

**STUDIES ON INCIDENCE OF INSECT PESTS
AND NATURAL ENEMIES OF DIRECT SEEDED
RICE *VIS-A-VIS* TRANSPLANTED RICE AND
MANAGEMENT OF PLANTHOPPERS**

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AUGUST, 2016

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AND NATURAL ENEMIES OF DIRECT SEEDED
RICE *VIS-A-VIS* TRANSPLANTED RICE AND
MANAGEMENT OF PLANTHOPPERS**

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By

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CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON INCIDENCE OF INSECT PESTS AND NATURAL ENEMIES OF DIRECT SEEDED RICE VIS-A-VIS TRANSPLANTED RICE AND MANAGEMENT OF PLANTHOPPERS**” submitted by **Mr. RANJITH KUMAR, E.** in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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AFFECTIONATELY DEDICATED
TO

MY PARENTS
Sri. Eranna K.N. Smt. Nalina V.P.

MY DEAR SISTER
Miss. Kavitha, E.

& GRANDMA, *Smt. Jayamma*

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(RANJITH KUMAR, E.)

LIST OF ABBREVIATIONS

<i>viz.</i>	:	Namely
<i>et al.</i>	:	And other people
Anon.	:	Anonymous
CD (P=0.05%)	:	Critical Difference at 5 per cent level
Fig.	:	Figure
ha	:	hectare
g	:	gram
mm	:	milli meter
ml	:	milli litre
S. Em.	:	Standard Error mean
CD	:	Critical difference
kg	:	kilo gram
DAS	:	Days after sowing
cm	:	centi meter
/	:	per
%	:	per cent
°C	:	Degree Celsius
RH	:	Relative humidity
RF	:	Rainfall
CV	:	Coefficient of variation
SW	:	Standard week
DSR	:	Director seeded rice
TPR	:	Transplanted rice
DDSR	:	Dry direct seeded rice
BPH	:	Brown planthopper
WBPH	:	Whitebacked planthopper
GLH	:	Green leafhopper
<i>vis-à-vis</i>	:	Vice versa

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Introduction

I. INTRODUCTION

Rice (*Oryza sativa* L.) is an important 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). Nearly 92 per cent of the world's rice is produced and consumed in Asia.

In India, rice is being grown in an area of 43.95 m ha with an annual production of about 106.54 m tonnes and the productivity is about 2.37 tonnes per ha. In Karnataka, rice is cultivated in command areas of Bhadra, Cauvery, Tungabhadra and Upper Krishna project command areas, where conventional puddling with transplanting are the major system of cultivation. In Western ghats and high rainfall areas, the rice is cultivated as drill sown. The total area under rice in Karnataka is 1.42 m ha with an annual production of 3.5 m tonnes and the productivity is about 2.63 tonnes per ha (Anon., 2015a).

Many biotic and abiotic constraints have to be addressed to meet the productivity gap. Among the various biotic stress constraints 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 indiscriminate use of agrochemicals have further aggravated the pest incidence (Saraswati *et al.*, 2011). Insects, mite and nematode pests are the key biotic stresses limiting rice production in India (Prakash *et al.*, 2006). The annual yield loss due to insect pest varies from 21-51 per cent (Singh and Dhaliwal, 1994) in India and 26-34 per cent (Widowsky and Toole, 1996) across the world.

Kalode and Pasalu (1986) reported over 100 species of insect pests of rice crop at various stages of its growth, of which 20 are economically important. The major insect pests are Brown planthopper (BPH), *Nilaparvata lugens* (Stal), White backed plant hopper (WBPH), *Sogatella furcifera* (Horvath), Yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) and leaf folder *Cnaphalocrocis medinalis* (Guenee). BPH and WBPH cause huge crop loss of 10 - 70 per cent (Kulshreshtha, 1974 and Herdt, 1991), whereas the yield loss caused by leaf folder has been reported to the extent of 10 per cent. Yellow stem borer caused losses range from 25 - 30 per cent (Anon., 2013).

The possibility of expanding area under rice in the near future is limited. Therefore, the additional requirement can be met out by increasing the productivity.

Imminent water crisis, water demanding nature of traditionally cultivated rice and climbing labour costs and pest aggravation led to the search for alternative management methods to increase water productivity, system sustainability and profitability. All these factors led to major shift in cultivation from puddled transplanted rice production to dry direct seeding of rice (DDSR). It refers to the process of establishing the crop from seeds sown in the field rather than by transplanting seedlings from the nursery. This avoids three basic operations *viz.*, puddling, transplanting and maintenance of standing water. Production in DDSR is negligible in irrigated areas but is practiced traditionally in most of the Asian countries in rain fed upland ecosystems (Joshi *et al.*, 2013).

A large number of insect pests specially stem borers breed or over winter in the rice stubbles. The quantum of stubbles left in the machine harvested (combine harvesters) is more under such circumstances if paddy seeds are drilled directly without incorporation resulting in increased infestation on succeeding crop. Unlike, in transplanted rice stubbles are ploughed and later puddled which may reduce the pest complexity particularly stem borer. This change in planting geometry may affect the pest incidence. The stem borer attacks rice crop from the seedling stage to the harvesting stage and thus causes complete loss of affected tillers (Salim and Masih, 1987). The larvae hibernate in rice stubbles from November to the end of March and early April (Rehaman *et al.*, 2002a). So there is a scope on the assessment of rice yellow stem borer emergence from stubbles and losses made by them.

However, insects are cool blooded organisms and changes in temperature, humidity and other weather parameters influence the behaviour, distribution, growth, development and reproduction rates of the insect fauna in rice ecosystem. So relation between the rice insect fauna and weather parameters needs to be assessed (Hafizal and Idris, 2014).

Conservation of natural enemy fauna *in-situ* for suppressing the pest population seems to be very good alternative. In India, there is sufficient evidence to justify the vital role of natural enemies in suppressing the pest population in rice (Rao *et al.*, 1983; and Chelliah *et al.*, 1989). It has been reported that there are 79 species of natural enemies of BPH consisting of 42 parasitoids and 37 predators (Chiu and Lung, 1975). The potential of biological control would decrease as a result of the injudicious use of insecticide

(Geiger *et al.*, 2010). Hence, documentation and assessment of dynamics of natural enemies under DSR is need of the hour.

During the last decade, studies on biological control of BPH have been conducted in several countries, but they have been generally restricted to the ecology and biology of natural enemies. However, little practical effectiveness has been demonstrated on to identify species and estimate the amount of parasitism or predation the field. Otake (1976) indicated that the natural enemies of planthoppers on rice have been much less intensively studied than those of the rice stem borer. Hence, naturally occurring biological control agents have a potential role to play in management of rice fields of tropical South and South East Asia and there is a need to emphasize the impact of indigenous natural enemies as an essential part of integrated pest management programmes (Way and Heong, 1994). Further, it is more importance for identification of natural enemies and understanding of their role in order to optimize the strategies for the management of insect pests.

As there is no full proof method to get rid of planthoppers either through a resistant variety or through certain biological agents, the use of insecticides becomes unavoidable. For quick knock down effect, the application of judicious dose of insecticides is desired as a part of IPM (Prasad *et al.*, 2014).

A variety of studies have been conducted in different ecosystems of rice elsewhere on food web interactions, economics of insect pest damage, predatory and parasitoid biology, ecology and impact of inputs in to the ecosystem have highlighted the rich biodiversity of rice field fauna and flora. So it is needed to study the complex and rich web of general and specific insect pests and natural enemies of both TPR and DDSR ecosystems, the detailed information on seasonal activity associated with meteorological parameters, carryover of insect pests on subsequent crop and management of planthoppers in DDSR. Keeping this in view, the present investigation was undertaken during 2015-16 at Agricultural Research Station, Gangavathi, with the following objectives:

- To document and compare the insect pests and natural enemies in dry direct seeded and transplanted rice ecosystem.
- To know the impact of left over crop residues on stem borer incidence for subsequent crop.

- To manage planthoppers by newer insecticides in dry direct seeded rice ecosystem.

Review of Literature

II. REVIEW OF LITERATURE

The literature pertaining to documentation of pest and natural enemies under dry direct seeded rice system, assessment of pest and natural enemies dynamics, impact assessment of left over residue on stem borer damage incidences for subsequent crop and management of planthoppers through novel insecticides is scanty and scattered. Hence, literature presented here includes mainly work with respect to transplanted rice and other related crops.

2.1 To document and compare the insect pests and natural enemies in dry direct seeded transplanted and rice ecosystem

Weather factors are the major regulating factors for the insect pest populations under field conditions. Abiotic factors, such as, temperature, relative humidity, sun shine hours, rainfall and wind velocity may affect the distribution, growth, survival, behaviour, movement, reproduction, population dynamics and outbreaks of insect pests of rice (Kisimoto and Dyck, 1976).

