

**BIOECOLOGY AND MANAGEMENT OF RICE
EARHEAD BUG, *Leptocorisa oratorius*, FABRICIUS
(HEMIPTERA: ALYDIDAE) IN RAINFED ECOSYSTEM
OF UTTARA KANNADA DISTRICT**

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
Degree of

MASTER OF SCIENCE (AGRICULTURE)

IN

AGRICULTURAL ENTOMOLOGY

By

BASAVARAJ ASHOKAPPA H. T.

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE,
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005**

JULY, 2011

ADVISORY COMMITTEE

DHARWAD
JULY, 2011

(S.T. PRABHU)
CHAIRMAN

Approved by :

Chairman : _____
(S.T. PRABHU)

Members : 1. _____
(MANJAPPA .K)

2. _____
(JAVAREGOWDA)

3. _____
(SHRIPAD KULKARNI)

CONTENTS

Sl. No.	Chapter Particulars
	CERTIFICATE
	ACKNOWLEDGEMENT
	LIST OF TABLES
	LIST OF FIGURES
	LIST OF PLATES
	LIST OF APPENDICES
1.	INTRODUCTION
2.	REVIEW OF LITERATURE
	2.1 Taxonomy, species complex of <i>Leptocorisa</i> spp
	2.2 Seasonal incidence of rice earhead bug and its natural enemies
	2.3 Biology of rice earhead bug, <i>Leptocorisa</i> spp
	2.4 Management of rice earhead bug, <i>Leptocorisa</i> spp
3.	MATERIAL AND METHODS
	3.1 Study on species complex of <i>Leptocorisa</i> spp in rainfed ecosystem of Uttara Kannada district
	3.2 Seasonal incidence of rice earhead bug and its natural enemies in rainfed ecosystem of Uttara Kannada district
	3.3 Bioecology of rice earhead bug, <i>Leptocorisa oratorius</i> in rainfed ecosystem of Uttara Kannada district
	3.4 Evaluation of plant extracts, entomopathogenic fungi and new molecules of insecticides against rice earhead bug in rainfed rice ecosystem
4.	EXPERIMENTAL RESULTS
	4.1 Study on species complex of <i>Leptocorisa</i> spp in rainfed ecosystem of Uttara Kannada district
	4.2 Survey for rice earhead bug incidence and its natural enemies in rainfed ecosystem of Uttara Kannada district
	4.3 Bioecology of rice earhead bug, <i>Leptocorisa oratorius</i> under laboratory condition

Contd.....

Sl. No.	Chapter Particulars
	4.4 Management of rice earhead bug, <i>Leptocorisa</i> spp using plant extracts, entomopathogenic fungi and new molecules of insecticides
	4.5 Per cent grain damage
	4.6 Yield
	4.7 Cost economics
5.	DISCUSSION
	5.1 Species complex of <i>Leptocorisa</i> spp in rainfed ecosystem of Uttara Kannada district
	5.2 Survey on incidence of rice earhead bug and its natural enemies in rainfed ecosystem of Uttara Kannada district
	5.3 Bioecology of rice earhead bug, <i>Leptocorisa oratorius</i> under laboratory condition
	5.4 Evaluation of plant extracts, entomopathogenic fungi and new molecules of insecticides against rice earhead bug in rainfed rice ecosystem
6.	SUMMARY AND CONCLUSIONS
	REFERENCES

LIST OF TABLES

Table No.	Title
1.	Details of places surveyed for rice earhead bugs and its natural enemies in rainfed paddy ecosystem of Uttara Kannada district
2.	Treatment details for the management of rice earhead bug
3.	Species complex of <i>Leptocorisa</i> spp on paddy in Uttara Kannada district during <i>kharif</i> (2010) and <i>Rabi</i> (2011)
4.	Incidence of rice earhead bug at Sirsi during <i>kharif</i> and <i>rabi/summer</i> , 2010-2011
5.	Incidence of rice earhead bug at Siddapura during <i>kharif</i> and <i>rabi/summer</i> , 2010-2011
6.	Incidence of rice earhead bug at Honnavara during <i>kharif</i> and <i>rabi/summer</i> , 2010-2011
7.	Incidence of rice earhead bug at Kumta during <i>kharif</i> and <i>rabi/summer</i> , 2010-2011
8.	Incidence of rice earhead bug at Mundgod during <i>kharif</i> and <i>rabi/summer</i> , 2010
9.	Incidence level of <i>Leptocorisa</i> spp in rainfed ecosystem of Uttara Kannada district during <i>kharif</i> and <i>rabi</i> (2010-2011)
10.	Natural enemies complex in Uttara Kannada during <i>karif</i> , 2010
11.	Natural enemies complex in Uttara Kannada during <i>rabi/summer</i> , 2011
12.	Fauna of natural enemies in rice fields of Uttara Kannada district during <i>khari</i> and <i>rabi</i> , 2010-2011
13.	Alternate weed hosts of rice earhead bug observed during survey in Uttara Kannada district
14.	Morphometric data of different stages of <i>Leptocorisa oratorius</i>
15.	Duration of life stages of <i>Leptocorisa oratorius</i> on paddy under laboratory condition
16.	Duration of life stages of <i>Leptocorisa oratorius</i> on paddy under potted cage condition
17.	Effect of plant extracts, entomopathogenic fungi and new molecules of insecticides on rice earhead bug population
18	Cost economics for eco-friendly approaches in the management of rice earhead bug in Uttara Kannada during <i>kharif</i> , 2010

LIST OF FIGURES

Figure No.	Title
1.	Village level incidence of rice earhead bug at Uttar Kannada district during <i>kharif</i> , (October) 2010 and <i>rabi</i> , (May) 2011
2.	Taluk level incidence of rice earhead bug at Uttar Kannada district during <i>kharif</i> , (October) 2010 and <i>rabi</i> , (May) 2011
3.	Effect of plant products, entomopathogenic fungi and new molecules of insecticides on rice earhead bug population
4.	Cost economics for ecofriendly approaches in the management of rice earhead bug in Uttara Kannada during <i>Kharif</i> , 2010

LIST OF PLATES

Plate No.	Title
1.	Map showing surveyed area
2.	General view of experimental plot
3.	<i>Leptocorisa</i> spp
4.	Different species of natural enemies found in rainfed paddy ecosystem
5.	Biology of rice earhead bug <i>Leptocorisa oratorius</i>
6.	Adults, mating and fecundity of <i>Leptocorisa oratorius</i>
7.	Habits of nymphs and adults of rice earhead bug
8.	Nature of damage by rice earhead bug

LIST OF APPENDICES

Appendix No.	Title
I.	Taluk- wise monthly rainfall data of the year 2010 in Uttara Kannada district
II.	Meteorological observation at 2010, ARS, Sirsi during the 2010

1. INTRODUCTION

The Rice plant, *Oryza sativa* L. is a member of the grass family, Gramineae. Rice is one of the leading major cereal crop of the world and staple food crop for more than two third of the population of India and more than 65 per cent of the world population (Mathur *et al.*, 1999). More than 90 per cent of the world's rice is grown and consumed in Asia. The rice plays a vital role in our national food security and is a means of livelihood for millions of rural households. Wherever rice is cultivated, it becomes integrate to the economic, social, cultural and religious lives of the associated populations. Rice therefore, becomes the life of the communities that it influences. It has been under cultivation over thousands of years under diverse agro-ecological and climatic condition. Globally, loss in rice due to infestation of insect pests, diseases, and weeds is about 51.4 per cent of which 20.7 per cent is due to insect pests (Oerke *et al.*, 1994).

The Rice agro-ecosystems of the world are categorized into five major types: (i) Irrigated rice fields (ii) Rainfed rice fields, (iii) Deep water rice fields, (iv) Upland rice fields and (v) Tidal water rice fields.

In India, rice is grown over an area of 1.5 billion hectare with production of 30.5 million tonnes and an average grain yield of 1296 kg/ha (Anon., 2010). The major seasons for low productivity in India are the losses due to insect pests, diseases and wheat. Insect pest alone are responsible for 10-25 per cent yield loss in India. Karnataka occupies a prominent place in rice map of India accounting for nearly 11,29,883 hectare of area with grain production of 27,25,229 tonnes and productivity of 2,539 kg/ha (Anon., 2009). Among various constraints of rice production, damage due to insect pests is substantial and needs regular attention. Large-scale cultivation of high yielding varieties, monocropping, close planting, water regime, excessive use of nitrogenous fertilizers and misuse of agrochemicals have further aggravated the pest incidence.

The rainfed rice area is about 24.4 million hectare with productivity of less than 0.98 tonnes/hectare, due to uncertainty of available water. Rainfed rice ecology is a fragile ecology and divides into sub-ecologies *viz.*, rainfed uplands (plain area and high altitude hill rice), deep water, semi-deep water and shallow rainfed (drought prone, lowland and submerged prone) and coastal saline rice. Upland rice is grown in unfavourable rainfed soil and weather conditions.

Rice is the major cereal crop of Uttar Kannada district covering as much as 77373 ha with a production of about 119812 tonnes and yield of 1630 kg/ha (Anon., 2009). Uttara Kannada district comprises both coastal and hilly area with rainfall ranging from 1000 mm to 5000 mm annually. This district also comprises ecologically sensitive biodiversity which lies in Western Ghats. All the rice area of this district is under rainfed situation and starts with onset of monsoon every year. Rainfed rice ecosystem of Uttara Kannada district comprises of three distinct conditions depending on altitude. They are coastal, 'Upghat' and drill sown rice ecosystems.

Over 1400 insect species attack standing and stored rice in the world (Grist and Lever, 1969), while Kalode and Pasalu (1986) reported that over 100 species of insect pests attack rice crop at various stages of its growth. Of the several insect pests on rice, the rice earhead bug (*Leptocorisa oratoius*) is one of the important pest in the earhead stage causing economic damage. Both nymphs and adults suck the plant sap and attack the rice grains, particularly during milky stage (Akbar, 1958). This leads to production of empty or "pecked" grains. Heavy infestation of this pest can result in total loss of the crop. In addition, they have a pungent odour, which is imparted to the rice (Rai, 1981).

The rice earhead bug occurs in epidemic form chiefly in Australia, Burma, Srilank, and Fiji islands, India, Indonesia, Japan, Malaysia, Pakistan and Philippines. In India, the pest has been reported to cause 10 to 40 per cent yield loss (Israel and Rao, 1954) and sometimes complete loss (Srivastava and Saxena, 1964). In some years, it assumes serious proportions and spreads in an epidemic form causing heavy damage as it happened in 1952 and 1958 in Bihar. Thus, the pest has received considerable attention from a number of workers (Sen and Chaudhuri, 1959).

Rice earhead bug, though said to occur mainly in coastal and heavy rainfall tracts of the Karnataka state (Malnad), its spread to other areas cannot be ruled out. Rice cultivators, especially in rainfed rice ecosystem of Karnataka, faced problems of earhead bug, *Leptocorisa* spp which is said to cause great loss in rice production. Present management practices against rice earhead bug are based on insecticide application and needs exploration of environmentally sound ways of management.

Many insecticides have been screened against rice earhead bugs and many workers have reported their relative efficacy. But, the information generated was scanty especially as for as using of botanicals, entomopathogenic fungi and new molecules of insecticides are concerned. Studies on the biology and ecology of different species of *Leptocorisa* spp have been carried out by quite a few workers. However, it is meager. Therefore, it was felt necessary to take up a detailed study on rice earhead bug and to develop management practices. The present investigations were undertaken with the following objectives:

1. Study on species complex of *Leptocorisa* spp in rainfed ecosystem of Uttara Kannada district
2. Seasonal incidence of rice earhead bug and its natural enemies in rainfed ecosystem of Uttara Kannada district
3. Bioecology of rice earhead bug, *Leptocorisa oratorius* in rainfed ecosystem of Uttara Kannada district
4. Evaluation of plant extracts, entomopathogenic fungi and new molecules of insecticides against rice earhead bug in rainfed rice ecosystem

2. REVIEW OF LITERATURE

The review of work done on rice earhead bugs, *Leptocorisa* spp pertaining to its taxonomy, distribution, species complex, bioecology, seasonal incidence, natural enemies, nature of damage, extent of grain damage and chemical control is presented below.

2.1 Taxonomy

Genus *Leptocorisa* was first recorded from India by Atkinson (1889) who recorded the occurrence of *Leptocorisa acuta* (Thunberg). *Leptocorisa acuta* was first described by Thunberg in 1783 under the genus *Cimex*. Fabricius described *Leptocorisa oratoria* in 1794 and *Leptocorisa varicornis* in 1803 under the genus *Gorris*. Earlier to the publication of Ahmad's (1965) paper, both *L. acuta* and *L. varicornis* were treated as distinct species, whereas *L. oratoria* as a synonym of *L. acuta*. However, Ahmad clarified the position of these species and reinstated *L. oratoria* as a distinct species from *L. acuta*, might be suppressed *L. varicornis* as a synonym of *L. acuta*. Grist and Lever (1969) opined that all the references to *L. acuta* before the publication of Ahmad's paper actually referred to *L. oratoria*.

From India, only three species mainly *L. acuta*, *L. lepida* (Bredd.) and *L. oratoria* are known (Distant, 1902; China, 1924; Ahmad, 1965).

2.1.1 Common names

Leptocorisa spp is being called by wide range of common names based on its nature of damage and physical appearance and emitting unpleasant odour. It is commonly referred as "Gundhi", "Gundhi Hakki" and "Malanga" in Hindi, "Bambutola", "Rasa Hiruva Hula" "Bambuchi" "Battada Tene Tigane" and "Bambina Hula" (Uttara Kannada district) in Kannada, "Chazhi" in Malayalam, "Dhhekoon" in Marathi, "Kaninu Choosiyu" in Gujarathi, "Pachansli" in Telugu, "Gundhi Poka" in Bengali, "Kathirpuchi", "Navaipuchi" and "Chedi Penkel" in Tamil, "Bhoma" in Bihari. In English, the pest is called as paddifly, paddy bug, rice bug, paddy sapper, rice stink bug, paddy stink bug, rice earhead bug, paddy earhead bug, rice seed bug, and Asian rice bug. In Spanish it is called as chinche común Del arroz. In Bangladesh it is called as "gundhi poka". In Germany, Reiswanze, Gemeine. In Indonesia, walang sangit. In India, gundhi bug. In Netherlands, Rijstwanze gewone, Zaadwanze van de rijst. (Corbett, 1923a; Puttarudriah, 1955; Srivastava and Saxena, 1964; Vevai, 1968).

2.1.2 Distribution

According to Ahmad (1965) and Srivastava and Saxena (1967) the distribution of rice earhead bugs is as follows:

L. acuta

Bhutan, China, Fiji, India, Indonesia (Sumatra), Malaysia, New Caledonia and Samoa.

L. oratoria

Australia (Queensland), Bangladesh, Bhutan, China, India (Malabar), Indonesia (Sumatra), Malaysia, Solomon island, Sri Lanka and Tibet.

L. lepida

Burma, India, Malaysia, Sikkim and Sri Lanka. Barrion and Litsinger (1981) stated that *L. oratorius* and *L. acuta* shared a common distribution and the former was more abundant. *L. oratorius* occurred throughout Asia (Valencia and Heinrichs, 1982), South and South East Asia (Argente and Heinrichs, 1983).

A new distribution map was provided for *L. oratorius* (Fabricius) (Heteroptera: Alydidae) which attacks rice. The information was given on the geographical distribution in Asia, Andaman Islands, Bangladesh, Bhutan, Brunei, China; Xizangy (Tibet). In India the insect was reported from Assam, Karnataka, Kerala, Maharashtra, Meghalaya, Nagaland, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal.

It is also reported from other countries like Java, Indonesia, Sulowesi, Sumatra, Laos, Malaysia, Sabh, Sarwak, Peninsular Malaysia, Nepal, Philippines, Sri Lanka, Thailand, Vietnam, and Pacific Islands, Australia, Queensland, Papua New Guinea, and Solomon Islands (Anon., 1996).

2.1.3 Species complex of *Leptocorisa* spp

Nayak (1984) reported among the species, *L. oratorius* was more common in almost all the places in Karnataka, wherever the incidence of bug was noticed on rice. *L. acuta* was mostly confined to southern districts of maidan areas and *L. lepida* to malnad and coastal region. The genus *Leptocorisa* was first recorded by Atkinson (1989) he identified the specimen as *Leptocorisa acuta* and reported its occurrence in Pakistan, Gorakhpur and Uttar Pradesh. From India only three species mainly *L. acuta*, *L. lepida* and *L. oratoria* are known (Distant, 1902). China (1924) classified seven species of this genus in the oriental region of Landon according to structure of the male claspers, colour, length and other external characteristics. Van Den Berg, H. and Soehardi (2000) reported *Leptocorisa oratorius*, misidentified as *L. acuta* (Thunb.) in the literature prior to 1965, has been reported from south, east and south-east Asia through to Australia (Ahmad 1965). Although several species of *Leptocorisa* are found in rice, *L. oratorius* is by far the most dominant species associated with lowland paddy fields in Indonesia (van der Goot 1949; Siwi & van Doesburg 1984). Siwi & van Doesburg (1984) assumed that all rice bugs were *L. oratorius*, which was confirmed by observing this species' characteristic ventrolateral spots on the abdominal segments on several occasions, but other species, particularly *L. acuta*, occasionally might have been present.

2.2 Seasonal incidence of rice earhead bug *Leptocorisa* spp and its natural enemies

Many earlier reports indicated that the rice earhead bug thrived on grasses and millets before migration to paddy in milky stage (Lefroy, 1908; Fletcher, 1913-14; Hutson, 1930; Sen, 1955; Srivastava and Saxena, 1964). According to Hutson (1920) the rice earhead bug, *Leptocorisa* spp caused maximum damage to Maha paddy in February-March in Sri Lanka. In the West Coast, *L. varicornis* breed and increased in large numbers during monsoon season and the first crop was not much damaged. Uichanco (1921) first noticed *L. acuta* in large numbers during August and were abundant during November-December. During the drier months the bugs said to move to shady places to undergo aestivation (Austin, 1922 and Hutson, 1930).

Tateisi (1939) reported that the adults of *L. varicornis* have been found during winter on a conifer tree, *Cryptomoria* sp. from which they migrated to grasses in April-May and attacked rice from July-October in Japan. Venkatachalam (1944) reported that the second crop (Mundakan) transplanted in August-September suffered more from rice bugs in Cochin. Saxena (1952) reported that asilid fly (Rober fly), preying on adults and nymphs of *L. varicornis*, and the only other record of an insect preying on adults and nymphs *L. varicornis* in India, is that of a cicindelid, *Cicindela sexpunctata* Fabr. Found in small number in many important paddy areas.

According to Narayanan (1953) the maximum activity of *L. varicornis* in Bihar was from middle of September to first week of October. Biswas (1953) reported that the period of activity of *L. varicornis* was from middle of August to first week of November. He also stated that a couple of good showers in October or fall in temperature reduced the population which bred on alternate hosts in the adjoining jungles at slower rates thereafter. Sen (1955) observed *L. varicornis* feeding on *Panicum crusgalli* from end of March to June, later they spread to minor millets. The period of maximum attack on paddy was from middle of September to first week of October. The bugs were found hibernating on *Clerodendron infortunatum* Gaertn. from November to February and feed on new flush of mango trees during March to April.

According to Akbar (1958) *L. varicornis* breed on grasses in June-July and migrated to paddy in July-August. Maximum damage was done during September-October and bugs remained inactive during November-December.

Paddy sown in June and harvested in September was the main target of attack, while late maturing varieties escaped the damage (Sen and Chaudhuri, 1959). Banerjee (1961) reported that maximum activity of the paddy bug in relation to weather conditions was seen from August to November on Aman paddy in Bengal. He also stated that the damage was more in the adjoining areas of reserved forests.

Israel *et al.* (1961b) reported that *L. acuta* was serious crises in West Bengal and Kerala and *L. varicornis* in Andaman and Nicobar Islands, Madhya Pradesh, Orissa, Rajasthan, Delhi, Uttar Pradesh and West Bengal. According to Das (1961) the activity of *L. varicornis* was more during June to August and October to November in Assam, August-September and middle of October-middle of November in West Bengal, middle of July to middle of September and middle of October to middle of November in Bihar, middle of August to middle of October in Uttar Pradesh and Madhya Pradesh.

The studies on seasonal abundance at Cuttack indicated that the infestation was severe from October to mid November (Israel and Rao, 1961b; Rao *et al.*, 1978). Banerjee and Chatterjee (1965) reported that during off-season *L. acuta* multiplied on grasses, millets and wild paddy and hibernated during winter on the forest trees. The findings of Misra (1968) indicated that the adults of *L. varicornis* were active from July to middle of November and entered hibernation during winter.

Rothschild (1970) reported that the adults of *L. oratorius* feed on grasses like *Echinochloa crusgalli* L. Seauv. *Paspalum serobiculstum* L. and *Pennisetum* sp. before migrating to paddy fields. During off-season, small number of adults and nymphs were found on ratoon rice plants and various grasses.

Butani and Jotwani (1976) observed that *L. acuta* hibernate in adult stage on grasses, weeds or in cracks and crevices in the soil. Sands (1977) reported that *Echinochloa colona* L. Link helped in the multiplication of *L. oratorius* and he also stated that the abundance of the pest in bush land and grasses surrounding the paddy crop influenced on the extent of damage on paddy.

Singh and Sinha (1978) carried out fortnightly observation in Bihar from July to December in 1976 and reported that activity period of *L. acuta* was from second to third week of October and the average number per 100 sweeps varied from 10 to 500.

Chhabra and Jaswant Singh (1979) conducted survey on the rice pests during *kharif* season in Punjab. The crop was surveyed at the tillering stage, panicle emergence and pre-harvest stage. *L. acuta* was found during the pre-harvest stage. Garg and Sethi (1980) reported that weekly averages of 28° to 59° C, 69.55 per cent relative humidity, 8 to 18 hours of sunshine and 0 to 71.7 mm rain were found to favor the highest population buildup of *L. acuta* in rice, during *kharif* season in New Delhi.

Taylor *et al.* (1987) reported that rice bug *L. oratorius* comprises 80 per cent of the *Leptocorisa* bug from the collections in wet land and dry land rice in Philippines. Similarly, *L. acuta* and *L. palawanensis* also found in significant number. Plants in the milk or dough stage are nutritionally acceptable to *L. oratorius* and *E. colona* as the principle alternate weed host. Rai *et al.* (1990) reported that peak pest population of *L. acuta* was found from 37th to 40th standard weeks when the crop was at milky grain stage.

Suwat Ruayaree (1994) studied the seasonal occurrence of *Leptocorisa* spp and found that bug population was more abundant in milky stage of crop. Sugimoto and Nugaliyadde (1995) reported that *L. oratorius* damage occurs mainly from the very early stage of grain development to the milk ripe stage when the bug infestation was severe. Considerable proportion of damage was seen at the dough and hard-dough stages when the degree of infestation was lower. Chander (1996) studied the intrinsic rate of natural increase of *L. varicornis* on alternate host food plant, *E. colona* during *kharif* season. The maximum intrinsic rate of natural increase was estimated during the period from the last week of August to the 3rd week of September.

Nudrin and Artati (2000) conducted a survey to study the insect pests of upland rice during August to September 1998 in Indonesia. Among the different insect pests damaging in different stages of the crop growth, seed suckers such as rice bug occur in milky stage of the crop.

Chakraborty and Chatterjee (2002) indicated that gundhi bug, *L. varicornis* (*L. acuta*) on rice was high during panicle formation (from mid-September to October) when the temperature was 27° to 34° C and the relative humidity was 85 to 90 per cent.

Samui *et al.* (2004) studied the weather based forewarning models for rice bug, *L. acuta*. Daily observations on pest and weather during *kharif* and *rabi* season were recorded using light trap for fifteen years (1987-2001). The forewarning models for gundhi bug showed the population variation of 71 per cent and multiple regression models developed for the pest was validated by using meteorological data. Results showed that there were distinctly different weather requirements for adult, egg laying, hatching, larval and pupal stages. The median density of *L. oratorius* in farmers' fields (pooled from panicle emergence until the milky stage of rice) was 0.10 adults per hill (i.e. 2.6 adults m²) in the dry season (75 sites) and 0.14 adults per hill (3.5 adults m²) in the wet season (94 sites) Van Den Berg H. and Soehardi (2000).

Kikuchi *et al.* (2004) studied the relationship of occurrence of rice ear bugs and pecky rice damage. The data obtained from light traps indicated that occurrence of rice ear bug was less prevalent under low temperature and or high precipitation. Takeuchi *et al.* (2005) reported that the occurrence patterns of rice bugs were found to be closely related to the abundance of three stages of spikelet and cumulative degree days was used to uniformly express the changes in the incidence of rice bugs among different rice varieties, season and fields.

