"BIOLOGY AND INSECTICIDE SENSITIVITY OF RICE WHITE BACKED PLANTHOPPER, *Sogatella furcifera* (Horvath) (HEMIPTERA : DELPHACIDAE) IN KERALA"

By

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THESIS

submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

(AGRICULTURAL ENTOMOLOGY)

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2006

DECLARATION

I, Prathibha, P.S (2003-11-09) hereby declare that this thesis entitled **'Biology and insecticide sensitivity of rice white backed planthopper, *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) in Kerala'** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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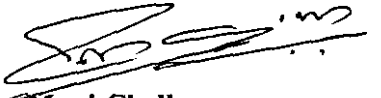
Certified that this thesis, entitled **'Biology and insecticide sensitivity of rice white backed planthopper, *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) in Kerala'** is a record of research work done independently by **Ms. Prathibha, P. S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.



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We, the undersigned members of the Advisory Committee of **Ms. Prathibha, P. S,** a candidate for the degree of **Master of Science in Agriculture**, agree that this thesis entitled **'Biology and insecticide sensitivity of rice white backed planthopper (WBPH) *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) in Kerala'** may be submitted by **Ms. Prathibha, P. S,** in partial fulfillment of the requirement for the degree.

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ACKNOWLEDGEMENT

Work is done. Thanks are due.

It is with great respect, I place on record my wholehearted gratitude to my major advisor **Dr. Mani Chellappan,** *Assistant Professor, Department of Entomology and chairperson of my Advisory Committee for his sustained and valuable guidance, constructive suggestions, unfailing patience, friendly approach, constant support and encouragement during the conduct of this research work and preparation of the thesis.*

I deeply express my whole hearted thanks to **Dr. Jim Thomas,** *Associate Professor and Head, Department of Entomology and member of my Advisory Committee for his constructive criticisms, precious suggestions and generous support during my entire study and the completion of this endeavor.*

I thankfully acknowledge **Dr. Haseena Bhaskar** *Assistant Professor, Department of Entomology and member of my advisory committee for her wholehearted co-operation, help and valuable suggestions during various stages of study.*

My wholehearted gratitude to **Dr. R. Kesavachandran** *and for his timely advise, Associate Professor, Centre for Plant Biotechnology and Molecular Biology and member of my advisory committee for valuable suggestions, and inspiring encouragement rendered during the course of this research work and my study period.*

I respectfully thank **Dr. Sossamma Jacob,** *her ardent interest, valuable suggestions, critical scrutiny of the manuscript and ever willing help, which has helped a lot in the improvement and preparation of the thesis.*

I would like to specially thank **Dr. Usha Kumari** *for her relentless support during the course of my research work.*

My sincere and heartfelt thanks to **Dr. Augustin,** *Associate Professor Centre for Plant Biotechnology and Molecular Biology for his precious suggestions and valuable guidance for doing Biochemical analysis.*

I would like to specially thank Krishnan Sir, for his inexorable support in resolving the statistical intricacies of data.

I extend my profound sense of gratitude to Dr Ranjith, Dr. Sairam Kumar, Dr. Susannama, Dr. Lyla K. R., Dr Pathummal Beevi for their timely suggestions and encouragement provided through out the course of my study.

I sincerely express my deep sense of gratitude to Dr. Sankaran, pathology Department, KFRI who identified the entomopathogenic fungi isolated during the course of study

I wish to extend my wholehearted gratitude to Mr. Gopakumar, Wood Science Department, College of Forestry for his timely help during my research work.

I am genuinely indebted to Dr. Srinivasan, Asst. Professor of Entomology Department, Tamil Nadu Agricultural University for the immense help rendered to me during the commencement of research

I sincerely acknowledge the cooperation and sincere help rendered by Dr George Thomas, Dr Beena, Dr. Koshi Abraham, Dr. P.A. Nazeem, Dr. Achama Oommen and Dr. Nandini and all other teaching staff of College of Horticulture and non teaching staff especially Biju, Rathieesh, Jolly, Omana and Droupathy

I would like to express my deep sense of gratitude to my dear senior students, Mini Sankar, Deepthy, K.B, Smitha, M. S, Reshmi Vijayaraghavan, and Ramesh Sir for their mental support, encouragement, valuable suggestions and timely help during the course of my research work.

I extend my special thanks to my senior students Saina mol teacher, Sindhu, Jacob and Binisha

Sincere help rendered by Elaya Bharathy Ph.D. Scholar of Entomology Department, Tamil Nadu Agricultural University is greatfully acknowledged.

I find it difficult to translate in to words the love, affection, constant prayers and moral support of my friends Smitha Revi, Ramu, Basanth, Renitha, Sapheera, Deepa, Sreekrishna, Thankamony, Ampily, Lekha, Habeeba, Dhanya, Asha and Anuja and also my special thanks to Joshi and Eldo for their timely help.

A special word of heartfelt gratitude to my dear juniors ***shajna, Seena and Jyothi*** *for their sincere help and support*

I am happy to place on record my sincere thanks to my roommates ***Ramya*** *and* ***Saumya*** *for their help and support during preparation of thesis*

I place on record my gratitude to ***Family members*** *of Dr. Mani Chellappan, especially* ***Anitha teacher*** *for her valuable suggestions and advice*

With all regards I sincerely acknowledge the wholehearted co- operation and generous help rendered by the members of YESCOM.

With all regards I sincerely acknowledge the co- operation and generous help rendered by my batch mates ***Beethi, Gayathri, Ambika, Simi, Smitha, Reena, Jitha, Sai Jothi, Sujatha, Sreela, Jaisal, John Kutty, Sreejith, Shankar, Mohan, Smini, Smitha, Blessy, Mable*** *and* ***Resmi,***

A special word of thanks to ***Santhosh*** *for his help rendered during the course of study, seminar and preparation of manuscript.*

Words can't ever express my gratitude to my ***Parents and other family members*** *who guided and encouraged me in all my endeavors including this. Without them I would never been able to complete this work. The blessings given by them have been a constant source of inspiration to me.*

Special thanks to my brother ***Prasanth*** *and my sister* ***Priya***

Finally I acknowledge all others who directly or indirectly helped me in the completion of this work.

Above all I humbly bow my head before the Almighty, who blessed me with will power and courage to complete this endeavor successfully, in spite of the most difficult times which I have faced during the period of my study.

Prathibha, P. S

Affectionately Dedicated to My Loving Parents

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INTRODUCTION

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important cultivated plants in tropics and subtropics and the second most widely grown cereal next to wheat in the world. It is the staple food of the people of Kerala and grown in an area of 3.47 lakh hectare. Insect pest infestation is one of the major constraints in rice production all over the world. Among important insect pests, planthoppers inflict devastating damage to rice due to inadequate management measures.

The introduction and large-scale cultivation of high yielding, fertilizer responsive and semi dwarf cultivars of rice lead to prevalent outbreak of insect pests. Among planthoppers infesting rice, white backed planthopper (WBPH) *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) was a pest of minor importance earlier. It became a force to reckon with in recent years (Sharma *et al.*, 1998). It reduces the yield by 40- 51 per cent in rice (Dhaliwal and Arora, 1993; 1996). It is reported that the ecological niche vacated by brown planthopper (*Nilaparvata lugens* Stal.) due to cultivation of resistant varieties is gradually being invaded by *S. furcifera* (Khan and Saxena, 1985) and it is one of the key pests of rice under irrigated condition in Karnataka during *kharif* season (Vijayakumar and Patil, 2004a).

The hoppers cause direct damage by sucking the plant sap, which often results in hopper burn. Six to nine days after oviposition the nymphs hatch out from the eggs, undergo four moults, (five instars) and the fifth instar moults into adult. Both adults and nymphs congregate around the stem usually 15- 20 cm from the base near water level and cause damage by sucking the sap from the base of plants.

The outbreak of this pest generally occurs after the formation of dense rice canopy and during the period of high temperature and relative humidity. There are several reports about the outbreak of planthoppers in rice ecosystem in Kerala. Ambikadevi *et al.* (1998) described an outbreak of *S. furcifera* (WBPH) in

Kuttanad area due to predisposing weather conditions like high humidity (85-88 %) and prolonged monsoon season. Crop loss of 200 ha area has been reported from Dhoni *padashekaram* in Palakkad district due to severe attack of planthoppers during first crop season in 2005 (Anon., 2005a). Another severe crop loss of 700 ha area has also been reported from Palakkad district due to the combined attack of planthoppers, leaf folder and bacterial leaf blight (Anon., 2005b). Outbreak of WBPH has been accounted from many districts of Tamil Nadu also (Gunathilagaraj and Ganeshkumar, 1997). The warm and humid climate prevailing in south India, indiscriminate and heavy dose application of insecticides which leads to resurgence of the pest and destruction of natural enemy population in rice ecosystem might be the possible reasons for these sporadic outbreaks.

The current trend in integrated pest management with the use of resistant varieties has lead to the biotype build up among planthoppers. The use of natural enemies for the management of insect pest is a slow process and success is unpredictable. In such situation the use of insecticides is the sole management strategy widely adopted by the farmers which give quick and better result. But it is very important to use appropriate insecticide with correct dose to avoid unwanted phenomena *viz.*, pesticide resistance, pest resurgence and pesticide residue in the environment. In Kerala, there is no systematic study carried out on the biology and reasons for the sporadic outbreaks of WBPH. Hence, the present study is undertaken with the following objectives.

1. To study the biology of WBPH
2. To study the feeding and reproductive behaviour of WBPH
3. To determine LC_{50} values of commonly used ten insecticides in rice ecosystem under laboratory condition
4. To find out the relative toxicity of the insecticides and
5. To calculate the persistent toxicity of ten insecticides

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

White backed planthopper (WBPH) *Sogatella furcifera* (Horvath) is distributed throughout South East and East Asia (Nasu, 1967). *S. furcifera* feeds on several host plants but its main host plant is rice. Several outbreaks have been reported from different parts of the world.

2.1 Outbreak of *Sogatella furcifera*.

From India, WBPH attack on paddy was accounted in Bihar and Bengal (Fletcher, 1916), Jabalpur and other neighboring districts in Madhya Pradesh (Berg, 1960). *S. furcifera* in Uttar Pradesh was first observed in 1969, but the infestation was severe only during 1972 and 1977 (Verma *et al.*, 1979). Dhaliwal and Singh (1983) described the first attack of *S. furcifera* in Punjab in 1966 and further outbreaks in 1972, 1975, 1976, and 1981. Saini (1984) explained the reason for a severe crop loss in rice on an area of 1000 ha in Punjab during 1983 because of heavy WBPH infestation. Population built up to 15- 35 planthoppers/ hill in the first week of September, reached 200-500/ hill by 20th of September and caused a grain yield loss of 10- 40 per cent. Kushwaha and Singh (1986) elucidated a severe outbreak of *S. furcifera* on rice in Haryana in 1984-1985, when the weather was warm and humid the pest population was 100-2000 / hill. In the recent past, Kerala experienced an outbreak of *S. furcifera* in Kuttanad area due to predisposing weather conditions like, high humidity (85-88 %) and prolonged monsoon season (Ambikadevi *et al.*, 1998).

Lim and Heong (1977) noticed the outbreak of *Sogatella* spp. in 1925 and 1929 in Karian and Province Wallesley of Malaysia, but no other outbreaks were reported until 1967; however, isolated patches of infestation was accounted in 1968-1976. Ooi (1977) published a list of outbreak of *S. furcifera* and *Nilaparvata lugens* (Stal.) as major insect pests in the Malaysian Peninsula during 1973-1975. According to Ooi *et al.* (1980) the possible reasons for the outbreak of *S. furcifera* in Muda irrigation scheme area in North West of Malaysia were low level of natural enemy population, the neglected nurseries near the rice fields,

increased use of insecticides against other pests of rice prior to infestation by *S. furcifera,* which might have lead to development of resistance against those insecticides by planthoppers and also the weather factors. In Pakistan, *S. furcifera* was first appeared in 1976 at Dokri and Sind (Mahar *et al.*, 1978). In 1978 an outbreak of *S. furcifera* occurred in the Punjab province of Pakistan, where the pest had previously been of sporadic and minor importance (Majid *et al.*, 1980). Although *S. furcifera* was normally a minor pest of rice, it caused hopper burn on 2,709 ha area in Kathmandu, Bhaktapur and Lalithpur of Nepal in 1982 (Gyawali, 1983). A severe outbreak of *S. furcifera* and *Cnaphalocrocis medinalis* (Guenee) occurred in rice of south west Japan in 1980. The outbreak attributed several waves of migrating insects during a period of abnormal weather in July-September, (temperature was lower than the normal, very high precipitation and little sunshine). The abundant rainfall also favoured the outbreak (Hirao, 1981). Outbreaks of WBPH were compared with data of the occurrence of El Nino/ Southern Oscillation (ENSO) and a significant association was detected. Thirteen outbreaks were recorded and 11 of them occurred in years immediately after ENSO events (Morishita, 1992).

2.2 Seasonal abundance of WBPH

For continuous monitoring of pest populations in rice field, light trap with a circular metal shade, a 125-watt mercury- vapour bulb and a collection chamber was described and illustrated in IARI, New Delhi (Sriharan and Garg, 1975). Daily examination of light trap collection made in Punjab during *kharif* season of 1974-1975 showed WBPH, brown planthopper (BPH), green leafhopper (GLH) and leaf folder as common pests. All these pests were abundant during September to October (Chhabra *et al.*, 1976). Traps of different colours were tested for their effectiveness in monitoring rice planthoppers and leafhoppers in Philippines in 1988 showed that white light attracted significantly more individuals of BPH, WBPH and GLH and the yellow was the second most effective than light of other colours tested (Abenes and Khan, 1990). The seasonal activity of *Nephotettix* spp., *S. furcifera* and other rice pests were studied using light trap in Karnal and

Haryana which showed the peak insect activity in August to September and number caught were in the order *Nephotettix* followed by *S. furcifera*. There was a correlation between maximum and minimum temperature, relative humidity and cumulative rainfall and the light trap catches in the different years. Cumulative rainfall had the greatest effect on number of insect caught (Quadeer *et al.*, 1990). Studies conducted by Khan and Kushwaha (1991a) revealed that the first appearance of *S. furcifera* was in the first week of August in all varieties except in HKR-120, on which it appear a week later due to thinner canopy and sudden decline observed at the end of September. According to a survey conducted in rice fields of Punjab in 1987, the population of *S. furcifera* was first observed four weeks after transplanting and increased at a slow rate for three weeks and more rapidly for further two weeks (Bhathal and Dhaliwal, 1991). The light trap data collected during 1955-1990 in Japan revealed a downward trend of the annual catches of BPH over 40 year period and upward trend of annual catches of *S. furcifera* from the mid 1970s (Watanabe *et al.*, 1994a).

Heong *et al.* (1982) established a tentative Economic Threshold Level (ETL) for WBPH as 25 nymphs or 7 adults/hill. Naba (1992) estimated economic threshold (5% yield loss) at 10- 20 delphacids/hill during panicle formation However, Zhang *et al.* (1999) estimated the ETL as 180-250 planthopper/100 hills.

2.3 Weather parameters and Population dynamics of WBPH

In a three year study conducted on the biology of *S. furcifera* showed that the pest had three generations a year with a peak in the third in August. The occurrence of each generation was earlier in early transplanted rice field than in later one (Hirao, 1972). Field study carried out in China on the biology of three planthopper species associated with rice, *Laodelphax striatella* (Fallen), *S. furcifera* and *N. lugens* suggested that the factors affecting biology of *S. furcifera* were, irrigation, planting time and density (Liu *et al.*, 1982a). Population of *S. furcifera* was low during early growth stages of rice crop and reached a peak 62 days after transplanting. Spider populations in the fields were initially higher than those of *S. furcifera* and followed a trend similar to that of pest (Kartohardjono,

1984). An investigation undertaken by Gunathilagaraj and Chelliah (1984) showed that, when first instar nymphs or brachypterous females of *S. furcifera* and *N. lugens* were placed simultaneously on rice seedlings, the number of *Sogatella* individuals increased more rapidly than those of *N. lugens*. BPH population increased after heading and those of WBPH were greatest during 70-90 days after seeding. Physical factors affecting outbreak of *S. furcifera* in the paddy field studied by Kumar (1989) in Delhi revealed that the temperature (22- 27 °C) and relative humidity (60%) during morning did not affect the population. However, variation in the RH during evening and rainfall controlled the population significantly. It was reported that the maximum and minimum temperatures and sunshine hours had the positive effects on the populations of *S. furcifera* on rice in Madhyapradesh in 1982-1984. But, rainfall and relative humidity did not affect the population levels (Shukla and Shrivastava, 1990). Experiments conducted in China showed that WBPH comprise more than 95 per cent of planthoppers with two nymphal population peaks in late June and July (Yan *et al.*, 1992). It was reported that WBPH population had clumped hill-to-hill distribution and clumping increased with density and population fluctuation primarily due to the number of broods and natural enemies. There were two or three generations per crop period. The macropterous adult density exceeded brachypterous adult density by 7 to 99 times (Kamal and Dyck, 1994). Gunathilagaraj (1996) studied the ecology of WBPH in rice field and accounted that the number was generally low. But, crop sown during August to November infested with larger population of insects. The temperature, relative humidity during evening, sunshine hours and wind velocity were the weather parameters which affect the population significantly.

