“TAXONOMIC STUDIES ON LEAFHOPPER AND PLANTHOPPER FAUNA ASSOCIATED WITH RICE ECOSYSTEM AND THEIR MANAGEMENT”

By

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CERTIFICATE

Mr. **P.R. SHASHANK** has satisfactorily prosecuted the course of research and that the thesis entitled **"TAXONOMIC STUDIES ON LEAFHOPPER AND PLANTHOPPER FAUNA ASSOCIATED WITH RICE ECOSYSTEM AND THEIR MANAGEMENT"** submitted is the result of original research work and of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

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This is to certify that the thesis entitled **"TAXONOMIC STUDIES ON LEAFHOPPER AND PLANTHOPPER FAUNA ASSOCIATED WITH RICE ECOSYSTEM AND THEIR MANAGEMENT"** submitted in partial fulfillment of the requirements for the degree of Master of science in the major field of **ENTOMOLOGY** of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by Mr. **P.R.SHASHANK** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

B. *B. lucida* (Butler)

8. A. *B. pararubrostriata* Ramasubba Rao and Ramakrishnan

   B. *B. rubrostriata* (Melichar)

9. A. *B. saltuella* (Kirschbaum)

   B. *Cicadulina (Cicadulina) bipunctata* (Melichar)

10 A. *Doratulina indra* (Distant)

11. A. *Cemus* sp.

    B. *Nilaparvata lugens* (Stal)

12. A. *Sogatella furcifera* (Horvath)

    B. *Sardia rostrata* Melichar

13. A. *Tagosodes pusanus* (Distant)

    B. *Nisia nervosa* (Motschulsky)

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Place: Bapatla (***P. R. SHASHANK***)

Date :

LIST OF SYMBOLS AND ABBREVIATIONS

@	:	at the rate of
&	:	and
%	:	per cent
a.i.	:	active ingredient
CD (0.05)	:	Critical Difference at 5 per cent probability
cm	:	centimeter
DAS	:	Days after spraying
DAT	:	Days after treatment
EC	:	Emulsifiable concentration
♀	:	Female
et al.	:	and others
etc.	:	et cetera
Fig.	:	Figure
g	:	gram
G	:	Granules
ha	:	hectare
ha^{-1}	:	per hectare
i.e.	:	that is
kg	:	kilogram
l	:	litre
l^{-1}	:	per litre
Ltd.	:	Limited
m	:	metre
m^2	:	squaremetre
M.ha	:	Million hectare
mg	:	milligram
ml	:	millilitre
♂	:	Male
mm	:	millimeter
M.t	:	Million tonnes
NS	:	Non significant

ppm	:	parts per million
Pvt.	:	Private
q	:	quintals
RBD	:	Randomised block design
RH	:	Relative humidity
SC	:	Soluble Concentrate
SED	:	Standard error of difference
Sig.	:	Significant
SL	:	Soluble Liquid
t	:	tonnes
Viz.,	:	namely
WDP	:	Water Dispersible Powder
WG	:	Wettable Granules
WP	:	Wettable Powder

DECLARATION

I, Mr. **P.R. SHASHANK** hereby declare that the thesis entitled **"TAXONOMIC STUDIES ON LEAFHOPPER AND PLANTHOPPER FAUNA ASSOCIATED WITH RICE ECOSYSTEM AND THEIR MANAGEMENT"** submitted to the Acharya N.G. Ranga Agricultural University for the degree of Master of Science in Agriculture in the major field of **Entomology** is the result of original research work done by me. I also declare that the thesis or any part there of has not been published earlier in any manner.

Date:

[**P.R. SHASHANK**]

ABSTRACT

Name of the Author	:	**P.R. Shashank**
Title of the Thesis	:	**"Taxonomic studies on leafhopper and planthopper fauna associated with rice ecosystem and their management"**
Degree to which it is submitted	:	**Master of Science in Agriculture**
Faculty	:	**Agriculture**
Department	:	**Entomology**
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The investigations on "Taxonomic studies on leafhopper and planthopper fauna associated with rice ecosystem and their management" were undertaken during 2008-2009 at Agricultural College, Bapatla and Agriculture College Farm, Bapatla.

Investigations on the leafhopper and planthopper fauna associated with rice crop in costal and central Karnataka was undertaken at Agricultural College, Bapatla, Guntur District. Among the leafhoppers collected, 20 species belonging to 11 genera under 8 tribes were identified, illustrated and described. The leafhopper species *viz., Banus* sp. nr. *consfuscus* (Pruthi), *Exitianus indicus* (Distant),

E. nanus (Distant), *Nephotettix virescens* (Distant) , *Chiasmus alata* Pruthi, *Cofana spectra* (Distant), *C. unimaculata* (Signoret), *Deltocephalus* (*Recilia*) *distinctus* Motschulsky, *D.* (*R.*) *dorsalis* Motschulsky, *D.* (*R.*) *pruthii* Metcalf, *Empoascanara indica* (Datta), *Hecalus arucatus* (Motschulsky), *H. pusae* Ramasubba Rao and Ramakrishnan, *Balclutha incisa* (Matsumura), *B. lucida* (Butler), *B. pararubrostriata* Ramasubba Rao and Ramakrishnan, *B. rubrostriata* (Melichar), *B. saltuella* (Kirschbaum), *Cicadulina* (*Cicadulina*) *bipunctata* (Melichar) and *Doratulina indra* (Distant) were among the identified.

Six planthopper species belonging to six genera *viz.*, *Cemus sp*, *Nilaparvata lugens* (Stal), *Sogatella furcifera* (Horvath), *Sardia rostrata* Melichar, *Tagosodes pusanus* (Distant) and *Nisia nervosa* (Motschulsky) were identified, illustrated and adequately described. The identification “key” for distinguishing all these leafhoppers and planthoppers was provided along with the line drawings and the colour photographs of each specimen for easy understanding.

A field experiment was conducted to evaluate the efficacy of some new insecticides against leafhoppers and planthoppers of rice at Agriculture College Farm, Bapatla during *Kharif,* 2008-09. The insecticides are evaluated during present investigation against brown planthopper (BPH), *Nilaparvata lugens* (Stal); white backed planthopper (WBPH), *Sogatella furcifera* (Horvath) and green leafhopper (GLH), *Nephotettix virescens* (Distant). All the treatments were found to be superior over untreated check. Among the treatments, ethiprole (0.01%) and buprofezin (0.04%) were found to be highly effective against BPH and WBPH.

Buprofezin (0.04%) and thiamethoxam (0.005%) were found to be highly effective against GLH. They also recorded higher yield *viz.*, 5.16 t/ha, 5.13 t/ha and 4.98 t/ha, respectively. The other insecticides thiacloprid (0.024%), acetamiprid (0.004%), clothianidin (0.003%) and acephate (0.12%) were also found moderately effective against BPH, WBPH and GLH. Emamectin benzoate (0.0025%) although significantly superior over untreated control was the least effective against all the three pests and also recorded lowest yield (3.67 t/ha).

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.), is the staple food crop for more than half of human population. More than 90% of rice is produced and consumed in Asian countries. India occupies a major position in rice cultivation with an area of 44 million hectares, production of 90 million tones and productivity of 2.04 tons per hectare (The Hindu Survey of Indian Agriculture, 2007). It constitutes 52 per cent of total food grain production and 55 per cent of total cereal production (Saxena and Singh, 2003).

Adoption of modern technologies of plant production had aggravated the insect pest problem in rice. The insect pests became a major constraint in rice production. Yield loss due to insect pests of rice ranges from 25 to 51 per cent (Panda and Rath, 2003). Grist and Lever (1969) listed over 800 species of insects that have been causing damage either to standing crop or stored rice. Pathak and Dhaliwal (1981) considered 20 species are of major significance out of 100 species damaging rice. Among various insect pests damaging rice, sap sucking insect's *viz.*, leafhoppers (*Nephotettix viresence* (Distant) and *Nephotettix nigropictus* (Stal)) and planthoppers (*Nilaparvata lugens* (Stal) and *Sogatella furcifera* (Horvath)) are regular occurrence and cause devastating damage. Use of synthetic insecticides forms one of the best effective management tool apart various other tactics like cultural, biological methods *etc.* Although many attempts were made to evaluate insecticides against the rice insect's pests (Krishnaiah and Kalode, 1986;

Reddy *et al.*, 1987; Krishnaiah and Kalode, 1993), efforts should be continued to generate information on the efficacy of newer insecticides.

Leafhoppers are economically important group of Auchennorrhynchan Hemiptera belonging to family Cicadellidae. They are phytophagus, commonly suck sap from the leaves and also act as vectors for several of the MLO's, spiroplasms, xylem restricted bacterial diseases *viz.*, rice tungro, rice yellow dwarf, rice transitory yellowing *etc*.

Planthoppers belong to super family Fulgoroidea of Auchennorrhynchan Hemiptera and economically important planthoppers belong to Family Delphacidae. They are also phytophagus and vectors of diseases like grassy stunt and ragged stunt.

The introduction of new high yielding varieties in rice had aggravated the problems due to leaf and planthoppers. Coastal and central Karnataka forms rice bowl for entire Karnataka state, and little work has been done with regard to preparation of identification keys for recognition of leaf and planthopper species associated with rice crop ecosystem. Correct and quick identification of leaf and planthopper species with adequate description and keys for their easy recognition are most important for managing them effectively.

Keeping this in view the present work is proposed with the following objectives-

1. Collection, identification and description of leaf and planthoppers associated with rice ecosystems in coastal and central Karnataka.
2. Construction of the keys for easy identification.
3. Evaluation of some new insecticides for management of leaf and planthoppers in rice.

CHAPTER II

REVIEW OF LITERATURE

Review of literature is of paramount importance to any research endeavour. This not only helps to acquire a broad general background in the given field but also provides bases for theoretical framework and interpretation of the findings. The present investigation is concerned with the "Taxonomic studies on leafhopper and planthopper fauna associated with rice ecosystem and their management". Hence, an earnest effort was made to review the relevant and updated literature having direct or indirect bearing on the study.

The literature pertaining to the taxonomy of leafhoppers and planthoppers and their identification is scattered in many journals and monographs, published over many years in various languages in India and abroad.

2.1 LEAFHOPPERS

2.1.1 GENUS EXITIANUS BALL

It is the most widely spread and abundant on grasslands having cosmopolitan distribution. Ball (1929) has erected the genus, *Exitianus* with its type species as *Cicadula obscurinervis* Stal. The North American species of this genus were studied by Delong and Hershaberger (1947) and provided a key for separation of ten species based on the characters such as colour pattern, number and position of pygofer spines. Ross (1968) revised the old world species of the genus with a key for the identification of 17 species and he has divided old world species into five

distinct groups *viz, okhahandia, nanus, obscurinervis, distani* and *taeniaticeps* and discussed phylogenetic relationship of these species. Ghauri (1972) described two new species *viz., E. curvipenis* and *E. upensis* from Africa. Rao (1988) studied two new species *viz., E. indicus* (Distant), *E. nanus* (Distant) and provided a key for distinguishing these species. Jacob *et al.,* (2000) reported *E. indicus* and *E. nanus* on groundnut from Andhra Pradesh.

Reddy and Rao (2001) reported the occurrence of *E. indicus* on chilles spinach, amaranthus, ridge gourd, brinjal and cucumber in Andhra Pradesh. The occurrence of *E. indicus* and *E. nanus* on rice was reported by Kamala (2001). Jacob *et al.,* (2002) reported the occurrence of *E. indicus* on greengram, blackgram, soybean and *E. nanus* on greengram and blackgram. Chalam (2003) reported that *E. indicus* is distributed in all the districts of Andhra Pradesh.

2.1.2 GENUS NEPHOTETTIX MATSMURA

Matsmura (1902) erected this genus with type species as *Selenocephalus cincticeps* Uhler. He also transferred three species *viz., Cicada bipunctatus* Fabricius, *Pediopsis nigromaculatus* de Mostchulsky and the North American *Eutettix terebrans* Gillet and Baker to this genus.

Ishihara (1964) revised this genus and later Ghauri (1971) delt it exhaustively. Ghauri redefined and described previously known seven species and one subspecies of the genus and also described a new species *N. sympatricus*. Among them *N. virescens* (Distant), *N. nigropictus* (Stal), *N. malayanus* Ishihara and Kawase and *N. parvus* Ishihara and Kawase were known from India. Rao

(1988) studied *N. virescens* and *N. nigropictus* and provided a key for identification. Kamala (2001) reported wide spread occurrence of *N. viresence* and *N. nigropictus* in Andhra Pradesh on rice crop. The occurrence of *N. virescens* on greengram, pigeonpea and blackgram was reported by Jacob *et al.,* (2002). Chalam (2003) reported occurrence of *N. virescens* on rice, blackgram, redgram, pillipesara, foddergram and fodder berseam crop ecosystems in Andhra Pradesh.

2.1.3 GENUS CHIASMUS MULSANT AND REY

This is the old genus represented in almost all parts of the world. Distant (1908) described *C. uzelli* and *C. mustelina*. Pruthi (1934) described three species *C. alata*, *C. niger* and *C. jagdishi*. Datta (1988) studied *C. alata* Pruthi, *C. jagdishi* Pruthi and *C. mustelina* (Distant). So far this genus was known through five species in India. Jacob *et al.,* (2001) reported the incidence of *C. alata* on groundnut in Andhra Pradesh. Chalam (2003) reported *C. niger* for the first time in Andhra Pradesh and provided a key for identification of species belonging to genus *Chiasmus*.

2.1.4 GENUS COFANA MELICHAR

Young (1979) reviewed this genus and reported nineteen species from all over the world. The male genitalia are not very useful for identification and external characters are sufficient for separation of different species.

Rama Krishnan (1985) described a new species *C. karjatensis* from India. So far, this genus represented by five species *viz.*, *C. lineata* (Distant), *C. nigrilinea* (Stal), *C. spectra* (Distant), *C. unimaculata* (Signoret) and *C. karjatensis*

Ramakrishnan. The description of the two species, *C. spectra* and C. *unimaculata* with a key for separation was provided by Wilson and Claridge (1991). Jacob (2000) reported the occurrence of two species *viz., C. spectra* on groundnut and *C. unimaculata* on groundnut, blackgram, greengram in Andhra Pradesh. Kamala (2001) reported occurrence of *C. spectra* and *C. unimaculata* on rice. *C. unimaculata* was first time reported on rice from Andhra Pradesh. Chalam and Rao (2005) reported the occurrence of *C. spectra* and *C. unimaculata* on rice from Andhra Pradesh.

2.1.5 GENUS DELTOCEPHALUS BURMEISTER

This is the one of the largest genus of the family Cicadellidae and belongs to the subfamily Deltocephalinae. The first Indian species of *Deltocephalus* namely *Deltocephalus infirmus* was described by Melicher (1903). Distant (1908) described *D. brunnescens* from Bengal and Bombay and *D. pulvisculus* from Bengal. Distant (1918) described *D. butleri* and *D. cambpelli* from Kodaikanal and *D. coloratus* from Manipur. Rao and Rama Krishnan (1988) described one new species *Recilia krameri* and two species *R. banda* Kramer and *R. hospes* Kirkaldy as new records in India and provided a key for distinguishing six Indain species *viz., R. banda* Kramer, *R. hospes* Kirkaldy, *R. dorsalis* (Mostschulsky), *R. veinatus* (Purthi), *R. krameri* and Ramakrishnan and *R. prabha* (Pruthi).

Rao (1989) described a new species; *R. indica* and transferred *Cicadulina maculata* Pruthi and *Deltocephalus intermedius* Melicher to *Recilia*. Viraktamath (1991) and Wilson and Claridge (1991) transferred *Deltocephalus porticus*

Melicher and *D. distintus* Motschulsky into genus *Recilia* and thus they reported eleven Indian species under this genus *Deltocephalus*. Dash and Viraktamath (1995) treated the genus *Recilia* as a subgenus of *Deltocephalus* following Ribaut (1952) and Knight (1975). They described two species *viz.*, *Deltocephalus (Recilia) tareni* and *Deltocephalus (Recilia) jagannathi* and provided a key to distinguish 13 Indian species of *Deltocephalus (Recilia).*

Dash and Viraktamath (1998) redefined and revised the genus *Deltocephalus* from India and Nepal region, and they separated the genus into twp subgenera *viz.*, *Recilia* consisting of 48 species and *Deltocephalus* represented by only one species *viz*., *D. (D.) vulgaris*. Viraktamath and Dash (2001) transferred *Allophelps indicus* Pruthi, *Allophleps menoni* Rao & Ramakrishnan and *A. delhiensis* Rao & Ramakrishnan to *Deltocephalus*. The second species in subgenus *Deltocephalus viz., D. (D.) bapatlensis* was described by Jacob *et al.*, (2002).

The occurrence of *Deltocephalus (Deltocephalus) sp*., *D. (D.) vulgaris, D. (R.) dorsalis*, *D. (R.) krameri* and *D. (R.) subviridis* on groundnut and *D. (Recilia) sp*. on groundnut and sunflower was reported by Jacob *et al.,* (2000) in Andhra Pradesh. Reddy and Rao (2001) reported *D. (D.) vulgaris* on spinach in Andhra Pradesh. Kamala (2001) reported the occurrence of *D. (R.) distincticus*, *D. (R.) dorsalis*, *D. (R.) pruthii* and *D. (R.) subviridis* on rice from Andhra Pradesh. Jacob *et al*., (2002) reported the occurrence of *D. (D.) vulgaris* on greengram, blackgram, *D. (R.) dorsalis* on greengram, blackgram and *D. (R.) subviridis* on greengram, horsegram and blackgram in Andhra Pradesh.

2.1.6 GENUS EMPOASCANARA DISTANT

Distant (1918) described this genus with *Empoascanara prima* as its type species. Rama Krishnan and Ghauri (1979) described this genus as a complex of genera and assigned the known species to 15 new genera in addition to *Empoascanara*. Later Dworakowska (1980b) synonymised all these genera with *Empoascanara*. Dworakowska (1980b) described 13 new species and three new subspecies of the nominated subgenus and two new species of the subgenus *Bza* Dworakowska. Sohi and Dworakowska (1983) reported 22 species belonging to this genus. Sohi (1983) reported two species on cotton and 11 species on rice from oriental region. Among these he reported *E. (Empoascanara) maculifrons* (Motschulsky) on rice from Sri Lanka.

Jacob (2000) reported the occurrence of *E. indica* (Datta) on groundnut, greengram, blackgram where as *E. maculifrons* on greengram and *E. prima* on groundnut, blackgram and greengram in Andhra Pradesh.

2.1.7 GENUS HECALUS STAL

This genus was described by Stal (1864) with its type *H. paykulli* Stal. Melichar (1903) described a new species *H. nervosus* Distant (1908) described five species including two new, *H. umballaensis* and *H. lefroyi* Distant. Later Distant (1918) described three more species, *H. facialis*, *H. capitatus* and *H. godavariensis* from India. Morrison (1973) studied and reported that oriental *Hecalinae* which consist of 20 species including five new species and eight new combinations. Rao and Ramakrishnan (1990a) described three new species (*H. ghaurii*,

H. morrisoni and *H. pusae*) and one new record from India *viz*., *H. prasinus* Matsmura and provided key to distinguish the Indian species *viz., H. lutescens* (Distant), *H. apicalis* (Matsmura), *H. umballaensis* Distant, *H. morrisoni* Rao and Ramakrishnan, *H. porrectus* (Walker), *H. ghaurii* Rao and Ramakrishnan, *H. prasinus* (Matsmura), *H. pusae* Rao and Ramakrishnan, and *H. wallengreni* Stal.

Rao (1997) published a new name, *H. paraumballensis* for *H. morrisoni* Rao and Ramakrishnan (1990a) which is a primary junior homonym of *H. morrisoni* Kwon and Lee (1979). Jacob *et al.,* (2000) reported *H. prasinus* on groundnut and sunflower crops in Andhra Pradesh. The occurrence of *H. porrectus* on cucumber and brinjal was reported by Reddy and Rao (2001) in Andhra Pradesh.

Kamala (2001) reported of *H. arcuatus*, *H. ghaurii* and *H. paraumballensis* and *H. pranisus* on blackgram and *H. porrectus* on greengram reported by Jacob *et al.,* (2002) in Andhra Pradesh. Chalam (2003) studied and described six species of *Hecalus viz., H. arcuatus* (Motschulsky), *H. ghaurii* Rao and Ramakrishnan, *H. paraumballensis* Rao and Rama Krishnan, *H. porrectus* (Walker), *H. pransinus* (Matsmura), *H. pusae* Rao and Ramakrishnan.

2.1.8 GENUS BALCLUTHA KIRKALDY

Blocker (1987) revised the genus and described thirty six species including fifteen new species and four new combinations and provided a key for all western Hemisphere species.

Ghauri (1971) described a new species, *B. versicoloroides* on clover from India. Sharma and Badan (1985) described *B. rubrostriata* (Melicher) *B. ocellatus*

(Pruthi), *B. incisa* (Matsmura), *B. indica* (Pruthi), *B. micropterous* (Pruthi) from Kashmir and Jammu (India) and a key for identification of these species was given.

Knight (1987) revised the genus from the Pacific region and provided a key for distinguishing 30 valid species including 14 new. He established 28 new synomymies and designated 24 lectotypes. He further discussed the economic importance of the genus with a check list of the 98 world species together with their 90 synonymies.

Rao and Ramakrishnan (1990b) described two new species and three new records from India and provided key to the Indian species *viz.*, *B. incisa* (Matsmura), *B. rubrolineata* (Melicher), *B. paraubrostriata*, Rao and Ramakrishnan, *B. lucida* (Butler), *B. versicoloroides* Ghauri, *B. noonadana* Knight, *B. punctata* (Fabricius), *B. knighti* Rao and Ramakrishnan, *B. viridinervis* Mastmura and *B. saltella* (Krischabaum)

Webb and Vilbaste (1994) revised the oriental fauna and described 5 new species *viz., B. bispinosa, B. gangesiensis, B. sinuata, B. thaiensis* and *B. viraktamathi*. A check list and key to the 25 species and two species complexes recognized from oriental region was provided. Jacob *et al.*, (2000) reported the occurrence of *B. incisa* on groundnut, castor, sunflower and mustard, *B. saltuella* on groundnut, castor and niger. The occurrence of *B. incisa* on broadbean, tomato, brinjal, mesta, spinach, ridgegourd, clusterbean, bitter gourd and cucumber, *B. pararubrostriate* on tomato, bittergourd, *B. saltuella* on broadbean, cauliflower, tomato, ridgegourd, bittergourd, cucumber okra and brinjal was reported by Reddy

and Rao (2001). Kamala (2001) reported that occurrence of *B. incisa, B. pararubrostriata* and *B. rubrostriata* on rice from Andhra Pradesh. Jacob *et al.,* (2002) reported the occurrence of *B. incisa* on greengram, pigeon pea, blackgram, *B. pararubrosiriata* on blackgram and *B saltuella* on greengram, pigeon pea, blackgram, chick pea, soybean and cow pea in Andhra Pradesh.

Chalam (2003) described six species *viz., B. incisa* (Matsmura), *B. lucida* (Butler), *B. pararubrostriata*, Rao and Ramakrishnan, B. *rubrostriata* (Melicher), *B. saltuella* (Krischbaum) and *B. thea* (Distant) and a key for separating the species is also provided.

2.1.9 GENUS CICADULINA CHINA

The genus *Cicadulina* revised by Ruppel (1965) and gave a key to identify thirteen known species. Heller and Linnavuori (1968) symonymised *Cicadula bipunctella* with *Gnathodus bipunctatus* Melicher. Ghauri (1971) described *C. niger* from Africa. Dabrowski (1987) described two new species *viz., C. ghauri* and *C. hartmansi* from West Africa, Webb (1987) reviewed the genus and described two new species *C. dabroskii* and *C. immaculate* and provided identification key for the 22 species.

Rao (1988) studied this genus and gave key for the identification of five Indian species *viz., C. bipunctata bipunctata* (Melicher), *C. bipunctata bipunctella* (Matsmura), *C. arachidis* China, *C. chinai* Ghauri and *C. mbila* (Naude). Jacob *et al*., (2000) reported the occurrence of *C. (C.) bipunctata* on castor, groundnut

and niger. The occurrence of *C. (C.) bipunctata* was reported on broadbean, amaranthus, mesta and spinach in Andhra Pradesh by Reddy and Rao (2001).

Kamala (2001) reported the occurrence of *C. bipunctata* (Melichar) on rice in Andhra Pradesh. The occurrence of *C. bipunctata* was reported on greengram and blackgram by Jacob *et al.,* (2002) in Andhra Pradesh.

2.1.10 GENUS DORATULINA MELICHER

The genus was erected by Melicher (1903) based on the type species *Doratulina jocosa.*

Kirkaldy (1906) Distant (1918) Pruthi (1930 and 1936), Ribaut (1948), Ishihara (1963) described some more species under different genera which were subsequently synonymised by Vilbaste (1965). A new subgenus *Cymbopogonella* was erected by Viraktamath (1976) under this genus and described a new species *D. (Cymopogonella) longivertex*. Jacob *et al*., (2000) reported the occurrence of *D. apicallis* and *D. rubrolineata* on groundnut and sunflower in Andhra Pradesh.

Kamala (2001) reported the occurrence of *Doratulina* sp. a new record on rice from Andhra Pradesh. The occurrence of *D. apicalis* on horsegram, *D. rubrolinenata* on greengram, pigeon pea, black gram, soybean and cow pea and *D. tolla* on blackgram was reported by Jacob *et al.*, (2002) from Andhra Pradesh

2.1.11 GENUS BANUS DISTANT

This genus was erected by Distant (1908) with *Banus oblates* as its type. He described only one species *i.e., B. oblatus* Distant in this genus.

2.2 PLANTHOPPERS

Planthoppers belong to the superfamily Fulgoroidea of Auchenorrhynchous Homoptera comprising 20 families. The pioneer worker in the field of oriental leaf and planthoppers was Melichar (1903).

Distant (1906 and 1916) worked on the taxonomy of Indian Delphacidae and described 15 genera including 34 species. Distant (1908 and 1918) made more extensive study and monographed his work in 'Rhychota' the fauna of British India. Ishihara and Low (1969) reported *Nilaparvata lugens* (Stal), *Sogatella furcifera* (Horvath), *Unkanodas sapparonus* Matsmura, *Sardia rostrata* Melicher, *Nisia atrovenosa* Lethierry and *Eponisia guttula* Matsmura from different rice growing states in India.

Mammen and Menon (1972) reported 29 new species of delphacids for the first time in India. Mammen and Menon (1974) studied 44 species of delphacids and given a key for separation of 25 genera of Indian delphacids. Misra (1980) studied the morphology, biology, behaviour and control of four important leafhoppers and two planthoppers *viz., S. furcifera* and *N. lugens*.

Chung- Lin (1983) reported 67 species of leafhoppers and 22 species of planthoppers on rice in china. The commonest planthoppers reported by him were *N. lugenus*, *N. bakeri* Muir *S. furcifera*, *S. longifurcifera* (Esaki and Ishihara) *Loadelphax striatellus* (Fallen) *U. sapporona*, *Toya propinqua* (Fiber), *Saccharosydne procerus* Matsmura and *Tropidocephala brunnecipennisa* Signoret.

Ding *et al.*, (1983) studied 25 delphacids species in two tribes and provided key for separation of nymphs based on the two median keels on the frons and arrangement of sensory pits on the frons, thorax and abdomen.

The commonly occurring Auchenorrhynchan rice fauna from India reported by Kalode (1983) includes *N. lugens*, *S. furcifera*, *Nephotettix virescens*, *N. nigropictus*, *Recilia dorsalis*, *Cofona (Cicadella) spectra*, *C. unimaculata* (*Kolla mimica*) *Nisia atrovenosa*, *Emposcanara indica*, *U. sapporonus* and *Laodelphax striatellus*. Among these three are widely distributed in India in all rice growing states *viz.*, Brown Planthopper (BPH) *N. lugens*, white backed planthopper (WBPH), *S. furcifera* and white winged planthoppers, *Nisia atrovenosa* Lethierry. Further he also reported other planthopper species *viz.*, *U. sapporouns* Matsmura from Orissa, the small brown planthoppers *L. striatellus* from Punjab, the sugarcane leaf hopper *Pyrilla perpusilla* on rice from Uttar Pradesh.

Wilson (1983) studied, described and provided an illustrated key for identification of nymphal stages of planthoppers and leafhoppers commonly associated with rice in Asia to separate sexes and to distinguish common species for the fifth instar. Among them, important planthoppers studied were *Nisia nervosa* (Motsah) (Meenoplidae) *N. lugens* (Delphacidae) *S. furcifera* (Delphacidae), *Sogatodes pusanus* (Distant) (Delphacidae) and *L. striatellus* (Delphacidae).

A comprehensive account of planthopper systamatics and their external morphology and an illustrated key to the 20 planthopper families have given by O' Brien and Wilson (1985).

Wilson and Claridge (1985) provided an annotated list of 78 species of Auchenorrhyncha associated with rice in major rice growing regions of the world. They discussed geographical, seasonal distribution, migration and host plant specificity of Auchenorrhyncha.

Ahmed and Yunus (1986) conducted a survey of insects on grasses around Karachi, Pakistan in February to April 1983; and found twelve species of planthoppers (Delphacidae, Cixiidae and Flatidae) accounting for 10.22% of all insects collected. They reported *Toya propinqua* was the most common planthopper.

Wilson and O' Brien (1987) reported 150 fulgorid species in 16 families *viz.*, Acanaloniidae, Cixiidae, Delphacidae, Derbidae, Dictyopharidae, Eurybrachidae, Flatidae, Fulgoridae, Hypochthonellidae, Issidae, Lophopidae, Menoplidae, Nogodinidae, Ricaniidae, Tettigometridae and Tropiduchidae and listed as pests of 99 economically important plants.

Kaldandelen (1988) discussed the taxonomy and provided the keys for separation of four species in genus *Cixius* and five species in genus *Tachy* (Cixiidae) found in Turkey.

Wilson and Claridge (1991) studied and provided diagnosis, distribution and illustrations for the identification of *Cemus sp., T. pusanus, T. oryzicolous* (Muir), *T. cubanus* (Crowford), *Harmalia anacharsis* Fennah, *Terthron albovittatum* Matsmura, *S. rostrata*, *Toya propinqua* Fieber, *N. nervosa*.

Bhuyan and Ramakrishnan (1992) described the male genitalia of six species of Derbidae including *Proutista moesta.*

Fatima *et al.,* (1996) conducted a survey to determine the abundance of leafhoppers and planthoppers on different crops like rice, wheat, maize and grasses in Sindhu Pakistan. The results showed that among planthoppers, *T. propinqua* and *S. furcifera* and among leafhoppers *Exitianus spp*. and *Chiasmus spp*. were the dominant species.

The planthoppers associated with rice were revised by Gunathilagaraj (1999) and he reported 10 species *viz., N. lugens, N. bakeri, S. furcifera, S. vibix, T. pusanus, L. striatellus, U. sapporonus, Eudellana celadon* Fennah, *N. nervosa* and *P. perpusilla* in India. He also provided synonyms, distribution, host plants, symptoms of damage, factors responsible for losses, biology and management for major pests *viz., N. lugens* and *S. furcifera*. The small brown plant hopper *L. striatellus* and sugarcane leaf hopper, *Pyrilla perpusilla* were reported as occasional pests. Larivieri (1999) reviewed the New Zealand Cixiidae fauna and illustrated 11 genera and 25 species along with identification key.

2.2.1 GENUS NILAPARVATA DISTANT

Okada (1977) reported 14 species under genus *Nilaparvata* of which he described 7 species *viz, N. lugens, N. albotristriate, N. bakeri, N, muri, N. myerisi, N. seminula* and *Nilaparvata sp*. He provided a key for identification of six *Nilaparvata* species *viz., N. bakeri, N. albotristriate, N, muri, N. myerisi, N. lugens* and one unknown species, *Nilaparvata* sp of Asia and Pacific region.

Mochida and Okada (1979) reported that there are fourteen determined and two undetermined species as members of the genus *Nilaparvata* so far in the world.

Wilson and Claridge (1991) described *Nilaparvata* on the basis of the possession of small spines on the first tarsal segments of the hind leg and also provided key for identification of male and females of *N. lugens, N. bakeri, and N. muri*.

Seven planthopper species *viz., S. kolophon, S. vibix, T. pusanus, T. albovittatum, T. propinqua, H. anacharsis and Cemus spp*. (Delphacidae: Homoptera) associated with different rice ecosystems were reported for the first time from Andhra Pradesh. An illustrated key is provided to identify 10 known planthoppers from Andhra Pradesh (Narayana *et al*., 2005).

Rao and Chalam (2007) reported that species belong to *Nilaparvata* were predominantly found in association with rice ecosystem of South India. They also provided key for identifying the species.

2.2.2 GENUS SOGATELLA FENNAH

Horvath (1899) first described the species *furcifera* under *Delphax* on the basis of male specimens collected from Japan.

Fennah (1963) subsequently changed the genus name *Delphax* to *Sogatella* and he also described and provided a key for the separation of sixteen species in this group *viz., Sogatella furcifera, S. vibex, S. longifurcifera, S. catopteran,*

S. nigrigenis, S. capensis, S. kolophon, S. nigriensis, S. derelicta, S. colorata, S. balteata, S. gemina, S. mehetho, S. nebris, S. petax and *S. camptistylis.*

Asche and Wilson (1990) have redefined the genus *Sogatella* and related groups and provided a key to males of the 14 inculded species. According to them *Sogatella* species are found throughout the subtropical and tropical regions of the world. A key is provided to distinguish the four genera *viz., Sogatella, Tagosodes, Latistria and Sogatellana.* A check list of specimens in each genus was also given.

Rao and Chalam (2007) reported the dominance of *Sogatella* in rice ecosystem of South India and they provided key for the separation of *S. furcifera, S. kolophon* and *S. vibex*.

2.2.3 GENUS CEMUS FENNAH

Two new species *Cemus quilicii* and *Thriambus reynaudi* from *Pennisetum clandestineum* and sugarcane respectively were described by Bonfils (1993) in Reunion. Narayana *et al*., (2005) reported *Cemus* sp. for the first time from Andhra Pradesh and provide identification key. Rao and Chalam (2007) reported *Cemus* sp. from rice ecosystems of South India.

2.2.4 GENUS NISIA MELICHAR

Shun-Cheran-Tsaur (1989) described two new species of *Nisia* (Meenoplidae) and provided keys to Taiwanese *Nisia* and *Eponisia* species. Narayana *et al*., (2005) reported *N. nervosa* from different rice ecosystems of Andhra Pradesh.

2.3 EFFICACY OF INSECTICIDES TESTED ON MAJOR PESTS OF RICE

2.3.1 Acephate

It is an organophosphorus compound with systemic action and effective against sucking pests and lepidopteran borers. It acts as cholinesterase inhibitor.

Sakabale *et al.,* (1991) reported that acephate @ 0.05% was superior to untreated check (7.72/leaf) in reducing the population of *Bemisia tabaci* (G.) (4.8/leaf) on cotton.

Dominick and Mohansundaran (1992) reported that acephate 75SP @ 0.75 kg/ha recorded lower population of *B. tabaci* (9.33/plant) as compared to control (61.33/plant) on cotton.

Thirumal Prasad e*t al.,* (1993) reported that acephate @0.15% gave highest percentage reduction of 93.3 and 86.9 of aphids (*Aphis gossypii* (G.)) and leafhoppers (*Amrasca biguttula biguttula* (I.)), respectively on okra.

Kumar (1993) reported that acephate (0.1%) reduced the population of *Aphis craccivora* Koch by 89.67% over untreated control on groundnut and resulted in higher yield.

Giraddi *et al.,* (1998) reported an increase in the population of leafhopper, *Amrasca biguttula biguttula* on okra one day after application of insecticidal treatments; the increase was low in monocrotophos (500 g a.i./ha) (5.8/top 5 leaves) and acephate (600 g a.i./ha) (7.4/top 5 leaves) compared to chlorpyriphos 20EC + cypermethrin 10EC @ 100 g a.i./ha (9.1/ top 5 leaves).

Asaf Ali and Chinniah (1999) reported highest mortality of aphids and leafhoppers with carbosulfan (0.075%) followed by dimethoate (0.06%) and acephate (0.1%) on cotton.

