jyothi and Aiswarya. There was no marked difference in the biology of the blue beetle between the two rice varieties. Eggs were seen glued to the leaf surface. The fecundity ranged from 10 to19 eggs during an oviposition period of six days. A pre oviposition period of 14 to 16 hours was also observed.

The eggs hatched into grubs within 3 to 4 days. The grub period lasted for 6 to 11 days with five instars, each with duration of 1 to 2 days. The grub pupated for 2 to 4 days and the adult beetle emerged out. The total life cycle from egg to adult stage was completed within 12 to 19 days.

The longevity of adult varied with the sex of blue beetle. Males lived longer than females. The male life span was 37 to 41 days, while the females lived for 25 days.

Among the duration of different stages *viz.*, egg, larva, pupa and adult of *L. pygmaea*, the period of adult stage was found to be longest (39 days) followed by larva (8 days), egg (3 days) and pupa (3 days).

The emergence of adult beetle was highest during morning period between 0800 to 0900 hours and then it was reduced as the day temperature increased. No emergence was observed between 1300 and 1500 hours when the temperature was high at the noon. The number of male beetles in the field was more, compared to the females with a sex ratio of 1.5: 1.3.

Study on the morphology and morphometrics of different stages of blue beetle showed that the size of egg measured 0.39 mm in length and 0.19 mm in width. Freshly laid eggs were light green and changed to yellow towards hatching. The grub was light green in colour with brown head. It showed a small head capsule, long body and a tail like projection at the posterior end of the body. The newly emerged first instar grub was light green coloured with a brown head and changed to dirty white towards pupation. The head capsule measured a width of 0.17 to 0.26 mm from 1st to 5th instar, while the body measured an average length and width of 4.56 and 0.90 mm respectively. The tail length increased from 0.1 to 0.2 mm from first to fifth instar. Freshly formed pupa was white in colour and later it changed to brown and was seen loosely attached to the leaf by its distal end. It measured a maximum length of 3.89 mm and minimum length of 3.73 mm.

Newly emerged adult beetle was metallic bluish green in colour dorsally and white coloured on the ventral side of the body. The male and female beeles could be differentiated based on the body size. The males were bigger in size than the females. The male had a longer antenna (1.1mm) than the female (0.08mm).The basal two segments were larger than the rest. In case of females, the basal scape was the largest (truncated) with 0.15 mm in width. In both sexes, the 3rd, 4th, 5th and 6th antennal segments were small and uniform, while the 7th to 11th segments were larger than the middle four segments.

Dissection of the reproductive systems revealed that male reproductive system consisted of tegmen and sipho. The aedeagus showed an average length of 1.36 mm and width of 0.09mm. The female reproductive system consisted of spermatheca and two lateral coxites with an average length of 1.60 mm and width of 0.52 mm.

Survey on the field population dynamics of blue beetle during Kharif and Rabi, 2005 showed that in Kharif'05, the field incidence of *L. pygmaea* started from fourth week of June at 10 days after transplanting and there was an increasing trend in the population up to the second week of July'05. The peak population was found coincided with the early tillering stage of the crop. After the second week of July'05, there was a declining trend in the population and reached the lowest during the third week of September'05. The field population of blue beetle was highest during the month of July in Kharif season. The abiotic factors viz., maximum temperature, minimum temperature, relative humidity, rainfall and sunshine during the peak period were 29.8°C, 23.7°C, 95 %, 50.9 mm and 2.9 hours respectively. In Rabi'05, the beetle population showed an increasing trend from the third week of October at 10 days after transplanting and reached a peak during the first week of November'05, when the crop was in the tillering stage. The population indicated a decreasing trend from the second week of November onwards. Highest population occurred at 24 DAT when the crop was in the early tillering stage during both seasons (Kharif and Rabi). Therefore, stage of the crop is a critical factor for the rapid build up of *L. pygmaea*. The weather parameters during the peak period were maximum temperature 31.8 °C, minimum temperature 23.2 °C, relative humidity 95 %, rainfall 70.2 mm and sunshine 4.2 hours. Two abiotic factors *viz.*, minimum temperature of 23° C and relative humidity of 95 % were found to influence the peak population in both the Kharif and Rabi seasons.