2.1.1 Insect pests

Noor *et al.* (1987) reported the incidence of about 12 insect pests in dry direct-seeded rice fields in Malaysia and compared with the scenario in transplanted fields. The population of leafhoppers (*C. medinalis* and *Marasmia patnalis*) in the tillering stage and bugs (*Leptocoris oratorius* and *Nezara viridula*) in the reproductive stage of the crop were noticed more in direct-seeded than in transplanted fields. Yellow Stem borer was more abundant in direct seeded rice.

Chaun and Chul (1997) investigated the incidence of insect pests in transplanted and direct seeded paddy fields in Korea Republic. Population densities of *Nephotettix cincticeps* (Uhler) and *C. medinalis* were higher in machine transplanted than in direct seeded rice while, *N. lugens* and *Laodelphax striatellus* Fallén were abundant in direct seeded rice. However, no significant difference was found between machine transplanted and direct seeded fields with regard to the incidence of striped rice stem borer *Chilo suppressalis* (Walker), WBPH and rice stem maggot *Chlorops oryzae* Matsumura. The occurrence of key rice pests was affected more by transplanting method than by other cultural practices. Later transplanting induced higher populations of *N. lugens*,

S. furcifera, *L. srtiatellus* and *N. cincticeps*, however, *C. suppressalis* and *C. medinalis* caused greater damage in earlier transplanted paddy fields.

2.1.2 Natural enemies

Saxena (1953) reported the first record of an Asilid fly (Robber fly), probably a species of the genus *Ommatius* preying on adult and nymph of rice bug *Leptocorisa varicornis* (Fab.) and only other record of an insect preying on adult and nymph of *L. varicornis* in India is that of a Cicindelid, *Cicindela sexpunctata* (Fab.).

Others predators that may be found preying on rice plant hoppers in rice fields include odonatas, nabids, anthocorids, reduvids, hebrids, hydrometrids, ochterids, pleids, salids and veliids; empidids and asilids, specids, nyssonids, stizids and pemphedonids; Birds, frogs and a gaint toad (Habu, 1958; Kobayashi, 1961; Hinckley, 1963; Asahina *et al.*, 1972 and Yasumatsu *et al.*, 1975).

Rao (1964) reported *Telenomus* sp. (egg parasitoid), *Apanteles ruficrus* Haliday (larval parasitoid), *Bracon* sp. (larval parasitoid) and *Brachymeria euploeae* Westwood (pupal parasitoid) as natural enemies of rice skipper in India. Likewise, Bharati and Kushwaha (1988) noticed four pupal parasitoids of leaf folder in Haryana. They were *Xanthopimpla flavolineata* (Cameron), *Xanthopimpla* sp. (Ichneumonidae), *Brachymeria* sp. (Walker) and *Tetrastichus ayyari* (Rohwer) with a parasitism of 7.5, 1.0, 1.5 and 2.5 per cent, respectively.

Sasaji (1968) studied the fauna of coccinellids in paddy fields and 33 species were recorded, seven of which were recorded as predators of BPH. Yasumatsu *et al.* (1975) reported 6 species of coccinellids in the rice fields of Thailand. Among them *Micropis discolour* (Fab.) and *Micropeplus vincta* Gorb. were abundant in Malaysia.

Rao *et al.* (1970) reported *Telenomus* sp. (egg parasitoid), *Apanteles* sp. (Larval parasitoid) and *Xanthopimpla stemmator* (Thunberg) (pupal parasitoid) as natural enemies of paddy horned caterpillar in India.

Four mymarid parasites *viz.*, *Anagrus optabilis* (Perkins), *Mymarta probanicum* (Ward), *Polynema* sp. and *Gonatocerus* sp. contributed much in the reduction of planthoppers in Thailand (Yasumatsu *et al.*, 1975).

A mirid bug, *Cyrtorhinus lividipennis* Reuter is widely distributed in Southeast Asia, Australia and the pacific islands. It preys on eggs, nymphs and adults of rice leaf

hoppers and planthoppers and considered as an effective predator of BPH and GLH (Murthy *et al.*, 1976).

Samal and Misra (1978) reported that the carabid ground beetle *Cosnoidea indica* Thunberg predate an average of six nymphs of *N. lugens* or adults daily, leaving behind legs and wings of prey. Similarly, staphylinid beetles, particularly *Paederus fuscipes* Curtis., are probably significant in the control of insect pests in rice. They usually migrate to the young rice plants shortly after transplanting in Taiwan. *P. fuscipes* and *Stenus cicindeloides* (Schaller) were the most common staphylinid species in paddy fields (Chill *et al.*, 1979).

Gupta *et al.* (1986) observed that predators and spiders are the most familiar and ubiquitous obligate carnivores, which feed on different types of prey in different cropping systems. In India 76 spider species have been reported from Orissa, Andhra Pradesh and 21 common species observed belong to the genera *Tetragnatha*, *Necoscona*, *Oxyopes* and *Pardosa*. Chakravarthy (1987) recorded six spiders per 10 clumps on the main rice crop and one spider on ratoon crop in Karnataka.

The staphylinid beetle was observed to the tune of 5-20/m² in Avinasi and periyanaicken villages of Coimbatore district (Anon., 1988). Ferrer and Shepard (1988) studied two sampling methods (a water pan and carbon dioxide sampler) for BPH, WBPH, a predatory *C. levidpennis* and spiders wherein, significantly higher number of spiders ($p < 0.05$) were sampled using the carbon dioxide sampler in DSR and TPR at Philippines. Finally they found that pan sampler required less time and was less expensive than the carbon dioxide sampler.

Based on population and predation efficacy *P. fuscipes* is considered as the important predator of rice pests, following wolf spiders (Lycosidae) and other spiders (Gu *et al.*, 1989).

Surveys were carried out at an experimental farm in Maduri, Tamil Nadu, India for predatory coccinellids in rice, cowpea, blackgram and soyabean. Eight species of predatory coccinellids were found feeding on BPH, WBPH and leaf hopper in rice. Of the coccinellids, *Menochilus sexmaculata* (Fabricius) accounted for 43 per cent and *Schymnus* sp. for 10 per cent (Parasuraman, 1989).

Bottenberg *et al.* (1990) studied abundance of natural enemies in different rice habitats of Malaysia for leaf hopper and natural enemies. They found that spiders or web

weavers were the major natural enemies in all habitats except in direct seeded rice and single-stage nurseries, where predatory insects were more abundant.

Barrion and Lissinger (1995) recorded nearly 350 species of the spiders in the rice ecosystem in south and Southeast Asia. Similarly, Bambaradenyia and Edirisinghe (2001) observed that more than 50 per cent of the terrestrial arthropod species in rice fields consisted of predators and spiders were the dominant group comprising 60 species.

Tiwari *et al.* (2001) observed the occurrence of spider, dragon fly (*Crocothemis* sp.), damsel fly (*Agriocnemis* sp.), predatory cricket, rove beetle (*P. fuscipes*), ground beetle (*Ophionea indica* [*Cosnoidea indica*]), predatory grass hopper (*Conocephalus* sp.) and brown bug (*Andrallus spinidens*) in Rice ecosystem of Jabhalpur, Madhya Pradesh, India.

Ramzan *et al.* (2007) studied the population of predators in zero tillage and conventional methods of rice ecosystem. Significantly higher population of rove beetle were found than the remaining species of the predators in zero tillage compared to conventional methods.

Ashrith (2014) also observed the natural enemy activities in Dry DSR and TPR condition and noticed that activity of spiders, mirid bugs and coccinellid was more in transplanted condition compared to DSR.

Devigne and Jean (2014) compared five different types of traps currently used in biodiversity studies of flying insects. Among them the yellow pan trap was most effective trap particularly for Hymenoptera, Diptera and Homoptera.

Girish *et al.* (2015) observed Odonata (Dragon and Damselfly), coccinellids, spider and carabids as natural enemies of transplanted, drill sown and aerobic cultivation of paddy during *kharif* 2010.

2.1.3 Studies on dynamics and activity of pest and their natural enemies in relation to weather parameters under transplanted and dry direct seeded rice ecosystem

2.1.3.1 Brown planthopper

Influence of microclimate weather on planthoppers was more in low land rice than upland rice. Direct sown fields are often preferred to transplanted ones

as thick vegetation was a better habitat for upland rice planthoppers (Suenaga, 1963).