Girish Kumar and Giraddi (2001) reported that acephate @1 g/l was effective in controlling mango leafhoppers (*Idioscopus niveosparsus* (Leth.), *I. clypealis* (Leth.) and *Amritodus atkinsoni* (Leth.)) upto 21 days after spray (1.69 leafhoppers/ inflorecence) as compared to control (6.72 leafhoppers/inflorecence).

Chandrasekaran and Balasubramanian (2002) reported that acephate @0.075% was found to be very effective in reducing population of *A. craccivora* upto 75.8% on greengram.

Nisha *et al.*, (2004) reported that acephate 75SP effectively brought down the population of *Myzus persicae* (S.) on potato from 33 to 9/plant and recorded highest tuber yield of 213q/ha.

Bhavani and Rao (2005) reported that imidacloprid (confidor 200SL) @ 25 g a.i./ha and acephate (starthene 75SP) 600 g a.i./ha were effective against brown planthoppers, *Nilaparvata lugens* (99.46 and 94.36% mortality) and white backed planthoppers, *Sogatella furcifera* (98.51 and 84.49% mortality) as compared to untreated control.

Bhavani and Punnaiah (2006) revealed that acephate @ 0.07% concentration showed population reduction of *Lypaphis erysimi* (Kalt) upto 74.94% over control on cabbage crop.

Sarangdevot *et al.*, (2006) revealed that acephate @ 1.5 g/ l was most effective in reducing the population of aphid, *A. gossypii* (46.41%), leafhopper , *A. biguttula biguttula* (49.39%) and whitefly, *B. tabaci* (42.52%) after 14th day after 2nd spray, as compared to untreated control on brinjal.

Kumaran *et al.*, (2007) reported that acephate @ 468.75 g a.i./ha reduced the population of brown planthopper (BPH) up to 61.83% when compared with untreated control in rice.

Sekh *et al.*, (2007) reported that acephate @ 468.75 g a.i./ha showed population reduction of BPH upto 86.36% over untreated control with an yield of 37.33 q/ha in rice.

2.3.2 Thiamethoxam

It is a second generation neonicotinoid belonging to chlorothiazole heterocycle with an oxadiazinane ring. It is a broad spectrum insecticide. Immediately after spray it is absorbed by the plants and thus provides longer protection to the treated crop.

Misra (2002) reported that imidacloprid and thiamethoxam both belonging to nitro-guanidine group used at 25 g a.i./ha proved significantly superior in controlling aphids and leafhoppers on okra.

Sharma and Lal (2002) revealed that thiamethoxam was superior to other treatments against both the leafhoppers and the whitefly on brinjal.

Khutward *et al.*, (2002) reported that imidacloprid (70WS) 0.2% seed treatment + imidacloprid (200SC) 0.02% foliar spray recorded minimum leafhopper population followed by thiamethoxam (25WG) 0.02% foliar spray on greengram.

In controlling the leafhoppers, *A. biguttula biguttula* on cotton, thiamethoxam foliar spray @ 25 g a.i./ha was significantly better than oxydemeton methyl and was at par with imidacloprid (Dhawan and Simwat ,2002).

Balaji (2002) reported that thiamethoxam 25WG @0.025% recorded 67.55 % mean reduction of whitefly population on brinjal.

Venkatesan (2003) reported that Actara 25WG (thiamethoxam) @ 50 and 100 g a.i./ha effectively reduced the leafhopper, *A. atkinsoni* population from 7 to 1 per inflorescence in mango.

Nagangoud (2003) reported that Actara 25WG (thiamethoxam) @ 0.75 and 1.0 g/l was effective in reducing the population of mango hoppers, *A. atkinsoni*, *I. niveosparsus* and *I. clypealis* upto 98.30 and 97.94 per cent, respectively than carbaryl 50WP @ 3.0 g/l (94.30%) and monocrotophos 36SL @1.25 ml/l (92.96%).

Ghongale (2003) reported that different doses of thiamethoxam (Actara 25WG) viz., 25, 37.5 and 50 g a.i./ha were at par with each other and has significantly reduced population of citrus psylla, *Diaphornia citri* (Kuwaxama).

Srinivasan (2004) revealed that seed treatment with thiamethoxam 70 WS @ 4.3 g/kg seed and 2.8 g/kg seed and foliar spray of thiamethoxam 25 WS @ 50 g a.i./ha recorded lowest sucking pest population (thrips, whiteflies and leafhoppers)

compared to imidacloprid 70 WS @ 5 g and 10 g/kg seed and imidacloprid 20SL @ 20 g a.i./ha as a foliar spray on cotton.

Bhavani and Rao (2004) reported that thiamethoaxam @ 25g a.i./ha was found most effective in controlling planthoppers (BPH and WBPH) with an yield of 3769 kg/ha and this was followed by thiocyclam hydrogen oxalate @ 357 g a.i./ha (3747 kg/ha) in rice.

Higher doses of imidacloprid (18 and 22.5 g/ha) and thiamethoxam (25 and 50 g/ha) were effective against leafhopper and whitefly on brinjal (Mhaske and Mote, 2005)

Javaregowda and Krishna Naik (2005) reported that application of thiamethoxam @ 100 and 125 g a.i./ha was effective in reducing the white backed planthopper (*S. furcifera*) population upto 85.8% and 91.1%, respectively with an yield of 43.4 q/ha and 43.6 q/ha in rice.

Among various insecticide treatments, thiamethoxam @ 100 g /ha recorded highest mortality (100%) in whitefly population followed by monocrotophos 0.8 lit/ha on soybean (AICRP report on Soybean, 2006-07).

Sinha and Sharma (2007) reported that thiamethoxam @ 25 g a.i./ha, thiacloprid @ 20 g a.i./ha and seed treatment with imidacloprid @ 3 and 5.4 g a.i./kg seed was effective in managing the leafhopper on okra.

Vasanta Bhanu *et al.,* (2007) reported that thiamethoxam 25WG @ 0.2 g/l was effective in reducing the population of BPH (33.5/20 hills) and WBPH (15.3/20

hills) upto 85 DAT as compared to untreated control (102.3 and 199/20 hills, respectively) and it registered grain yield of 3765 kg/ha in rice.

2.3.3 Acetamiprid

It is a cyanoamidine chemical with excellent systemic properties. It diffuses rapidly in treated plant from base to top and brings about destruction of hidden pests and assures the protection of young rapidly growing shoot. It acts on the central nervous system causing irreversible blockage of post synaptic nicotinergic acetylcholine receptors. Acetamiprid is used for controlling sucking insects, including, rice hoppers, aphids, thrips and whiteflies. It is also effective on some species of biting insects, such as rice water weevil and colorado beetle (Tomlin, 1995).

Dos *et al.,* (1999) revealed that spraying of acetamiprid 20SP @ 40 g a.i./ha, acetamiprid + endosulfon @ 20+350 g a.i./ha, acetamiprid + carbosulfon @ 20+120 g a.i./ha gave more than 95% control of cotton aphid, *A. gossypii* upto eight days after treatment on cotton.

Vinod and Sonalkar (1999) reported that acetamiprid @ 20 g a.i./ha reduced the whitefly, *B. tabaci* population significantly in okra.

Acharya *et al.,* (2002) reported that acetamiprid @ 20 g a.i./ha was highly effective in controlling leafhoppers on okra giving 92.64% and 80% reduction over control at 7 and 14 days after spraying, respectively and was on par with thiamethoxam and imidacloprid.

Kendappa *et al.,* (2002) reported that spraying of acetamiprid @ 20 g a.i./ha recorded lowest population (6.93/ three leaves) of aphid, *M. persicae* on tobacco.

Venkateshwara Rao (2004) reported that spraying of acetamiprid @ 0.004% showed 54.55% reduction of thrips, *Scirtothrips dorsalis* (H.) population over control in chilli.

Application of acetamiprid @ 40 and 80 g a.i./ha which were 2 and 4 times than recommended dose (20 g a.i./ha) did not cause any phytotoxic symptoms on cotton and are very effective in controlling sucking pests *viz.,* aphids (*A. gossypii*) and leafhoppers (*A. biguttula biguttula*) and recorded higher seed cotton yield than untreated control (Suganya *et al.*,2007)

Kumawal and Kumar (2007) revealed that acetamiprid @ 80 g a.i./ha proved significantly superior against leafhoppers on soybean followed by acetamiprid @ 40 g a.i./ha, indoxacarb @ 100 g a.i./ha and lamda cyahalothrin @40 g a.i./ha.

Raghuraman *et al.,* (2008) revealed that acetamiprid 20SP @ three different doses *viz.,* 20, 40, 80 g a.i./ha was found to be effective in suppression of leafhopper and whitefly population upto nine days on cotton.

2.3.4 Emamectin benzoate

It is a semi-synthetic avermectin derived from fermentation of avermectin B (Abamectin). The avermectins are a group of macrocyclic lactones isolated from fermentation products of the soil microorganism, *Streptomyces avermitilis* Burg.

These compounds act as agonist for Gamma Amino Butyric Acid (GABA)-gated chloride channel.

Emamectin benzoate is a potent compound for controlling the western flower thrips, *Frankliniella occidentalis* (P.), whiteflies and leaf miners (Ishaaya *et al.*, 2002).

Among various insecticidal treatments on soybean, Emamectin benzoate was found to be very effective over control, which recorded 2.33 whitefly population per plant followed by profenophos (3.5/plant) (AICRP report on soybean, 2006-07)

Balikai and Patil (2007) reported that Emamectin benzoate 5 SG (Proclaim 5SG) @ 220 g/ha was found highly effective in reducing thrips (*Thrips palmi* Karney and *S. dorsalis* population upto 78.92% on grape.

Kulkarni and Adsule (2007) reported that Emamectin benzoate at 11 g a.i./ha was found most effective against thrips on grapes.

Dhanalakshmi and Mallapur (2008) reported that Emamectin benzoate 5SG @ 0.2 g/l reduced the population of aphids (65%), leafhoppers (64.7%) and thrips (81.51%) upto 3 days after spraying on okra as compared to untreated control.

2.3.5 Buprofezin

It is a chitin synthesis inhibitor (Benzoyl phenyl urea) acting specifically on sucking insects and found harmless to the natural enemies, has low mammalian toxicity (Gerling and Sinai, 1994). It inhibits chitin synthatase enzyme this results in inability of insect to shed off the old cuticle and synthesize new cuticle.

Korat *et al.,* (1999) revealed that the lowest (2.72 to 3.73 hoppers/hill) number of the WBPH were observed following treatment with buprofezin 25 WP (0.5 kg a.i./ha) followed by acephate 75 SP (0.75 kg a.i./ha).

Lin Kejian *et al.,* (2002) reported that three insecticides *viz.,* imidacloprid, buprofezin and beta-cypermethrin were applied to control the whiteflies, *B. tabaci* and their effects for adults and nymphs ranged from 20.07 to 33.19, 20.62 to 44.88 and 4.05 to 6.78% and 51.91 to 64.46, 54.30 to 63.99 and 16.73 to 26.97%, respectively.

Bhavani and Rao (2005) reported that Buprofezin 25 WP at 50 g a.i./ha and 100 g a.i./ha was effective in suppressing the population (82% and 85%) of planthoppers (BPH and WBPH) over control with 5067 and 5148 kg/ha yield in rice.

Kendappa *et al.,* (2005) conducted a field experiment to evaluate new insecticides against rice BPH. From the result it can be concluded that buprofezin 25 SC (applaud) @ 200 and 250 g a.i./ha , imidacloprid 200SL (tatamida) @ 25 g a.i./ha and thiamethoxam 25 WG @ 25 g a.i./ha, were significantly superior in suppressing of BPH upto 16 days after application.

Balikai (2005) reported that buprofezin at 2250 ml/ha recorded the least number of mealy bug (*M. hirsutus*) colonies per grape vine (27.7, 19.3 and 8.2) after 10 days of 1st, 2nd and 3rd spray respectively and was at par with buprofezin at 1500 ml/ha, which in turn was at par with buprofezin at 1125 ml/ha.

2.3.6 Thiacloprid

It belongs to neo-nicotinoid group. It is a novel agent with broad spectrum of efficacy against sucking and biting insects. It acts agonistically on the nicotinic acetylcholine receptor. As a result cross resistance to pyrethroids, organo phosohates and carbamates has not been observed. Thiacloprid is an acute contact and stomach insecticide with systemic properties, (Elbert *et al,* 2001).

Varma *et al.,* (2003) reported that thiacloprid @ 120 g a.i./ha reduced the populations of BPH (129.0/10 hills) and WBPH (31.8/10 hills) as compared to untreated control (570.3 and 151.5/ 10 hills, respectively) in rice.

Sinha and Sharma (2007) reported that thiacloprid @ 20 g/ha reduced the population of *A. biguttula biguttlula* (0.40/leaf) as compared to untreated control (8.60/leaf) on okra.

2.3.7 Clothianidin

Clothianidin is an active ingredient in the chemical class of neonicotinoids.

Dewar *et al.,* (2002) revealed that clothianidin applied to pelleted sugarbeet seeds @ 30, 45, 60 and 90 g a.i./unit, resulted in excellent control of green aphids upto 10 weeks after sowing, comparable to the standard imidacloprid seed treatment @ 90g a.i./unit.

Misra (2005) reported that clothianidin @ 25 g a.i./ha and ethiprole @ 50g a.i./ha showed superior control of BPH and the control efficacy was 92.05-95.03% over the control in rice.

Misra (2006) reported that clothianidin 50 WDG @ 15g a.i./ha recorded highest reduction of WBPH (90.28%) over control followed by acetamiprid 0.4% + quinalphos 20% EC@510 g a.i./ha in rice.

Sahithi and Misra (2006) revealed that clothianidin 50 WDG @ 25 g a.i./ha recorded 83.3% of reduction of green leafhopper (GLH) over control in rice.

Patil *et al*., (2007) reported that Clothianidin 50% WDG @ 25 g a.i./ha reduced the population of *Amarasca devastans* (Distant) (3.01 /leaf) followed by Clothianidin 50% WDG @ 20 g a.i./ha (3.84/leaf) as compared to untreated control (27.58/leaf) and also significantly highest seed cotton yield (11.29 q/ha) was harvested from the Clothianidin 50% WDG @ 25 g a.i./ha treated plots which was on par with Acetamiprid 20 SP @10 g a.i./ha and to its next lower dose @ 20 g a.i./ha (10.97 q/ha).

2.3.8 Ethiprole

Ethiprole is a newer chemical belonging to phenyl pyrazole group. The pyrazoles act on the Gamma Amino Butyric Acid (GABA) receptors of insects by blocking the passage of chloride ions, thereby causing disruption of the central nervous system (Cole *et al.,* 1993)

Varma *et al.,* (2003) reported that Ethiprole 10EC @ 50 g a.i./ha was found effective against planthoppers (31.5 BPH and 8.8 WBPH/10 hills) followed by imidacloprid (43.0 BPH and 14.5 WBPH/10hills) compared to check insecticides, monocrotophos (994 BPH and 405 WBPH/10hills) three days after treatment and with an yield of 4151.4, 4032 and 2830 kg/ha yield, respectively in rice.

Sahithi and Misra (2006) revealed that Ethiprole 10SC @ 50 g a.i./ha recorded significantly lowest population of GLH/clump (0.8) with 89.7% reduction over control followed by alpha-cypermethrin @ 25 g a.i./ha (1.0 GLH/clump) at 15 days after spraying in rice.

Kumaran *et al,* (2007) reported that ethiprole 10 SC @ 50 g a.i./ha reduced 67.95 per cent of BPH population when compared untreated control, which was followed by acephate @ 468.75 g a.i./ha (61.83% reduction) and ethiprole 10 SC @ 37.5 g a.i./ha (60.39% reduction) in rice.

Sekh *et al.,* (2007) reported that Ethiprole @ 37.5 and 50 g a.i./ha recorded 99.9 and 100% reduction of BPH population with yield of 31.33q/ha, this was followed by combination of ethiprole 10SC + imidacloprid 200SL @ 37.35+ 25 g a.i./ha (99.99% reduction) (31.66q/ha) over untreated control in rice.

CHAPTER III

MATERIALS AND METHODS

An experiment entitled “Taxonomic studies on leafhopper and planthopper fauna associated with rice ecosystem and their management” was conducted at Agricultural College, Bapatla and Agriculture College Farm, Bapatla, Guntur district as head quarters during 2008-2009. The details of the material and methods employed during the course of investigations are given in this chapter.

3.1 **Taxonomic Studies on Leafhopper and Planthopper Fauna**

Leafhopper and planthopper collection were made intensively in different rice ecosystems in the central and coastal districts of Karnataka (Table1).

3.2 **METHODS OF STUDY**

3.2.1 **Collection, Killing, Drying and Preservation of the Specimens**

Leafhoppers and planthoppers were collected by sweep netting with the help of an insect collection net and trapped in aspirator. The killed specimens were dried in hot air oven at 45-50^{0}C for about 4 to 5 hours. The dried specimens were preserved in homeopathic vials and labelled. A narrow strip of filter paper with its tip dipped in formaldehyde was placed in each vial, held hanging with the cork not touching the specimens which prevents the fungal infection during long storage.

Table1: Districts surveyed for collection of leafhopper and planthopper fauna in Karnataka.

Sl.No.	District	Places visited
1	Dharwad	1. Dharwad
		2. Mugad
2	Belgaum	3. Kittur
		4. Kanapur
3.	Uttar Kannada	5. Sirsi
		6. Yellapura
4	Udupi	7. Udupi
		8. Karkala
5	Dakshin Kannada	9. Mangalore
		10. Bantval
6	Shimoga	11. Badravathi
		12. Shikaripura
7	Davanagere	13. Davanagere
		14. Honnalli
8	Haveri	15. Haveri
		16. Ranebennur

3.2.2 **Processing of Material for Study**

The procedure advocated by Knight (1965) was followed for mounting and preparation of genitalia for both leafhoppers and planthoppers.

3.2.3 **Mounting of specimens**

Leafhoppers and planthoppers were mounted on a good quality white triangular thick paper points on the right hand side of the thorax by using the gum prepared by diluting quickfix in amylacetate. This facilitates the examination of head, wings, legs and abdomen from all desired angles on which identification was based and also useful for easy detaching of the abdomen for the study of male genitalia. The label with information regarding host plant, locality, date of collection and name of the collector was transfixed to each specimen. The sex of the respective specimen was indicated on the right side of the label by using standard notations '♀' for female and '♂' for male.

3.2.4 **Preparation of male genitalia**

Male genitalia have to be studied for identification of specimens. For preparation of male genitalia, the specimen was gently supported on a cork piece on its back and the abdomen detached from the thorax with the help of a sharp needle by pressing down at the junction of the two. The abdomen was then transferred into a cavity dish containing few milli litres of 10 per cent KOH and kept for overnight at room temperature. Abdomen was then transferred to another cavity dish containing water and digested soft tissues were pressed out with the help of a pair of blunt needles. The abdomen is rinsed twice or thrice in water to remove the potassium hydroxide remnants and then transferred to a glycerol drop on cavity

slide for further dissection and observations, which were made under stereoscopic microscope. The above treatment will render the entire abdomen completely transparent and will suffice in many cases to permit the study of genitalia. For more detailed examination and for illustrations, the male genitalia was dissected out under stereozoom binocular microscopic following technique given by Knight (1965). After study is over the dissected parts were placed inside the abdominal capsule, which was finally stored in a microvial with a drop of glycerine. The vial was stopperd with a cork and transfixed to the same pin which is holding the rest of the specimen.

3.2.5 **Illustrations**

Illustrations of genitalia parts were made by keeping them in a position by applying a very small quantity of ‘fevi’ stick gum at the bottom of the cavity slide before placing a glycerine drop on it. The genital structures were gently pressed after arranging them in desired orientation. The dissected male genital structures were further studied in detail with Olympus Trinocular Research Microscope and illustrations were made with the same microscope using drawing apparatus. For studying wing venation, wing mounts were prepared with DPX mountent. All drawings were made with pencil and inked later. The scales of magnification were indicated on right side of the paper which equals to 0.1 mm and indicated at right hand side of particular structure.

3.2.6 **Measurements**

Measurements of the specimens were made by standardized ocular micrometer placed in one eyepiece of the stereoscopic binocular microscopic. The

measurements of width of leafhopper and planthopper were taken across the compound eyes. The total length of the leafhopper and planthopper including the folded forewings were also taken.

3.3 **General structure of leafhopper and planthopper and terminology adopted**

In present investigations the terminology suggested by Blocker and Triplehorn (1985) and O'Brien and Wilson (1985) were followed for leafhoppers and planthoppers, respectively, in describing the different body parts.

3.3.1 **Terminology Adopted for Leafhopper**

3.3.1.1 **Head**

Head is divided into dorsal and facial aspects for descriptive purpose. Head in dorsal aspect consist of vertex with eyes located laterally. The vertex (or crown) is either pointed, subacute or rounded. A sulcus (coronal suture) is a median line or groove present on vertex. Leafhoppers usually have two ocelli that are located either on vertex or on face and may be close to or away from eyes. The face is defined as the entire cephalic aspect of the head. It is divided by lateral frontal sutures into the basal central area, clypeus (postclypeus or frontoclypeus) which is separated by transverse suture into a small area, clypellus (anteclypeus). The semi circular plates nearer to clypeus are known as lora and remaining lateral areas referred as genae. Genal margin may be sinuated and sometimes expanded beyond eyes and visible in dorsal aspect behind eyes. The antennae arise anterior to the eyes and consist of three segments *viz.*, basal scape, middle pedicel with a long thread like flagellum that may show marks of segmentation basally, with a ledge present

above. Mouthparts are typically hemipteran type and are not used for taxonomic purpose.

3.3.1.2 **Thorax**

Thorax consists of three segments pro, meso and meta-thorax and bears two pairs of wings and three pairs of legs. The pronotum, scutellum and scutal suture of the mesonotum can be seen from the dorsal side and are used for descriptive purpose. The length and width of pronotum, its shape, nature of margins, plain or carinate, texture or surface like striated or plain, flat or glabrous *etc.*, are used for description. The scutellum is triangular with a transverse suture in the middle and usually pointed with a linear extension posteriorly. The scutum is most useful character in describing species.

3.3.1.3 **Wings**

Macropterous (fully developed) or brachypterous (reduced) wing forms are present. Fore wings are thicker than the hind wings and these are opaque, hyaline or sub hyaline, may be uniformally coloured or with different colour patterns. The terminology of the forewing proposed by Young (1952) is adopted. The longitudinal veins in the wing are referred as radial, medial, cubital (claval) and vanal (anal) veins. The radial, medial and cubital veins delimit the apical and anteapical cells which vary in different genera. These are counted from innermargin and are referred as first, second, third and fourth apical cell; similarly starting from inner margin anteapical cells are referred as inner, middle and outer anteapical cells. At apex of the fore wing a submarginal vein separates the narrow membranous area from the apical cells which is known as appendix and it may be broad or narrow and

in some cases it may be absent. The hind wings are usually hyaline and uniform in different subfamilies and have not been used for classification of various taxa. The shape of the wings, the number of anteapical cells, apical cells, the shape of apical cells, the appendix, presence of additional cross veins and the pigmentation often form good characters for classification.

3.3.1.4 **Legs**

Each leg consists of typical parts but hind pair is different in having femora and tibiae elongated which enable the leafhoppers to jump. The shape, hair-covering and spinulation of the legs provide good characters for classification. Nature of fore tibia and presence or absence of setae, their nature, arrangement of spines at the apex of hind femora, structure of hind tibiae with setal arrangement referred as pectans, basal hind tarsomere, its structure and length in proportion to other leg parts and setal arrangement *etc*., have been used for distinguishing various taxa. The spines at the apex of hind femora have been expressed in a formula called posterior femoral setal pattern such as 2-2-1 or 2-1-1, which designates the number and arrangement of setae at the femoral apex by numbering each pair or individual setae in a sequence from distal end to proximal end.

3.3.1.5 **Abdomen**

The abdomen consists of eleven distinct segments. The first eight segments in male forms pregenital segments, ninth genital segment; tenth and eleventh form the anal tube which may be reduced in size and variously sclerotised. In females the eighth segment is also associated with genital segment. In male, amongst the pregenital segments the first and second sternites of males have apodemes which

are taxonomically important for species separation. The male genital segment (ninth abdominal segment) consists of dorsal tergite called the pygofer and the ventral sternite called valve. The subgenital plates are triangular being attached to the valve and articulated with pygofer basally. The Pygofer is incised dorsally in the middle to accommodate the anal tube. The pygofer serves as a clasper during copulation, while the subgenital plates serve the dual purpose of protecting the aedeagus and acting as accessory clasping organs. The shape of pygofer lobes, presence or absence of macro and microsetae, presence or absence of sclerotised appendages form important taxonomic characters. In males the internal genitalia consist of a pair of styles (parameres), a connective which has been regarded as basal piece of intromittent organ and the aedeagus. Accessory genital structures, paraphyses are of frequent occurrence. The connective may be fused or articulated with the base of aedeagus; 'Y' or 'U' shaped or linear with closely apposed arms. Styles, structures for clasping during copulation consist of a ventral arm, basal part, pre apical lobe and apophysis. The shape and variation in these parts are often regarded as distinguishing characters. The distal part may be variously modified and these differences may be diagnostic.

The aedeagus is the most consistently used character in leafhopper species differentiation. The aedeagus is typically articulated or fused with the apex of the connective. The aedeagus is free at its apex and consists of pre-atrium, an atrium *i.e.*, basal opening of the shaft through which enters the gonoduct; a dorsal apodeme, a process from dorsum of the atrium, and the shaft which is traversed by the gonoduct and opens externally through a opening known as gonopore. The aedeagus in some cases have two shafts with two gonopores. There may be various

processes called aedeagal processes on the aedeagus especially associated with shaft. Pair of accessory genital structure known as paraphyses are often present and these occur between the connective and base.

3.3.2 **Terminology Adopted for Planthopper**

For describing the different body parts the terminology suggested by O'Brien and Wilson (1985) was followed.

3.3.2.1 **Head**

The dorsal aspect of the head bounded posteriorly by the back of the head laterally by the compound eyes is referred as vertex. The frons is bordered laterally by carinae and is separated from the clypeus by the frontoclypeal suture. The frons may bear a median ocellus in those planthoppers that have three ocelli. A longitudinal carina (median carina) or a pair of carinae (inner carinae) may also be present on the frons. The beak is as in cicadellidae. The region between the lateral border of the frons and the compound eye is referred as gena, it contains a lateral ocellus. The clypeus consists of a proximal post clypeal , and distal anteclypeus which is separated by partial transclypeal suture. The labrum is small piece distal to anteclypeus. The compound eyes are large in almost all planthoppers. The antennae are situated ventral to the compound eyes and surrounded by an anterior cup-like extension of the gena and the lateral carina of the frons. The head may be variously modified. The cephalic extension is due to the elongation of the vertex and frons or may be an extension of the frons and clypeus.

3.3.2.2 **Thorax**

Thorax is three segmented *viz.,* pro, meso and meta thorax. It bears two pairs of wings and three pairs of legs. The pronotum is generally collar- like and extends laterally overlapping the reduced plural sclerites. Pronotum bears a dorsal longitudinal carinae and one or two pairs of variously shaped lateral longitudinal carinae. In dorsal view mesonotum is subpentagonal with a posteriorly directed triangular scutellum. A median longitudinal carina and one or two pairs of lateral carinae may also be present. The metanotum is obscured by the overlapping mesonotum and wings.

3.3.2.3 **Wings**

A pad like tegula present at the base of forewings. In delphacids venation is reduced to some extent. Major features in wing venation are whether the claval suture extends to the wing margin or ends before the wing margin and whether or not the apices of the forwings overlap. The veins in wings include Cu, M, R-Sc and the costa which arises before the basal cell. In the absence of non-marginal costa, there is precostal area. The hind wings are entirely covered by the forewings and the venation is generally reduced and usually hyaline.

3.3.2.4 **Legs**

Each leg consists of typical parts *viz.*, coxa, trochanter, femur, tibia and tarsus. The foretibia and midtibia are generally slender although some may be foliaceous and armed with spines. The metathoracic tibia may bear one to several teeth on the lateral aspect of the shaft and a row of teeth at the apex. Delphacids are charecterised by the presence of a moveable apur at the apex of both hind tibia. The

spur varies with shape from slender spike-like structure that lacks teeth to a flattened curved foliaceous structure with a row of small teeth on the lateral edge. The tarsus is three segmented.

3.3.2.5 **Abdomen**

Abdomen consists of eleven visible segments. Tergite one is reduced, two to eight are generally subrectangular and extended ventrolaterally, and the ninth segment forms a partial or complete capsule termed as pygofer. The tenth tergite forms the anal tube that often bears spines, and the eleventh is represented by the anal style. Anal tube and anal style serve as a dorsal cover for the genitalia. The anal tube is usually movable but may be fused to the pygofer. The male genitalia proved to be authentic diagnostic features useful for the identification of species. The pygofer forms a capsule that has other parts of male genitalia. The aedeagus is a sclerotised tube bearing an apical or subapical gonopore and may bear a number of teeth or spines the styles (parameres) are moveable, paired often plate like structures, which may bear spines or hooks. The parameres in some are greatly enlarged and seal off the genital chamber. The styles are attached to the aedeagus by a ‘Y’ or ‘T’ shaped movable connective. The female genitalia have been little used in planthopper taxonomy when compared to the structure of the male genitalia.

3.4 EVALUATION OF SOME NEW INSECTICIDES FOR MANAGEMENT OF LEAFHOPPERS AND PLANTHOPPERS IN RICE

An experiment was conducted at Agriculture college farm, Bapatla, Guntur district during 2008-2009. Details of experimentation are discussed here under.

3.4.1 **Details of Experimentation**

3.4.1.1 **Variety of the Crop**

A popular and commonly grown variety of rice, BPT-5204 (Samba Mahsuri) was selected for the present investigation.

3.4.1.2 **Rising of Nursery**

Dry seed nursery was raised by selecting required quantity of healthy seeds. The nursery was splash watered twice daily till the seedlings were taken out for transplanting. The nursery bed was fertilized with 1.5 Kg N, 0.5 Kg P_2O_5 and 0.5 Kg K_2O per 100m^2 area. No insecticidal treatments were given to the crop in nursery bed.

3.4.1.3 **Main Field Preparation**

The experiment area was dry ploughed twice with tractor drawn cultivator and puddled with power driven rotovator after letting in water into the field to obtain the required puddle for transplanting of rice seedlings and leveled uniformly.

3.4.1.4 **Layout**

After through puddling and scrupulous land leveling, the experiment was laid out in randomized block design replicated 3 times with 9 treatments including untreated check. Plots of 5×5 m^2 size were prepared for each treatment and false bunds erected around to prevent loss of fertilizers applied to each plot. To mitigate border effect on crop and pest incidence one meter buffer space was left out from the main bunds of field on all sides including between replications.

3.4.1.5 **Transplanting**

Thirty days old seedlings were transplanted on 28/08/2008. A spacing of 20×15 cm was adopted in between and within rows respectively and two seedlings were planted per hill. Gap filling was done a week after transplanting to ensure uniform plant stand in each treatment.

3.4.1.6 **Irrigation**

Water level of upto 2 cm was maintained in the experimental field upto tillering phase. Water level increased to 5 cm from post-tillering stage to dough stage. The field was completely drained ten days before harvesting.

3.4.1.7 **Weeding**

Hand weeding done at 20 and 40 DAT and there after whenever necessary to keep the plots weed free.

3.4.1.8 **Fertilizer Application**

The crop was fertilized with a dose of 80Kg N, 40Kg P_2O_5 and 30Kg K_2O and 50 Kg $ZnSO_4$ ha^{-1}. Nitrogen was applied in three and potash in two split doses where as total phosphorus and zinc was applied as basal dose.

3.4.2 **Preparation and Application of Insecticides**

The insecticides were applied as foliar spray when the population of green leafhopper, brown planthopper and white backed planthopper reached above economic threshold level. The quantity of each insecticides required to treat a plot was calculated based on the dose fixed per hectare and mixed with required quantity

of water to get desired dilution and sprayed with a hand compression knapsack sprayer. After every application of treatments the sprayer was thoroughly rinsed twice with water and used for further application.

3.4.3 **Collection of Data**

The green leafhoppers were identified by the light green coloured nymphs and green winged adults having a black spot on the forewings and black patch on the posterior margin of the wing. Similarly the brown planthopper was identified with the brownish nymphs and brownish adults. The white backed planthopper was identified with their yellow coloured nymphs and hyaline adults having white streak at the junction of forewings.

For estimation of leaf and planthopper populations selected hills were gently tapped and those falling into the water were counted. The data on population were recorded one day before (pretreatment data) and 1, 5, 10 and 15 days after imposing treatments. Population of both nymphs and adults of BPH, WBPH and GLH on ten randomly selected hills per treatment were recorded.

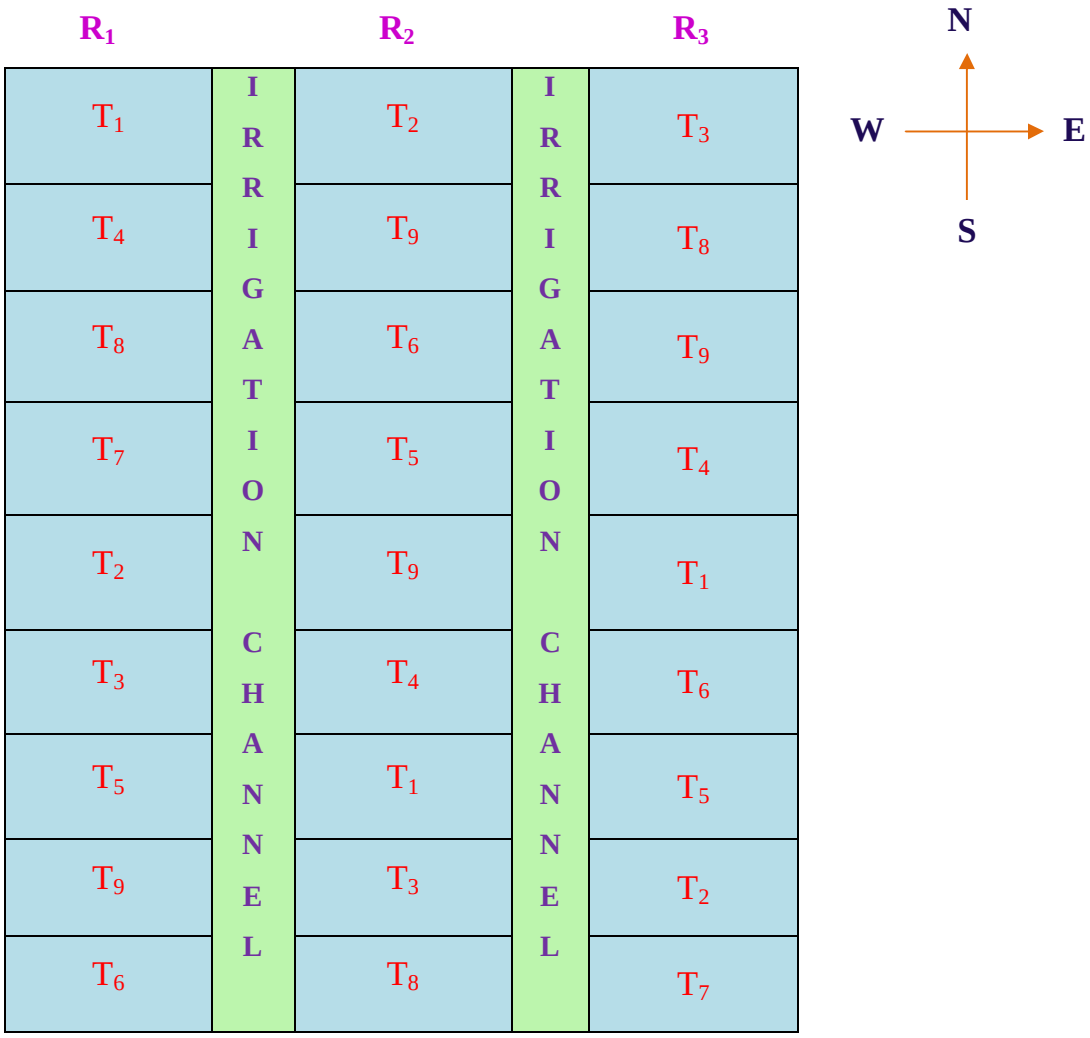
3.4.4 **Yield**

The data pertaining to yield per plot is obtained by manual harvesting and threshing of individual treatments and yield per ha is also calculated.