Kulagod (2009) reported earhead bug incidence peaked during second fortnight of October and first fortnight of November in *kharif* season in Uttara Kannada. The mean earhead bug was highest in Mundagod (9.06 bug/hill), followed by Siddapura (7.84 bug/hill), Kumta (3.33 bug/hill), Honnavara (2.45 bug/hill), Sirsi (1.77 bug/hill) and Yellapura (0.57 bug/hill) the incidence was nill in Bhatkal, Ankola, Joida, Karwar and Haiyal taluks.

Rajendra Prasad (2010) reported that incidence of ear head bug was 3.87 nymphs and adults per hill in coastal Kumta, being the highest and the lowest of 0.75 nymphs and adults per hill in Siddapura was recorded during reproductive stage.

Mishra *et al.* (2010) surveyed the spread of insect pests in rice in farmer's fields and government farms in Rewa district of north eastern Madhya Pradesh for two years. In all the locations 12 insect pests were observed in rice fields of surveyed area out of them eight insects were found as serious pests based on economic threshold limit. Normally, gundhi bug was observed during mid growth stage (30 to 45 days after sowing) of high yielding varieties. The population increased just after flowering of the crop and it prevailed upto month of September to October.

Sinu *et al.* (2006) reported that *Cicindela (Calochroa) whithilli* (Hope) and *Cicindela (Calochroa) flavomaculata* Hope (Cicindelidae: Coleoptera) are seasonally dominant predatory insects in the cultivated and irrigated rice paddy fields of the South Indian peninsula while studying the feeding ecology of these tiger beetles in rice paddy agro-ecosystems in Sringeri area of the central Western Ghats, as potential biocontrols on the major rice paddy pest populations available in this region. *Cicindela (Calochroa) duponti* Dejean is another common species that occurs abundantly in the *Areca* orchards and on the bunds that separate rice paddy fields from adjacent uncultivated lands. That both *C. whithilli* and *C. flavomaculata* are ineffective as biocontrol agents of rice paddy agro-ecosystems. They appear to have only a marginal impact on the larvae of *Leptocorisa acuta*, a major insect pest of paddy rice.

2.2.1 Alternate hosts of earhead bug, *L. oratorius*

Rothschild (1970) reported that the adults of *L. oratorius* feed on grasses like *Echinochloa crusagalli* L., *Paspalum scrobiculatum* L. and *Pennisetum* sp. before migrating to paddy fields. During off season, small number of adults and nymphs were found on ratoon rice plants and various grasses. Sands (1977) reported *E. colona* as a principal wild food plant of *L. oratorius*. Morill *et al.* (1990) reported that *E. crusagalli* is most preferred resting site for *L. oratorius* than rice, whereas rice was more preferred for feeding compared to *E. indica*, *E. colona*, *Brachiaria mutica* Stapf, *P. conjugatum* Berg, *P. paspalodes* and *D. ciliaris*. Nymphs completed their development only in *E. crusagalli*, *E. colona*, *D. ciliaris* or rice after panicle emergence.

Rajapakse and Kulasekera (1980) observed 16 species of graminaceous weeds including *E. crusagalli*, *E. colona*, *E. indica* and *P. repens* as alternate host plants of *L. oratorius* during fallow periods between rice cropping in Sri Lanka. Nayak (1984) recorded the alternate hosts of *L. oratorius* as *E. colona*, *Oryza rufipogon*, *D. ciliaris*, *D. violascens*, *P. scorbiculatum*, *Alloteropsis cimicina*, *Cyperus rotundus*, *C. iria*, *E. indica*, *Brachiaria reptans*, *Sacciolepis interrupts* and other tender leaves of other plants like *Areca catechu*, *Piper betel* and *Hedychium coronarium*.

Vreden and Ahmadjabidi (1986) recorded *E. colona*, *E. crusagalli* and *E. indica* as alternate host plants of *L. oratorius* from Penninsular Malaysia. Morill *et al.* (1990) studied that nymphal development of rice earhead bug completed on *E. crusgalli*, *E. colonom*, *D. ciliaris* and rice after panicle emergence who also concluded that weed control as an important factor to prevent the initial population build up of *L. oratorius*.

Shah (1993) reported that *E. colona*, *E. crusgalli* and *E. indica* served as alternate food plants for rice earhead bug. Presence of these weeds in rice fields during fallow periods allowed the pest to survive when its main food plants, rice was not being grown. Hence, eliminating these weeds from the field edges would help to reduce the initial populations build up. Nugaliyadde *et al.* (1994) reported that paddy bug does not lay eggs on weeds under natural conditions. It laid significantly low number of eggs on caged *Echinochoa colona* (34 eggs/female), *E. glabrescens* (27), *Anicum ripens* (39) and *Cyper iria* (25) as compared to rice (80). The first generation adults emerged on the above weed- host was respectively 1.2, 2.6, 4.2, and 5 as compared to rice (16).

Estoy (1996) reported *E. colona* and *E. crusagalli* as the alternate host plant of *L. oratorius* in Philippines. Chander (1996) reported that the intrinsic rate of natural increase of rice earhead bug, *L. varicornis* on alternate host plant *E. colonom*. The maximum intrinsic rate of natural increase was estimated during the period from the last week of August to 3rd week of September. Sugimoto and Nugaliyadde (1996) studied the occurrence of *L. oratorius* in weedy sites of paddy fields in Sri Lanka. They investigated with reference to the adult - nymphal structure and ovarian development in adult females and proved that nymphal development takes place in paddy fields before rice flowering, when the fields were infested with adults whose ovaries had already matured by feeding on panicles of weeds (*E. crusgalli*, *E. colona* and *D. ciliaris*) or early flowering rice plants. They concluded that weed control should be conducted to eliminate panicle bearing weeds in and around paddy fields before the onset of rice flowering to prevent advanced ovarian development in the adult pest population which migrates to paddy fields to oviposit. Saha *et al.* (2005) conducted a survey in 2002-03 in Midnapur area, West Bengal. The crop was surveyed from seed bed to maturing stage. Weeds such as *Cyperus rotundus*, *Cynadon dactylon* and *Cyperus iria* act as alternate hosts for rice bug before flowering of rice crop.

2.3 Biology of rice earhead bug, *Leptocorisa* spp

2.3.1 Egg

Incubation period

The incubation period for *L. varicornis* and *L. acuta* varied from 5 to 8 days (Lefroy, 1908; Srivastava and Saxena, 1964; Misra, 1968; Rai, 1981). Rothschild (1970), Soon (1971), Sands (1977) and Domingo *et al.* (1982), reported 6 to 9 days as the incubation period for *L. oratorius*. Li (1985) reported that the eggs of *L. oratorius* took 5 to 8 days for hatching.

Cobblah *et al.* (1992) reported that the incubation period varied from 6 to 9 days at 29^o C for *L. oratorius*. Misra (2003) reported that incubation period ranged from 3.3 to 7.7 days with mean of 6.24 days. Venkatesh Hosamani *et al.* (2009) revealed that eggs had an incubation period of 7 and 6.98 days under field and greenhouse conditions, respectively.

2.3.2 Egg hatching

The egg burster cuts the shell along a longitudinal lateral line that nearly separates the whole of the ventral side from the rest, unlike other Alydids, where both ends of eclosion split meet at the anterior pole and the cap thus formed is separated from the rest of the shell (Hinton, 1981).

Cobblah *et al.* (1992) studied the egg hatching pattern in *L. oratorius*. They reported that the egg hatching was aided by a crescent shaped egg burster on the head of the nymph. Despite the lack of an operculum, a line of weakness is seen in most eggs just prior to hatching. The embryonic cuticle left attached to the inside of chorion and the dorsal of the egg was neatly broken off from the micropylar end, leaving a cup shaped portion.

2.3.3 Nymphs and nymphal period

According to Srivastava and Sexena (1964) and Misra (1968), the total nymphal period varied from 14 to 25 days with five moults in *L. varicornis*. Rothschild (1970) found that the nymphs of *L. oratorius* moulted five times and their duration was 18 to 26 days. Domingo *et al.* (1982) and Nayak (1984) observed five instars in *L. oratorius* with the nymphal duration ranging from 19 to 22 days.

Li (1985) reported that there was 4 to 5 nymphal instars with nymphal development lasted for 15 to 32 days in *L. oratorius*. Misra (2003) reported that total nymphal duration ranged from 15.3 to 21.8 days with a mean of 18.51 days. Venkatesh Hosamani, *et al.* (2009) revealed that nymphs were observed to pass through five instars and the duration of each instar was 3.98, 3.30, 3.48, 3.83 and 4.15 days for I,II,III,IV and V instars respectively. The nymphal period 14 to 25 and 15 to 23 with a mean of 18.9 and 18.7 days under field and greenhouse conditions, respectively.

2.3.4 Adult

2.3.4.1 Longevity

The longevity of *L. acuta* found to be 15 to 31 days (Uichanco, 1921; Corbett, 1930; Rai, 1981). Whereas *Leptocorisa varicornis* completed its life cycle in 15 to 30 days (Hutson, 1930; Akbar, 1958; Srivastava and Saxena, 1964). According to Rothschild (1970), Soon (1971) and Sands (1977), the longevity of adult *L. oratorius* was 5 to 27, 48 to 62 and 26 to 134 days respectively.

Nayak (1984) reported that the males and females of *L. oratorius* lived up to 42.5 days and 52.8 days, respectively. Li (1985) reported that the adult males and females of *L. oratorius* lived for 37 days and 172 days, respectively. Anand Prakash and Jagadiswari Rao (1999) reported that the longevity of ovipositing females of *L. acuta* was 27 to 57 days with an average of 44.5 days. Misra (2003) reported that adult males lived on an average 19.8 days with a range of 18 to 23 days, while the females lived 52.9 days with a range of 44 to 62 days. And the total life cycle of the male completed in 44.55 days as compared to 77.65 days in case of female.

Venkatesh Hosamani *et al.* (2009) revealed that total development period female and male was 50 to 83 and 20 to 37 days under greenhouse condition. Where as in field conditions total development period of female and male was 35 to 80 and 23 to 61 days, respectively. Only a little variation was noticed in its biology under both conditions. The length of adult females was measured to be 17.50 to 18.50 mm (18.00 ± 0.37) and 2.40 to 3.00 mm (2.63 ± 0.21) in width and that of males length was varied from 18.00 to 19.00 mm (18.49 ± 0.42) and width from 1.95 to 2.50 mm (2.19 ± 0.22).

2.3.4.2 Mating, oviposition and fecundity

Uichanco (1921) reported that the females of *L. acuta* began mating when they are 7 to 25 days old. Copulation was accomplished with male and female in opposite directions to each other and the process last for about 6 to 10 hours. The copulation took place from early in the morning till noon and in some cases during afternoon. Eggs were laid 11 to 14 days after adult emergence and total egg laying period extended up to 65 days. Females laid eggs most actively between 6 pm and 6 am in one or two rows generally along the mid rib on the upper surface of leaf.

Corbett (1930) reported that the pre oviposition period of *L. acuta* was 9 to 11 days. Oviposition occurred at dusk and eggs were fastened to the leaf by means of gummy substance.

Van der Goot (1949) reported that the bugs of *L. acuta* copulated after 3 days of attaining adult hood. Oviposition occurred 6 to 12 days after last moult. Eggs laid in one or two rows on both surfaces of the upper leaves of flowering rice and wild grasses. Female continued to lay eggs until the crop had reached the milk ripe stage. The highest number of eggs laid per female was 359 eggs.

Rothschild (1970) reported that the preoviposition and oviposition period of *L. oratorius* varied from 9 to 24 and 3 to 60 days, respectively. Females continued to lay eggs until the crop had reached milk-ripe stage. Life cycle (egg to adult) of *L. oratorius* was completed in about 46 days in Malaysia. Sands (1977) recorded the average pre-mating period and pre-oviposition period of *L. oratorius* was 9 days and 23 days, respectively. Eggs laid in one mass of 10 eggs on leaves. He also opined that the ovipositional behaviour of the females was associated with the flowering of rice crop.

Rai (1981) conducted laboratory studies on biology of *L. acuta* and recorded the pre-oviposition and oviposition period which lasted for 1 to 5 days and 2 to 15 days, respectively. Copulation lasted for 2 to 6 hours. Eggs were laid on the upper surface of leaves usually very close to the midrib in rows containing 6 to 18 eggs and females laid a maximum of 45 eggs and bugs completed 3 to 4 generations during a cropping season. Domingo *et al.* (1982) reported that the oviposition period of *L. acuta* was last for 9 to 25 days with an average of 18 days. Eggs laid in one or two rows on upper surface of leaves and sometimes on the panicles singly. A female laid upto 569 eggs with an average of 284.5 eggs.

Nayak (1984) recorded the oviposition period of *L. oratorius* as 5 to 17 days with an average of 13.90 days. Life cycle from egg to adult varied from 23 to 30 days with an average of 27.30 days. Bugs completed two generations on graminaceous hosts before migration to the paddy and six to seven generations completed on paddy. Cobblah *et al.* (1992) studied the oviposition behaviour of *L. oratorius*. According to them, the *L. oratorius* deposited their eggs in a single row on upper surface of the leaves and the arrangement was regular. Out of 60 egg mass collected, the mean number of eggs per mass was 9.5 (ranges 5 to 19). Most of the eggs were laid on the upper surface of leaves with 44 per cent near the tip, 34 per cent at the middle and 20 per cent on the ventral surface and panicle and 2 per cent of the eggs on nylon net cages.

Anand Prakash and Jagadiswari Rao (1999) reported that preoviposition period of *L. acuta* lasted for 4 to 20 days. Misra (2003) reported that on an average 244.7 eggs were laid by a single female, the lowest being 204 and highest 294. The egg hatchability ranged between 84.36 to 92.52 per cent with a mean of 88.54 per cent. The pre-oviposition period ranged from 1 to 5 days with a mean of 3.9 days. The oviposition varied between period 7 to 15 days with a mean of 11.2 days. Venkatesh Hosamani *et al.* (2009) revealed that preoviposition period 3 to 5 and 8 to 17 days under greenhouse and field conditions, respectively and oviposition 6 to 29 and 5 to 17 days under greenhouse and field conditions respectively average fecundity was recorded to be 50 to 135 and 75 to 137 eggs per female under greenhouse and field conditions, respectively. The length and width of the eggs was ranged from 1.00 to 1.20 mm (1.10 ± 0.07), 0.80 to 0.86 mm (0.83 ± 0.02), respectively.

2.3.4.3 Habits of nymphs and adults

Rice earhead bugs generally appeared on grasses when the early rains received and continued to feed on them. Later, they migrated to paddy fields at the time of emergence of earheads. They were diurnal, active in the morning and evening hours and took shelter under shady portions of the plants during hot part of the day. They remained in the paddy fields till the grain hardens and the successive generations migrate from early maturing varieties to late maturing ones where they caused heavy damage. Both nymphs and adults emitted pungent odour when handled (Corbett, 1930; Akbar, 1958; Srivastava and Sexena, 1964).

Gunawardena and Bandumathie (1993) reported that both male and female adults of *L. oratorius* produced defensive secretions. This was analyzed by a combined gas chromatography-mass spectroscopy technique which revealed that the presence of 2 major components such as (E) – 2 – octenal and n-octyl acetate and some trace compounds such as hexylacetate, 3-octenal, 1-octanol and (Z) – 3-octanyl acetate. This secretion has potential to repel natural enemies of *L. oratorius* and elicits alarm responses, alerting and dispersing aggregated males and females.

Estoy (1996) reported the dispersal ecology of rice earhead bug *L. oratorius*. During off season they were commonly found on weed host plants near the rice fields suggesting that bugs move from one area to another in response to food availability. Nymphs in non-rice habitat tend to move further in search of available food than the nymphs present in the rice habitat.

2.3.4 Nature of Damage

The general nature and symptoms of damage in brief as reported by a number of workers are as follows.

Uichanco (1921) reported that insect feeding by inserting a part of its stylets in to the interior of the rice grain in the milky stage through a weak spot at the place where the edges of the large glumes meet to form the hull. The feeding caused diffused yellowish brown spot leads to empty hull and the bugs might secrete harmful enzyme in to the plant cell in addition to the mechanical injury. According to Rai (1981) both nymphs and adults of rice earhead bugs sucked the milky juice from developing grains, thereby prevented grain formation and such grains later shriveled. The earheads in badly infested fields showed numerous empty grains, which turned brown and dried. Lee *et al.* (1986) reported that *L. oratorius* was the most dominant species associated with grain discoloration in association with fungal pathogen *Fusarium solani* causing "Dirty panicle" disease of rice.

Sugimoto and Nugaliyadde (1995) reported that the grains damaged by *L. oratorius* leads to unfilled grains and showed a dark spot on the grain surface. Damage mainly occurred from the very early stage of grain development. However, a considerable proportion of grains were damaged at the dough and hard dough stages. Litsinger *et al.* (1998) reported that the bugs of *L. oratorius* produced proteinaceous stylet sheaths in all nymphal stages and both adult sexes. Feeding causes unfilled grains and about 95 per cent of the sheaths were found at the juncture of lemma and palea. All rice bugs produced sheaths on milk, soft and hard dough grains but adults produced significantly fewer on hard dough rice. Bugs feed mostly in the early morning and least at night.

Berg and Soehardi (2000) reported that *L. oratorius*, which feeds on the panicle of rice, caused the empty seed. Anand Prakash *et al.* (2002) reported that feeding of *L. acuta* caused rice grain discoloration and it was more severe when associated with fungus *Fusarium moniliforme*. Kikuchi *et al.* (2004) reported that the rice ear head bug damage results in pecky rice formation. Takeuchi *et al.* (2004) found that feeding of rice stink bug *L. chinensis* cause pecky rice. Feeding marks were mainly found on the grain surface along the hooking portion and the basal part of the grain. Jahn *et al.* (2004) studied the effect of *L. oratorius* on grain quality. Feeding caused the unfilled and partially filled grains and also grain discoloration.

2.3.5 Ecology of rice earhead bug

Sen (1955) claimed that intermittent rains accompanied by high temperature ranging from 29.4° to 37.7° C during April-May was highly favourable for epidemic outbreak of *L. varicornis*. According to Israel and Rao (1961), the infestation of *L. varicornis* was severe at temperature of 26.9° to 28.2° C and relative humidity of 80.6 to 82.1 per cent. Banerjee and Chatterjee (1965) observed population buildup of *L. acuta* at 27° to 37° C and 75 to 86 per cent relative humidity with intermittent rains. Rao *et al.* (1978) reported that a minimum temperature of 23.2° to 27.2° C and maximum temperature of 29.1° to 30.9° C which prevailed during 11th to 25th October favored the development of bugs at Cuttack. At places where temperature was optimum and rice was grown continuously, the bugs remained active throughout the year without distinct diapause.

Garg and Sethi (1980) reported that the weekly averages of 28.59° C, 69.55 per cent relative humidity, 8.18 hour sunshine and 0 to 71.7 mm rainfall was found to be favourable for the highest population buildup of *L. acuta*, during *kharif* season. Chakraborty and Chatterjee (2002) reported that the rice gundhi bug, *L. varicornis* (*L. acuta*) was high during panicle formation from mid September to October when the temperature was 27° to 34° C and relative humidity was 85 to 90 per cent.

2.4 Management of rice earhead bug, *Leptocorisa* spp

A number of workers have tried various insecticides against rice bugs in different countries. However, the review is restricted to only old chemicals that were tried during the study. A number of reports bring out the effectiveness of BHC against rice earhead bugs. The rice bugs were effectively controlled by dusting BHC and DDT 5 per cent dusts at 10 to 25 pounds per acre (Biswas, 1953; Sen and Chaudhuri, 1959; Banerjee, 1961). The findings of Fernando *et al.* (1957) are interesting to note that 0.65 per cent BHC dust was recommended for the control of *L. varicornis*. Srivastava and Saxena (1960) reported that dusting with BHC (5 per cent) was more economical than many other modern insecticides tested. *L. acuta* was satisfactorily controlled by the sprays with carbaryl at 0.75 pounds/acre at Sarawak (Anon, 1964); whereas, Gusathion 0.04 per cent, endosulfan 0.06 per cent and gamma BHC 0.022 per cent were found effective against rice bugs at International Rice Research Institute, Manila (Anon, 1965).

Teotia and Misra (1965) reported that BHC and aldrin dusts were more effective than spraying DDT (0.3 %) and dieldrin (0.15 %). They also opined that dusting with BHC was more economical. Alam (1965) reported that carbaryl at 0.05 concentration was as effective as other chemicals tried. Comparative assessment on the effectiveness of BHC (25 kg/ha), fenitrothion (1125 ml/ha) and three other chemicals made by Krishnamurthy *et al.* (1977) revealed that fenitrothion recorded maximum reduction of bugs with higher yields per acre followed by BHC dust. Pruthi (1969) reported that dusting the crop with BHC 5 per cent dust at 13 to 17 kg per hectare or spraying with 0.2 per cent BHC or DDT suspension at 1120 litres per hectare was effective against rice bug.

Soon (1971) reported that BHC and carbaryl at 0.1 per cent concentration controlled the pest effectively. During 1971 again he reported that BHC 0.05 per cent and carbaryl 0.1 per cent spray were most effective against *L. oratorius* at Malaysia. Custodio (1969) reported that 2 to 3 foliar sprays of carbaryl and endosulfan when tested with two other chemicals controlled *L. acuta* effectively. Israel *et al.* (1969) and Chatterjee *et al.* (1977) stated that BHC dusting at 10 to 20 kg per hectare controlled the bugs. Pathak *et al.* (1978) obtained a good control of bugs with BHC and carbaryl 5 per cent dusts 20 to 25 kg/ha and carbaryl 50 per cent WP 1 g/l of water. Rai and Vidyachandra (1980) recorded 50.55 per cent reduction in population of *L. acuta* in plots treated with sevidol at 0.1 per cent when compared to 93.26 and 88.13 per cent in malathion and fenthion treated plots, respectively.

Rai and Vidyachandra (1980) recorded 50.55 per cent reduction in population of *L. acuta* in plots treated with sevidol at 0.1 per cent when compared to 93.26 and 88.13 per cent in malathion and fenthion treated plots, respectively. Spraying IR-36 variety at flowering with endosulfan at 0.06 per cent and carbaryl at 0.12 per cent resulted in 100 and 91 per cent mortality of bugs, respectively (Heinrichs *et al.*, 1982).

Krishnakumar and Visalakshi (1989) studied the laboratory bioassay of 12 insecticides on *L. acuta*. Among them malathion, formothion, fenthion and methyl -parathion ranked superior in relative toxicity viz., 7.26, 7.12, 7.06 and 5.74 times toxic to the bug, respectively over the rest of the chemicals. Against *L. acuta*, a number of botanicals viz., 5 per cent aqueous leaf extract of king of bitters (*A. paniculata*), 3 per cent oil emulsion spray of neem (*A. indica*), seed extract of orange (*C. reticulata*) and leaf extract of lemon grass (*C. citrates*) are found to protect developing rice grains and reduce the population of *L. acuta* (Gupta *et al.*, 1990).

Jena *et al.* (1990) opined that chemicals viz., ethofenoprox, monocrotophos and oxydemeton methyl each at 0.5 kg a.i./ha controlled the *Leptocorisa acuta* and were effective for the entire milky grain period of the crop for 9, 11 and 15 days, respectively. Other chemicals like, fenabucarb, methyl parathion, malathion, quinalphos and chlorpyrifos gave good knock down control but were not persistent.

Mayabini *et al.* (1990) evaluated 12 insecticides on CV. Java at 0.04 per cent concentration both in green house and field condition for their effectiveness against rice gundhi bug *L. oratorius*. Ethofenoprox, monocrotophos and oxydemeton methyl controlled the population effectively during the entire milky stage of panicles whereas BPMC, methyl parathion, malathion, chlorpyrifos and quinalphos though did not persist for a longer period, were capable of knocking down the pest immediately.

Pangtey (1990) reported the efficacy of seven insecticides against *L. acuta*. Of the severe chemicals tested, malathion dust applied at 1 kg a.i/ha was the most effective insecticide (43.75 q/ha), as compared to methyl parathion dust applied at 1 kg a.i/ha (43.25 qt/ha) and dichlorvos Ec @ 0.08% (40.91 q/ha) followed by carbaryl dust 1 kg a.i/ha (39.80 q/ha).

Durairaj and Venugopal (1993) studied the different neem products and their effectiveness against *L. acuta*, compared with that of malathion. The plot treated with 0.05 per cent malathion showed a reduction in the pest incidence of 86.2 per cent, followed by (0.5 %) neemark (2.0%) neem oil and (5.0%) *Vitex negundo* leaf extract showed a reduction in the pest incidence of 82.8, 69.0, and 50.7 per cent, respectively. Prakash and Rao (1994) reported that (0.5%) and (1.0%) Achook spray effectively controlled the pest of *Leptocorisa acuta*.

Krishnakumar and Visalakshi (1996) conducted a field experiment to assess the efficacy of different insecticides for controlling *L. acuta* at different population levels. In the first experiment, where there was more of a population stress, insecticides such as malathion (0.10 %), methyl parathion (0.05 %) and fenthion (0.10 %) were found to be more effective in controlling the bug with the percentage reduction being 75.72 to 97.15, 72.71 to 94.76 and 69.92 to 91.85 per cent, respectively. In the second experiment with lesser population stress also the same insecticides showed the maximum effect in controlling the population in the field.