Narayanaswamy *et al.* (1979) recorded populations of BPH with both maximum and minimum temperature. Although, they were positively correlated with relative humidity, but population peaks were recorded when there was little or no rainfall (6-10 mm) and declined when rainfall exceeded 10 mm. Whereas, non-significant relationship between *N. lugens* population and maximum temperature, relative humidity and rainfall was noticed by Mancharan and Jayaraj (1979). Correlation studies showed that the planthopper population had significant and negative association with rainfall and relative humidity (which had adverse effect on the planthopper) and positive association with high temperatures (Nair *et al.*, 1980). Jayaram (1981) reported a negative correlation (- 0.286) between the rainfall and trap catches. Relative humidity also had a significant and negative effect on population of *N. lugens* (Reddy *et al.*, 1983).

Dense planting increases populations of BPH due to the high relative humidity present in the microclimate. Dense planting also provides more plant surface area and less competition for oviposition or feeding sites (Kenmore *et al.*, 1984). Significant correlation between light catch and maximum temperature was reported by Srinivasa (1984).

Reddy *et al.* (1983) found that, relative humidity had a significant and negative effect on populations of BPH. Barwal and Rao (1986) noticed negative correlation with temperature on BPH incidence, but incidence was enhanced by reduced sunshine, thick crop canopy and crop succulence. However, relative humidity is the most important environmental factor determining the microhabitat of nymphs of *N. lugens*, which preferred more than 90 per cent relative humidity as observed by Ichikawa and Ishii (1994). Naganagoud *et al.* (1999) noticed the occurrence of planthoppers at 60 days after transplanting during the *kharif* season which coincided with the peak occurrence during October – November in Tungabhadra Project Area of Karnataka.

Vijaykumar and Patil (2004) observed the peak population of BPH during second fortnight of November in Raichur, Manvi and Sindhanoor and during first fortnight of November in Siruguppa and Gangavathi talukas of Karnataka. Yadav *et al.* (2010) developed multiple linear regression models (pest-weather models) and opined that BPH light trap catches were directly influenced by monthly mean values of minimum

temperature (T min), maximum temperature (T max) and evening relative humidity (RH2). Hegde and Nagappa (2011) recorded the highest planthopper population in direct seeded method followed by random planting method. The yellow stem borer incidence was statistically higher in SRI and ICM methods.

Similarly, maximum temperature, RH1 (morning relative humidity), RH2 (Evening relative humidity) and sunshine hours were positively correlated with BPH light trap catches in Mandya. (Prasannakumar and Subhash, 2014). However, Hafizal and Idris (2014) opined that change in temperature directly influenced the population abundance of BPH but not GLH. There was no significant correlation found between humidity and population abundance. Similarly, the maximum temperature, morning relative humidity and evening relative humidity were found to be in significantly positive association with the light trap catches of brown planthopper (Ashrith, 2014).

2.1.3.2 Whitebacked planthopper

Reddy *et al.* (1983) found a significant and negative relationship between relative humidity and population of *S. furcifera* at Hyderabad, Andhra Pradesh, India. Ram (1986) reported that early heavy monsoon followed by a long period of dry humid weather was responsible for spread of hopper burn in Haryana during *kharif*, 1983. An outbreak of WBPH in Punjab was favoured by high rainfall in early April followed by the prolonged dry period with high temperature and humidity in May (Saha, 1986).

The abundance of WBPH activity was correlated with weather parameters which revealed that maximum temperature, morning relative humidity and evening relative humidity had significantly positive relationship with light trap catches of WBPH (Ashrith, 2014). Likewise, the activity of WBPH through the light trap catches had significantly positive association with minimum temperature, morning and evening relative humidity (Guruprasad *et al.*, 2014).

2.1.3.3 Green leafhopper

The heavy and continuous rainfall during summer led to the decline in green leafhopper population as reported by Alam (1971). Warm and moderately wet climate was found to facilitate the population growth in the Philippines (Anon., 1973).

In India, the increase in population of *N. virescens* both at maximum and minimum temperatures was reported by Narayanswamy *et al.* (1979). A positive

correlation

for the above parameters and negative correlation with high bright sunshine hours, rainfall and humidity. Further, he observed the increase in population of hoppers with more bright sunshine hours and the population decreased with fewer sunshine hours.

Mukhopadhyay *et al.* (1985) stated that the maximum and minimum temperature 37-42 °C and 11-17 °C were responsible for the upper and lower thresholds, respectively for catching green leafhopper in light traps. The temperature and relative humidity were positively correlated with pest density whereas rainfall was negatively correlated. Mukopadhyay *et al.* (1985) opined that peak incidence of GLH population in October and November had positive correlation with rainfall during the months of August and September. Weather factors had no significant influence on the population of green leaf hopper (Reddy *et al.*, 1983 and Bhaskar, 1994).

2.1.3.4 Yellow stem borer

The rice stem borer, *S. incertulas* is one of the most important pests of rice in India and the yield losses ranged from 3 to 65 per cent (Ghose *et al.*, 1960). Calora and Ferino (1968) observed the incidence of stem borers and leaf folders and populations were generally high during rainy months.

Ayyanna and Hamidali (1970) observed that *S. incertulas* emerged from second week of September with a peak activity during the first week of October between temperatures of 30.6 °C and 21.6 °C, respectively and 82.70 per cent relative humidity. Saroja (1982) reported stem borer damage occurrence as below the economic threshold (5%) on crops planted in September and from December to June.

Rao and Padhi (1988) studied the effect of weather on outbreaks of the *S. incertulas* in Orissa, during 1976-85. Brood emergence was larger in outbreak years than in normal years and relatively greater solar radiation was recorded during outbreak years than in normal years. Rainfall during August-November and rainy days in October-November were negatively correlated with infestation. Further, they concluded that rainy days adversely affected mating, flight, oviposition, egg hatchability, larval survival and tiller penetration.

Nandihalli *et al.* (1990) noticed positive correlation between YSB trap catches and average maximum temperature and morning relative humidity. Adiroubane and Raja (2007) monitored the infestation of stem borer and recorded high pest incidence during month of March and October - November and found that favourable weather conditions for high stem borer incidence were 30.1 °C as mean temperature with 65.71 - 95.1 per cent relative humidity.

Mohammad and Abdullah (2011) studied seeding technique (direct seeding on flat or ridges, transplanting on flat or ridges and parachute planting), transplanted and wet seeded rice in relation to onset of rice stem borer for two consecutive seasons. The lowest borer incidence was observed in transplanting and parachute planting after 30, 45 and 60 DAS. Ashrith (2014) noticed that the maximum temperature had significantly positive correlation with the light trap catches of yellow stem borer.

2.1.3.5 Leaffolder

Incidence of leaffolder population in paddy crop was assessed during four consecutive *kharif* crop seasons at West Bengal. The leaffolder population was initiated at about 25 standard meteorological weeks. Maximum incidence was attained during September to October then population got slowly declined Pathak and Khan (1994). Studies by Sabir *et al.* (2006) on the pest-weather interaction of major insect pests in rice ecosystem in Pakistan indicated that population of rice leaf folder, *C. medinalis* and stem borers attained their peaks in September (7.4 and 7.75 larvae/ 20 hills, respectively). They also found that the maximum and minimum temperatures and rainfall were vital for a change in the population of leaffolder. As a whole, 82.99 per cent change in population of *C. medinalis* was due to environmental factors.

Kuligod (2009) noticed peak occurrence of leaffolder population during September and October. The mean population of leaffolder was 5.62 per cent in rain fed drill sown area of Uttar Kannada district.

Mohan and Janarathanan (1985) conducted studies on seasonal abundance of leaf folder population through a modified Robinson light trap and reported peak activity of leaffolder which varied between October to March.

Incidence of leaffolder population in paddy was assessed by using light trap and results revealed that populations were initiated at 25 standard meteorological weeks

(SMW), improved slowly up to 27 SMW, then steadily up to 32 SMW attaining maximum at 34 SMW which was maintained up to about 37 SMW. Abiotic factors such as minimum temperature, temperature gradient, maximum relative humidity and average relative humidity had significant positive influence on *C. medinalis* population. In case of minimum relative humidity and sunshine hours a negative influence was observed. Other factors such as maximum temperature, relative humidity gradient, average relative humidity, number of rainy days and rainfall imparted insignificant positive effect on population development (Chakraborty and Deb, 2011).