2.4 Damage by WBPH

The plant protection measures evaluated at different stages of development of rice showed that the attack at ear head stage resulted in significant yield loss by WBPH (Khan and Kushwaha, 1991b). It was reported from Japan that the high WBPH density during tillering stage caused some damage, but yield was mostly

affected by feeding damage during the panicle formation to the booting stages which suppressed internode elongation and reduced grain number per panicle. Severe feeding damage from booting to heading stage produced a decrease in numbers and ripening of grain (Naba, 1992). The effects of different levels of infestation by *S. furcifera* on the vegetative growth and yield of paddy were studied in Japan. However, there was no correlation observed between the planthopper densities and number of spikelet/ panicle yield. The infestation by second generation (early to mid August.) decreased the number and spikelets per panicle (Watanabe and Sogawa, 1994). It was also shown that the oviposition by *S. furcifera* caused the damage to leaf sheath resulting in reducing leaf area index, dry weight and number of tillers (Watanabe *et al.*, 1994b).

2.5 Biology of WBPH

Ammar *et al.* (1980) studied the biology of *S. furcifera* on wheat seedlings. It showed shorter incubation period (7.1 days) at normal temperature (23- 34° C), longer incubation period (9.3 days) at lower temperature (17- 28 ° C) and longest incubation period (21 days) at the lowest tested temperature (13-22 ° C). The hatching per cent averaged between 64.3 and 88.9. The duration of nymphal stage was also shorter at lower temperature than that at higher temperature. The adult longevity was also found to be longer at lower temperatures. Huang *et al.* (1982) experimentally illustrated that, the duration of bio stages were shorter at higher temperatures and longer at lower temperatures. Another study conducted by Liu *et al.* (1982b) revealed that, the macropterous adults migrated into rice fields from late May to early August, reached a peak in late July to early August. There was 3-4 generations in the field and the most of adults left the field in late August. The incubation period was 8-15 days, nymphal stage 11-17 days, the oviposition period of brachypterous female 3-7 days and that of macropterous female 3- 9 days. The adult females lived for 7.5- 13 days. The preferred oviposition stage was the luxuriant and tender growth of the rice plant and plants at the tillering and booting stages were most susceptible to attack. Studies conducted by Singh (1989) in Bulandshahar revealed that, in the laboratory the duration of egg,

nymphal, adult male and female stages of *S. furcifera* averaged 5, 16.3, 9 and 8 days respectively on rice. The corresponding periods in the field were 4.5, 16, 4.1 and 3.6 days respectively

2.6 Reproductive behaviour of WBPH

Singh and Pathak (1995) reported much lower oviposition on resistant accession than on susceptible ones and also noticed reduced egg hatch on resistant cultivars and resistant cross hybrids. A study conducted by Khan and Saxena (1985) accounted that the adult survival, fecundity, egg hatchability and population build up were significantly lower on resistant cultivars than on susceptible TN- (1); however, there was no significant difference in oviposition by WBPH on resistant and susceptible cultivar.

It was suggested that the adult emergence as males peaked at noon while females at mid night. Mating behaviour peaked in the afternoon and in second half of midnight, while the oviposition at noon. Female copulate once during her life span, while the males copulate between one and three times. The premating stage of macropterous females lasted 1.79 ±0.33 days which was longer than brachypterous type. The oviposition period of unmated females was significantly longer than that of mated females (Zhang *et al.*, 1990). According to Suzuki *et al.* (1993) among the factors affecting egg mortality in WBPH, physiological death caused by plant reaction against oviposition was greatest at seven weeks old transplanted rice and decreased there after. The overall mortality was more than 80 per cent with a peak of 92.7 per cent at seven weeks after transplanting. The oviposition site of *S. furcifera* on rice plants was on the lower part of the leaf blade and on the upper part of the leaf sheath. Preference of leaf blade for oviposition was 51- 97 per cent more than the other parts which increased with rice development (Iitomi, 1995).

2.7 Feeding behaviour

It was showed that three kinds of aromatic amines *viz.*, phenethylamine hydrochloride, tyramine hydrochloride and hordenine sulfate as sucking deterrent for BPH and WBPH. The amines at 100 ppm and 10-50 ppm concentrations in 5

per cent sucrose reduced the sucking rate by 80-90 per cent and 50 per cent respectively (Kurata and Sogawa, 1976). When analysed, the honeydew excretion of *S. furcifera* adults, collected from one month old susceptible and resistant rice cultivars, the excretion were alkaline in nature, indicating that the delphacids fed mostly sap of phloem sieve tubes (Auclair and Baldos, 1982). Studies conducted by Khan and Saxena (1984a) suggested that *N. virescence* was a xylem feeder and BPH and WBPH were primarily phloem feeders which produce a clear honeydew excreta when reared on seedlings treated with safranine, a dye that selectively translocated through xylem vessels. The feeding activity of *S. furcifera* on susceptible and resistant cultivars monitored using electronic device by Khan and Saxena (1984b) recorded more feeding marks on resistant cultivars and few on susceptible. The wave form indicated that the bugs were primarily phloem feeder.

Honeydew excretion of WBPH collected from susceptible variety was more than that on the resistant variety (Auclair and Baldos, 1982; Gunathilagaraj and Chelliah, 1985; Liu *et al.*, 1993; Lal *et al.*, 1988; Rath *et al.*, 1999; Singh and Pathak, 1997; Lal and Pathak, 1999). Studies on the feeding preference of *S. furcifera* showed that there is no mechanical barrier for feeding by the insect, more feeding marks made by the females on resistant cultivars and fewer on the susceptible TN- (1) (Singh and Pathak, 1997; Rath *et al.*, 1999; Mani Chellappan *et al.*, 2002a). Rubia *et al.*, (2003) compared the feeding effects caused by *S. furcifera* and *N. lugens* at vegetative stages of rice. Though both were phloem feeders, the reduction in plant height caused by *S. furcifera* feeding was greater than *N. lugens.* The effects of *N. lugens* feeding on roots were greater than those of *S. furcifera.*

The orientation response of females due to visual attraction was identical on susceptible and resistant varieties. But after 8 h, significantly more individuals settled on susceptible cultivar. The quantity of food ingested on resistant cultivar was significantly low on resistant cultivar while highest on susceptible TN- (1) (Khan and Saxena, 1985).

Sucking rate increased with the age of planthopper and the relative sucking rate of nymphs with at the first, second, third, fourth, and fifth instars and

macropterous male adult was 0.19, 0.27, 0.37, 0.49, 0.59, 0. 69 respectively when compared to macropetrous female adult. The relationship between injury to rice by WBPH in cage and yield loss assessment showed that yield loss was mainly caused by decreased filling per cent of kernels rather than the number of panicle / spikelet (Zhu and Cheng, 2002).

Amino acid analysis of the phloem sap of rice and honeydew excretion of white backed planthopper revealed that the major amino acids among 18 detected were, asparagine, aspartic acid, glutamic acid, glutamine, serine and valine (Liu *et al.*, 2000). However, Liu, *et al.* (1993) also reported that WBPH produces significantly lesser amount of amino acids on resistant variety than on susceptible variety.

2.8 Mechanisms of rice varietal resistance against WBPH

Laboratory studies showed that plant chemicals had a potential role in resistance against insect pests. Resistant cultivar contained the chemical which had deterrent activity as in Rathu Hennati and susceptible variety contained feeding stimulant as detected in TN- (1) (Liu and Wilkins, 1988). Out of 71 varieties screened for resistance to *S. furcifera* in Philippines, 11 were found to be resistant, 7 moderately reistant, 9 moderately susceptible and 44 highly susceptible to the pests (Pathak and Heinrichs, 1990). Antixenosis in *S. furcifera* was studied in four varieties of rice with 15, 30, 45, 65 and 75 days old rice plants. The lowest and greatest adult population was recorded in 15 and 45 days old plants respectively (Shukla and Sajjan, 1994). Benzyl benzoate was identified in extracts of the watery oviposition lesion formed by rice plants in response to oviposition by *S. furcifera.* The aquous solution of benzyl benzoate exhibited the ovicidal activity at a concentration of 6.4 ppm at 25° C. This substance was not detected in intact rice plants and also in non watery oviposition sites (Seino *et al.*, 1996). Investigation on the effect of different population levels of WBPH on five rice varieties revealed that var. Thriveni to be more tolerant than other varieties tested because of its ability to produce productive tillers at higher population level (Ramaraju *et al.*, 1996).

Twenty seven rice varieties with known resistance to WBPH at Hyderabad were evaluated for their susceptibility to WBPH in Ludhiana. Thirteen varieties gave differential reactions indicating that the pest population at Ludhiana and Hyderabad belonged to different biotypes. In another experiment, the reaction of 12 rice varieties to 5 samples of pest population collected from different locations in Punjab were similar indicating that only one biotype of this insect present is in Punjab (Shukla and Saini, 1989).

2.9 Natural enemies of WBPH

The mirid *Cyrtorhinus lividipennis* (Reut.) and *Tyttlus parviceps* (Reut.) were found to be feeding on nymphs of *S. furcifera* and *N. lugens* in Tarai region of India (Pathak and Saha, 1976; Pawar, 1975). *Cyrtorhinus* spp. was more important than spiders in maintaining *S. furcifera* population at lower level (Ooi, 1980). Population of *S. furcifera* in India was held in check by *C. lividipennis* and a staphilinid, *Paederus* spp. (Shukla *et al.*, 1983). A single mirid predator could devour 2.66 and 3 WBPH nymphs per day on TN-1 and ADT-36 varieties respectively (Alice *et al.*, 2001). Garg and Sethi (1983; 1984) first reported that the adults of coccinellids, *Brumoides suturalis* (Fab.) preying on nymphs and adults of WBPH, BPH and GLH. The staphilinid, *P. fuscipes* was found at a population densities of 5-20 beetles/m^2 in rice fields of Tamil Nadu, showed that the mean number of adults of BPH, WBPH and GLH consumed/ beetle/ day was 8.7, 8.3 and 8.4 respectively (Rajendran and Gopalan, 1988). Thirteen species of *Araneae* preying on WBPH were recorded in Punjab, out of those, seven were hunting spiders and five species were web spinners. Feeding efficiency of predators of WBPH indicated that *Salticus scenicus* (Clerk) was the most effective predator of WBPH which consumed 4.95 nymphs/day followed by *Oxyopus pandae* (3.76), *Paradosa bimanica* (3.67) *Thomisus* spp. (3.45) *Neoscona nautica* (L. Koch) (2.55) and *Casnoidea indica* (Thunberg) (1.83) (Bhathal and Dhaliwal, 1990). Population dynamics of planthopper and their natural enemy in rice ecosystem studied by Heong *et al.* (1992) showed that the dominant predators were mostly hemipteran, *Microvelia douglasi* (Bergroth) and *C. lividipennis*

followed by spiders *Paradosa pseudoannulata* (Boesenberg and Strand) and parasitoid *Tetrastichus* spp. Survey conducted in paddy eco system at Karnataka showed that BPH population were positively correlated but not significantly correlated with spider population WBPH population were positively and significantly correlated with both spider and mirid population (Vijayakumar and Patil, 2004b).

Larvae of *Tetrastichus* spp. a hymenopteran parasitoid had been found feeding the eggs of BPH and WBPH (Chandra, 1979). Five species of drynid parasiting the leafhopper were reported as potential biocontrol agents of WBPH, BPH and GLH (Chandra, 1980). The parasitoids *Ecthrodelphax fairchildii* (Perkins), *Pseudogonatopus apicalis* (Perkins), *P. hospes* (Perkins) and *Pseudogonatopus* spp. were recorded attacking BPH and WBPH on rice in Madhya Pradesh (Yadav and Pawar, 1989).

2.10 Fungal and nematode pathogen of WBPH

Laboratory studies indicated that several Asian strains of *Beauveria bassiana* (Balsamo) were potential biological controlling agents of BPH, WBPH, and GLH (Aguda *et al.*, 1984).

Studies conducted about pathogenisity of *Entomophthora delphacis* (Hori) to rice planthopper showed that 68.29 per cent infection six days after the treatment at 18- 20° C and at a relative humidity of 95- 100 per cent. Infection rates on nymphs of *N. viresces, S. furcifera, Delphacodes striatella* (Fallen) and *C. medianalis* reached more than 80 per cent. Relative humidity was apparently an important factor influencing the infection (Li, 1984).

It was found that the micro organism infecting rice planthopper pest were *Entomophthora delphacis, B. bassiana, B. tenella* (Delacr.), *Metarhizium anisopliae* (Metsch.), *Hirsutella* spp., *Paecilomyces* spp., *Cephalosporium* spp., *Nomuraea rileyi* (Farlow) and *Serratia marcescens* in China. Application of suspension of conidia of *B. bassiana* to hopper population resulted in 60-90 per

cent infection after 15 days of incubation. High levels of nematodes *Amphimermis unka* were also found parasiting on *S. furcifera* (Li, 1985).

A study conducted to find out the nematode parasitism on three species of hopper pests on rice by observing the nematode emergence from caged samples of GLH, BPH and WBPH in dry and wet seasons. Result showed that a very low per cent of parasitism during the wet season, while some what higher parasitism during the dry season (Pena and Shepard, 1985).

2.11 Insecticide sensitivity

It was showed that the carbamate insescticides were effective against homopteran pests like GLH, BPH and WBPH. Carbaryl (0.1%) spray applied to the base of plant gave 95 per cent mortality on WBPH and 100 per cent on BPH by third day of application (Heong, 1975). Granular application of sevidol (mixture of carbaryl and γ- BHC) to standing water effectively controlled the BPH and WBPH population (Kulshresth *et al.*, 1976). Results of tests on chemical control of WBPH carried out in farmers field in Pakistan showed 97 per cent and 70 per cent reduction in population after three days and 15 days of insecticide application respectively with a necessity of repetition of the treatment in every 10-15 days (Zafar, 1982). Based on field plot studies conducted in Hariyana to compare the effectiveness of different insecticide to control WBPH, dichlorvos applied at 0.38 kg ai/ha was the most effective and gave greatest per cent reduction in pest number (Khan and Kushwaha, 1990). Seven insecticides were evaluated against WBPH at the rate of 0.5 kg ai /ha in a field trial at Cuttack on rice. Though 90 per cent mortality of dephacids were recorded within 24 h from all insecticides, quinalphos, carbaryl, chlorpyriphos and carbosulfan had given prolonged control for five days after the treatment (Sasmal *et al.*, 1984). Organo phosphorus insecticides such as phosphamidon, monocrotophos and chlorpyriphos had been successively used for the control of sucking pest *viz.*, GLH, BPH and WBPH (Rao *et al.*, 1984). A green house experiment carried out in India to determine the comparative effectiveness of seven granular insecticides against WBPH showed that, carbofuran, cypermethrin, fenvalerate, fenitrothion and

isoprocarb were the most effective chemicals causing 100 per cent mortality within 4h (Krishnaiah and Kalode, 1986). Saha (1986) reported that chloripyriphos @ 0.5 kg ai/ha and phosphamidon at 0.5 kg ai/ ha were effective against WBPH. Laboratory study conducted by Ramaraju *et al.* (1987) indicated that phosphamidon @ 0.05 % had high ovicidal action and reduced the reproductive rates. But Senguttuvan and Gopalan (1990) reporting carbofuran and monocrotophos reducing the egg hatch of WBPH but not with phosphamidon and deltamethrin. The efficacy of monocrotophos (monocil) was studied by Khan and Kushwaha (1991b) against WBPH at various stages of development and they confirmed that the protection at the ear head stage of the crop was highly essential. Korat *et al.* (1997) proved that phosphamidon and phorate were affected against WBPH and the grain yield was also high in the treated plots. Foliar spray with monocrotophos at 80 days after transplanting gave very effective control of WBPH adults (Kushwaha *et al.*, 1986). Panda *et al.* (1989) compared monocrotophos with synthetic pyrethroid and proved that monocrotophos gave the highest mortality of WBPH. Haq *et al.* (1991) observed that monocrotophos resulted in the highest mortality of WBPH after 72 h of treatment. Field experiments conducted by Panda *et al.* (1991) substantiated that monocrotophos @ 500 g ai/ ha gave the best control even upto 90 days after treatment. It was proved that rice yields were greatest when the plots were sprayed with methamidophos (40%) at 100-150 ml and isoprocarb (10%) at 150-200 g / mu (1mu = 0.067 ha) (Yan *et al.*, 1992). Shukla and Kaushik (1994) reported that sprays of monocrotophos @ 0.5 kg ai/ha resulted in 91.3 percent reduction of WBPH. Srinivasan (2000) studied the bio efficacy of phosphamidon (40 SL) against WBPH and observed that, a persistent toxicity of seven days on *S. furcifera* under green house condition.

In a field experiment conducted to control the *S. furcifera*, monocrotophos (@ 500 g ai/ha) gave the best control of WBPH up to 90 days (Panda *et al.*, 1996). Among the tested insecticides (cartap, phorate and carbofuran), carbofuran was the effective chemical against *S. furcifera* (even at 0.5 kg ai/ha) and also highly

toxic to predators of WBPH, while cartap was comparatively safer to the natural enemies of the hoppers (Panda and Misra, 1999).