Correlation analysis of beetle population and per cent leaf damage with the weather parameters revealed a negative correlation with regard to maximum temperature and sunshine hours (respective correlation values -0.281 and -0.400). A positive correlation of blue beetle population with minimum temperature and relative humidity was observed. Rainfall showed no significant effect on beetle population. Damaged leaves by *L. pygmaea* were found to be positively correlated with minimum temperature and relative humidity while it was negatively correlated with maximum temperature and sunshine hours. However, there was no significant relationship between rainfall and per cent damaged leaves. Thus, it is indicated that minimum temperature and relative humidity were the two important abiotic factors that influence the damage by *L. pygmaea.*

Study on the nature of attack and symptoms of damage of *L. pygmaea* showed that both the grub and adult feed on the upper surface of rice leaves by scrapping chlorophyll tissueleading to longitudinal white streaks on them. The streaks made by the larvae were shorter and narrower than those by the adults. In case of severe damage, the rice leaves were seen folded longitudinally and ultimately dried up. The plants became very weak or dried up. From a distance, the damaged rice patch showed severe drying. Symptoms of damage by rice blue beetle resembled those caused by leaffolder.

Observations on the feeding intensity of different stages of the blue beetle revealed that grubs caused highest damage followed by adult female and adult male in both Jyothi and Aiswarya. The grub caused 69.0-73.7 per cent more damage than males while female caused 48-59 per cent more damage than males. The study on leaf area consumption by different stages also indicated similar results. Leaf area consumption by *L. pygmaea* was more in Jyothi than in Aiswarya.

Early tillering stage was found to be the most susceptible stage for the infestation of blue beetle in both Kharif and Rabi . Damage was found to increase from the seedling stage and reached peak at early tillering and thereafter it gradually declined. The order of susceptibility of growth stages to rice blue beetle damage was early tillering > seedling > maximum tillering > panicle initiation > booting > flowering.

Transplanted rice suffered more damage by *L. pygmaea* than the direct seeded rice in both the rice varieties Jyothi and Aiswarya during Kharif and Rabi'05 seasons. In Kharif the transplanted rice suffered 42.40-83.15 per cent more damage over direct seeding in Jyothi during seedling stage. In early tillering stage, the transplanted rice suffered 34.24 to 58.17 per cent more damage over direct seeding.

Studies were also carried out on integrated pest management methods involving screening of resistant lines / varieties, effect of plant spacing and oil cakes, chemical management by nursery treatment with granular insecticides and main field treatment with eco-friendly foliar insecticides against *L. pygmaea*.

Among the 106 varieties / entries screened for their field reaction against *L. pygmaea,* none of them was found to be completely resistant. No high yielding variety except Hraswa (a short duration Mannuthy variety) showed moderate resistance. But nine traditional Pattambi varieties *viz.,* Ptb.3, Ptb.4, Ptb.7, Ptb.9, Ptb.18, Ptb.19, Ptb.20, Ptb.25, Ptb.26 revealed a damage score of '3' indicating moderate resistance. Therefore, these varieties could be utilized for future breeding programmes for resistance against rice blue beetle. Other KAU varieties showed susceptibility, while three varieties *viz*., Jyothi (Ptb.39), Rangini (MO10) and Bharathy (Ptb.4) were found to be highly susceptible to *L. pygmaea*. The most popular rice variety of Kerala, Jyothi,was found to be highly susceptible to rice blue beetle.

Search for the alternative hosts for *L. pygmaea* revealed that among the 10 commonly seen weed plants in rice fields, the beetle was found to oviposit only on two grassy weeds *viz., Panicum repens* and *Isachne miliacea*. Though eggs were laid, there was no hatching of eggs on *I. miliacea*. But on *P. repens,* the beetle laid 12-15 eggs with cent per cent hatchability and the beetle was able to carry out its normal life cycle on this weed host in 10-13 days. A comparative study on the biology of *L. pygmaea* on Jyothi, Aiswarya and *Panicum repens* indicated that the life cycle of rice blue beetle was shortest (11.5 days) on *P. repens* followed by Aiswarya (14 days) and Jyothi (15 days).