Maximum temperature and sunshine hours had significant positive correlation with larval population of rice leaf folder, while wind velocity and rainy days had significant negative correlation. Minimum temperature, average temperature, morning relative humidity, evening relative humidity and rainfall had non-significant negative correlation with the rice leaffolder population. Larval population (0.5 larvae/ plant) and per cent damaged leaves (0.55) of rice leaffolder initiated from 36th standard week and reached its peak level (3.12 larvae/plant and 3.20% damaged leaves) during 43rd standard week in *kharif* 2005 while the larval population (0.53 larva/plant) and per cent damaged leaves (0.72) of rice leaf roller initiated from 13th standard week and reached to peak level (1.51 larvae/ plant and 1.75% damaged leaves) by 15th week during summer 2006 in Gujarat (Patel *et al.*, 2011)

The light trap studies by Guruprasad *et al.* (2014) indicated that minimum temperature, evening relative humidity and morning relative humidity had significantly positive association with the activity of leaffolder.

2.1.3.6 Natural enemies

Studies on spiders in a rice field in Suwean, Korea during June-September 1975 revealed that spider fauna was relatively poor in the early period of crop growth (June). The lycosid, *Pirata subpiraticus* Boes. and the two erigonids, *Gnathonarium dentatum* (Wider) and *Oedothorax insecticeps* (Bosenberg and Strand) were the early settlers. *P. subpiraticus* increased in number rapidly and was the dominant species throughout the season Okuma *et al.* (1978). The density of spiders (Theridiids, Erigonids and Lycosids) in the field was positively correlated with *N. lugens*. Population of *L. pseudoannualata* exhibited positive correlation with the planthopper population (Lua, 1985).

Chau (1987) reported highest peak of spiders at mean temperature of 23 - 25 °C and with relative humidity of 89 to 94 per cent. Decrease in minimum temperature during summer and maximum temperature during *kharif* reduced the spider population. Population of spiders during summer season showed a significant and positive correlation with the mean minimum temperature. Further, sampling of predators of brown plant hopper revealed that a carabid appeared between 35 and 75 DAT in winter-spring and a summer-autumn peak was observed 40 DAT. During *kharif* season, spider population showed significant negative correlation with maximum temperature and evaporation (Venkateshalu, 1996).

The abundance of spiders was correlated negatively with the abiotic factors *viz.*, minimum temperature, rainfall, pan evaporation, vapour pressure and wind speed and positively with maximum temperature. However, the 'r' values were not significant for the weather parameters (Mohan Reddy, 2000). Ashrith (2014) observed the natural enemy activities in Dry DSR and TPR condition and noticed that activity of spiders, mirid bugs and coccinellid was more in transplanted condition compared to DSR. Staphylinid activity was more in DSR.

Girish *et al.* (2015) studied dynamics of spider population in different planting methods *viz.*, drill sowing, transplanting and aerobic cultivation method and reported that predatory population of spider increased slowly from beginning and attained peak at 105 DAS and thereafter declined under transplanted and drill sown condition but peak was at 90 DAS under aerobic planting method.

2.1.4 Population dynamics of natural enemies of planthoppers in transplanted and dry direct seeded rice ecosystem

Survey conducted by Lin (1974) on BPH egg parasitoids in Taiwan indicated *Anagrus* sp. as the most prevalent among the trichogrammatid and mymarid parasites which constituted 93 per cent of the egg parasitoids of BPH in Taipei paddy fields. Similarly, Chiu and Lung (1975) observed egg parasitism at four sites in northern Taiwan during 1974 and 1975. Most of mymarid parasites appeared in May to June and also noticed during September and continued till November. The parasitism ranged from 11.3 to 29.6 per cent in the first crop and 3.3 to 38.1 per cent in the second crop.

Yasumatsu *et al.* (1975) found that four mymarid parasites *viz.*, *Anagrus optabilis* (Perkins), *Mymarta* sp., *Polynema* sp. and *Gonatocereus* sp. contributed much in the reduction of plant hoppers. Similarly, *Paracentrobi* sp and *Oligosita* sp. were abundant and effectively suppressed the population of leafhoppers or planthoppers in Thailand.

Rohan *et al.* (1982) observed five larval parasitoids regulating leaf folder populations. They were *Apanteles favipes* (Cameron) (Hymenoptera: Braconidae) *Elasmus* sp. (Hymenoptera: Elasmidae) and *Bactromyia framsoni* Bar. (Diptera: Tachinidae) and parasitization of leaf folder larvae ranged from 48 to 70 per cent. Similarly, Panda *et al.* (1983) noticed the occurrence of egg parasitoids *Telenomus dignoides* (Nixon), *Trichogramma japonica* Ashmead and *Tetrastichus schoenobii* Ferriere which parasitized stem borer eggs and recorded parasitisation of 21.49, 0.28 and 5.30 per cent, respectively.

Bentur and Kalode (1984) made intensive survey in Andhra Pradesh and observed ten egg parasitoids; 7 nymphs-adult parasitoids, one hyper parasitoid and two predators of BPH of rice. Of these, the egg parasitoid, *Oligosita* sp and *Anagrus* sp. and the nymphal/adult parasitoid, *Gonatopus* sp. appeared to be a new record of parasitoids in Andhra Pradesh. Similarly, Shankar and Bhaskaran (1987) reported that three species of egg parasitoids of BPH from India, *viz.*, Mymarid, *A. optabilis*, Trichogrammatid, *Oligosita nanae* (Walker) and Eulophid, *Tetrastichus* sp caused parasitism to the tune of 42 per cent, with a major contribution by *A. optabilis* as dominant species throughout the season (27%) followed by *Tetrastichus* sp. (11%). The egg parasitism by *Anagrus* sp. which was observed to be highest (30%) on WBPH during July while, on BPH it was 24.7 per cent parasitisation during early August (Anon., 1987).

Bharati and Kushwaha (1988) reported four pupal parasitoids of leaf folder in Haryana during *kharif*. They were *Xanthopimpla favolineata* (Cameron), *Xanthopimpla* sp. (Ichneumonidae), *Brachymeria* sp. *nr. lasus* (Walker) (Chalcididae) and *Tetrastichus ayyari* (Rohawer) (Eulophidae) with a parasitism of 7.5, 1.0, 1.5 and 2.5 per cent, respectively. A survey carried out by Ahmed *et al.* (1989) in Pakistan revealed the presence of parasitoids *Trichogramma* sp. (in 8.35% of eggs), *Apanteles angustibasis* Gahan (in 6.41% of larvae) and *Brachymeria* sp. (in 7.72% of pupae) on leaf folder. Manisegaran *et al.* (1997) recorded most effective parasitoids from the rice leaf folder

C. medinalis, including *Goniozus* sp. and *Elasmus johnstoni* (Ferriere). The parasitism ranged from 4.0 to 22.0 per cent.

Total egg parasitization of hoppers was 16.35 per cent with *Anagrus*, *Oligosita* and *Gonatocerus* accounting for 10.58, 4.49 and 1.28 per cent respectively. *Anagrus* was the dominant parasitoid accounting for 64.71 per cent followed by *Oligosita* (27.46%) and *Gonatocerus* (7.84%) at Gangavathi (Anon., 2013). Similarly, 19.37 per cent of parasitisation was noticed on planthopper eggs. Among them *Anagrus*, *Oligosita* and *Gonatocerus* accounted for 66.37, 28.32 and 5.31 per cent parasitisation, respectively at Gangavathi, Karnataka (Anon., 2014).

2.3 Impact to know the left over crop residues on stem borer incidence for subsequent crop

Shiraki (1917) reported that stubble placed on ground harboured hibernating larvae of stem borers. Kawada *et al.* (1934) observed that larvae of yellow stem borer overwinter in the stubbles and pupate in cocoons, prior to the onset of the hot season, which lasts for about three weeks. Further they stated that the larvae were vulnerable to low temperature and high moisture; the percentage of mortality increased during cold winter. Since the stem borer cannot survive in the cut straw, it goes down into the stubble to spend the period between harvests.

Unithan and Gebre (1989) reported incidence, diapause and the role of crop residues in the carryover of cereal stem borer, *Busseola fusca* (Fuller) and suggested that majority of the second generation stem borers survived in long rainy sorghum crop, during off-season (July or August-February or March) as diapausing larvae in crop residues. *C. partellus* on the other hand, survived mostly as an active population, but in low numbers. Most of maize stalk borer *B. fusca* also noticed at base of stubbles appeared to be the source of infestation of the newly planted crop.

Rehaman *et al.* (2002 b) reported that rice stem borer *S. incertulas* (Walker) and *S. innotata* are the serious pests of rice in South and South-East Asia. In winter the rice stem borer (RSB) larvae hibernate in rice stubbles. The survival of larvae was monitored in conventional and zero tillage wheat. The highest larval survival was noticed in fallow unploughed tillage and conventional tillage fields. At the end of hibernation period (March-April), the larval density in both conventional and zero tillage system was almost equal. Regression analysis indicated a linear increase in larval mortality over a time. The

data indicated that the major overwintering sites of RSB is unploughed fallow fields and growing of wheat after rice, either by conventional or zero tillage minimizes the RSB problem. The stem borer larvae generally hibernate during October-March in subtropics. This follows a pupal stage noticed in April. The planting of summer rice and availability of volunteer rice in wheat fields during spring season may ensure survival of first generation.