Studies conducted in Philippines suggested that third instar nymphs of BPH, GLH and WBPH died at molting when either directly sprayed with buprofezin (0.075 %) or confined on rice plant sprayed with buprofezin (0.075%) (Valencia *et al.*, 1983). Different bioassay tests conducted in China showed that the contact activity was the most important mode of action of buprofezin against delphacids although there was some systemic activity. In the field, buprofezin was much more effective than the conventional insecticides *viz.*, MIPC (isoprocarb) and methamidophos against BPH and WBPH. Buprofezin (@ 37.5-75g ai/ha) reduced the number of delphacids to a very low level without harming the spider population and other important predators of the pest (Pan and Chin, 1989). Insect growth regulators on *S. furcifera* resulted in the survival of individuals with varying reproductive potential (Salin *et al.*, 1990). In a study to evaluate the effects of flufenoxuron on *S. furcifera* and GLH were in cage experiments, application on to the freshly laid eggs resulted in a rapid mortality of developing embryo. If eggs were treated just before hatching, the young ones had various morphological deformities and if the compound was applied during moulting, the insect remained in the moulting position itself and died. Those individuals that successfully developed into adults typically had deformed wings. If females developed on plants treated with 600 ppm, their fecundity got reduced (Mani and Gopalan, 1991). It was suggested that when infestation occurs earlier than usual, buprofezin should be applied twice, first mainly for the control of *S. furcifera* and second for the control of *N. lugens* (Jiang *et al.*, 1992). Antijuvenile hormone precocene-II also showed biological activity against *S. furcifera.* When newly hatched nymphs released on plants treated with 500 ppm of precocene-II, about half of the insects died as first instar nymphs. Others survived for 2-3 nymphal instars and developed into precocious adults. When insects were transferred from the treated rice plant to untreated plants, supernumerary nymphs were developed (Miyake and Mitsui, 1995). A study conducted in Andra Pradesh showed that buprofezin (0.01%) exhibited a higher degree of persistent toxicity to

nymphs of BPH and WBPH. Synthetic pyrethroids, *viz.*, cypermethrin (0.005%) and deltamethrin (0.0025%) which showed only moderate toxicity to WBPH and BPH (Krishnaiah *et al.*, 1996).

Etofenprox (200g ai/ha) as an oil formulation was effective against *S. furcifera* and *C. suppressalis* in Japan (Asayama *et al.*, 1991). Under the laboratory condition it was found that imidacloprid, a new insecticide was more effective than etofenpox (a best standard insecticide against WBPH). The use of imidacloprid in nursery boxes (a single application @ 0.2-0.3 kg ai/ha) was more effective than repeated application of conventional insecticide. Dusting with imidacloprid controlled the most important planthoppers of rice. The toxicity of imidacloprid was superior to that of standard insecticides such as buprofezin, etofenprox, pirimicarb and cartap (Iwaya and Tsuboi, 1992; Shiokawa *et al.*, 1994). Manjunatha and Shivanna (2001) evaluated the efficacy of imidacloprid against brown planthopper and green leafhopper and found that imidacloprid was superior to monocrotophos. The effects of quinalphos, isoprocarb and buprofezin on population of planthoppers were evaluated using life tables and interference indices of population control (IIPC) in China. All the above three insecticides controlled *S. furcifera* effectively and the IIPCs of quinalphos, isoprocarb and buprofezin sprays were 3.77, 2.44 and 0.37 respectively (Huang and Pang, 1992). Zhang and Lu (1996) conducted an experiment by applying imidacloprid (10 % @ 2-6 g ai/667 m^2 to rice seedlings 5 days before transplanting, and @ 1g ai/667 m^2 to transplanted plants) in paddy fields when the pest population peaked in August. The result showed that imidacloprid gave more than 92 per cent control, which was significantly higher than that of buprofezin.

Field studies conducted in Orissa revealed that the population of *S. furcifera* on rice was high during *rabi* than the *kharif* season. Applying neem oil and insecticides (monocrotophos, chlorpyriphos, carbaryl and quinalphos) either alone or in combination reduced the number of *S. furcifera* compared with untreated plots (Sontakke *et al.*, 1994). A study about comparative efficacy of synthetic insecticides, monocrotophos and methyl parathion and neem extract revealed that monocrotophos was the most effective against nymphs and adults of

WBPH with a maximum overall mortality of 63.5 and 66.8 per cent recorded on nymphs and adults of WBPH, respectively (Akbar *et al.*, 1996).

Field evaluation of some neem derivatives alone and in combination with monocrotophos and chlorpyriphos against planthoppers showed that neem derivatives were effective in suppressing the population. The maximum protection was obtained by the seedling root dip with chlorpyriphos and spraying with monocrotophos at 45 and 75 days after transplanting (Dash *et al.*, 1996).

Field experiments were conducted in Andhra Pradesh, India during the *kharif* seasons of 2001 and *rabi* seasons of 2002 to study the efficacy of chlorpyriphos, cypermethrin, beta cyfluthrin, acephate, imidacloprid, thiacloprid, ethiprole, deltamethrin, phosphamidon and monocrotophos, alone or in combination on BPH and WBPH infesting rice. Ethiprole (10 EC @ 50g ai/ha), a combination of imidacloprid (5%) and beta cyfluthrin (5%) (@ 30g ai/ha), and imidacloprid (@ 25g ai/ha) were the most effective in managing planthopper populations and realizing higher grain yield. These insecticides were also relatively safer to natural enemies. Beta cyfluthrin (@ 12.5 g ai/ha) and deltamethrin (@10 g ai/ha) were the least effective against the planthoppers (Varma *et al.*, 2003).

2.12 Effects of plant derivatives on WBPH

Nine plant derivatives (1% oils of *Azadirachta indica* (L.) (neem), *Calophylum inophyllum* (L.) (*Pinnai*), *Pongamia glabra* (L.) (*pungam*) and *Madhuca longifolia* (L.) (*Illupai*), 2% extracts of neem seed kernal and other three plants, 5% neem cake extract followed by 2% *pungam* seed extract) were tested for their inhibitory effects on nymphs of BPH and WBPH on IR-20 rice variety. The greatest reduction in population of WBPH was observed when treated with neem cake extract (5%) followed by *pungam* seed extract (2%) (Ramaraju and Babu, 1989).

Efficacy of neem oil (3%), and NSKE (5%) were evaluated and compared with monocrotophos (0.5kg ai/ha) against WBPH in Madhya Pradesh. Monocrotophos spray resulted in the highest mortality of 91. 3 per cent and 66 per

cent during *kharif* and *rabi* seasons respectively, followed by NSKE (5%) and neem oil (3%) (Shukla and Kaushik, 1994).

Effect of different neem formulations on feeding of WBPH had been tested at different concentrations of different formulations exhibited significant feeding deterrent action on all pests of rice (Krishnaiah *et al.*, 2001). Among the six commercial neem formulations and chlorpyriphos evaluated in Orissa for their efficacy against major rice pests showed that, Rakshak and Nimbicidine (2%) were significantly more effective for controlling all rice pests (Dash *et al.*, 2001). Effect of neem formulations on reproduction and oviposition of rice hopper revealed that all the formulations tested had a significant reproductive inhibitory effect at all tested concentrations (Kumar *et al.*, 2001).

2.13 Development of resistance against insecticides

The insecticide susceptibility of WBPH and BPH collected from Bogor in Indonesia and Chikugo in Japan was assessed in the laboratory using topically applied unsynergised organo phosphorus, organo chlorine, carbamates and pyrethroid insecticide formulations. The LD_{50} of lindane and p, p-DDT for males and females of the Bogor strain of WBPH were lesser compared to the Chikugo strain. The Bogor strain was 2.7 times more resistant to malathion than the Chikugo strain (Endo *et al.*, 1989).

A laboratory study on the susceptibility of *S. furcifera* and *N. lugens* to thirteen insecticides showed that the strains of both species were most susceptible to carbofuran and least susceptible to malathion. The development of resistance was faster in the population of *S. furcifera* than that in *N. lugens*. There was a negative relationship between resistance of population of *N. lugens* and the chemical used (Mao and Liang, 1992). Zhang *et al.* (1999) observed that the productivity of both macropterous and brachypterous BPH was increased by triazophos application.

Resistance to organo phosphorus insecticide was studied in *S. furcifera*, by comparing the topical LD_{50} with a reference laboratory strain. The strains

collected from the field in Japan showed a high level of resistance to OP compounds and a low level of resistance to organo chlorine and carbamates compounds (Hosoda, 1989).

The activities of enzymes related to insecticide resistance (general esterase, carboxyl esterase acetyl choline esterase) in different strains of WBPH were measured and compared with susceptible strain. It showed that the malathion resistant strain had a higher carboxyl esterase activity (Yao *et al.*, 2003).

The banding pattern of six soluble enzymes of *S. furcifera* population in Sri Lanka studied by using crude homogenates of macropterous adults of both sexes showed a higher esterase, lactate dehydrogenase, phosphoglucomutase and hexokinase enzyme activity. The number and relative mobility of bands varied between enzyme systems (Rajendram, 1991).

Presence and the prevalence of elevated carboxylesterase, an important mechanism of insecticide resistance, and their interaction with different insecticide groups were investigated in 10 agriculturally important pests including *N. lugens*. When the insect homogenates were run on a native polyacrylamide (7.5%) gel electrophoresis (PAGE) and the gels were stained for esterase activity using alpha and beta naphthyl acetate (α- NA and β- NA) as substrate, elevated carboxylesterase bands were observed (Karunaratne *et al.*, 1999a), indicting the possible insecticide resistance. The insecticide resistant strains of BPH had a single diffused elevated esterase band on native PAGE while the WBPH, (*S. furcifera)* had two elevated esterase bands with lower relative mobilities than the *N. lugens* esterases. All these bands indicating their possible role in OP insecticide resistance. Partial purification of esterase from BPH had an estimated molecular weight of approximately 60 Dalton. Insecticide resistance was determined by these elevated esterases through rapid banding and slow turn over of the carbamate or insecticidally active oxone analogues of the phosphorothionate *ie.*, sequestration rather than metabolism was the primary resistance mechanism (Karunaratne *et al.*, 1999b).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present research work has been delineated to study the biology and to manifest the insecticide sensitivity of rice white backed planthopper (WBPH), *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) to commonly used insecticides in the rice field, under laboratory condition in College of Horticulture, Vellanikkara, Kerala Agricultural University, Thrissur during 2003- 2005.

3.1 MASS CULTURING OF TEST INSECT

Field collected WBPH adults formed the nucleus culture. For mass culturing of WBPH, rice plants were raised in mud pots (20 cm diameter and 30 cm height). Rice seedlings (var. 'Jyothi') of 15-20 days old were transplanted in tumbler plots and kept in plastic trays filled with water. Thirty days old rice seedlings were used for studying the biology, fecundity, feeding behaviour and oviposition behaviour of the test insect, and also for doing the bioassay of insecticides. The insect culture was kept in cylindrical rearing cages covered with nylon net (Plate 1).

Adults separated from the stock culture were released on 30 days old rice plants @ 10 pairs per plant and confined in a rearing cage for oviposition (Plate 2). The insects were allowed to mate and oviposit only for 24 h in one plant inorder to get uniform stage of insect for conducting further experiments. After 24 h the insects were carefully transferred to fresh plants in another rearing cage. The exposed plants were observed for nymphal emergence. The newly emerged nymphs were immediately transferred to fresh plants and covered with net cage to protect them from predators.

3.2 BIOLOGY OF TEST INSECT

As the biology of an insect gives accurate information on duration of different stages helping in locating weak link of the lifecycle, the biology of the test insect was studied under laboratory condition during December 2004 and March 2005. One month old rice seedlings (var. 'Jyothi') planted singly in tumbler pots were used for studying the biology of *S. furcifera* (Plate 3). The outer leaf

Plate 1. Cylindrical net cage

Plate 2. Mass culturing of *S. furcifera*

sheath of the plants was removed to avoid the eggs of predators and other leaf hopper, if any. The plant was covered with mylar film cage through which the insects could be observed. Freshly emerged male and female adults were introduced into the cage and allowed for only 24 h in that cage. After 24 h, the pair was carefully transferred to another fresh plant enclosed in mylar film cage. The transferring of insects continued till the death of the insects. The exposed plants were observed for pre oviposition period, incubation period, adult longevity, total number of eggs laid by female, total number of nymphs emerged and number of unhatched eggs. Another set of exposed plants were taken out for examining the oviposition punctures, eggs and feeding probes made by *S. furcifera* by staining technique (Backus *et al.*, 1980; Mani Chellappan *et al.*, 2002b).

3.2.1 Observations recorded

3.2.1.1 Pre oviposition period: Time taken from the adult emergence to first oviposition was recorded

3.2.1.2 Incubation period: Time taken from oviposition and first nymphal emergence. Number of nymphs emerged was recorded regularly in the morning between 8.00 and 10.00 a.m. and carefully transferred to fresh plants @10 nymphs per plant for studying the duration of each instars

3.2.1.3 Duration of each nymphal instars: The period between two consecutive moulting was recorded and considered as duration of particular instar

3.2.1.4 Number of eggs laid per day: The total number of nymphs emerged in each cage was noted. On termination of nymphal emergence, the plants were dissected out under binocular microscope and number of unhatched eggs were counted

3.2.1.5 Ovipositon period: The period upto which the female laid eggs was recorded as oviposition period

3.2.1.6 *Fecundity:* Total number of eggs laid by single adult during life span was counted

3.2.1.7 Per cent hatchability

$$\text{Per cent hatch} = \frac{\text{Number of nymphs emerged}}{\text{Total eggs laid (No. of nymphs emerged + No. of unhatched eggs)}} \times 100$$

3.2.1.8 Per cent survival

$$\textit{Per cent survival} = \frac{\text{Number of adults emerged}}{\text{Number of nymphs emerged}} \times 100$$

3.2.1.9 Adult longevity: The period between adult emergence and the death of the insect

3.2.1.10 Sex ratio: The total number of males and females emerged in each cage was noted and sex ratio expressed as females: males.

3.2.2 Feeding behaviour of WBPH

3.2.2.1 Filter paper technique

The quantity of honeydew excreted by the WBPH indicates the relative amount of feeding by them. Adults were subjected to feed the plant individually and the honeydew was collected in filter paper dipped in bromocresol green kept in feeding chamber following Sogawa and Pathak (1970)

Bromocresol green dye (2%) was prepared using absolute alcohol. Whatman No. 1 filter paper was dipped in the dye solution and allowed to air dry (for 10 minutes). Air dried filter paper was then carefully placed in the feeding chamber. After prestarving for 30 minutes, gravid females were introduced into the feeding chamber @ 1 gravid female per feeding chamber. After 24 h, the filter paper was taken out and traced the area where honeydew excreta had dropped, which appeared as bluish green colour. The experiment was done with five different gravid females, males and fifth instar nymphs in different feeding chambers (Plate 4).

Plate 3. Singly planted 'Jyothi' rice seedlings

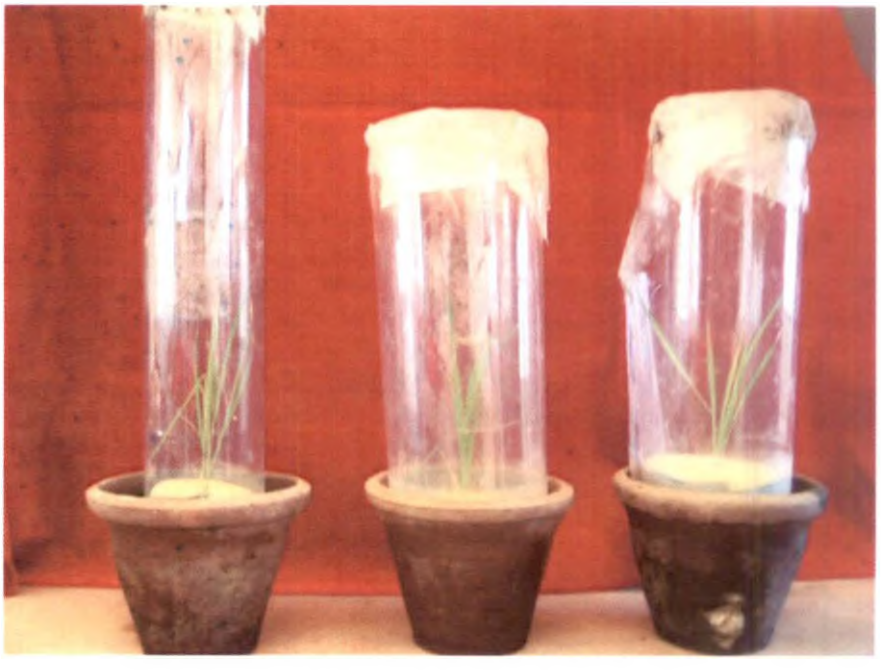

Plate 4. Feeding chamber

3.2.2.2 Analysis of amino acid in honey dew by thin layer chromatography (TLC)

Honeydew excreted by the test insect was collected by capillary method following Lakshmi *et al.* (2003).