Listinger *et al.* (1998) recommended carbaryl 85 per cent WP at 0.75 kg a.i. per hectare against *L. oratorius* at Phillipines which was observed to be relatively safe to mammals as against emulsifiable concentrate and granular formulations of endosulfan and gamma BHC granules that were reported to be moderately safe.

Misra (1999) evaluated two insecticides *viz.*, malathion and phosphamidon, two-neem products *viz.*, multilineem and RD-9 repelin, and fermented snails for their efficacy against the bug. Fermented snail as a bait controlled the bugs effectively as envisaged from the lowest post treatment population, per cent grain damage (8.37%) and highest grain yield (2279 kg /ha) of paddy. However, neem product multilineem was at par with fermented snails in Gundhi bug population control, per cent grain damage (8.75 %) and grain yield (2139 kg /ha).

Verma and Gupta (2001) conducted field experiment and tried seven emulsifiable concentrate insecticides @ 250 ml a.i/ha which were sprayed after 45 and 60 days after transplanting of paddy crop against gundhi bugs *L. varicornis*. Among the different chemicals tried phosphamidon gave good control with a reduction of bug population by 89.85 per cent over untreated check followed by quinalphos and phenthoate with a reduction in population of 83.32 and 79.02 per cent, respectively. Significant grain yield increase was obtained compared with number treatment. Maximum grain yield (37.86 q/ha) was obtained by phosphamidon spray closely followed by quinalphos and phenthoate (37.73 q/ha and 34.40 q/ha, respectively).

Deore (2002) reported that chlorpyrifos as effective against *Leptocorisa* spp recorded least infestation (1.87%) and on par with imidacloprid (2.33%), acetamiprid (2.51%), Profenophos (2.76%), and nukil (2.96%). The ancillary observation of white earhead indicate that the treatment of acetamiprid recorded significantly lowest per cent white ear head (92.40%) which was on par with all other pesticide. The untreated control recorded maximum populations of spider (2.26/plant) are statistically at par with endosulfan (2.17/plant) while the treatment of imidacloprid (1.78/plant) and chlorpyrifos (1.61/ plant) where remain next in order while DDVP was effective against earhead bugs but more toxic on spider than above. Considering yield based performance imidacloprid recorded significantly highest grain yield (6229 kg/ha) followed by chlorpyrifos (6189 kg/ha) and acetamiprid (6142 kg/ha).

Jayarajan *et al.* (2003) reported that dust formulations were applied using rotary duster during the milky stage when the bug population reached 8 box/m². The rice bug population was recorded 3, 7 and 14 DAT i.e., the number of nymphs and adult present in a 1m² area /plot was observed. Among the plant product, *Acorus calamus* 10 D recorded the lowest bug population (3.56/ m²), followed by *Nicotiana tabacum* 50 D (4.56 /m²) and *Ocimum basilicum* 50 D (4.67 /m²). There was a (72.43%) reduction in bug population over the check (fly ash control) in *A. calamus* 10 D-treated plots.

The same plots recorded a grain yield of 4.5 t/ha, which was at par with Fenthion 100 EC @ 500 ml/ha (4.5 t/ha). The results showed that *A. calamus* 10 D can effectively control the rice bug.

Dhingra *et al.* (2003) evaluated four combination of insecticide *viz.* acephate 45% + cypermethrin, BPMC 5% + fipronil, beta-cyfluthrin + chlorpyrifos and BPMC + chlorpyrifos including a promising insecticide monocrotophos against gundhi bug on cv. Basmati. Application of beta-cyfluthrin and chlorpyrifos combination controlled the bug population effectively, reduced per cent grain damage (6.78%) and increased the grain yield (19.44 q/ha). However, it was at par with the combination of acephate the cypermethrin with respect to control of bug population, per cent grain damage (8.33%) and grain yield (20.66 q/ha). Rest of the treatment showed significant difference with most effective combination of beta-cyfluthrin and chlorpyrifos in relation to reducing the per cent grain damage. The grain yield statistically at par in all the treatments and was significantly more than control.

Efficacy of fenobucarb, malathion, abamectin, carbaryl and dichlorvos against rice gundhi bug *Leptocorisa* spp in field experiment was tested during *kharif* 2000 in Orissa. All the insecticides reduced the number of gundhi bug. One day after spraying, provided the better control of the pest compared to the control. No significant difference in the number of bugs observed after the insecticidal treatments and spraying with dichlorvos resulted in the highest yield of the crop (Misra, 2003).

Ponnusamy (2003) studied that effect of neem based bio-insecticide containing azadirachtin (0.03%) in controlling the earhead bug population on rice variety white ponni. Application of neem based insecticide (Azadirachtin 0.03%) @ 500 ml/ha twice once at flowering stage and second at 15 days later reduced the incidence of earhead bug by 24.2 per cent and the neem based insecticide treated plots recorded 11.79 per cent increased grain yield over the control.

Nguyen and Thi (2005) conducted experiments in the greenhouse and field to evaluate the efficacy of some new isolates of *Metarhizium anisopliae* and *Beauveria bassiana* against rice earhead bug, *L. acuta*. The results in greenhouse showed that all of 12 selected isolates of *M. anisopliae* and *B. bassiana*, which have been isolated from naturally infected insects during 2003-2005, were found to be pathogenic to the tested rice earhead bug. The mortality percentage of *L. acuta* caused by *B. bassiana* and *M. anisopliae* isolates ranged from 57.5 to 77.7 per cent and from 74.7 to 87 per cent at 10 DAT, respectively. Among 12 new selected isolates of *M. anisopliae* and *B. bassiana* have been tested, *M. anisopliae* (OM3-BD), *M. anisopliae* (HG3-B) and *M. anisopliae* (HG5-BD) exhibited higher pathogenicity to rice earhead bug as compared to the rest. In field experiments, all of 12 selected isolates of *M. anisopliae* and *B. bassiana* were found to be effective for controlling rice earhead bug. The efficacy could be seen from 7 DAT and reached to its highest peak at 14 DAT. The field mortality of *L. acuta* caused by *B. bassiana* and by *M. anisopliae* isolates ranged from 45.3 to 74.9 per cent and from 63.6 to 86.6 per cent at 10 DAT.

Singh *et al.* (2009) noticed that the pre-treatment observation on gundhi bug population/m² before 24 hrs spraying did not show the significant variation. Three days after spraying multiplex neem product controlled 80.8 per cent and rest of the treatment (except control) controlled insect population after 3 days of spray, no insect population was recorded with the application of beta-cyfluthrin and thiacloprid while reduction of population due to phosphamidon, malathion, monocrotophos and multiplex was 88.5, 85.7, 82.8 and 80.8 per cent, respectively.

2.4.1 Per cent of damage by *Leptocorisa* spp

The loss caused by rice earhead bugs has been reported to be 2.5 per cent (Malagode, 1922) and 1 to 100 per cent (Fernando *et al.*, 1954) in Sri Lanka, 30 per cent in Malaysia (Corbett, 1923a), 10 to 40 and 25 to 50 per cent in India (Israel and Rao, 1954; Singh and Sinha, 1978).

According to Tateisi (1939) and Soon (1969) the damage done by the bug was 30 per cent in Japan and Malaysia. Pruthi (1953) estimated the loss from rice earhead bug and it ranged from 10 to 40 per cent. Further, he reported that in 1952, the bug infested seven to eight million acres of rice in Uttar Pradesh, Bihar, Madhya Pradesh and Orissa.

During 1958, 1.86 lakh acres of Bhadai paddy and 4.07 lakh acres of main crop (Katia) and Aghani paddy were infested by *L. varicornis* in Bihar (Sinha,1961). Gupta *et al.* (1993) reported 2.5 to 6.21 per cent damage and 1.72 to 5.23 per cent damage during wet season and dry seasons, respectively. As the bug density increased, damage per cent also increased during flowering stage to maturity and milky stage to maturity proving the logical assumption that the bug damage is reflected on infestation and on reduction in yield.

3. MATERIAL AND METHODS

The present investigation includes four aspects on rice earhead bug, *Leptocorisa oratorius* (Fabricius) which were conducted during *kharif*, 2010 namely, (1) Species complex, (2) Survey on seasonal incidence, damage and its natural enemies, (3) Bioecology and (4) Management of rice earhead bug using plant extracts, entomopathogenic fungi and new molecules of insecticides. The material used and methods followed for different investigations are presented here under.

Uttara Kannada district is having three distinct rice growing ecosystems *viz.*, 1. 'Upghat' drill sown paddy 2. 'Upghat' transplanted paddy and 3. Coastal transplanted paddy. Out of 11 taluks of the district, five taluks representing all rice ecosystem were selected for the study. The rice is grown by drill sowing method in some parts of Mundgod, Sirsi and Siddapura taluks with comparatively plain landscape and mean rainfall of 1000 mm. Region second is 'Upghat' transplanted paddy comprises Siddapura, and Sirsi, with forest covered hills and cultivated valleys with a mean rainfall of 2000 mm. Region third is Coastal transplanted paddy comprises Kumta and Honnavara with seashore, steep hills covered with forest and mean rainfall of more than 3500 mm. Further there exists a lot of diversity within each taluk.

3.1 Study on species complex of *Leptocorisa* spp in rainfed ecosystem of Uttara Kannada district

The survey for the species composition of *Leptocorisa* spp was undertaken during *kharif* 2010 and *rabi* 2011 seasons in different taluks of Uttara Kannada district *viz.*, Sirsi, Siddapura, Honnavara, Kumta and Mundgod. Survey for insect collection was carried out in the months of October in *kharif* and in May during *rabi* crop seasons. During survey the adult bugs were collected from randomly selected places/localities were pinned and sent for identification.

3.2 Seasonal incidence of rice earhead bug and its natural enemies in rainfed ecosystem of Uttara Kannada district

A roving survey was conducted during *Kharif* season of (October) 2010 and *Rabi* season of (May) 2011 in different taluks of Uttara Kannada district. Survey was conducted during panicle initiation stage onwards and observations were recorded in five taluks of paddy ecosystem (Plate 1). In each taluk, three villages/locations and in each location three fields of one acre rice field were selected. In each field, 10 hills of paddy earheads were selected diagonally and randomly for the observation on rice earhead bug (Adults and Nymphs) occurrence and averaged to per hill basis for expression.

Subsequently, number of both nymphs and adult population per 10 hills of paddy was counted for predators like spiders, dragonflies, damselflies, coccinellids, cicindellids, hemipterans and dipterans. Apart from this, some of the weed/ alternate hosts of rice earhead bug were also recorded. Questionnaires were filled up while interaction with farmers regarding information on varieties, plant protection measures, incidence of insect pests *etc.*

Specimen samples of rice earhead bugs and predators were collected and brought to laboratory for systemic taxonomic observations. They are pinned and preserved for further identification. Later the specimens were taken for identification with taxonomic experts. Rice earhead bug and predators were got identified by Dr. C.A. Viraktmath, Professor Emeritus, College of Agriculture, GKVK, Bangaluru.

3.3 Bioecology of rice earhead bug, *Leptocorisa oratorius* in rainfed ecosystem of Uttara Kannada district

An experiment was conducted in laboratory to study the biology of paddy earhead bug during *Kharif* 2010 at Agriculture Research Station (Paddy), Sirsi, Uttara Kannada. Materials used are earthen pots, nylon net, bamboo sticks, plastic boxes, filter paper, camel brush, rice seedlings and rice earhead bugs.

For studying the biology, paddy seedlings were transplanted in earthen pots and covered with nylon net by supporting bamboo sticks on either side of the corner and cages were erected near the form house. A group of 20 adults of either sex of *L. oratorius* were collected from the paddy fields and were released on flowering rice plants covered with nylon net cages and maintained as stock culture. The eggs were collected from the cage by clipping the leaf portion containing the eggs and placed in a plastic box containing moist filter paper and top lid provided with small holes for aeration and kept for hatching. Early emerged nymphs were released in each plastic box with the help of camel brush and provided milky stage (the grain contains a white liquid in this stage) rice earheads two times in the morning and evening hours daily. The room temperature and relative humidity were also recorded and averaged, it was 18.1^o to 29.2^o C temperature and 66.6 to 89.0 per cent relative humidity and ten such plastic boxes served as replicates. The observations were recorded on incubation period, nymphal period, changes in morphometric characters like colour of body, antennae, legs, wings, abdomen and feeding behaviour of the nymph at 12 hr interval. With the help of micrometer scale taken the morphometric observation like length and width of eggs, nymphs and adults. Observation taken every day for the survival and moulting of the nymph till they transformed into adults.

A pair of freshly emerged male and female bugs were enclosed in each cage covered by nylon net to study the biological characters like feeding behaviour, mating behaviour, pre-oviposition period, fecundity, oviposition period, adult longevity, nature of damage and habits of adults. Observations were made on the above mentioned parameters.

3.4 Evaluation of plant extracts, entomopathogenic fungi and new molecules of Insecticides against rice earhead bug in rainfed rice ecosystem

A field study was under taken at Agricultural Research Station (Paddy), Sirsi ('upghat' transplanted paddy) during *Kharif*, 2010 to evaluate eco friendly approaches for the management of rice earhead bug in rainfed transplanted rice ecosystem. Sirsi taluk is located at 14° 26' N latitude, 74° 50' E longitudes and at an altitude of 619 m above MSL. The annual rainfall of Sirsi taluk during 2009 was about 2500 mm. This taluk comes under hilly zone (zone-9) of Karnataka representing the rainfed rice tract. The experiment was laid out in completely randomized block design (RBD) where 15 treatments were randomized by randomization technique. Each treatment was replicated thrice and treatment details are given in (Table 2) rice variety "Abhilash" was selected which is a coarse grain type and long duration variety with maturity period of about 155 days and recommended for hill zone of Uttara Kannada.

Raised seed bed was prepared in paddy field for making wet nursery. Sprouted seeds were sown in nursery bed on 11th July, 2010. About 3 weeks old seedlings were uprooted manually for transplanting in the main experimental field. In mainfield, a plot size of 4x4.5 m was maintained for each treatment and seedlings were transplanted on 3rd August in rows with spacing of 20x10 cm. All agronomical practices along with recommended dose fertilizers were followed for uniform crop raising. Between each plot 50 cm of gap was allowed for separation of treatments. All field plots were labeled for easy identification and recording observation and application of treatments (Plate 2).

The planting was done with 2 to 3 seedlings per hill with inter row spacing of 20 cm and intra row spacing of 10 cm. Plant population of 50 hills per square meter was maintained in all the experimental plots. All agronomic practices with recommended dose of fertilizers were followed to maintain good plant stand till the harvest of crop. Harvesting was done manually on 24th December, 2010. All the required parameters of observation were recorded accordingly.

Application of treatments: All the liquid formulations were applied by spraying high volume water diluted spray with the help of high volume of knapsack sprayer. The dusting was applied by using a thin cloth. Dusting and spraying was done during afternoon hours. Treatment application was done only once on 6th November depending on economic threshold level (ETL). Pre-treatment observations were made on bug population level.



Plate 2. General view of experimental plot

All field observations recorded were subjected to data transformation before going for statistical analysis. Analysis of variance was done by single factor RBD analysis in computer with software programs of MSTAT C. and treatment means were compared by using Duncan Multiple Range Test (DMRT).

All the treatments were imposed at milky stage (93 days after transplanting) of crop in the experiment field by using high volume knapsack sprayer.

Preparation of botanicals

Preparation of leaf extract of *Strychnus nox vomica* (Kasarka), *vitex negundo* and *Adathoda vasica*

The fresh samples of 100 g leaves of *Strychnus nux uomica*, *vitex negundo* and *Adathoda vasica* were collected and washed in water and ground into paste. The paste was mixed in one liter of water filtered to get 10 per cent solution. In the morning the suspension was filtered and sprayed.

Preparation of *Randia spinosa* (Kare Kayi) and *Acorus calamus* (Sweet flag) extracts

50 g of fresh fruits of *Randia spinosa* and *Acorus calamus* rhizome were collected and washed in water and crushed. The crushed material was mixed in one liter of water and filtered to get 5 per cent solution. In the morning the suspension was filtered and sprayed.

3.4.1 Observations recorded

3.4.1.1 Rice earhead bug population

Observations were recorded in each treatment plot on rice earhead bug population on randomly selected ten hills per plot and counted for both nymphs and adults one day before three and seven days after treatment.

3.4.1.2. Grain yield (kg/ha)

For the purpose of recording grain yield, fully matured crop was harvested manually from the experimental plots and grains were threshed by using small scale foot operated paddy thresher with rotating drum. Later grains were winnowed and weighed in electronic weighing machine. Grain yield per plot was converted into kg per ha by using the formula as below.

$$\frac{\text{Weight of grains (kg)}}{\text{Plot size (m}^2\text{)}} \times 10000$$

3.4.1.3 Straw yield (kg/ha)

The weight of straw harvested from each treatment was recorded after complete drying under shade. The straw yield was also expressed in kg/ha.

3.4.1.4 Percent of grain damage

For assessing the per cent grain damage the bug infested panicles randomly from five hills per plot were collected. The number of discolored or chaffy grains were counted. Following formula was used for calculating per cent grain damage.

The per cent grain damage was estimated using formula adopted by Gupta *et al.* (1993).

$$\text{Per cent grain damage} = \frac{\text{Number of earhead bug damaged grains/sterile grains}}{\text{Total number of grains}} \times 100$$

3.4.1.5 Cost economics

The cost economics of management of rice earhead bug were worked out by using the below mentioned formulae.

- a. Cost of cultivation = Cost of production+ Cost of chemical (Rs/ha)
- b. Gross income = Grain yield + Straw yield (Rs/ha)
- c. Net profit = Gross income – Cost of cultivation (Rs/ha)
- d. B: C ratio = $\frac{\text{Gross income (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$

3.4.2 Statistical analysis

During reproductive stage, (panicle emergence) rice earhead bug population per hill was recorded a day before, 3 and 7 days after imposition of treatments. The data thus obtained from all the observations were subjected to appropriate statistical analysis after suitable transformations and economics of chemical, plant product and entomopathogenic fungi applications were computed on the basis of economic returns from grain yield and cost of treatments. The net return and cost benefit ratios (C.B.R.) thus calculated were used for judging the economics of treatments.

Table 1. Details of places surveyed for rice earhead bugs and its natural enemies in rainfed paddy ecosystem of Uttara Kannada district during *kharif* and *rabi*, 2010-2011

Rice Ecosystem	Taluk	Place/Village
Upghat transplanted ecosystem	Sirsi	Kangodu
		Samphakanda
		Doddamane
	Siddapura	Kansur
		Tyagli
		Nanikatta
Coastal transplanted paddy	Kumta	Dhareshwar
		Ghore
		Deevigi
	Honnavaara	Gerusoppa
		Kavalakki
		Balkur
Upghat drill sown ecosystem	Mundgod	Haraganahalli
		Malagi
		Sanavalli

Table 2: Treatment details for the management of rice earhead bug

Sl. No.	Treatments	Dosage (formulated products)
1	(commercial neem insecticide with 3000 ppm Azadirachtin content)	3 ml/l
2	<i>Acorus calamus</i> (Linn.) aqueous rhizome extract	10 %
3	<i>Strychnos nux vomica</i> (L.) aqueous leaf extract	10 %
4	<i>Vitex negundo</i> (Linn.) aqueous leaf extract	10 %
5	<i>Adathoda vasica</i> (Ness.) aqueous leaf extract	10 %
6	<i>Randia spinosa</i> karekayi (Thunb.) aqueous fruit extract	5 %
7	<i>Metarhizium anisopliae</i>	2 gm/l
8	<i>Beauveria bassiana</i>	2 gm/l
9	Malathion (Cythion) D	8 kg/ac
10	Indoxacarb (Avant) 14.8 SL	0.5 ml/l
11	Dimethoate (Rogor) 30 EC	1.75 ml/l
12	Emamectin benzoate (Proclaim) 5 SG	0.2 g/l
13	Imidacloprid(Confidor)17.8 SL	0.25 ml/l
14	Thiomethoxam (Renova) 25 WG	0.3 g/l
15	Untreated check	-

4. EXPERIMENTAL RESULTS

Investigations were undertaken to elicit the information on species complex, seasonal incidence, natural enemies, bioecology and management of paddy earhead bug *Leptocorisa oratorius* at Agricultural Research Station (Paddy), Sirsi in Uttara Kannada District during *Kharif* season of 2010. The results of this investigation are presented under the following headings.

4.1 Study on species complex of *Leptocorisa* spp in Uttara Kannada district

The survey for the species composition of the genus *Leptocorisa* was undertaken during *kharif* and *rabi* (2010-2011) season in different taluks of Uttara Kannada district viz., Sirsi, Siddapura, Honnavara, Kumta and Mundgod. The results of identification studies are presented in the Table 3.

Specimen collected from the survey area were identified and found to compose two species of rice earhead bug. Two species belong to the genus *Leptocorisa*, viz., *L. oratorius*, and *L. lepida*. Assumed that all rice earhead bugs were *L. oratorius*, it was confirmed by observing this species' characteristic black ventrolateral spots on the abdominal segments and length was 17.40 to 18.20 mm with mean of 17.86 mm on several occasions where as *L. lepida* very small less than 13 mm without black ventrolateral spots on the abdominal segments (Plate 3) and among the two species *L. oratorius* was of high abundance and noticed in almost all places of surveyed. The incidence of *L. oratorius* (nymphs and adults) ranged from 1.93 to 2.03, 1.73 to 2.40, 2.73 to 3.31, 2.03 to 2.36 and 2.16 to 4.36 bugs/hill in Sirsi, Siddapura, Honnavara Kumta and Mundgod taluk, respectively in *kharif* season. In *rabi* season also *L. oratorius* was found in higher population (1.30 to 1.55, 1.16 to 1.70, 1.70 to 1.93, 0.96 to 1.23 and 1.76 to 2.60 bugs/hill in Sirsi, Siddapura, Honnavara. Kumta and Mundgod taluk, respectively). But the second species *Leptocoisa lepida* was noticed in low number 0.03 nymphs and adults per hill in one small patch in Sirsi taluk at Sampakanda village.

4.2 Survey for rice earhead bug incidence and its natural enemies in Uttara Kannada district during *kharif*, 2010 and *rabi*, 2011

The results of the survey revealed that maximum incidence of the bugs were noticed in Mundgod (3.04/hill) taluk in *kharif* (2010) season followed by Honnavara (2.97/hill), Kumta (2.15/hill) and Siddapura (2.04/hill) taluk. The least incidence of the rice earhead bug was seen in Sirsi (1.97/hill) taluk. Survey conducted during *rabi* (2011) shows that maximum incidence of the bugs was noticed in Mundgod (2.04/hill) followed by Honnavara (1.76/hill), Siddapura (1.43/hill), Sirsi (1.41/hill) and least incidence in Kumta (1.08/hill) taluk (Table 9).

In Sirsi taluk the incidence of the bugs (adults and nymphs) ranged from 1.93 to 2.03 bugs/hill (mean 1.97 bugs/hill) on paddy, during *kharif*, 2010. Among the villages surveyed, the highest incidence of bug was noticed in Kangodu village followed by Sampkhanda and Doddamae with a mean of 2.03, 1.96 and 1.93 bugs/hill, respectively.

During *rabi* 2011, the incidence of the bugs (adults and nymphs) ranged from 1.30 to 1.55 bugs/hill with a mean of 1.41 bugs/hill of paddy. Among the villages surveyed, the highest incidence of bug was noticed in Kangodu followed by Doddamane and Sampkhanda with a mean of 1.55, 1.40 and 1.30 bugs/hill, respectively, (Table 4). The popularly grown varieties in Sirsi taluk were Pushea, Jadegori, Ondu kaddi, Mysore sanna, Abhilash, MTU-1001 and Intan. Farmers followed insecticidal management (Quinalphos 25 EC, Chlorpyrifos 20 EC, Neem oil, Monocrotophos 36 SL and Carbofuran 3G) for rice leaf folder, *Cnaphalocrosis medinalis* which is a major defoliator.

In Siddapura taluk, the incidence of the bugs (adults and nymphs) ranged from 1.73 to 2.40 bugs/hill (mean 2.04 bugs/hill) of paddy, during *kharif*, 2010. Among the villages surveyed, the highest incidence of bug was noticed in Kansur followed by Tyagli and Nanikatta with a mean of 2.40, 2.00 and 1.73 bugs/hill, respectively.