Saroj *et al.* (2005) observed that fallow unploughed fields followed by growing of Oilseeds, Lathyrus, Chickpea and Berseem with minimal tillage represent the major overwintering sites of rice stem borers. These studies have revealed that the larvae of *Scirpophaga* sp. usually overwinter at the basal part of rice stubbles and migration of larvae to underground stems seems to be an adaptation to their specialized feeding. Hence, the ploughing or harrowing of fields immediately after harvest is helpful in preventing the surviving populations.

Ramzan *et al.* (2007) studied on carryover and population build-up of predators of insect pests in rice-wheat system under zero tillage and conventional wheat planting methods at Muridke (District Sheikhpura) and Bhalwal (District Sargodha) at Punjab province of Pakistan. Population of predators at both the sites remained high throughout the study period in wheat fields sown with zero-till drill than the wheat fields sown conventionally. Populations of spiders and rove beetles were significantly higher than the remaining species of the predators. The magnitude of difference in the populations of predators between zero tillage and the conventional method of sowing of wheat increased with the passage of time at both the locations.

Ashrith *et al.* (2015) studied the carryover of stem borers in DDSR and TPR for subsequent crop. It was found that population of yellow stem borer (*S. incertulas*) and pink stem borer (*Sesamia inferens* Walker) were higher in direct seeded rice than in transplanted condition. Further maximum emergence of stem borer was found in unprotected DDSR than protected plot. They also concluded that YSB goes in to hibernation in stubbles which results in maximum emergence at end of May. Hence, they clearly indicated that tillage practices and crop rotation will greatly influence survival of stem borers.

2.4.1 To manage planthoppers by newer insecticides in dry direct seeded rice ecosystem

Cheng and Liu (1978) and Balasubramanian (1979) found acephate 75 WP to be one of the best chemicals against BPH.

Studies in Philippines showed that buprofezin was effective against third instar nymphs and did not afford effective control of BPH adults in greenhouse (Valensia *et al.*, 1983). Bae and Hyun (1989) observed that buprofezin reduced adult life span when earlier instar nymphs were treated. Hence, this compound could suppress planthopper populations if applied when early nymphal stages are predominant.

Shivamurthappa (1993) evaluated six insecticides for their efficacy in curtailing population of BPH and recorded carbofuran 3G as the best, followed by acephate, monocrotophos, buprofezin, carbosulfan and neem oil. Spraying of imidacloprid at 75 g a.i./ ha gave much efficient control of BPH than that provided by methamidaphos at 750 g a.i./ ha or buprofezin at 187.5 g a.i. / ha (Qiang *et al.*, 1995).

Korat *et al.* (1999) recorded lowest number of hoppers (2.72 to 3.73 hoppers /hill) in the field treated with buprofezin (500 g a.i./ha), followed by acephate (750 kg a.i./ha). An excellent control of BPH was achieved by spraying novel insecticide pymetrozine that resulted in paralysis of legs and cessation of feeding. More than half of the treated individuals died from direct poisoning. The survivors did not contribute to reproduction, primarily because of reduced fecundity caused by delayed ovary maturation. The effect was more obvious in immature than mature females (Sato *et al.*, 1996).

Among combination products imidacloprid 50 g + beta cyfluthrin 50 g (Confidor Ultra 100 EC) proved the best in recording 58.6 BPH/10 hills followed by acephate 45% + cypermethrin 5% (Upacy 50 DF) treatment with 130.9 BPH/ 10 hills, and were better than the check insecticide monocrotophos (191.1 BPH/ 10 hills). Chloropyriphos 50% + cypermethrin 5% (Nurelle D505 EC) and beta cyfluthrin 125 g + chloropyriphos 250 g (Bulldock Star 262.5 EC) registered 202.4 and 218.3 BPH/10 hills, respectively and were inferior to monocrotophos (Anon., 2001).

According to Byeongryeol *et al.* (2001) even the residual effect of imidacoprid at 0.3 kg and 0.032 kg a.i. per ha, respectively lasted for 40 days and was very effective when applied against BPH.

In a field study at Mandya, Anilkumar *et al.* (2002) found that imidacloprid 17.8 SL at 25 g a.i./ha and a combination product, imidacloprid 50 + beta cyfluthrin 50 (Confidor Ultra 100 EC) @ 30 g a.i./ha were highly effective in suppressing the planthoppers. Similarly, Krishnaiah *et al.* (2003) reported that application of thiamethoxam (25 g a.i./ha) and imidacloprid (25 g a.i./ha) as well as combination treatments involving deltamethrin + thiamethoxam (25 + 25 g a.i./ha) and deltamethrin + imidacloprid (25 + 25 g a.i./ha) were effective against BPH as compared to monocrotophos. Similarly, Krishnaiah *et al.* (2004) continued their efforts to evaluate later generation insecticides like neonicotinoids and phenyl pyrazoles against BPH, WBPH and green leaf hopper. Neonicotinoids like imidacloprid, thiamethoxam and thiacloprid and phenyl pyrazoles like fipronil and ethiprole exhibited good toxicity to BPH and WBPH.

Bhavani and Rao (2005) opined that imidacloprid (25 g a.i./ha) and acephate (600 g a.i./ha) were effective against BPH and WBPH. Likewise, buprofezin (50 g a.i./ha and 100 g a.i./ha) were effective in suppressing the populations of planthoppers (BPH and WBPH). In a field trial at Mandapeta, Rajahmundry in Andhra Pradesh, buprofezin (200 and 250 g a.i./ha) was the most effective chemical and was comparable to imidacloprid (25 g a.i./ha) and thiamethoxam (25 g a.i./ha) in suppressing the BPH population upto 16 days after application (Kendappa *et al.*, 2005). Field studies by Bhavani (2006) at Maruteru, Andhra Pradesh, during 1999 indicated that thiamethoxam @ 25 g a.i. / ha recorded 42.2 hoppers per 50 hills with a mortality of 99.1 per cent, preceded by buprofezin @ 200 g a.i. / ha with 122.9 hoppers per 50 hills with 96.9 per cent mortality, whereas a combination of deltamethrin + buprofezin 5.63 EC @ 84.4 g a.i. / ha was only moderately effective.

Kumaran *et al.* (2007) opined that acephate @ 468.75 g a.i. / ha was moderately effective in reducing the BPH population by 61.83 per cent. Hegde and Nidagundi (2009) reported that buprofezin (1 ml / l) recorded the lowest planthopper population at 10 days after spray and highest yield, followed by the same compound at 0.75 ml per lit in suppressing the pest.

Misra (2009 a) recorded significantly lowest WBPH population with a novel molecule UPI-206 @ 150 g a.i. / ha with a reduction of 90.43 and 90.81 per cent over control in 2007 *kharif* and 2008 *summer*, respectively.

Field study by Misra (2009 b) observed 88.73 and 90.30 per cent reduction of BPH population over untreated control during *kharif* 2007 and summer 2008, respectively by application of UPI-206 (flonicamid 50 WG) @ 150 g a.i. ha⁻¹. Similarly, application of Chess (Pymetrozine 50 WP) @ 400 g a.i. ha⁻¹ and 350 g a.i. ha⁻¹ was noticed to be best novel insecticide by registering 89.34 and 87.56 per cent reduction in population of WBPH over untreated check, respectively (Muralibaskaran *et al.*, 2009).

Ghosh *et al.* (2013) conducted a laboratory experiment to find out efficacy of Sulfoxamine 100 and 75 g a.i. /ha a new class of molecule and also under field condition on BPH and reported that Sulfoxamine100 and 75 g a.i. /ha was found effective for management of BPH.

Efficacy of DPX-RAB 55 (Triflumezopyrim 106 SC) @ 25 g a.i./ha was found to be superior treatment by recording 39.5 hoppers/ 10 hill and 36.3 hoppers/ 10hill in BPH and WBPH, respectively and was preceded by Dinotefuran20 SG @ 40 g a.i./ha which recorded 53.2 and 49.5 hoppers/ 10 hills in BPH and WBPH respectively in Six locations across India (Anon., 2015 b).