Thin layer chromatography (TLC) was performed following Sadasivam and Manickam (1997) to qualitatively estimate the amino acids present in the honeydew, using Silica Gel G adsorbant prepared in distilled water (1:2 v/v) coated on glass plate. After activating the glass plate the sample (20 µl) and standards (0.2%) prepared in isopropanol (10%) (10 µl) were spotted at equal distance on glass plate. The developing solvent used was the mixture of butanol, water and acetic acid (80:20:20). After running the chromatogram, ninhydrin (0.1%) prepared in acetone was sprayed on glass plate and developed at 100-110°C for five minutes. The R_f values of the standard and sample were calculated

3.2.3 Fecundity study by *in situ* egg staining technique

Fecundity study conducted by *in situ* egg staining technique for leaf hopper within the unsectioned plant tissues following Backus *et al.* (1980) and Mani Chellappan *et al.* (2002b).

Two solutions *viz.*, Mc.Bride's stain (0.2 % acid fuchsin in 95% ethanol and glacial acetic acid 1:1; v /v) and the clearing agent were prepared (Annexure I).

The oviposited rice seedlings were cut down from collar region of the plant and further to convenient length and placed in the staining solution in test tubes. The tissues were left at room temperature for 19 to 20 h, while the stain permeated the tissue. The plant parts along with clearing solution were autoclaved (120° C and 15 lb *psi* for 20 minutes). After cooling, the plant parts were taken out and once again placed in the clearing solution and examined under a binocular microscope. Observations were made by counting the total number of eggs laid and also the feeding probe made by the female insect.

3.3 ISOLATION OF ENTOMOPATHOGENIC FUNGI FROM WBPH

The mycosed WBPH cadaver was collected from the rearing cages and surface sterilized with mercuric chloride (0.1%) exactly for one minute and then washed three times with sterile distilled water. After drying, the cadaver was carefully picked up with a sterilized forceps and placed in potato dextrose agar (PDA) plate. The petridish incubated at room temperature and examined daily for the growth of the fungus. The pure culture of the fungus was maintained on PDA slants also. The identification was done based on fungal characters, morphology of the spore and sporulating structure. Pathogenicity test was conducted by spraying aqueous suspension of fungal spore on healthy adult insects. The treated insects were released on rice plant confined in mylar film cage and examined daily. The infection usually obtained after 5- 7 days of incubation was reisolated to obtain pure culture, proving Koch's postulates

3.4 IDENTIFICATION OF PREDATORS OF WBPH

While maintaining the culture of test insect in glass house, predators obtained were recorded daily and identified

3.5 BIOASSAY OF INSECTICIDES

Bioassay was done for the following insecticides (Table 1) under laboratory conditions

Table. 1 Insecticides used for bioassay on 5th instar nymphs of *S. furcifera*

Treatments	Insecticides used	Field recommended dose (%)	Tested doses in laboratory (%)				
T_1	Imidacloprid 200SL	0.006	0.002	0.004	0.006	0.008	0.010
T_2	Lambda cyhalothrin 5% EC	0.005	0.001	0.003	0.005	0.007	0.009
T_3	Acephate 75% SP	0.16	0.040	0.060	0.080	0.100	0.120
T_4	Triazophos 40% EC	0.05	0.010	0.030	0.050	0.070	0.090
T_5	Carbaryl 50 %WDP	0.1	0.050	0.100	0.150	0.200	0.250
T_6	Quinalphos 25 % EC	0.02-0.05	0.010	0.020	0.030	0.040	0.050
T_7	DDVP 76% EC	0.05	0.010	0.030	0.050	0.070	0.090
T_8	Phosphamidon 40% SL	0.05	0.010	0.030	0.050	0.070	0.090
T_9	Monocrotophos 36% SL	0.05	0.010	0.030	0.050	0.070	0.090
T_{10}	Neem oil	2.00	0.500	1.000	1.500	2.000	2.500
T_{11}	Water	-	-				

For determining LC_{50}, above mentioned five different concentrations of each treatment were tested with three replications. Twenty nymphs of fifth instar were used per replication in the bioassay studies. Required concentrations of insecticides tested were prepared in water and sprayed on thirty days old rice seedlings till runoff stage. The test insects were released after covering with mylar film cage.

The plants sprayed with water alone without adding any insecticide treated as control (T_{11}). After spraying water, 20 nymphs of 5th instar stage were released in to the cage and mortality was recorded after 24 h and 48 h of treatment.

3.5.1 Persistent toxicity of insecticides

Persistent toxicity of above mentioned insecticides were tested under laboratory conditions (mean temperature of 25.85±4°C and mean relative humidity of 88±8.5). The calculated LC_{50} dose of each insecticide was applied on rice seedlings. The seedlings were allowed to air dry and then ten fifth instrar nymphs were confined on it using mylar film cage. The insects were observed at 24 h interval and the number of dead insects recorded daily. After removing all dead and live insects, another fresh set of ten nymphs were released again. This process was continued till the insects released into the cage remain unaffected. Thus, the persistent toxicity (PT) index was calculated.

3.6 BIOCHEMICAL ESTIMATION OF PROTEIN PRESENT IN INSECT HOMOGENATE

Total protein present in the insecticide treated and untreated insect homogenate were estimated by the method described by Lowry *et al.* (1951) with slight modifications.

3.6.1 Sample preparation

Samples for protein analysis were extracted after insecticide treatment by dry film method. The field recommended doses of 10 insecticides were prepared in water and sprayed on petridish. After drying, fifth instar nymphs of test insect were released in it. Protein was estimated by taking known quantities of insects. Crude homogenate of the sample was obtained using pestle and mortar (test insect in 500µl 50 mM. sodium phosphate buffer of pH 7.4) (Annexure II) following Karunaratne *et al.* (1999a). The homogenate was spinned at 13,000 g for 2 minutes at 4° C to remove coarse materials. Supernatant was taken and added an equal volume (500 µl) of trichloro acetic acid (TCA) to precipitate the protein. Again it was centrifuged at 10,000 rpm for 20 minutes at 4°C. The precipitated protein was dissolved in 0.1 N NaOH and estimated as per Lowry *et al.* (1951). The intensity of blue colour developed was read in spectrophotometer at 660 nm absorbance and compared with the standard curve (Fig 1).

3.6.2 Preparation of standard

Bovine serum albumin (BSA) was used as standard. BSA (50 mg) was dissolved in the extraction buffer (50 mM Sodium phosphate buffer pH 7.4) in a standard flask and kept as stock solution. From the stock, 10 ml was drawn and made up to 50 ml with buffer in another standard flask. In order to get the required concentrations (*ie.*, 200µg/ 1ml of solution), from this stock solution different aliquots (100µl, 200µl, 300µl, 400µl, 500µl, 600µl and 700µl) were pipetted out in different test tubes and the volume was made up to one ml with buffer. A test tube with extraction buffer (1 ml) alone served as blank.

3.7 ESTERASE ASSAY IN CRUDE INSECT HOMOGENATE

An attempt was made to estimate esterase isozymes present in insecticide treated and untreated insect homogenate, following Van Asperen (1962).

3.7.1 Preparation of 1-naphthol standard

Stock solution of 1-naphthol (10 mM) was prepared by dissolving 0.0721g in of methanol (50 ml). From this, working standard of varying concentrations (0.01 mM, 0.02 mM, 0.03 mM, 0.04 mM, 0.05 mM and 0.06 mM) were prepared by pipetting out different aliquots (10 µl, 20µl, 30µl, 40µl, 50µl and 60µl) and made up to one ml with methanol. To this one ml of standard, extraction buffer (sodium phosphate buffer pH 7.4) was added (2 ml). Phosphate buffer alone served as blank. The mixture was subjected to aerobic incubation at 30° C for 30 minutes with constant agitation. Dye solution containing fast blue RR (1%) and sodium lauryl sulphate (5%) (2:5 v/v) (0.5 ml) was added to this. Dye and buffer without sample served as control. After that the mixture was incubated at 37° C for ten minutes for the colour development. The intensity of red colour developed was read at 600 nm absorbance in spectrophotometer. The control value was deducted from other readings (readings of standards and sample) prior to plot the graph.

3.7.2 Preparation of sample

Insect sample (25 mg) was homogenized in of sodium phosphate buffer (50 mM) (2 ml), spinned at 13,000g for 2 minutes at 4°C to remove the coarse

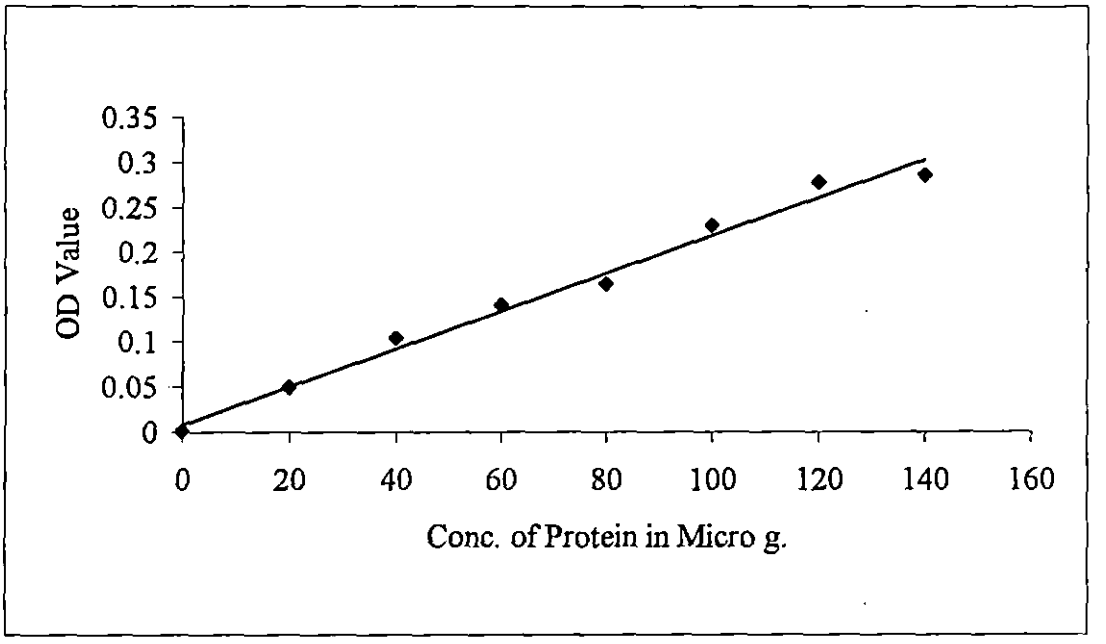

Fig 1. Protein standard curve

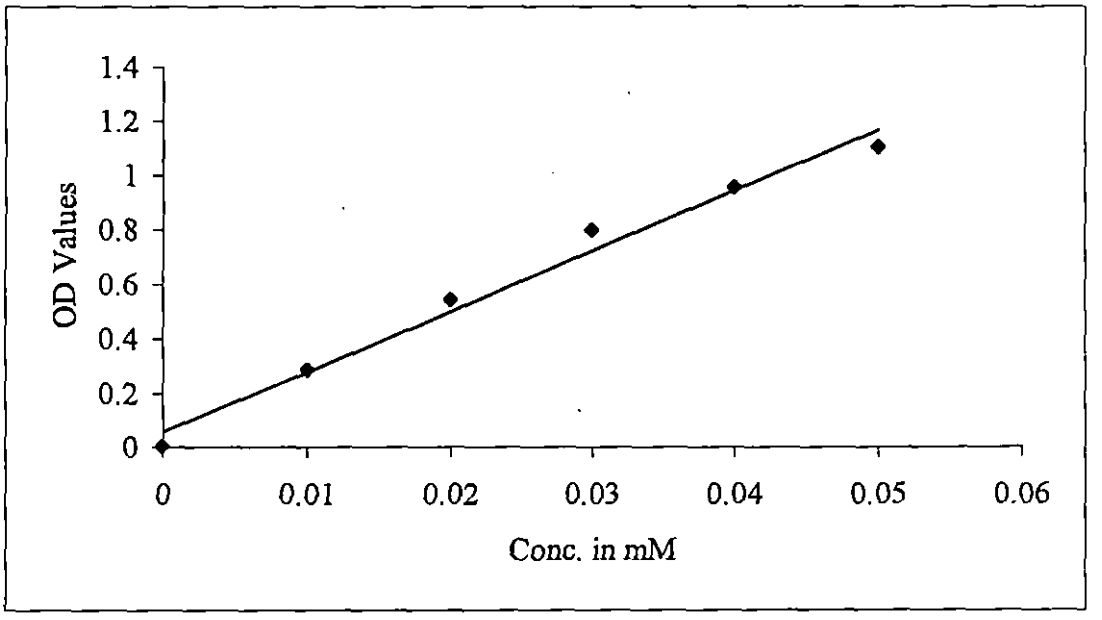

Fig 2. 1- Naphthol standard curve

materials. The pellets were discarded and the supernatent was taken for doing enzyme assay following Karunaratne *et al.* (1999a). To this one ml of sample, enzyme substrate (1-naphthyl acetate, $3.3x10^{-3}$ M, Sigma pH 7.4) dissolved in ethanol (1% v/v) was added (2.5 ml). Other steps of enzyme analysis were carried out as described above. The amount of 1-naphthol formed at the end of the reaction was deduced from the standard graph (Fig 2).

3.8 STATISTICAL ANALYSIS

LC_{50} was calculated by probit analysis ((Finney, 1952). Mortality data under each treatment was tabulated and analysed statistically in a completely randomized design (CRD) as proposed by Panse and Sukhatme (1967). The mean mortality of different concentrations of each treatment was ranked according to Duncan's Multiple Range Test (DMRT).

RESULTS

4. RESULTS

Results of experiments conducted in the laboratory on the study entitled "Biology and insecticide sensitivity of rice white backed planthopper, *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) in Kerala" are presented in this chapter.

4.1 BIOLOGY OF TEST INSECT

The biology of *S. furcifera* was studied on 30 days old rice seedling (var. 'Jyothi') during the months of December 2004 and March 2005. The meteorological parameters during the course of study are furnished below (Table 2). The biology studied over two seasons showed a significant difference in incubation period, nymphal instar duration, sex ratio, per cent hatchability, fecundity and per cent survival of the test insect.

Table 2. Meteorological parameters

		December 2004	March 2005
Temperature	Maximum	32.10± 0.59	35.63± 1.40
	Minimum	22.60± 1.85	24.59± 0.92
	Monthly mean	27.00± 6.72	30.46± 6.88
Relative Humidity	Morning	68.16± 8.03	82.71± 8.80
	Evening	42.97± 7.07	42.19±12.13
	Monthly mean	55.57±17.81	62.45±28.65

4.1.1 Description of bio stages

4.1.1.1 Eggs

Eggs were elongate banana shaped, creamy and protruding on one end was visible out of the plant tissue (Plate 5). Incubation period varied from 7- 9 (average 8.4± 0.55) days during December and 6-7 (average 6.88±0.55) days during March (Table 3a and 3b).

4.1.1.2 Nymphs

Nymphs dispersed immediately after emergence and started feeding. There were four moulting and five nymphal instars. Fifth instar nymph moulted into adult. The different instars were identified based on the moulting. Duration of each nymphal instar during the months of December and March are furnished in Table 3a and Table 3b respectively. Just emerged nymphs were greyish in colour with red eyes and having carrot shaped body with tapering posterior and broad anterior ends (Plate 6). The duration of first nymphal instar was 2-3 days during the month of December (average 2.4±0.55) and during March (average 2.2±0.45) (Table 3a and 3b).

Second instar nymphs were white in colour (Plate 7). Duration was 2- 3 with an average 2.8±0.45 and 2.4±0.55 days during the month of December and March respectively.

The second instar nymphs moulted in to third instar nymphs also white in colour (Plate 8) lasted for 3.2±0.45 days during December while 2.8±0.45 days during March.

Fourth instar nymphs (Plate 9) had 3.8±0.4 days duration during December and 3.4±0.55 days during March.