3.4.5 **Statistical Analysis**

The data generated was statistically analyzed. The per cent reduction over control was calculated in different treatments by using the modified Abbott's formula as given by Flemming and Ratnakaran (1985).

$$\text{Per cent population reduction} = \left[1 - \left(\frac{\text{Post treatment population in the treatment}}{\text{Pretreatment population in the treatment}} \times \frac{\text{Pretreatment population in the untreated check}}{\text{Post treatment population in the untreated check}}\right)\right] \times 100$$



Crop : Rice
Variety: BPT 5204
Spacing: 20×15cm^2
Treatments: 9(Nine)

Design: RBD
Plot size: 5 x 5 m (25m^2)
Replications: 3 (Three)

Fig. 1: Layout of the experimental field

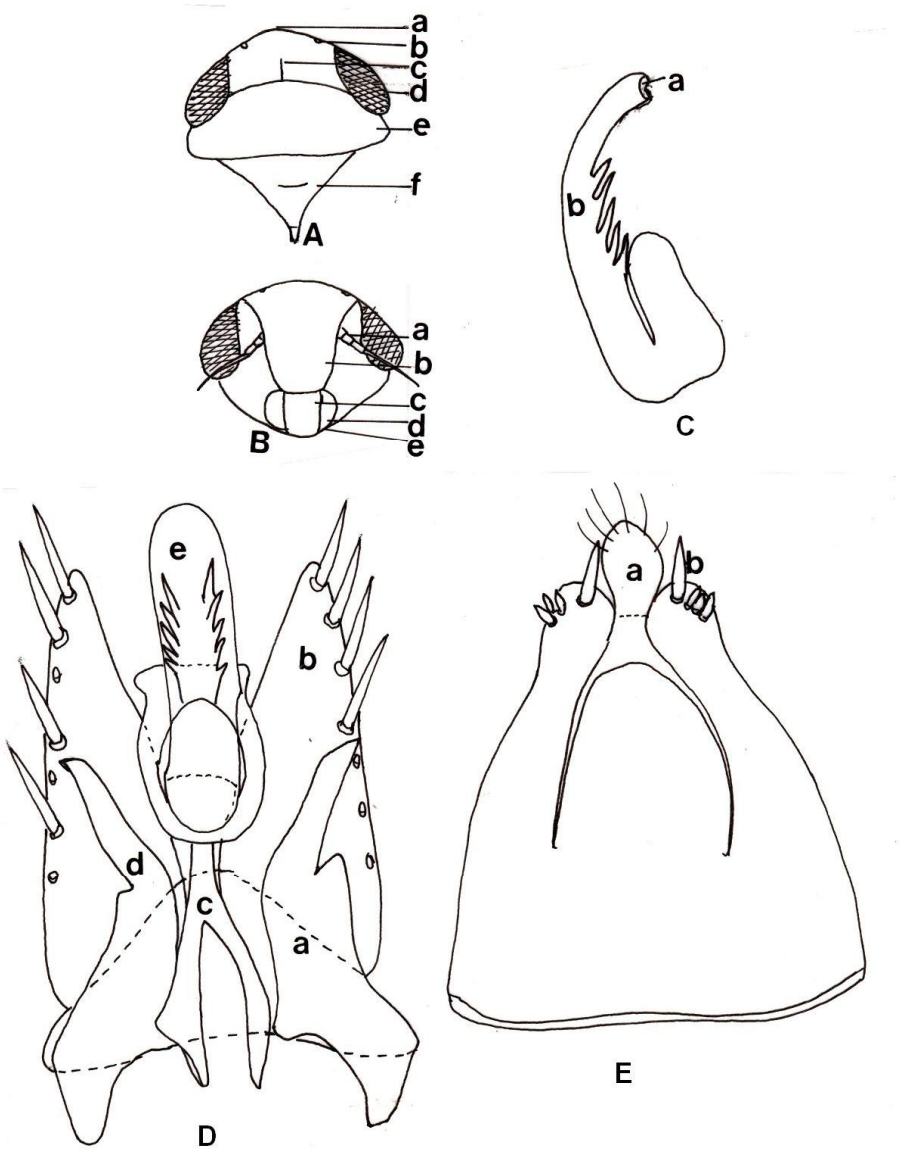


Fig 2A-E: Different body parts of a leafhopper

A. Head and Thorax, dorsal view: a. Vertex; b. Ocellus; c. Coronal suture; d. Eye; e. Pronotum; f. Scutellum.

B. Face: a. Antenna; b. Clypeus; c. Clypellus; d. Lorum; e. Gena.

C. Aedeagus, lateral view: a. Gonopore; b. Shaft.

D. Male genitalia (pygofer removed): a. Valve; b. Subgenital plate; c. Connective; d. Style; e. Aedeagus.

E. Pygofer, dorsal view: a. Anal tube; b. Setae.

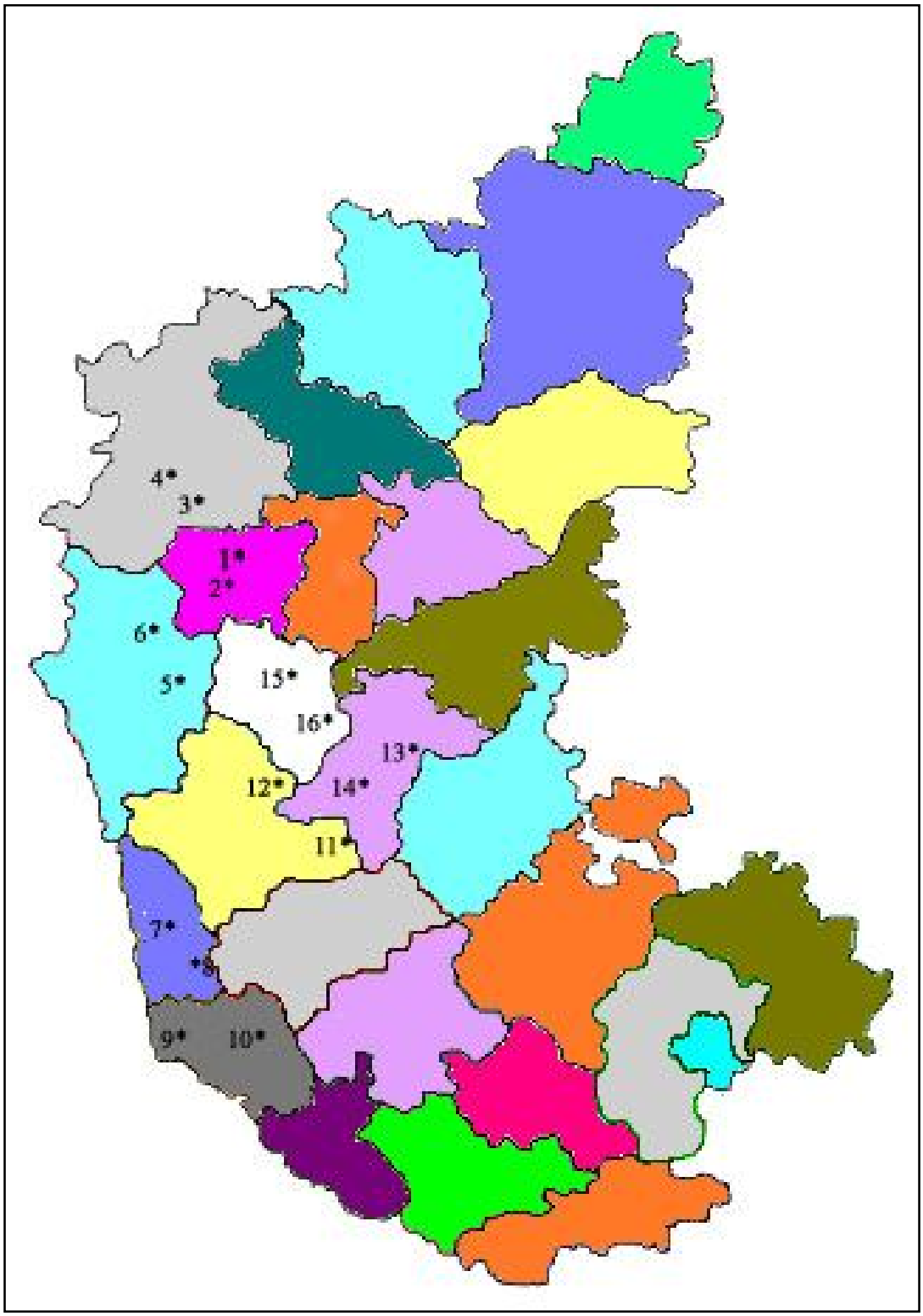


Fig 1: Map showing the areas surveyed for collection of leafhoppers and planthoppers fauna associated with rice ecosystems in costal and central Karnataka

Table 2: Particulars of insecticides used and their sources.

Sl. No.	Common Name	Trade Name	Formulation used	Dosage applied	Source of supply
1	Acephate	Lucid-75	75 WP	1.5 g/L	M/S Cheminova India Ltd.,Mumbai.
2	Thiamethoxam	Actara	25 WG	0.2 g/L	M/S Syngenta India Ltd., Mumbai.
3	Acetamiprid	Sharp	20 SP	0.2 g/L	M/S Insecticides India Ltd., Samba (J&K).
4	Emamectin benzoate	Proclaim	5 SG	0.45 g/L	M/S Syngenta India Ltd., Mumbai.
5	Buprofezin	Applaud	25 SC	1.6 ml/L	M/S Tata Rallis India Ltd., Mumbai.
6	Thiacloprid	Alanto	240 SC	0.1 g/L	M/S Bayer India Ltd., Mumbai.
7	Clothianidin	Dantop	50 WDG	0.06 g/L	M/S Nagarjuna Agrichem Ltd., Hyderabad.
8	Ethiprole	Curbex	10 SC	1.0 ml/L	M/S Bayer India Ltd., Mumbai.

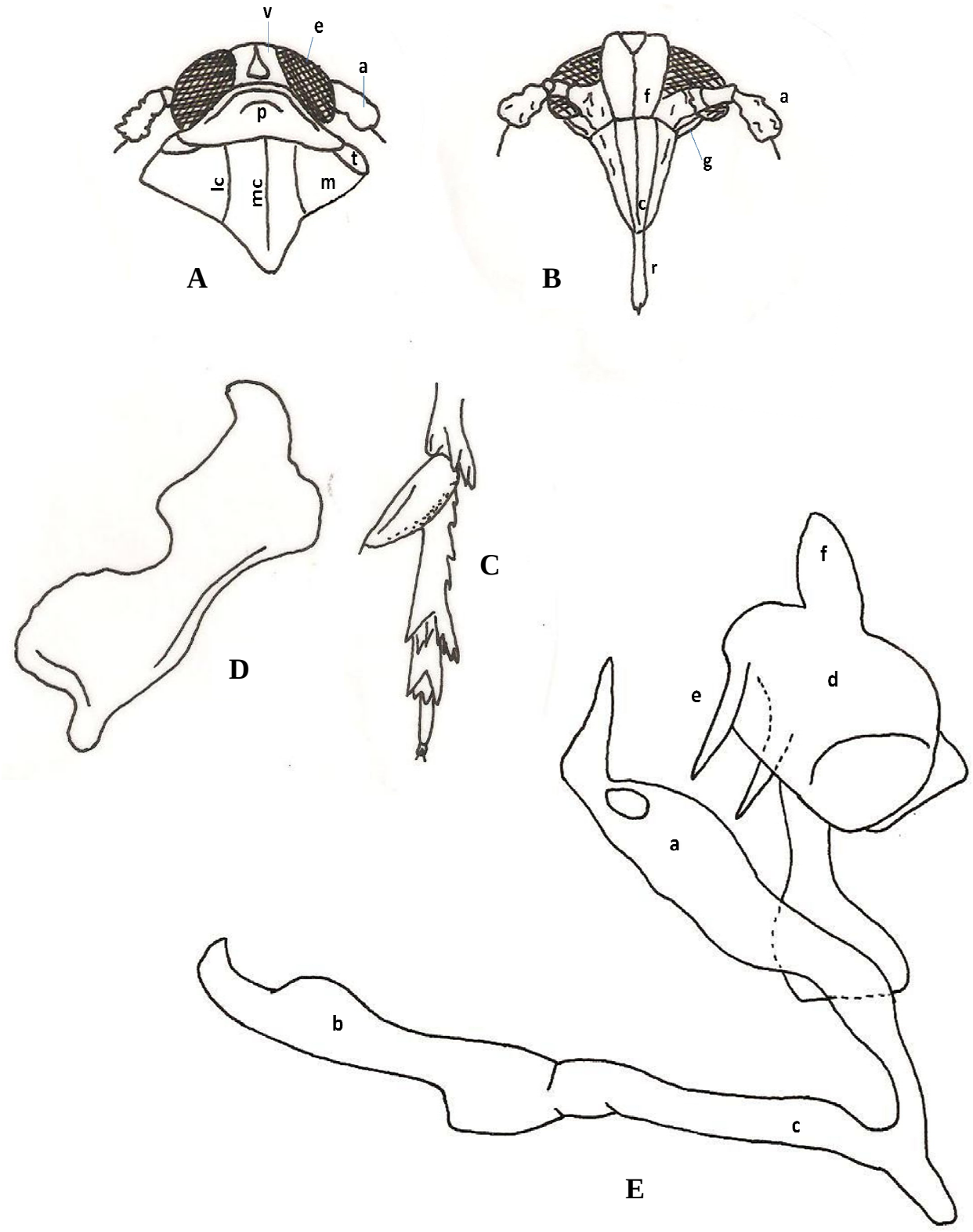


Fig 3A-E: Different body parts of a planthopper

A. **Head and Thorax, dorsal view:** v. Vertex; o. Ocellus; a. antenna; mc. median carina; lc. lateral carina; e. Eye; p. Pronotum;
B. **Face:** f. frons; a. antenna; g. gena; c. clypellus; r. rostrum
C. **Hind leg. D. Style. E. male genitalia, lateral view, dissected:** a. aedeagus; b. style; c. connective; d. anal tube; e. anal tube appendage; f. anal style

CHAPTER-IV

RESULTS

The present investigation titled as “Taxonomic studies on leafhopper and planthopper fauna associated with rice ecosystem and their management” was conducted during 2008-2009 at Agricultural College, Bapatla and Agricultural College Farm, Bapatla. The results of the present investigation are presented hereunder in different sections.

4.1.1 LEAFHOPPER SPECIES IDENTIFIED

In the present studies 20 species belonging to 11 genera under 8 tribes of the family Cicadellidae were identified in different rice growing districts of Karnataka which were furnished here under.

(I) Tribe Athysanini

1) *Banus* sp. nr. *consfuscus* (Pruthi)

2) *Exitianus indicus* (Distant)

3) *E. nanus* (Distant)

4) *Nephotettix virescens* (Distant)

(II) Tribe Chiasmusini

5) *Chiasmus alata* Pruthi

(III) Tribe Cicadellini

6) *Cofana spectra* (Distant)

7) *C. unimaculata* (Signoret)

(IV) Tribe Deltocephalini

8) *Deltocephalus* (*Recilia*) *distinctus* Motschulsky

9) *D.* (*R.*) *dorsalis* Motschulsky

10) *D.* (*R.*) *pruthii* Metcalf

(V) Tribe Erythroneurini

11) *Empoascanara indica* (Datta)

(VI) Tribe Hecalini

12) *Hecalus arucatus* (Motschulsky)

13) *H. pusae* Ramasubba Rao and Ramakrishnan

(VII) Tribe Macrostelini

14) *Balclutha incisa* (Matsumura)

15) *B. lucida* (Butler)

16) *B. pararubrostriata* Ramasubba Rao and Ramakrishnan

17) *B. rubrostriata* (Melichar)

18) *B. saltuella* (Kirschbaum)

19) *Cicadulina* (*Cicadulina*) *bipunctata* (Melichar)

(VIII) Tribe Stenometopiini

20) *Doratulina indra* (Distant)

4.1.2 KEY TO THE LEAFHOPPERS ASSOCIATED WITH RICE ECOSYSTEMS OF CENTRAL AND COASTAL KARNATAKA.

1. Mostly larger species clypeus and clypellus swollen; pale green or white species ------2

--- Mostly smaller species, clypeus and clypellus not swollen with various colouring patterns ------3

2. Larger species, pale whitish brown; vertex with four black spots, two central at base and apex and the other two on the lateral margins of face. The central black spot at the margin of face and vertex is distinct (Plate 4B)

----------***Cofana spectra*** **(Distant)**

---- Small than *C. spectra*, pale yellowish white, vertex without a distinct central dark spot at the margin. Two large spots on the anterior margin and two very small spots on disc (Plate 5B) ---------***C. unimaculata*** **(Signoret)**

3. Vertex sub-angularly acute to foliaceous, anterior margin usually with a dorsal ridge broadly triangular to round in dorsal view ------4

---- Vertex not with above characters -------5

4. Yellowish green with sanguineous faceae forming inverted 'V' on vertex, two concentric parabolic lines on pronotum, three longitudinal lines on scutellum, forewings yellowish green with five veins; aedeagus with two pairs of terminal processes which are subequal in length (Fig. 16a & Plate 6B) --------***Hecalus arucatus*** **(Motschulsky)**

---- Without sanguineous faceae; Aedeagus long, uniformly tapering distally, with wavy lateral margins; a pair of laterally directed processes, with tooth like projection on each side of shaft below the processes (Fig. 17 a, b & Plate 6C) ------***H. pusae*** **Rao and Ramakrishnan**

5. Aedeagus and connective are fused --------6

--- Aedeagus and connective are articulated --------8

6. Forewings with many accessory cross veins on clavus and corium, outer anteapical cell narrowed into two or more cells; aedeagal shaft slender,

tubular, curved in lateral aspect, gradually tapering towards apex (Fig. 14a, b & Plate 5C) -------***Deltocephalus (Recilia) pruthii*** **(Distant)**

---- Forewings without accessory cross veins outer anteapical cells not divided

------7

7. Fore wing with zig-zag reddish brown markings; aedeagal shaft wider basally and tappering gradually with acute apex; abdominal sternal apodemes with blunt apex (Figs. 13a, b, e & Plate 5B)

------***D. (R.) dorsalis*** **Motshulsky**

--- Anterior margin of vertex with a black transverse stripe spotted with white; subgenital plates as wide as or wider than inner margin, rounded apically; style with apophyses curved laterally; aedeagus shaft more or less of uniform width (Figs. 12a,b,e & Plate 5A) --------- ***D.(R.) distinctus*** **Motschulsky**

8. Presence of one or two spots on vertex ---------9

--- Vertex devoid of any spots; may be with bands or clear--------11

9. Vertex, pronotum and scutellum yellow, vertex with a large central black spot, Subgenital plates wider at middle, slightly narrowed towards base, connective 'Y' shaped; aedeagal shaft simple tubular, without any processes, broader at base, abruptly narrowed towards apex (Figs. 15a,b,c,f & Plate 6A) ------- ***Empoascanara indica*** **(Datta)**

---- Presence of two spots on vertex ----------10

10. Vertex pale yellowish gray colour with two prominent black spots between the anterior margins of eyes, two black spots are also present on face a little before its apex, Subgenital plates basally broad and gradually narrowing to apex, connective arms 'U' shaped; aedeagus wider at base deeply bent in the middle, shaft slightly curved apically (Figs. 24a, b, e & Plate 10A)

----------***Doratulina indra*** **(Distant)**

---- Vertex with a pair of round black spot on the anterior margin, Pygofer with an elongate dorsal process with curved subapically spines; aedeagus shaft cylindrical ‘C’ shaped laterally (Figs. 23a,b,e & Plate 9B)

---- ***Cicadulina (Cicadulina) bipunctata*** **(Melicher)**

11. Opaque green coloured leafhoppers, vertex without any black markings, face blackish. Fore wings with a black patch which does not touch the claval region, aedeagus with four to five pairs of spines (Figs. 8a,c & Plate 3B)

------ ***Nephotettix virescens*** **(Distant)**

---- Forewings without a black patch green or brown leafhoppers -------12

12 Colour dull brown with various pattern of dark brown or black markings aedeagus simple, without lateral paraphyses and spines --------13

---- Colour maybe green or may be red, if red pale or dark reddish longitudinal stripes run upto posterior margin of vertex and scutellum, clavus and adjacent cells in basal half of forewing pale or dark reddish --------14

13. Pygofer with two brown or black spines, spine two much thicker and shorter than spine one (Fig. 6a & Plate 1B)

-------- ***Exitianus indicus*** **(Distant)**

---- Pygofer with four to seven brown or black spines and all the spines are more or less uniform thickness (Fig. 7a & Plate 2B)

--------***Exitianus nanus*** **(Distant)**

14. Green or light green or pale green coloured leafhoppers ---------16

---- Dark red or pale reddish green coloured leafhoppers ---------15

15. Pale reddish leafhoppers, pygofer process bifurcated, branches not hooked, directed caudad (Fig. 21f & Plate 8B)

----- ***Balclutha rubrostriata*** **(Melichar)**

--- Dark reddish leafhoppers, Pygofer processes bifurcated, branches hooked, dorsal one directed ventrad and ventral one directed dorso-caudad (Fig. 20f & Plate 8A)

----- ***Balclutha pararubrostriata*** **Ramasubba Rao and Ramakrishnan**

16. Aedeagus with three pairs of basal processes or projections (Figs. 18a, b & Plate 7A) -------***Balclutha incisa*** **(Matsumura)**

---- Aedeagus without process or projections simple and filamentous ------17

17. Mostly smaller species, white or pale green coloured, connective with stem approximately as long as the length of the arms aedeagus with basal apodemes moderately long (Figs. 22a, b & Plate 9A)

------ ***Balclutha saltuella*** **(Kirschbaum)**

---- Medium sized species, connective stem more or less equal to length of arms aedeagus simple, shaft elongated cylindrical, curved dorsally and then anteriorly (Figs. 19a, b & Plate 7B)

------- ***Balclutha lucida*** **(Butler)**

4.1.3 DESCRIPTION OF DIFFERENT LEAFHOPPER SPECIES

Banus sp. **nr.** ***confuscus*** **(Pruthi)**

(Figs. 5 (a-e) & Plate 2A)

Colour

Greyish with brownish maculations on vertex and pronotum. Fore wings with distinct brown maculae.

External morphology

Head as wide as pronotum, vertex medially sulcate; shorter than pronotum with ocelli on anterior margin; clypeus narrower than clypellus which is wider at apex; genae sinuated below compound eye. Fore wings subhyaline with four apical and three anteapical cells and appendix well developed.

Male genitalia

Pygofer longer than its height in lateral view with marginal and submarginal macro and microsetae. Valve broadly triangular. Subgenital plates long, broader at base and abruptly narrowed to apex with long hair like microsetae all over and macrosetae basally. Styles with apophyses strongly arched and with sharply pointed apex. Connective long, arms as long as stem and bifurcated at apex. Aedeagus with a pair of long paraphyses arising from atrial base; shaft tubular, shorter than paraphyses, and with apical gonopore.

Measurements

The total length including forewings 1.05 (1.04 - 1.06) mm, width across the compound eyes 0.87 (0.86 - 0.88) mm.

Specimens studied

1 male, 1 female, Shikaripur, rice, 5. XII. 2008, Shashank P R; 2 males, 1 female, Badravathi, rice, 5. XII. 2008, Shashank P R.

***Exitianus indicus* (Distant)**

(Figs. 6 (a-b) & Plate 2B)

Athysanus indicus Distant, 1908: 344

Athysanus atkinsoni Distant, 1908: 12

Exitianus indicus (Distant) Ross, 1968

Exitianus coronatus (Distant) Ross, 1968

} Synonymised by Rao, 1988

Exitiantus ootacamundus (Distant) Ross, 1968

Colour

A black band between compound eyes with a yellowish brown body.

External morphology

Head as wide as pronotum. Vertex moderately acute with a median coronal suture. Ocelli located on anterior margin of vertex away from the eyes by their own diameter. Clypellus slightly narrower towards vertex and extended upto the margins of genae. Pronotum wider than long. Forewings elongate, subhyaline with four apical and three anteapical cells and appendix wider**.**

Male genitalia

Pygofer with two conspicuous dark brown or black spines along the apical margin, upper spine is longer than lower spine and is wider and short. Subgenital plates narrow, triangular, with uniseriate macrosetae. Valve triangular in shape and wider than long. Connective 'Y' shaped, arms more or less equal to its stem; styles with a sharp apophysis and distinct preapical lobe; aedeagus simple, curved having an articulation between shaft and base, apex notched; gonophore large and subapical.

Measurements

Total length including forewings 4.34 (4.21 - 4.48) mm, width across the compound eyes 1.3 (1.25 - 1.36) mm.

Specimens studied

6 males, 5 females, Mugad, rice, 2. XII. 2008, Shashank P R; 2 male, 4 females, Dharwad, rice, 30. XI. 2008, Shashank P R; 6 males, 5 females, Kittur, rice, 2. XII. 2008, Shashank P R; 2 males, Sirsi, rice, 3. XII. 2008, Shashank P R; 3 females, Shikaripur, rice, 5. XII. 2008, Shashank P R; 1 male, Davangere, rice, 7. XII. 2008, Shashank P R; 2 males, 7 females, Mangalore, rice, 26. I. 2009, Shashank P R; 3 males, 5 females, Udupi, rice, 27. I. 2009, Shashank P R; 3 males, 1 female, Bantval, rice, 29. I. 2009, Shashank P R.

***Exitianus nanus* (Distant)**

(Figs. 7 (a-b) & Plate3A)

Athysanus nanus Distant, 1908

Athysanus insularis Distant, 1908

Athysanus simillimus Matsumura, 1914 Ross, 1968: 7

Euscelis vulnerans Bergevin, 1925

Exitianus nanus (Distant)

Colour

Stramineous with a pale black band between compound eyes on the vertex. A pair of conspicuous black spots present at the base of scutellum slightly below the posterior margin.

External morphology

Head as wide as or slightly wider than pronotum; vertex subacute with a median coronal suture. Ocelli located on anterior margin of vertex away from the eyes by their own diameter. Clypellus slightly narrower towards vertex and extend upto the margin of genae. Pronotum wider than long. Tegmina elongate, subhyaline, with four apical and three anteapical cells. Appendix wider.

Male genitalia

Pygofer with four dark brown and black spines along apical margin which are more or less equal in size. Subgenital plates elongated, narrow with marginal and submarginal macrosetae. Valve triangular in shape and longer than wide. Connective 'Y' shaped, arms more or less equal. Styles with sharp apophyses and distinct preapical lobes. Aedeagus simple, slightly curved having articulation between base and shaft, gonopore large and subapical.

Measurements

The total length including forewings 3.83 (3.47 - 4.20) mm, width across the compound eyes 1.13 (1.11 - 1.15) mm.

Specimens studied

1 male, Mugad, rice, 2. XII. 2008, Shashank P R; 1 male, 1 female, Dharwad, rice, 30. XI. 2008, Shashank P R; 2 males, 6 females, Kittur, rice, 2. XII. 2008, Shashank P R; 2 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 1 male, 3 females, Shikaripur, rice, 5. XII. 2008, Shashank P R; 2 male, Davangere, rice, 7. XII. 2008, Shashank P R; 1 male, 2 females, Mangalore, rice, 26. I. 2009, Shashank P R; 2 males, 1 female, Udupi, rice, 27. I. 2009, Shashank P R.

***Nephotettix virescens* (Distant)**

(Figs. 8 (a-d) & Plate 3B)

Selenocephalus virescens Distant, 1908

Cicada bipunctata Fabricius, 1803

Nephotettix bipunctatus (Fabricius) Distant, 1908

} Ghauri, 1971a: 484

Nephotettix impicticeps Ishihara and Kawase, 1968.

Colour

Yellowish green, vertex without any black markings, face blackish. Fore wings with a black patch which does not reach the claval region, apical third black in males.

External morphology

Head as wide as pronotum, vertex moderately acute with a median suture. Ocelli located on the anterior margin of vertex; clypeaus long at base and gradually narrowed towards apex, clypellus long extending beyond the genae at apex. Forewings subhyaline with four apical and three anteapical cells with broad appendix.

Male genitalia

Pygofer broader at the base and gradually narrowed, apex with few black spines and marginal hair like setae. Valve triangular and broader at base. Subgenital plates broader at base and gradually narrowed to an acute apex with submarginal macrosetae. Connective with stem longer than arms and broader and notched at apex. Styles robust highly sclerotised with longer apophyses, apex blunt. Aedeagus with a pair of lateral paraphyses, dorsal surface elongate sclerotized with five pairs of spines laterally and directed towards apex; gonopore apical.

Measurements

The total length including forewings 4.95 (4.70 - 5.2) mm, width across the compound eyes 1.45 (1.38 - 1.53) mm.

Specimens studied

16 males, 24 females, Mugad, rice, 2. XII. 2008, Shashank P R; 14 male, 25 females, Dharwad, rice, 30. XI. 2008, Shashank P R; 13 males, 19 females,

Khanapur, rice, 2. XII. 2008, Shashank P R; 3 males, 20 females, Kittur, rice, 2. XII. 2008, Shashank P R; 18 males, 21 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 8 male, 10 females, Yellapura, rice, 4. XII. 2008, Shashank P R; 18 male, 12 females, Shikaripur, rice, 5. XII. 2008, Shashank P R; 16 males, 30 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 16 male, 10 females, Davangere, rice, 7. XII. 2008, Shashank P R; 11 males, 18 females, Haveri, rice, 6. XII. 2008, Shashank P R;6 males, 5 females, Mangalore, rice, 26. I. 2009, Shashank P R; 9 males, 6 females, Udupi, rice, 27. I. 2009, Shashank P R; 3 males, 12 females, Bantval, rice, 29. I. 2009, Shashank P R.

***Chiasmus alata* Pruthi**

(Figs. 9 (a-e) & Plate 4a)

Chiasmus alata Pruthi, 1934: 23

Colour

Brownish, with black spots on the anterior margin of vertex. A pair of black spots on the pronotum near compound eyes.

External morphology

Head as wide as or slightly wider than pronotum . Vertex subacute slightly shorter than the width between eyes with a median suture. Ocelli black and present on the posterior part of vertex. Clypellus long extended upto the lower margins of

genae. Tegmina subhyaline with four apical and three anteapical cells and with broader appendix.

Male genitalia

Pygofer broader than height in lateral view with marginal and submarginal microsetae posteriorly. Subgenital plates triangular shorter than pygofer, with marginal microsetae. Connective 'Y' shaped, stem with notched apex, the arms are very close over lapping each other. Styles with claw like apophyses. Aedeagus with a rounded apex and big apical gonopore.

Measurements

The total length including forewings 3.2 (3.1 - 3.3) mm, width across the compound eyes 0.79 (7.77 - 7.81) mm.

Specimens studied

2 males, 1 female, Sirsi, rice, 3. XII. 2008, Shashank P R; 1 male, 1 female, Shikaripur, rice, 5. XII. 2008, Shashank P R; 2 male, Badravathi, rice, 5. XII. 2008, Shashank P R.

***Cofana spectra* (Distant)**

(Figs. 10 (a-d) & Plate 4B)

Tettigoniella spectra Distant, 1908: 211

Cofana spectra (Distant) Young, 1979:1-21.

Colour

Pale yellowish white. Vertex with a black spot towards posterior margin and a central one present at the margin of face and vertex, two spots on the margin near eyes and located more towards the face, muscle impression distinct. Veins of tegmina darker.

External morphology

Head wider than pronotum. Vertex shorter than pronotum with distinct ocelli on the basal portion of vertex. Clypeaus and clypellus are swollen. Tegmina subhyaline with four apical and three anteapical cells and appendix is present. Sternal abdominal apodemes present.

Male genitalia

Pygofer broader than its length in lateral view with submarginal macrosetae. Subgenital plates broader at base and gradually narrowed to an acute apex with marginal macrosetae. Connective with stem short, arms broad, strong and extended laterad. Aedeagus broad at the base gradually narrowed to a blunt apex in dorsal view. It is ‘C’ shaped with the caudal end bifurcated in lateral view.

Measurements

The total length including forewings 10.75 (10.39 - 11.11) mm, width across the compound eyes 2.25 (2.0 - 2.5) mm.

Specimens studied

2 males, 1 female, Kittur, rice, 2. XII. 2008, Shashank P R; 5 males, 4 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 2 male, 6 female, Shikaripur, rice, 5. XII. 2008, Shashank P R; 2 male, 3 female, Badravathi, rice, 5. XII. 2008, Shashank P R.

Cofana unimaculata (Signoret)

(Figs. 11 (a-d) & Plate 4C)

Tettigonia unimaculata (Signoret) } Synonymised by Young (1979)

Kola mimica Distant

Cofana unimaculata (Signoret) Young, 1979:1-21.

Colour

Pale yellowish white, black spot on vertex, muscle impressions distinct. Tegmina with darker veins.

External morphology

Head wider than pronotum. Vertex shorter than pronotum with distinct ocelli on the basal portion of vertex. Clypeus and clypellus are swollen. Tegmina, subhyaline with four apical and three anteapical cells and with appendix.

Male genitalia

Pygofer broader than its length in lateral view with macrosetae apically and hair like setae all over except in the apical portion. Subgenital plates broader at the base abruptly narrowed at the basal one third and then gradually narrowed with submarginal macrosetae and marginal hair like setae. Styles small, connective stem short with a notch at apex, arms strong, long and extended laterad. Aedeagus broader at base and then uniform sided, caudal end bifurcated and gonopore apical.

Measurements

The total length including forewings 7.66 (6.22 - 9.10) mm, width across the compound eyes 1.46 (1.43 - 1.49) mm.

Specimens studied

3 males, 8 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 5 male, 9 female, Shikaripur, rice, 5. XII. 2008, Shashank P R.

***Deltocephalus (Recilia) distinctus* Motschulsky**

(Figs. 12 (a-e) & Plate 5A)

Deltocephalus distinctus Motschulsky, 1859: 112

Deltocephalus distinctus Motschulsky. Dash and Viraktamath, 1998: 27.

Colour

Stramineous yellow. Vertex with a black patch on anterior margin, three distinct white patches in between. Blackish face with pale strips across. Forewings have distinct black spot.

External morphology

Head wider than pronotum. Vertex subacute as long as its width between the eyes, a median sulcus is seen extending more than half of the vertex from the base. Ocelli located close to the eyes. Pronotum wider than its length. Tegmina subhyaline with four apical and three anteapical cells, inner anteapical cells open behind and with appendix.

Male genitalia

Pygofer broader basally in lateral view with dense macrosetae apically. Valve triangular, wider than long. Subgenital plates with marginal macrosetae and apical microsetae, and is wider at middle with strongly convex lateral outer margin and straight inner margin. Styles robust, apophyses thumb like. Connective longer than aedeagus and is fused. Aedeagal shaft gradually tapering and pointed at apex then slightly curved dorsocaudally, gonopore large and subapical.

Measurements

The total length including forewings 3.67 (3.45 - 3.90) mm, width across the compound eyes 0.98 (0.92 - 1.05) mm.

Specimens studied

1 male, 1 female, Honnalli, rice, 7. XII. 2008, Shashank P R; 3 males, Dharwad, rice, 30. XI. 2008, Shashank P R; 2 males, 6 females, Khanapur, rice, 2. XII. 2008, Shashank P R; 2 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 1 male, 3 females, Yellapura, rice, 4. XII. 2008, Shashank P R; 1 female, Davangere, rice, 7. XII. 2008, Shashank P R; 2 males, 1 female, Mangalore, rice, 26. I. 2009, Shashank P R; 1 male, 3 females, Udupi, rice, 27. I. 2009, Shashank P R.

Deltocephalus (Recilia) dorsalis **Motschulsky**

(Figs. 13 (a-e) & Plate 5B)

Deltocephalus (Reciia) dorsalis Motschulsky, 1859: 14.

Deltocephalus (Recilia) dorsalis Motschulsky, Dash and Viraktamath, 1998: 27.

Colour

Pale yellowish brown, tegmina with distinct reddish brown zig-zag markings, hence the name zig zag leafhopper.

External morphology

Head more or less equal in width of pronotum. Vertex moderately acute, shorter than its width between the eyes, a median sulcus is seen extending more than half of the length of the vertex from base. Ocelli located on the anterior margins of vertex very close to the eyes. Clypellus parallel sided and on line with the edge of

genae. Pronotum wider than its length. Tegmina subhyaline with four apical cells and three anteapical cell and with appendix.