Dorsal view

Leptocorisid oratorius



Ventral view



Dorsal view

Leptocorisid oratorius



Ventral view

Plate 3. *Leptocorisid* spp

Table 3. Species complex of *Leptocorisa* spp on paddy in Uttara Kannada district during *kharif* (2010) and *Rabi* (2011)

Sl. No	taluk	Place of observation	Average number of rice earhead bugs (adults and nymphs/hill)			
			<i>Kharif</i>		<i>rabi</i>	
			<i>L. oratorius</i>	<i>L. lepida</i>	<i>L. oratorius</i>	<i>L. lepida</i>
1	Sirsi	Kangodu	2.03	-	1.55	-
2		Samphakanda	1.96	-	1.30	0.30
3		Doddamane	1.93	-	1.40	-
4	Siddapura	Kansur	2.4	-	1.70	-
5		Tyagli	2.0	-	1.43	-
6		Nanikatta	1.73	-	1.16	-
7	Honnavaara	Gerusoppa	3.31	-	1.93	-
8		Kavalakki	2.73	-	1.70	-
9		Balkur	3.06	-	1.76	-
10	Kumta	Dhareshwar	2.36	-	1.23	-
11		Ghore	2.06	-	0.96	-
12		Deevigi	2.03	-	1.06	-
13	Mundagod	Haraganahalli	4.36	-	2.60	-
14		Malagi	2.16	-	1.76	-
15		Sanavalli	2.6	-	1.76	-
Mean ±S.D			2.44±0.66	0.0±0.0	1.55±0.39	0.30±0.52

- = No incidence

In the consecutive *rabi* season, 2011 the incidence of the bugs (adults and nymphs) ranged from 1.16 to 1.70 bugs/hill with a mean 1.43 bugs/hill. Among the villages surveyed, the highest incidence of bug was noticed in Nanikatta followed by Kansur and Tyagli with a mean of 1.70, 1.43 and 1.43 bugs/hill, respectively (Table 5). The popularly grown varieties were Dodgya, Aluru sanna, Abhilash, MTU-1001, Intan, Mysore sanna, Ambemori and Jaya. Chlorpyrifos 20 EC and monocrotophos 36 SL were the major chemicals used by the farmers for chemical management of defoliators. However farmers did not spray any insecticide for rice earhead bug management.

In Honnavara taluk the incidence of the bugs (adults and nymphs) ranged from 2.73 to 3.13 bugs/hill (mean 2.97 bugs/hill) of paddy, during *kharif*, 2010. Among the villages surveyed, the highest incidence of bug was noticed in Gerusoppa followed by Balkur and Kavalakki with a mean of 3.13, 3.06 and 2.73 bugs/hill, respectively. During *rabi* 2011, the incidence of the bugs (adults and nymphs) ranged from 1.70 to 1.93 bugs/hill (mean 1.79 bugs/hill) on paddy. Among the villages surveyed, the highest incidence of bug was noticed in Gerusoppa followed by Balkur and Kavalakki with a mean of 1.93, 1.76 and 1.70 bugs/hill, respectively (Table 6). The popularly grown varieties were IET-7191, Abhilash, Intan, Jaya, Chittaga, Bantval. Chlorpyrifos 20 EC, quinalphos 25 EC and monocrotophos 36 SL were the major chemicals used against rice defoliators.

In Kumta taluk the incidence of the bugs (adults and nymphs) ranged from 2.03 to 2.36 bugs/hill (mean 2.15 bugs/hill) of paddy, during *kharif*, 2010. Among the villages surveyed, the highest incidence of bug was noticed in Dhareshwara followed by Ghore and Deevigi with a mean of 2.36, 2.06 and 2.03 bugs/hill, respectively. In the second season *rabi*, 2011, the incidence of the bugs (adults and nymphs) ranged from 0.96 to 1.23 bugs/hill (mean 1.08 bugs/hill) of paddy. Among the villages surveyed, the highest incidence of bug was noticed in Deevigi followed by Dhareshwara and Ghore with a mean of 1.23, 1.06 and 0.96 bugs/hill, respectively (Table 7). The popularly grown varieties were Jaya, MTU-1001, Rasi, Intan, Ujala and Halaga. Chlorpyrifos 20 EC and monocrotophos 36 SL were the major chemicals used by the farmers in this area for rice insect pests management.

In Mundgod taluk, the incidence of rice earhead bug (adults and nymphs) ranged from 2.16 to 4.36 bugs/hill (mean 3.04 bugs/hill) of paddy, during *kharif*, 2010. Among the villages surveyed, the highest incidence of bug was noticed in Haraganahalli followed by Sanavalli and Malagi with a mean of 4.36, 2.60 and 2.16 bugs/hill, respectively. In the ensuing season of *rabi* 2011, incidence of the bugs (adults and nymphs) ranged from 1.76 to 2.60 bugs/hill (mean 2.04 bugs/hill) of paddy. Among the villages surveyed, the highest incidence of bug was noticed in Malagi followed by Haraganahalli and Sanavalli with a mean of 2.60, 1.76 and 1.76 bugs/hill, respectively (Table 8). The popularly grown varieties were Dodgya, Mysore sanna, BPT-5204, IR-64, MTU-1010, Intan and Jaya. Chlorpyrifos 20 EC and malathion 50 EC were the major chemicals used in this area for rice insect pests management.

4.2.1 Natural enemy complex in paddy fields of Uttara Kannada district

Natural enemy complex in paddy fields of Uttara Kannada district during *kharif*, 2010 and *rabi*, 2011 are presented in the Table 10 and 11.

Among the predators, spiders were found to be major predators. They were *Pardosa pseudoannulata* (Boesenberg) and *Tetragnatha* sp. Odonata includes dragon fly species, viz., *Pantala flavescens* (Fabricius), *Crocothemis servilia* (Drury), *Tholymis tillarga* (Fabricius), *Orthetrum Sabina* (Drury), *Orthetrum glaucum* (Brauer) and damsel fly, *Ischnura aurora* (Brauer) and *Protosticta gravelly* (Laidlaw). In Coleoptera, coccinellidae species includes, *Cheilomenes sexmaculata* (Linnaeus), *Coccinella transversalis* (Fabricius) and cicindelidae species, *Cicindela whitthilli* (Hope), *Cicindela flavomaculata* (Hope) (feed on nymphs of *Leptocorisa* spp) and carabidae species includes, *Chlaenius pictus* (Chaud), *Ophionea indica* (Thunberg). Order hemiptera includes pentatomidae species, *Andrallus spinidens* (Fabricius). In Dipteran predators, rober fly was recorded as the major and active during earhead stage of crop (Table 12) (Plate 4).

In Sirsi taluk, the mean Spider population was highest (0.46/hill) followed by population of Odonatan (0.29/hill), Coleopteran (0.26/hill) and the least population of Dipterans with 0.25/hill and Hemipterans with 0.17/hill during *kharif*, 2010.

Table 4. Incidence of rice earhead bug at Sirsi taluk during *kharif*, (October) 2010 and *rabi*, (May) 2011

Location	Mean number of bugs / hill						Varieties/ Hybrids grown	Plant protection measures *
	<i>Kharif</i>			<i>Rabi</i>				
	Adults	Nymphs	Total	Adults	Nymphs	Total		
Sirsi								
Kangodu	1.36±1.22	0.66±0.86	2.03±2.09	0.96±0.88	0.58±0.72	1.55±1.27	Pushea, Jadegori, ondukaddi, Mysore sanna, Abhilash, MTU-1001 and Intan	Quinalphos 25 EC 2 ml/l ,Chlorpyriphos 20 EC 2 ml/l, Neem oil 3 ml/l, Monocrotophos 36 SL 1.3 ml/l and Carbofuran 3G 30kg/ha
Samphakanda	1.23±1.33	0.73±1.03	1.96±2.36	0.63±0.80	0.66±0.95	1.30±1.39		
Doddamane	1.3±1.18	0.63±0.75	1.93±1.93	0.96±0.83	0.43±0.66	1.40±1.71		
Mean	1.29±1.24	0.58±0.88	1.97±1.46	0.85±0.83	0.55±0.77	1.41±1.45		

* Farmers adapted insecticide used for rice insect pests management except rice earhead bug

Table 5. Incidence of rice earhead bug at Siddapura taluk during *kharif*, (October) 2010 and *rabi*, (May) 2011

Location	Mean number of bugs / hill						Varieties/ Hybrids grown	Plant protection measures *
	<i>Kharif</i>			<i>Rabi</i>				
	Adults	Nymphs	Total	Adults	Nymphs	Total		
Siddapura								
Kansur	1.76±1.20	0.63±0.91	2.4±2.11	1.06±0.90	0.36±0.61	1.43±1.13	Dodgya, Aluru sanna, Abhilash, MTU-1001, Intan, Mysore sanna, Ambemori and Jaya	Chlorpyriphos 20 EC 2 ml/l and Monocrotophos 36 SL 1.3 ml/l
Tyagli	1.53±1.23	0.46±0.61	2.00±1.84	0.70±0.70	0.46±0.73	1.16±1.01		
Nanikatta	1.3±1.03	0.43±0.71	1.73±0.96	1.26±1.01	0.43±0.56	1.70±1.11		
Mean	1.43±1.15	0.50±0.74	2.04±1.63	1.00±0.87	0.41±0.63	1.43±1.08		

* Farmers adapted insecticide used for rice insect pests management except rice earhead bug

Table 6. Incidence of rice earhead bug at Honnavara taluk during *kharif*, (October) 2010 and *rabi*, (May) 2011

Location	Mean number of bugs / hill						Varieties/ Hybrids grown	Plant protection measures *
	<i>Kharif</i>			<i>Rabi</i>				
	Adults	Nymphs	Total	Adults	Nymphs	Total		
Honnavara								
Gerusoppa	2.26±1.45	0.86±0.95	3.13±2.41	1.46±1.35	0.46±0.77	1.93±1.55	IET -7191, Abhilash, Intan, Jaya, Chittaga and Bantval	Monocrotophos 36 SL 1.3 ml/l, Chlorpyriphos 20 EC 2 ml/l, and Quinalphos 25 EC 2 ml/l
Kavalakki	1.93±1.41	0.8±1.27	2.73±2.68	1.13±1.04	0.56±0.77	1.70±1.36		
Balkur	1.96±1.04	1.1±1.24	3.06±2.29	1.13±0.70	0.60±1.00	1.76±1.04		
Mean	2.05±1.30	0.92±1.15	2.97±2.46	1.25±1.03	0.54±0.84	1.79±1.31		

* Farmers adapted insecticide used for rice insect pests management except rice earhead bug

Table 7. Incidence of rice earhead bug at Kumta taluk during *kharif*, (October) 2010 and *rabi*, (May) 2011

Location	Mean number of bugs / hill						Varieties/ Hybrids grown	Plant protection measures *
	<i>Kharif</i>			<i>Rabi</i>				
	Adults	Nymphs	Total	Adults	Nymphs	Total		
Kumta								
Dhareshwar	1.56±1.17	0.8±1.19	2.36±2.36	0.46±0.62	0.53±0.86	1.06±1.01	Jaya, MTU-1001, Rasi, Intan, Ujala and Halaga	Monocrotophos 36 SL 1.3 ml/l and Chlorpyriphos 20 EC 2 ml/l
Ghore	1.53±1.25	0.53±1.05	2.06±2.31	0.53±0.88	0.43±0.67	0.96±0.92		
Deevigi	1.36±1.04	0.66±0.90	2.03±1.95	0.76±0.72	0.46±0.81	1.23±1.16		
Mean	1.48±1.15	0.66±1.04	2.15±2.20	0.58±0.68	0.47±0.78	1.08±1.03		

* Farmers adapted insecticide used for rice insect pests management except rice earhead bug

Table 8. Incidence of rice earhead bug at Mundagod taluk during *kharif*, (October) 2010 and *rabi*, (May) 2011

Location	Mean number of bugs / hill						Varieties/ Hybrids grown	Plant protection measures *
	<i>Kharif</i>			<i>Rabi</i>				
	Adults	Nymphs	Total	Adults	Nymphs	Total		
Mundagod								
Haraganahalli	2.66±1.67	1.7±1.90	4.36±3.57	1.16±1.14	0.60±0.85	1.76±1.59	Dodgya, Mysore sanna, BPT -5204, IR-64, MTU-1010, Intan and Jaya	Chlorpyriphos 20 EC 2ml/l and Malathion 50 EC 2 ml/l
Malagi	1.83±1.67	0.33±0.53	2.16±2.21	2.03±1.44	0.58±0.81	2.60±1.65		
Sanavalli	1.70±1.34	0.9±1.44	2.6±2.79	1.30±1.23	0.46±0.77	1.76±1.33		
Mean	2.06±1.56	0.97±1.62	3.04±2.85	1.49±1.27	0.54±0.81	2.04±1.52		

* Farmers adapted insecticide used for rice insect pests management except rice earhead bug

Table 9. Incidence level of *Leptocorisa* spp in rainfed ecosystem of Uttara Kannada district during *kharif* and *rabi* (2010-2011)

Sl. No	taluk	Place of observation	Average number of rice earhead bugs (adults and nymphs/hill)			
			<i>Kharif</i>		<i>rabi</i>	
			<i>L. oratorius</i>	<i>L .lepida</i>	<i>L. oratorius</i>	<i>L .lepida</i>
1	Sirsi	Kangodu	2.03	-	1.55	-
2		Samphakanda	1.96	-	1.30	0.30
3		Doddamane	1.93	-	1.40	-
		Mean	1.97	-	1.41	0.30
4	Siddapura	Kansur	2.4	-	1.70	-
5		Tyagli	2.0	-	1.43	-
6		Nanikatta	1.73	-	1.16	-
		Mean	2.04	-	1.43	-
7	Honnagara	Gerusoppa	3.31	-	1.93	-
8		Kavalakki	2.73	-	1.70	-
9		Balkur	3.06	-	1.76	-
		Mean	2.97	-	1.76	-
10	Kumta	Dhadeshwar	2.36	-	1.23	-
11		Ghore	2.06	-	0.96	-
12		Deevigi	2.03	-	1.06	-
		Mean	2.15	-	1.08	-
13	Mundagod	Haraganahalli	4.36	-	2.60	-
14		Malagi	2.16	-	1.76	-
15		Sanavalli	2.6	-	1.76	-
		Mean	3.04	-	2.04	-
Mean± S.D			2.44±0.66	0.0±0.0	1.55±0.39	0.30±0.52

- : No incidence



Cicindela whitthilli (Hope)



Rober fly



Cicindela flavomaculata (Hope)



**Predatory pentatomid nymphs attacking
On earhead bug in paddy**

Plate 4. Different species of natural enemies found in rainfed paddy ecosystem

Table 10. Overall mean status of natural enemies complex in paddy ecosystem in Uttara Kannada during *kharif*, 2010

Natural Enemies (Orders)	Reproductive stage					Mean
	Upghat drill sown	Upghat transplanted		Coastal transplanted		
	Mundgod	Sirsi	Siddapura	Honnavara	Kumta	
Spider (adults/hill)	0.48±0.61	0.46±0.59	0.47±0.60	0.66±0.70	0.39±0.54	0.49±0.60
Coleoptera (adults/hill)	0.21±0.49	0.26±0.52	0.27±0.51	0.26±0.49	0.16±0.42	0.22±0.48
Odonota (adults/hill)	0.28±0.55	0.29±0.56	0.31±0.54	0.33±0.62	0.25±0.49	0.29±0.55
Hemiptera (adults/hill)	0.14±0.41	0.17±0.44	0.15±0.43	0.22±0.58	0.06±0.22	0.14±0.41
Diptera (adults/hill)	0.14±0.38	0.25±0.32	0.07±0.26	0.27±0.49	0.06±0.18	0.15±0.32

Table 11. Overall mean status of natural enemies complex in paddy ecosystem in Uttara Kannada during *rabi*, 2011

Natural enemies	Reproductive stage					Mean
	Upghat drill sown	Upghat transplanted		Coastal transplanted		
	Mundgod	Sirsi	Siddapura	Honnavara	Kumta	
Spider (adults/hill)	0.42±0.57	0.43±0.58	0.49±0.60	0.61±0.66	0.36±0.49	0.46±0.58
Coleoptera (adults/ hill)	0.24±0.48	0.27±0.51	0.30±0.52	0.24±0.53	0.20±0.45	0.25±0.49
Odonota (adults/hill)	0.20±0.48	0.26±0.52	0.28±0.53	0.29±0.54	0.22±0.44	0.25±0.51
Hemiptera (adults/hill)	0.10±0.31	0.12±0.31	0.14±0.38	0.38±0.58	0.07±0.33	0.16±0.38
Diptera (adults/hill)	0.08±0.30	0.08±0.28	0.04±0.20	0.08±0.27	0.09±0.14	0.07±0.23

Table 12. Fauna of natural enemies in rice fields of Uttara Kannada district during *Kharif* and *Rabi*, 2010-2011

Insect order	Family	Scientific name	Host
Predators			
Coleoptera	Coccinellidae	<i>Cheilomenes sexmaculata</i> (Linnaeus) <i>Coccinella transversalis</i> (Fabricius)	General predators
	Cicindellidae	<i>Cicindela flavomaculata</i> (Hope) <i>Cicindela whithilli</i> (Hope)	Feeds on nymphs of <i>Leptocorisa</i> spp
	Carabidae	<i>Chlaenius pictus</i> (Chaud) <i>Ophionea indica</i> (Thunberg)	General predators
Hemiptera	Pentatomidae	<i>Andrallus spinidens</i> (Fabricius)	General predators
Odonata	Libellulidae	<i>Pantala flavescens</i> (Fabricius)	General predators
		<i>Tholymis tillarga</i> (Fabricius)	
		<i>Crocothemis servilia</i> (Drury)	
		<i>Orthetrum sabina</i> (Drury)	
	Coengrionidae	<i>Ischnura aurora</i> (Brauer)	
		<i>Protosticta gravelyi</i> (Laidlwa)	
Diptera	Asilidae	Rober fly	General predators
Non insect predators			
Spiders	Lycosidae	<i>Pardosa pseudoannulata</i> (Boesenberg and Strand)	General predators
	Tetragnathidae	<i>Tetragnatha</i> sp.	

Table 13. Alternate hosts of rice earhead bug observed during survey in different locations of Uttara Kannada District

Sl. No.	Weed hosts	Family
1.	<i>Echinochloa crusagalli</i> (L.) Beauv.	Poaceae
2.	<i>Echinochloa colonum</i> (L.) Link.	Poaceae
3.	<i>Eleusina indica</i> (L.) Gaertn.	Poaceae
4.	<i>Digitaria sanguinalis</i> (L.)	Poaceae
5.	<i>Cyperes rotundus</i> (L.)	Cyperaceae
6.	<i>Cyperus iria</i> (L.)	Cyperaceae
7.	<i>Brachiaria mutica</i> Stapf. (Para grass)	Poaceae

Whereas in *rabi*, 2011, the highest population was of Spider (0.43/hill), followed by Coleoptera (0.27/hill), Odonata (0.26/hill) and least population of Hemiptera (0.12/hill) and Diptera (0.08/hill).

In Siddapura taluk, the mean spider population of 0.47/hill was highest followed by population of Odonata (0.31/hill), Coleoptera (0.27/hill), Hemiptera (0.15/hill) and Diptera (0.07/hill) during *kharif*, season. During *rabi*, the highest mean population of spider (0.49/hill), followed by Coleoptera (0.30/hill), Odonata (0.28/hill) and least population of Hemiptera (0.14/hill) and Diptera (0.04/hill) were recorded.

In Honnavara taluk, the mean spider population of 0.66/hill was highest and followed by population of Odonata (0.33/hill), Diptera (0.27/hill), Hemiptera (0.22/hill) and Coleoptera (0.21/hill) were observed during *kharif*. During *rabi*, the highest population of Spider (0.61/hill) followed by population of Hemiptera (0.38/hill), Odonata (0.29/hill) and least population of Coleoptera (0.24/hill) and Diptera (0.08/hill) were recorded.

In Kumta taluk the mean Spider population (0.39/hill) was highest followed by population of Odonata (0.25/hill), Coleoptera (0.16/hill), Hemiptera (0.06/hill) and Diptera (0.06/hill) were recorded during *kharif*, 2010. During *rabi*, 2011 the highest population of spider (0.36/hill) followed by population of Odonata (0.22/hill), coleoptera (0.20/hill) Diptera (0.09/hill) and Hemiptera (0.07/hill) were recorded.

In Mundgod taluk, the mean Spider population of 0.48/hill recorded as the population was highest followed by population of Odonata (0.28/hill), Coleoptera (0.21/hill) and least population of Hemiptera (0.14/hill) and Diptera (0.14/hill) during *kharif*, 2010. During *rabi*, 2011, the highest population was Spider (0.43/hill), followed by population of Coleoptera (0.27/hill), Odonata (0.26/hill) Hemiptera (0.12/hill) and Diptera (0.08/hill) were recorded.

The overall mean population of different predators of paddy earhead bug in *kharif* and *rabi* seasons are listed here. The spiders (0.49 and 0.46 per hill in *kharif* and *rabi*, respectively), Odonatans (0.29 and 0.25 adults per hill), Coleopterans (0.22 and 0.25 adults per hill), Hemipterans (0.14 and 0.16 adults per hill) and dipterans (0.15 and 0.07 adults per hill) were recorded as the major predator insect orders during the study (Table 10 and 11).

4.2.2 Alternate host plants of earhead bug

While documenting the alternate host plants of rice earhead bug, in Uttara Kannada district bugs were found to feed on below mentioned alternate hosts and also the egg masses were recorded on rice weeds and grasses adjacent to the paddy fields. Which include *Echinocloa crusagalli* (L.) Beauv., *Echinocloa colona* (Link)., *Eleusine indica* (L.) Gaertn., *Digitaria sanguinalis*, *Cyperes rotundus* (L.), *Cyperes iria* (L.), *Bracheria mutica* Stpf. (Table 13).

4.3 Bio-ecology of rice earhead bug, *Leptocorisa oratorius* under laboratory condition

4.3.1 Egg

Details of biology of rice earhead bug studied in laboratory condition are presented here.

Eggs of *Leptocorisa oratorius* were dark brownish to dark in colour, oval in shape, seed like as well as in appearance they resembled red blood cell and shiny in nature. They were flattened dorsally by small depression and ventrally convex in shape (Plate 5). The length of the egg ranged from 0.08 to 1.15 mm with a mean of 1.00 ± 0.12 mm and width varied from 0.05 to 0.85 mm with a mean of 0.74 ± 0.10 mm (Table 14).

4.3.2 Incubation period

The incubation period of *L. oratorius* under laboratory condition ranged from 5 to 8 days with a mean of 6.70 ± 1.10 days (Table 15).



Mass rearing in potted cage



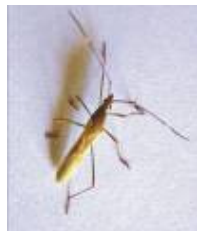
General view for rearing of rice earhead bug in laboratory



Early instars nymphs hatched from eggs



a. Hatched eggs



Eggs 5 to 8 days

Adult



5th instar 3 to 6 days



4th instar 3 to 4 days



3rd instar 3 to 4 days



Plate 5. Biology of rice earhead bug *Leptocorisa oratorius*

4.3.3 Hatching

A crescent shaped egg burster on the head of the nymph aided egg hatching. Even with lack of operculum, a line of weakness is seen prior to hatching and dorsal surface of the egg neatly broken off from the micropylar end and leaving a cup shaped portion and with silver colour appearance inside the cup (Plate 5.a).

4.3.4 Nymphal period

4.3.4.1 First instar

Freshly hatched nymphs were pale greenish in colour and had long reddish antennae with whitish bands. The antennae and legs were longer than the body. Eyes were reddish and legs were reddish brown in colour and there was no wing formation in this stage. The length of the first instar nymph varied from 1 to 2.20 mm with an average of 1.83 ± 0.34 mm and width varied from 0.30 to 0.70 mm, with an average of 0.49 ± 0.12 mm (Table 14). The duration of the first instar nymph lasted for 3 to 5 days with an average of 4.2 ± 0.87 days under laboratory condition (Table 15).

4.3.4.2 Second instar

Second instar nymph was similar to that of first instar in appearance except for the body size. The second instar nymph measured 3.35 to 6.80 mm in length with a mean of 5.00 ± 0.99 mm and width ranged from 0.10 to 1.00 mm with an average of 0.75 ± 0.24 mm (Table 14). The duration of this instar lasted for two to five days with an average of 4.20 ± 1.40 days (Table 15)

4.3.4.3 Third instar

The third instar nymph was dark greenish in colour. Reddish antennae with two whitish bands and legs were brownish in colour. In this stage, the antennae were not much longer than the body. Pale green wing pads were appeared in this instar. Third instar nymph measured 7.95 to 11.10 mm in length with an average of 9.60 ± 0.95 mm and width ranged from 0.90 to 1.20 mm with an average of 1.09 ± 0.0 mm (Table 14). The duration of third instar lasted for 3 to 4 days with an average of 3.70 ± 0.64 days (Table 15).

4.3.4.4 Fourth instar

The fourth instar nymph was greyish green in colour with reddish to reddish brown eyes. The dark greenish stripe on the lateral side of the head becomes reddish brown. Lateral margins of the pronotum became cream-coloured and femora became reddish brown. The nymph measured from 9.00 to 15.00 mm in length with an average of 11.91 ± 2.06 mm and 1.20 to 1.50 mm in width with an average of 1.33 ± 0.10 mm (Table 14). This instar ends/completes 3 to 4 days with an average of 3.50 ± 0.50 days (Table 15).