Fifth instar nymphs (Plate 10) had an average duration of 3.6±0.55 days during December and 3.0±0.7 days during March. The total nymphal duration was 15.8 ±0.8 days and 13.8±1.5 days during December and March respectively. The fifth instar nymph molts (Plate 11) into adult

4.1.1.3 Adult

Adult females exist in macropterous forms with well-developed wings (Plate 12) and brachypterous form with reduced wings (Plate 13). Life span of each form exhibited no significant difference even among the two seasons. Macropters lived for an average duration of 11±2.92 days during the month of December and 10±3.7 days during the month of March. Brachypterous forms also lived an average duration of 10.8±3.5 days during December and 9.6±3.9 days during March. Males were short lived compared to the females and had an

Plate 5. Stained eggs of WBPH

Plate 6. First instar nymph

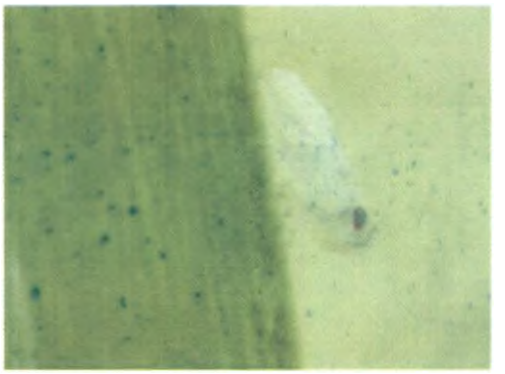

Plate 7. Second instar nymph

Plate 8. Third instar nymph

Plate 9. Fourth instar nymph

Plate 10. Fifth instar nymph

Plate 11. Exuvia

Plate 12. Macropterous female

Plate 13. Brachypterous gravid female

Table 3a. Duration of different stages of *S. furcifera* during December 2004

Stage		*Duration (days)		
		Maximum	Minimum	Average
Egg		9	7	8.4±0.55
Nymph	First instar	3	2	2.4±0.55
	Second instar	3	2	2.8±0.45
	Third instar	4	3	3.2±0.45
	Fourth instar	4	3	3.8±0.45
	Fifth instar	4	3	3.6±0.55
	Total nymphal duration	17	15	15.8±0.80
Adult	Macropterous female	14	5	11.0±2.92
	Brachypterous female	13	9	10.8±3.50
	Male	9	5	6.6±1.50

*Mean of ten observations

Table 3b. Duration of different stages during March 200

Stages		*Duration (Days)		
		Maximum	Minimum	Average
Egg		7	6	6.9±0.55
Nymph	First instar	3	2	2.2±0.45
	Second instar	3	2	2.4±0.55
	Third instar	3	2	2.8±0.45
	Fourth instar	4	3	3.4±0.55
	Fifth instar	4	2	3.0±0.70
	Total nymphal duration	16	12	13.8±1.50
Adult	Macropterous female	16	7	10.0±3.70
	Brachypterous female	14	9	9.6±3.90
	Male	9	4	7.0±1.87

*Mean of ten observations

4.1.2 Reproductive behaviour of *S. furcifera*

4.1.2.1 Pre oviposition period

After adult emergence, the females had a pre oviposition period ranging from 2- 3 days with an average of 2.4±0.55 days during December and 2.2±0.45 days during March (Table 4).

4.1.2.2 Oviposition period

The insects started to lay eggs from 3-4 days of adult emergence. During December, an oviposition period of 6.33±3.2days was observed while during March, it was 7.25±2.8 days.

The female laid eggs in groups varying from 4- 16 with an average of 13.24±5.62 during December and 13.68±3.6 during March (Plate 5). The eggs were found to be inserted on the upper part of the central leaf sheath, if 30 days old rice seedling were used. In case of older seedlings, the egg laying was found in the mid rib on the lower surface of leaf blade. The total number of eggs laid by an insect varied from 56 to 130 during December with an average of 85.67±42.2, while during March it varied from 58 to 149 with an average of 106±41.6 (Table 4).

Table 4. Reproductive behaviour and fecundity of female *S. furcifera* over two seasons

Observations	*Duration (Days)	
	December 2004	March 2005
Pre oviposition period	2.40± 0.55	2.20± 0.45
Oviposition period	6.33± 3.20	7.25± 2.80
Number of eggs laid / day	13.24± 5.62	13.68± 3.60
Total number of eggs laid during life period	85.67±42.20	106.00±41.60
Per cent hatchability	87.30± 7.10	82.00± 4.49
Per cent survival	66.50±10.00	63.80± 8.40
Sex ratio	1:1.17	1:1.34

*Mean of seven observations

4.1.2.3 Fecundity

The total number of eggs laid during life period was calculated as the fecundity of test insect. The observed fecundity during December was 85.67±42.2 and March was 106±41.6 (Table 4). There was a significant difference in the fecundity of the insect over two seasons studied. The fecundity was greater during March than December.

4.1.2.4 Per cent hatchability

Per cent hatchability was more during the winter (December) compared to the summer (March) with 87.3±7.10 and 82.0±4.49 respectively (Table 4). To ascertain the significant difference in the hatchability over two seasons, 'case t' Test was performed. It was observed that the 't' statistics 2.02 was found to be significant at 2.9 per cent level of significance. Thus, it was concluded that there was a significant difference in hatchability over two seasons. Even though the fecundity of test insect was higher during March, the per cent hatchability was more during December compared to March.

4.1.2.5 Per cent survival

Per cent survival of *S. furcifera* was observed to be 66.5±10.0 and 63.8±8.4 during December and March respectively (Table 4). Statistically there was no significant difference among per cent survival of the test insect studied over the two seasons.

4.1.2.6 Sex ratio

Sex ratio of WBPH studied over two seasons showed a significant difference. Sex ratios (female: male) were 1:1.17 and 1:1.34 during December and March respectively (Table 4). To ascertain the significant difference in the sex ratio over two seasons, 'case t' Test was performed. The 't' statistics 2.9 was found to be significant at 1.99 per cent level of significance. Thus it was concluded that there existed a significant difference in sex ratios over the two seasons studied.

4.1.3 Population build up of *S. furcifera*

Study on population build up was conducted from March 2005 to April 2005. Population build up was calculated as fecundity of test insect over two successive generations. Higher mean fecundity was observed during the first generation in March (109.5) compared to the second generation in April (103.5). *ie.*, a reduction in population was recorded during second generation. Average number of eggs hatched were 83.1 and 84.5 during first and second generations respectively. While the survival percentage was 67.22 per cent during first generation and 68.2 during second generation (Table 5). The hatching per cent and survival percent were not significantly fluctuated over the two successive generations.

Table 5. Comparison of parameters affecting population over two successive generations

Parameters	First generation	Second generation
Average fecundity (Eggs/ female)	109.5	103.5
Average No. of unhatched eggs	18.5	16.0
Per cent hatchability (%)	83.1	84.5
Survival per cent (%)	67.2	68.2

4.1.4 Feeding potential of *S. furcifera*

Feeding rate of adults and fifth instar nymphs of WBPH was studied on 30 days old (var. 'Jyothi') rice seedling by estimating the amount of honeydew excreted by the insect (Table 6). Adult females produced more honeydew than males and fifth instar nymphs indicating more feeding by the female population (Plate 14). The stained feeding probe of *S. furcifera* is shown in Plate 15.

Plate 14. Feeding study by filter paper method

Plate 15. Feeding probe made by *S. furcifera*

Table 6. Feeding potential of *S. furcifera* using honeydew test

Stages	Amount of honey dew in mm^2		
	Maximum	Minimum	Average
Brachypterous female	85.0	58.0	73.00±13.74
Macropterous female	79.0	55.0	64.67±12.67
Adult male	18.5	6.5	12.67± 6.00
Fifth instar nymphs	69.0	53.0	61.67± 6.60

4.1.4.1 Qualitative analysis of amino acids in honeydew by T.L.C

Honeydew of *S. furcifera* was subjected into thin layer chromatography to analyse the amino acids present in it (Plate 16). There were two bands with R_f values almost equal to that of glutamic acid and aspartic acid.

4.2. OCCURANCE OF NATURAL ENEMIES

The major natural enemies recorded were spiders. Adult and nymphs of spiders were found to be predating on young nymphal instars of *S. furcifera*. The common spiders observed were *Thomisus* spp. (Plate 17), *Salticus* spp (Plate 18). *Oxyopus* spp (Plate 19), *Lycosa* spp. (Plate 20) and *Argeops* spp. Mirid bug *Cyrtorhinus lividipennis* (Reut.) (Plate 21) also observed predating on eggs and nymphs of white backed planthopper.

4.2.1 Isolation of entomopathogenic fungi

Two entomopathogenic fungi were isolated from *S. furcifera*. Pure culture was obtained on proving Koch's postulates. The fungi were identified as *Aspergillus flavus* (Dirk.) (Plate 22) and *Penicillium oxalicum* (Currie and Thomb) (Plate 23). The infection of *A. flavus* and *P. oxalicum* on adult WBPH are shown in Plate 24 and Plate 25 respectively.

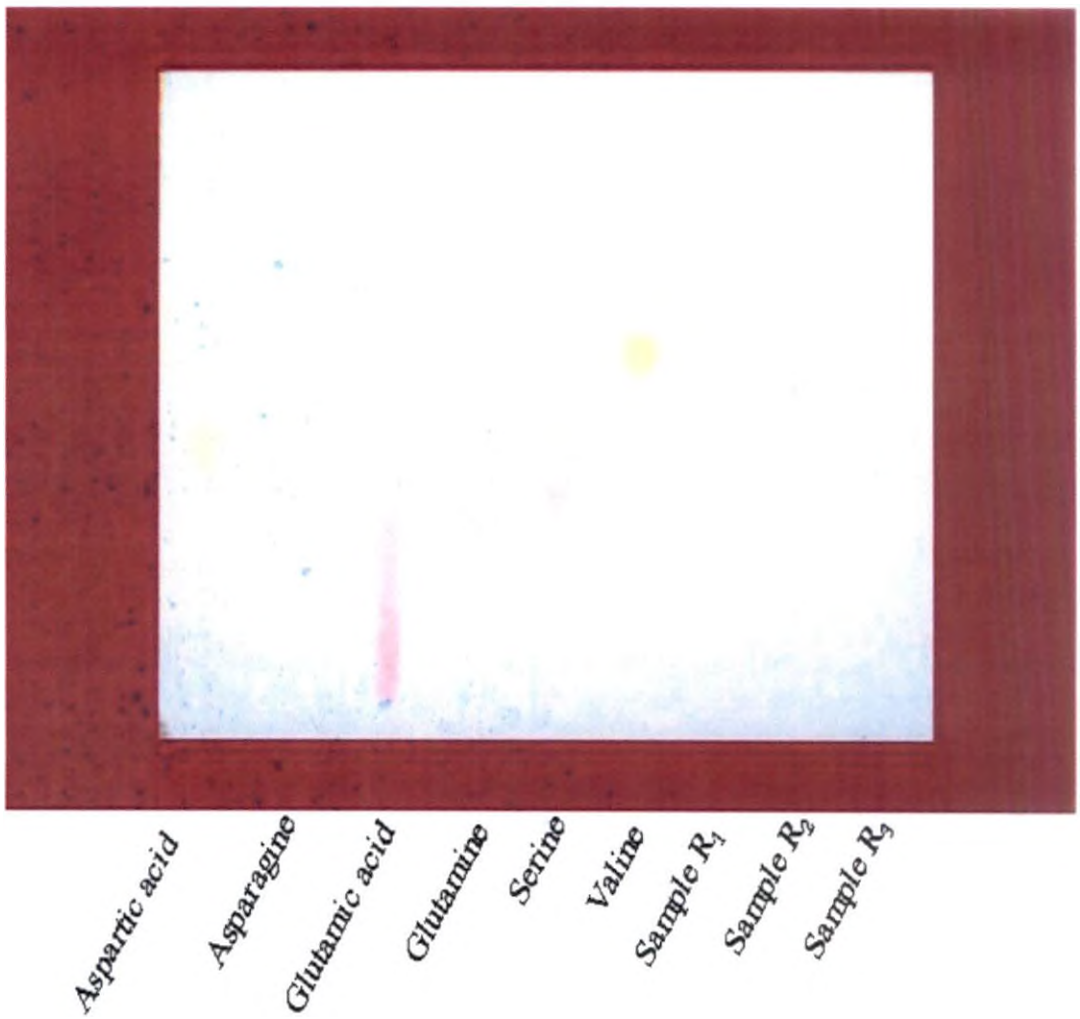

Plate 16. Qualitative analysis of amino acids by TLC

Plate 17. *Thomisus* spp

Plate 18. *Salticus* spp.

Plate 19. *Oxyopus* sp.

Plate 20. *Lycosa* spp.

Plate 21. *Cyrtorhinus lividipennis*

Plate 22. *Aspergillus flavus*

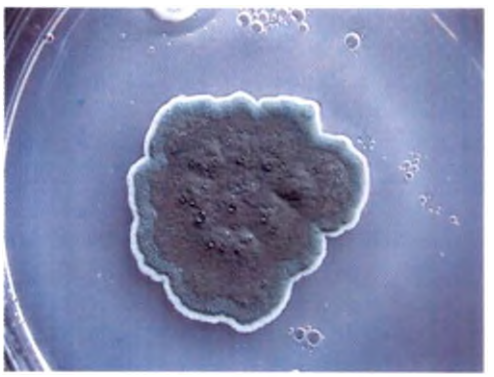

Plate 23. *Penicillium oxalicum*

Plate 24. Infection of *Aspergillus flavus* on WBPH

Plate 25. Infection of *Penicillium oxalicum* on WBPH

4.3 BIOASSAY OF INSECTICIDES

Bioassay of ten commonly used insecticides in the rice field was conducted under laboratory conditions on fifth instar nymphs of *S. furcifera* reared out in the laboratory.

The Table 17a and Table 17b give the summary of the results of mortality of 24 h and 48 h after treatment respectively.

Table 7. Bioassay of imidacloprid on *S. furcifera* (5^{th} instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48 h	
1	0.002	28.33 ^{d} (0.56)	43.33^{d} (0.72)	35.83 (0.64)
2	0.004	48.33^{c} (0.77)	58.33^{c} (0.87)	53.33 (0.82)
3	0.006	65.00^{b} (0.94)	73.33^{b} (1.03)	69.17 (0.99)
4	0.008	94.58^{a} (1.35)	98.80^{a} (1.46)	96.69 (1.41)
5	0.010	98.75^{a} (1.46)	98.80^{a} (1.46)	98.78 (1.46)
Mean		67.00 (1.02)	74.52 (1.11)	70.76 (1.06)

Figures in parenthesis indicate arc sin $\sqrt{p}$ transformation
With in columns figures followed by same letters do not differ significantly (P= 0.05; DMRT)

Table 7 shows the mortality data taken 24 h and 48 h after treatment of five different concentrations of imidacloprid. The maximum mortality was observed at 0.01 per cent concentration, and there was no significant difference in mortality at 0.008 per cent and 0.01 per cent level of concentrations. Least mortality was observed at 0.002 per cent. A similar trend was observed after 48 h of treatment.

Table 8. Bioassay of lambda cyhalothrin on *S. furcifera* (5th instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48h	
1	0.001	35.00^{c} (0.63)	41.67^{d} (0.70)	38.33 (0.67)
2	0.003	48.33^{c} (0.77)	58.33^{c} (0.87)	53.33 (0.82)
3	0.005	70.00^{b} (0.99)	86.67^{b} (1.20)	78.33 (1.10)
4	0.007	90.00^{b} (1.256)	96.27^{a} (1.38)	93.13 (1.32)
5	0.009	95.87^{a} (1.39)	98.80^{a} (1.46)	97.33 (1.43)
	Mean	67.84 (1.01)	76.35 (1.123)	72.09 (1.07)

Figures in parenthesis indicate arc sin $\sqrt{p}$ transformation
With in columns figures followed by same letters do not differ significantly (P= 0.05; DMRT)

The mortality data observed after 24 h and 48 h of treatment of lambda cyhalothrin at five different doses revealed that, no significant difference in mortality after 24 h of treatment, even though the concentration was increased three folds (from 0.001% to 0.003%). However, there was a significant difference in the mortality after 48 h of treatment at the same concentrations. There was no significant difference in mortality observed between 0.005 per cent and 0.007 per cent level of concentration after 24 h of treatment. But 48 h after treatment, exhibited a significant difference in mortality. The highest mortality observed was at 0.01 per cent level of concentration after 24 h of treatment and at 0.007 per cent and 0.009 per cent concentration 48 h after treatment (Table 8).

Table 9. Bioassay of acephate on *S. furcifera* (5th instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48 h	
1	0.04	8.33[d] (0.29)	15.00[d] (0.39)	11.67 (0.34)
2	0.06	25.00[c] (0.522)	38.33[c] (0.67)	31.67 (0.60)
3	0.08	50.00[b] (0.79)	58.33[b] (0.87)	54.17 (0.83)
4	0.10	91.27[a] (1.29)	97.53[a] (1.42)	94.40 (1.36)
5	0.12	97.53[a] (1.42)	98.80[a] (1.46)	98.17 (1.44)
	Mean	54.43 (0.86)	61.60 (0.96)	58.01 (0.91)

Figures in parenthesis indicate arc sin √p transformation
With in columns figures followed by same letters do not differ significantly (P= 0.05; DMRT)

In the bioassay of acephate, the highest mortality was observed at 0.1 per cent and 0.12 per cent concentrations 24 and 48 h after treatment without any significant differences in mortalities. Least mortality observed was at 0.04 per cent concentration 24 and 48 h after treatment (Table 9).