Male genitalia

Pygofer longer than its height in lateral view with apical macrosetae. Subgenital plates wider basally, gradually narrowed towards apex, outer margins convex, with marginal macro and microsetae. Styles robust, apophyses slender and finger like. Connective longer than aedeagus and fused. Aedeagal shaft wider basally, tappering gradually with acute apex and gonopore subapical.

Measurements

The total length including forewings 3.82 (3.69 - 3.96) mm, width across the compound eyes 1.05 (1.04 - 1.07) mm.

Specimens studied

8 males, 4 females, Mugad, rice, 2. XII. 2008, Shashank P R; 11 males, 1 females, Khanapur, rice, 2. XII. 2008, Shashank P R; 2 males, 10 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 9 male, 2 females, Shikaripur, rice, 5. XII. 2008, Shashank P R; 16 males, 10 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 11 male, 10 females Davangere, rice, 7. XII. 2008, Shashank P R; 2 males, 8 females, Haveri, rice, 6. XII. 2008, Shashank P R; 5 males, 5 females, Mangalore, rice, 26. I. 2009, Shashank P R; 8 males, 2 females, Udupi, rice, 27. I. 2009, Shashank P R; 2 males, Bantval, rice, 29. I. 2009, Shashank P R.

Deltocephalus (Recilia) pruthii Metcalf

(Figs.14 (a-e) & Plate 5C)

Deltocephalus notatus Pruthi, 1936: 128

Deltocephalus pruthii Metcalf, 1967: 1173

Deltocephalus (Recilia) pruthii Dash and Viraktamath, 1998: 22

Colour

Pale brown, ochraceous. Vertex pale brown, with a row of black minute but well defined markings at the anterior margin. Pronotum greyish ochraceous, with irregular row of minute black markings near the anterior margin.

External morphology

Vertex longer than the breadth between eyes. Ocelli marginal and away from the eyes. Pronotum almost as long as vertex. Fore wings with many accessory cross veins both on coruim or clavus. Abdominal cross veins at proximal part of fore wing makes the venation reticulate. Sternal apodemes poorely developed.

Male genitalia

Pygofer twice as long as height. Valve wider than long with convex lateral margin. Subgenital plates triangular, lateral margin convex with a few strong marginal hairs. Apophysis of style slender, curved apically, and acutely pointed.

Aedeagus rather uniform width in lateral aspect, slightly curved, apically rounded except for acutely pointed ventral margin which extends beyond gonopore.

Measurements

The total length including forewings 3.23 (3.22 - 3.24) mm, width across the compound eyes 0.67 (0.66 - 0.68) mm.

Specimens studied

5 male, 2 females, Shikaripur, rice, 5. XII. 2008, Shashank P R; 1 male, 3 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 1 male, 1 female, Davangere, rice, 7. XII. 2008, Shashank P R.

***Empoascanara indica* (Datta)**

(Figs 15 (a - f) & Plate 6A)

Zygina indica Datta, 1969:391

Empoascanara indica (Datta, 1969) Dworakowska and Viraktamath, 1975:527

Zygina sindhensis Ahmed. Dworakowska and Viraktamath, 1975:527 (Synonymised).

Zygina unipunctata Ramakrishnan and Menon, 1974, 447: Dworakowska, 1979:149 (Synonymised).

Colour

Vertex, pronotum and scutellum yellow, vertex with a large central black spot. Abdomen black and the fore wings pale grey, transparent without any other markings.

External morphology

Head as wide as or slightly broader than pronotum. Vertex subacute, smaller than its width between the eyes, median sulcus seen clearly. Ocelli present on face away from the eyes. clypellus wider at base and gradullay narrowed to apex, extending to margins of genae. Forewings subhyaline with four apical cells. Anteapical cells and appendix are absent. Hindwings hyaline with two apical cells.

Male genitalia

Pygofer lobe more or less triangular shaped, broader at base and narrowed towards apex, with its dorsomesal processess curved, rounded at base and gradually narrowed towards apex; microsetae scattered all over the apical half. Subgenital plates wider at middle, slightly narrowed towards base and apex, apex obtusly rounded mesalconvex, microsetae scattered all over. Styles long with its outer margin bilobed in middle, inner margin straight, apical extension broadened at apex obliquely truncated, cephalic end of styles shorter than caudal part which is gradually narrowed. Connective more or less 'Y' shaped, arms longer than its stem, joined by the membrane ay base. Aedeagus with its shaft simple tubular,

without any processes, broader at base, abruptly narrowed towards apex and gonopore subapical.

Measurements

The total length including fore wings 2.5 (2.55 - 2.71) mm, width across the compound eyes 0.52 (0.50 - 0.54) mm.

Specimens studied

1 male, 2 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 1 male, Davangere, rice, 7. XII. 2008, Shashank P R; 2 male, 2 females, Haveri, rice, 6. XII. 2008, Shashank P R; 2 males, 1 female, Mangalore, rice, 26. I. 2009, Shashank P R.

***Hecalus arcuatus* (Motschulsky)**

(Figs. 16 (a-e) & Plate 6B)

Aceocephalus arcuatus Motschulsky, 1859: 15

Thomsoniella arcuata Distant, 1908: 280

(Tettigonia kalidasa Kirk)

Parabolocratus arcuatus Distant, 1918: 32

(Thomsoniella arcuata (de Motcshulky)

(Linnovuoriolla arcuata (de Motschulsky) Evans, 1966: 134

Varta moshiensis Rao, 1973: 96 Syn. Nov

Hecalus arcuatus (de Motschulsky) Rao, 1989: 7

Colour

Yellowish green with sanguineous faceae forming inverted 'V' on vertex, two concentric parabolic lines on pronotum, three longitudinal lines on scutellum. Forewings yellowish green with 5 veins sanguneious, apical 1/3 light brown with faint white spots in apical and anteapical cells, a dark spot at the tip of clavus and two spots on costal margin.

External morphology

Head is wider than pronotum. Vertex subangularly produced and broadly triangular, shorter than pronotum, a median sulcus is seen extending upto the inverted ‘V’ shaped marking. Ocelli located on the anterior margins of vertex on lateral side close to the eyes. Genae sinuated below the eyes. Forewings subhyaline with four apical cells and three anteapical cells, inner anteapical cell open basally, and appendix narrow.

Male genitalia

Pygofer lobe subacute apically and heavily bristly in posterior half. Valve broadly triangular. Subgenital plates elongated, broader at base, and abruptly narrowed apically, submarginal macrosetae all along except at base and apex, microsetae apically. Styles shorter and broader basally, apophyses thumb like. Connective short inverted ‘Y’ shaped and stem slightly shorter than its arms.

Aedeagus with two pairs of terminal processes which are subequal in length, shaft tubular, dorsal apodeme long, gonopore subapical.

Measurements

The total length including forewings 5.25 (5.0 - 5.5) mm, width across the compound eyes 1.38 (1.35 - 1.42) mm.

Specimens studied

3 males, 1 female, Khanapur, rice, 2. XII. 2008, Shashank P R; 2 males, 1 female, Sirsi, rice, 3. XII. 2008, Shashank P R; 2 males, 1 female, Yellapura, rice, 4. XII. 2008, Shashank P R; 2 male, 1 female, Shikaripur, rice, 5. XII. 2008, Shashank P R.

Hecalus pusae Ramasubba Rao and Ramakrishnan

(Figs. 17 (a-e) & Plate 6C)

Hecalus pusae Rao and Ramakrishnan, 1990a : 385-397.

Colour

Stramineous.

External morphology

Vertex subangularly acute to foliaceous; anterior margin usually with a dorsal ridge; broadly triangular to rounded in dorsal view. Eyes with two reddish lines. Fore wings with a black spot at the end of clavus. Ocelli on margin, next to

compound eye. Margin of eye below gena strongly sinuate. Pronotum as wide as or wider than head and carinate laterally. Fore wings with a black spot at the end of clavus.

Male genitalia

Aedeagus long, uniformly tapering distally, with wavy lateral margins; a pair of laterally directed processes, with tooth like projection on each side of shaft below the processes.

Specimens studied

2 males, 1 female, Mugad, rice, 2. XII. 2008, Shashank P R; 2 males, Khanapur, rice, 2. XII. 2008, Shashank P R.

***Balclutha incisa* (Matsumura)**

(Figs. 18 (a-e) & Plate 7A)

Gnathodus incius Matsumura, 1902 : 358

Balclutha hortensis Lindberg 1948, Linnavuori, 1975 : 631.

Balcutha incisa (Matsumura). Evans, 1977 : 83-125.

Balclutha incisa (Matsumura). Sharma and Badan, 1985 : 152.

Eugnathodus indica Pruthi. Knight, 1987 : 1206

Balclutha incisa (Matsumura). Rao and Ramakrishnan, 1990b: 68

Balclutha incisa (Matsumura). Webb and Vilbaste 1994 : 64.

Colour

Yellowish to greenish yellow in colour.

External morphology

Head more or less as wide as pronotum. Vertex mostly of uniform length, much shorter than pronotum. Ocelli on anterior margin of vertex visible dorsally. Fore wings long and slender with wider appendix and with four apical cells and only two anteapical cells, inner one being open basally.

Male genitalia

Pygofer rounded posteriorly. Styles with apophysis well developed, usually strongly arched. Connective 'Y' shaped; stem longer than arms and articulating with aedeagus. Aedeagus broad basally with 3 pairs of processes, shaft slender directed posteriorly and curved anteriorly; gonopore apical.

Measurements

The total length including forewings 2.69 (2.65 - 2.75) mm, width across the compound eyes 0.69 (0.64 - 0.71) mm.

Specimens studied

3 males, 1 female, Mugad, rice, 2. XII. 2008, Shashank P R; 2 males, Khanapur, rice, 2. XII. 2008, Shashank P R; 2 males, Shikaripur, rice, 5. XII. 2008,

Shashank P R; 1 male, 1 female, Badravathi, rice, 5. XII. 2008, Shashank P R; 1 male, 2 females Davangere, rice, 7. XII. 2008, Shashank P R; 4 males, 2 females, Udupi, rice, 27. I. 2009, Shashank P R; 1 female, Bantval, rice, 29. I. 2009, Shashank P R.

***Balclutha lucida* (Butler)**

(Figs. 19 (a-e) & Plate 7B)

Jassus lucidus Butler, 1877: 91

Gnathodus laevis Melichar, 1903: 209

Nesosteles glauca Kirkaldy, 1906: 344

Eugnathodus floridana Delong and Davidson, 1933: 56

Nesosteles marquesane Osborn, 1934: 265

Balclutha filum Linnavuori, 1960 : 342

Balclutha lucida (Butler). Knight, 1987: 1184

Balclutha lucida (Butler). Webb and Vilbaste, 1994: 63

Colour

Pale yellow to greenish yellow, stramineous.

External morphology

Head as wide as pronotum. Ocelli situated by their own diameter away from corresponding eye. Anterior margin of vertex broadly rounded.

Male genitalia

Pygofer rounded posteriorly without any processes. Subgenital plates elongate, narrowing at mid length to finger like apex, with marginal macrosetae. Styles with slender apophysis and as shown in figure. Connective stem more or less equal to the length of arms. Aedeagus simple, shaft elongate, cylindrical, curving dorsally and then anteriorly and gonopore apical.

Measurements

The total length including forewings 2.75 (2.85 - 2.2.90) mm, width across the compound eyes 0.67 (0.65 - 0.70) mm.

Specimens studied

2 males, 1 female Davangere, rice, 7. XII. 2008, Shashank P R; 4 males, 1 female, Haveri, rice, 6. XII. 2008, Shashank P R.

Balclutha pararubrostriata Ramasubba Rao and Ramakrishnan

(Figs. 20 (a-f) & Plate 8A)

Balclutha pararubrostriata Rao and Ramakrishnan 1990b :106

Balclutha pararubrostriata Rao and Ramakrishnan. Webb and Vilbaste 1994 : 64

Colour

Cream or light yellowish.

External morphology

Light orange red longitudinal stripes on the vertex, pronotum and scutellum. Fore wings pale cream, clavus and adjascent cells in basal half of the wing with reddish stripes.

Male genitalia

Pygofer with spine like bifid process, the dorsal branch of process is smaller, hooked, directed ventrad, the ventral branch longer, recurved, hooked and directed dorsad. Aedeagus very much broader basally and gradually narrower towards apex, shaft broadly curved dorsocephalad.

Measurements

The total length including forewings 2.54 (2.52 - 2.56) mm, width across the compound eyes 0.65 (0.63 - 0.68) mm.

Specimens studied

2 male, 1 female, Davangere, rice, 7. XII. 2008, Shashank P R; 1 male, 2 females, Haveri, rice, 6. XII. 2008, Shashank P R.

Balclutha rubrostriata **(Melichar)**

(Figs. 21 (a-f) & Plate 8B)

Anathodus rubrostriatus Melichar, 1903: 208

Typhlocyba rubrostriata Distant, 1918, Knight, 1987: 1211-1212

Typhlocyba rufuscula Distant, 1918

Eugnathodus (*Neosteles*) *sanguinescens* (Kirkaldy). Pruthi, 1930 : 52.

Balclutha sanguinescens (Kirkaldy). Malhotra and Sharma, 1977: 1-19.

Balclutha rubrostriata (Melichar). Sharma and Badan, 1985 : 150.

Colour

Cream coloured species.

External morphology

Pronotum with pale reddish longitudinal stripes medially as well as on lateral sides extending on to posterior margin of vertex and scutellum. Clavus and adjascent cells in basal half of fore wing pale reddish.

Male genitalia

Pygofer with a posteriorly directed bifurcated process arising medially on ventral margin and extending to posterior margin of lobe, the dorsal branch smaller than ventral. Subgenital plates tapering gradually to relatively short finger like apex. Aedeagus enlarged basally with a pair of lateral wing like expansions; shaft directed dorsally tapering to midlength, distal half filamentous and recurved anteriorly.

Measurements

The total length including forewings 2.56 (2.54 - 2.58) mm, width across the compound eyes 0.66 (0.63 - 0.69) mm.

Specimens studied

1 male, Davangere, rice, 7. XII. 2008, Shashank P R; 2 males, 2 females, Haveri, rice, 6. XII. 2008, Shashank P R.

***Balclutha saltuella* (Kirschbaum)**

(Figs. 22 (a-c) & Plate 9A)

Jassus (Thamnotettix) saltuellus Krischbaum, 1868 : 22.

Gnathodus saltuellus (Kirschbaum) Horvath, 1899 : 365-374.

Balclutha saltuellus (Kirschbaum). Oshanin, 1906 : 1-192.

Typholocla delicatula Distant, 1918

Empoanara lineolata Distant, 1918 } Knight, 1987 21:1182-1183

Anomiana longula Distant, 1918

Eugnathodus ocellatus Pruthi, 1930

Balclutha ocellatus (Pruthi). Sharma and Badan, 1985 : 151.

Balclutha saltuella (Kirschbaum). Rao and Ramakrishnan, 1990b : 69

Balclutha saltuella (Kirschbaum). Webb and Vilbaste 1994 : 64

Colour

Cream to pale yellowish brown.

External morphology

Head wider than pronotum. Vertex rounded. Ocelli located on anterior margin of vertex near to the eyes. Clypellus narrow. Scutellum shorter than pronotum. Pronotum shorter in length than width, plain and glabrous. Forewings long, slender, hyaline to subhyaline. Appendix wider, three apical and two anteapical cells.

Male genitalia

Pygofer broadly rounded posteriorly, posteroventral margin slightly produced. Subgenital plates very short with fingers like apex. Connective with arms as long as stem. Aedeagus with elongate simple, narrow shaft; gonopore apical.

Measurements

The total length including forewings 2.79 (2.75-2.85) mm, width across the compound eyes 0.70 (0.65-0.71) mm.

Specimens studied

2 males, Mugad, rice, 2. XII. 2008, Shashank P R; 1 male, 2 females, Khanapur, rice, 2. XII. 2008, Shashank P R; 9 male, 2 females, Shikaripur, rice, 5. XII. 2008, Shashank P R; 2 males, 1 female, Badravathi, rice, 5. XII. 2008, Shashank P R; 1 male, 2 females Davangere, rice, 7. XII. 2008, Shashank P R; 2 males, 7 females, Haveri, rice, 6. XII. 2008, Shashank P R; 6 males, 2 females, Udupi, rice, 27. I. 2009, Shashank P R; 2 males, Bantval, rice, 29. I. 2009, Shashank P R.

***Cicadulina (Cicadulina) bipunctata* (Melicher)**

(Figs. 23 (a-f) & Plate 9B)

Gnothodus bipunctatus Melicher,1904

Cicadulinabipunctella zeae China. Ruppel, 1965:406

Cicadulina bipunctella Matsumura. Heller and Linnvuori, 1968:1-42

Cicadulina zeae China. Vilbaste, 1976:27

Cicadulina (Cicadulina)bipunctata(Melicher). Webb, 1987:694

Colour

Vertex with a pair of round black spot on the anterior margin. Vertex, pronotum and scutellum are yellowish orange in colour and the dorsum of abdomen is black in colour.

External morphology

Head as wide as or slightly wider than pronotum. Vertex subacute. Ocelli located close to the eyes on the face. Clypellus narrow and parallel sided and extended upto the margin of genae. Pronotum wider than long, anterior margin smoothly arched. Tegmina hyaline with three apical and two anteapical cells.

Male genitalia

Pygofer with an elongate dorsal process which is bifid, with curved, short and robust ventral subapical spine, subgenital plates with lateral margin concave at midlength, narrower towards apex and upturned. Connective 'Y' shaped, arms close together approximately equal in length to the stem. Aedeagus shaft cylindrical 'C' shaped and curved dorsally with a pair of dorsal processes basally.

Measurements

The total length including forewings 2.65 (2.30-3.00) mm, width across the compound eyes 0.62 (0.56-0.68) mm.

Specimens studied

1 male, 1 female, Mugad, rice, 2. XII. 2008, Shashank P R; 2 males, 1 female, Khanapur, rice, 2. XII. 2008, Shashank P R; 3 males, Sirsi, rice, 3. XII. 2008, Shashank P R; 1 male, 2 females, Yellapura, rice, 4. XII. 2008, Shashank P R; 2 male,1 female, Davangere, rice, 2. XII. 2008, Shashank P R; 1 female, Mangalore, rice, 26. I. 2009, Shashank P R; 1 male, 1 female, Karkala, rice, 27. I. 2009, Shashank P R.

***Doratulina indra* (Distant)**

(Figs. 24 (a-e) & Plate 10A)

Typhlocyba indra Distant, 1908: 415.

Paivanana Indra (Distant, 1918): 95

Paivanana Indra (Distant). Pruthi, 1930: 98

Doratulina indra (Distant), Vilbaste, 1965: 10

Colour

Pale yellowish grey coloured species. Vertex with two prominent black spots between the anterior margins of eyes, spots slighly nearer to the eyes than to each other. Two large black spots are also present on face a little before its apex.

External morphology

Vertex slightly longer than its breadth, subacute basally. Face much longer than broad. Pronotum about twice as broad as long. Fore wing with four apical and three anteapical cells, with narrow appendix.

Male genitalia

Subgenital plates basally broad, gradually narrowing to apex, with few marginal macrosetae; apex bluntly rounded. Styles with slender apophyses. Connective arms 'U' shaped and strongly bifid at apex. Aedeagus wider at base deeply bent in the middle, shaft slightly curved apically.

Measurements

The total length including forewings 2.86 (2.81 - 2.91) mm, width across the compound eyes 0.81 (0.78-0.83) mm.

Specimens studied

1 male, 1 female, Shikaripur, rice, 5. XII. 2008, Shashank P R; 2 males, 3 females, Badravathi, rice, 5. XII. 2008, Shashank P R.

4.2.1 PLANTHOPPER SPECIES IDENTIFIED

In the present studies six planthopper species belonging to 6 genera belonging to families Delphacidae and Meenoplidae were identified in different rice growing districts of Karnataka which were furnished here under.

(I) Tribe: Delphacini

Family: Delphacidae

1. *Cemus sp*
2. *Nilaparvata lugens* (Stal)
3. *Sogatella furcifera* (Horvath)
4. *Sardia rostrata* Melichar
5. *Tagosodes pusanus* (Distant)

(II) Tribe: Meenoplini

Family: Meenoplidae

1. *Nisia nervosa* (Motschulsky)

4.2.2 KEY TO THE PLANTHOPPERS ASSOCIATED WITH RICE ECOSYSTEMS OF CENTRAL AND COASTAL KARNATAKA

1. Hind tibia with a movable apical spur ----------2

--- Hind tibia without a movable apical spur; claval vein of tegmina granulate; median ocellus pearl like; aedeagus very broad basally, gradually narrowed and slightly curved with a pair of transparent wing like structures; genital styles broader basally, elongated with claw like structures in the middle (Fig. 30a, b, c & Plate 13B) .....***Nisia nervosa*** **(Motschulsky)**

2 Presence of one or more lateral spines on the basal segment of hind tarsus; aedeagus slender, broader medially, tapering apically and apex upturned; genital styles flattened, inner margin deeply concave in the middle (Fig. 26 b, c & Plate 11B) ---------- ***Nilaparvata lugens*** **(Stal)**

---- Absence of one or more lateral spines on the basal segment of hind tarsus

---------- 3

3. Aedeagus twisted, tapering towards apex with two rows of small teeth's; tegmina with a pterostigma; clypeus, genae and frons blackish; diaphragm 'U' shaped; genital styles strongly dilated at the base, apex relatively small and almost equally bifurcated (Fig. 27b, c, d & Plate 12A)

--------- ***Sogatella furcifera*** **(Horvath)**

--- Aedeagus not twisted tubular without two rows of small teeth ------- 4

4. Frons with conspicuous raised pits on either side of the median carina; tegmina with black dots along veins; aedeagus elongated, curved with a pair of processes apically; genital styles broader basally gradually narrowed apically with spines (Fig. 25c, d & Plate 11A) ---------- ***Cemus*** sp.

---- Frons without pit on either side of median carina, wings not with black spots but may be entirely blackish --------- 5

5. Aedeagus basally wider, gradually narrowed with two to three teeth like spines apically; genital plates relatively flattened, trapezoidal, shallowly bifurcated apically (Fig. 29a & Plate 13A)

---------- ***Tagosodes pusanus*** **(Distant)**

---- Aedeagus more or less straight tubular with subapical serrations; genital styles relatively short, broader medially with a deep sinuation along the inner margin (Fig. 28c, d & Plate 12B) ---------- ***Sardia rostrata*** **Melichar**

4.2.3 DESCRIPTION OF DIFFERENT PLANTHOPPER SPECIES

Cemus sp

(Figs. 25(a-d) & Plate 11A)

Cemus sp Wilson and Claridge, 1991:70

Colour:

Vertex, pronotum reddish black with cream coloured carinae. The forewings with blackish dots all along the veins and with fuscous maculae apically.

External morphology

Vertex very short and broad. Frons with conspicuous raised pits on either side of the median carina. The inner carinae extending from the vertex, meeting in the middle of the frons into a single median carina. Clypeus blackish distally. Genae reddish black in colour with cream coloured pits. A pair of ocelli presently by the side of outer carina and margin of eyes. Tegmina with characteristic black dots along veins, fuscous streaks,apically with a distinct pterostigma. Legs are blackish brown in colour. The hind legs with a mobile apical spur leaf like, 1^{st} tarsal segment longer than 2^{nd} and 3^{rd} segments put together.

Male genitalia

Pygofer dorsoventrally elongated with an elongated ventral opening. Anal segment collar like with a pair of slender processes dissected ventrally. Diaphragm as shown in the figure. Aedeagus elongated, curved with a pair of processes apically. Genital styles broader basally, gradually narrowed apically with spines.

Measurements

Length of macropterous including forewings 4.32 (4.10-4.55) mm and width across the compound eyes 0.96 (0.82-1.10) mm.

Specimens studied

1 male, 1 femals, Kittur, rice, 2. XII. 2008, Shashank P R; 3 males, 4 females, Shikaripura, rice, 5. XII. 2008, Shashank P R; 1 male, 2 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 1 male, Davangere, rice, 7. XII. 2008, Shashank P R; 2 male, 2 females, Haveri, rice, 6. XII. 2008, Shashank P R; 2 males, 1 female, Mangalore, rice, 26. I. 2009, Shashank P R.

***Nilaparvata lugens* (Stal)**

(Figs. 26 (a-d) & Plate 11B)

Nilaparvata lugens (Stal). Okada, 1977:3

Nilaparvata lugens (Stal). Wilson and Claridge, 1991:49

Synonyms

Delfax lugens Stal

Liburnia greeni Motschulsky

Nilaparvata greeni Distant

Kalpa aculeata Distant

Delphax oryzae Matsumura

Delphax ordovix Kirkaldy

Delphax parysatis Kirkaldy

Dicranotropis anderida Kirkaldy

Hikona formosana Matsumura

Colour

Yellowish brown or dark brown in colour with eyes slightly bluish.

External morphology

Vertex about as long as wide at base. Frons longer than broad not excavated with a distinct median carina, forked basally, lateral carina conspicuous on the either side of median carina. Clypeus triangular with median and lateral carina, very much shorter than frons. Genae normal, eyes reniform, incised medially above the antennae, ocelli present near the edge of the compound eye below the lateral carina of the frons. Antennae surpassing fronto-clypeal suture, second segment longer and thicker than first, with numerous sensoria. Pronotum shorter than mesonotum with a median and lateral carina. Mesonotum with distinct median and lateral carinae with a triangular scutellum. Tegmina transparent, veins darker with pterostigma, apically Sc+R forked near middle of wing. Legs slender with hind tibial spur foliaceous, one or more lateral spines present on the basal segment of hind tarsus.

Male genitalia

Pygofer moderately long, posterior opening slightly longer dorsoventrally than broad. Anal segments collar like with a pair of moderately long slender spine like processes. Diaphragm shape as shown in the figure. Aedeagus slender, broader medially, tapering apically and apex upturned. Genital styles flattened, inner margin deeply concave in the middle with wider margin sub-apically.

Measurements

Length of macropterous including forewings 4.00 (3.80-4.20) mm and width across the compound eyes 1.02 (1.01-1.03) mm.

Species studied

2 males, 3 females, Mugad, rice, 2. XII. 2008, Shashank P R; 4 males, 5 females, Dharwad, rice, 30. XI. 2008, Shashank P R; 5 males, 2 females, Khanapur, rice, 2. XII. 2008, Shashank P R; 2 males, 5 females, Kittur, rice, 2. XII. 2008, Shashank P R; 5 males, 2 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 5 male, 2 females, Yellapura, rice, 4. XII. 2008, Shashank P R; 2 male, 2 females, Shikaripura, rice, 5. XII. 2008, Shashank P R; 5 males, 2 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 2 males, 1 female, Davangere, rice, 7. XII. 2008, Shashank P R; 1male, 8 females, Haveri, rice, 6. XII. 2008, Shashank P R; 4 males, 2 females, Mangalore, rice, 26. I. 2009, Shashank P R; 1 male, 1 female, Udupi, rice, 27. I. 2009, Shashank P R; 1 male, 1 female, Bantval, rice, 29. I. 2009, Shashank P R.

Sogatella furcifera (Horvath)

(Figs. 27 (a-d) & Plate 12A)

Sogatella furcifera (Horvath). Asche and Wilson, 1990:9

Sogatella furcifera (Horvath). Wilson and Claridge, 1991:56

Synonyms

Delphax furcifera Horvath

Sogata distincta Distant

Sogata pallescens Distant

Sogata kyusyuensis Matsumura and Ishihara

Sogata tandojamensis Qadri and Mirza

Colour

Yellowish white vertex, blackish beyond mediolateral carina. Frons, clypeus and genae blackish with whitish yellow carina. Yellowish white and laterally darkened pronotum, forewing sub-transparent with black pterostigma. The body is black dorsally, creamy white ventrally with a distinct yellowish white longitudinally in the middle of mesothorax in both males and females and hence the name white backed planthopper.

External morphology

Vertex longer than broad at base, lateral margins carinate. Frons longer than broad with lateral margins carinate. Antennae pale brown, second segment about 1.5 times as long as the first and with sensoria on the ventral surface. Eyes black, reniform, deeply incised below, lateral ocelli well developed. Clypeus and genae blackish with whitish yellow carinae.

Pronotum yellowish white and laterally darkened, lateral carinae not reaching posterior margin. Mesonotum is whitish yellow in the middle broader. Tegmina sub-transparent, longer than wide, Sc+R forked in the middle, M forked at nodal line of crossveins. Cu forked distally at the level of Sc+R. the cell between the claval veins as long as common claval vein. Legs usually pale dirty yellow, first segment of hind segment of hind tarsus distinctly longer than the length of second and third segment put together, tibial spur thin foliaceous, rather large, minutely setose.

Male genitalia

Pygofer moderately long, posterior opening slightly longer dorsoventrally than broad. Anal segment collar-like with a pair of stout spine like processes, directed ventrally. Diaphragm broadly 'U' shaped. Aedeagus twisted, tubular usually sinuate with two rows of teeth and gonopore apical. Genital styles strongly dilated at base, apex relatively small and almost equally bifurcated.

Measurements

Length of macropterous including forewings 3.84 (3.66-4.03) mm and width across the compound eyes 1.05 (1.04-1.07) mm.

Species studied

1 male, 1 female, Mugad, rice, 2. XII. 2008, Shashank P R; 2 males, 1 female, Khanapur, rice, 2. XII. 2008, Shashank P R; 2 males, 2 females, Kittur, rice,

2. XII. 2008, Shashank P R; 1 male, 2 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 1 male, 1 female, Yellapura, rice, 4. XII. 2008, Shashank P R; 2 males, 2 females, Shikaripura, rice, 5. XII. 2008, Shashank P R; 5 males, 2 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 2 males, 1 female, Davangere, rice, 7. XII. 2008, Shashank P R; 1male, 8 females, Haveri, rice, 6. XII. 2008, Shashank P R; 4 males, 2 females, Mangalore, rice, 26. I. 2009, Shashank P R; 2 males, 1 female, Bantval, rice, 29. I. 2009, Shashank P R.

Sardia rostrata Melichar

(Figs. 28 (a-d) & Plate 12B)

Sardia rostrata Melichar. Wilson and Claridge, 1991:72

Colour:

The overall colouration of vertex, thorax, tegmina dark brown with black fuscous markings.

External morphology

Vertex narrow, elongated between the larger compound eyes. Frons much longer sinuated medially and broader apically with raised median and lateral carinae. The clypeus black in colour gradually narrower apically. Genae blackish. Eyes large and as long as vertex. Pro and mesonotum with a distinct median carina and the lateral carinae reaching the posterior margin. Forewings are dark brown with pterostigma and fuscus apically. Legs light yellowish in colour, the first hind

tarsus more or less twice the length of 2nd and 3rd segment put together and the tibial spur foliaceous.

Male genitalia

Pygofer broadly rounded, posterior opening longer dorsoventrally. Anal segment collar like with a pair of moderately longer, slender processes. Aedeagus more or less straight tubular with subapical serration, gonopore apical. Genital styles relatively short, broader medially with a deep sinuation along the inner margin and number of spines are scattered.

Measurements

Length of macropterous including forewings 3.99 (3.59-4.40) mm and width across the compound eyes 0.89 (0.78-1.01) mm.

Species studied

1 male, Mugad, rice, 2. XII. 2008, Shashank P R; 1 female, Khanapur, rice, 2. XII. 2008, Shashank P R; 1 males, Kittur, rice, 2. XII. 2008, Shashank P R; 3 males, 2 females, Sirsi, rice, 3. XII. 2008, Shashank P R; 1 male, 1 female, Shikaripura, rice, 5. XII. 2008, Shashank P R; 5 males, 2 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 1 male, 2 females, Davangere, rice, 7. XII. 2008, Shashank P R; 4 females, Haveri, rice, 6. XII. 2008, Shashank P R; 2 males, 1 female, Mangalore, rice, 26. I. 2009, Shashank P R; 2 males, Bantval, rice, 29. I. 2009, Shashank P R.

Tagosodes pusanus (Distant)

(Figs. 29 (a - d) & Plate 13A)

Tagosodes pusanus (Distant). comb.n. Wilson and Claridge, 1991: 63.

Synonyms

Sogata pusana Distant

Kelisia fieberi Muir

Unkana formosella Matsumura

Sogata striatus Quadri and Mirza

Himeunka chibana Tian and Kuoh

Sogatodes assimillis Yang

Colour

It resembles *S. furcifera* but can be distinguished by the pattern of the dark markings of the forewings and by the male genitalia.

External Morphology

Vertex slightly longer than wide, lateral margins carinate. Frons longer than broad with yellowish white median and lateral marginal carinae. Frons and genae are black in colour where as clypeus light brown in colour. Eyes black reniform deeply inscised below lateral ocelli well developed. Tegmina subtransparent longer than wide with a pattern of dark markings and pterostigma. Legs usually pale dirty yellow, first segment of hind tarsus distinctly longer than the length of second and third segments put together, tibial spur thin, foliaceous and with minute teeth marginally.

Male genitalia

Pygofer moderately long, posterior opening slightly longer dorsoventrally than broad. Anal segment collar like with a pair of short spine like processes directed ventrally. Aedeagus tubular never twisted as found in *Sogatella* wider basally gradually narrowed and tubular, two to three spines are there sub-apically, gonopore apical. Genital styles relatively flattened trapezoidal distally and shallowly bifurcated. The shape of diaphragm as shown in figure.

Measurements

Length of macropterous including forewings 4.32 (4.10-4.55) mm and width across the compound eyes 0.96 (0.82-1.10) mm.

Species studied

2 male, 1 female, Sirsi, rice, 3. XII. 2008, Shashank P R; 2 male, 1 female, Yellapura, rice, 4. XII. 2008, Shashank P R; 3 males, 2 females, Shikaripura, rice, 5. XII. 2008, Shashank P R; 4 males, Davangere, rice, 7. XII. 2008, Shashank P R.

Nisia nervosa (Motschulsky)

(Figs. 30(a - c) & Plate 13B)

Nisia nervosa (Motschulsky), Wilson and Claridge, 1991: 47.

Synonyms

Livilla nervosa Motschulsky

Nisia atrovenosa (Lethierry**)**

Colour

Stramineous to whitish in colour, claval vein of the tegmina granulate.

External Morphology

Vertex deeply excavated and is not demarcated from the frons. Frons very much elongated, excavated and curved along the eyes with outer carina very much raised, black in colour and median carina absent. Clypeus shorter and triangular in shape. Eyes comparatively smaller, ocelli three in number, median ocellus pearl like, present just above the frontoclypeal suture. Pronotum short and very much narrower. Mesonotum longer than pronotum with a median carina. Tegmina light straw colour, veins darker, claval vein granulate or tuberculate. Legs slender, mobile spur absent, first 2 tarsal segments with a row of spines.

Male genitalia

Pygofer moderately long, posterior opening slightly longer dorsoventrally. Pygofer is shoe shaped laterally. Anal segment without a pair of spines. Aedeagus very broad basally, gradually narrowed and slightly curved with a pair of

transparent wing like structures. Genital styles broader basally, elongated and with claw like structures in the middle and broader.

Measurements

Length of macropterous including forewings 3.46 (3.41-3.51) mm and width across the compound eyes 1.17 (1.13-1.23) mm.

Specimens studied

1 male, 2 females, Mugad, rice, 2. XII. 2008, Shashank P R; 2 males, 3 females, Dharwad, rice, 30. XI. 2008, Shashank P R; 3 males, Kittur, rice, 2. XII. 2008, Shashank P R; 2 males, Sirsi, rice, 3. XII. 2008, Shashank P R; 1 male, 2 females, Yellapura, rice, 4. XII. 2008, Shashank P R; 2 male, 2 females, Shikaripura, rice, 5. XII. 2008, Shashank P R; 3 males, 2 females, Badravathi, rice, 5. XII. 2008, Shashank P R; 2 males, 1 female, Davangere, rice, 7. XII. 2008, Shashank P R; 1male, 8 females, Haveri, rice, 6. XII. 2008, Shashank P R; 1 male, 1 female, Udupi, rice, 27. I. 2009, Shashank P R; 1 male, 1 female, Bantval, rice, 29. I. 2009, Shashank P R.