4.3.4.5 Fifth instar

The fifth instar nymph was larger and pale brown in colour with well developed wings. The length and width of the fifth instar nymph varied from 11.00 to 17.00 mm and 1.45 to 1.90 mm with an average of 15.38 ± 1.70 mm and 1.62 ± 0.13 mm, respectively (Table 14). The duration of this instar ranged from 3 to 6 days with an average of 4.20 ± 1.16 days (Table 15).

The total nymphal period under laboratory condition ranged from 14 to 24 days with an average of 19.8 ± 4.57 days after moulting five times (Table 15).

Total developmental period from egg to adult under laboratory condition varied from 19 to 32 days with a mean of 26.5 ± 5.67 days (Table 15).

4.3.5 Adult

Adult bugs were more slender, robust with variation in colour ranging from green to brownish-orange and they can be distinguished from other species by the presence of brownish to black coloured ventro-lateral spots on the abdomen of *L. oratorius*.

Table 14. Morphometric data of different stages of *Leptocorisa oratorius*

Sl. No.	Stages	Length (mm)		Width (mm)	
		Range	Mean \pm S.D	Range	Mean \pm S.D
1.	Egg	0.80-1.15	1.00 \pm 0.12	0.50-0.85	0.74 \pm 0.10
2.	Nymph				
	I instar	1-2.20	1.83 \pm 0.34	0.30-0.70	0.49 \pm 0.12
	II instar	3.35-6.80	5.00 \pm 0.99	0.10-1.0	0.75 \pm 0.24
	III instar	7.95-11.10	9.60 \pm 0.95	0.90-1.20	1.09 \pm 0.09
	IV instar	9-15	11.91 \pm 2.06	1.20-1.50	1.33 \pm 0.10
	V instar	11-17	15.38 \pm 1.70	1.45-1.90	1.62 \pm 0.13
3.	Adult				
	Female	17.40-18.20	17.86 \pm 0.36	2.40-3.00	2.70 \pm 0.23
	Male	17.95-19.10	18.48 \pm 0.50	1.95-2.50	2.15 \pm 0.28

Table 15. Duration of life stages of *Leptocorisa oratorius* on paddy under laboratory condition

Sl. No.	Developmental stages	Duration of stage Range (days)	Mean \pm S.D
1	Incubation period	5-8	6.7 \pm 1.1
2.	Nymph I instar II instar III instar IV instar V instar	3-5 2-5 3-4 3-4 3-6	4.2 \pm 0.87 4.2 \pm 1.4 3.7 \pm 0.64 3.5 \pm 0.5 4.2 \pm 1.16
3.	Total nymphal period	14-24	19.80 \pm 4.57
4.	Total developmental period (egg to adult)	19-32	26.5 \pm 5.67

Table 16. Duration of adult longevity of *Leptocorisa oratorius* on paddy under caged pots

Sl. No.	Parameter	Range	Mean \pm S.D
1.	Preoviposition period (Days)	3-7	5.00 \pm 1.29
2.	Oviposition period (Days)	5-18	11.00 \pm 5.44
3.	Mating period (Hours)	2-6	2.83 \pm 1.34
4.	Fecundity (number of eggs/female)	50-167	108 \pm 42
5.	Adult longevity (Days) Female Male	37-76 22-39	55.83 \pm 14.75 29.66 \pm 5.76

The female bug was slightly smaller and more robust than the male (Plate 6a) and measured 17.40 to 18.20 mm with mean of mean 17.86 ± 0.36 mm in length and 2.40 to 3.00 mm with mean of 2.70 ± 0.23 mm in width. The male bug was slightly larger than female measured 17.95 to 19.10 mm in length with a mean of 18.48 ± 0.50 mm and 1.95 to 2.50 mm with a mean of 2.15 ± 0.21 mm in width (Table 14).

4.3.5.1 Adult longevity

The adult females lived for 37 to 76 days with a mean of 55.83 ± 14.75 days and males lived for 22 to 39 days with a mean of 29.66 ± 5.76 under laboratory condition (Table 16).

4.3.5.2 Mating

The bugs mated during morning hours and late evening hours but very rare in after noon. The mating period ranged from 2 to 6 hours with an average of 2.83 ± 1.34 hours. The male and female faced in opposite directions and moved about during copulation (Plate 6b). They separated with slightest disturbances. Mating was also observed on grassy weeds present on bunds (Table 16).

4.3.5.3 Pre-oviposition period

The pre-oviposition period ranged from 3 to 7 days with an average of 5.00 ± 1.29 days under laboratory condition.

4.3.5.4 Oviposition period

The oviposition period under laboratory ranged from 5 to 18 days with an average of 11.00 ± 5.44 days (Table 16).

4.3.5.5 Site of oviposition

The eggs were usually deposited on both upper and lower surface of the paddy leaves of its various positions like tip, middle, margin and base of leaf and ranged from 5 to 27 eggs in a batch. Each egg was placed in contact with the previous egg and cemented to the surface in single row or in double rows or in triple rows and irregular pattern. Sometimes egg laid on cages, grass, grains of paddy was also observed.

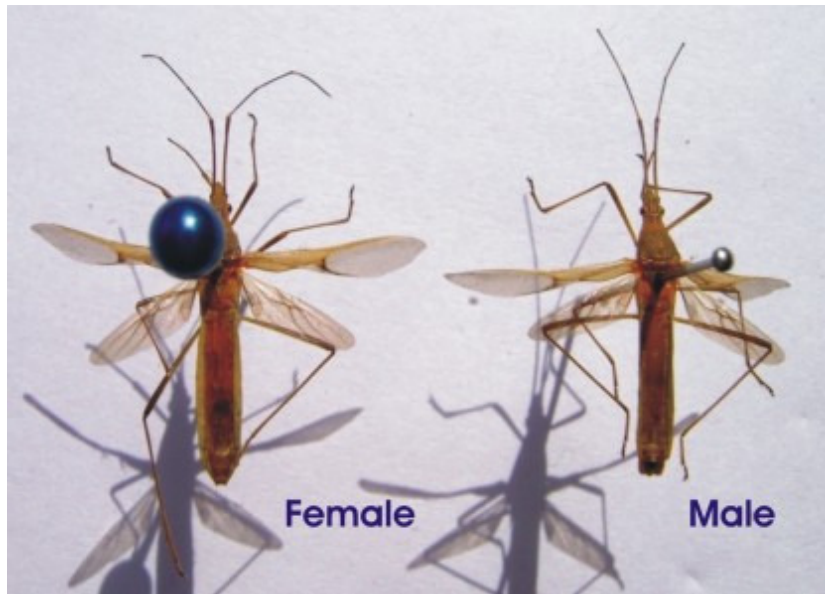
4.3.5.6 Fecundity

The female bugs laid varied number of eggs (Plate 6c). However, fecundity ranged from 50 to 167 eggs per female with an average of 108 ± 42.00 eggs under laboratory condition (Table 16).

4.3.5.7 Habitate of nymphs and adults of *L. oratorius*

Due to early summer showers during April-May, the alternate host plants which grow fast on paddy bunds and in the adjoining plantation areas served as food source for the bugs. The bugs were found to feed and breed on alternate hosts till the paddy crop reached flowering stage. Once the rice earheads emerged, the bugs migrate from the alternate hosts to paddy fields. It was also observed that the bugs were migrating to grasses soon after the harvest of the *kharif* crop and later moved to paddy fields after emergence of earheads in summer crop and continued to stay on paddy upto April-May. The bugs breed on early maturing varieties and migrated to late maturing varieties causing heavy damage on the latter.

The peak period activities of rice earhead bugs were observed more in early morning hours and late evening hours. Further it was observed that bugs were more active during cooler hours of the day in the field and took shelter under shady portions of the plants during hot period of the day. The nymphs exhibited feigning death and in most of the cases the later instars fell down from the plants when disturbed. This behavior may serve as defensive mechanism to escape from their enemies. Adults are very active when disturbed flying from one plant to another plant. First and second instar nymphs were found to be congregating on tip of the earheads (Plate 7) and raise their abdomen while feeding. Both nymphs and adults emit pungent odour when handled or threatened.



a. *Leptocoris oratorius*



b. mating behaviour



c. 26 eggs in two rows

Plate 6. Adults, mating and fecundity of *Leptocoris oratorius*

4.3.6 Nature of damage

Both the nymphs and adults of *L. oratorius* started feeding on the grains soon after emergence of earheads and continued to feed on them till the grain gets hardened. The sucking of milky juice from the developing grains resulted in partial or full chaffyness of grains. The nymphs and adults inserted their proboscis into the developing grains. At the site of feeding, small yellowish brown spot developed initially and enlarged later to form yellowish brown elliptical spot with grayish centre. Bugs produced proteinaceous stylet sheaths in all nymphal stages and both adult sexes. During soft and hard dough stages, the feeding caused deformed and spotty grains and later these grains stained (discoloration) partially or wholly by bacteria or fungi, which invaded the grains at the sucking point (Plate 8).

4.3.7 Ecology of the pest

Warm weather, over cast sky and frequent drizzle favor the buildup of *L. oratorius* in the field during flowering season. The infestation of earhead bug was severe at temperature of 18.1^o to 29.2^o C, relative humidity of 66.6 to 89.0 per cent and in Uttara Kannada district intermittent rains accompanied by high temperature during October-November were highly favorable for buildup of rice earhead bug, *L. oratorius*.

4.4 Management of rice earhead bug, *Leptocorisa* spp using plant extracts, entomopathogenic fungi and new molecules of insecticides

4.4.1 Rice earhead bug Management

Rice earhead bug, *L. oratorius* was found as a major yield constraint in paddy growing areas of Uttara Kannada. Several ecofriendly approaches were used to manage the rice earhead bug are presented here (Table 17 and Fig. 3 and 4).

4.4.1.1 Pest population before imposition of treatments

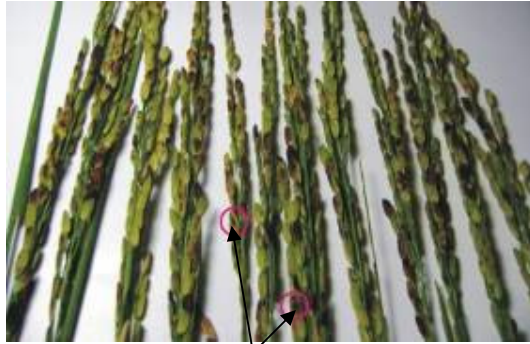
Pre-treatment count of rice earhead bug in all treatments was similar and the variation was non significant. Indicating uniformity in the distribution of bugs in the field a day before spray. *Metarhizium anisopliae* @ 2 g/l, *Vitex negundo* leaf extracts @ 10%, Indoxacarb 14.8 SL @ 0.5 ml/l, *Beauveria bassiana* @ 2 g/l, *Acorus calamus* rhizome extract @ 10%, Thiomethoxam 25 WG @ 0.3 g/l, *Randia spinosa* fruit extracts @ 5%, Imidacloprid 17.8 SL @ 0.25 ml/l, Malathion D @ 20 kg/ha, Emamectin benzoate 5 SG @ 0.2 g/l, Dimethoate 30 EC @ 1.75 ml/l, *Adathoda vasica* leaf extracts @ 10%, (Azadirachtin 3000 ppm) 3 ml/l, *Strychnos nux vomica* leaf extracts @ 10% and untreated control plots recorded bug population of 1.03, 1.03, 1.03, 1.10, 1.10, 1.13, 1.13, 1.20, 1.27 1.30, 1.30, 1.30, 1.30, 1.4 and 1.50 bugs per hill, respectively.

4.4.1.2 Three days after treatment

Observation on bug population 3 days after application of treatments exhibited significant difference among the treatments. Imidacloprid recorded lowest population of bugs (0.03/hill) which was at par with thiomethoxam (0.13/hill), malathion (0.13/hill) and azadirachtin (0.33/hill). The next best treatments in the order of efficacy were *Acorus calamus* followed by dimethoate, indoxacarb, emamectin benzoate and *Randia spinosa* which recorded moderate bug population of 0.47, 0.50, 0.63, 0.67 and 0.67 per hill, respectively. While, rest of the treatments *Vitex negundo*, *Adathoda vasica*, *Strychnos nux vomica*, *Metarhizium anisopliae* and *Beauveria bassiana*, recorded bug population of 0.73, 0.77, 0.90, 1.01, and 1.04 per hill, respectively and were at par with each other (Table 17).

4.4.1.3 Seven days after treatment

Minimum appearances of the bugs in all the treatments were noticed after seven days of spraying. imidacloprid sustained its superiority even 7 days after treatment by records significantly lowest in bug population of 0.07/hill and was found at par with thiomethoxam (0.13/hill), malathion (0.20/hill).



Yellowish brown spot



Typical damaging symptoms of rice earheads



Healthy and damaged grains



Healthy and damaged rice

Platte 8. Nature of damage by rice earhead bug



Congregation of nymphs of earhead tip



Congregation of adults



Plate 7. Habits of nymphs and adults of rice earhead bug

4.4.1.4 Mean bug population

The overall mean bug population was calculated and among all the treatments imidacloprid recorded lowest bug population (0.05/hill), which was at par with thiomethoxam (0.13/hill) and malathion (0.16/hill) were found. Other next best treatment includes azadirachtin (0.38/hill) and *Acorus calamus* (0.48/hill) which were at par with each other. These two botanicals were significantly superior over rest of the treatments which followed by dimethoate, emamectin benzoate, indoxacarb, *Randia spinosa*, *Vitex negundo*, *Adthoda vasica*, *Strychnos nux vomica*, *Metarhizium anisopliae* and *Beauveria bassiana*, treatments with bug population of 0.58, 0.68, 0.70, 0.73, 0.76, 0.83, 0.93, 0.96 and 1.03 per hill, respectively in the trial (Table 17).

4.5 Per cent grain damage

All the treatments showed significant difference over control for the per cent grain damage. However, the results indicated that the lowest per cent of grain damage was observed in imidacloprid treated plot (4.14 %) and moderate per cent grain damage was observed in thiomethoxam treated plot (5.45%) and was at par with malathion (6.23%) and azadirachtin (6.53%), *Acorus calamus* (7.26%), emamectin benzoate (7.71%), dimethoate (7.94%), indoxacarb (8.12%), *Vitex negundo* (8.05%), *Randia spinosa* (8.34%), *Adthoda vasica* (9.19%), *Strychnos nux vomica* (9.51%), *Metarhizium anisopliae* (10.02%) and *Beauveria bassiana* (10.87%), which recorded significantly lesser grain damage over the untreated control. However, malathion, azadirachtin and thiomethoxam treatments were found at par with each other (Table 17).

4.6 Grain yield

The highest grain yield of 7049.26 kg/ha was obtained with imidacloprid treated plot and it was at par with thiomethoxam (6461.11 kg/ha) and malathion (6253.33 kg/ha) and all these treatments were significantly superior over rest of the treatments and this was followed by azadirachtin (6057.78 kg/ha) which was at par with *Acorus calamus* (5705.19 kg/ha), indoxacarb (5625.56 kg/ha), over other treatments viz., emamectin benzoate (5501.48 kg/ha), *Beauveria bassiana* (5335.19 kg/ha), *Metarhizium anisopliae* (5076.30 kg/ha), dimethoate (5049.63 kg/ha), *Randia spinosa* (4879.93 kg/ha), *Vitex negundo* (4709.26 kg/ha), *Adthoda vasica* (4573.33 kg/ha) and *Strychnos nux vomica* (4426.67 kg/ha), were statistically at par in all the treatments, respectively and was significantly more than control (Table17).

4.7 Cost economics

The economics of management of rice earhead bug was worked out and presented in Table 18. Among the treatments, imidacloprid recorded highest gross return of Rs. 52619.93/ha followed by thiomethoxam (Rs.48386.11/ha), malathion (Rs.46781.00/ha), azadirachtin (Rs. 45281.78/ha). Whereas, *Strychnos nux vomica* treatment recorded lowest gross return (Rs.33425.33/ha). Among the treatments imidacloprid recorded highest net profit of Rs.35489.93/ha followed by thiomethoxam (Rs.30905.11/ha), malathion (Rs.29241.00/ha). *Strychnos nux vomica* recorded lowest net profit of Rs.16485.33/ha among the treatments. The highest BC ratio of 3.07 was obtained from imidacloprid treatment followed by thiomethoxam 2.77, malathion 2.67, azadirachtin 2.57, *Acorus calamus* 2.51 and lowest obtained from *Strychnos nux vomica* 1.97 (Table18).

4.7.1 Per cent yield increase over control

The per cent increase in grain and straw yield in different treatments when compared to control was maximum in imidacloprid treated plot of 73.76 per cent and 67.67 per cent, respectively, followed by thiomethoxam (59.20% and 61.69%) and malathion (54.14% and 53.98%). The per cent increase with plant extracts was found to be maximum with azadirachtin (49.32% and 47.31%) and *Acorus calamus* (40.63% and 37.90%) (Table 18).

Table 17. Effect of plant products, entomopathogenic fungi and new molecules of insecticides on rice earhead bug population

Sl. No	Treatments	Number of nymphs and adults of rice earhead bug / hills *			Average **	% grain damage	Grain yield kg/ha
		1DBS	3DAS	7DAS			
1	Azadirachtin 3000 ppm @ 3 ml/l	1.30 (1.34) ^a	0.33 (0.91) ^{ab}	0.43 (0.97) ^b	0.38 (0.91) ^{bc}	6.53 (2.65) ^{bcd}	6057.78bcd
2	<i>Acorus calamus</i> aqueous rhizome extract @ 10%	1.10 (1.26) ^a	0.47 (0.98) ^{bc}	0.50 (1.00) ^{bc}	0.48 (0.99) ^{cd}	7.26 (2.87) ^{cd}	5705.19bcde
3	<i>Strychnos nux vomica</i> aqueous leaf extract @ 10%	1.40 (1.38) ^a	0.90 (1.18) ^{de}	0.97 (1.21) ^{de}	0.93 (1.21) ^{gh}	9.51 (3.16) ^{efg}	4426.67hi
4	<i>Vitex negundo</i> aqueous leaf extract @ 10%	1.03 (1.24) ^a	0.73 (1.11) ^{cde}	0.80 (1.14) ^{cde}	0.76 (1.12) ^{fg}	8.05 (2.92) ^{def}	4709.26fghi
5	<i>Adathoda vasica</i> aqueous leaf extract @ 10%	1.30 (1.34) ^a	0.77 (1.13) ^{cde}	0.90 (1.18) ^{de}	0.83 (1.18) ^{gh}	9.19 (3.11) ^{efg}	4573.33ghi
6	<i>Randia spinosa</i> aqueous fruit extract @ 5%	1.13 (1.28) ^a	0.67 (1.08) ^{bcd}	0.80 (1.14) ^{cde}	0.73 (1.15) ^{gh}	8.34 (2.97) ^{def}	4875.93efgh
7	<i>Metarhizium anisopliae</i> @ 2 g/l	1.03 (1.24) ^a	0.93 (1.20) ^e	1.00 (1.22) ^{de}	0.96 (1.23) ^h	10.02 (3.24) ^{fg}	5076.30efgh
8	<i>Beauveria bassiana</i> @ 2 g/l	1.10 (1.26) ^a	0.97 (1.21) ^e	1.10 (1.26) ^e	1.03 (1.24) ^h	10.87 (3.37) ^g	5335.19cdef
9	Malathion (Cythion) D @ 20 kg/ha	1.27 (1.33) ^a	0.13 (0.80) ^a	0.20 (0.84) ^a	0.16 (0.82) ^{ab}	6.23 (2.59) ^{bc}	6253.33abc
10	Indoxcarb (Avant) 14.8 SL @ 0.5 ml/l	1.03 (1.24) ^a	0.63 (1.06) ^{bcd}	0.77 (1.13) ^{cde}	0.70 (1.09) ^{ef}	8.12 (2.93) ^{def}	5625.56bcde
11	Dimethoate (Rogor) 30 EC @ 1.75 ml/l	1.30 (1.34) ^a	0.50 (1.00) ^{bcd}	0.67 (1.08) ^{bcd}	0.58 (1.00) ^{cde}	7.94 (2.90) ^{cde}	5049.63efgh
12	Emamectin benzoate (Proclaim) 5 SG @ 0.2 g/l	1.30 (1.34) ^a	0.67 (1.08) ^{bcd}	0.70 (1.10) ^{bcd}	0.68 (1.08) ^{def}	7.71 (2.85) ^{cde}	5501.48cdef
13	Imidacloprid (Confidor) 17.8 SL @ 0.25 ml/l	1.20 (1.30) ^a	0.03 (0.73) ^a	0.07 (0.75) ^a	0.05 (0.74) ^a	4.14 (2.15) ^a	7049.26a
14	Thiomethoxam (Renova) 25 WG @ 0.3 g/l	1.13 (1.28) ^a	0.13 (0.80) ^a	0.13 (0.80) ^a	0.13 (0.80) ^a	5.45 (2.44) ^b	6461.11ab
15	Untreated check	1.50 (1.41) ^a	2.67 (1.78) ^f	3.00 (1.87) ^f	2.83 (1.82) ⁱ	17.08 (4.19) ^h	4056.67i
S. EM. ±		0.05	0.05	0.05	0.03	0.10	255.80
C. D. (0.05)		NS	0.15	0.13	0.10	0.28	741.03
C. V. (%)		6.00	8.56	7.02	5.29	5.77	8.23

*Values in parentheses are $\sqrt{x+0.5}$ transformed values,
D B S = Day before spray, D A S = Day after spray,

** Mean of 3 DAS and 7 DAS which differ significantly,
Means followed by the same letter in a column are not significantly different (p=0.05) by DMRT

Table 18. Cost economics of treatments for the management of rice earhead bug in Uttara Kannada during Kharif, 2010

Sl. No	Treatments	Grain Yield (kg/ha)	Per cent increase over control	Straw Yield (kg/ha)	Per cent increase over control	Gross income (Rs/ha)	Cost of cultivation (Rs/ha)	Net Profit (Rs/ha)	Net gain over control (Rs/ha)	B:C ratio
1	Azadirachtin 3000 ppm @ 3 ml/l	6057.78	49.32	9591.11	47.31	45281.78	17640	27641.78	100.35	2.57
2	<i>Acorus calamus</i> aqueous rhizome extract @ 10%	5705.19	40.63	8978.89	37.90	42629.96	16990	25639.96	86.00	2.51
3	<i>Strychnos nux vomica</i> aqueous leaf extract @ 10%	4426.67	9.86	8128.89	24.85	33425.33	16940	16485.33	19.00	1.97
4	<i>Vitex negundo</i> aqueous leaf extract @ 10%	4709.26	16.08	8255.56	26.79	35441.48	16990	18451.48	32.38	2.09
5	<i>Adathoda vasica</i> aqueous leaf extract @ 10%	4573.33	12.73	7627.96	17.15	34301.72	16990	17311.72	25.15	2.02
6	<i>Randia spinosa</i> aqueous fruit extract @ 5%	4875.93	20.19	7857.04	20.67	36488.59	16990	19498.59	41.09	2.15
7	<i>Metarhizium anisopliae</i> @ 2 g/l	5076.30	25.14	8295.56	27.41	38022.74	16990	21032.74	52.72	2.24
8	<i>Beauveria bassiana</i> @ 2 g/l	5335.19	31.51	8258.52	26.84	39823.85	16990	22833.85	65.05	2.34
9	Malathion (Cythion) D @ 20 kg/ha	6253.33	54.14	10025.56	53.98	46781.00	17540	29241.00	111.59	2.67
10	Indoxcarb (Avant) 14.8 SL 2 0.5 ml/l	5625.56	38.67	8775.93	34.79	42011.67	17715	24296.67	76.37	2.37
11	Dimethoate (Rogor) 30 EC @ 1.75 ml/l	5049.63	24.47	8350.37	28.25	37852.52	17064	20788.52	49.52	2.22
12	Emamectin benzoate (Proclaim) 5 SG @ 0.2 g/l	5501.48	35.27	8414.07	29.23	41034.59	18105	22929.59	65.78	2.27
13	Imidacloprid (Confidor)17.8 SL @ 0.25 ml/l	7049.26	73.76	10917.04	67.67	52619.93	17130	35489.93	156.74	3.07
14	Thiomethoxam (Renova) 25 WG 0.3 g/l	6461.11	59.20	10527.78	61.69	48386.11	17481	30905.11	124.34	2.77
15	Untreated check	4056.67	-	6511	-	30349.44	16590	13759.44	-	1.83
	S.Em ±	255.8		414.95		1806.39		1806.39		0.11
	CD @ 5%	741.3		202.07		5232.90		5232.90		0.31

5. DISCUSSION

Paddy is one of the important crop, in rainfed ecosystem of coastal and hilly regions of Uttara Kannada. However, the crop suffers great losses due to rice earhead bug both in upland and low land conditions in the region. Rice is the major cereal crop during the *kharif* season. During *rabi*/summer the crop has been grown in a limited area. Ever since the rice earhead bug was reported from India on paddy by Atkinson (1889), it was known to cause considerable crop loss in almost all the states. The per cent yield loss caused by rice earhead bugs has been reported to be 10 to 50 per cent under varying conditions (Israel and Rao, 1954; Banerjee, 1961; Singh and Sinha, 1978; Banerjee and Chatterjee, 1982). During dry and wet seasons the bug also caused reduction in crop yield to an extent of 1.72 to 5.23 and 2.50 to 6.21 per cent, respectively (Gupta *et al.*, 1993) and 10 per cent (Sugimoto and Nugliyadde, 1995) in India. In view of its economic importance, the biology of this insect has been studied by many entomologists in the country starting from Lefroy (1908) to Anand and Prakash (1999).