Material and Methods

III. MATERIAL AND METHODS

The present study on documentation and comparison of insect pest and natural enemies, impact assessment of previous crop residues on yellow stem borer incidence on subsequent crop and insecticidal approach for management of planthoppers were conducted at Agricultural Research Station (ARS), Gangavathi, Koppal district, Karnataka during *kharif* 2015-16. The ARS, Gangavathi is situated at 76° 32' E longitude and 15° 15' N latitude with an altitude of 419 m above mean sea level. The average rainfall received during the period of crop growth was 243.5 mm. The micro climate observations of relative humidity, temperature and carbon dioxide was taken using the “Data logger” and data on climatic parameters, such as relative humidity, rainfall, minimum temperature and maximum temperature were also obtained from station observatory at ARS, Gangavathi.

3.1 To document and compare the insect pests and natural enemies in dry direct seeded and transplanted rice ecosystem

3.1.1 Incidence of the insect pests and natural enemies in transplanted and dry direct seeded rice through yellow pan trap

For documentation of insect pest and natural enemies using yellow pan trap a separate layout was carried out where DSR plot was sub divided into two blocks of each 1000 m² area for protected and unprotected condition. Similarly, in transplanted rice plot was also divided into two blocks of each 1000 m² area for protected and unprotected condition, in which 25 yellow pan traps were installed in each block for recording and documenting the natural enemies. The observations on natural enemies was recorded at 24 hrs after installation of yellow pan trap starting from 15 days after transplanting or sowing to till harvest with an interval of 10 days. The collected pest and natural enemies were identified by the experts (Plate 1).

Methodology of sampling using yellow pan trap:

- Circular plastic bowl of 500 ml capacity (with 17 cm diameter and 5 cm depth) was used.
- Bowl was painted with two top coats of yellow paints. The bowl was placed at same height as that of vegetation (50-100cm) using a wire frame.



General field view of yellow pan traps installed in rice ecosystem



Transplanted rice ecosystem



Dry direct seeded rice ecosystem

Plate 1. Installation of yellow pan traps installed in rice field

Inside the bowl, a mixture of 400 ml water, 1.2 g of sodium benzoate preservative and one drop of liquid detergent was added.

- The observations on pest and natural enemies were documented at 10 days interval and the collected natural enemies were assorted group wise and preserved in 95 per cent ethyl alcohol for documentation and same was sent to Indian Council of Agriculture Research - National Bureau of Agricultural Insect Resources (NBAIR), Bangalore for identification.

3.1.2 Documentation of natural enemies of planthopper and leafhopper reared under laboratory condition

The egg masses of planthoppers and larvae of leafhopper were collected from the unprotected plots of both transplanted and DSR and reared in lab condition. The emerged parasitoids were collected and preserved in 70% ethyl alcohol and sent to ICAR-NBAIR, Bangalore for identification (Plate 2).

3.1.3 Studies on dynamics of insect-pests and natural enemies in dry direct seeded rice *vis- a-vis* transplanted rice ecosystem under field condition

Documentation of insect pests and natural enemies in DDSR and TPR ecosystem were made to compare differences in pest and natural enemies complex. This experiment was carried out at ARS, Gangavathi to know the dynamics of pests and natural fauna in DDSR and TPR using JGL-1798 variety. Dry direct seeded rice plot was divided into two blocks of each 1000 m² area for protected and unprotected condition. In each block 10 micro plots were made to record observations. Similarly, in transplanted rice also the plot was divided into two blocks of each 1000 m² area for protected and unprotected condition. Randomly ten plants were selected and tagged to record the observation in each plot starting from 15 days after transplanting or sowing till harvest with 10 days interval in a Randomized block design with four treatments and ten replication. The data obtained were subjected to statistical analysis adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984).

.1.3.1 Observation on planthoppers (BPH and WBPH) and leafhopper

The number of motile stages (nymphs and adults) of planthoppers (BPH and WBPH) and green leafhopper from 10 randomly tagged hills were counted by tapping and physical counting and expressed per hill. Data were transformed to square root ($\sqrt{x + 1}$) values prior to statistical analysis.



A) Rice leaf sheath with planthopper eggs
C) Larva of leaf folder

B) Eggs of leaf folder
D) Pupa of leaf folder

Plate 2. Emergence of parasitoids of rice planthopper and leaf folder in laboratory.

3.1.3.2 Observation on stem borer

Observation on incidence of stem borer was made on 10 hills by counting number of dead and total tillers at 30 and 50 days after transplanting and number of white ears at pre-harvesting stage. The per cent stem borer incidence was calculated using the formula given below (Singha and Pandey, 1997).

$$\text{Per cent stem borer incidence} = \frac{\text{Number of dead hearts/ white ears}}{\text{Total number of plants/ panicles/ ear heads}} \times 100$$

3.1.3.3 Observation on Leaffolder

Leaffolder incidence was recorded at 60 and 80 days of after transplanting/ sowing, where damaged leaves and total leaves from 10 randomly selected tagged hills were observed in each block. The per cent leaf damage was calculated by using the following formula as advised by Muhammad Sagheer *et al.* (2008).

$$\text{Per cent leaf folder incidence} = \frac{\text{No of damaged leaves}}{\text{Total number of leaves observed}} \times 100$$

3.1.3.4 Natural enemies

The population of natural enemies was observed simultaneously in all blocks on same hills which were selected for insect pest population. The common predators *viz.*, spiders and mirid bugs were counted on 10 hills on each plot and later averaged to per hill basis. The observations were started from a month after sowing up to crop maturity with an interval of 10 days.

3.1.4 Activity of pest and their natural enemies in relation to weather parameters under transplanted and dry direct seeded rice ecosystem

The data of pest and natural enemies dynamics made under different planting system were subjected to correlation studies to know the influence of microclimatic factors on incidence of biotic factors. Data on micro weather parameters which were recorded using data logger (Model : SD800, Make: Extech instruments, Nashua, New

Hampshire, USA) in the hills where insect pest observations were made. The data logger is an instrument that provides real time information about temperature, carbon dioxide and relative humidity. These parameters were stored in SD card and transferred to digital computer for further statistical analysis. The same set of data was correlated with abiotic factors obtained from station observatory situated at ARS, Gangavathi (Plate 3). Correlation coefficient values (r) were calculated and test of significance were applied as per the procedure outlined by Panse and Sukhatme (1967).

3.1.5 Correlation between insect pests of rice monitored through light trap and weather parameters during 2015-16

Dynamics of insect pest of rice were also assessed through light trap during 2015. A light trap unit made up of galvanized iron sheet, comprising of two main components *i.e.* trapping device and collection-cum fumigation chamber to catch the trapped adult insect. Mercury vapour lamp (MVL) of 160 watts was used as light source for attracting adult population. Dichlorovos 76 EC was kept inside the fumigation chamber in plastic pocket/ bag to kill the trapped insects. The unit was installed at the ARS, Gangavathi, and unit was operated every night from dusk to dawn. The observations were recorded by counting the daily trapped adult insect pests under light trap and were grouped and subjected to further correlation studies.

3.1.6 Population dynamics of natural enemies of planthoppers in transplanted and dry direct seeded rice ecosystem

The egg masses of planthoppers were collected on 50th, 70th and 90th days of crop period from the unprotected plots of both transplanted and DSR and reared under lab condition on. The per cent parasitization was calculated and based on the colour of parasitized eggs, they were grouped into different species and dynamics of different parasitized egg species were analysed using student t-test.

3.2 To know the impact of left over crop residues on stem borer incidence for subsequent crop

The experiment was laid out in Randomized complete block design (RCBD) with seven treatments in three replicated trials under DSR system.



A



B

A. Datalogger

B. Automatic weather station at ARS, Gangavathi.

Plate 3. Equipments used for weather parameters

Treatment details:

T₁ - Zero tillage with normal time of sowing

T₂ - Zero tillage followed by 10 days late sowing

T₃ - Recommended package of practice except plant protection

T₄ - Residue burning followed by tillage

T₅ - Burning of crop residues

T₆ - Zero tillage without nylon cage (open condition)

T₇ - Chemical management

The crop was sown in an area of 30 m² (6 m x 5 m) out of 55 m² area of each individual plot in the *khariif* season and crop was raised without any plant protection measures and remaining 25 m² of area was kept as fallow for subsequent crop in *rabi* season to know impact of the carry over. The variety used for sowing was GGV-05-01 (Gangavathi Sona) which was susceptible to the yellow stem borer. Before one month harvest of previous crop the subsequent *rabi* crop was sown in the fallow plots of 25m² area and further the nylon cage (6 x 11 m) was placed at time of sowing to avoid escape of YSB from those particular treatments and further treatments were imposed after the harvest the previous crop (Plate 4).