4.3 FIELD EVALUATION OF VARIOUS TREATMENTS AGAINST PEST SPECIES OBSERVED

A field experiment was conducted during *kharif*, 2008-2009 to evaluate the efficacy of thiamethoxam, acetamiprid, thiacloprid, clothianidin (neo-nicotinoids), emamectin benzoate (avermectin), ethiprole (phenyl pyrazole), acephate

(organophosphate) and buprofezin (chitin synthesis inhibitor) against sucking pest of rice *viz.*, brown planthopper (BPH), white backed planthopper (WBPH) and green leafhopper (GLH). The treatments were given twice during the crop period. The results pertaining to the efficacy of treatments are presented under the following sections.

4.3.1 Efficacy of Different Treatments against Brown Planthopper (BPH), *Nilaparvata lugens* (Stal)

4.3.1.1 Efficacy of different treatments after first spray

The results pertaining to the efficacy of the test insecticides against BPH are presented in table 3.

The pretreatment data of the BPH population one day prior to first spray revealed that populations in different treatments including untreated check were more or less uniformly distributed. The mean number of BPH population ranged between 128.67 and 149.00 per ten hills.

The populations in different insecticidal treatments were reduced significantly after the insecticidal applications. The data recorded one day after treatment revealed that ethiprole (0.01%), buprofezin (0.04%) and thiamethoxam (0.005%) recorded highest population reduction of 91.49, 90.59 and 88.95 per cent, respectively over untreated check and were on par with each other. Acetamiprid (0.004%), thiacloprid (0.024%), clothianidin (0.003%) and acephate (0.12%)

recorded next highest population reduction of 77.91, 75.73, 74.56 and 71.06 per cent respectively and were on par with each other. Emamectin benzoate (0.0025%) was the least effective by recording 39.52 per cent reduction over untreated check.

The treatments were significantly superior over untreated check even after five days. Ethiprole recorded the highest per cent reduction (94.25) which was followed by buprofezin (93.56%) and thiamethoxam (91.83%) and these were on par with each other. Acetamiprid, thiacloprid, clothianidin and acephate were moderately effective as compared to above and recorded 86.78, 84.23, 75.58 and 69.63 per cent reduction, respectively. Acetamiprid and thiacloprid were on par with each other. Emamectin benzoate was found to be the least effective by recording 42.09 per cent reduction compared to untreated check.

The observations made at ten days after treatment revealed that ethiprole significantly reduced the population upto 92.33 per cent. This was followed by buprofezin (91.27%) and thiamethoxam (87.08%) which were on par with each other in reducing the BPH population. Ethiprole with 92.33 per cent and buprofezin with 91.27 per cent reduction were on par with each other. After thiamethoxam next treatments in the decreasing order of efficacy were acetamiprid (82.29%), thiacloprid (77.87%) and clothianidin (77.21%) and were on par with each other. Thiamethoxam with 87.08 per cent and acetamiprid with 82.29 per cent population reduction were on par with each other. The next treatment in the decreasing order of efficacy was acephate (60.30%). Emamectin benzoate gave the least reduction in

population (46.10%). But, all the treatments were significantly superior over the untreated control in reducing the BPH population.

The data recorded at fifteen days after first treatment showed a decrease in the efficacy of clothianidin, acephate and acetamiprid leading to build up of the BPH population. Here also, ethiprole was the most effective treatment showing 36.84 per cent reduction, which was on par with buprofezin showing 34.12 per cent reduction over control. This was followed by thiamethoxam (27.89%) and acetamiprid (26.86%) which were on par with each other. Buprofezin with 34.12 per cent and thiamethoxam with 27.72 per cent reduction were on par with each other. This was followed by clothianidin with a reduction of 25.72 per cent which was on par with thiamethoxam (27.89%) and acetamiprid (26.86%). The next treatment in the decreasing order of efficacy was acephate (18.44%) over control. Emamectin benzoate gave the least reduction in population (13.70%). However, all the treatments were significantly superior over the untreated control in reducing the BPH population.

The overall efficacy of insecticides after first application reveals that, among the insecticidal treatments ethiprole recorded highest reduction of 78.73 per cent followed by buprofezin (77.38%), and were on par with each other. After buprofezin next in the order of efficacy was thiamethoxam with a reduction of 73.94 per cent over control, and was on par with buprofezin. It was followed by acetamiprid (68.46%) which was on par with thiacloprid showing 65.51 per cent reduction over control. Clothianidin with 63.27 per cent reduction was on par with

thiacloprid which was followed by acephate with 54.86 per cent reduction over control. Emamectin benzoate with 35.35 per cent reduction was the least effective treatment; however, all the treatments were significantly superior over the untreated control in reducing the BPH population on rice during, *kharif* 2008-2009.

4.3.1.2 Efficacy of different treatments after second spray

The results with regard to the efficacy of the treatments after second spray were represented in table 4.

The observations made at one day after spraying revealed that ethiprole (89.00%) and buprofezin (87.54%) were the most effective treatments and were on par with each other. The next best treatment was thiamethoxam with 80.70 per cent reduction over control and was on par with buprofezin. Acetamiprid showed 71.59 per cent reduction which was on par with thiacloprid (71.91%). The remaining treatments in the descending order of efficacy were clothianidin (57.16%), acephate (51.36%) and emamectin benzoate (48.26%). However, all the treatments were significantly superior over the untreated control in reducing the BPH population.

The observations made at five days after the second spray revealed that ethiprole was the most effective treatment by recording 94.16 per cent reduction over untreated control and it was on par with buprofezin which showed 91.50 per cent reduction over untreated control. This was followed by thiamethoxam which showed 87.94 per cent reduction over control and was on par with buprofezin. The next treatment in the decreasing order of efficacy was thiacloprid (76.02%) which

was significantly superior over control. This was followed by acetamiprid (65.77%), clothianidin (69.28%) and acephate (65.78%) which recorded more than 50 per cent reduction over control. Emamectin benzoate was the least effective with 29.89 per cent reduction over control. However, all the treatments were significantly superior over untreated control at five days after spraying.

The observations made at ten day after spraying indicated all the treatments were effective and significantly superior to untreated control with substantial reduction in population of BPH. Buprofezin was the most effective treatment showing 90.57 per cent reduction of BPH population over control followed by ethiprole showing 87.50 per cent reduction of BPH population, the two being on par. The next best treatment was thiamethoxam with 84.40 per cent reduction of BPH population over control. Thiacloprid (77.54%) and acetamiprid (75.75%) came next in the order of efficacy and were on par with each other. This was followed by clothianidin (67.11%) and acephate (62.70%) which were on par with each other. Emamectin benzoate was the least effective among all treatments showing only 26.91 per cent reduction of BPH population over control.

The observations made at fifteen days after second spray revealed that ethiprole (40.85%) and buprofezin (39.77%) were most effective treatments in reducing BPH population and were on par with each other. The remaining treatments in descending order of efficacy were thiamethoxam (29.04%), thiacloprid (28.94%), clothianidin (26.15%), acetamiprid (23.38%) and acephate (22.22%), and were on par with each other. Emamectin benzoate (21.61%) was the

least effective among all the treatments. However, all the treatments were significantly superior over the control in reducing the BPH population.

The overall efficacy of the treatments against BPH on rice after second spray revealed that ethiprole (77.88%) and buprofezin (77.48%) were most effective insecticides and were on par with each other. The next best treatments were thiamethoxam (70.52%) and thiacloprid (63.91%) which recorded more than sixty per cent reduction in BPH population over control. This was followed by acetamiprid (59.12%), clothianidin (55.53%) and acephate (50.75%) which recorded more than fifty per cent reduction. Acetamiprid (59.12%) and clothianidin (55.53%) were on par with each other. The least effective treatment was emamectin benzoate showing only 31.24 per cent reduction in BPH population over control. However, all the treatments showed significantly effect in reducing the BPH population on rice over untreated control.

4.3.1.3 Overall cumulative efficacy of treatments against BPH

The data regarding cumulative efficacy of the treatments against BPH is presented in table 5 and fig.

The overall mean efficacy of the two sprays revealed that ethiprole (0.01%) and buprofezin (0.04%) were the most effective treatments by reducing the population of BPH to an extent of 78.30 and 77.36 per cent, respectively and were on par with each other. Thiamethoxam (0.005%) was the next best treatment recording 72.23 per cent reduction over control. This was followed by thiacloprid

@ 0.024 per cent (64.56%) and acetamiprid @ 0.004 per cent (63.79%) which recorded more than 60 per cent reduction of BPH population over untreated control.

Clothianidin @ 0.003 per cent (59.10%) and acephate @ 0.12 per cent (52.69%) were found to be moderately effective, recording more than 50 per cent reduction of BPH population over untreated control. Emamectin benzoate (0.0025%) was the least effective with only 33.51 per cent reduction over control. However, all the treatments showed significant reduction in BPH population over control.

4.3.2 Efficacy of different treatments against white backed planthopper (WBPH), *Sogatella furcifera* (Horvath)

4.3.2.1 Efficacy of different treatments after first spray

The results pertaining to efficacy of the treatments against white backed planthopper (WBPH) on rice during *kharif* 2008-2009, after first spray is presented in table 6.

The pretreatment population of the WBPH ranged between 103.3 and 123.67 per ten hills and did not vary significantly among different treatments including untreated control and indicated uniform distribution of the pest.

The WBPH population recorded at one day after spraying showed that ethiprole (0.01%) and buprofezin (0.04%) were the best treatments by recording the highest mean reduction in population of WBPH and being on par, with 88.63 per

cent and 87.87 per cent reduction, respectively. The next best treatment was thiamethoxam (0.005%) with 84.17 per cent reduction in WBPH population and was on par with buprofezin (87.87%). It was closely followed by thiacloprid @ 0.024 per cent (74.94%) and clothianidin @ 0.003 per cent (73.47%) being on par and significantly superior over remaining treatments.

The treatments that followed in the descending order of efficacy, recording more than 60 per cent mean reduction of WBPH population over control were acetamiprid (67.38%) and acephate @ 0.12 per cent (64.70%) being on par. Emamectin benzoate @ 0.0025 per cent (21.12%) was significantly the least effective but superior over control in bringing down the population of WBPH at one day after spraying.

At five days after spraying buprofezin, ethiprole and thiamethoxam were found to be most effective treatments by recording the highest reduction in population of WBPH (91.95, 91.41 and 89.75 per cent, respectively) over untreated control. Thiacloprid and clothianidin were found on par with each other by recording 80.24 and 75.30 per cent reduction. The next best treatments were acephate (69.92%) and acetamiprid (69.75%) being on par and significantly superior over control. Emamectin benzoate was least effective with only 37.16 per cent reduction in WBPH population over control. However all the treatments were significantly superior over control in bringing down the WBPH population at five days after spraying.

The post treatment data at ten days after spraying showed that ethiprole and buprofezin being on par were found to be the best and most effective treatments and significantly superior over all the other treatments by recording highest mean reduction (90.13 and 89.06%) in population of WBPH. These were followed by thiamethoxam with 82.26 per cent reduction of population over control. The next best treatments that followed in descending order of efficacy were thiacloprid (76.69%), acetamiprid (73.97%), acephate (69.94%) and clothianidin (69.22%) with more than 68 per cent mean reduction in WBPH population over control and were significantly superior to control. Among all the treatments emamectin benzoate was significantly the least effective with only 18.72 per cent reduction. However, all the treatments were significantly superior over control in bringing down WBPH population at ten days after spraying.

The post treatment data at fifteen days after spraying showed that thiamethoxam was found significantly superior over all the other treatments by recording the 46.76 per cent reduction of WBPH over control. Ethiprole (37.45%), clothianidin (37.40%), buprofezin (36.26%) and acetamiprid (32.38%) being on par were found significantly superior over control. This was followed by acephate with 22.40 per cent reduction in WBPH over control. Emamectin benzoate (5.86%) was least effective among all the treatments. However, all the treatments were significantly superior to control in bringing down the WBPH population at fifteen DAT.

The overall efficacy after spray against *S. furcifera* revealed that ethiprole (77.56%), buprofezin (75.79%) and thiamethoxam (73.44%) being on par were the best and the most effective treatments and significantly superior to all the other treatments by recording highest per cent reduction of population of WBPH over untreated control. The next best treatments were acetamiprid (65.61%), thiacloprid (65.35%) and clothianidin (62.16%) being on par and were significantly superior over control. This was followed by acephate (54.41%) by recording more than 50 per cent reduction of WBPH population over control. Among the treatments emamectin benzoate with 32.99 per cent was significantly the least effective but it was also significantly superior to the untreated control in bringing down the WBPH population.

4.3.2.2 Efficacy of different treatments after second spray

The results with regard to the efficacy of the treatments after second spray are represented in table 7.

The observations made at one day after spraying indicated all the treatments were effective and significantly superior to untreated control with substantial reduction in population of WBPH. Among the treatments, ethiprole (88.59%) and buprofezin (88.18%) were found best and the most effective treatments, being on par and with more than 85 per cent reduction of WBPH population over control. The next best treatment was thiamethoxam with 81.26 per cent reduction of population and was also significantly superior to the rest of the treatments. It was

closely followed by thiacloprid (75.19%) and acetamiprid (73.64%) being on par and significantly superior over remaining treatments.

This was followed by clothianidin (66.48%) and acephate (63.87%) in the order of efficacy by recording more than 60 per cent reduction of WBPH population. Emamectin benzoate was the least effective among all other treatments by recording only 33.56 per cent reduction of WBPH population.

At five days after spraying ethiprole and buprofezin were again found to be the most effective and significantly superior over all the other treatments by recording the highest reduction in population of WBPH (92.68 and 91.19%, respectively) over untreated control. The next best treatment was thiamethoxam (82.93%) which was on par with thiacloprid (80.75%), acetamiprid (78.90%) and acephate (76.59%) in reducing the population of WBPH and significantly superior over the control. Clothianidin recorded 72.76 per cent reduction of WBPH population which is significantly superior over control. Among all the treatments emamectin benzoate was significantly the least effective with only 37.15 per cent reduction over control. However, all treatments were significantly superior over control in bringing down WBPH population at five DAT.

At ten days after spraying ethiprole and buprofezin were again found to be the most effective and significantly superior over all the other treatments by recording the highest reduction in population of WBPH (91.81 and 90.02%, respectively) over untreated control. The third best chemical was thiamethoxam

with 85.63 per cent and was also significantly superior to the remaining treatments. Closely behind were thiacloprid, acetamiprid and clothianidin being on par with 81.00, 79.88 and 78.04 per cent reduction in WBPH population over control and were also significantly superior to the rest of the treatments. Acephate recorded 70.77 per cent reduction of WBPH population which is significantly superior over control. Among all the treatments emamectin benzoate was significantly the least effective with only 30.09 per cent reduction over control. However, all the treatments showed significant reduction in WBPH population over control at ten DAT.

The observations made at fifteen days after second spray revealed that ethiprole (40.86%), buprofezin (39.32%) and thiamethoxam (36.29%) were most effective in reducing WBPH population and were on par with each other. These were followed by acephate (28.29%), acetamiprid (27.81%) and thiacloprid (24.46%) being on par and significantly superior over control. Clothianidin recorded 22.78 per cent reduction of WBPH population which was significantly superior over control and was on par with thiacloprid (24.46%). Emamectin benzoate was the least effective with 15.51 per cent reduction over control. However, all the treatments showed significant reduction of WBPH population over control at fifteen days after spraying.

The mean efficacy of the four observations at one, five, ten and fifteen days after spraying showed that ethiprole (77.72%) and buprofezin (77.29%) being on par were best and most effective treatments and significantly superior to all the

other treatments by recording highest per cent reduction of population of WBPH over untreated control. The next best chemical was thiamethoxam with 70.51 per cent population reduction and was significantly superior to the remaining treatments. The treatments that followed closely were thiacloprid (63.57%) and acetamiprid (59.12%) being on par and significantly superior over control. The next best chemicals were clothianidin (54.49%) and acephate (50.91%) and were significantly superior over control. Clothianidin (54.49%) was on par with acetamiprid (59.12%) and also on par with acephate (50.91%). Emamectin benzoate (24.70%) was the least effective against all the treatments and significantly superior over control in reducing the WBPH population on rice.

4.3.2.3 Overall cumulative efficacy of treatment against WBPH

The data regarding cumulative efficacy of the treatments against WBPH is presented in table 8 and fig.

The overall mean efficacy of the four observations recorded at one, five, ten and fifteen days after two sprayings indicated that ethiprole @ 0.01 per cent (77.69%) and buprofezin @ 0.04 per cent (76.73%) being on par recorded highest reduction of WBPH population and remained significantly superior over all the other treatments and were followed by thiamethoxam (0.005%) and thiacloprid (0.024%) with 73.63 and 65.22 per cent reduction, respectively. The next best treatments were acetamiprid @ 0.004 per cent (62.96%), clothianidin @ 0.003 per cent (61.93%) and acephate @ 0.12 per cent (58.31%) with more than 55 per cent

reduction in WBPH population over untreated control. Acetamiprid (62.96%) and clothianidin (61.93%) were on par with each other. Emamectin benzoate (0.0025%) was the least effective with only 24.90 per cent reduction over control. However, all treatments showed significant reduction in WBPH population over control.

4.3.3 Efficacy of Different Treatments against Green Leafhopper (GLH), *Nephotettix virescens* (Distant).

4.3.3.1 Efficacy of different treatments after first spray

The results with regard to the efficacy of the treatments after first spray are presented in table 9.

The population recorded one day before first application revealed that there is no significant variation among different treatments including untreated check and ranged between 201.33 and 231.67 per ten hills.

The post treatment data recorded at one day after first spraying indicated that all the treatments were statistically superior over untreated control in reducing the green leafhopper (GLH) population. Among the treatments, buprofezin (0.04%), thiamethoxam (0.005%) and ethiprole (0.01%) were found to be most effective and significantly superior over all the other treatments by recording the highest reduction of GLH population of 85.91, 84.31 and 83.48 per cent, respectively and were on par with each other. The next best treatment was thiacloprid (0.024%) with 78.86 per cent reduction of GLH population over control. Acetamiprid (0.004%)

with 75.26 per cent and clothianidin (0.003%) with 73.45 per cent reduction were on par with each other. Acetamiprid and acephate were next in efficacy with 75.26 and 68.59 per cent respectively. Emamectin benzoate @ 0.0025 per cent (38.17%) was the least effective treatment; however, all the treatments were superior over the untreated control in reducing the GLH population.

Data at five days after spraying revealed that buprofezin significantly reduced the GLH population upto 92.62 per cent. This was followed by thiamethoxam (90.08%) and ethiprole (88.25%) which were equally effective in reducing the GLH population. Thiacloprid (85.22%) and acetamiprid (83.79%) were on par with each other in reducing the GLH population. This was followed by clothianidin (78.95%) and acephate (74.45%) which were effective in reducing the GLH population. Emamectin benzoate (45.39%) was the least effective in reducing the GLH population over the untreated control. All the treatments were superior over the untreated control at 5 days after spraying.

At ten days after spraying buprofezin and thiamethoxam being on par, were found to be the best and most effective and significantly superior over all the other treatments by recording the highest reduction of GLH with 90.84 per cent and 89.11 per cent over untreated control. Ethiprole and thiacloprid with 76.22 and 73.42 per cent reduction in GLH population over control, respectively were next in order of efficacy. This is followed by acetamiprid (69.05%) and acephate (66.44%) which were on par with each other. The next best treatment was clothianidin with 62.68 per cent reduction of GLH population and it was superior over untreated control.

Among all the treatments, emamectin benzoate was significantly the least effective with only 38.53 per cent reduction. However, all the treatments were significantly superior over control in bringing down the GLH population at ten days after spraying.

The post treatment data at fifteen days after first spraying showed that thiamethoxam with 31.10 per cent reduction over control was more effective followed by acetamiprid (25.49%) and ethiprole (25.44%) which were on par with each other. Next best treatments were buprofezin (25.30%) and thiacloprid (22.06%) being on par and were significantly superior over control. These were followed by clothianidin (21.66%) and acephate (16.24%) and were significantly superior over control. Emamectin benzoate (10.59%) was least effective among all the treatments. However, all the treatments were significantly superior to control in beginning down the GLH population at fifteen DAT.

The overall efficacy after first spraying against GLH revealed that buprofezin (73.67%) and thiamethoxam (73.65%) being on par were the best and the most effective treatments and significantly superior to all the other treatments by recording highest per cent reduction of GLH population over untreated control. This is followed by ethiprole with 68.35 per cent reduction of GLH population over control. The next best treatments were, thiacloprid (64.89%) and acetamiprid (63.40%) being on par and were significantly superior over control.

4.3.3.2 Efficacy of different treatments after second spray

The results with regard to the efficacy of the treatments after second spray are represented in table 10.

The observations made at one day after the second spray revealed that buprofezin was the most effective with 91.24 per cent reduction of GLH population over control, followed by thiamethoxam which showed 88.32 per cent reduction over control. These were followed by ethiprole and acetamiprid with population reduction of 85.26 per cent and 76.62 per cent respectively over control. The next best treatments were thiacloprid and clothianidin showing 74.87 per cent and 73.62 per cent reduction respectively and were on par with each other. It was closely followed by acephate with 65.11 per cent reduction of GLH population over control. Emamectin benzoate was least effective by recording 38.12 per cent reduction compared to untreated control.

The observations made at five days after spraying revealed that buprofezin (93.71%) and thiamethoxam (92.67%) were most effective treatments and were on par with each other. The next best treatment was ethiprole with 90.83 per cent reduction over control. This was followed by thiacloprid (86.12%) and acetamiprid (85.31%) which were equally effective in reducing the GLH population. The next best treatments that followed in descending order of efficacy were clothianidin (77.77%) and acephate (74.95%). Among all the treatments emamectin benzoate was significantly least effective with only 40.78 per cent reduction. However, all

the treatments were significantly superior over control bringing down GLH population at fifteen days after spraying.

The observations made at ten days after the second spray revealed that buprofezin was the most effective with 87.27 per cent reduction of GLH population over control. This was followed by ethiprole and thiamethoxam which were on par with each other showing reduction of 83.05 and 81.99 per cent respectively over control. The next best treatment was thiacloprid showing 74.27 per cent reduction of GLH population over control. Clothianidin, acetamiprid and acephate were being on par with 65.85, 64.30 and 62.74 per cent reduction over control. Emamectin benzoate was the least effective showing only 36.28 per cent reduction of GLH population over untreated control. However, all the treatments were significantly superior over untreated control.

The observations made at fifteen days after first spraying revealed that thiamethoxam significantly reduced the GLH population upto 36.93 per cent over control followed by buprofezin (33.75%), Ethiprole (29.17%), acetamiprid (27.82%) and thiacloprid (27.36%) came next in order of efficacy and were on par with each other. These treatments were followed by acephate (27.14%) and clothianidin (21.00%) being on par and significantly superior over control. Emamectin benzoate was the least effective among all the treatments showing 14.38 per cent reduction of population of GLH over control. However, all the treatments were superior over untreated control in reducing the GLH population.

The overall mean efficacy of the treatments at one, five, ten and fifteen days after second spraying revealed that buprofezin being the most effective treatment recording 76.49 per cent mean reduction of GLH population over untreated control. The next best treatment was thiamethoxam with 74.98 per cent reduction of GLH population over control. The third best treatment was ethiprole with 72.08 per cent reduction of GLH population over control.

The insecticides with moderate efficacy were thiacloprid (65.66%), acetamiprid (63.53%), clothianidin (59.56%) and acephate (56.49%). Emamectin benzoate was the least effective showing only 32.39 per cent reduction of GLH population over untreated control. However, all the treatments were significantly superior over untreated control in reducing the GLH population.

4.3.3.3 Overall cumulative efficacy of treatments against GLH

The data regarding two sprays were pooled together and the cumulative efficacy of the treatments against GLH is presented in table 11.

The overall mean efficacy of four observations recorded at one, five, ten and fifteen days after two sprays indicated that buprofezin @ 0.04 per cent (75.08%) and thiamethoxam @ 0.005 per cent (74.31%) recorded highest reduction of GLH population and remained significantly superior over all the other treatments and were followed by ethiprole (0.01%) and thiacloprid (0.024%) with 70.21 per cent and 65.27 per cent reduction, respectively. The next best treatments were acetamiprid @ 0.004 per cent (63.45%), clothianidin @ 0.003 per cent (59.37%)

and acephate @ 0.12 per cent (56.46%) with more than 56 per cent reduction in GLH population over untreated control. Emamectin benzoate (0.0025%) was the least effective with only 32.78 per cent reduction over control. However, all treatments showed significant reduction in GLH population over control.

4.4 Influence of treatments on yield

The yield data was recorded after the harvest to study the impact of the treatments. The variation in yield was attributed due to the effect of the different insecticidal treatments since all the other management practices were the same. The data pertaining to the yield revealed that all the treatments recorded significantly higher yield than untreated check.

Among the treatments, ethiprole and buprofezin recorded the highest yield of 12.90 Kg/plot (5.16 t/ha) and 12.83 Kg/plot (5.13 t/ha) with an increase of 65.60 per cent and 64.74 per cent over control, respectively and were on par with each other. The next best treatment was thiamethoxam with 12.47 Kg/plot and was on par with buprofezin (12.83 Kg/plot). The other treatments in the descending order of yields obtained were thiacloprid (11.87 Kg/plot and 4.75 t/ha), acetamiprid (11.30 Kg/plot and 4.52 t/ha), clothianidin (11.20 Kg/plot and 4.48 t/ha), acephate (10.60 Kg/plot and 4.24 t/ha) and emamectin benzoate (9.07 Kg/plot and 3.62 t/ha) resulting in 52.33, 45.06, 43.77, 36.77, 36.07 and 16.39 per cent increase in yield, respectively over control. Among all the treatments, emamectin benzoate recorded the lowest yield with only 16.39 per cent increase in yield over the untreated control.

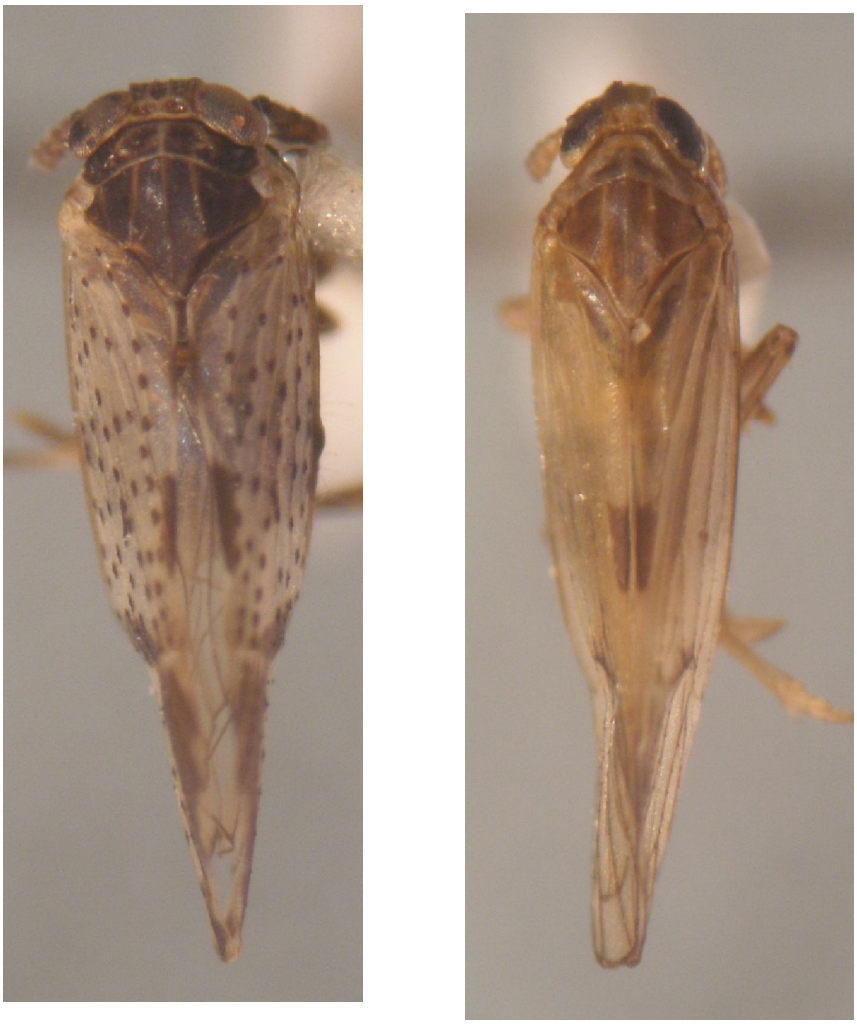


Plate 11: A. *Cemus* sp.

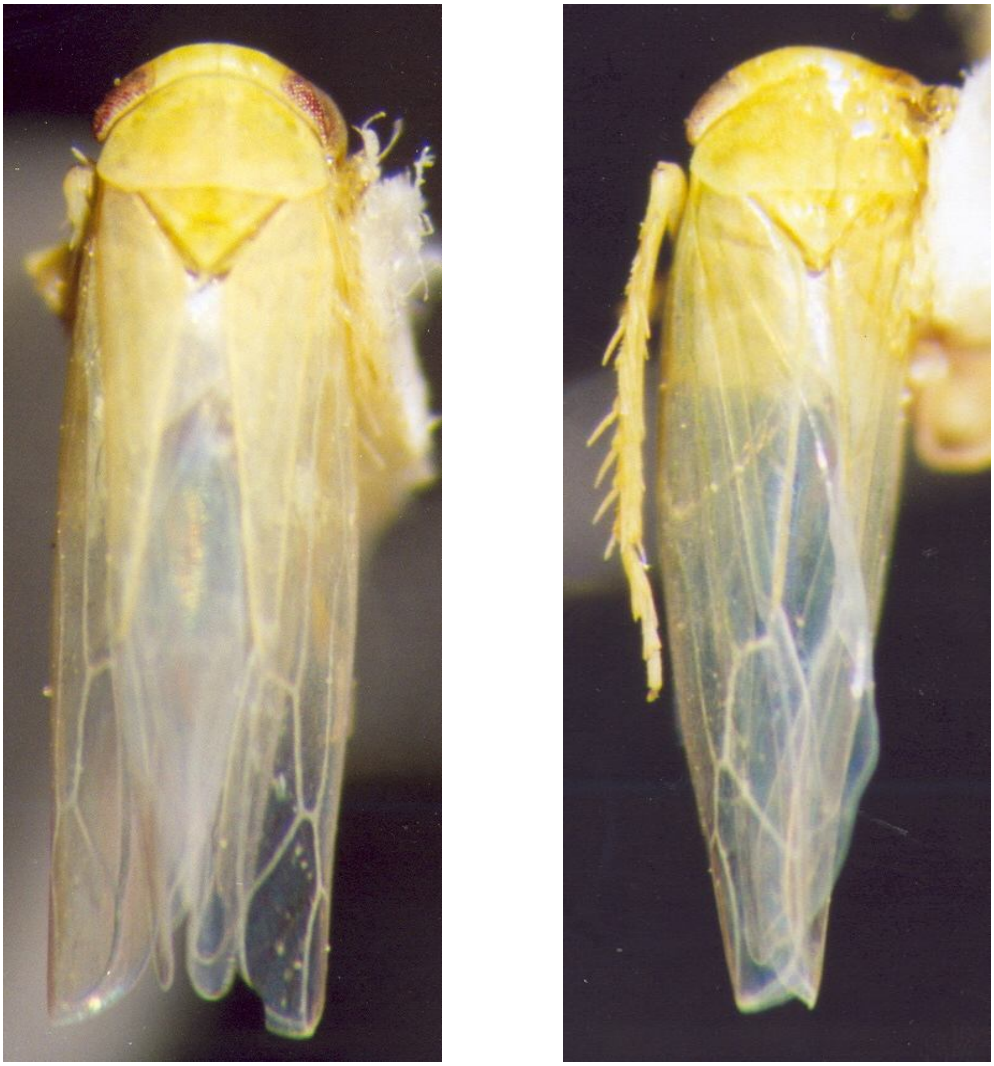
B. *Nilaparvata lugens* (Stal)

Plate 12: A. *Sogatella furcifera* (Horvath)

B. *Sardia rostrata* Melichar

Plate 13: A. *Tagosodes pusanus* (Distant)

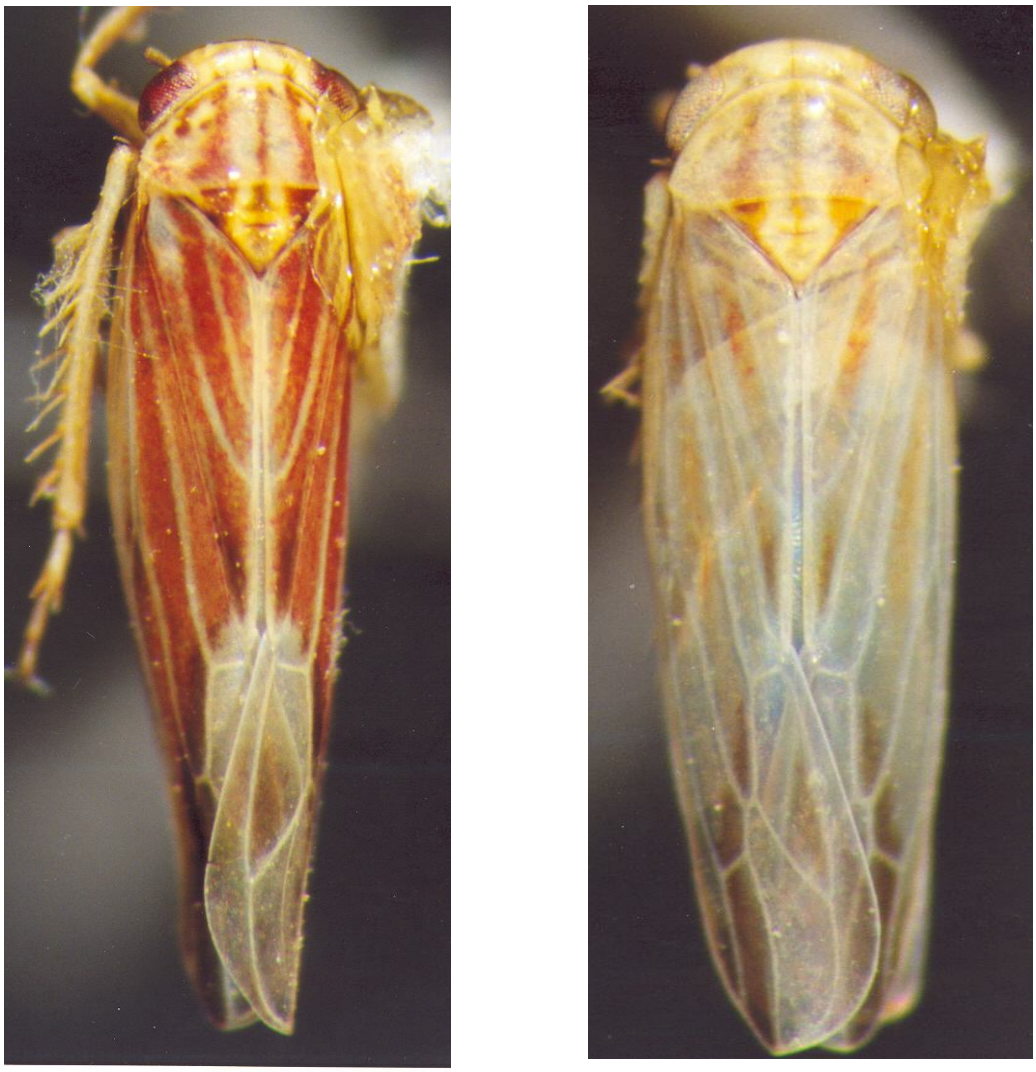
B. *Nisia nervosa* (Motschulsky)



A **B**

Plate 7: A. *Balclutha incisa* (Matsumura)