However, detailed studies have not been carried out on species complex, incidence and its natural enemies, bio-ecology, nature of damage, alternate host plants and chemical control under rainfed situation of rice ecosystem of Uttara Kannada in general and Western Ghats of Karnataka in particular. Hence, the bio-ecology, seasonal incidence, alternate hosts and effective management strategies particularly plant extracts, entomopathogenic fungi and new molecules of insecticides were studied during the present investigation and the results are discussed here under.

5.1 Species complex of *Leptocorisa* spp in Uttara Kannada district

Since, only microscopic differences exist between *Leptocorisa* spp distinction could not be made between them. Hence, survey was conducted during *kharif*, 2010 and *rabi* 2011 covering five taluks in Uttara Kannada district. During the survey, all the bugs collected from infested area were pinned and sent for identification. It was identified as *L. oratorius* (Fabricius) (Hemiptera: Alydidae) and *L. lepida* Breddin. The findings of the survey indicated the occurrence of the species of bug namely, *Leptocorisa oratorius* as dominate species wherever the incidence on paddy seen in this region. The present finding is in conformity with the observations of Nayak (1984) who reported that among the three species, *L. oratorius* was common in almost all the places of Karnataka state. Van Den Berg, H. and Soehardi (2000) reported *Leptocorisa oratorius*, misidentified as *L. acuta* (Thunb.) in the literature prior to 1965, has been reported from south, east and south-east Asia through to Australia (Ahmad 1965). Although several species of *Leptocorisa* are found in rice, *L. oratorius* is by far the most dominant species associated with lowland paddy fields in Indonesia supports the present findings. During present study all rice earhead bugs were *L. oratorius*, which was confirmed by observing this species' characteristic brownish black spots on ventrolateral region of the abdominal segments and length was 17.40 to 18.20 mm with mean of 17.86 mm on several occasions. Siwi & van Doesburg (1984) assumed that all rice bugs were *L. oratorius*, which was confirmed by observing this species' characteristic ventrolateral spots on the abdominal segments supports the present observation. In present study on rice earhead bug, five taluks have been selected which represent three distinct rice growing ecosystems of Uttara Kannada district. In future study, remaining taluks may be included to know the species diversity of rice earhead bug in rainfed rice ecosystem.

5.2 Survey on incidence of rice earhead bug and its natural enemies during *kharif* and *rabi* growing seasons

Though the occurrence of this insect has been reported from Uttara Kannada district, the information on the incidence, its natural enemies and alternate hosts is not clearly known. In view of this, survey was conducted during *kharif* and *rabi* seasons covering major rice growing taluks of Uttara Kannada district. In each taluk around 3 villages in each village 3 locations were surveyed.

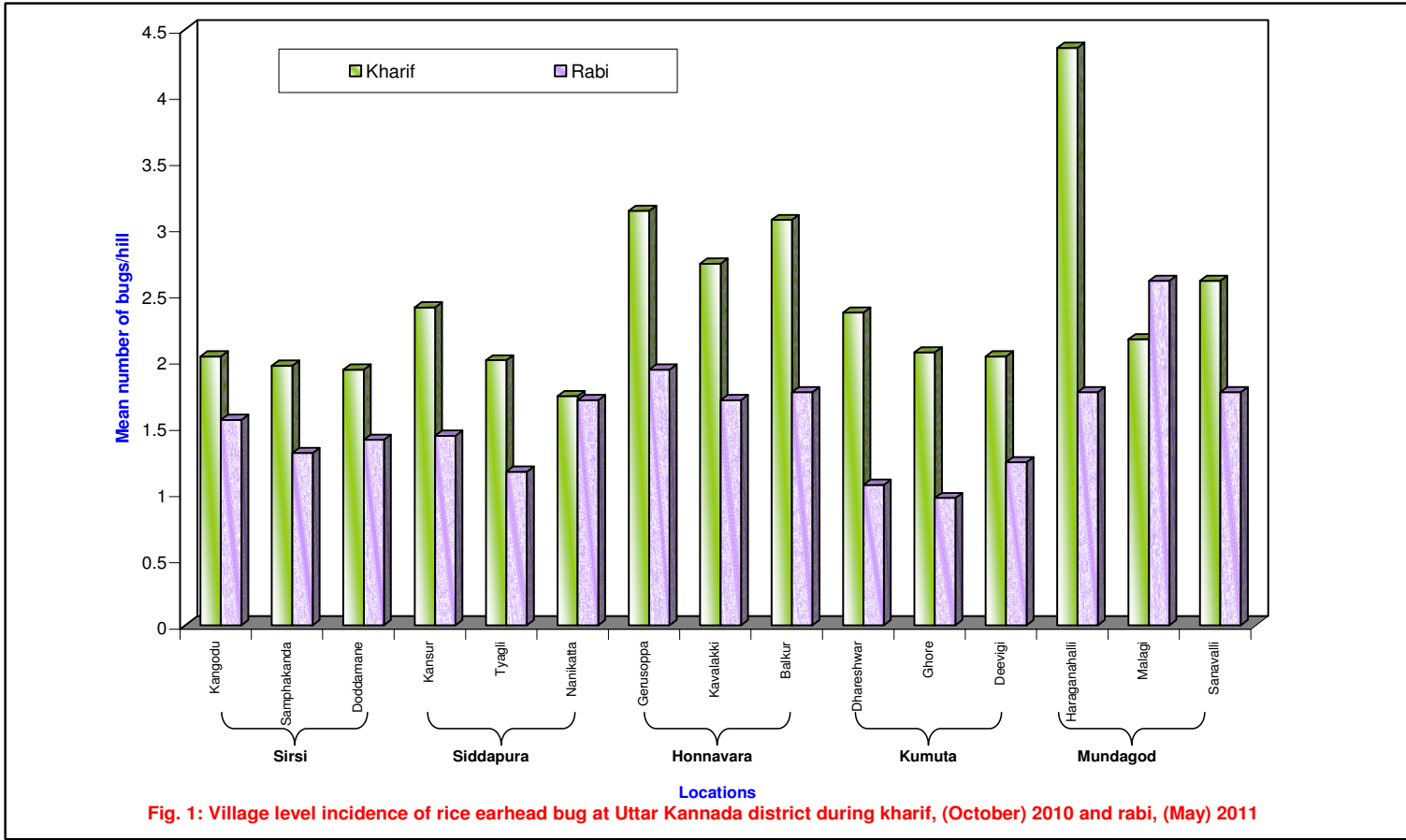


Fig. 1: Village level incidence of rice earhead bug at Uttar Kannada district during kharif, (October) 2010 and rabi, (May) 2011

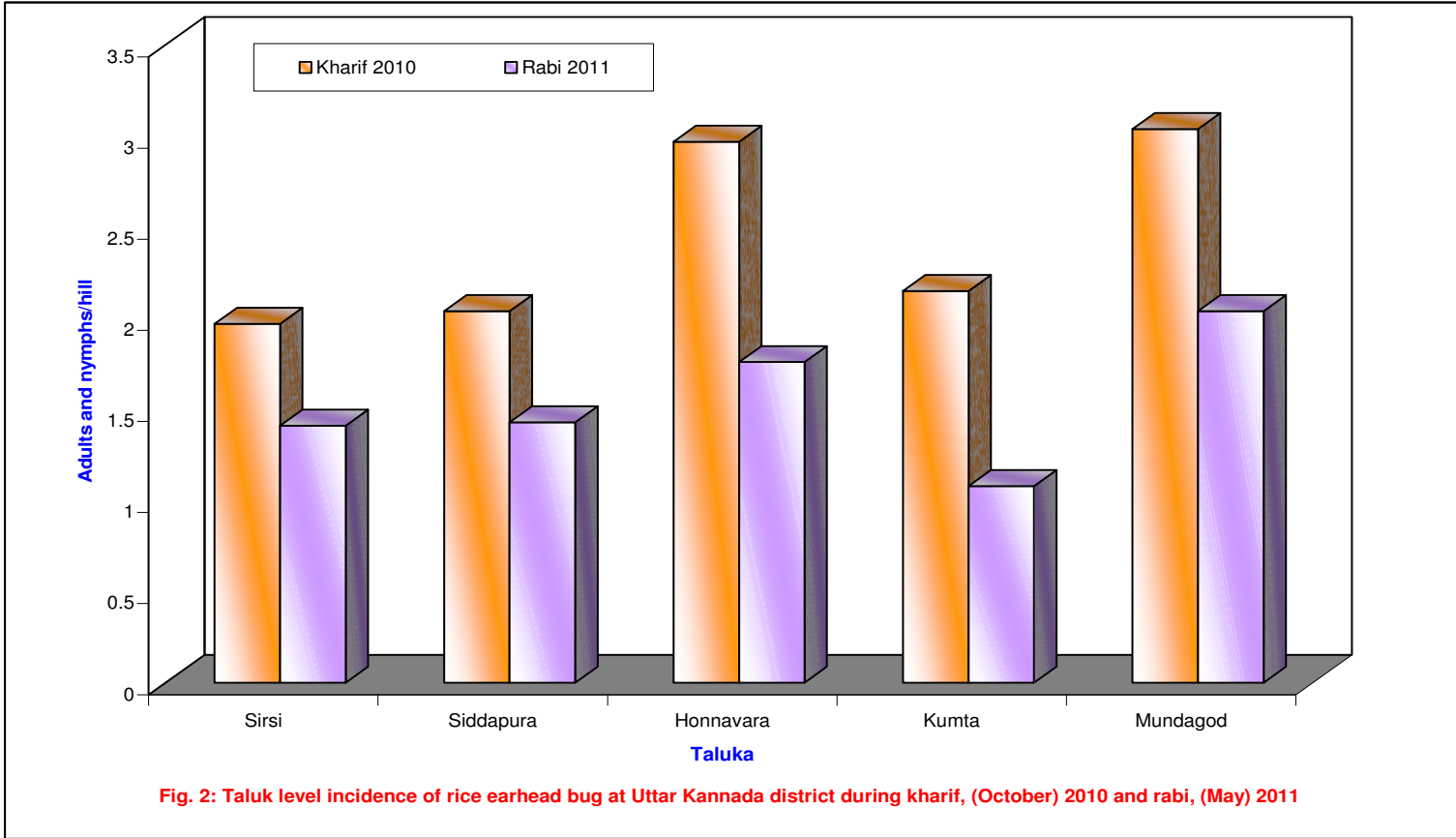


Fig. 2: Taluk level incidence of rice earhead bug at Uttar Kannada district during kharif, (October) 2010 and rabi, (May) 2011

Among the five taluks viz., Sirsi, Siddapura, Honnavara, Kumta and Mundgod surveyed, the highest bug incidence was noticed in Mundgod taluk and the least in Sirsi taluk. During *kharif*, season the incidence of *L. oratorius* ranged from 2.16 to 4.36, 2.73 to 3.31, 2.03 to 2.36, 1.73 to 2.40 and 1.93 to 2.03 bugs per hill in Mundgod, Honnavara, Kumta, Siddapura and Sirsi taluks, respectively and in *rabi* season it ranged from 1.76 to 2.60, 1.70 to 1.93, 1.16 to 1.70, 1.30 to 1.55 and 0.96 to 1.23 bugs/hill in Mundgod, Honnavara, Siddapura, Sirsi and Kumta taluks, respectively (Fig. 1 and 2).

In Sirsi and Siddapura taluks the incidence was found to be least compared to other taluks during *kharif*. Lower bug incidence may be attributed to weather factors where excess rainfall in the month of September (375.5 mm) and lower rains received in October (77.6 mm) (Appendix I). Further, lower temperature (19.5°C) and high humidity (88%) are also important in influencing bug activity. The present findings close conformity with the Biswas (1953) stated that a couple of good showers in October or fall in temperature reduced the population which bred on alternate hosts in the adjoining jungles at slower rates thereafter.

In Mundgod taluk, higher incidence of rice earhead bug was seen during reproductive phase of the crop in both the growing seasons. Alternate hosts as identified in this study (Table 13) might have helped the population buildup of rice earhead bug and later shifted to rice crop. Further, the normal rainfall received at reproductive phase of the crop in October (119 mm) and high humidity which have created favorable condition for buildup of rice earhead bug population it may also due to large area covered with variation in maturity of rice fields. Chakraborty and Chatterjee (2002) who reported that gundhi bug, *L. varicornis*, *L. acuta* on rice was high during panicle formation (from mid-September to October) when the temperature was 27 to 34°C and the relative humidity was 85 to 90 per cent and these findings support the present study results. Kulgod (2009) reported that higher incidence of earhead bug 9.06/hill during both *kharif* and *rabi* seasons in Mundgod taluk during the year 2008-2009. Banerjee (1961) reported that maximum activity of the paddy bug was found from August to November on Aman paddy in Bengal. He also stated that the damage was more in the adjoining areas of reserved forests supports the present findings.

The incidence of rice earhead bug was above the economic threshold level (1-2 bugs/hill) in Honnavar (2.97/hill) and Kumta (2.15/hill) during reproductive phase of the crop in the *kharif* season 2010. This might be due to prevailing weather with higher humidity and moderate temperature. Further the rainfall of 320 mm in Honnavara and 453 mm in Kumta during October month might have favoured the bug activity. Weed association in paddy crop may also influence the earhead bug activity. Kulgod in 2009 reported that mean bug population was highest in Mundgod, followed by Siddapura, Kumta, Honnavar and lowest in Sirsi which supports the present findings. Chakraborty and Chatterjee (2002) indicated that gundhi bug, *L. varicornis* (*L. acuta*) on rice was high during panicle formation (from mid-September to October) when the temperature was 27 to 34°C and the relative humidity was 85 to 90 per cent and this supports the present findings.

Low level incidence of rice earhead bug in all the taluks in *rabi/summer* crop during 2011. Observation of two seasons on earhead bug incidence indicated the lower incidence may be attributed to significantly less cropped area of rice in *rabi* season. Further, the alternate hosts like different grass plants are also scarce during *rabi* season and did not help for population build up of bugs. Rothschild (1970) reported that the adults of *L. oratorius* fed on grasses like *Echinochloa crusgalli* (L.) Seauv. *Paspalum serobiculstum* L. and *Pennisetum* sp. before migrating to paddy fields. During off-season, small numbers of adults and nymphs were found on ratoon rice plants and various grasses supports the present findings.

5.2.1 Natural enemies

Among major natural enemies found in all three rice ecosystems are the spider which composed of two species (*Pardosa pseudoannulata* and *Tetragnatha* sp.) Odonata including dragon fly (*Pantala flavescens*, *Crocothemis servilia*, *Thoymis tillarga*, *Orthetrum Sabina*, *Orthetrum glaucam*) and damsel fly (*Protosticta gravelyi*, *Ischnura aurora*). Coleoptera, coccinellid species (*Cheilomenes sexmaculata*, *Coccinella transversalis*) and cicindelid species (*Cicindela whithilli*, *Cicindela flavomaculata* feed on nymphs of *Leptocorisa* spp) and carabid species (*Chlaenius pictus*, *Ophionea indica*).

Among the hemipterans pentatomid bugs were dominant which includes *Andrallus spinidens*. Diptera includes only rober fly. However natural enemy population was almost similar in both the growing seasons.

All the natural enemies are general predators and their population is known to be directly related on their prey population. Reported by Rajendra Prasad (2010) on the natural enemy complex of rice ecosystem in Uttara Kannada district which revealed that 27 species of predators, 6 species of spiders were found active in rice crop. Spiders and mirids were most prominent natural enemies on brown plant hopper (BPH), white backed plant hopper (WBPH) and yellow stem borer support the present findings. The present observations are close comparison with the findings of Saxena (1952) who reported asilid fly (Rober fly), preying on adults and nymphs of *L. varicornis* and the only other record of an insect preying on adults and nymphs *L. varicornis* in india, is that of a cicindelid, *Cicindela sexpunctata* Fabr. found in large number in many important paddy areas. Sinu *et al.* (2006) reported the *Cicindela (Calochroa) whithilli* (Hope) and *Cicindela (Calochroa) flavomaculata* Hope (Cicindelidae: Coleoptera) are seasonally dominant predatory insects in the cultivated and irrigated rice paddy fields of the South Indian peninsula supports the present findings.

5.2.2 Alternate hosts

The observations were made to document the alternate hosts of earhead bug in Uttara Kannada district. Present study revealed that, *L. oratorius* was found feeding on 7 species of cyperaceous and poaceae weed plants in adjacent to paddy fields and in main field. These hosts included *Echinoloa crusagalli*, *Echinochloa colona*, *Eleusina indica*, *Cyperes rotundus*, *Cyperes iria*, and *Brachiria mutica* (Para grass). The present results are in agreement with those of Venkatesh Hosamani *et al.* (2009) documented the alternate hosts of earhead bug in Shimoga district, where *L. oratorius* was found feeding on graminaceous and cyperaceous weed plants in the vicinity of paddy fields and in main field before the emergence of earheads of paddy. These hosts included *E. crusagalli*, *E. colona*, *E. glabrescens*, *D. ciliaris*, *D. marginata*, *E. indica*, *C. rotundus* and *C. iria*. Sands (1977) reported *E. colona* as a principle wild food plant of *L. oratorius* supports the present findings. Morill *et al.* (1990) opined that *E. crusagalli* is most preferred resting site for *L. oratorius* than rice, where as rice was more preferred for feeding compared to *E. indica*, *E. colona*, *Brachiarua mutica* Stapf, *P. conjugatum* Berg, *P. paspalodes* and *D. ciliaris*. Nymphs have completed their development only in *E. crusagalli*, *E. colona*, *D. ciliaris* or rice after panicle emergence supports the present findings.

5.3 Bioecology of *L. oratorius* under laboratory condition

The incubation period of *L. oratorius* lasted for 5 to 8 with mean of 6.70 days under laboratory conditions which is in agreement with studies of Lefroy (1908), Srivastava and Saxena (1964), Misra (1968), Rai (1981). Rothschild (1970), Soon (1971) and Sands (1977). Total nymphal period lasted for 14 to 24 with a mean of 19.80 days under laboratory condition which is more or less in agreement with the findings of Li (1985), Rothschild (1970), Domingo *et al.* (1982), Nayak (1984) and Venkatesh Hosamani *et al.* (2009).

The pre oviposition period under laboratory conditions was 3 to 7 days with a mean of 5.00 days. The present observations are in close agreement with the findings of Rai (1981), Misra (2003), Venkatesh Hosamani *et al.* (2009). The total time taken by rice earhead bug to complete its life cycle from egg to adult was 19 to 32 with a mean of 26.5 days under laboratory condition which is more or less in agreement with those of Uichanco (1921), Corbett (1930), Rai (1981), Hutson (1930) Akbar (1958), Srivastava and Saxena (1964) and Venkatesh Hosamani *et al.* (2009). Copulation last for 2 to 6 hours with a mean of 2.83 hours. Mated females laid an average of 50 to 167 eggs with an average of 108 eggs in their total oviposition period of 5 to 18 days with an average of 11.00 days under laboratory conditions. Similar results were also obtained by Domingo *et al.*, (1982), Rai (1981), Li (1985) and Venkatesh Hosamani *et al.* (2009).

Under laboratory condition, adult female and male lived for 37 to 76 and 22 to 39 days with an average of 55.8 and 29.66 days respectively. These results are more or less close to the results were obtained by Soon (1971), Nayak (1984), Misra (2003) and Venkatesh Hosamani *et al.* (2009).

5.3.1 Habits of nymphs and adults

In the course of the present study, it was constantly noticed that the bugs appeared on rice fields only at the time of earhead emergence and their activity was not noticed on rice during the vegetative stage. Though the bugs were observed to feed on milky grains, they remained in the field until the harvest of the crop. This was commonly noticed in fields where there was variation in the maturity among rice plants. The present findings are in conformity with earlier workers who reported that the bugs moved to paddy fields at earhead emergence and feed on the milky grains (Lefroy, 1908, Sen and Chaudhuri, 1959, Venkatesh Hosamani *et al.* 2009).

Bugs were seen active more in morning and evening hours and took shelter under shady portions of the plant during hot part of the day. The present finding is in conformity with Corbett, 1930a; Srivastava and Sexena, 1964 and Akbar, 1958 who reported that bugs were more active during cooler parts of the day and they took shelter under shady portions of the plants during hot part of the day.

In addition both nymphs and adults of *L. oratorius* produce defensive secretion during when handled, which is having stinky smell. It may act as defensive mechanism against enemies and also elicit alarm responses. This insect behavior is in conformity with Gunawardena and Baundumathie (1993) who reported that the defensive secretions of both adults males and females of *L. oratorius* contain chemical components such as (E) – 2 – octenal and n-octyl acetate and this mechanism acts as repellent to enemies of *L. oratorius* and elicits alarm responses.

5.3.2 Nature of damage

Both the nymphs and adults of *L. oratorius* feed on the grains soon after the emergence of earheads and continued feeding till the grains get hardened. Sap sucking resulted in partial or full chaffyness. Small yellowish brown spot developed initially at the site of feeding and later enlarged to form yellowish brown elliptical spot with grayish center. Under severe infestation causes deformed and spotty grains and later these grains become discolored which is in agreement with Uichanco (1921), Li (1985) and Jahn *et al.* (2004).

5.3.3 Ecology of the pest

The occurrence of higher population rice earhead bugs in *kharif* season than in *rabi* season may probably by the reason of favourable weather conditions like high relative humidity and rainfall and very less fluctuation in diurnal temperatures during crop growth and especially in milky grain stage.

During present study, temperature ranged from 19.0 to 29.3⁰ C and RH of 68.0 to 88.0 per cent favoured the rapid development of rice earhead bug and intermittent rain of 77.6 mm, warm weather found to favour the pest life cycle. The present finding is in conformity with studies of Israel and Rao (1961), Sen (1955), Banerjee and Chatterjee (1965), Rao *et al.* (1978) and Gupta *et al.* (1993).

5.4 Evaluation of plant extracts, entomopathogenic fungi and new molecules of insecticides on rice earhead bug population

Rice earhead bugs inflict considerable damage to rice at milky stage. In order to combat this insect, many insecticides were tried since its appearance in rice. Comparative effect of six plant extracts, two entomopathogenic fungi, and six new molecules of insecticides *viz.*, azadirachtin @ 3 ml/l, *Acorus calamus* aqueous rhizome extract @ 10%, aqueous extract of *Strychnos nux vomica* leaf @ 10%, *Vitex negundo* aqueous leaf extract @ 10%, *Adathoda vasica* aqueous leaf extract @ 10%, *Randia spinosa* aqueous fruit extract @ 5%, *Metarhizium anisopliae* @ 2 gm/l, *Beauveria bassiana* @ 2 gm/l, malathion D @ 20 kg/ha, indoxacarb 14.8 SL @ 0.5 ml/l, dimethoate 30 EC @ 1.75 ml/l, emamectin benzoate 5 SG @ 0.2 g/l, imidacloprid 17.8 SL @ 0.25 ml/l and thiomethoxam 25 WG @ 0.3 g/l was assessed against *L. oratorius* and the results are discussed below.