Observation on incidence of stem borer was made on 10 hills by counting number of dead and total tillers at 30, 60 and 90 days after sowing and at pre-harvesting stage. The percent dead hearts or white ears were calculated using following formula as suggested by Singha and Pandey (1997).

$$\text{Per cent stem borer incidence} = \frac{\text{Number of dead hearts/ white ears}}{\text{Total number of plants/ panicles/ ear heads}} \times 100$$

The mean original data of percentage of dead heart and white ear damage was calculated as percentage reduction over control with the following formula (Abbott, 1925)

$$\text{Per cent reduction over control} = \frac{\text{Control} - \text{Treatment}}{\text{Control}} \times 100$$



Plate 4. Experimental field view of carryover of yellow stem borer on subsequent crop

3.3 To manage planthoppers by newer insecticides in dry direct seeded rice ecosystem

A field experiment was conducted at ARS Gangavathi to know the efficacy of novel insecticides on planthoppers under DSR ecosystem during *khariif* 2015. Crop was sown on 19th August 2015 using JGL-1798 variety in a Randomized block design (RBD) with 12 treatments and replicated thrice (Plate 5). The crop was raised by following all the recommended package of practices prescribed by University of Agricultural Sciences, Dharwad and Raichur in 2013 except plant protection measures. The treatments were imposed by Knapsack spray with hollow cone nozzle and 500 lit of spray solution per hectare was used.

Observations on numbers of BPH and WBPH were recorded on 10 randomly selected hills per plot one day before spray (DBS), 5, 10, and 15 days after each spray and further also presented as average number of insects per hill. The details of treatments for management of insect pests under DDSR system are mentioned in Table 1.

Table 1. Treatment details of newer insecticides used for management of planthoppers

Sl. No.	Insecticide	Trade name	g a.i/ha
T ₁	Pymetrozine 50% WG	Chess	200
T ₂	Ethiprole + Imidacloprid 80% WG	Glamore	100
T ₃	Dinotefuran 20% SG	Osheen	40
T ₄	Buprofezin 25% SC	Applaud	175
T ₅	Buprofezin 15% + Acephate 35% WP	Tapuz	625
T ₆	Acephate 50% + Imidacloprid 1.8% WG	Lancer Gold	300
T ₇	Triflumezopyrim 106% SC	RAB	25
T ₈	Flubendiamide 14% + Buprofezin 24% SC	Astro	96
T ₉	Flonicamid 50% WG	Ulala	35
T ₁₀	Acephate 75% SP	Hunk	600
T ₁₁	Imidacloprid 17.8% SL	Confidor	22.25
T ₁₂	Control	-	-



Plate 5. General experimental field view of bio efficacy of newer insecticides against plant hoppers under dry direct seeded rice ecosystem

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the present studies on documentation of insect pests and their natural enemies, influence of abiotic factors on incidence of insect pests and natural enemies, impact assessment of left over crop residue on stem borer damage incidence on subsequent crop and novel insecticidal approach for management of planthoppers were undertaken at Agricultural Research Station (ARS), Gangavathi, University of Agricultural Sciences, Raichur during 2015-16 are presented here under.

4.1 To document and compare the insect pests and natural enemies in dry direct seeded and transplanted rice ecosystem

Regular monitoring of the occurrence of insect pests and natural enemies complex of rice ecosystem was made from research plots of ARS, Gangavathi during 2015-16 in *kharif* season. The collection of insect pests and natural enemies was made through collection of specimens in the yellow pan trap placed in both DDSR and TPR rice ecosystem.

4.1.1 Incidence of the insect pests and natural enemies in transplanted and dry direct seeded rice ecosystem through yellow pan trap

4.1.1.1 Transplanted rice ecosystem

The categorization of different insect-pests and natural enemies was carried out and it was observed that nine insect-pests were recorded on the crop (Table 2). The recorded insect-pests belonged to three orders mainly Lepidoptera, Coleoptera and Homoptera (Table 2). Similarly, six natural enemies were recorded including both predators and parasitoids (Plate 6).

Among the insect pests trapped in yellow pan trap were leaf folder (*Cnaphalocrosis medinalis* (Guenee), yellow stem borer (*Scirpophaga incertulas* Walker), pink stem borer (*Sesamia inferens* (Walker)), rice hispa *Dicladispa armigera* (Olivier), rice skipper *Pelopida mathias* Fabricius, green leafhopper *Nephotettix virescens* (Distant), *Exitianus* sp. and unidentified Membracidae group.

Table 2. Incidence of insect pests and natural enemies fauna in dry direct seeded rice and transplanted rice ecosystem collected under yellow pan trap

Insect order	Family	Dry direct seeded rice	Transplanted rice
Lepidoptera	Pyralidae	<i>Scirpophaga incertulas</i> Walker <i>Cnaphalocrosis medinalis</i> (Guenee) <i>Cnaphalocrosis patnalis</i> (Bradley) <i>Sesamia inferens</i> (Walker)	<i>Scirpophaga incertulas</i> Walker <i>Cnaphalocrosis medinalis</i> (Guenee) <i>Cnaphalocrosis patnalis</i> (Bradley) <i>Sesamia inferens</i> (Walker)
	Hespiridae	<i>Pelopidas mathias</i> Fabricius	<i>Pelopidas mathias</i> Fabricius
Coleoptera	Chrysomellidae	-	<i>Dicladispa armigera</i> (Olivier)
Homoptera	Delphacidae	Member of Delphacid	Member of Delphacid
	Cicadellidae	<i>Nephotettix virescens</i> <i>Exitianus</i> sp.	<i>Nephotettix virescens</i> <i>Exitianus</i> sp.
	Membracidae	Member of Membracidae	Member of Membracidae
Natural enemies			
Hymenoptera	Chalcididae	-	<i>Brachymeria</i> sp.
	Encyrtidae	<i>Ooencyrtus</i> sp.	-
	Braconidae	Member of Braconidae	Member of Braconidae
	Trichogrammatidae	-	<i>Trichogramma</i> sp.
Hemiptera	Miridae	Member of Miridae	Member of Miridae
	Pentatomidae	Member of Pentatomidae	Member of Pentatomidae
Coleoptera	Coccinellidae	Member of Coccinellidae	Member of Coccinellidae

Six natural enemies were recorded belonging to Chalcididae (*Brachymeria* sp.), Braconidae, Trichogrammatidae, Pentatomidae, Miridae and Coccinellidae of which first three groups were recognised as parasitoids and rest three were predators (Plate 6).

4.1.1.2 Dry direct seeded rice ecosystem

Different insect-pests and natural enemies trapped under yellow pan trap were categorized systematically and results revealed nine insect-pests recorded on the crop (Table 2). The recorded insect-pests belonged to 3 orders *i.e.*, Lepidoptera, Coleoptera and Homoptera (Table 2). Similarly, five natural enemies were recorded including both predators and parasitoids.

Insect pests documented during the experimental periods were leaffolder (*C. medinalis* and *C. patnalis*), yellow stem borer (*S. incertulas*), pink stem borer (*S. inferens*), rice skipper, *P. mathias*, Delphacidae, green leaf hopper, *N. virescens*, *Exitianus* sp. and an unidentified membracidae (Plate 6).

Group of natural enemies included mainly *Ooencyrtus* sp. and members belonging to Encyrtidae, Braconidae, Coccinellidae, Miridae and Pentatomidae were noticed (Table 2).

4.1.2 Documentation of natural enemies of planthopper and leaffolder reared under laboratory condition

Few parasitoids of planthoppers and leaffolders emerged in laboratory from the field collected samples (Table 3). These were Trichogrammatidae, *Anagrus* sp (Mymaridae), *Gonatocerus* sp (Mymaridae) and *Camptoptera* sp from the planthopper eggs, whereas an unidentified Braconidae was noticed from leaffolder pupa (Plate 7 & 8).

4.1.3 Studies on dynamics of insect-pests and natural enemies in dry direct seeded rice *vis- a-vis* transplanted rice ecosystem under field condition

4.1.3.1 Brown Planthopper

Incidence of BPH was observed from 40 DAS and the peak population noticed at 60 DAS varied from 3.50 to 26.13 per hill. Lowest population of BPH (3.56/hill) was noticed in dry direct seeded rice under protected situation while the higher members were

Table 3. Natural enemies associated with of planthoppers and leaffolder

Insect order	Family	Scientific name	Host
Hymenoptera	Trichogrammatidae	-	-
	Mymaridae	<i>Anagrus</i> sp.	Emerged from planthopper eggs
	Mymaridae	<i>Gonatocerus</i> sp.	
	Mymaridae	<i>Camptoptera</i> sp.	
	Braconidae	-	Emerged from leaffolder



Plate 6. Natural enemies collected from the field (unidentified)



Plate 6 (Contd...) Natural enemies collected from the field (unidentified)



Plate 6 (Contd...) Natural enemies collected from the field (unidentified)



Plate 6 (Contd.....) Natural enemies collected from the field (unidentified)



Plate 6 (Contd.....) Natural enemies collected from the field (unidentified)

recorded in transplanted crop under unprotected condition (26.13/hill). The population of planthoppers recorded was more in unprotected conditions (7.75 and 26.13/hill in DDSR and TPR, respectively) of both the planting methods. Population of BPH increased till 90 DAS and later started declining (Table 4).