Table 10. *Bioassay of triazophos on S. furcifera* (5th instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48 h	
1	0.01	6.67[d] (0.26)	11.67[d] (0.35)	9.17 (0.30)
2	0.03	16.00[d] (0.39)	26.67[c] (0.54)	21.33 (0.46)
3	0.05	60.00[c] (0.89)	71.67[b] (1.01)	65.83 (0.95)
4	0.07	90.00[b] (1.26)	95.87[a] (1.39)	92.93 (1.32)
5	0.09	98.80[a] (1.46)	98.80[a] (1.46)	98.80 (1.32)
	Mean	54.29 (0.85)	60.93 (0.95)	57.61 (0.90)

Figures in parenthesis indicate arc sin √p transformation
With in columns figures followed by same letters do not differ significantly. (P= 0.05; DMRT)

The mortality data observed 24 h after treatment of triazophos at five different concentrations showed the highest mortality (98.80%) at 0.09 per cent concentration (Table 10). But 48 h after treatment, the highest mortality obtained was at 0.09 and 0.07 percent and there was no significant difference in mortality at these doses. The least mortality was obtained at 0.01 and 0.03 per cent concentrations after 24 h of treatment and there was no significant difference among the mortalities even though the concentration was increased three fold. But the mortalities obtained 48 h after treatment exhibited a significant difference at these doses. The least mortality (11.67%) was obtained at 0.01 per cent concentraion after 48 h of treatment.

Table 11. Bioassay of carbaryl on *S. furcifera* (5th instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48h	
1	0.05	16.00^{e} (0.42)	28.33^{c} (0.56)	22.50 (0.49)
2	0.1	55.00^{d} (0.84)	73.33^{b} (1.03)	64.17 (0.94)
3	0.15	65.00^{c} (0.94)	80.00^{b} (1.11)	72.50 (1.02)
4	0.2	78.33^{b} (1.09)	92.93^{a} (1.33)	85.63 (1.21)
5	0.25	98.80^{a} (1.46)	98.80^{a} (1.46)	98.80 (1.46)
	Mean	62.760 (0.948)	74.68 (1.10)	68.72 (1.02)

Figures in parenthesis indicate arc sin $\sqrt{p}$ transformation
With in columns figures followed by same letters do not differ significantly. (P= 0.05; DMRT)

The mortality data observed 24 h and 48 h after treatment of carbaryl at five different concentrations exhibited significant differences at all tested doses. The least mortality (16.0%) was observed at 0.05 per cent and the highest mortality (98.8%) at 2.5 per cent concentration 24 h after treatment. But there was no significant difference in mortality at all tested doses after 48 h of treatment. The least mortality (28.33%) was recorded at 0.05 per cent concentration. There was no significant difference in mortality found at 0.1 per

cent and 0.15 per cent doses and also between 0.2 per cent and 0.25 per cent (Table 11).

Table 12. Bioassay of quinalphos on *S. furcifera* (5th instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48h	
1	0.01	23.33^{e} (0.50)	33.33^{e} (0.62)	28.33 (0.56)
2	0.02	35.00^{d} (0.63)	50.00^{d} (0.79)	42.50 (0.71)
3	0.03	55.00^{c} (0.84)	73.33^{c} (1.04)	64.17 (0.94)
4	0.04	68.33^{b} (0.97)	86.67^{b} (1.10)	77.50 (1.09)
5	0.05	97.53^{a} (1.42)	98.80^{a} (1.461)	98.17 (1.44)
	Mean	55.84 (0.87)	68.43 (1.02)	62.13 (0.95)

Figures in parenthesis indicate arc sin √p transformation
With in columns figures followed by same letters do not differ significantly. (P= 0.05; DMRT)

The mortality data observed 24 h and 48 h after treatment of quinalphos at five different doses exhibited significant differences at all the tested doses (Table 12). Only 23.33 and 33.33 per cent mortality was recorded at 0.01 per cent concentration after 24 h and 48 h of treatment respectively. However, the highest mortality was obtained at 0.05 per cent after 24 h and 48 h of treatment.

Table 13. Bioassay of DDVP on *S. furcifera* (5th instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48h	
1	0.01	26.67^{d} (0.58)	35.00^{d} (0.62)	31.67 (0.60)
2	0.03	40.00^{d} (0.67)	48.33^{c} (0.74)	41.67 (0.70)
3	0.05	60.00^{c} (0.85)	70.00^{b} (0.94)	60.83 (0.90)
4	0.07	80.00^{b} (1.17)	94.60^{a} (1.34)	97.93 (1.26)
5	0.09	98.80^{a} (1.46)	98.80^{a} (1.46)	98.80 (1.46)
	Mean	61.09 (0.95)	69.35 (1.02)	64.18 (0.98)

Figures in parenthesis indicate arc sin √p transformation
With in columns figures followed by same letters do not differ significantly. (P= 0.05; DMRT)

The mortality observed after 24 h and 48 h of treatment of DDVP at five different doses revealed the least mortality at 0.01 per cent concentration. Even though the concentration was increased three fold (from 0.01 % to 0.03 %) there was no significant difference in mortality observed 24 h after treatment. The highest mortality (98.8%) was observed 24 h after the treatment of 0.09 per cent concentration. At 48 h after treatment, the maximum mortality (98.80%) was observed at 0.09 per cent dose and the least (35.00%) at 0.01 per cent, however, there was no significant difference in mortality between 0.09 and 0.07 per cent concentrations (Table 13).

Table 14. Bioassay of phosphamidon on *S. furcifera* (5^{th} instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48h	
1	0.01	26.56[e] (0.50)	36.00[d] (0.63)	30.83 (0.59)
2	0.03	41.00[d] (0.69)	47.33[c] (0.75)	44.17 (0.73)
3	0.05	60.00[c] (0.90)	70.00[b] (0.98)	65.00 (0.94)
4	0.07	80.00[b] (1.10)	94.60[a] (1.37)	87.30 (1.23)
5	0.09	98.80[a] (1.46)	98.80[a] (1.46)	98.80 (1.46)
	Mean	61.43 (0.94)	66.93 (1.04)	64.18 (0.99)

Figures in parenthesis indicate arc sin $\sqrt{p}$ transformation
With in columns figures followed by same letters do not differ significantly. (P= 0.05; DMRT)

The mortality observed after 24 h of treatment of phosphamidon at five different doses exhibited a significant difference at all the tested concentrations. Minimum mortality was observed at 0.01 per cent concentration after 24 and 48 h of treatment (26.56 and 36.00 % respectively). Maximum mortality (98.8%) was recorded at a 0.09 per cent concentration after 24 h of treatment. Though at 0.09 per cent concentration the maximum mortality (98.8%) was recorded after 48 h of treatment, it was on par with 0.07 % concentration

Table 15. Bioassay of monocrotophos on *S. furcifera* (5th instar nymph)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48 h	
1	0.01	18.33 [e] (0.442)	25.00 [d] (0.522)	21.667 (0.482)
2	0.03	38.33 [d] (0.667)	46.667 [c] (0.752)	42.500 (0.710)
3	0.05	70.00 [c] (0.992)	76.667 [b] (1.067)	73.333 (1.030)
4	0.07	81.667 [b] (1.138)	89.600 [a] (1.285)	85.633 (1.211)
5	0.09	98.800 [a] (1.461)	98.800 [a] (1.461)	98.800 (1.461)
	Mean	61.427 (0.940)	67.347 (1.017)	64.387 (0.979)

Figures in parenthesis indicate arc sin $\sqrt{p}$ transformation
With in columns figures followed by same letters do not differ significantly. (P= 0.05; DMRT)

The bioassay of monocrotophos showed significant differences at all tested concentrations. Maximum (98.80%) and minimum (18.33%) mortalities obtained at 0.09 per cent and 0.01 per cent concentrations respectively. But after 48 h of treatment the maximum mortality obtained at 0.07 and 0.09 per cent concentration and there was no significant difference in mortality (Table 15). Minimum (25.00%) mortality obtained was at 0.01 per cent concentration at 48 h.

Table 16. Bioassay of neem oil on *S. furcifera* (5th instar nymphs)

Serial No	Concentration (%)	Mortality % at		Mean
		24 h	48h	
1	0.5	16.67[d] (0.42)	28.33[d] (0.56)	22.50 (0.49)
2	1.0	60.00[c] (0.89)	70.00[c] (0.10)	65.00 (0.94)
3	1.5	65.00[bc] (0.94)	78.33[bc] (1.10)	71.67 (1.02)
4	2.0	71.67[b] (1.01)	86.67[b] (1.20)	79.17 (1.11)
5	2.5	86.67[a] (1.20)	97.53[a] (1.42)	92.10 (1.31)
	Mean	60.00 (0.89)	72.17 (1.06)	66.09 (0.97)

Figures in parenthesis indicate arc sin √p transformation
With in columns figures followed by same letters do not differ significantly. (P= 0.05; DMRT)

At the lowest concentration of neem oil only 16.67 per cent mortality was recorded at 24h. As the concentration increased, the mortality per cent was also increased (Table 16). However, the mortality per cent at 1.5 and 2 per cent concentrations were found to be on par. The maximum mortality (86.67 %) of *S. furcifera* nymphs was recorded at 2.5 per cent concentration. Similar trend was recorded at 48 h of treatment also. At 48 h, the maximum mortality (97.53%) was recorded at 2.5 per cent concentration.

4.3.1 Determination of LC_{50} of insecticides on *S. furcifera*

Median lethal concentrations (LC_{50}) of insecticides were determined by testing different concentrations. Mortality of insect was recorded 24 h and 48 h after treatments. The data were analysed by probit analysis and the summary of results of LC_{50} after 24 h and 48 h of treatments are given in Table 17a Table 17b respectively.

LC_{50} of imidacloprid 24 h after treatment was found to be (0.0034 %) and was lower than normal field recommended dose (0.006%). The intercept (a) of the log dose-probit mortality line ('ld-p' line) plotted was –9.81 and the slope of

Table 17 a. Toxicity of various insecticides to 5th instar nymphs of *S. furcifera* after 24 h

Insecticides	Heterogenity (Chi^2)	Regression equation (Y= a+ bx)*	LC_{50} in %	Fiducial limits		Relative toxicity
				Lower	Upper	
Imidacloprid	5.58	Y = - 9.81+ 3.26X	0.0034	0.0027	0.0045	1.000
Lambda cyhalothrin	5.89	Y = - 2.63 + 1.78X	0.0018	0.0011	0.0032	1.889
Acephate	3.99	Y = - 34.62 + 6.77X	0.0706	0.0641	0.0777	0.048
Triazophos	6.61	Y = - 13.78 + 3.39X	0.0359	0.0289	0.0426	0.095
Carbaryl	3.56	Y = -15.36+ 3.34 X	0.0992	0.0803	0.1225	0.034
Quinalphos	6.37	Y = -18.43 + 4.24 X	0.0340	0.0291	0.0398	0.100
DDVP	10.76	Y = - 5.64 +1.92 X	0.0270	0.0179	0.0380	0.126
Phosphamidon	8.42	Y = - 6.25 + 2.01 X	0.0270	0.0191	0.0384	0.126
Monocrotophos	5.16	Y = - 9.20 +2.60 X	0.0289	0.0221	0.0379	0.118
Neem oil	1.00	Y = - 14.01 +2.66 X	1.3950	0.0295	1.8929	0.002

*X= Log (Concentration X 10^4)

Table 17b. Toxicity of various insecticides to 5th instar nymphs of *S. furcifera* after 48 h

Insecticides	Heterogenity (Chi^2)	Regression equation (Y= a+ bx)*	LC_{50} in %	Fiducial limits		Relative toxicity
				Lower	Upper	
Imidacloprid	7.26	Y = - 5.61+2.43X	0.0024	0.0015	0.0038	1.000
Lambda cyhalothrin	5.31	Y = - 2.36 +1.79 X	0.0013	0.0007	0.0025	1.839
Acephate	4.14	Y= - 32.13+ 6.39X	0.0642	0.0576	0.0714	0.037
Triazophos	7.50	Y = - 13.41+3.35X	0.0307	0.0251	0.0376	0.077
Carbaryl	1.41	Y = - 12.68+3.03 X	0.0697	0.0502	0.0968	0.034
Quinalphos	3.08	Y = - 17.72+4.19 X	0.0265	0.0215	0.0326	0.089
DDVP	9.19	Y = - 5.62+1.99X	0.0211	0.0138	0.0323	0.112
Phosphamidon	7.36	Y = - 4.85+1.87 X	0.0192	0.0118	0.0312	0.123
Monocrotophos	4.26	Y = -8.14+2.45X	0.0232	0.0168	0.0322	0.102
Neem oil	2.00	Y =- 14.41+2.78 X	0.9363	0.5686	1.5420	0.003

*X= Log (Concentration X 10^4)

the line (b) was 3.26. The regression equation obtained was Y= -9.81+3.26X. The lower and upper fiducial limits were 0.0027 and 0.0045 respectively. LC_{50} 48 h of treatment was 0.0024 per cent. The lower and upper fiducial limits were 0.0015 and 0.0038 respectively. The intercept (a) of 'ld-p' line was –5.61 and the slope was 2.43. Thus, the regression equation was Y=-5.61+2.42X.

The LC_{50} of lambda cyhalothrin 24 and 48 h after treatment was 0.0018 and 0.0013 per cent respectively under laboratory condition, lesser than the recommended dose (0.005%). The 'ld-p' line plotted was with an intercept (a) and slope (b) of –2.63 and 1.78. The regression equation obtained was Y= 2.63+1.78X. The lower and upper fiducial limits calculated were 0.0011 and 0.0032 per cent respectively for the mortality data 24 h after treatment. For the mortality data 48 h after treatments, the intercept (a) and slope (b) of the 'ld- p' line plotted were –2.36 and 1.79 respectively. Lower and upper fiducial limits calculated were 0.0007 and 0.0025 per cent.

The LC_{50} determined for acephate after 24 h and 48 h of treatment were 0.0710 and 0.0640 per cent respectively, again this was lesser than the normal field recommended dose (600g ai/ ha or 0.12 %) in field. The regression curve plotted showed an intercept of –34.62 and slope (b) of 6.39 and the regression equation obtained was Y= -34.62 +6.39X for the mortality data of 24 h after treatment. An intercept (a) of –32.13 and a slope of 6.78 obtained for the 'ld- p' line plotted using the mortality data after 48 h of treatment. The regression equation was Y=-32.13+6.78X. The lower and upper fiducial limits calculated in two sets of observations were 0.0641, 0.0777 and 0.0576, 0.0714 per cent for LC_{50} after 24 h and 48 h of treatments respectively.

LC_{50} of triazophos after 24 h of treatment was 0.0359 per cent. 'Ld- p' line showed an intercept (a) of –13.78 and a slope (b) of 3.39. The regression equation was Y= -13.78+3.39 X. The lower and upper fiducial limits calculated were 0.0289 and 0.0426 respectively. LC_{50} of triazophos was determined 48 h after treatment obtained as 0.0307 per cent. Intercept (a) and slope (b) of the 'ld-

p' line plotted were –13.41 and 3.35 and the regression equation was Y=-13.41 + 3.35. The lower and upper fiducial limits were 0.0251 and 0.0376.

In the case of carbaryl, the LC_{50} observed after 24 h of treatment was 0.0992 per cent and after 48 h of treatment 0.0697 per cent. The intercept (a) of the ld-p lines plotted were –15.36 and –12.68 and the slope (b) of the graphs were 3.34 and 3.35 for the mortality data after 24 and 48 h of treatments respectively. The regression equations were Y= -15.36+3.34X and Y=-12.68+2.03X. The fiducial limits were calculated and it was between 0.0803, 0.1225 and 0.0502, 0.0968 for the mortality data obtained after 24 and 48 h of treatments respectively.

Quinalphos showed an LC_{50} value of 0.0340 per cent and 0.0265 per cent at 24 and 48 h of treatment respectively. The intercept (a) and the slope (b) of the graph was –18. 43 and 4.24 respectively for the mortality data after 24h of treatment and was –17.72 and 4.19 respectively for the mortality data after 48 h of treatment. The lower and upper fiducial limits were 0.0291, 0.0398 and 0.0215, 0.0326 respectively for 24 and 48h after treatment.

LC_{50} of DDVP after 24 h of treatment was 0.0270 per cent and that after 48 h was 0.0211 per cent. The intercept (a) and slope (b) of the regression curve plotted were –5.64 and 1.92 and the regression equation was Y= -5.64+1.92X for the mortality data observed after 24 h of treatment. The lower and upper fiducial limits were calculated as 0.0179 and 0.0380 respectively. The intercept (a) and slope (b) of the ld-p line plotted with mortality data taken after 48 h of treatment were –5.62 and 1.99 respectively and the regression equation was Y= -5.62 + 1.99X. Here, the lower and upper fiducial limits were 0.0138 and 0.0323 respectively. The mortality data is shown in Table 13.

The LC_{50} of phosphamidon was determined as 0.0270 per cent and 0.0192 per cent after 24 and 48 h of treatment respectively. It was also lesser than the field recommended dose (0.05%). The intercept (a) of the 'ld-p' line was -6.25 and the slope (b) was 2.01 for the mortality data recorded after 24 h of treatment. While, the intercept of –4.85 and slope of 1.87 were observed, the regression

equation was Y= -6.25+2.01 X and Y= -4.85+1.87 X for the data observed after 48 h of treatment. The lower and upper fiducial limits calculated were 0.0191, 0.0384 and 0.0118, 0.0312 respectively for 24 h and 48 h of treatments.