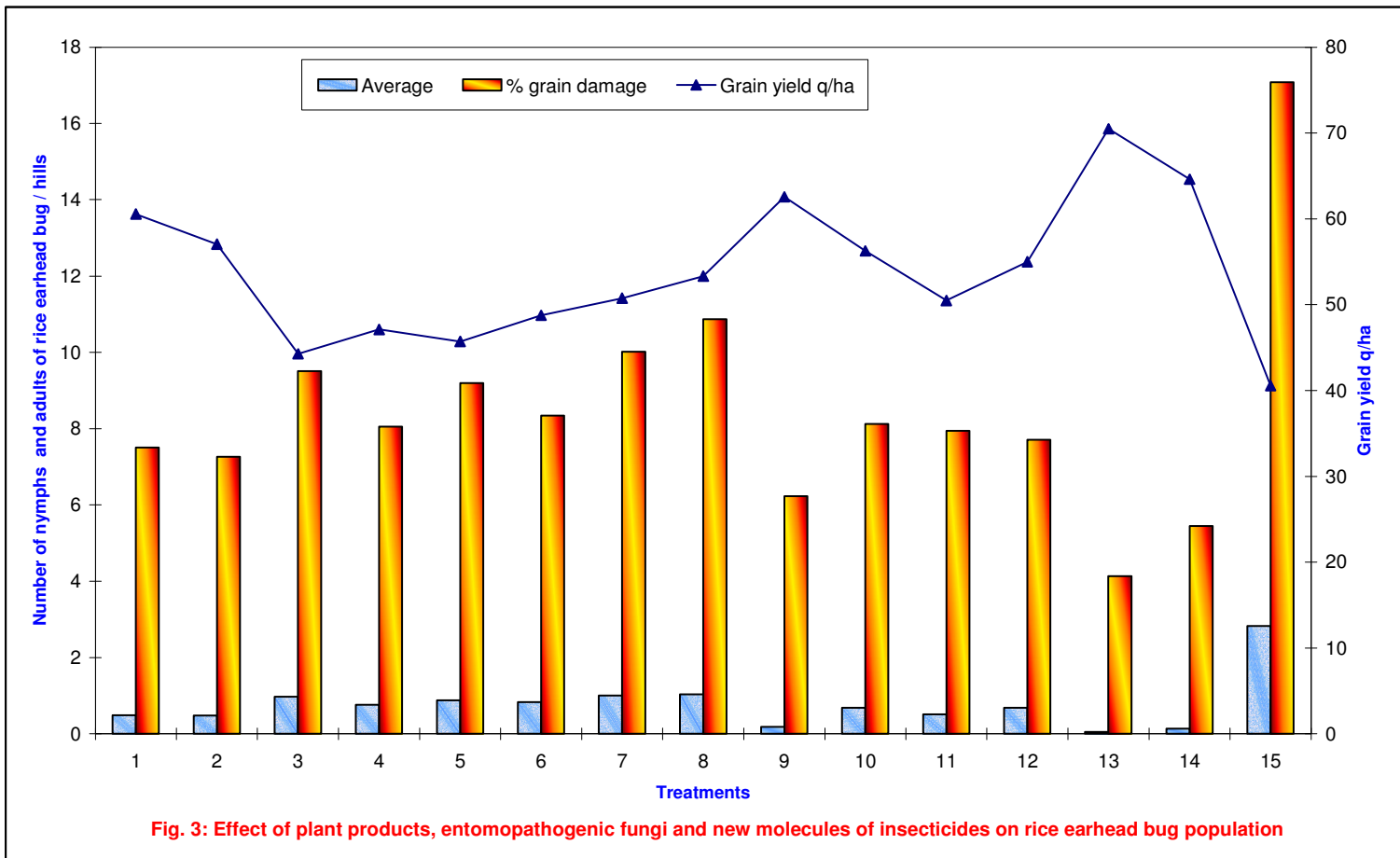


Fig. 3: Effect of plant products, entomopathogenic fungi and new molecules of insecticides on rice earhead bug population

Field experiment was conducted to evaluate the effect of spray and dust formulation of insecticides against *Leptocorisa* spp in *kharif* season 2010 showed that synthetic insecticides are superior to plant product and fungal pathogens. Imidacloprid has emerged as promising insecticide and recorded lowest bug population (0.05/hill), followed by thiomethoxam (0.14/hill) and malathion (0.18/hill) which are at par with each. Deore (2002) reported that chlorpyrifos as effective against *Leptocorisa* sp. recorded least infestation (1.87%) and on par with imidacloprid (2.33%), acetamiprid (2.51%), profenophos (2.76%) and nukil (2.96%) which support the present findings. The present finding is in conformity with Rai and Vidyachandra (1980) who reported 93.26 per cent reduction of population by the application of malathion (0.1 %) and Pangtey (1990) who reported malathion dust applied at 1 kg a.i/ha was the most effective insecticide in reducing the per cent bug population.

Among the plant products evaluated against rice earhead bug, azadirachtin (0.33/hill) and *Acorus calamus* aqueous rhizome extract (0.48/hill) which are at par with each other and emerged as promising in controlling rice earhead bugs effectively (Fig. 3). The present finding is in conformity with Ponnusamy (2003) who reported (24.2%) reduction in bug population by application of neem based insecticide (Azadirachtin 0.03%) @ 500 ml/ha twice once at flowering stage and second at 15 days later. Singh *et al.*, (2009) reported that three days after spraying neem product multiplex controlled 80.8 per cent support the present findings. Nelson *et al.* (2002) reported among the plant product, *Acorus calamus* 10 D recorded the lowest bug population (3.56/ m²), followed by *Nicotiana tabacum* 50 D (4.56 /m²) and *Ocimum basilicum* 50 D (4.67 /m²) support the present findings. Among other insecticides evaluated dimethoate, indoxacarb, emamectin benzoate, *Vitex negundo*, *Randia spinosa*, *Adthoda vasica*, *Strychnos nux vomica*, *Metarhizium anisoplia* and *Beauveria bassiana*, treatments recorded of 0.48, 0.51, 0.68, 0.68, 0.76, 0.83, 0.88, 0.97, 1.01, 1.04 bugs per hill, respectively in the trial. There is lack of literature on management of rice earhead bug using these botanicals and chemicals. However, Durairaj and Venugopal (1993) who reported (50.7%) reduction in bug population by application of *Vitex negundo* leaf extract. Nguyen *et al.* (2005) reported the mortality percentage of *L. acuta* caused by *B. bassiana* and *M. anisopliae* isolates ranged from 57.5 to 77.7 per cent and from 74.7 to 87 per cent at 10 DAT respectively supports the present findings. The present study on effect of *Metarhizium anisoplia* and *Beauveria bassiana* revealed the inefficacy against rice earhead bug may be influenced by weather factors.

5.4.1 Per cent grain damage caused by earhead bug during *kharif* 2010

The per cent grain damage was observed in the year 2010 in all treatments and control. During *kharif* season per cent damage caused by earhead bug varied from 4.14 to 10.87 per cent in different treatments and (17.08 %) in control. All the treatments showed significant difference over control for the per cent grain damage. Whereas the per cent grain damage was lowest in imidacloprid treatment (4.14%), which showed significant difference with thiomethoxam, (5.45%) and malathion, (6.23%). The effectiveness of these treatments might due to neonicotinoids and organophosphate insecticides as it increased the efficacy against the rice earhead bug. The present finding is in conformity with Pruthi (1953), estimated that the loss from 10 to 40 per cent and reported that in 1952, the bug infested seven to eight million acres of rice in Uttar Pradesh, Bihar, Madhya Pradesh and Orissa. Singh (2009) reported the per cent grain damage ranged from (9.3 to 12.3 %) supports the present findings.

5.4.2 Grain yield

Among the various treatments evaluated for management of rice earhead bug, imidacloprid 17.8 SL @ 0.25 ml/l found to be very effective in reducing bug population by increasing grain yield (7049.26 kg/ha). Imidacloprid was found at par with thiomethoxam 25 WG @ 0.3 g/l recording (6461.11 kg/ha) and malathion D @ 20 kg/ha (6253.33 kg/ha). This was followed by azadirachtin @ 3 ml/l (6057.78 kg/ha) and *Acorus calamus* aqueous rhizome extract @ 10 %, (5705.19 kg/ha), indoxacarb 14.8 SL @ 0.5 ml/l (5625.56 kg/ha), emamectin benzoate 5 SG @ 0.2 g/l (5501.48 kg/ha), *Beauveria bassiana* @ 2 gm/l (5335.19 kg/ha), *Metarhizium anisopliae* @ 2 gm/l (5076.30 kg/ha), dimethoate 30 EC @ 1.75 ml/l (5049.63 kg/ha), *Randia spinosa* aqueous fruit extract @ 5 % (4875.93 kg/ha), *Vitex negundo* aqueous leaf extract @ 10% (4709.26 kg/ha), *Adthoda vasica* aqueous leaf extract @ 10 % (4573.33 kg/ha), *Strychnos nux vomica* aqueous leaf extract @ 10 (4426.67 kg/ha), respectively.

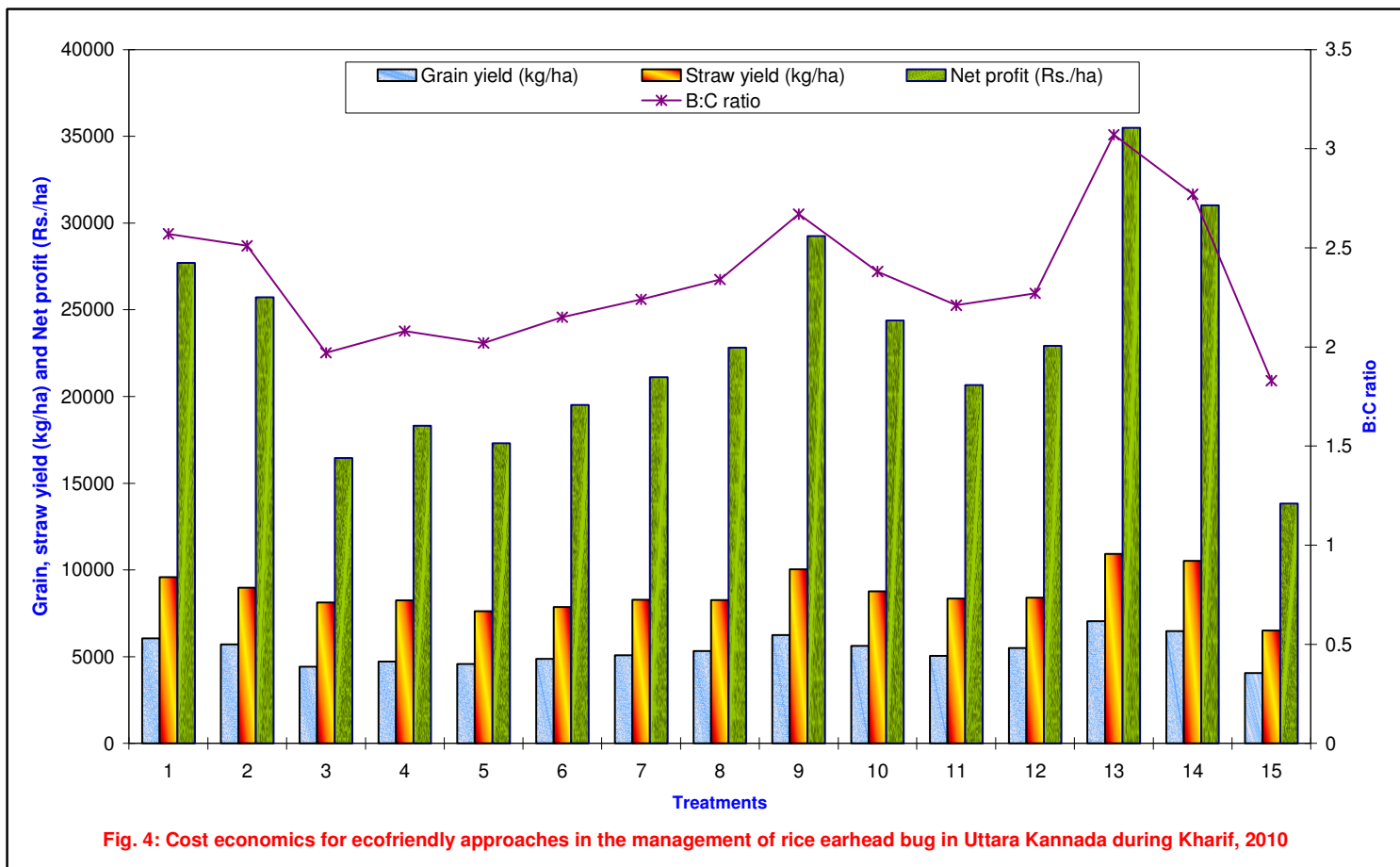


Fig. 4: Cost economics for ecofriendly approaches in the management of rice earhead bug in Uttara Kannada during Kharif, 2010

5.4.3 Cost economics

Highest net returns were obtained in imidacloprid 17.8 SL 2 0.25 ml/l treated plot (35489.93 Rs/ha) followed by thiomethoxam 25 WG @ 50 0.3 g/l (30905.11 Rs /ha) and Malathion D @ 20 kg/ha (29241.00 Rs /ha). Highest benefit cost ratio were obtained in imidacloprid 17.8 SL @ 0.25 ml/l (1: 3.07 Rs/ha) followed by thiomethoxam 25 WG @ 0.3 g/l (1:2.77 Rs/ha) and Malathion D @ 20 kg/ha (1: 2.67 Rs/ha) (Fig. 4). Among the botanicals evaluated azadirachtin @ 3 ml/l was very effective and cheaper for management of rice earhead bug. Whereas, *Acorus calamus* rhizome extract @ 10 %, was the next best to azadirachtin for management of rice earhead bug. However, azadirachtin, *Acorus calamus* rhizome extract was found most promising botanical in suppressing rice earhead bug as that of chemical toxicants. Hence, a detail study with different concentrations has to be carried out.

Hence, among synthetic insecticides imidacloprid, thiomethoxam and malathion can be alternatively used for rice earhead bug management. Where organic rice production is needed, environment friendly tools like azadirachtin and *Acorus calamus* can be used.

6. SUMMARY AND CONCLUSION

Investigations were undertaken to elicit the information on species complex, seasonal incidence, natural enemies, bio-ecology and management of paddy earhead bug *Leptocorisa oratorius* at Agriculture Research Station (Paddy), Sirsi in Uttara Kannada District during *Kharif* season 2010 and in *rabi* 2011. The results of the investigations are summarized below.

The roving survey comprising three rice ecosystems including coastal and 'upghat' transplanted paddy and paddy drill sown of Uttara Kannada district was carried out during *kharif*, 2010 and *rabi*, 2011. The genus *Leptocorisa* comprised *oratorius* species as a dominant one in almost all places wherever the infestation of rice earhead bug was noticed on paddy. The incidence of *L. oratorius* (nymphs and adults) ranged from 1.93 to 2.03, 1.73 to 2.40, 2.73 to 3.31, 2.03 to 2.36 and 2.16 to 4.36 bugs/hill in Sirsi, Siddapura, Honnavara, Kumta and Mundgod taluk, respectively in *kharif* season. Whereas in *rabi* season the incidence of *L. oratorius* (nymphs and adults) ranged from 1.30 to 1.55, 1.16 to 1.70, 1.70 to 1.93, 0.96 to 1.23 and 1.76 to 2.60 bugs/hill in Sirsi, Siddapura, Honnavara, Kumta and Mundgod taluk, respectively. But *L. lepida* was recorded 0.30 /hill in Sirsi taluk.

The results of the survey revealed that maximum incidence of the bugs were noticed in Mundgod (3.04/hill) taluk in *kharif* season followed by Honnavara (2.97/hill), Kumta (2.15/hill), and Siddapura (2.04/hill) taluk and with of 1.97/hill least incidence in Sirsi taluk, respectively. During *rabi* season shows that maximum incidence of the bugs was noticed in Mundgod (2.04/hill) followed by Honnavara (1.97/hill), Siddapura (1.43/hill), Sirsi (1.41/hill) and least incidence in Kumta (1.08/hill) taluk, respectively. It revealed that maximum incidence of rice earhead bug was found in *kharif* than in *rabi* season.

The mean population of predators recorded was almost similar in reproductive phase of the crop in both the seasons. The highest population of predators recorded was Spiders (0.49/hill) followed by Odonata (0.29/hill), Coleoptera (0.22/hill), Hemiptera (0.14/hill) and Diptera (0.15/hill) in *kharif* season, respectively. Whereas in *rabi* season similarly Spider population was more (0.46/hill) followed by Odonata, Coleoptera, Hemiptera and Diptera population 0.25, 0.25, 0.16 and 0.07 per hill, respectively.

In Uttara Kannada district nearly 7 alternate host plants were identified for rice earhead bug. Rice earhead bugs were found to feed on these alternate hosts and also the laid egg mass on weeds and grass. These weed grasses were found adjacent to the paddy fields and in main fields, viz., *Echinoloa crusagalli*, *Echinocloa colona*, *Eleusina indica*, *Cyperes rotundus*, *Cyperes iria* and *Brachiria mutica*, respectively.

Eggs of *L. oratorius* had an incubation period of 6.7 ± 1.1 days under laboratory condition. The nymphs were observed to undergo five instars and the total nymphal period was an average of 19.80 ± 4.57 days after moulting five times. The total developmental period of *Leptocorisa oratorius* took an average of 26.5 ± 5.67 days to complete life cycle from egg to adult under laboratory condition.

The mating period of rice earhead bug was 2.83 ± 1.34 days. Pre oviposition period was 5.00 ± 1.29 days with the fecundity of 108.0 ± 42.0 eggs in laboratory condition with an ovipositional period of 11.0 ± 5.44 days, the longevity of adult male and female was 29.66 ± 5.761 and 55.83 ± 14.75 , respectively.

Warm weather, over cast sky and frequent drizzle favor the buildup of *L. oratorius* in the field during flowering season. The peak period of activity of rice earhead bugs was observed in cooler hours of the day viz., in early morning hours and late evening hours in the field and took shelter under shady portions of the plants during hot period of the day. Both the nymphs and adults of *L. oratorius* started feeding on the grains soon after emergence of earheads and continued to feed on them till the grain gets hardened. The sucking of milky juice from the developing grains resulted in yellowish brown spot developed initially and enlarged later to form yellowish brown elliptical spot with grayish centre resulted in partial or full chaffyness of grains.

Among six plant extracts, two entomopathogenic fungi and six new molecules of insecticides evaluated against *L. oratorius*, the field data show that all chemicals could bring down the population of rice earhead bug in comparison to untreated control plots where there was a minor increase of population. Insecticides, imidacloprid 17.8 SL @ 0.25 ml/l, thiomethoxam 25 WG @ 0.3 g/l and malathion D @ 20 kg/ha recorded lowest bug population 0.05, 0.14, 0.18 bugs/hill and also highest yield of 7049.26, 6461.11 and 6253.33 kg/ha, respectively. Among the plant products tested azadirachtin @ 3 ml/l and *Acorus calamus* augeous rhizome extract @ 10% recorded 0.33, 0.48 bugs/hill and also moderate yield of 6057.78 and 5705.19 kg/ha, respectively.

In view of limitation of use persistent synthetic insecticides for the management of rice earhead bug, safer and environment friendly insecticides from plant origin gain upper hand. Present study has come out with such two promising botanical pesticides viz., *Azadirachtin indica* and *Acorus calamus* against rice earhead bug.

Conclusion

Based on the findings of the present study, the following strategies are suggested to improve the management of rice earhead bug:

- ❖ Weed the rice and adjacent non-rice areas to keep the populations of flower bearing weeds low.
- ❖ Apply insecticides if the paddy bugs populations exceed economic threshold level (1 to 2 bugs per hill) before the flowering stage of rice.
- ❖ Since paddy bug is a migratory, pest management methods should be undertaken at community level.
- ❖ Management practices should be oriented towards the conservation of predators. Since many potential natural enemies are active in Uttara Kannada rice ecosystem.
- ❖ Develop an awareness programme to farmers to improve their present knowledge and paddy bug management methods.

The data derived from present study, strongly indicate that the role played by the use of botanicals and some new group of insecticides is extremely important and our future study on the control of rice earhead bug should be focused on the integration of both botanical and new group of chemical control through the judicious use of fertilizer.

Salient findings of investigation

- ❖ The species *Leptocorisa oratorius* Fabricius found to be dominant species in Uttara Kannada district during survey.
- ❖ Rice earhead bug has been found major pest of 'Upghat' drill sown, 'Upghat' transplanted and Coastal transplanted paddy in Uttara Kannada district during survey.
- ❖ Tiger beetles and pentatomid bugs found major predators in rice ecosystem among many potential predators.
- ❖ Rice earhead bug has been documented on many alternate host plants, but rice seems to be the preferred host.
- ❖ Most important findings in this study are identification of two new botanical insecticides (*Azadirachtin indica* and *Acorus calamus*) for safe management of rice earhead bug.
- ❖ Imidacloprid, thiomethoxam and malathion were found most promising insecticides in suppressing the rice earhead bug and also recorded highest grain yield and BC ratio.

Future line of work

1. There is a need to develop weather based fore warning models for the pest.
2. To study the key mortality factors i.e., parasites, predators and entomopathogens against earhead bug and use them in biological suppression of the pest.
3. Persistence and residual studies of imidacloprid need to be studied after harvest of the crop.

REFERENCES

- *Ahmad, I., 1965, The *Leptocorisinae* (Heteroptera: Alydidae) of the world. *Bull. (Entom.) British Mus. (Natural Hist.)* Suppl. No. 5 145 P.
- Akbar, S. S., 1958, The morphology and life history of *Leptocorisa varicornis* Fabr. a pest of paddy crop in India. *Publ. Aligarh Univ. (Zool. Ser.) India. Ins. Typ*, 5: 1-50.
- Alam, M. Z., 1965, Insect pests of rice in East Pakistan and their control. *Agric. Int. Ser.*, Bangladesh.
- Anand Prakash and Jagadishwari Rao., 1999, Age specific fecundity, life tables and intrinsic rate of natural increase of rice earhead bug, *Leptocorisa acuta* Thunb. *J. Exptl. Zool., India.*, 2: 153-155.
- Anand Prakash and Prakash, A., 1999, Sterility caused by feeding of different stages of rice earhead bug, *Leptocorisa acuta* Thunberg in rice. *J. Appl. Zool. Res.*, 10: 89-93.
- *Anonymous, 1964, Entomology Division. Rep. Res. Brech. Dep. *Agric. Sarawek*, pp. 79-89.
- *Anonymous, 1965, Effectivity of three chemicals For Rice bug control. *A. Rep. Irri.*, p. 262.
- *Anonymous, 1996, Distribution maps of plant pests, Map 567. *Commonw. Inst. Ent. London.*
- Anonymous, 2009, Centre for Monitoring Indian Economy Report. pp. 54-58.
- *Anonymous, 2010, National agricultural policy, Directorate of economics and statistics, Department of agriculture and cooperation.
- Argente, A. M. and Heinrichs, E. A., 1983, Residues of carbaryl, lindane and monocrotophos on rice treated for control of rice bug, *Leptocorisa oratorius* (Fab). *Crop Prot.*, 2 (3): 361-369.
- Atkinson, H. T., 1889, Notes on Indian insect pests. *Indian Mus. Notes*, 1: 1-4.
- *Austin, G. D., 1922, A Preliminary Report On Paddy Fly Investigation. *Bull. Cevlon Dep. Agric.*, 59: 22.
- Anand Prakash., Jagadishwari Rao, Prakash, A. and Rao, J., 2002, Heteropterans and *Fusarium moniliformae* Synder and Hansen interactions to deteriorate grain quality in rice. *Seed Res.*, 30 (2): 339-341.
- Banerjee, S. N., 1961, Incidence of the rice gunghi bug and its control in North Bengal in 1958. *Proc. Rice Res. Work. Conf.*, Cuttack, pp. 295-97.
- Banerjee, S. N. and Chatterjee, P. B., 1965, On the alternate host plants and hibernation of rice bug, *Leptocorisa acuta* Thunberg in North Bengal. *Sci. Cult.*, 31: 259-260.
- Barrion, A. T. and Litsinger, J. A., 1981, *Leptocorisa acuta* Vs *oratorius* : A clarification of rice bug species. *Int. Rice Res. Newsl.*, 14 (1): 13-20.
- Banerjee, P. H and Chatterjee, P. B., 1982, Pests of hill rice west Bengal (India), *Int. Rice Res. News.*, 7(4): 11.
- Berg, H. V. and Soehardi, 2000, The influence of the rice bug, *Leptocorisa oratorius* on the yield. *J. Appl. Ecology.*, 37: 959-970.
- Biswas, P. K., 1953, The rice bug. Damage, life history and control. *Allahabad Fmr.*, 27 (1): 25-27.
- Butani, D. K. and Jotwani, M. G., 1976, Crop Pest and Their Control-2: *Rice Pesticides*, 10 (3): 29-35.
- Chakraborty, M. R. and Chatterjee, N. C., 2002, Epidemiological studies in relation to the incidence of diseases and pests of Burdwan, West Bengal. *Pl. Archives.*, 2 (2): 317 – 321.
- Chander, S., 1996, Intrinsic rate of natural increase of gundhi bug, *Leptocorisa varicornis* on alternate host plant, *Echinochloa colona* *J. Ent. Res.*, 20 (3): 281-283.