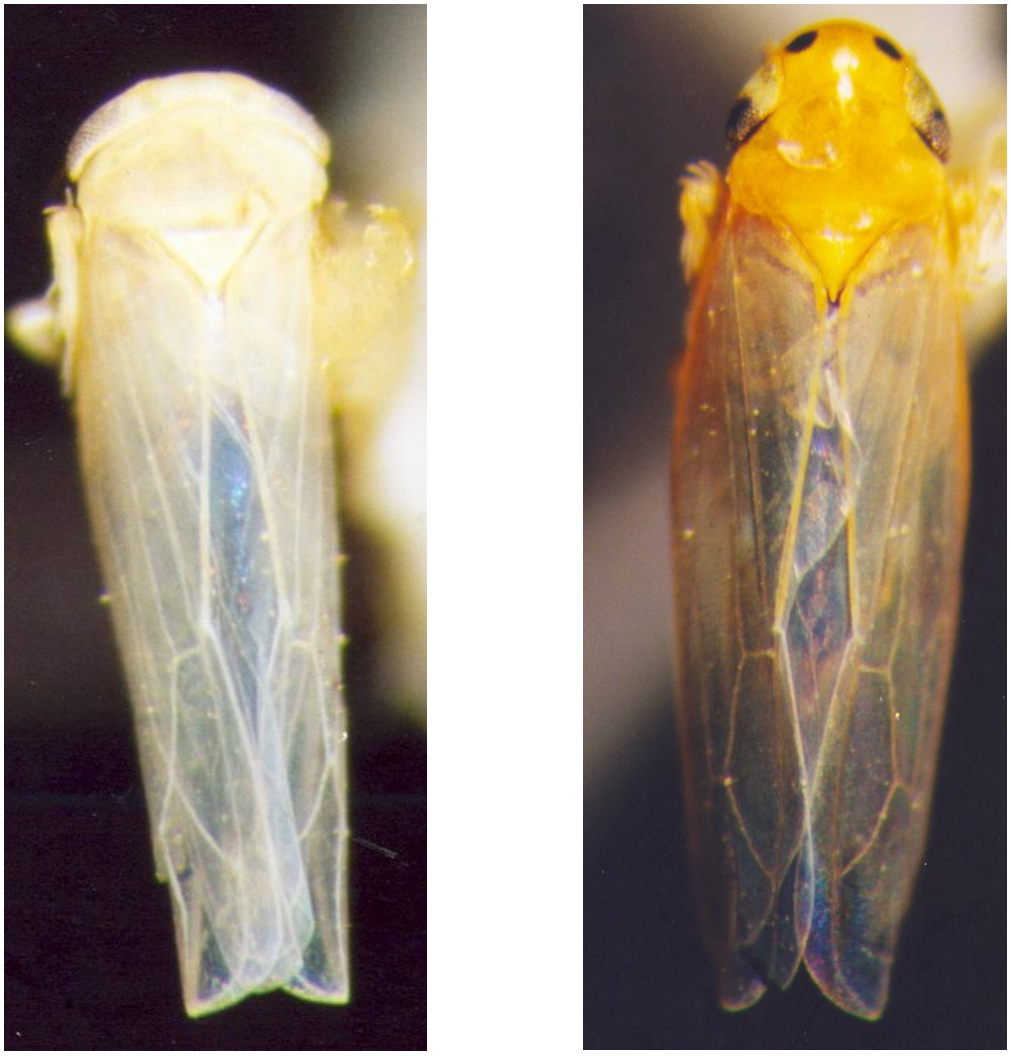
B. *Balclutha lucida* (Butler)



A **B**

Plate 8: A. *Balclutha pararubrostriata* Ramasubba Rao and Ramakrishnan

B. *Balclutha rubrostriata (Melichar)*



A **B**

Plate 9: A. *Balclutha saltuella* (Kirschbaum)

B. *Cicadulina (Cicadulina) bipunctata* (Melichar)

A **B**

Plate 2: A. *Banus* sp. nr. *consfuscus* (Pruthi)

B. *Exitianus indicus* (Distant)

A **B** **C**

Plate 4: A. *Chiasmus alata* Pruthi

B. *Cofana spectra* (Distant)

C. *Cofana unimaculata* (Signoret)

A **B** **C**

Plate 5: A. *Deltocephalus (Recilia) distinctus* Motschulsky

B. *Deltocephalus (Recilia) dorsalis* Motschulsky

C. *Deltocephalus (Recilia) pruthi* Metcalf

A

Plate 10: A. *Doratulina indra* (Distant)

A **B**

Plate 3: A. *Exitianus nanus* (Distant)

B. *Nephotettix virescens* (Distant)

A **B** **C**

Plate 6: A. *Empoascanara indica* (Datta)

B. *Hecalus arucatus* (Motschulsky)

C. *Hecalus pusae Ramasubba Rao and Ramakrishnan*

Table 3. **Efficacy of treatments against BPH after first spray**

Treatments	Dose (Conc.)	Pretreatment population/10 hills	Percentage reduction of population				
			1DAT	5DAT	10DAT	15DAT	Overall efficacy
T_1 Acephate 75WP	1.5 g/L (0.12%)	131.33 (4.87)*	71.06^{b} (57.50)**	69.63^{d} (56.66)**	60.30^{d} (50.98)**	18.44^{de} (25.37)**	54.86^{e} (47.80)**
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	132.67 (4.88)	88.95^{a} (70.69)	91.83^{a} (73.37)	87.08^{b} (69.06)	27.89^{cb} (31.79)	73.94^{b} (59.32)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	134.67 (4.90)	77.91^{b} (62.15)	86.78^{b} (67.82)	82.29^{cb} (65.14)	26.86^{cb} (31.22)	68.46^{c} (55.84)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	149.00 (5.00)	39.52^{c} (38.94)	42.09^{e} (39.75)	46.10^{e} (42.75)	13.70^{e} (21.64)	35.35^{f} (36.47)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	141.33 (4.95)	90.59^{a} (72.27)	93.53^{a} (74.80)	91.27^{ab} (72.89)	34.12^{ab} (35.74)	77.38^{ab} (61.61)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	128.67 (4.85)	75.73^{b} (60.50)	84.23^{b} (66.62)	77.87^{c} (62.02)	24.23^{cd} (29.40)	65.51^{cd} (54.04)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	135.67 (4.90)	74.56^{b} (59.80)	75.58^{c} (60.44)	77.21^{c} (61.54)	25.72^{c} (30.25)	63.27^{d} (52.71)
T_8 Ethiprole 10SC	1.0 ml/L (0.01%)	139.67 (4.94)	91.49^{a} (73.10)	94.25^{a} (75.97)	92.33^{a} (73.96)	36.84^{a} (37.35)	78.73^{a} (62.54)
T_9 Untreated Check		146.00 (4.99)	0.00^{d} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{g} (0.00)
F test		NS	Sig	Sig	Sig	Sig	Sig
SEm±			1.66	1.31	1.60	1.55	0.98
CD(P=0.05)			4.98	3.92	4.81	4.64	2.93

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 4. **Efficacy of treatments against BPH after second spray**

Treatments	Dose (Conc.)	Pretreatment population/10 hills	Percentage reduction of population				
			1DAT	5DAT	10DAT	15DAT	Overall efficacy
T_1 Acephate 75WP	1.5 g/L (0.12%)	201.67^{d} (5.30)*	51.36^{e} (45.78)**	65.78^{d} (54.27)**	62.70^{d} (52.37)**	22.22^{b} (28.53)**	50.75^{e} (45.43)**
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	177.67^{ab} (5.17)	80.70^{bc} (64.18)	87.94^{c} (69.71)	84.40^{b} (66.83)	29.04^{b} (32.60)	70.52^{b} (57.12)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	184.00^{bc} (5.21)	71.59^{d} (57.84)	65.77^{d} (54.21)	75.75^{c} (60.53)	23.38^{b} (28.91)	59.12^{d} (50.26)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	240.00^{e} (5.48)	48.26^{e} (44.00)	29.89^{e} (33.11)	26.91^{e} (31.24)	21.61^{c} (20.23)	31.24^{f} (33.93)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	174.00^{a} (5.15)	87.54^{ab} (69.51)	91.50^{ab} (73.27)	90.57^{a} (72.16)	39.77^{a} (39.03)	77.48^{a} (61.69)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	181.33^{bc} (5.20)	71.91^{cd} (58.11)	76.02^{c} (60.71)	77.54^{c} (61.72)	28.94^{b} (32.43)	63.91^{c} (53.08)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	186.33^{c} (5.22)	57.16^{e} (49.17)	69.28^{d} (56.36)	67.11^{d} (55.02)	26.15^{b} (29.43)	55.53^{d} (48.18)
T_8 Ethiprole 10SC	2.0 ml/L (0.01%)	164.67^{a} (5.13)	89.00^{a} (70.71)	94.16^{a} (76.04)	87.50^{ab} (69.47)	40.85^{a} (39.43)	77.88^{a} (61.95)
T_9 Untreated Check		272.67^{f} (5.60)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{d} (0.00)	0.00^{g} (0.00)
F test		Sig	Sig	Sig	Sig	Sig	Sig
SEm±		0.015	2.12	1.46	1.26	1.82	0.90
CD(P=0.05)		0.045	6.34	4.38	3.79	5.44	2.69

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 5. **Overall cumulative efficacy of treatments against BPH**

Treatments	Dose (Conc.)	Pretreatment population/ 10 hills	Per cent reduction of population				
			1DAT	5DAT	10DAT	15DAT	Overall cumulative mean efficacy
T_1 Acephate 75WP	1.5 g/L (0.12%)	165.17 (5.10) *	61.21^{d} (51.50) **	67.71^{e} (55.45) **	61.50^{e} (51.65) **	20.33^{c} (26.77) **	52.69^{e} (46.54) **
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	155.17 (5.04)	84.82^{b} (67.16)	89.88^{b} (71.49)	85.74^{b} (67.91)	28.47^{b} (32.23)	72.23^{b} (58.20)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	159.33 (5.07)	74.75^{c} (59.88)	76.28^{cd} (60.87)	79.02^{c} (62.74)	25.12^{b} (30.08)	63.79^{c} (53.01)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	194.50 (5.27)	43.89^{e} (41.49)	35.99^{f} (36.86)	36.51^{f} (37.16)	17.66^{c} (24.82)	33.51^{f} (35.36)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	157.67 (5.05)	89.06^{ab} (70.79)	92.52^{ab} (74.23)	90.92^{a} (72.52)	36.95^{a} (37.43)	77.36^{a} (61.60)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	155.00 (5.04)	73.82^{c} (59.26)	80.12^{c} (63.54)	77.70^{c} (61.86)	26.58^{b} (31.02)	64.56^{c} (53.46)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	161.00 (5.07)	65.86^{d} (54.28)	72.43^{de} (58.35)	72.16^{d} (58.17)	25.94^{b} (30.57)	59.10^{d} (50.24)
T_8 Ethiprole 10SC	3.0 ml/L (0.01%)	154.67 (5.04)	90.25^{a} (71.82)	94.21^{a} (76.08)	89.91^{a} (71.53)	38.85^{a} (38.56)	78.30^{a} (62.24)
T_9 Untreated Check		209.33 (5.34)	0.00^{f} (0.00)	0.00^{g} (0.00)	0.00^{g} (0.00)	0.00^{d} (0.00)	0.00^{g} (0.00)
F test		NS	Sig	Sig	Sig	Sig	Sig
SEm±			1.40	1.23	1.00	0.86	0.65
CD(P=0.05)			4.20	3.69	3.00	2.59	1.95

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 9. **Efficacy of treatments against GLH after first spray**

Treatments	**Dose (Conc.)**	**Pretreatment population/10 hills**	**Percentage reduction of population**				
			1DAT	**5DAT**	**10DAT**	**15DAT**	**Over all efficacy**
T_1 Acephate 75WP	1.5 g/L (0.12%)	201.33 (5.30)*	68.59[d] (55.92)**	74.45[e] (59.66)**	66.44[d] (54.60)**	16.24[f] (23.75)**	56.43[e] (48.70)**
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	231.67 (5.44)	84.31[a] (66.67)	90.08[b] (71.68)	89.11[a] (70.75)	31.10[a] (33.88)	73.65[a] (59.12)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	207.67 (5.33)	75.26[c] (60.18)	83.79[c] (66.28)	69.05[d] (56.20)	25.49[b] (30.32)	63.40[c] (52.77)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	221.67 (5.40)	38.17[e] (38.15)	45.39[f] (42.36)	38.53[f] (38.37)	10.59[g] (18.92)	33.17[f] (35.16)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	212.33 (5.35)	85.91[a] (67.96)	92.62[a] (74.25)	90.84[a] (72.41)	25.30[bcd] (30.16)	73.67[a] (59.13)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	219.67 (5.39)	78.86[b] (62.65)	85.22[c] (67.40)	73.42[c] (58.97)	22.06[cd] (27.99)	64.89[c] (53.67)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	225.67 (5.42)	73.45[c] (59.00)	78.95[d] (62.69)	62.68[e] (52.35)	21.66[e] (27.74)	59.19[d] (50.29)
T_8 Ethiprole 10SC	1.0 ml/L (0.01%)	224.00 (5.42)	83.48[a] (66.06)	88.25[b] (69.98)	76.22[b] (60.83)	25.44b[c] (30.28)	68.35[b] (55.77)
T_9 Untreated Check	Dose (Conc.)	217.33 (5.38)	0.00[e] (0.00)	0.00[g] (0.00)	0.00[g] (0.00)	0.00[h] (0.00)	0.00[g] (0.00)
F test		NS	Sig	Sig	Sig	Sig	Sig
SEm ±			0.772	0.575	0.584	0.772	0.361
CD (P=0.05)			2.314	2.377	1.750	2.316	1.493

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 10. **Efficacy of treatments against GLH after second spray**

Treatments	**Dose (Conc.)**	**Pretreatment population/10 hills**	**Percentage reduction of population**				
			1DAT	**5DAT**	**10DAT**	**15DAT**	**Over all efficacy**
T_1 Acephate 75WP	1.5 g/L (0.12%)	261.67^{c} (5.57)*	65.11^{f} (53.80)**	74.95^{e} (59.97)**	62.74^{d} (52.38)**	23.14^{d} (28.74)**	56.49^{g} (48.73)**
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	247.33^{b} (5.51)	88.32^{b} (70.02)	92.67^{a} (74.30)	81.99^{b} (64.89)	36.93^{a} (37.42)	74.98^{b} (59.99)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	240.00^{a} (5.48)	76.62^{d} (61.08)	85.31^{c} (67.47)	64.35^{d} (53.34)	27.82^{c} (31.83)	63.53^{e} (52.85)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	306.00^{e} (5.72)	38.12^{g} (38.12)	40.78^{f} (39.69)	36.28^{e} (37.04)	14.38^{e} (22.23)	32.39^{h} (34.68)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	246.00^{b} (5.50)	91.24^{a} (72.80)	93.71^{a} (75.49)	87.27^{a} (69.12)	33.75^{b} (35.52)	76.49^{a} (61.00)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	265.67^{c} (5.58)	74.87^{e} (59.92)	86.12^{c} (68.16)	74.27^{c} (59.53)	27.36^{c} (31.54)	65.66^{d} (54.12)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	274.33^{d} (5.61)	73.62^{e} (59.10)	77.77^{d} (61.88)	65.86^{d} (54.25)	21.00^{d} (27.27)	59.56^{f} (50.51)
T_8 Ethiprole 10SC	2.0 ml/L (0.01%)	259.00^{c} (5.56)	85.26^{c} (67.43)	90.83^{b} (72.39)	83.05^{b} (65.69)	29.17^{c} (32.67)	72.08^{c} (58.10)
T_9 Untreated Check		337.33^{f} (5.82)	0.00^{g} (0.00)	0.00^{g} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{i} (0.00)
F test		Sig	Sig	Sig	Sig	Sig	Sig
SEm ±		0.012	0.344	0.517	0.493	0.570	0.258
CD (P=0.05)		0.03	1.031	1.552	2.038	1.710	0.773

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 11. **Overall cumulative efficacy of treatments against GLH**

Treatments	Dose (Conc.)	Pretreatment Population/ 10 hills	Per cent reduction of population				
			1DAT	5DAT	10DAT	15DAT	Overall cumulative mean efficacy
T_1 Acephate 75WP	1.5 g/L (0.12%)	231.50^{efg} (5.44)*	66.85^{f} (54.85)**	74.70^{f} (59.81)**	64.59^{f} (53.48)**	19.69^{d} (26.34)**	56.46^{f} (48.71)**
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	239.50^{def} (5.47)	86.31^{b} (68.29)	91.38^{b} (72.94)	85.55^{b} (67.66)	34.01^{b} (35.67)	74.31^{a} (59.55)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	223.83^{g} (5.41)	75.94^{d} (60.63)	84.55^{d} (66.86)	66.70^{e} (54.76)	26.66^{bc} (31.08)	63.46^{d} (52.81)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	263.83^{b} (5.57)	38.14^{g} (38.14)	43.09^{g} (41.02)	37.41^{g} (37.71)	12.48^{e} (20.64)	32.78^{g} (34.92)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	229.16^{fg} (5.43)	88.57^{a} (70.24)	93.17^{a} (74.85)	89.06^{a} (70.69)	29.52^{a} (32.90)	75.08^{a} (60.05)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	242.66^{cd} (5.49)	76.87^{d} (61.26)	85.67^{d} (67.77)	73.84^{d} (59.25)	24.71^{c} (29.81)	65.27^{c} (53.89)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	250.00^{bc} (5.52)	73.53^{e} (59.04)	78.36^{e} (62.29)	64.27^{f} (53.29)	21.33^{d} (27.50)	59.37^{e} (50.40)
T_8 Ethiprole 10SC	3.0 ml/L (0.01%)	241.50^{cde} (5.48)	84.37^{c} (66.72)	89.54^{c} (71.15)	79.63^{c} (63.18)	27.30^{b} (31.50)	70.21^{b} (56.92)
T_9 Untreated Check		277.33^{a} (5.62)	0.00^{h} (0.00)	0.00^{h} (0.00)	0.00^{h} (0.00)	0.00^{f} (0.00)	0.00^{h} (0.00)
F test		Sig	Sig	Sig	Sig	Sig	Sig
SEm±		0.015	0.357	0.407	0.389	0.516	0.259
CD(P=0.05)		0.045	1.071	1.221	1.167	1.548	0.777

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 6. **Efficacy of treatments against WBPH after first spray**

Treatments	Dose (Conc.)	Pretreatment population/10 hills	Percentage reduction of population				
			1DAT	5DAT	10DAT	15DAT	Overall efficacy
T_1 Acephate 75WP	1.5 g/L (0.12%)	123.67 (4.81)*	64.70^{d} (53.56)**	69.92^{c} (56.75)**	69.94^{d} (56.79)**	22.40^{d} (28.17)**	54.41^{c} (47.54)**
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	113.00 (4.72)	84.17^{b} (66.62)	89.75^{a} (71.56)	82.26^{b} (65.10)	46.76^{a} (43.14)	73.44^{a} (58.99)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	108.33 (4.68)	67.38^{d} (55.19)	69.75^{c} (56.64)	73.97^{cd} (59.32)	32.38^{bc} (34.66)	65.61^{b} (54.12)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	103.33 (4.63)	21.12^{e} (27.28)	37.16^{d} (37.53)	18.72^{e} (25.45)	5.86^{e} (13.97)	32.99^{d} (35.02)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	104.67 (4.64)	87.87^{ab} (69.72)	91.95^{a} (73.59)	89.06^{a} (70.73)	36.26^{bc} (36.95)	75.79^{a} (60.54)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	104.67 (4.64)	74.94^{c} (59.97)	80.24^{b} (63.62)	76.69^{c} (61.16)	28.48^{cd} (32.20)	65.35^{b} (53.94)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	115.67 (4.77)	73.47^{c} (59.01)	75.30^{b} (60.27)	69.22^{d} (56.34)	37.40^{b} (37.67)	62.16^{b} (52.05)
T_8 Ethiprole 10SC	1.0 ml/L (0.01%)	118.33 (4.77)	88.63^{a} (70.43)	91.41^{a} (72.99)	90.13^{a} (71.75)	37.45^{b} (37.68)	77.56^{a} (61.73)
T_9 Untreated Check		120.33 (4.78)	0.00^{f} (0.00)	0.00^{e} (0.00)	0.00^{g} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)
F test		NS	Sig	Sig	Sig	Sig	Sig
SEm±			1.243	1.184	1.182	1.656	1.007
CD(P=0.05)			3.725	3.551	3.544	4.964	3.019

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 7. **Efficacy of treatments against WBPH after second spray**

Treatments	Dose (Conc.)	Pretreatment population/10 hills	Percentage reduction of population				
			1DAT	5DAT	10DAT	15DAT	Overall efficacy
T_1 Acephate 75WP	1.5 g/L (0.12%)	238.00^{c} (5.47)	63.87^{d} (53.06)**	76.59^{bcd} (61.09)**	70.77^{d} (57.27)**	28.29^{b} (32.13)**	50.91^{e} (45.52)**
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	149.00^{a} (5.00)	81.26^{b} (64.36)	82.93^{b} (65.78)	85.63^{b} (67.79)	36.29^{a} (37.04)	70.51^{b} (57.12)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	181.33^{b} (5.19)	73.64^{c} (59.11)	78.90^{bcd} (62.69)	79.88^{c} (63.37)	27.81^{b} (31.83)	59.12^{cd} (50.26)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	241.00^{c} (5.48)	33.56^{e} (35.40)	37.15^{e} (37.54)	30.09^{e} (33.26)	15.51^{d} (23.19)	24.70^{f} (29.75)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	164.33^{ab} (5.09)	88.18^{a} (69.90)	91.19^{a} (72.80)	90.02^{a} (71.63)	39.32^{a} (38.81)	77.29^{a} (61.57)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	185.00^{b} (5.21)	75.19^{c} (60.13)	80.75^{bc} (64.01)	81.00^{c} (64.16)	24.46^{bc} (29.61)	63.57^{c} (52.88)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	179.00^{b} (5.18)	66.48^{d} (54.64)	72.76^{d} (58.57)	78.04^{c} (62.07)	22.78^{c} (28.46)	54.49^{de} (47.58)
T_8 Ethiprole 10SC	2.0 ml/L (0.01%)	184.67^{b} (5.20)	88.59^{a} (70.28)	92.68^{a} (74.44)	91.81^{a} (73.51)	40.86^{a} (39.70)	77.72^{a} (61.85)
T_9 Untreated Check		298.00^{d} (5.69)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{f} (0.00)	0.00^{e} (0.00)	0.00^{g} (0.00)
F test		Sig	Sig	Sig	Sig	Sig	Sig
SEm±		0.046	0.700	1.381	0.861	1.081	0.997
CD(P=0.05)		0.139	2.099	4.139	2.580	3.242	2.990

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 8. **Overall cumulative efficacy of treatments against WBPH**

Treatments	Dose (Conc.)	Pretreatment Population/ 10 hills	Per cent reduction of population				
			1DAT	5DAT	10DAT	15DAT	Overall cumulative mean efficacy
T_1 Acephate 75WP	1.5 g/L (0.12%)	180.83 (5.19)	64.29^{e} (53.31)**	73.26^{d} (58.87)**	70.36^{e} (57.03)**	25.35^{d} (30.21)**	58.31^{e} (49.79)**
T_2 Thiamethoxam 25WG	0.2 g/L (0.005%)	131.00 (4.87)	82.72^{b} (65.46)	86.34^{b} (68.50)	83.94^{b} (66.39)	41.53^{a} (40.12)	73.63^{b} (59.11)
T_3 Acetamiprid 20SP	0.2 g/L (0.004%)	144.83 (4.97)	70.51^{d} (57.12)	74.33^{d} (59.56)	76.92^{cd} (61.29)	30.10^{c} (33.26)	62.96^{d} (52.52)
T_4 Emamectin benzoate 5SG	0.45 g/L (0.0025%)	172.17 (5.15)	27.34^{f} (31.52)	37.16^{e} (37.54)	24.41^{f} (29.56)	10.68^{e} (19.08)	24.90^{f} (29.92)
T_5 Buprofezin 25SC	1.6 ml/L (0.04%)	134.50 (4.99)	88.03^{a} (69.78)	91.57^{a} (73.15)	89.54^{a} (71.15)	37.79^{b} (37.93)	76.73^{a} (61.16)
T_6 Thiacloprid 240SC	0.1 ml/L (0.024%)	144.83 (4.97)	75.07^{c} (60.05)	80.50^{c} (63.79)	78.84^{c} (62.62)	26.47^{d} (30.94)	65.22^{c} (53.86)
T_7 Clothianidin 50WDG	0.06 g/L (0.003%)	147.33 (4.99)	69.97^{d} (56.77)	74.03^{d} (59.36)	73.63^{de} (59.12)	30.09^{c} (33.26)	61.93^{d} (51.90)
T_8 Ethiprole 10SC	3.0 ml/L (0.01%)	151.50 (5.02)	88.61^{a} (70.34)	92.05^{a} (73.67)	90.97^{a} (72.58)	39.15^{ab} (38.72)	77.69^{a} (61.83)
T_9 Untreated Check		209.17 (5.34)	0.00^{g} (0.00)	0.00^{f} (0.00)	0.00^{g} (0.00)	0.00^{f} (0.00)	0.00^{g} (0.00)
F test		NS	Sig	Sig	Sig	Sig	Sig
SEm±			0.754	0.982	0.730	0.659	0.259
CD(P=0.05)			2.259	2.883	2.188	1.976	0.777

**Values in parentheses are angular transformed values
*Values in parentheses are log-transformed values

Sig. : Significant
NS : Non Significant
DAT : Days After Treatment

Table 12. **Effects of insecticidal treatments on yield**

Treatments	**Dose**	**Mean yield per 25m^2 (kg)**	**Mean yield per hectare (tonnes)**	**Per cent increase over control**
T_1 Acephate 75WP	5 g/L	10.60^{e}	4.24	36.07
T_2 Thiamethoxam 25WG	0.2 g/L	12.47^{b}	4.98	60.03
T_3 Acetamiprid 20SP	0.2 g/L	11.30^{d}	4.52	45.06
T_4 Emamectin benzoate 5SG	0.45 g/L	9.07^{f}	3.62	16.39
T_5 Buprofezin 25SC	1.6 ml/L	12.83^{ab}	5.13	64.74
T_6 Thiacloprid 240SC	0.1 ml/L	11.87^{c}	4.75	52.33
T_7 Clothianidin 50WDG	0.06 g/L	11.20^{d}	4.48	43.77
T_8 Ethiprole 10SC	1.0 ml/L	12.90^{a}	5.16	65.60
T_9 Untreated Check		7.97^{g}	3.19	-
F test		Sig	-	-
SEm±		0.19	-	-
CD(P=0.05)		0.56	-	-

Fig 34: Effect of treatments on yield

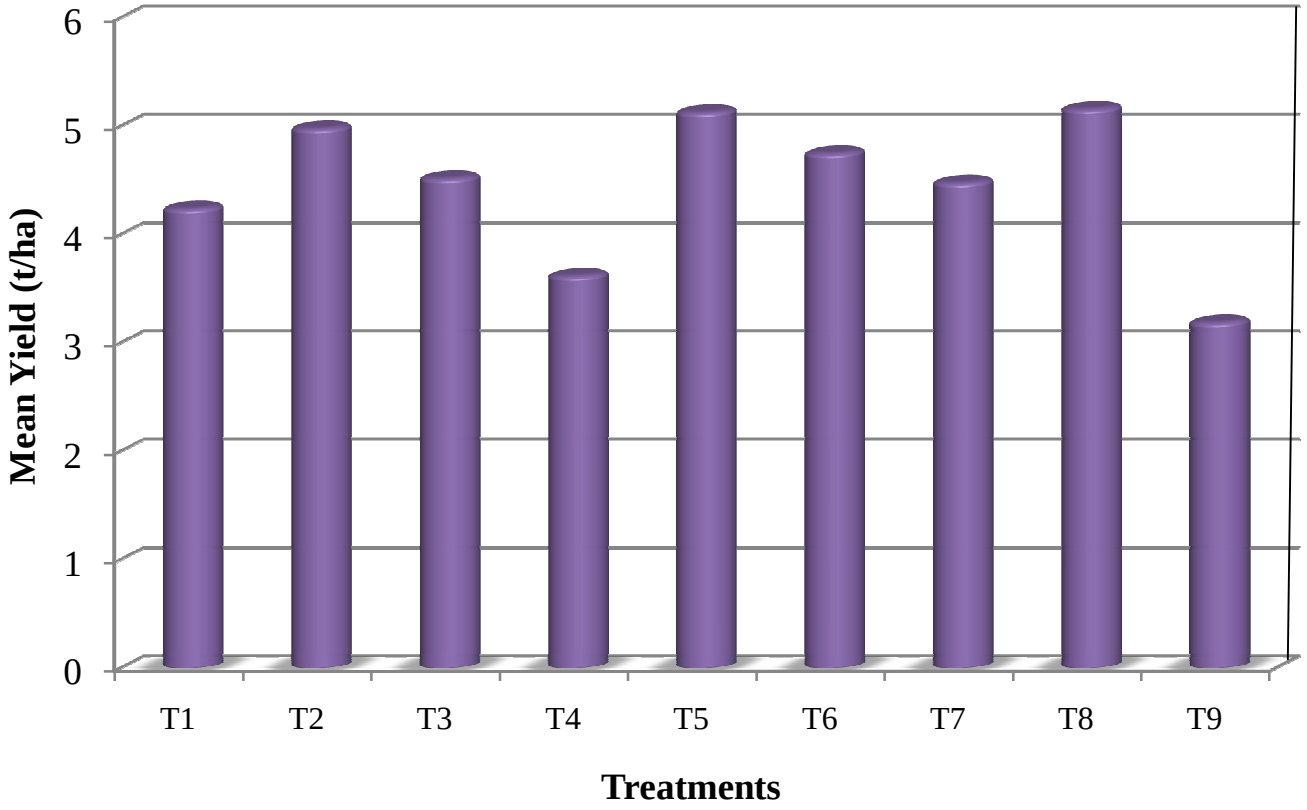


Fig 33: Overall cumulative efficacy of treatments against GLH

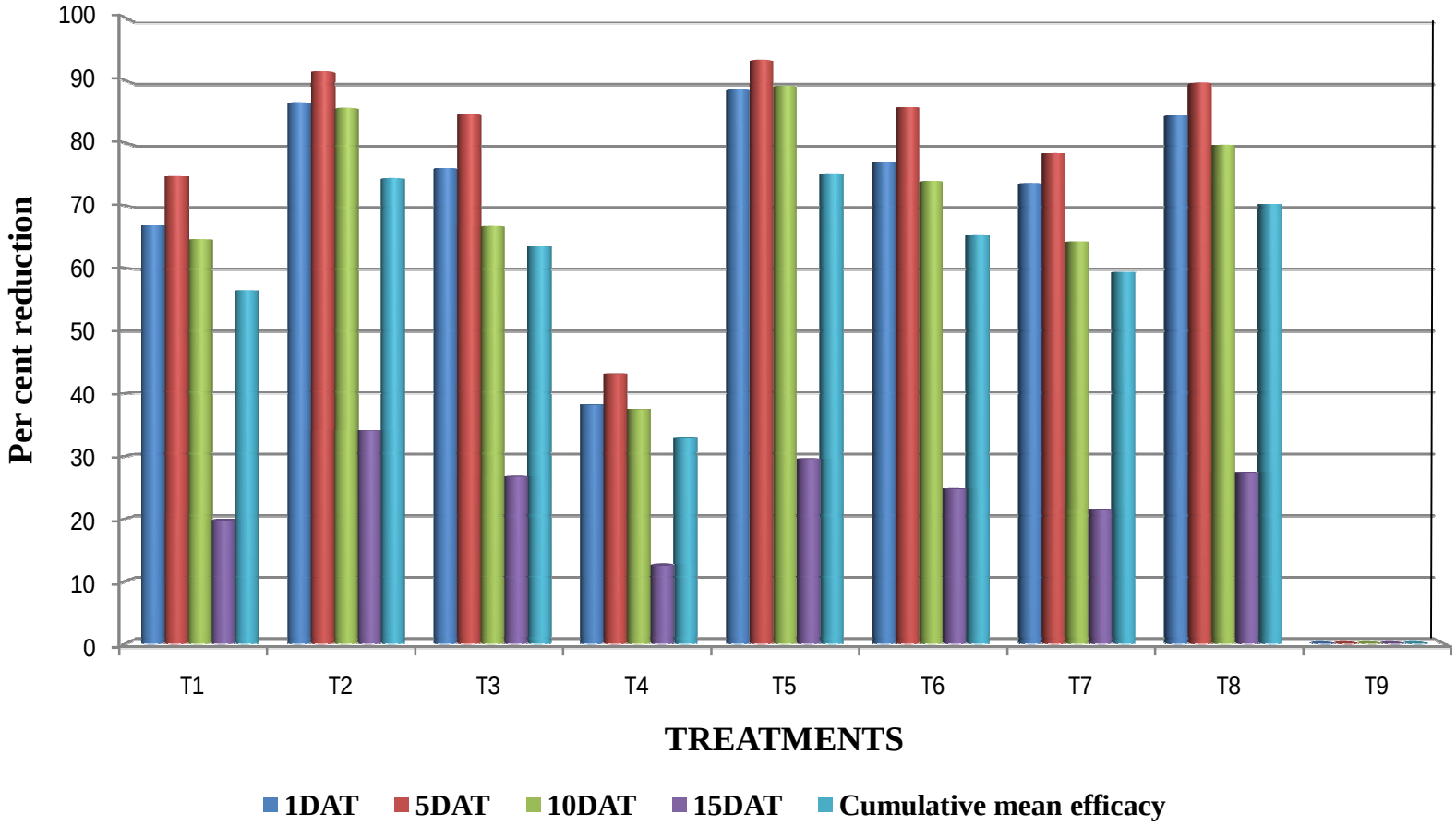


Fig 32: Overall cumulative efficacy of treatments against WBPH

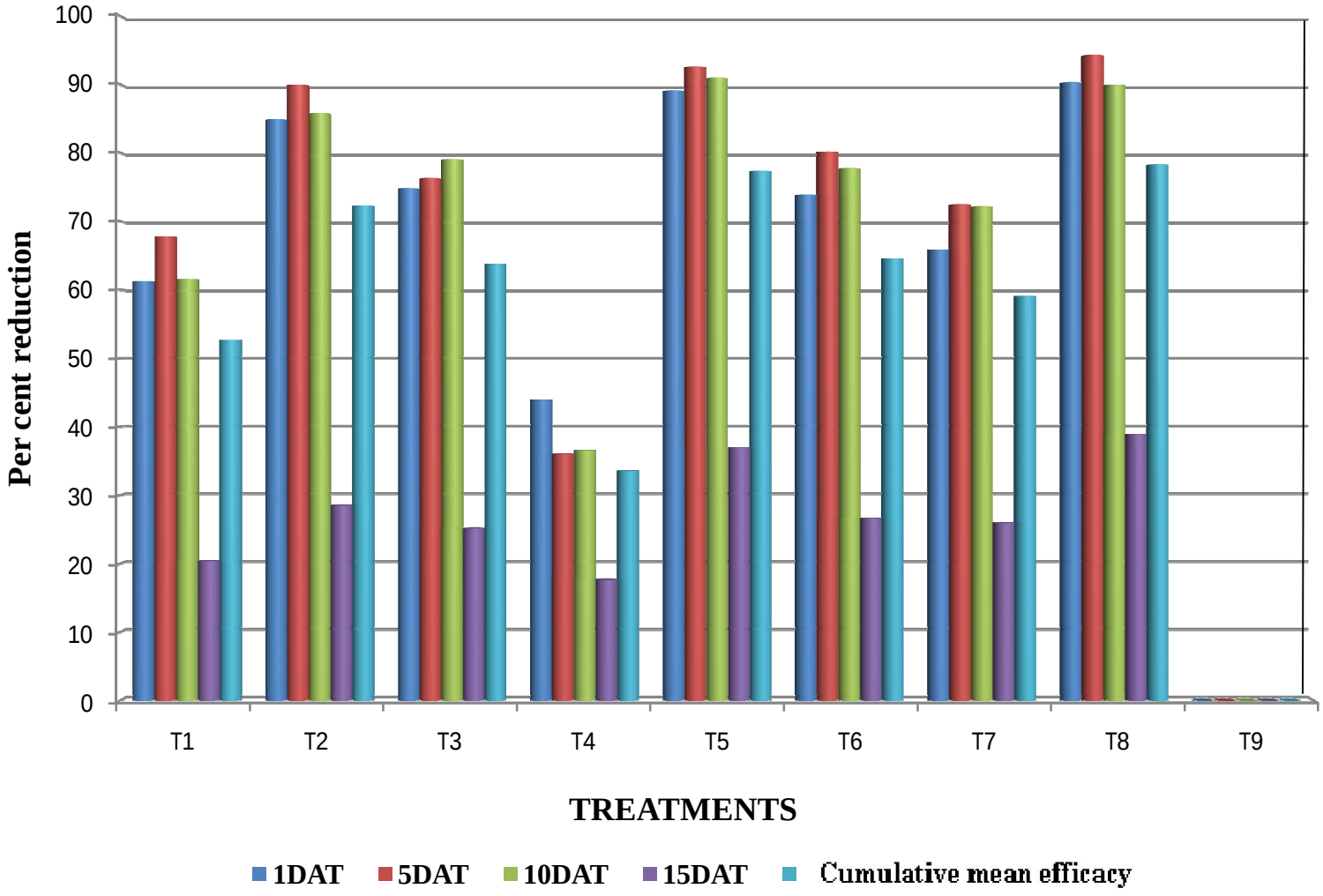
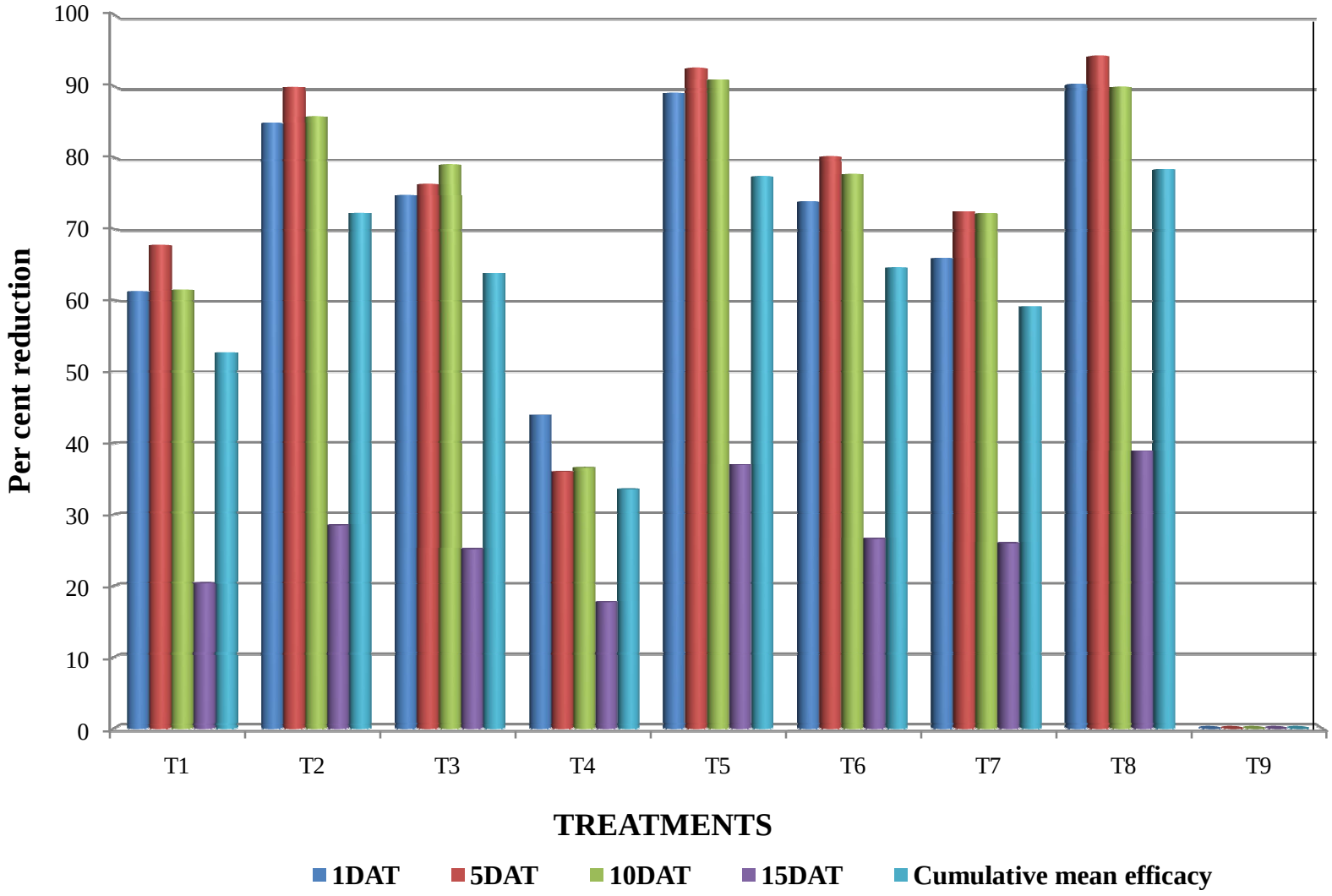


Fig 31: Overall cumulative efficacy of treatments against BPH



CHAPTER V

DISCUSSION

The present research entitled “Taxonomic studies on leafhopper and planthopper fauna associated with rice ecosystem and their management” was conducted at Agricultural College, Bapatla and Agriculture college farm, Bapatla, Guntur district as head quarters during 2008-2009. The results obtained in this present study are discussed in the light of available literature and presented below.