After 24 h of treatment the LC_{50} of monocrotophos was calculated as 0.0289 per cent which was lower than field recommended dose. 'Ld-p' line plotted showed an intercept (a) of –9.20 and a slope of 2.60, the regression equation was Y= -9.20+2.60X. LC_{50} of monocrotophos determined 48h after treatment was 0.0232 per cent. The intercept (a) and slope (b) of the 'ld-p' line plotted were –8.14 and 2.45 respectively. The regression equation was Y= -8.14+ 2.45X. Lower and upper fiducial limits were calculated in two sets of observation and it was 0.0221, 0.0379 and 0.0168, 0.0322 respectively.

LC_{50} of neem oil was 1.3950 per cent and 0.9363 per cent after 24 and 48 h of treatment respectively. The regression curve plotted was with a slope of 2.66 and an intercept of –14.01, so the regression equation obtained was Y= -14.01+2.66X for the mortality data after 24 h of treatment. Regression curve with a slope of 2.78 and an intercept of –14.41 obtained for the mortality data taken after 48 h of treatment. The regression equation was Y= -14.41+2.78X. The upper and lower fiducial limits calculated for two sets of observations were 1.8929, 1.0295 and 1.5420 and 0.5686 respectively for the mortality data taken 24h and 48 h of treatments respectively.

4.3.2 Relative toxicity of tested insecticides

Among the insecticides tested, taking imidacloprid as standard, lambda cyhalothrin was the most toxic to fifth instar WBPH nymphs. The relative toxicity of lambda cyhalothrin was 1.89. The toxicities of all other insecticides tested were lower than that of imidacloprid. Phosphamidon and DDVP had the same relative toxicity of 0.126. The relative toxicities of other insecticides were in the following descending order: monocrotophos (0.118)> quinalphos (0.100) >

triazophos (0.095) > acephate (0.048) > carbaryl (0.034)> neem oil (0.002) (Table 17a). Relative toxicity was determined after 48h of treatment and the toxicity was in the following decreasing order: lambda cyhalothrin (1.89)> Imidaclorprid (1)> phosphamidon (0.123)> DDVP (0.112)> monocrotophos (0.102)> quinalphos (0.089)> triazophos (0.077)> acephate (0.037)> carbaryl (0.034)> neem oil (0.003) (Table 17b).

4.3.3 Persistent toxicity of insecticides

Persistent toxicity (PT) of 10 insecticides on fifth instar nymph of WBPH was tested under laboratory condition at a temperature of 25.85±4 ° C and at a relative humidity of 88±8.5 %. The highest persistent toxicity was observed for phosphamidon and monocrotophos (7 days), followed by triazophos (6 days), imidacloprid and acephate with a persistent toxicity of five days each. Lambda cyhalothrin and carbaryl had the same persistent toxicity of four days. The toxicity of DDVP persisted only for three days and showed the least persistency among all the tested insecticides. Neem oil showed a persistent toxicity of 4 days under laboratory condition.

The PT index was calculated for all the ten insecticides (Table 18). Phosphamidon was more toxic among the tested insecticides with a PT value of 253.33, followed by triazophos (236.64). PT index of other insecticides were in the following descending order: monocrotophos (226.66)> imidacloprid (203.35)> acephate (190)> quinalphos (173.35)> lambda cyhalothrin (156.68)> carbaryl (126.68)> DDVP (123.33)> neem oil (115.32).

Table 18. Persistent toxicity of insecticides on 5th instar nymphs of *S.furcifera*

Insecticides	Dose (%)	Mortality per cent after days of treatment							Mean percent mortality T	Period in days P	PXT Value	Order of Relative Efficacy (ORE)
		1	2	3	4	5	6	7				
Imidacloprid	0.003	76.67	53.33	43.33	16.67	13.33	-	-	40.67	5	203.35	4
Lambda cyhalothrin	0.002	66.67	46.67	26.67	16.67	-	-	-	39.17	4	156.68	7
Acephate	0.020	73.33	46.67	36.67	20.00	13.33	-	-	38.00	5	190.00	5
Triazophos	0.040	73.30	60.00	36.67	26.67	23.33	16.67	-	39.44	6	236.64	2
Carbaryl	0.100	53.33	36.67	23.33	13.33	-	-	-	31.67	4	126.68	8
Quinalphos	0.025	66.67	43.33	33.33	20.00	10.00	-	-	34.67	5	173.35	6
DDVP	0.030	66.67	43.33	13.33	-	-	-	-	41.11	3	123.33	9
Monocrotophos	0.030	70.00	56.67	40.00	23.33	20.00	10.00	6	32.38	7	226.66	3
Phosphamidon	0.030	73.00	60.00	36.67	33.33	23.33	16.67	10	36.19	7	253.33	1
Neem oil	1.000	56.67	33.33	16.67	6.60	-	-	-	28.83	4	115.32	10
Control	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	000.00	0

4.4 BIOCHEMICAL ANALYSIS

4.4.1 Estimation of protein present in the crude homogenate of 5th instar nymphs of *S. furcifera*

Amount of protein present in insecticide treated and untreated insect homogenate were estimated by Lowry's method. In the untreated insect 72.5 µg protein per 100 mg of sample was estimated while in the acephate treated insect it was 65.5 µg protein per 100 mg of insect sample (Table 19). Imidacloprid treated sample contain 66.5µg protein per 100 mg of sample.

Table 19. Amount of protein present in insect homogenate after treatment of *insecticides*

Treatments	Dose (%)	Protein (µg/100 mg)
Imidacloprid	0.005	66.5
Lambda cyhalothrin	0.005	70.0
Acephate	0.080	65.5
Triazophos	0.050	69.5
Carbaryl	0.100	68.0
Quinalphos	0.025	68.0
DDVP	0.050	71.0
Monocrotophos	0.050	70.0
Phosphamidon	0.050	69.5
Neem oil	1.000	69.5
Untreated control	Water	72.5

4.4.2 Isozyme assay crude insect homogenate

An attempt was made to estimate esterase isozyme present in the insecticide treated and untreated samples by the method described by Van Asperen (1962). However the assay was aborted due to the colour development even in the denatured samples (by TCA). The reason would be investigated.

DISCUSSION

5. DISCUSSION

Results obtained in the laboratory study on "Biology and insecticide sensitivity of rice white backed planthopper (WBPH), *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) are discussed under this chapter.

5.1 BIOLOGY

The biology of WBPH was studied under laboratory conditions over two seasons *i.e.*, during December 2004 (mean temperature of 27±6.72°C and relative humidity of 55.5±17.8%) and during March 2005 (mean temperature of 30.69±6.88 and relative humidity of 62.42±28.65%). Significant differences were observed in the biological parameters like incubation period, duration of each nymphal instars, total nymphal period, fecundity, hatchability and sex ratio of the test insect.

5.1.1 Duration of bio stages

The duration of bio stages observed during March was shorter than that during December. The rate of moulting was faster during March. Comparatively higher temperature and higher relative humidity prevailed during March might be the reasons for the faster development.

The incubation period of egg was 6.9 ±0.55 days at a temperature of 30.46± 6.88° C (March) and 8.4±0.55 days at a temperature of 27± 6.72° C (December), *i.e.*, higher the temperature shorter the incubation period. This is in confirmity with the result obtained by Ammar *et al.* (1980); Huang *et al.* (1982) Singh *et al.* (1992) and Vaidya and Kalode (1981).

In the present study, the instar wise nymphal durations were 2.4, 2.8, 3.2, 3.8, and 3.6 days (Table 3a) successively during December (mean temperature 27± 6.72° C) and the total nymphal period observed was 15.8± 0.80 days (Table 3a). Similar results were observed by Mani (1990) at 27° C on T (N) 1 rice variety and Singh *et al.* (1992). But, during March (temperature 30.69±6.88 ° C) there was slight reduction in the duration of nymphal stages *viz.*, 2.2, 2.4, 2.8, 3.4, and 3 days for 1st 2nd, 3rd, 4th and 5th instars respectively and the total nymphal

duration was 13.8±1.50 days (Table 3b). The total life cycle depends on the prevailing abiotic factors. This is in accordance with Ammar *et al.* (1980); Huang *et al.* (1982); Singh (1989).

Sogatella spp. infesting a variety of host plants, but its main host is rice. Biology of *S. vibix* (Haupt), a pest of wheat studied by Ammar (1977) observed prolonged life stages at lower temperature and the shorter developmental cycle at the higher temperature.

There was no significant difference observed in pre oviposition period under the two tested temperature regimes. Pre oviposition period varied from 2 to 3 days during both the seasons and oviposition period varied from 4 to 11 days. Female had an average longevity of 11± 2.92 and 10.8±3.5 days for macropterous and brachypterous forms respectively during December. But during March, it was 10±3.7 and 9.6±3.9 days for macropterous and brachypterous forms respectively. Females lived three days more than the males. Males had an average longevity ranging from 4 to 9 days in both the seasons. Similar observations were made by Mani (1990) and Singh *et al.* (1992).

But, the fecundity of test insect examined over two seasons of study showed significant differences. Eggs laid per female varied from 46 to 130 (average 85.67±42.2) during December and 58 to 149 (average 106±41.6) during March (Fig 3). This is in confirmity with Khan and Kushwaha (1991a). Favourable abiotic factors prevailed during March (comparatively higher temperature and higher relative humidity) might be the possible reasons for the increased fecundity of female. Shukla and Shrivastava (1990) reported that maximum and minimum temperatures and sunshine hours had positive response on population of *S. furcifera*. Singh *et al.* (1992) accounted the average fecundity of female as 108±2.88 during July, 117.8±4.6 during August and 113.2±6.83 during September. Vaidya and Kalode (1981) at Hyderabad recorded the fecundity of *S. furcifera* as 164 eggs per female. Misra (1980), however, reported maximum number eggs laid by *S. furcifera* as 756 and minimum as 541.

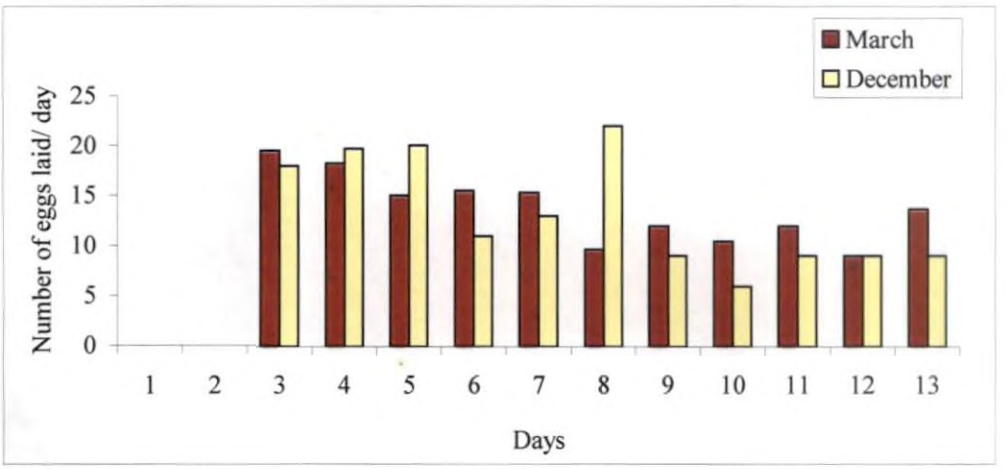

Fig 3. Fecundity of *S. furcifera* over two seasons

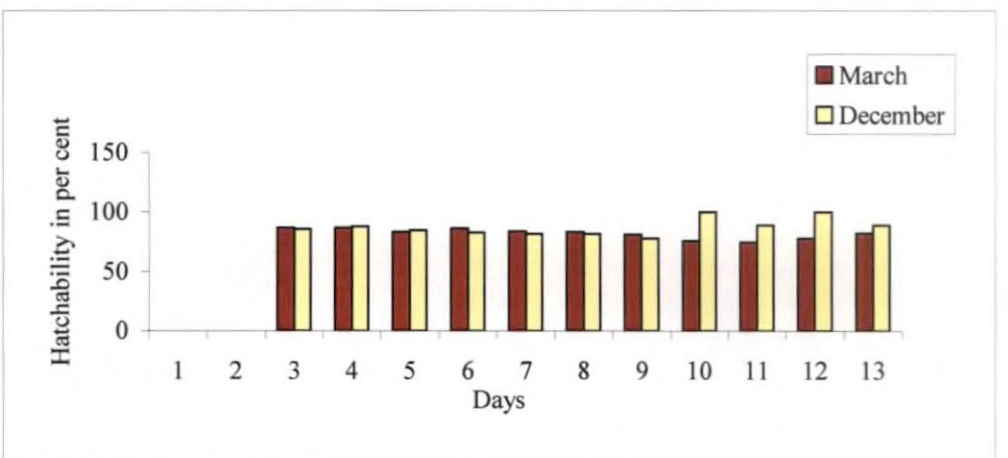

Fig 4. Per cent hatchability over two seasons

Even though the fecundity of female was higher during March, the egg hatchability was comparatively lower. It was 87.3± 7.1 per cent during December and 82±4.49 per cent during March (Fig 4). The results are in contrast to the study conducted by Ye, *et al.* (1994) where the egg hatchability did not differ significantly with the temperatures. The hatching per cent varied from 80 to 88.89 per cent in the present study. This result is in accordance with Singh *et al.* (1992); Khan and Saxena (1985); Gunathilagaraj and Chellaih (1985) and Bhathal and Dhaliwal (1994).

Survival per cent of the nymphs did not show any significant differences with the seasons. It was 66.5±10 and 63.8±8.4 per cent during December and March respectively (Fig 5).

5.1.2 Sex ratio

Males dominated the population over two seasons of study. Sex ratios (female: male) were 1:1.17 and 1:1.34 during December and March, respectively. The sex ratio showed significant difference over the two seasons. More number of males were produced during summer months (Fig 6). Similar phenomenon was observed in the case of copepod (*Macrocyclops albidu*) also where the sex ratio appeared to be temperature dependent. As the temperature rises there was a significant increase in the number of males. In the plague flea (*Xenopsylla cheopis*) also males outnumbered the females at higher temperature (Ananthakrishanan and Viswanathan, 1976).

5.1.3 Feeding behaviour

Study conducted on the feeding behaviour of *S. furcifera* revealed that the adult females caused more feeding damage than any other stage of the test insect. Brachypterous females produced more honeydew (73±13.74) mm^2 (Table 5) than the 5^{th} instar nymphs and males. The studies conducted by Zhu and Cheng (2002) and Rath *et al.* (1999) support the above result.

Qualitative analysis of amino acids present in the honeydew by thin layer chromatography (TLC) revealed that the presence of two amino acids (glutamic

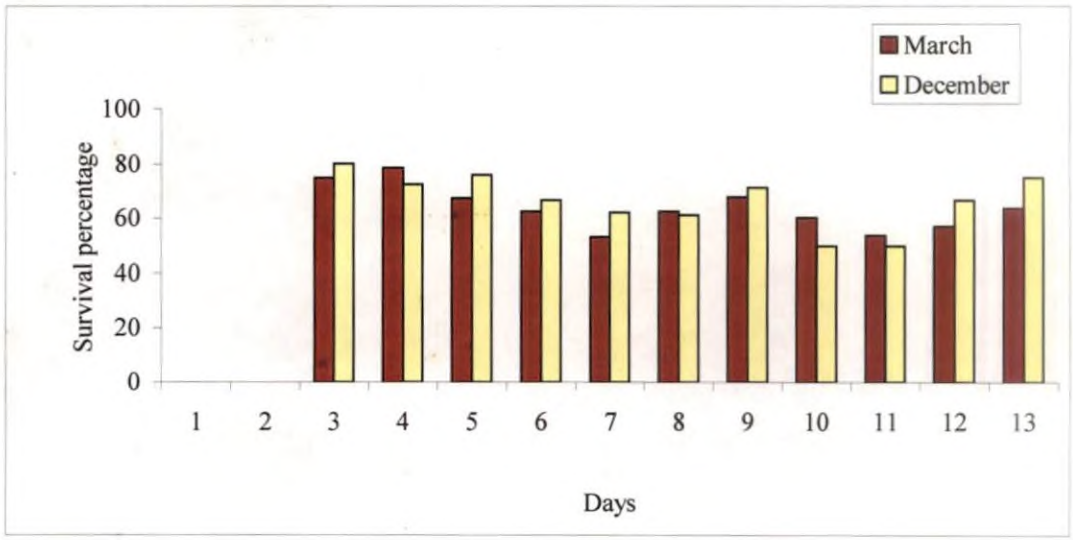

Fig 5. Per cent survival of *S. furcifera* over two seasons

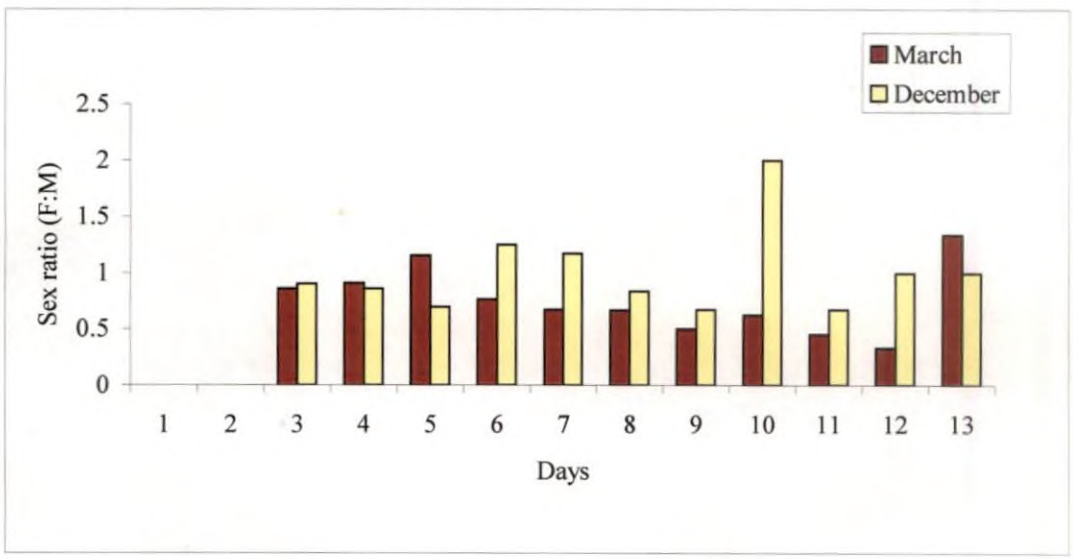

Fig 6. Sex ratio of *S. furcifera* over two seasons

acid and aspartic acid) in it. However, Liu *et al.* (2000), detected aspartic acid, serine, asparagines, glutamic acid, glutamine and valine as the major amino acids among the total of 18 detected. The same author had reported that the WBPH produce significantly lesser quantities of amino acids on resistant variety than on susceptible variety.