- Chatterjee, S. H., Kulasherestha, J. P. and Raamani, S., 1977, Recent advance in the management of rice insects in India. *Ind. Far. Dig.*, 10 (7): 9-12.
- Chhabra, K. S. and Jaswant Singh., 1979, Rice Pests situation in Punjab during 1975. *Indian J. Pl. Prot.*, 7 (1): 73-76.
- China, W. E., 1924, A preliminary revision of the Oriental species of *Leptocorisa* spp (Hemp: Coreidae). *Bull. Ento. Res.*, 14 (3): 235-39.
- Cobblah, M. A., Hollander, J. and Denhollander, J., 1992, Specific differences in immature stages, oviposition sites and hatching patterns in two rice pests, *Leptocorisa oratorius* (Fabricius) and *L. acuta* (Thunberg) (Heteroptera: Alydidae). *Insect Sci. Appl.*, 13: 1-6
- Corbett, G. H., 1923a, Food Plants of *Leptocorisa* Spp ("Padifly, "Rice Saper", Pisaggang"). *Malay. Agric. J.*, 11: 213-215.
- Corbett, G. H., 1930, Food plants of *Leptocorisa* spp (Paddyfly, Rice sapper, Piaggang). *Malayan Agric. J.*, 11 (7-9): 213-215.
- Custodio, H. A., 1969, Chemical control of Insect pests and diseases of rice in the Philippines. *Jao.Pestic. Inf.*, 17 (10): 39-59.
- Das, S. K., 1961, Epidemics of rice bug in northern plains of India during the last decade. *Ind. Pl. Prot. Bull.*, 13: 25-27.
- Deore, N. R., 2002, Biology and chemical control of rice earhead bug *Leptocorisa acuta* Thurnberg (Coridae: Hemiptera) on rice. *M. Sc. (Agri.) Thesis*, submitted to GAU, Nvasari.
- Dhingra, M. R., Dingh, S. B. and Bhagat, 2003, Field Efficacy of some Insecticide against *Leptocorisa vericornis* in rice. *J. Soils and Crops*, 13 (1): 29-32.
- Distant, W. L., 1902, *Leptocorisa*, Fauna of Br. India (Rhynch: Heteroptera), Tylor and Francis, London, 1: 409-411.
- Domingo, I. T., Heinrichs, E. A. and Medrano, F. G., 1982, Life history of rice bug, *Leptocorisa oratorius* (F.). *Int. Rice Res. Newsl.*, 7 (6): 17-18.
- Durairaj, C. and Venugopal, M. S., 1993, Effects of neem and nochil on rice bug, *Leptocorisa acuta*. *Int. Rice Res. Notes.*, 18 (3): 34.
- *Estoy, G. F., 1996, Dispersal ecology of rice bug *Leptocorisa oratorius* F. (Hemiptera: Alydidae) in Nueva Ecija (Philippines). College Laguna (Philippines) 81 leaves.
- Fernando, H. K., Weerawasdana, G. V. and Manickavasagar, P., 1954, Paddy pest control in Ceylon. *Trop. Agric.*, 110: 159-174.
- Fernando, H. K., Elikewela, Y. and Manickavasagar, P., 1957, Resistance to benzene hexachloride of the rice bug, *Leptocorisa Varicornis* F. (Fam:coreidae. Ord: Hemiptera) and its insecticidal control. *Trop. Agric.*, 113: 229-240.
- * Fletcher, T. B., 1913-14, Rice Bug, *Madras agric.Cal.P.*21.
- Garg, A. K. and Sethi, G. R., 1980, Succession of insect pests in *Kharif* paddy. *Indian J. Ent.*, 42: 482-487.
- Grist, D. H. and Lever R. J., 1969, Pests of Rice, London : Longmans, Green.
- Gupta, S. P., Prakash, A. and Rao, J., 1990, Bio-pesticidal activity of certain plant products against rice earhead bug, *Leptocorisa acuta* Thunb. *J. Appl. Zool. Res.*, 1 (2): 55-58.
- Gupta, S. P., Ananda Prakash, Jagadishwari Rao and Amita Gupta, 1993, Qualitative losses of paddy grain due to bugs in the farmers' fields of costal Orissa. *Indian J. Ent.*, 55 (3): 29-236.

- Gunawardane, N. E. and Bandumathie, M. K., 1993, Defensive secretion of rice bug, *Leptocorisa oratorius* Fabricius (Hemiptera: Coreidae): A unique chemical combination and its toxic, repellent, and alarm properties. *J. Chem. Ecology* (USA). 19 (4): 851-861.
- Heinrichs, E. A., Valencia, S. L. and Basilio, R. P., 1982, Insectary evaluation of insecticides to control rice stink bugs. *Int. rice res. Newsl.*, 7 (2): 12.
- Hinton, H. E., 1981, Biology of insect eggs. Pergamon Press. Oxford. 1125 p.
- Hutson, J. C., 1920, the paddy bug (*Leptocorisa varicornis* F.). *Trop. Agric.*, 54: 363-36.
- Hutson, J. C., 1930, Some notes on the paddy fly in Ceylon, *Trop. Agric.*, 75: 341-346.
- Israel, P. and Rao, Y.S., 1954, Rice bugs. *Rice. News letter*, 2 (3-4): 139-143.
- Israel, P. and Rao, Y. S., 1961, The Incidence of gundhi bug and steps for its control. Proc. Rice Conf., Cuttack, pp. 297-99.
- Israel, P., Rao, Y.S. and Saxena, H. P., 1969, Studies on parasites and predators of rice pests. *A. Rep. Cent. Rice res. Institute* (Cuttack), (1965), pp 122-23.
- Israel, P., Veda Moorthy, G. and Seshagiri Rao, Y., 1961b, Distribution economic status of rice pests in India. *Rice News letter.*, 9 (2): 23-26.
- Jahn, G. C., Domingo, I., Almazan, M. L. P. and Pacia, J., 2004, Effect of rice bug on rice yield, grain quality and seed viability. *J. Economic Ent.*, 97 (6): 1923-1927.
- Jena, M., Dani, R. C. and Rajamani, S., 1990, Effectiveness of insecticides against rice gundhi bug, *Oryza*. 27: 96-98.
- Jeyarajan, N. S., Murugesanj, N., Sathyanandam, V., Johnson, T. D. and Muthusamy, M, 2003, New botanical insecticide for managing rice bug. *Internat. Rice Res. Notes*, 28 (1): 44.
- Kalode, M. B. and Pasalu I. C., 1986, Pest management in rice. *Indian Farming*, 9: 31-34.
- *Kikuchi, A., Kanno, H., Kimura, T., Goto, J., Ono, T., Niiyamma, T., Takita, M., Matsuki, N., Ohba, A. and Horisue, N., 2004, A survey on the occurrence of rice earhead bugs and their damage in the Tohoku region from 1999 to 2004. *Bull. Natn. Agric. Res. Center for Tohoku Regions.*, 102: 101-180.
- Krishnakumar, R. and Visalakshi, A., 1989, Relative toxicity of insecticides to rice bug, *Leptocorisa acuta* Thunberg. *Entomon*. 14: 365-366.
- Krishnakumar, R. and Visalakshi, A., 1996, Field evaluation of insecticides on the control of rice bug (*Leptocorisa acuta* Thunberg) in epidemic out breaks. *J. Trop. Agric.*, 33: 137-140.
- Krishnamurthy, P., Venkatachalam, S. and Symprakasam, S., 1977, A note on the chemical control of earhead bug, *Leptocorisa acuta* (Thumb). Coreidae : Hemiptera on paddy. *Pesticides*, 11 (1): 38-39.
- Kulagod, S. D., 2009, Status of paddy pests under rainfed ecosystem in Uttara Kannada district of Karnataka. *M. Sc. (Agri) Thesis*, Uni. Agric.Sc i., Dharwad.
- *Lee, S. C., Alvenda, M. E., Bonman, J. M. and Heinrichs, E. A., 1986, Insects and pathogens associated with rice grain discolouration and their relationship in the Philippines. *Korean J. Pl. Prot.*, 25 (2): 107-112.
- Lefroy, H. M., 1908, The rice bug, *Leptocorisa varicornis*. Fabr. Mem. Dep. Agric. India. *Ent. Ser.*, 2 (5): 1-13.
- Li. C. S., 1985, Biological and ecological studies of the rice bug. *Leptocorisa oratorius* (F.) (Hemiptera : Alydidae) and its control in Papua New Guinea. *Mushi*, 50 (1): 1-2.

- Litsinger, J. A., Gyawali, K. and Wilde, G. E., 1998, Feeding behaviour of the rice bug *Leptocorisa oratorius* (Fabricius) (Hemiptera: Alydidae). *J. Pl. Prot. Trop.*, 11: 23-25.
- Mathur, K. C., Reddy, P. R., Rajamali, S. and Moorthy, B. T. S., 1999, Integrated pest management of rice to improve productivity and sustainability. *Oryza*, 36 (3): 195-207.
- Mayabini, J., Dani, and Rajamani., 1990, Effectiveness of insecticides against rice gundhi bug. *Oryza*. 27: 96-98.
- Misra, S. S., 1968, Bionomics of the rice gundhi bug *Leptocorisa varicornis* Fabr. (Hemiptera: Coreidae). *Allahabad Fmr.*, 42: 75-77.
- Misra, H. P., 1999, Control of gundhi bug in upland rice. *Indian J. Ent.*, 61 (2): 169-172.
- Misra, H. P., 2003, Evaluation of new insecticides against rice gundhi bug. *Indian J. Pl. Prot.*, 31 (2): 107-108.
- Mishra Neeta., Sharma, L. P. and Choubey Geeta., 2010, Prevalence of insect pests on rice in north eastern Madhya Pradesh. *Oryza*. 47 (1): 66-68.
- Molegode, W., 1922, Paddy cultivation in Yatinuwara. *Trop. Agric.*, 59: 211-215.
- Morill, W. L., Penelee, N. and Almazon, L. P., 1990, Effects of weeds on fecundity and survival of *Leptocorisa oratorius* (Hemiptera: Alydidae). *Environmental Ent.*, 19: 1469-1472.
- Nugaliyadde, L., Edirisinghe, J. P. and Hidaka, T., 1994, Role of weed hosts on the survival of paddy bug, *Leptocorisa oratorius* (Hemiptera: Alydidae). *JIRCAS journal*, 3: 1-14.
- Narayanan, E. B., 1953, Seasonal pests of crops: Some major insect pests of rice and their control. *Indian. Fmg.*, 3 (5): 8-13.
- Nayak, 1984, Studies on bioecology and chemical control rice earhead bug *Leptocorisa oratoria* and loss due to its damage. *Ph. D. Thesis*, Uni. Agric. Sci., Dharwad, p.155.
- Nguyen, T. C. and Thi, B. C, 2005, Efficacy of some new isolates of *Metarhizium anisopliae* and *Beauveria bassiana* against rice earhead bug, *Leptocorisa acuta*. *Omonrice*. 13: 69-75.
- *Nudrin, F. and Artati, F., 2000, Insect pests of upland rice in west Sumatra (Indonesia): Its Problem and control Technology, pp. 488-492.
- Oerke, E. C., Dehne, H. W., Schonbeck, F. and Weber, A. (eds.) 1994, Crop Production and Crop Protection: Estimated losses in major food and cash crops. Elsevier, Amsterdam, 808p.
- Pangtey, V. S., 1990, A note on the efficacy of selected insecticides against gundhi bug, *Leptocorisa acuta* (Thunberg). *Indian J. Ent.*, 52: 715-717.
- Pathak, P. K., Verma. S. K., Lal, M. N. and Koshiya, D. J., 1978, Protect your paddy crop from insect enemies. *Indian Fmr. Dig.*, 11 (55): 33-38.
- Prakash, A. and Rao, J., 1994, Bio-deterioration of paddy seed quality due to insects and mites and its control using botanicals. Annual Report of ICAR Ad-hoc Scheme (1993-1994), C.R.R.I., Cuttack, India, 37 PP.
- Ponnusamy, P., 2003, Farmers participatory assessment of neem based insecticide in controlling the ear head bug (*Leptocorisa acuta*) in rice. *Madras Agric. J.*, 90 (7-9): 564-566.
- Pruthi, H. S., 1953, An epidemic of rice bug in India. *FAO Pl. Prot. Bull.*, 1: 6.
- Pruthi, H. S., 1969, Pest of paddy. In. Text book on agricultural Entomology. *Job Pr. Pvt. Ltd.*, Kanpur. 977 P

- Puttarudriah, K., 1955, "Battakka Beeluva Keetagalu Mattu Avugala Hatoti"-Battada Tigane. *Sasye Samrakshane Pustaka Male-1*. Govt. Mysore, 9 pp.
- Rai, P. S., 1981, Life cycle of rice earhead bug *Leptocorisa acuta* (Thunberg) (Coreidae: Hemiptera) *J. Maharashtra Agric. Univ.*, 6 : 252-253.
- Rai, P. S. and Vidyachandra, B., 1980, Rice earhead bug in coastal Karnataka can be controlled by malathion spraying. *Curr. Res.*, 9: 22.
- Rai, A. B., Singh, H. J. and Rai, L., 1990, Rice bug (*Leptocorisa varicornis* Fabr.) appearance to light trap in eastern Uttar Pradesh, India. *Oryza*. 27: 66-72.
- Rajapakse, R. H. S. and Kulasekera, V. L., 1980, Survival of rice bug, *Leptocorisa Oratorius* (F) on Gramineaceous weeds during the fallow period between rice cropping in Sri Lanka. *Int. Rice Res. Newsl.*, 5(5): 18-19.
- Rajendra Prasad, B. S., 2010, Status of paddy insect pests and their natural enemies in rainfed ecosystem of Uttara Kannada district and management of rice leaf folder. *M. Sc. (Agri) Thesis, Uni. Agric. Sci., Dharwad (India)*. pp,134
- Rao, P. S. P., Padhi, G. and Natarajan, K., 1978, Studies on prevalence and abundance of insects in light trap and weather factors. A. Rep. Cent. Rice. Res. Inst. Cuttack., p. 41.
- Rothschild, G. H. L., 1970, Some notes on the effects of rice earhead bugs on grain yields. *Trop. Agriculturists.*, 47 (2): 145-149.
- *Saha, S., Dutta, A. and Mallik, G. K., 2005, Pest incidence in *kharif* rice in Maidanpur (West): a glance. *J. Interacademica.*, 9 (2): 296-297.
- Samui, R. P., Chattopadhyay, N., Sabale, J. P. and Balchandran, P.V., 2004, Weather based forecasting models for major pests of rice in Pattambi region in Kerala. *J. Agrometeorology.*, 6 :105-114.
- Sands, D. P. A., 1977, The biology and ecology of *Leptocorisa* (Hemiptera : Alydidae) In Papua New Guinea. *Res. Bull. Dep. Prim. Ind. Papua, New Guinea*, 18: 104.
- Saxena, H. P., 1952, Observation on a predator of the gundhy bug (*L. varicornis* Fab.) *Indian J. Ent.*, p. 22.
- Sen, A. C., 1955, Basic factors for forecasting epidemic outbreaks of the rice bug (*Leptocorisa varicornis* F.). *Indian J. Ent.*, 17: 127-128.
- Sen, A. C. and Chaudhuri, D. P., 1959, Incidence of rice gundhy bug and steps for its control. *Indian J. Ent.*, 21: 287-288.
- Shah, N. K., 1993, Alternate host plants of gundhy bug in bay islands. *Madras Agric. J.*, 80: 515- 516.
- Singh, J. and Sinha, M. M., 1978, Studies on the occurrence of different paddy pests under North Bihar conditions. *Sci. Cult.*, 44: 508-509.
- Singh, S. B., Mahendra Singh and Dingra, M. R., 2009, Effectiveness of insecticides against rice gundhy bug. *Ann. Pl. Protec. Sci.* 17 (2): 449-526.
- Sinha, B. K., 1961, Epidemic of gundhy bug of paddy in Bihar in 1958, *Indian Pl. Prot. Bull.*, 13 (1-4): 36-37.
- Sinu, P. A., Nasser, N. and Rajan, P. D., 2006, Feeding fauna and foraging habits of tiger beetles found in agro-ecosystems in Western Ghats, India. *Biotropica*. 38 (4): 500-507.
- Siwi, S. S. and van Doesburg, P. H. 1984, *Leptocorisa* Latreille in Indonesia (Heteroptera, Coreidae, Alydinae). *Zoologische Mededelingen*, 58: 117-129.
- Soon, L. G., 1969, Chemical control of rice insects and diseases in Malayasia. *Jap. Pestic, Inf.*, 17(10): 27-36
- *Soon, L. G., 1971, The rice bug (*Leptocorisa*) and its control in West Malaysia. *Minist. Agric. Lands. K. Lumpur.*, p. 9.

- Srivastava, A. S. and Sexena, H. P., 1960, Bionomics, distribution and control of important pests of paddy in Uttara Pradesh. *Res. Mem. Dep. Agric., Uttara Pradesh*, 1: 1-11.
- Srivastava, A. S. and Sexena, H. P., 1964, Taxonomy, distribution, habits, bionomics and control of rice bug, *Leptocoris varicornis* Fabricius with reference to allied species. *Labdev. J. Sci. Tech.*, 2: 122-130.
- Srivastava and Sexena, 1967, Rice bug, *Leptocoris varicornis* Fabricius and allied species. In: The major insect pests of the rice plant. John Hopkins pr., Baltimore, p. 729.
- Sugimoto, A. and Nugaliyadde, L., 1995, Relation between population density of the rice bug, *Leptocoris oratorius* (Fabricius) (Heteroptera : Alydidae) and damage of rice in grains. *JIRCAS-J.*, 2: 59-64.
- *Suwat Ruayaree., 1994, Study on seasonal occurrence of major rice insect pests on recommended rice varieties. *Thai. Agril. Res. J.* (Thailand), Warssan Wichakan Kaset, 12 (1): 4-15.
- *Takeuchi, H., Wantanabe, T. and Suzuki, Y., 2004, Species specific feeding marks on rice grain by *Leptocoris chinensis* dallas (Hemiptera: Alydidae), *Lagynotomus elongates* (Dallas) Hemiptera : Pentatomidae) and *Cletus punctiger* (Dallas) (Hemiptera : Coreidae). *Jap. J. Appl. Ent. Zool.*, 48 (1): 39-47.
- *Takeuchi, H., Wantanabe, T., Ishizaki, M., Oku, S. and Suzuki, Y., 2005, The relationship between development stages of rice spikelets and the incidence of the rice bugs. *Leptocoris chinensis*, *Lagynotomus elongatus* and *Stenotus rubrovittatus* in rice fields. *Jap. J. Appl. Ent. Zool.*, 40 (2): 351-357.
- Tateisi, I., 1939, Notes on *Leptocoris varicornis* Fabricius a pest of the rice plant in hukuoks. Prefecture. *Oyo- Kontyu*, 2 (2): 63-71.
- Taylor, L. D., Litsinger, J.A. and Cadapan, E.P., 1987, Plant host range of the rice bug (Philippines). *Int. Rice Res. Newsl.*, (Philippines). 12 (2): 36.
- Teotia, T. P. S. and Mishra, S. S., 1965, Chemical control of *Leptocoris varicornis* fabr. On paddy with some modern insecticides. *Rice news lettler.*, 13: 87-88.
- *Uichanco, L., 1921, The rice bug, *Leptocoris acuta* (Thunerg) in the Philippines. *Philip. Agric. Rev.*, 14: 87-125.
- Valencia, S. and Heinrichs, E. A., 1982, Mass rearing of rice stink bug. *Intl. Rice. Res. Newsl.*, 7(2): 12-13.
- *Van Der Goot, P., 1949, de walang sangit (*Leptocoris acuta*) als vijand van hetrijstage was in Indonesia. (The rice bug (*L. acuta*) as a pest of rice in Indonesia). *Meded. Alg. Proefst. Landb.*, 88 (1): 66.
- Van Den Berg, H. and Soehardi, 2000, The influence of the rice bug *Leptocoris oratorius* on rice yield. *J. Appl. Ecol.* 37: 959-970.
- Venkatesh Hosamani, Pradeep, S., Sridhara, S. and Kalleshwaraswamy, C. M., 2009, biological Studies on paddy earhead bug, *Leptocoris oratorius*, *Acad. J. Entomol.*, 2 (2): 52-55.
- Venkatachalam, C. S., 1944, Paddy cultivation in Cochin. *Indian Fmg.*, 5: 236-238.
- Verma, R. A. and Gupta, A. K., 2001, Effectiveness of some insecticides against *Cnaphalocrosis medinalis* and *Leptocoris varicornis* on paddy crop. *Indian J. Ent.*, 63 (1): 71-77.
- Vevai, E. J., 1968, Know your crop, its pest problems and control-2. *Pesticides*, 2 (4): 18-22.
- *Vreden, Van, G. and Ahmadjabidi Abdul Latif, 1986, Pests of rice and their natural enemies in penninsular Malaysia. Pudoc Wageningen, Nether Lands. 66-69.

Appendix I. Taluk- wise monthly rainfall data of the year 2010 in Uttara Kannada district

Sl. No.	Name of taluk	Rainfall (mm)												
		January	February	March	April	May	June	July	August	September	October	November	December	Total
1	Ankola	1.0	1.0	1.0	9.0	149	941	1153	704	299	138	54	14	3464
2	Bhatkal	1.0	1.0	2.0	20	159	990	1279	903	417	188	62	15	4037
3	Haliyal	1.0	1.0	6.0	51	108	204	420	231	122	130	47	10	1331
4	Honnavar	1.0	1.0	2.0	15	149	847	1141	751	367	161	59	12	3506
5	Karwar	1.0	1.0	1.0	12	148	943	993	612	304	142	50	11	3218
6	Kumta	1.0	1.0	2.0	14	144	913	1148	721	351	147	54	11	3507
7	Mundod	1.0	1.0	6.0	59	105	214	404	241	150	142	49	12	1384
8	Siddapur	1.0	1.0	3.0	23	89	766	1264	705	208	136	46	7.0	3249
9	Sirsi	1.0	1.0	3.0	22	87	451	972	538	187	126	46	7.0	2441
10	Joida	1.0	1.0	4.0	32	82	491	974	546	174	115	48	8.0	2476
11	Yellapur	1.0	1.0	2.0	23	86	620	1117	630	205	118	40	7.0	2850
	Total	11	11	32	280	1306	7380	10865	6582	2784	1543	555	114	31463
	Mean	1.0	1.0	2.91	25.45	118.73	670.91	987.73	598.36	253.09	140.27	50.45	10.36	2860.27

Appendix II. Meteorological observation at 2010, ARS, Sirsi during the 2010

Sl.No	Months	Temperature (°c)		Relative humidity (%)		Rainfall (mm)
		Max	Min	Max	Min	
1	January	29.6	14.7	87.8	91.7	3.4
2	February	32.8	15.4	89.3	90.0	0.0
3	March	34.9	17.7	87.0	89.0	7.1
4	April	35.6	19.8	80.0	48.8	35.3
5	May	33.6	28.2	83.4	53.8	44.3
6	June	29.5	20.2	87.2	76.0	396.0
7	July	26.2	19.6	90.0	84.4	723.8
8	August	26.7	19.7	91.8	82.0	366.6
9	September	27.5	19.5	90.6	78.5	376.5
10	October	29.3	19.0	88.0	68.3	77.6
11	November	29.2	18.1	89.0	66.6	140.6
12	December	28.6	14.0	82.6	54.2	0.4
	Mean	55.9	34.7	161.0	135.8	180.9

BIOECOLOGY AND MANAGEMENT OF RICE EARHEAD BUG, *Leptocorisa oratorius*, FABRICIUS (HEMIPTERA: ALYDIDAE) IN RAINFED ECOSYSTEM OF UTTARA KANNADA DISTRICT

BASAVARAJ A. H. T.

2011

Dr. S. T. PRABHU
MAJOR ADVISOR

ABSTRACT

Studies on bioecology and management of rice earhead bug, *Leptocorisa oratorius*, Fabricius (Hemiptera: Alydidae) were undertaken during *kharif*, 2010 in rainfed ecosystem of Uttara Kannada district.

Uttara Kannada district represents three distinct rice ecosystems, namely; 'upghat' drill sown paddy, 'upghat' transplanted paddy and coastal transplanted paddy. The roving survey taken up in these ecosystems revealed the two species belonging to the genus *Leptocorisa*, viz., *L. oratorius*, and *L. lepida*. Assuming that all rice earhead bugs were *L. oratorius*, it was confirmed by observing the characteristic black ventrolateral spots on the abdominal segments of this species. Among the two species *L. oratorius* was of high abundance and noticed in almost all places of surveyed.

The highest incidence of rice earhead bug was recorded at reproductive stage of crop during *kharif* season than *rabi*. The maximum population of 3.04 nymphs and adults per hill was recorded, during October (*kharif*-2010) in Mundgod and least in Sirsi (1.97/hill). Whereas, in *rabi* (2011) maximum population of 2.04 nymphs and adults per hill was recorded during May in Mundgod and least in Kumta (1.08/hill). The preadatory spiders, coccinellids, ground beetles, dragonflies, damselflies, bugs and roberflies were recorded during both the seasons. Seven alternate hosts of rice earhead bug were observed during survey which included *Echinocloa crusagalli* (L.), *Echinocloa colonum* (Link.), *Eleusina indica* (L.) Gaertn, *Digitaria sanguinalis* (L.), *Cyperes rotundus* (L.), *Cyperes iria* (L.) and *Brachiria mutica* (Stapf.).

Among the various botanicals, entomopathogenic fungi and synthetic insecticides evaluated for the management of rice earhead bug, imidacloprid 17.8 SL @ 0.25 ml/l was found very effective in reducing rice bug population and was at par with thiamethoxam 25 WG @ 0.3 g/l and malathion 5D @ 20 kg/ha. Next best treatments included azadirachtin 3000 ppm @ 3 ml/l and *Acorus calamus* aqueous rhizome extract @ 10%.