5.1 TAXONOMIC STUDIES ON LEAFHOPPERS

Studies conducted on various aspects of leafhoppers by various workers in India and abroad were available, but the literature on consolidated work on specific agro ecosystem is limited in India. Singh *et al.,* (1993) studied the leafhopper fauna of economic importance and their natural enemies in Karnataka state. In general the identification key for distinguishing the economically important leafhoppers is lacking. Viraktamath (1983) emphasized the need of keys for economic fauna and provided a key for some economically important leafhoppers. Rao (1998) reported 36 leafhopper species on rice, cotton, sugarcane and vegetable crop ecosystems in Andhra Pradesh and provided the identification key. Jacob *et.al.,* (2000) studied the leafhopper fauna associated with oil seed crops in Andhra Pradesh and an illustrated key for distinguishing forty species belonging to 20 genera of leafhoppers has been provided. Reddy and Rao (2001) reported seventeen leafhopper species associated with vegetable crops of Andhra Pradesh and provided a taxonomic key to separate

these species. Jacob *et.al.,* (2002) studied the leafhoppers associated with pulse crop eco-systems in Andhra Pradesh and reported twelve leafhopper species for the first time on pulse crops and their diagnosis.

During the course of investigations, 20 leafhopper species belonging to 11 genera were identified on rice in costal and central Karnataka. All these species was given in detail in results chapter.

Distant (1908) errected the genus, *Banus* with *Banus oblatus* as it's type species. Chalam (2003) reported *Banus* sp. from Andhra Pradesh. In the present investigation *Banus* sp. was collected on rice which can be characterised by greyish brown maculations on vertex and wings; aedeagus with a pair of long paraphyses arising from atrial base.

Genera *Exitianus* and *Nephotettix* belong to the tribe Athysanini which share common features like presence of robust spines on pygofer, and aedeagus articulated at the base of the shaft. These two genera can be readily differentiated based on their colour pattern and presence or absence of spines on aedeagus. The species belonging to the genus *Exitianus* are tawny with various patterns of brown or black colouration, with or without a black band between eyes on vertex. Jacob *et al.* (2000, 2002) and Reddy and Rao (2001) reported *E. indicus* on groundnut, green gram, black gram, soya bean and on certain vegetable crops like chillies, spinach, amaranthus, ridge gourd, brinjal and cucumber. In present investigation two species belongs to *Exitianus viz., E. indicus* and *E. nanus* were collected on rice from various localities of costal and central Karnataka.

The genus *Nephotettix* is closely related to the genus *Exitianus* and belongs to the same tribe Athysanini and is revised by Ghauri (1971). This genus is small, well defined with nine species, out of which four species *viz*., *virescens, nigropictus, malayanus* and *parvus* were reported from India. The occurrence of *N. virescens* on greengram, pigeonpea and blackgram was reported by Jacob *et al.,* (2002). Chalam (2003) reported occurrence of *N. virescens* on rice, blackgram, redgram, pillipesara, foddergram and fodder berseam crop ecosystems in Andhra Pradesh. In the present study one species *N. virescens* was collected on rice which can be recognized by the absence of black band on vertex and having five pairs of spines on aedeagus.

The genus *Chiasmus* belongs to the tribe Chiasmusini and is very old enjoying a worldwide distribution. So far five species were recorded in India. Jacob *et al.,* (2001) reported the incidence of *C. alata* Pruthi on groundnut in Andhra Pradesh. In the investigation one species *C. alata* Pruthi was collected on rice. The species of this genus can be recognised by having forewing with three anteapical cells and styles with claw like apophyses.

Young (1979) reviewed genus *Cofana* thoroughly. Jacob (2000) reported the occurrence of two species, *C. spectra* on groundnut and *C. unimaculata* on groundnut, blackgram, greengram in Andhra Pradesh. Kamala (2001) and Chalam and Rao (2005) reported occurrence of *C. spectra* and *C. unimaculata* on rice from Andhra Pradesh. In present studies *C. spectra* and *C. unimaculata* were collected on rice. These species can be easily distinguished by external characters, while male

genitalia characters are not very useful. These are large pale whitish insects characterised by having swollen frontoclypeus.

There is a difference of opinion in the generic status of *Deltocephalus* and *Recilia.* Ribaut (1952) and Knight (1975) treated *Recilia* as subgenus of *Deltocephalus.* Ghaurii (1980), Rao and Ramakrishnan (1988), Rao (1989), Oman *et al.,* (1990) and Viraktamath (1991) accepted Kramer's (1962) view in treating *Recilia* as a distinct genus from *Deltocephalus.* The only differentiating character separating these genera *Deltocephalus* and *Recilia* is the apex of aedeagal shaft. In *Deltocephalus,* the apex of aedeagal shaft is notched where as in *Recilia* it is entire and often it's ventral margin is produced in to a spine.

Jacob *et al.,* (2000) had given identification key and recorded the two species *D.* (*D.*) *vulgaris* and *D. (R.) dorsalis* on groundnut. *D.* (*D.*) *vulgaris* was also reported on vegetable crop, spinach by Reddy and Rao (2001). Jacob *et al.,* (2002) reported *D. (D.) vulgaris* and *D.* (*R.*) *dorsalis* for the first time in Andhra Pradesh on pulse crops *viz.,* blackgram and greengram. In the present studies *D. (R.) distinctus, D. (R.) dorsalis* and *D. (R.) pruthii* Metcalf were recorded on rice from costal and central Karnataka. The species, *D. (R.) distinctus* is stramineous yellow with a black patch on anterior margin, three distinct white patches in between. Connective longer than aedeagus and is fused. Aedeagal shaft gradually tapering and pointed at apex. The species, *(R.) dorsalis* is Pale yellowish brown, tegmina with distinct reddish brown zig-zag markings. Aedeagal shaft wider basally, tappering gradually with acute apex. The species, *D. (R.) pruthii* is Pale brown,

ochraceous. Apophysis of style slender, curved apically, and acutely pointed. Aedeagus rather uniform width in lateral aspect, slightly curved, apically rounded except for acutely pointed ventral margin which extends beyond gonopore.

The genus *Empoascanara* belongs to tribe Erythroeurini with 22 species (Sohi and Dworakowska, 1983). Jacob (2000) reported the occurrence of *E. indica* (Datta) on groundnut, greengram, blackgram where as *E. maculifrons* on greengram and *E. prima* on groundnut, blackgram and greengram in Andhra Pradesh. In the present investigation *Empoascanara indica* (Datta) was collected on rice. The leafhoppers are smaller in size, vertex, pronotum and scutellum yellow, vertex with a large central black spot. Pygofer with its dorsomesal processess curved.

Genus *Hecalus* consists of medium to robust leafhoppers mostly feeding on grasses. This genus was widely distributed in India. Morrison (1978) studied the Oriental Hecalinae and reported twenty species including 5 new species and eight new combinations. A total of 23 species from oriental region and 13 from India are known. Rao and Ramakrishnan (1990) have given a key to separate 9 species known by the males from India. The leafhopper species *H. porrectus* Walker, on grounut, *H. prasinus* (Matsumara) on groundnut and sunflower were reported by Jacob *et al.,* (2000).

Reddy and Rao (2000) reported single species *H. porrectus* Walker on vegetable crops *viz.,* cucumber and brinzal. Jacob *et al.,* (2002) studied leafhopper fauna of pulse crop eco systems and reported *H. ghauri* Rao and Ramakrishanan on blackgram and *H. porrectus* walker on greengram. In the present study the species

H. arucatus (Motschulsky*)* and H. *pusae* Ramasubba Rao and Ramakrishnan were collected from rice. *H. arucatus* can be identified by orange fasicae on the whole body forming inverted 'V' shaped markings on vertex and aedeagus with two pairs of processes and *H. pusae* by aedeagus with wavy lateral margins.

The leafhoppers belonging to the genus *Balclutha* are relatively small, slender and uniform in external appearance, but the male genitalia offered the most reliable characters. The genus *Balclutha* was revised by Knight (1987) and later by Webb and Vilbaste (1994). Rao and Ramakrishnan (1990b) studied the Indian species of *Balclutha*. Reddy and Rao (2001) reported *B. incisa* (Matsumura) on broadbean, cauliflower, tomato, brinzal, mesta, spinach, ridgegourd, clusterbean and cucumber; *B. pararubrostriata* Ramasubba Rao and Ramakrishnan on tomato and bittergourd; *B. saltuella* (Kirschbaum) on broadbean, cauliflower tomato, okra and brinjal. Jacob *et al.*, (2000 and 2002) studied *B. incisa, B. pararabrostriata* and *B. saltuella* on pulses and oil seed crop eco- systems of Andhra Pradesh. Kamala (2001) reported that occurrence of *B. incisa, B. pararubrostriata* and *B. rubrostriata* on rice from Andhra Pradesh. In the present study five species were collected in rice which belongs to genus *Balclutha viz., B. incisa, B. lucida, B. pararubrostriata, B. rubrostriata* and *B. saltuella*. These species were described in detail in results chapter and a key for seperating these species is also provided. *B. rubrostriata* and *B. pararubrostriata* though looks externally similar, can easily be diffrentiated by pygofer process which is bifurcated, branches not hooked and directed caudad in *rubrostriata* whereas, in *pararubrostriata* the processes are

hooked, dorsal one directed ventrad and ventral one directed dorsocaudad. *B. incisa* can be diagnosed by the presence of three pairs of basal processes on aedeagus. *B. lucida* can be diagnosed by finger like aedeagal shaft and finger like apodeme of aedeagus. *B. saltuella* can be identified by external features as well as features of aedeagus. The species, *B. saltuella* is cream to pale yellowish brown in colour. Aedeagus with elongate simple, narrow shaft.

The species of the genus *Cicadulina* are discussed, illustrated and a key for the identification of these species is given by Webb (1987). Jacob *et al*., (2000 and 2001), Reddy and Rao (2001) and Kamala (2001) reported the occurrence of *C. (C.) bipunctata* (Melichar) on different crops. In the present investigation species *C. (C.) bipunctata* was collected on rice. These leafhoppers have a pair of round black spots on anterior margin of vertex, yellowish orange in colour with black abdomen. The distinguishing character of male genitalia is pygofer with an elongated dorsal process with curved subapical spine.

The genus *Doratulina* was placed under tribe Stenometopiini. Jacob *et al*., (2000) reported the occurrence of *D. apicallis* (Pruthi) and *D. rubrolineata* (Distant) on groundnut and sunflower in Andhra Pradesh. Kamala (2001) reported the occurrence of *Doratulina* sp. on rice from Andhra Pradesh. In the present investigations *D. indra* (Distant) was collected on rice. These leafhoppers can be easily distinguished by the presence of two large black spots on vertex and two such spots on face. Aedeagus wider at base deeply bent in the middle, shaft slightly curved apically.

5.2 TAXONOMIC STUDIES ON PLANTHOPPERS

Revisionary work on many genera of planthoppers belongs to the super family Fulgoridae of Auchenorrhynchous-Hemiptera studied by various scientists in India and abroad is available. The literature on a consolidated work of a specific agro-ecosystem is limited. Okada (1977) reported 20 species of delphacid planthoppers as rice pests in Japan, however only three species, *Nilaparvatha lugens* (Stal.), *Sogatella furcifera* (Harvath) and *Laodelphax striatellus* (Fallen) considered being major rice pests. Wilson and Claridge (1991) published a comprehensive account of leafhopper and planthoppers found on rice in the major rice growing areas of world. They described 28 species of planthoppers belonging to the families of Delphacidae, Lophopidae, Meenoplidae and Cixiidae of Fulgoroidea on rice. Ishihara and Lowe (1969) reported six planthoppers associated with rice ecosystems in the major rice growing areas of India. *S. furcifera* and *N. lugens* are recorded by Misra (1980) and he considered these two planthoppers as seriously damaging pests of rice crop in Orissa.

During the course of investigation the following 6 planthopper species, belonging to the tribe Delphacini and Meenoplini which in turn belong to family Delphacidae and Meenoplidae of the super family Fulgoroidea were identified in different rice-ecosystems of costal and central Karnataka.

1. *Cemus sp*
2. *Nilaparvata lugens* (Stal)
3. *Sogatella furcifera* (Horvath)

4. *Sardia rostrata* Melichar

5. *Tagosodes pusanus* (Distant)

6. *Nisia nervosa* (Motschulsky)

All these species were adequately described, illustrated with line drawings and good colour photographs. The identification "key" for distinguishing these species was given in detail in the results chapter.

The Delphacidae is the largest family of planthoppers and its members can be recognized by the large flattened spur at the apex of the hind tibia. They are usually small insects lesser than 5mm in length with tectiform wings, often brachypterous, feeding mostly on monocots and also the dicots. There are about 1835 species of which 22 are recorded on rice (Wilson and O'Brein, 1987). In the present investigation 5 delphacid planthoppers were collected, described and identified. They are *Cemus* sp., *N.lugens, S. furcifera, S. rostrata and T. pusanus.* Wilson and Claridge (1985) reported 25 delphacids on rice in major rice growing areas in world. Wilson and O'Brein (1987) reported 22 delphacids on rice. Okada (1977) reported 20 species of delphacids on rice as pests in Japan. Ishihara and Lowe (1969), Kalode (1983), Misra (1980) reported only 4 delphacids *viz., N. lugens, S. furcifera, S. rostrata* and *U. sapporonus* from India. Narayana *et al.,* (2005) reported 7 planthoppers species associated with different rice ecosystems of Andhra Pradesh. Rao and Chalam (2007) reported that species belongs *Nilaparvata* predominantly found in association with rice ecosystem of South India. In the present investigation 5 delphacid planthoppers were collected, described and

identified *viz., Cemus* sp., *N. lugens, S. furcifera, S. rostrata and T. pusanus* from costal and central Karnataka.

Among the delphacid planthoppers, *N. lugens* commonly called as Brown planthopper (BPH), can be identified by their yellowish brown colour and its shape and by position of leaf like mobile spur on the apex of hind tibia and spinuation on hind tarsus externally, but authentically by its male genitalia given in the results chapter. The *S. furcifera* can be distinguished by distinct yellowish white longitudinal band in the middle of mesothorax and laterally darkened, hence the name White backed planthopper (WBPH); but it is authentically identified by its male genitalia. Aedeagus slender, broader medially, tapering apically and apex upturned. In the present investigation these two planthoppers are associated with rice-ecosystem and are in pest status. The species, *S. furcifera* is with diaphragm broadly 'U' shaped. Aedeagus twisted, tubular usually sinuate with two rows of teeth. *T. pusanus* resembles *S. furcifera* but aedeagus tubular never twisted as found in *Sogatella* wider basally gradually narrowed and tubular, two to three spines are there sub-apically, gonopore apical. *S. rostrata* characterized by subapical serration present on aedeagus. The distinguishing characters of *Cemus* sp. is aedeagus elongated, curved with a pair of processes apically and genital styles broader basally, gradually narrowed apically with spines. However, Wilson and Claridge (1991) reported all seven species on rice. All these species can be identified by following the "key" given in the results chapter.

Meenoplid planthoppers can be identified by the presence of one or both claval veins, tuberculate and hind tarsomere with apical spines. They are small 3-7 mm in size, pale grey to black insects. This family consists of 53 species of which *Nisia nervosa* Motschulsky is a minor pest of rice, taro, sugarcane (Wilson and O'Brein, 1987). Only one species *N. nervosa* was recorded in present study. Ishihara and Lowe (1969) reported this planthopper on rice at Maruteru, Warangal in Andhra Pardesh and also at Patna, Bihar; Coimbatore, Tamil Nadu and Cuttack in Orissa. Narayana *et al.* (2005) also reported *N. nervosa* on rice from Andhra Pradesh. In the present investigations *N. nervosa* was collected on rice. These planthoppers are characterized by Pygofer moderately long, posterior opening slightly longer dorsoventrally. Pygofer is shoe shaped laterally. Aedeagus very broad basally, gradually narrowed and slightly curved with a pair of transparent wing like structures.

5.3 FIELD EVALUATION OF VARIOUS TREATMENTS AGAINST PEST SPECIES OBSERVED

In order to evaluate the efficacy of certain insecticides for control of brown planthopper (BPH), white backed planthopper (WBPH) and green leafhopper (GLH) on rice, a field study was carried out during *kharif*, 2008-2009 at Agriculture college farm, Bapatla. The chemical insecticides chosen for the study included mostly new insecticides *viz.*, thiamethoxam, acetamiprid, clothianidin (neo-nicotinoids), emamectin benzoate (avermectin), ethiprole (phenyl pyrazole), besides

a conventional insecticide like acephate (organophosphate). Apart from the above, chitin inhibitor, buprofezin was also included in the study.

5.3.1 Efficacy of Insecticides against Brown Planthopper (BPH), *Nilaparvata lugens* (Stal).

The overall mean efficacy of the 2 sprays revealed superiority of ethiprole (0.01%) and buprofezin (0.04%) by reducing the population of BPH to an extent of 78.30 and 77.36%, respectively. Ethiprole was superior in present investigation; this was in line with the results of Varma *et al.,* (2003), who recorded the lowest population of *N. lugens* with the application of 50 g a.i./ha of ethiprole. Kumaran *et al.,* (2007) reported that ethiprole 10 SC @ 50 g a.i/ ha reduced the population of BPH upto 67.95 per cent. Sekh *et al.,* (2007) also reported that ethiprole @ 37.5 and 50 g a.i./ ha was very effective in managing brown planthopper of rice. The higher per cent population reduction may be due to novel molecular structure and novel mode of action (act on the Gamma Amino Butyric Acid (GABA) receptors of insects by blocking the passage of chloride ions) of ethiprole. Buprofezin was next best treatment after ethiprole and was on par with ethiprole. Buprofezin has shown maximum reduction (93.56%) of BPH at five days after treatment. This is probably due to fact that it acts as chitin synthesis inhibitor by inhibiting the enzyme chitin synthatase which is very essential for chitin synthesis of insects. Efficacy was reported by Bhavani and Rao (2005) who recorded reduction of BPH population upto 82 per cent. Kendappa *et al.,* (2005) also reported that buprofezin @ 200 and 250 g a.i./ha was significantly superior in suppressing BPH upto 16 days after

application. However, effectiveness of buprofezin against other sucking pests such as *Bemisia tabaci* on different host plants (Lin Kejian *et al.,* 20007) and *Macconellicoccus hirsutus* on grape (Balikai, 2005) were also reported.

Thiamethoxam (0.005%) was also effective against the BPH by reducing the population upto 72.23 per cent. The present result is in agreement with the findings of Vasanth Banu *et al.,* (2007) who reported good control of BPH (33.5/20 hills) with 0.2 g/l thiamethoxam upto 85 days after treatment as compared to untreated control (102.3/20 hills). The superior efficacy of thiamethoxam @ 25g a.i./ha against BPH was also reported by Bhavani and Rao (2004). However, effectiveness of thiamethoxam on other sucking pests such as aphids and leafhoppers on okra (Misra, 2002), whitefly on brinjal (Balaji, 2002), psylla on citrus (Ghongale, 2003), thrips, whiteflies and leafhoppers on cotton (Srinivasan, 2004) and leafhopper and whitefly on brinjal (Mhaske and Mote, 2005) was documented.

Thiacloprid (0.024%) and Acetamiprid (0.004%) excelled over the remaining treatments showing 64.56 and 63.79 per cent reduction of BPH population over control. The reports available on efficacy of acetamiprid against BPH is scanty. However, this result is in conformity with the studies of Das *et al.,* (1999) on aphids, *Aphis gossypii* on cotton, Vinod and Sonalkar (1999) on whitefly, *B. tabaci* on okra, Kendappa *et al.,* (2002) on aphid, *Myzus persicae* on tobacco, Kumawal and Kumar (2007) on leafhoppers on soybean and Raghuraman *et al.,* (2008) on leafhopper and whitefly of cotton. Very few reports are available regarding the efficacy of thiacloprid on BPH. Varma *et al.,* (2003) reported that thiacloprid @

120 g a.i./ha reduced the BPH population upto 129.0/10 hills as against 570.3/10 hills in untreated control..

Clothianidin (0.003%) and acephate (0.12%) were found to be moderately effective against BPH in the present investigation by recording 59.10 and 52.69 per cent reduction respectively over control. Misra (2005) reported that clothianidin @ 25 g a.i./ha showed 92 – 95 per cent reduction of *N. lugens* over control in rice. No further reports are available to confirm the present results pertaining to the efficacy of this treatment against BPH. However, this result was in conformity with the studies where clothianidin was effective against green peach aphid, *M. persicae* (Dewar *et al.,* 2002) and leafhopper on cotton (Patil *et al.,* 2007). The four chemicals *viz.,* thiamethoxam, acetamiprid, thiacloprid and clothianidin which were evaluated in present investigation belong to neo-nicotinoid group. They act on the central nervous system causing irreversible blockage of post synoptic nicotinergic acetyl choline receptors (Tomlin, 1995 and Elbert *et al.,* 2001). This may be the probable reason of effective control of BPH through these chemicals.

The results of acephate are in conformity with the studies of Kumaran *et al.,* (2007) who reported that acephate @ 468.75 g a.i./ha reduced the population of BPH upto 61.83 per cent. The efficacy of acephate against BPH was also reported by Sekh *et al.,* (2007). Likewise, its efficacy on some sucking pests like aphids, leafhoppers and whitefly on okra and cotton was also reported by Tirumal Prasad *et al.,* (1993), Giraddi *et al.,* (1998).

The least effective treatment was emamectin benzoate (0.0025%) with a reduction of 33.51 per cent over control. There is no supporting literature available to compare the efficacy of emamectin benzoate against *N. lugens*. However, the effectiveness of emamectin benzoate on other sucking pests such as thrips on grapes (Balikai and Patil, 2007), whitefly on soybean (AICRP report on soybean, 2006-20007), thrips on grapes (Kulkarni and Adsule, 2007) and aphids, leafhoppers and thrips on okra (Dhanalakshmi and Mallapur, 2008) were reported. The poor efficacy of emamectin benzoate was probably due to its limited systemic action.

5.2.2 Efficacy of Insecticides against White Backed Planthopper (WBPH), *Sogatella furcifera* (Horvath).

The overall mean efficacy of the insecticides in reducing white backed planthopper (WBPH) recorded at 1, 5, 10 and 15 days after two sprayings clearly revealed the superiority of ethiprole (0.01%) and buprofezin (0.04%) over rest of treatments which offered 77.69 and 76.73 per cent reduction respectively and were on par with each other. These results in conformity with the findings of Varma *et al.,* (2003) who recorded minimum population of 8.8 WBPH/ 10 hills with ethiprole 10EC @ 50 g a.i./ha. The efficacy of buprofezin against WBPH was reported by Karat *et al.,* (1999) who recorded lowest population of WBPH (2.72 to 3.73 hoppers/hill) with buprofezin 25WP @ 0.5 kg a.i./ha. The effectiveness of buprofezin against WBPH was also reported by Bhavani and Rao (2005).

Thiamethoxam (0.005%) was also effective against the WBPH in present investigation by reducing the population upto 73.63 per cent and was in conformity

with the results reported by Javaregowda and Krishna Naik (2005) who revealed that thiamethoxam @ 100 and 125 g a.i./ha reduced the population of WBPH upto 85.9 and 91.1 per cent respectively over control. The efficacy of thiamenthoxam against WBPH on rice was also reported by Bhavani and Rao (2004) and Vasanth Bhanu *et al.,* (2007).

The next best treatment was thiacloprid (0.024%) with 65.22 per cent reduction of WBPH population over untreated control. These results are in conformity with the findings of Varma *et al.,* (2003) who recorded minimum population of WBPH (31.8/10 hills) with thiacloprid @ 120g a.i./ha. The effectiveness of thiacloprid on *Amrasca biguttula biguttula* on okra was reported by Sinha and Sharma (2007).

The next best treatments in present investigation were acetamiprid (0.004%) and clothianidin (0.003%) by recording a population reduction of 62.96 and 61.93 per cent respectively and were on par with each other. Literature on acetamiprid against WBPH is lacking. However its efficacy on other sucking pests was reported by Dos *et al.,*(1999) on aphids, *A. gossypii* on cotton, Vinod and Sonalkar (1999) on whitefly, *B. tabaci* on okra, Kendappa *et al.,* (2002) on aphid, *M. persicae* on tobacco, Kumawal and Kumar (2007) on leafhoppers on soybean and Raghuraman *et al.,* (2008) on leafhoppers and whitefly of cotton. Literature on efficacy of clothianidin against WBPH is scanty. However, its efficacy on some sucking pests like brown planthopper on rice, green aphids on sugarbeat and leafhoppers on

cotton were reported by Misra (2005), Dewar *et al.,* (2002) and Patil *et al.,* (2007) respectively.

Acephate (0.12%) was found to be moderately effective against WBPH by recording 58.31 per cent reduction over control. Contrary to this, Bhavani and Rao (2005) reported that acephate @ 600g a.i./ha caused 84.49 per cent reduction of WBPH. The variability in efficacy may be attributed to differences in the susceptibility of the pest at different places as well as in the concentration of insecticide used.

The least effective treatment was emamectin benzoate (0.0025%) with only 24.90 per cent reduction over control. Literature on efficacy of emamectin benzoate against WBPH is not available. The less effectiveness of emamectin benzoate against sucking pests on okra was reported by Dhanalakshmi and Mallapur (2008). The effectiveness of emamectin benzoate against thrips on grape were reported by Balikai and Patil (2007), Kulkarni and Adsule (2007).

5.2.3 Efficacy of insecticides against Green leafhopper (GLH), *Nephotettix virecense*

The overall mean efficacy of 4 observations recorded at one, five, ten and fifteen days after two sprays revealed that buprofezin (0.04%) and thiamethoxam (0.005%) were the most effective treatments against Green leafhopper (GLH) with 75.08 and 74.31 per cent reduction over control. Literature on efficacy of buprofezin against GLH is lacking. However, effectiveness of buprofezin against other sucking pests like brown planthoppers and white backed planthoppers on rice

and mealy bug on grape were reported by Korat *et al.,* (1999), Bhavani and Rao (2005), Kendappa *et al.,*(2005) and Balikai (2005). The earlier reports on the efficacy of the thiamethoxam against GLH were scanty. However, its efficacy on other leafhopper pests was reported by Misra (2002) on okra, Sharma and Lal (2002) on brinjal, Dhawan and Simwat (2002) on cotton, Venkatesh (2003) on mango, Mhaske and Mote (2005) on brinjal, Nagangoud (2003) on mango and Sinha and Sharma (2007) on okra. The higher efficacy of buprofezin may be correlated with the feeding place of GLH where they probably more exposed to chemical as compared with BPH and WBPH.

Ethiprole (0.01%) and thiacloprid (0.024%) were next best treatments against GLH with 70.21 and 65.27 per cent reduction over untreated control, respectively. These results are supported by Sahithi and Misra (2006) who reported that ethiprole 10SC @ 50g a.i./ha was effective in controlling GLH upto 89.7 per cent over untreated control. Literature on thiacloprid against GLH is scanty. However, its efficacy on other sucking pests was reported by Varma *et al.,* (2003) on brown planthopper and white backed planthopper on rice and Sinha and Sharma (2007) on *A. biguttula biguttula* on okra.

Acetamiprid (0.004%), clothianidin (0.003%) and acephate (0.12%) were moderately effective with 63.45, 59.37 and 56.46 per cent reduction of GLH over untreated control. Literature on efficacy of acetamiprid against GLH is scanty. However, its higher efficacy against *A. biguttula biguttula* was also reported by Acharya *et al.,* (2002), Suganya *et al.,* (2007) and Raghuraman *et al.,* (2008).

Efficacy of clothianidin against GLH was contrary with Sahithi and Misra (2006) who reported clothianidin 50WDG @ 25g a.i./ha recorded 83.3 per cent reduction over control in rice. The reports on efficacy of acephate against GLH are lacking. However, its higher efficacy on other leafhopper species was reported by Thirumal Prasad *et al.,* (1993) on okra, Giraddi *et al.,* (1998) on okra, Asaf Ali and Chinniah (1999) on cotton and Girish Kumar and Giraddi (2001) on mango.

Emamectin benzoate (0.0025%) although significantly superior over untreated control was the least effective treatment against GLH with 32.78 per cent reduction over untreated control. No report is available on the effect of this molecule on GLH. However, emamectin benzoate @ 0.2 g/l reduced the population of leafhoppers on okra upto 64.7 per cent compared to untreated check (Dhanalakshmi and Mallapur, 2008).

5.2.4 Effects of treatments on the yield

Significant differences in the pest infestation as well as seed yield were noticed, indicating differential efficacy of the treatments imposed on sucking pests of rice. In the present investigation ethiprole (0.01%) and buprofezin (0.04%) recorded the highest yield of 5.16 t/ha and 5.13 t/ha and were on par with each other. These results are in agreement with findings of Varma *et al.,* (2003) who recorded grain yield of 4.15 t/ha with ethiprole 10EC @ 50g a.i./ha. Bhavani and Rao (2005) reported that buprofezin 25WP @ 50g a.i./ha and 100g a.i./ha recorded higher yields (5.06 t/ha and 5.14 t/ha). The treatments which also recorded higher

yield were thiamethoxam (0.005%) (4.98 t/ha), thiacloprid (0.024%) (4.75 t/ha), acetamiprid (0.004%) (4.52 t/ha) and clothianidin (0.003%) (4.48 t/ha).

These results about thiamethoxam are in confirmation with findings of Bhavani and Rao (2004), Javaregowda and Krishna Naik (2005) and Vasanth Bhanu *et al.,* (2007) who reported higher yields in rice due to thiamethoxam. Varma *et al.,* (2003) reported grain yield of 4044 kg/ha with thiacloprid @120g a.i./ha. Suganya Kumari *et al.,* (2007) reported increase in yield of seed cotton due to acetamiprid against sucking pests (aphids and leafhoppers) of cotton. Patil et al., (2007) reported increase in seed cotton yield due to clothianidin against *Amrasca devastance.*

The treatment which recorded intermediary yield was acephate (0.12%) with 4.24 t/ha. The efficacy of acephate in increasing yield was reported by Sekh *et al.,* (2007) against BPH on rice. Emamectin benzoate (0.0025%) gave the lowest yield among the treatments (3.62 t/ha) and it was significantly superior over control.

Conclusions

The following conclusions are drawn on the basis of results obtained

- Ethiprole (0.01%) and buprofezin (0.04%) were found highly effective against BPH and WBPH. While buprofezin (0.04%) and thiamethoxam (0.005%) are effective against GLH.
- Emamectin benzoate (0.0025%) was the least effective against all three pests viz., BPH, WBPH and GLH.

- Among other treatments acetamiprid (0.004%), thiacloprid (0.024%), clothianidin (0.003%) and acephate (0.12%) were found moderately effective against these pests.
- Ethiprole (0.01%) and buprofezin (0.04%) were found to be superior by recording the highest yield of 5.16 t/ha and 5.13 t/ha, respectively.
- Emamectin benzoate (0.0025%) recorded the lowest (3.62 t/ha) yield among all the treatments

CHAPTER VI

SUMMARY

The investigations on “Taxonomic studies on leafhopper and planthopper fauna associated with rice ecosystem and their management” was conducted at Agricultural College, Bapatla and Agriculture college farm, Bapatla, Guntur district as head quarters during 2008-2009. The summary of the results obtained from the above studies is presented here under.