5.1.4 Isolation of entomopathogenic fungi

Two entomopathogenic fiungi were isolated from WBPH and the pure culture was obtained which satisfied Koch's postulates. The fungi were identified as *Aspergillus flavus* (Dirk.) and *Penicillium oxalicum* (Currie & Thomb). This is the first report of these entomopathogenic fungi on WBPH. *A. flavus* took five days after application to infect *S. furcifera* under laboratory condition where as *P. oxalicum* required six to seven days to infect the test insect. Ponnamma *et al.* (2000) and Alka Guptha and Murali Gopal (2002) reported *A. flavus* infection on planthopper, *Proutista moesta* (Westwood) (Hemiptera: Derbidae), a pest of oil palm and coconut. Other Hemipteran pests from which *A. flavus* isolated were *Dysdercus cingulatus* (Fab.) (Prabhakar *et al.*, 1992 and Selvary *et al.*, 2002), coffee brown scale, *Saissetia coffeae* (Walker) (Valand and Vyas, 1991), different species of mealy bugs (Martinez and Bravo, 1989), lacewing bug, *Stephanitis typica* (Dist.) (Sathiamma *et al.*, 1998; Alka Guptha and Murali Gopal, 2002). *P. oxalicum* infection was reported from white jassid of rice *Cicadella spectra* (Dist.) (Kuruvilla *et al.*, 1980).

Other entomopathogenic fungi infecting WBPH reported were *Beauveria bassiana* (Aguda *et al.*, 1984; Li, 1985), *Beauveria tenella* (Li, 1985), *Entomophthora delphacis*, *Metarhizium anisopliae*, *Hirsutella saussaurei*, *Paecilomyces* sp., *Cephalosporium* spp., *Nomuraea rileyi* (Li, 1984; 1985) and *Metarhizium anisopliae* vr. *acridum* (Geng and Zhang 2004).

5.2 BIOASSAY OF INSECTICIDES

The results of the experiments on bioassay of ten commonly used insecticides in rice ecosystem on 5th instar nymphs of *S. furcifera* are summerised

in Table 18, 19 and 20. These experiments were aimed at evaluating relative toxicity and persistent toxicity of ten commonly used insecticides against WBPH.

The relative toxicity of the insecticides to fifth instar nymphs of *S. furcifera* was calculated based on the LC_{50} value of the insecticides. For all the insecticides tested, the LC_{50} was found to be much lesser than the normal field recommended doses. It means that, laboratory reared insects are more susceptible to insecticides and highly responsive to chemicals. Insecticides under laboratory conditions are not subjected to out door abiotic factors. All the applied insecticides reach the target area with out drift and run off. To support the present observation the studies conducted by Hosoda (1989) revealed that the field collected WBPH strains had high levels of resistance (9-37 folds) to organo phosphorus compounds and low levels of resistance to cabamates. According to Mao and Liang (1992), the development of resistance was faster in *S. furcifera* in the field than in *N. lugens*.

Among ten insecticides tested, imidacloprid and lambda cyhalothrin were more toxic to WBPH nymphs and recorded lower LC_{50} values. Similar results were observed by Xaofei *et al.* (2001) that the LD_{50} of chloronicotinyls and pyrethroids were much lesser than those of the organophosphates and organo chlorines.

In the present study, LC_{50} of imidacloprid obtained under the laboratory condition was 0.0034 per cent on the 5^{th} instar nymphs of *S. furcifera* as against the field recommended dose of imidacloprid (0.006 %). The persistent toxicity of imidacloprid to 5^{th} instar nymphs was 5 days and persistent toxicity (PT) index calculated was 203.35 (Table 18). Xaofei *et al.* (2001) accounted the LD_{50} of imidacloprid against WBPH as 0.72 to 1.5 μ g/g. Sun *et al.* (1996) estimated the LD_{50} of imidacloprid for contact activity against 5^{th} instar nymphs of *N. lugens* as 6.72×10^{-5} μg/ nymph. Studies on comparative efficacy of imidacloprid by Hegde (2005) revealed that the persistent toxicity against the BPH population remained in the treated plots even after three to seven days of spray. Imidacloprid was considered as the best standard chemical to control planthoppers in rice

ecosystem. Liu *et al.* (2002) revealed that only low level of resistance had developed in BPH to imidacloprid when compared to OP compounds.

Under laboratory conditions, the relative toxicity of lambda cyhalothrin was found to be the highest to 5th instar nymphs of *S. furcifera*. It was 1.8 times as much toxic as imidacloprid with LC_{50} of 0.0013 per cent (Table 17a) as against the field recommended dose of 0.005%. But, Ismail (1995) obtained relatively less control efficiency with lambda cyhalothrin one week after application and the best control with monocrotophos. This might be due to long persistent nature of monocrotophos. Even though the lambda cyhalothrin was more toxic to WBPH, its persistent toxicity was less. Its toxicity persisted only upto 4 days (Table 18) even under laboratory conditon. Varma *et al.* (2003) also observed the least effectiveness of synthetic pyrethroids (beta cyfuthrin at 12.5 g and deltamethrin at 10g) to control planthoppers. But the studies conducted by Gubbaiah *et al.* (1990) revealed that synthetic pyrethroid was superior over fenvalerate and monocrotophos against BPH.

DDVP recorded the least persistent toxicity among all other tested insecticides. Its toxicity persisted only for three days to 5th instar nymphs of *S. furcifera* with a PT index of 123.33. Eventhough its persistent toxicity was lesser, Khan and Kushwaha (1990) obtained good control of WBPH when treated with DDVP (at 0.38 kg ai/ha) in field trials.

Phosphamidon had the maximum persistent toxicity among other tested insecticides with a PT index of 253.33. This is in accordance with the result obtained by Srinivasan (2000) who observed a persistent toxicity of phosphamidon for seven days.

Monocrotophos had a LC_{50} of 0.0289 per cent under laboratory condition and was only 0.188 times toxic to imidacloprid. It also marked higher persistent toxicity (7 days) similar to phosphamidon. The PT value of monocrotophos was 226.66 (Table 18). According to Dash *et al.* (1996) the persistent toxicity of moncrotophos at recommended dose against planthopper population in rice ecosystem remained even upto 45 and 75 days after spraying. This indicated the long persisting nature of monocrotophos even under field condition. But Sarupa

et al. (1998) and Panda *et al.* (2002) reported the resurgence inducing nature of monocrotophos on BPH. However, there is no account about resugence of WBPH against monocrotophos.

LC_{50} of quinalphos estimated under laboratory condition obtained was in between the field recommended dose (0.02-0.05%) and was 0.034 per cent. Its toxicity was $1/10^{th}$ of toxicity of imidacloprid and having a persistent toxicity for five days with a PT index of 173.35 (Table 18). The comparative efficacy of quinalphos against planthopper was less. In the case of quinalphos also resurgence was reported in BPH (Panda *et al.*, 2002) and not in WBPH.

Triazophos had a LC_{50} value of 0.036 per cent which was lower than that of field recommended concentration (0.05%). Triazophos was relatively less toxic (0.094 times) compare to imidacloprid, but it recorded long persistent toxicity of (6 days). Its PT index obtained was 236.64 (Table 18) and it was the second most persistent insecticide among the tested insecticides. It was also comparatively less effective to BPH. Zhuang *et al.* (1999) observed the increased productivity of macropterous and brachypterous BPH by triazophos application

Among the chemical inseciticides tested, carbaryl was the least toxic to 5^{th} instar nymphs of WBPH. Its relative toxicity was only 0.03 with respect to imidacloprid. LC_{50} obtained under the laboratory condition was 0.0992 per cent and it was almost nearer to the field recommended dose. But, Heong (1975) observed that carbaryl (0.1%) spray applied to the base of the plant gave 95 per cent mortality of WBPH and 100 per cent BPH by 3^{rd} day of application. The persistent toxicity of carbaryl obtained in the laboratory was 4 days and PT index calculated was 126.68 (Table 18).

LC_{50} of neem oil obtained under laboratory condition was 1.395 (Table 17a) per cent 24h after treatment. But according to Dash *et al.* (2001), neem oil formulations (@ 2%) were effective against BPH and WBPH under field condition. However, there are some reports showing tolerance of rice BPH against neem oil. Haque *et al.*, (2002) observed that LC_{50} value of neem oil increased by 1.65 folds in the 10^{th} generation of the first set, 1.63 folds in the 5^{th} and 1.54 folds in 7^{th} generation of second set.

5.3 PROEIN PRESENT IN INSECT HOMOGENATE

The total protein present in the crude insect homogenate was quantitatively analysed by Lowry's method with slight modification. The highest amount of protein detected in the untreated insect homogenate, was 72 µg per 100 mg of sample. Lowest amount of protein was detected in acephate treated sample (65.5 µg per 100 g) (Table 20). Similarly, Verma (1992) reported that a decrease in haemolymph protein of *Spodoptera litura* (F.) 2h after treatment of carbaryl (@ 0.1 and 0.2 µg/g body weight of 5^{th} and 6^{th} instar larvae). The study conducted by Hebsy Bai (1996) observed that the rate of increase of protein deposition in the ovary, haemolymph and fat body of *Dysdercus cingulatus* (Fab.) when treated with leaf extracts of *Theivetia neriifolia* was at a decreasing level than untreated control. But, in the present study there was no significant difference observed in total protein present in the 5^{th} instar nymphs of WBPH with different insecticides treatment.

SUMMARY

SUMMARY

An investigation was carried out on; "the biology and insecticide sensitivity of rice white backed planthopper (WBPH), *Sogatella furcifera* (Horvath)" on 'Jyothi' rice variety under laboratory conditions in the College of Horticulture, Vellanikkara, during 2003- 2004. The experiment comprised of two parts. First part included the study of biology and the influence of weather parameters (temperature and relative humidity) on the biology of *S. furcifera*, while the second part consisted of the toxicological studies and the experiments were aimed at evaluating relative toxicity by means of LC_{50} and persistent toxicity of ten commonly used insecticides against WBPH under laboratory condition.

The biology of the WBPH was studied during winter (December) and summer (March) months. The duration of incubation period and nymphal period were shorter, resulting in a faster developmental cycle during summer month when compared to the winter. The fecundity of WBPH was more during March (106.00±41.6) than in December (85.67±42.2). But, the per cent hatchability was higher in December (87.30±7.10) than in March (82.00±4.49). However, there was no difference in per cent survival of the WBPH studied over the two seasons (66.50±10.00 in December and 63.80±8.40 in March). The sex ratio exhibited significant difference between the two seasons and more number of males were produced during March (1:1.34) than that in December (1:1.17)

Study on population build up showed a reduction in mean fecundity of WBPH in the second generation (103.5) compared to first generation (109.5) which might be due to inbreeding.

Adult females caused more feeding damage than adult males and fifth instar nymphs. Analysis of honeydew excretion revealed the presence of two amino acids (glutamic acid and aspartic acid) in it.

Major natural enemies recorded were spiders (*Argeops* spp., *Lycosa pseudoannulaata, Oxyopus* spp., *Thomisus* spp. and *Salticus* spp.) and mirid bug, (*Cyrtorhinus lividipennis*) which feed on eggs and early instars of *S. furcifera*

Two entomopathogenic fungi isolated from WBPH and satisfied Koch's postulate were identified as *Aspergillus flavus* (Dirk.) and *Penicillium oxalicum* (Currie & Thomb). This is the first report of the above mentioned entomopathogenic fungal infection on WBPH.

In the bioassay studies of ten commonly used insecticides, the LC_{50} under laboratory conditions was found to be much lower than the field recommended doses. Imidacloprid and lambda cyhalothrin were more toxic to WBPH nymphs with LC_{50} values of 0.0034 percent and 0.0018 per cent respectively at 24h of treatment. Among the tested insecticides, the higher relative toxicity (than the standard imidacloprid) was exhibited by lambda cyhalothrin (1.889). The relative toxicities of other eight insecticides were lower than that of imidacloprid and in the following descending order: DDVP (0.126) = phosphamidon (0.126)> monocrotophos (0.118)> quinalphos (0.100)> triazophos (0.095)> acephate (0.048)> carbaryl (0.034)> neem oil (0.002).

Under the laboratory conditions, the most persistent insecticides were phosphamidon and monocrotophos persisting for 7 days, while the least was DDVP (3days). The persistent toxicity index of the insecticides were in the following descending order: phosphamidon> triazophos> monocrotophos> imidacloprid> acephate> quinalphos> lambda cyhalothrin> carbaryl> DDVP> neem oil

In acephate treated insect samples total protein content was lesser (65.55 µg/100mg of sample) than the untreated control (72 µg/100mg of sample)

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*Originals not seen

Annexure I. Composition of Mc.Bride's stain and the clearing solution

(Backus *et al.*, 1980)

Ingredients	Quantity
i) Mc. Bride's stain	
Acid fuchsin	200 µg.
99 % Ethanol	50 ml
Glacial acetic acid	50 ml
ii) Clearing solution	
Distilled water	100 ml
99% Glycerin	100 ml
85 % Lactic acid	100ml

Annexure II. Preparation of 0.1 M Sodium Phosphate buffer at 25° C.

(Sambrook *et al.*, 1989)

pH	Volume of 1 M. Na_2HPO_4 (ml)	Volume of 1M. NaH_2PO_4 (ml.)
5.8	7.9	92.1
6.0	12.0	88.0
6.2	17.8	82.2
6.4	25.5	74.5
6.6	35.2	64.8
6.8	46.3	53.7
7.0	57.7	42.3
7.2	68.4	31.6
7.4	77.4	22.6
7.6	84.5	15.5
7.8	89.6	10.4
8.0	93.2	6.8

"BIOLOGY AND INSECTICIDE SENSITIVITY OF RICE WHITE BACKED PLANTHOPPER, *Sogatella furcifera* (Horvath) (HEMIPTERA : DELPHACIDAE) IN KERALA"

By

PRATHIBHA, P. S.

ABSTRACT OF THE THESIS

submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

(AGRICULTURAL ENTOMOLOGY)

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2006

ABSTRACT

Among planthoppers infesting rice, white backed planthopper (WBPH), *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) has become a menace to rice growers recently.

Biology of the *S. furcifera* studied during winter (December) and summer months (March) showed a shorter incubation period and nymphal duration in summer when compared to the winter month. The developmental cycle was longer in December. The fecundity of *S. furcifera* was more during March. But the per cent hatchability was higher in December. However, there was no significant difference in per cent survival of WBPH studied over two seasons. The sex ratio exhibited significant difference in two seasons with more number of males during March than that in December.

Population build up studied under laboratory condition recorded a reduction in fecundity of WBPH in the second generation.

Feeding study conducted by honeydew test revealed that adult females produced more feeding damage than the adult males and any other stages of WBPH. The insect excreted two amino acids (glutamic acid and aspartic acid) along with the honeydew excretion.

The important natural enemies recorded were spiders (*Argeops* sp., *Lycosa pseudoannulaata, Oxyopus* spp., *Thomisus* spp. and *Salticus* spp.) and mirid predator (*Cyrtorhinus lividipennis*).

Two entomopathogenic fungi isolated from WBPH were identified as *Aspergillus flavus* and *Penicillium oxalicum.* This is the first report of above mentioned entomopathogenic fungal infection on WBPH.

Imidacloprid and lambda cyhalothrin were more toxic to WBPH nymphs and recorded lower LC_{50} values. Among the tested insecticides, the higher relative toxicity (compared to imidacloprid) was exhibited by lambda cyhalothrin.

Under laboratory condition phosphamidon and monocrotophos, were more persistent insecticides which persisted for seven days while the DDVP was persisted only for three days. There was a slight reduction in total protein content of insecticide treated and untreated insect samples.