The influence of agronomic practice of different spacings on the incidence of *L. pygmaea* revealed that in closer plant spacings (10x15 cm and 10 x 10 cm), there was reduction on the incidence of blue beetle with reduced leaf damage, hill damage and beetle population. Infestation was significantly higher in the recommended wider spacing (20x15 cm), as compared to closer spacing. The effect of application of neem cake, castor cake and pungam cake in the field against *L. pygmaea* showed that there was no significant difference between these cakes on the leaf damage, damaged hills and beetle population. No interaction effect of plant spacings and oil cakes was observed.

Survey for the natural enemies of blue beetle in the field showed that the beetle eggs were parasitized by *Trichogramma* sp., *Telenomus* sp. and *Tetrastichus* sp. indicating a good scope for biological control of the pest.

Laboratory studies to assess the pathogenicity of white muscardine fungus, *Beauveria bassiana* against *L. pygmae*a illustrated the effective role of *B. bassiana* by causing a cumulative mortality of 56.67 to 80.00 per cent at 10^5 to 10^9 spores / ml. Its LC_{50} value was 2.26 x 10^4 spores / ml.

Evaluation of the entomopathogenic nematode (EPN), *Heterorhabditis indica* under the laboratory conditions indicated its bioefficacy by bringing out mortality against grubs of *L. pygmaea*. The EPN produced a cumulative mortality of 66.67 to 91.67 per cent at concentrations of 5 IJ's to 9 IJ's in the grubs with a LC50 value of 3.83 IJ's per ml.

Biological management studies thus resulted in the identification of three new egg parasitoids in the field. The pathogenicity of white muscardine fungus and the EPN against *L. pygmae*a were also explored.

Studies on the chemical management of *L. pygmaea* by nursery application of granular insecticides revealed the efficacy of cartap hydrochloride in reducing the leaf damage, hill damage and beetle population of *L. pygmaea* in both Kharif and Rabi seasons during 2004 and 2005.The leaf damage was reduced by 40.29 and 37.86 per cent (mean = 39.21 per cent) over control during 2004 and 2005 respectively while the beetle population was reduced by 30.73 and 61.13 per cent (mean = 45.9 per cent). Hill damage was reduced by 55.16 and 33.71 per cent (mean = 44.4 per cent) over control during the years. Carbofuran was the next best effective insecticide against *L. pygmaea*. It produced significant reduction of leaf damage by 30.16 and 23.62 per cent (mean = 26.9 per cent) over control in Kharif and Rabi respectively. Beetle population was reduced by 25.10 and 54.66 per cent (mean = 39.9 per cent) and hill damage by 55.70 and 10.11 per cent (mean = 32.9 per cent) over control. Fipronil was found least effective against *L. pygmaea*.

Persistent toxicity of granular insecticides applied in the nursery against blue beetle showed that carbofuran was the most persistent insecticide with highest PT value followed by carbosulfan, phosphamidon, cartap hydrochloride and fipronil.

Evaluation of eco-friendly foliar insecticides for the field toxicity against *L. pygmaea* indicated the effectiveness *of B. bassiana* at 10^7spores/ml. It significantly reduced leaf damage (mean = 46.7 per cent), population of blue beetle (mean = 47.7 per cent), and hill damage (45.9 per cent) over control. The insecticide, chlorpyriphos @ 0.05 % was equally effective against rice blue beetle. It was followed by carbaryl > econeem > paraffin oil > neem oil.

The persistent toxicity of foliar insecticides in the field was in the descending order *viz.,* carbaryl > chlorpyriphos > econeem > neem oil > paraffin oil > *B. bassiana.*

It is quite evident that the persistent toxicity of eco-friendly insecticides is low as compared to the chemical insecticides. Though. *B. bassiana* showed lowest persistence in the field, it was on par with chlorpyriphos in bioefficacy causing highest mortality of blue beetle.

-172709-