6.1 TAXONOMIC STUDIES ON LEAFHOPPERS

Investigations on the leafhopper fauna associated with rice crop in costal and central Karnataka was undertaken at Agricultural College, Bapatla, Guntur District. The leafhoppers were collected in different rice ecosystems from eight districts of coastal and central Karnataka, processed in the laboratory, identified and adequately described. In total, twenty leafhopper species from different rice ecosystems have been identified and are given hereunder:

(I) Tribe Athysanini

1) *Banus* sp. nr. *consfuscus* (Pruthi)

2) *Exitianus indicus* (Distant)

3) *E. nanus* (Distant)

4) *Nephotettix virescens* (Distant)

(II) Tribe Chiasmusini

5) *Chiasmus alata* Pruthi

(III) Tribe Cicadellini

6) *Cofana spectra* (Distant)

7) *C. unimaculata* (Signoret)

(IV) Tribe Deltocephalini

8) *Deltocephalus* (*Recilia*) *distinctus* Motschulsky

9) *D.* (*R.*) *dorsalis* Motschulsky

10) *D.* (*R.*) *pruthii* Metcalf

(V) Tribe Erythroneurini

11) *Empoascanara indica* (Datta)

(VI) Tribe Hecalini

12) *Hecalus arucatus* (Motschulsky)

13) *H. pusae* Ramasubba Rao and Ramakrishnan

(VII) Tribe Macrostelini

14) *Balclutha incisa* (Matsumura)

15) *B. lucida* (Butler)

16) *B. pararubrostriata* Ramasubba Rao and Ramakrishnan

17) *B. rubrostriata* (Melichar)

18) *B. saltuella* (Kirschbaum)

19) *Cicadulina* (*Cicadulina*) *bipunctata* (Melichar)

(VIII) Tribe Stenometopiini

20) *Doratulina indra* (Distant)

A key for distinguishing all these species were given along with 20 line diagrams and 20 colour microphotographs for clear understanding and for easy recognition. The identification of these leafhoppers and their earlier reports on different crops under different genera along with their diagnostic characters were discussed.

6.2 TAXONOMIC STUDIES ON PLANTHOPPERS

The planthoppers associated with rice ecosystems were collected form coastal and central districts of Karnataka, processed in the laboratory, identified and

adequately described. Six planthopper species belonging to two families were identified and given hereunder:

(I) Tribe: Delphacini

Family: Delphacidae

1. *Cemus sp*
2. *Nilaparvata lugens* (Stal)
3. *Sogatella furcifera* (Horvath)
4. *Sardia rostrata* Melichar
5. *Tagosodes pusanus* (Distant)

(II) Tribe: Meenoplini

Family: Meenoplidae

1. *Nisia nervosa* (Motschulsky)

The identification “key” for distinguishing all these planthoppers was provided along with the line drawings and the colour photographs of each specimen for clear understanding and for easy identification of these planthoppers. In the present investigation, the two delphacid planthoppers *viz.*, *N. lugens* and *S. furcifera* were observed as major pests. The remaining all other planthoppers may be feeding on rice plants or on grasses and weeds in rice ecosystems and may also be causal visitors on rice plants.

6.3 EVALUATION OF SOME NEW INSECTICIDES FOR MANAGEMENT OF LEAFHOPPERS AND PLANTHOPPERS IN RICE

A field experiment was conducted to evaluate the efficacy of some new insecticides against major sucking pests of rice at Agriculture College Farm, Bapatla diring *Kharif*, 2008-09. The insecticides are evaluated during present investigation against brown planthopper (BPH), *Nilaparvata lugens* (Stal); white backed planthopper (WBPH), *Sogatella furcifera* (Horvath) and green leafhopper (GLH), *Nephotettix virescens* (Distant).

The evaluation of efficacy of insecticides on BPH revealed that ethiprole (0.01%) and buprofezin (0.04%) were the most effective treatments by reducing the population of BPH to an extent of 78.30 and 77.36 per cent, respectively and were on par with each other. Thiamethoxam (0.005%) was the next best treatment recording 72.23 per cent reduction over control. This was followed by thiacloprid @ 0.024 per cent (64.56%) and acetamiprid @ 0.004 per cent (63.79%) which recorded more than 60 per cent reduction of BPH population over untreated control. Clothianidin @ 0.003 per cent (59.10%) and acephate @ 0.12 per cent (52.69%) were found to be moderately effective, recording more than 50 per cent reduction of BPH population over untreated control. Emamectin benzoate (0.0025%) was the least effective with only 33.51 per cent reduction over control.

Ethiprole @ 0.01 per cent (77.69%) and buprofezin @ 0.04 per cent (76.73%) being on par recorded highest reduction of WBPH population and remained significantly superior over all the other treatments and were followed by

thiamethoxam (0.005%) and thiacloprid (0.024%) with 73.63 and 65.22 per cent reduction, respectively. The next best treatments were acetamiprid @ 0.004 per cent (62.96%), clothianidin @ 0.003 per cent (61.93%) and acephate @ 0.12 per cent (58.31%) with more than 55 per cent reduction in WBPH population over untreated control. Acetamiprid (62.96%) and clothianidin (61.93%) were on par with each other. Emamectin benzoate (0.0025%) was the least effective with only 24.90 per cent reduction over control

Buprofezin @ 0.04 per cent (75.08%) and thiamethoxam @ 0.005 per cent (74.31%) recorded highest reduction of GLH population and remained significantly superior over all the other treatments and were followed by ethiprole (0.01%) and thiacloprid (0.024%) with 70.21 per cent and 65.27 per cent reduction, respectively. The next best treatments were acetamiprid @ 0.004 per cent (63.45%), clothianidin @ 0.003 per cent (59.37%) and acephate @ 0.12 per cent (56.46%) with more than 56 per cent reduction in GLH population over untreated control. Emamectin benzoate (0.0025%) was the least effective with only 32.78 per cent reduction over control.

Among the treatments, ethiprole and buprofezin recorded the highest yield of 12.90 Kg/plot and 12.83 Kg/plot, respectively and were on par with each other. The next best treatment was thiamethoxam with 12.47 Kg/plot and was on par with buprofezin (12.83 Kg/plot). The other treatments in the descending order of yields obtained were thiacloprid (11.87 Kg/plot and 4.75 t/ha), acetamiprid (11.30 Kg/plot and 4.52 t/ha), clothianidin (11.20 Kg/plot and 4.48 t/ha), acephate (10.60 Kg/plot

and 4.24 t/ha) and emamectin benzoate (9.07 Kg/plot and 3.62 t/ha), respectively over control. Emamectin benzoate (0.0025%) although significantly superior over untreated control was the least effective against all the three pests and also recorded lowest yield (3.67 t/ha).

LITERATURE CITED

Acharya S, Mishra H P and Dash D 2002 Efficacy of insecticides against okra jassid, *Amrasca biguttula biguttula* Ishida. Annals of Plant Protection Sciences 10(2): 230-232.

*Ahmad M and Yunus M 1986 Some leafhoppers and planthoppers of grasses in lower Sindh, Pakistan. Proceedings of Pakistan Congress of Zoology 6: 99-102.

AICRP report on soybean 2006-07. All India Coordinated Research Project report on soybean, 2006-07. Indore, Madhya Pradesh, India pp:50-64.

Asche M and Wilson M R 1990 The delphacid genus *Sogatella* and related groups: a revision with special reference to rice-associated species (Homoptera: Fulgoroidea). Systematic Entomology 15: 1-42.

Asif Ali K and Chinniah C 1999 Bioefficacy of carbosulfan (Marshal) 25EC against sucking pest of cotton, *Gossypium hirsutum.* Pestology 23(5):62-64.

Balaji K 2002 Efficacy of some new insecticides against pest complex of brinjal (*Solanum melongena* L.). M.Sc.(Ag) Thesis submitted to Acharya N.G. Ranga Agricultural University, Hyderabad.

Balikai R A 2005 Management of grape mealy bug, *Maconellicoccus hirsutus* (Green) using insect growth regulator. Research on Crops 6(1):68-71.

Baliki R A and Patil D R 2007 Bioefficacy of Emamectin benzoate 5SG (Proclaim 5SG) against grape pests and its effect on natural enemies and plants. Pestology 31(5):21-24.

Ball E D 1929 A supplemental revision of the genus *Athyasanus* in North America (Homoptera: Cicadellidae). Transactions of the American Entomological Society 55: 1-8

*Bergevin E 1925 Description d'une nouvelle espece d' *Athysanus* suceur de sang humain de l' extreme sud Algerien (Hemiptere - Homoptere - Jassidae). Inst. Pasteur d' Algerie Arch. 3: 42-44.

Blocker H D and Triplehorn B W 1985 External morphology of leafhoppers, pp. 41-60 In, the Leafhoppers and Planthoppers (eds Nault L R and Rodriguez J G) John Wiley and Sons, New York.

Bhavani B and Punnaiah K C 2006 Population dynamics of cabbage aphid, *Lipaphis erysimi* (Kalt) and its control with selected insecticides in cabbage. Pestology 30(11): 24-29.

Bhavani B and Rao P R M 2004 Bioefficacy of Thiomethoxam (Actara 20 WG) against rice planthoppers (BPH/WBPH) in irrigated field conditions. Pestology 28(12): 41-44.

Bhavani B and Rao P R M 2005 Bioefficacy of certain insecticides against rice planthoppers *vis-à-vis* natural enemies under irrigated field conditions. Indian Journal of Plant Protection 33(1): 64-67.

Bhuyan C and Ramakrishnan U 1992 Male genitalia of six species of Derbidae (Fulgoroidea: Homoptera). Bulletin of Entomology, New Delhi vol. 33(1-2): 63-67.

Blocker H D 1967 Classification of Western hemisphere *Balclutha* (Homoptera: Cicadellidae). Proceedings of the United States National Museum 122: 1-55.

*Bonfils J 1993 The two new species of delphacids from Reunion (Homoptera: Delphacidae) Bulletin de la societete Entomologique de France vol. 98 (3) 223-226.

Chalam M S V and Rao V R S 2005 Leafhopper fauna associated with graminaceous crops of Andhra Pradesh. Pest Management and Economic Zoology 13(2): 207-220.

Chandrasekaran M and Balasubramanian G 2002 Evaluation of plant products and insecticides against sucking pest of greengram. Pestology 26(1):48-50.

Chung Lin Kuoh 1983 The leafhoppers and planthoppers of rice in China In proceedings of the Ist International workshop on Bio-taxonomy, classification and Biology of leafhoppers and planthoppers (Auchenorrhyncha) of Economic importance. Knight W J, Pant N C, Robertson T S and Wilson M R (eds.) 500 pp. London, 4-7 October 1982, Commonwealth Institute of entomology, 56 Queen's Gate, London 277-278.

Cole L M, Nicholsan R A And Casida J E 1993 Action of phenyl-pyrazole insecticides at the GABA- gated chloride channel. Pesticide Biochemistry and Physiology 46:47p.

Dabrowski Z T 1987 Two new species of *Cicadulina* China (Hemiptera: Euscelidae) from West Africa. Bulletin of Entomological Research. 77(1): 53-56.

Dash P C and Viraktamath C A 1995 Two new species of grass feeding leafhopper genus *Deltocephalus* (*Recilia*) (Homoptera: Cicadellidae) from Orissa, India. Hexapoda 7(2): 71-78.

Dash P C and Viraktamath C A 1998 A review of the Indian and Nepalese grass feeding leafhopper *Deltocephalus* (Homoptera: Cicadellidae) with descriptions of new species. Hexapoda 10 (1&2): 1-59.

Datta B 1969 On Indian Cicadellidae (Homoptera) - I. Zoologischer Angeiger 182 (5-6): 391-392.

Datta B 1988 On Oriental Cicadellidae (Homoptera: Insecta). Records of Zoological Survey of India, Occasional Paper No. 90: 1-256.

Delong D M and Hershberger R V 1947 The genus *Exitianus* in North America including Mexico (Homoptera : Cicadellidae). Ohio Journal of Science 47: 107-116.

Dewar A M, Haylock L A, Garner B H, Baker P and Sands R J N 2002 The effect of clothianidin on aphids and virus yellows in sugar beet. The BCPC Conference; Pests and diseases, volume 1 and 2. Proceedings of an international conference held at the Brighton Hilton Metropole Hotel, Brightonm, UK pp. 647-652.

Dhanalakshmi D N and Mallapur C P 2008 Evaluation of promising molecules against sucking pests of okra. Annals of Plant Protection Sciences 16(1):29-32.

Dhawan A K and Simawat G S 2002 Field evaluation of thiamethoxam for control of cotton jassids, *Amrasca biguttula biguttula* (Ishida) on upland cotton. Pestology 26(1):15-19.

*Ding J H, Yard L F and Sheny J M 1983 A preliminary study on the classification of the nymphs of Delphacidae. Journal of Nanjing Agricultural College 12(4): 28-39.

Distant W L 1908 The fauna of British India, including Ceylon and Burma. Rhynchota - Homoptera IV. Taylor & Francis, London pp. 501

Distant W L 1918 The fauna of British India, Including Ceylon and Burma. Rhychota - Homoptera VII. Taylor & Francis, London. pp: 209.

Dominick S J and Mohansundaran M 1992 Susceptibly of *Bemisia tabaci* Genn. (Homoptera:Aleyrodidae) to insecticides. Pestology 16(2):5-7.

Dos S W J , Dos S K B, Santos W J D and Santos K B D 1999 Control of aphids, *Aphis gossypi* and thrips, *Frankliniella schultzei* on cotton. Anais II Congresso Bradileiro de Algodao: O algodao no seculo XX, Perspectivar Para O seculo. XXI, Ribeirao Preto, SP, Brosil.pp.175-177.

Dworakowska I 1979 On some Typhlocybinae from India and adjoining area (Homoptera, Auchenorrhyncha, Cicadellidae). Reichenbachia 19(18): 143-162.

Dworakowska I 1980 On some Typhlocybinae from India (Homoptera, Auchenorrhyncha, Cicadellidae). Entomologische Abhandlungen Staatliches Museum fur Tierkunde Dresden 43(8): 151-201.

Dworakowska I and Viraktamath C A 1975 On some Typhlocybinae from India (Auchenorrhyncha, Cicadellidae). Bulletin de l' Academie Polonaise des Sciences Serie des Sciences Biologiques 26: 529-548.

Elbert A, Erdelen C, Kuhnhold, Nauen R and Schmidt H W 2001 Calypso reg., a new plant protection product for foliar application in fruit crops. Mitteilungen der Deutschen Gesellschaft fur allgeneine und angewandte Entomologie 31(1-6): 223-226.

Evans J W 1966 The leafhoppers and froghoppers of Australia and New Zealand (Homoptera : Cicadelloidea and Cercopoidea) Part 2. Records of the Australian Museum 31: 83-125.

Fabricius J C 1803 Rhyngota Systema Rhyngotorum, secundum ordines, genera, species, adiectis synonymis, locis, observationibus, descriptionibus pp. 314.

*Fatima A, Naqui S N H, Ahmed I, Ahmed M And Ahmed M (ed.) 1996 Occurrence of some commonly found leafhoppers and planthoppers from cash crops and other graminaceous plants in Sindh, Pakistan. Sixteenth Pakistan Congress of Zoology, The Zoological Society of Pakistan held at the Quaid – Azam University Islamabad, Pakistan 13-15 April 1996 Proceedings of Pakistan Congress of Zoology vol. 16: 307-310.

Fennah R G 1963 The delphacid species complex known as *Sogatella furcifera* (Horvath (Homoptera: Fulgoroidea)) Bulletin of Entomological Research 54: 45-79.

Flemming R and Ratnakaran A 1985 Evaluating single treatment data using Abbot's formula with reference to insecticides. Journal of Economic Entomology 13:1179-1181.

Gerling D and Sinai P 1994 Buprofezin effects on two parasitoid species of whitefly (Homoptera: Aleyrodidae) Journal of Economic Entomology 87:142-146.

Ghauri M S K 1971 Revision of the genus *Nephotettix* Matsumura (Homoptera : Cicadelloidea : Euscellidae) based on the type material. Bulletin of Entomological Research 60: 481-512.

Ghauri M S K 1972 New species of *Exitianus* Ball (Homoptera, Cicadellide, Euscelidae) from Africa. Bulletin of Entomological Research 61: 689-692.

Ghongale P R, Naitam N R, Katole S R and Shivankar R S 2003 A new molecule thiamethoxam (Actara 25WG) in the management of citrus psylla (*Diaphorina citri*, Kuwaxama). Pestology 27(11):10-12.

Girish Kumar H M and Giraddi R S 2001 Bioefficacy of new molecules of insecticides against mango leafhoppers on crop variety alphanso. Pestology 25(6):25-28.

Girradi R S, Lingappa S and Hedge R 1998 Bioefficacy of chloropyriphos (Dursban) + cypermethrin (Cilcord) against insect pest of Bhendi. Pestology 22(6):25-28.

Grist D H and Lever R J A W 1969 Pests Of Rice. Longmans London pp.520.

Gunathilagaraj K 1999 Rice planthoppers. In, insect pests of cereals and their management Anand Prakash and Jagadeshwari Rao (eds.). Applied Zoologists Research Association CRRI Cuttack pp. 31-58.

Heller R and Linnavouri R 1968 Cicadelliden aus Athiopien. Stuttgarter Beitrage Zur Naturkunde aus dem Stattlichen Museum fur Naturkunde in Stuttgart Series A 186: 1-42.

*Horvath G 1899 Hemipteres de L'ile de yesso (Japon). Term. Fuzetek 22: 365-374.

Ishaaya I, Kontesedalor V S and Horowitz A R 2002 Controlling field crops pests. Pest management sciences 58(11):1091-1095.

Ishihara J and Lowe A John 1969 The leafhoppers of fields in India. All India Co-ordianated rice improvement project report. Rajendra nagar, Hyderabad-30, Andhra Pradesh, India pp. 1-14.

Ishihara T 1964 Revision of the genus *Nephotettix* (Hemiptera : Deltocephalidae). Transactions of Shikoku Entomological Society 8: 39-44.

Ishihara T and Kawase E 1968 Two new Malayan species of the genus *Nephotettix* (Homoptera: Cicadellidae). Applied Entomology and Zoology 3(3): 119-123.

Jacob P S 2000 Leafhopper fauna associated with oilseed and pulse crop ecosystems in Andhra Pradesh. M.Sc. (Ag.) Thesis Acharya N G Ranga Agricultural University, Rajendranagar, Hyderabad.

Jacob P S, Rao V R S and Punnaiah K C 2000 Leafhopper fauna associated with oilseed crops in Andhra Pradesh, India. Pest Management and Economic Zoology 8(1): 11-27.

Jacob P S, Rao V R S and Chalam M S V 2004 Description of new species belonging to the genus *Deltocephalus* Burmeister from India (Insecta, Hemipera, Auchenorrhyncha, Cicadellidae: Deltocephalini). Journal of Entomological Research 28(3): 187-191.

Jacob P S, Rao V R S and Punnaiah K C 2002 New record of leafhoppers (Cicadellidae: Homoptera) Associated with pulse crop-ecosystems in Andhra Pradesh. The Andhra Agricultural Journal 49(3&4): 256-261.

Jaware Gowda and Krishna Naik 2005 Bioefficacy of thiamethoxam 25WG against paddy white backed planthopper (WBPH) and their natural enemies. Pestology 29(5): 31-33.

Kaldandelen A 1988 Taxonomic studies on the species of Cixiidae (Homoptera) from Turkey. Bitki-koruma Bulenei 28(3-4): 113-140.

Kamala G 2001 Leafhopper fauna associated with rice-ecosystems in coastal Andhra Pradesh. M.Sc.(Ag.) Thesis Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad.

Kendappa G N, Mallikarjunappa S, Shankar G and Mithyantha M S 2002 Efficacy of some newer insecticides against green peach aphid, *Myzus persicae* (Sulzer) on tobacco. Pestology 20(9): 13-15.

Kendappa G N, Mallikarjunappa S, Shankar G and Mithyantha M S 2005 Evaluation of new insecticide Applaud 25EC (Buprofezin) against brown planthoppers, *Nilaparvatha lugens* (Stal.) (Family: Delphacidae, Order: Homoptera). Pestology 29 (2): 5-8.

Khutward D S, Nakat R V And Chavan B P 2002 Seed dressers and foliar spray on sucking pests of green gram (*Vigna radiata* (L.) Wilezek). Pestology 26(7): 57-59.

*Kirschbaum C L 1868 Die Cicadinen der gegend von Wiesbaden und Frankfurt. Nassau Ver. f. Naturk. Jahrb 21: 1-202.

Knight W J 1965 Techniques for use in the identification of leafhoppers (Homoptera : Cicadellidae). Entomologist's Gazette 16(4): 129-136.

Knight W J 1975 Deltocephalinae of Newzealand (Homoptera : Cicadellidae). Newzealand Journal of Zoology 2(2): 169-208.

Knight W J 1987 Leafhoppers of the genus *Balclutha* (Homoptera : Cicadellidae) in the Pacific region. Journal of Natural History 21: 1173-1224.

Korat D M, Patel M C, Dodia J F And Pathak A R 1999 Evaluaiton of some new insecticides against major paddy pests. Gujarat Agricultural University Journal 24(2): 68-73.

Krishnaiah N V and Kalode M B 1986 Toxicological investigation in rice against green leafhopper *Nephotettix viresence* (Dist). Tropical Pest Management 32: 44-48.

Krishnaiah N V and Kalode M B 1993 Efficacy of Ethofenprox against hoppers in rice. Crop Protection Journal 12: 532-538.

Kulkarni N S and Adsule P G 2007 Bioefficacy of proclaim 5SG (Emamectin benzoate) for the management of thrips in grapes. Pestology 21(9): 30-32.

Kumar C H R 1993 Studies on the efficacy of certain new insecticides against groundnut pest complex. M.Sc. (Ag) Thesis submitted to Acharya N.G.Ranga Agricultural University, Hyderabad.

Kumaran N, Vinoth Kumar B, Srinivasan T and Kuttalam S 2007 Bioefficacy of ethiprole 10 S.C. to brown planthopper, *Nilaparvata lugens* (Stal) (Homoptera: Delphacidae) in rice. Pestology 31(11): 22-25.

Kumawal M M and Ashok Kumar 2007 Bioefficacy of some novel insecticides against jassids in soybean. Pestology 31(2): 29-32.

*Larivieri M C 1999 Class Insecta, order Hemiptera, sub order Auchenorrhyncha family Cixiidae. Fauna of New Zealand no. 40: 5-7.

Linkejian, Wu Kong Ming, Wei Hongyi and Guo yuyunan 2002 population dynamics of *Bemisia tabaci* on different host plants and its chemical. Entomological Knowledge 39(4): 284-288.

Mammen K V and Menon M G R 1972 New records of delphacids from India. Entomologists Newsletter 2: 7- 9.

Mammen K V and Menon M G R 1974 Taxonomic key for identification of Indian Delphacidae. Agricultural Research Journal of Kerala 12 (2): 146-150.

*Matsumura S 1902 Monographie der Jassinen Japans. Termeszettudomanyi Fuzetek 25: 353-404.

*Matsumura S 1914 Die Jassinen end einige neue Acocephaline Japans. Journal of the College of Agriculture, Tohoku Imerial University 5: 165-240.

Melichar L 1903 Homopteren - Fauna Von Ceylon. Verlag von Felix L. Dames, Berlin pp: 248.

*Melichar L 1904 Beitrag zur Kenntnis der schutzfarbung Mimikry bei. Homopteren. Entomologique Jahrb 13: 213-217.

Mhaske and Mote U N 2005 Studies on evaluation of new insecticides against brinjal pest complex. Journal of Maharashtra Agricultural University 30(3): 303-306.

Mishra H P 2002 Field evaluation of some newer insecticides against aphids, *Aphis gossypii* and jassids, *Amrasca biguttula biguttula* on okra. Indian Journal of Entomology 64(1): 80-84.

Mishra H P 2005 Field evaluation of some new molecules against brown planthopper *Nilaparvata lugens* (Stal.) infesting rice. Indian Journal of Entomology 67(2): 137-139.

Mishra H P 2006 Chemical management of the white backed planthopper, *Sogatella furcifera* Horvath infesting rice. Indian Journal of Entomology 68(4):338-340.

Misra B C 1980 The leafhoppers and planthoppers of rice. Report of the Central Rice Research Institute, Orissa, India. pp 182.

Mochida and Okada T 1979 Taxonomy and Biology of *N. lugens* (Homoptera: Delphacidae) In. Brown planthopper: Threat to rice production Asia International Rice Research Institute Los Bonos Philippines pp. 21-44.

Morrison W P 1973 A revision of the Hecalinae (Homoptera : Cicadellidae) of the Oriental region. Pacific Insects 15: 379-438.

Motschulsky V I 1859 Homopteres. In, Insects des Indes Orientales, et de contrees Analogues. Etude Entomologie 8: 25-118.

Nagangoud A, Pramod Katti and Patil B V 2003 Bioefficacy of thiamethoxam (Actara 25WG) against mangohopper. Pestology 27(1):32-33.

Narayana N L, Rama Subba Rao V and Rajasekhar P 2005 New records of planthoppers (Delphacidae : Homoptera) associated with rice ecosystems from Andhra Pradesh. The Andhra Agricultural Journal, 52 (3&4): 488-495.

Nisha C, Suchitra M and Amitara K 2004 Efficacy of synthetic insecticides and biopesticides against potato aphid, *Myzus persicae* (Sculzer) and *Aphis gossypi* Glover in eastern gangatic plains. Journal of Entomological Research 28(4):351-353.

*O' Brien L B and Wilson S W 1985 Planthopper systematics and external morphology. In , Nault L R and Rodriguez J G (eds.) The leafhoppers and planthoppers, John wiley and sons , New York pp 61-102.

Okada T 1977 Taxonomic characters for identification of the rice brown planthopper (*Nilaparvata lugens)* and its related species in the Asian and Pacific Region. The rice brown planthopper. Food and Fertiliser Technology Centre for the Asian and Pacific Region pp. 1-26.

*Oshanin V T 1906 Verzeichnis der palaearktischen Hemipteren mit besonderer Berucksichtigung ihrer verteilung im Russischen Reiche II. Band. Homoptera. I Lieferung st.. Museum Zoologique Petersburg Annals 11: 1-192.

Panda B M and Rath L K 2003 Efficacy of certain newer formulation of insecticides for the control of *Sogatella furcifera* (Horvath) in rice. Indian Journal of Plant Protection 31(2):28-30.

Pathak M D and Dhaliwal G S 1981 Trends and strategies foe rice insect problems in Tropical Asia. IRRI research papers Series No. 64, Los. Banos, Philippines.

Pruthi H S 1934 Entomological investigations on the spike disease of Sandal (14). Jassidae (Homoptera). Indian Forest Records, Entomology Series 19(4): 1-30.

Raghuraman M, Ajanta Birah and Gupta G P 2008 Bioefficacy of Acetamiprid on Sucking Pests in Cotton. Indian Journal of Entomology. 70(4): 319-325.

Ramakrishnan U 1985 A new species of the genus *Cofana* Melichar (Cicadellidae: Cicadelloidea: Homoptera) from India. Journal of Entomological Research 9(2): 129-131.

Ramakrishnan U and Ghauri M S K 1979 New genera of the *Empoascanara* complex (Homoptera, Cicadellidae, Typhlocybinae). Reichenbachia Staatliches Museum fur Tierkunde Dresden 17(24): 193-213.

Ramakrishnan U and Menon M G R 1974 Studies on Indian Typhlocybinae (Homoptera, Cicadellidae). 5. The Tribe Erythroneurini. Oriental Insects 8(4): 433-455.

Rao K R 1973 Studies on a small collection of Jassids from Poona (Homoptera : Cicadellidae). Zoologischer Anzeiger 191: 93-98.

Rao K R 1989 Descriptions of some new leafhoppers (Homoptera: Cicadellidae) with notes on some synonymies and imperfectly known species from India. Hexapoda 1: 59-84.

Rao V R S 1988 Taxonomic studies of Indian Aphrodinae (*Sensu* Hamilton) (Cicadellidae: Homoptera) Ph.D thesis submitted to Division of Entomology, Indian Agricultural Research Institute, New Delhi.

Rao V R S 1997 A new name for *Hecalus morrisoni* Ramasubba Rao and Ramakrishnan. Journal of Bombay Natural History Society 94: 585-586.

Rao V R S and Chalam M S V 2007 biodiversity of planthopper fauna (Delphacidae: Hemiptera) associated with rice and sugarcane crop-ecosystems in South India. Hexapoda 14(2):129-141.

Rao V R S and Ramakrishnan U 1988 A new species and new records of *Recilia* Edwards (Homoptera: Cicadellidae) from India. Journal of Entomological Research 12(2): 132-135.

Rao V R S and Ramakrishnan U 1990a The Indian Species of *Hecalus* with descriptions of three new species (Homoptera: Cicadellidae). Oriental Insects. 24: 385-397.

Rao V R S and Ramakrishnan U 1990b Two new species and some new records of the genus *Balclutha* Kirkaldy from India. (Insecta: Homoptera, Auchenorrnyncha: Cicadellidae: Balcluthini). Reichenbachia. 27: 105-108.

Reddy P P and Rao V R S 2001 Leafhopper fauna associated with vegetable crops of Andhra Pradesh in India. Entomon 26(2): 121-130.

Ribaut H 1952 Homopters Auchenorhynques. II (Jassiae) Fauna de France 57: pp. 474.

Ross H H 1968 The evolution and dispersal of the grassland leafhopper genus *Exitianus*, with keys to Old World species (Cicadellidae : Hemiptera). Bulletin of British Museum (Natural History) Entomology 22(1): 1-30.

Ruppel R F 1965 A review of the genus *Cicadulina* (Hemiptera : Cicadellidae). Publications of the museum of Michigan State University, Biological Series 2(8): 385-428.

Sahithi S And Misra H P 2006 Control of rice green leafhoppers,*Nephotettix virescence* (Dist.) by the use of insecticides. Annals of Plant Protection Sciences 14(1):80-82.

Sakabale R V, Dhanokar B K and Puri S K 1991 Chemical control of cotton whitefly, *Bemisia tabaci* (Genn). Pestology 15(6): 40-43.

Sarangdevot S S, Sharma U S and Ameta O P 2006 Efficacy of insecticides and neem oil against sucking insect pests of brinjal (*Solanum melongena* Linn.). Pestology 30(2): 31:34.

Sekh K, Nair N, Jana S K and Somchoudhury A K 2007 Efficacy of ethiprole 10% S.C. against brown planthopper of Rice. Pestology 31(1):46-48.

Sexena R C and Singh R K 2003 Rice Research in India and the Asian Perspective Asian Biotechnology and Development Review Neem Foundation, Gurgaon, India. Formerly with IRRI, Philippines pp. 81-96.

Sharma B and Lal O P 2002 Bioefficacy of thiamethoxam in comparision to recommended insecticides against leafhopper and whitefly of brinjal (*Solanum melongena* L.). Journal of Entomological Research 26(3):256-262.

Sharma B and Badan P 1985 On genus *Balclutha* Kirkaldy (Homoptera : Cicadellidae) from Jammu. Entomotaxonomia 7 (2): 149-156.

*Shun Cheran Tsaur 1989 Addition to the fauna of Taiwanese Meenoplidae Journal of Taiwanb Museum 42(1): 25-29.

Sinha S R and Sharma R K 2007 Efficacy of Neonicotinoids against okra insect pests. Pesticides Research Journal 19(1): 42-44.

Sohi A S 1983 The Oriental Typhlocybinae with special reference to the pests of cotton and rice: a review. Pp. 47-74. in: "Proceedings of the first International workshop and Biotaxonomy, Classification and Biology of Leafhoppers and Plant hoppers (Auchynorrhyncha) of Economic Importance, London, 4-7 October, 1982. Eds: Knight W J, Pant W C Robertson T S and Wilson M R.

Sohi A S and Dworakowska I 1983 A review of the Indian Typhlocybinae (Homoptera: Cicadellidae) from India. Oriental Insects 17: 159-213.

Srinivasan M R, Sheeba Jasmine R and Palaniswamy S 2004 Evaluation of Thiamenthoxam 70WS and Thiamethoxam 25 WG against cotton sucking pests. Pestology 28(12): 37-40.

*Stal C 1864 Hemiptera nonnula nova vel minus, Cognita. Annales de la Societe Entomologique de France 4: 47-68.

Suganya Kanna S, Kuruppuchamy P, Kuttalam S and Sivasamy N 2007 Bioefficacy of acetamiprid 20SP against *Aphis gossypi* and *Amrasca biguttula biguttula* in cotton. Annals of Plant Protection Sciences 15(1): 15-20.

The Hindu Survey of Indian Agriculture, 2007.pp 30-31.

Tirumala Prasad R, Reddy G P V, Murthy M M K and Devaprasad V 1993 Efficacy and residues of certain new insecticides on okra. Indian Journal of Plant Protection 21(1): 47-50.

Tomlin Clive 1995 The Pesticide Manual. British Crop Protection Council. The Royal Society of Chemistry, United Kingdom pp. 154-708.

Varma R G N, Zaheruddeen S M, Bhavani B and Rao P R M 2003 Efficacy of certain new insecticides against rice planthoppers under field conditions. Indian Journal of Plant Protection 31(2): 31-33.

Vasant Bhanu K, Mallikarjuna Rao and Satyanarayana Reddy P 2007 Compatibility of certain promising pesticides against planthoppers and sheath blight in rice. Indian Journal of Plant Protection 35(2): 279-282.

Venkatesan S, Shanmugan K and Geetha B 2003 Biological efficacy of Actara 25WG against mangohoppers. Pestology 27(4): 20-22.

Venkateshwara Rao 2004 Study of Thrips (Order: Thysanoptera) Associated with pulses and chillies crop ecosystem in Khammam district and their

management on chillies. M.Sc.(Ag) Thesis submitted to Acharya N.G.Ranga Agricultural University, Hyderabad.

*Vilbaste J 1976 A revision of Homoptera - Cicadinea described by S. Matsumura from Europe and the Mediterranean area. Eesti NSV Teaduste Akadeemia Toimestised 25, Biologia No.1 : 25-36.

Vinod S and Sonalkar V 1999 *Bemisia tabaci* (Gennadius) control with acetamiprid on okra in Vidarbha region of Maharastra. Pest Management and Economic Zoology 7(1): 87-89.

Viraktamath C A 1983 Genera to be revised on a priority basis. pp.471-492, In, The proceedings of the first international workshop on leafhoppers and planthoppers of economic importance, (eds. Knight W J, Pant N C, Robertson T S and Wilson M R). Commonwealth Institute of Entomology, 56 Queenis Gate, London, SW75JR.

Viraktamath C A and Dash P C 2001 Taxonomic position of Indian species of grass feeding deltocephaline leafhoppers assigned to the genus *Allophleps* (Hemiptera : Cicadellidae). Journal of Bombay Natural History Society 98(1): 47-52.

Viraktamath S 1991 Redescription of *Deltocephalus porticus* Melichar (Homoptera: Cicadellidae). Karnataka Journal of Agricultural Sciences 4(12): 24-26.

Webb M D 1987 Species recognition in *Cicadulina* leafhoppers (Hemiptera: Cicadellidae) vectors of pathogens of graminae. Bulletin of Entomological Research 77: 683-712.

Webb M D and Vilbaste J 1994 Review of leafhopper genus *Balclutha* Kirkaldy in the Oriental region (Insecta: Homoptera: Auchenorrhyncha: Cicadellidae). Entomologische Abhandlungen Staatliches Museum fur Tierkunde Dresden 56: 55-87.

Wilson M R and Claridge M F 1985 The leafhopper and planthopper faunas of rice fields. The leafhoppers and planthoppers. Nault L R and Rodriguez (eds.) 500 pp. John Wiley and sons. pp: 381-404.

Wilson M R 1983 The nymphal stages of some Auchenorhynchan associated with rice in South-East Asia. In proceedings of the 1st international workshop on Biotaxonomy, classification and biology of leafhoppers (Auchenorhyncha) of economic importance Knight W J Pant N C Robertson T S and Wilson M R (eds.) 500 pp. London 4-7 October 1982 Commonwealth Institute of Entomology 56. Queen's Gate, London 121-134.

Wilson M R and Claridge M F 1991 Hand book for the identification of leafhoppers and planthoppers of rice. Commonwealth Agricultural Bureaux International, London, UK, pp.142.

Wilson S W and O' Brien L B 1987 A survey of planthopper pests of economically important plants (Homoptera: Fulgoroidea) In, Proceedings of

the IInd international workshop on leafhoppers and planthoppers of economic importance. Wilson M R and Nault L R (eds.) 368 pp London 23 rd July – 1st Aug. 1987 , Commonwealth Institute of Entomology, 56 Queen's Gate, London pp 343-360.

Young D A 1979 A review of the leafhopper genus *Cofana*. Proceedings of the Entomological society of Washington 81: 1-21.

*Originals not seen

Note: the literature is cited as per the "Thesis Guidelines" prescribed by Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad-30.