4.1.3.2 Whitebacked Planthopper

WBPH also started appearing from 40 DAS and the population varied from 3.56 to 44.08 per hill at 60 DAS and noticed to be peak second fortnight of October in crop season. Lowest population of WBPH (3.56/hill) was noticed in dry direct seeded rice followed by transplanted under protected conditions (12.89/hill). However, the population of planthoppers recorded was more in unprotected conditions of both the planting methods. The peak population of WBPH after 60 DAS started declining (Table 4).

4.1.3.3 Green leafhopper

Peak incidence of GLH was noticed at 60 DAS and remained there up to maturity (100 DAS) with a marginal incidence in all the four treatments, even though incidences started from 40 DAS. Among the different planting methods, the incidence level was comparatively high in transplanted rice in both protected and unprotected situations (4.75 and 6.83/hill) followed by dry direct seeded rice both protected and unprotected conditions (1.95 and 2.38/hill) at 60 DAS (Table 4).

4.1.3.4 Yellow stem borer

The maximum dead heart damage was observed under unprotected dry direct seeded (6.22%) and transplanted rice (3.80%) planting conditions, while, it was reduced to 3.08 and 2.02 per cent with protection at 60 DAS. At pre-harvest maximum white ear was noticed in dry direct seeded rice (7.27%) followed by transplanted rice (4.22%) under unprotected condition. There were significant differences in white ears includes among the planting methods (Table5).

4.1.3.5 Leaf folder

The leaf folder damage was highest under unprotected dry direct seeded (14.21%) and transplanted (4.94%) rice planting methods. However, in protected condition the damage was reduced to 3.48 and 1.83 per cent in dry direct seeded and transplanted rice respectively at 90 DAS (Table 6).

Table 4. Incidence of planthoppers and leafhoppers in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

Treatment	Brown planthoppers/hill at different crop stages*				Whitebacked planthoppers/hill at different crop stages*				Green leafhopper/hill at different crop stages			
	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
Dry direct seeded rice under unprotected condition	2.84 (1.96)	7.75 (2.94)	5.02 (2.45)	2.93 (1.98)	2.92 (1.98)	11.38 (3.51)	5.14 (2.46)	1.08 (1.44)	0.46 (1.21)	2.38 (1.83)	1.56 (1.60)	0.98 (1.40)
Dry direct seeded rice under protected condition	1.98 (1.72)	3.50 (2.06)	2.64 (1.91)	0.94 (1.39)	1.34 (1.52)	3.56 (2.13)	2.16 (1.77)	0.86 (1.36)	0.23 (1.11)	1.95 (1.72)	1.14 (1.43)	0.80 (1.34)
Transplanted rice under unprotected condition	9.66 (3.25)	26.13 (5.19)	16.27 (4.14)	10.29 (3.34)	16.54 (4.16)	44.08 (6.71)	14.35 (3.91)	3.39 (2.09)	5.18 (2.47)	6.83 (2.78)	3.58 (2.13)	1.95 (1.72)
Transplanted rice under protected condition	4.88 (2.41)	11.24 (3.45)	7.01 (2.80)	6.73 (2.76)	7.76 (2.92)	12.89 (3.69)	4.95 (2.43)	2.68 (1.92)	2.93 (1.98)	4.75 (2.39)	2.27 (1.80)	0.98 (1.41)
S.Em±	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
CD (@ = 0.05)	0.3	0.5	0.5	0.4	0.5	0.5	0.4	0.3	0.3	0.3	0.4	0.2
CV (%)	9.66	9.53	10.25	11.75	12.98	9.58	10.25	11.28	11.32	10.52	14.85	10.28

*Mean of 10 hills, DAS: Day after sowing/transplanting

Figures in parenthesis are square root transformed ($\sqrt{x + 1}$) values

Table 5. Incidence of yellow stem borer in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

Treatment	Per cent dead heart in different crop stages*			Per cent white ear at pre harvest
	50 DAS	60 DAS	70 DAS	
Dry direct seeded rice unprotected condition	2.13 (8.33)	6.22 (14.30)	3.00 (9.76)	7.27 (15.60)
Dry direct seeded rice protected condition	1.50 (6.98)	3.08 (10.09)	2.00 (8.10)	3.43 (10.64)
Transplanted rice unprotected condition	0.85 (5.24)	3.80 (11.09)	1.44 (6.81)	4.22 (11.60)
Transplanted rice protected condition	0.79 (4.95)	2.02 (8.10)	1.08 (5.88)	2.10 (8.31)
S.Em±	0.5	0.7	0.7	0.8
CD (p= 0.05)	1.4	2.0	2.1	2.4
CV (%)	16.48	13.37	20.40	14.94

* Mean of 10 hills DAS: Day after sowing/transplanting

Figures in parenthesis are arc sin transformed values

Table 6. Incidence of leaffolder in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

Treatment	Per cent leaffolder damage at different crop stages*			
	50 DAS	70 DAS	90 DAS	110 DAS
Dry direct seeded rice under unprotected condition	1.17 (6.18)	5.45 (13.45)	14.21 (22.11)	12.53 (20.69)
Dry direct seeded rice under protected condition	0.61 (4.41)	2.33 (8.69)	3.48 (10.73)	3.05 (9.75)
Transplanted rice under unprotected condition	0.12 (1.50)	2.59 (9.24)	4.94 (12.76)	4.64 (12.38)
Transplanted rice under protected condition	0.20 (1.61)	1.34 (6.64)	1.83 (7.75)	1.54 (7.03)
S.Em±	0.3	0.5	0.5	0.8
CD (p= 0.05)	0.8	1.6	1.5	2.4
CV (%)	15.83	11.94	9.05	14.11

* Mean of 10 hills DAS: Day after sowing/transplanting

Figures in parenthesis are arc sin transformed value

Table 7. Incidence of predators in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

Treatment	Mirid bugs per hill at different crop stages*				Spider per hill at different crop stages*			
	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
Dry direct seeded rice under unprotected condition	0.10 (1.05)	0.72 (1.31)	0.97 (1.40)	0.31 (1.15)	0.48 (1.22)	2.17 (1.78)	1.28 (1.51)	1.10 (1.45)
Dry direct seeded rice under protected condition	0.10 (1.05)	0.43 (1.19)	0.55 (1.24)	0.22 (1.11)	0.30 (1.14)	1.26 (1.50)	1.18 (1.47)	0.87 (1.37)
Transplanted rice under unprotected condition	2.20 (1.78)	8.92 (3.14)	7.69 (2.95)	5.12 (2.45)	3.05 (2.01)	3.82 (2.18)	2.18 (1.77)	1.98 (1.72)
Transplanted rice under protected condition	1.81 (1.67)	5.44 (2.51)	2.54 (1.88)	2.14 (1.77)	2.12 (1.77)	2.02 (1.74)	1.60 (1.61)	0.72 (1.31)
S.Em±	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CD (p= 0.05)	0.2	0.3	0.3	0.2	0.3	0.2	0.2	0.2
CV (%)	9.63	11.11	10.59	15.08	10.79	10.09	9.32	12.25

*Mean of 10 hills, DAS: Day after sowing/transplanting
 Figures in parenthesis are ($\sqrt{x + 1}$) transformed values

Table 8. Correlation between paddy insect pests and their natural enemies with weather parameters in transplanted paddy ecosystem under unprotected condition during *kharif*, 2015-16

Sl. No.	Insect pests and its natural enemies	Micro climate weather parameters			Station observatory weather parameters				
		Relative humidity (%)	Temperature (°C)	CO ₂ (ppm)	Temperature (°C)		Rainfall (mm)	Morning RH (%)	Evening RH (%)
					Maximum	Minimum			
1	Brown planthopper	-0.328	0.631*	0.613*	0.577*	0.001	-0.319	-0.437	-0.546
2	White backed planthopper	0.002	0.594*	0.526	0.608*	0.568	0.150	-0.393	0.028
3	Green leafhopper	-0.370	0.600*	0.566	0.619*	0.482	0.70	-0.413	-0.058
4	Yellow stem borer	0.026	-0.609*	-0.585*	-0.713**	-0.471	-0.169	0.460	-0.157
5	Leaffolder	0.224	-0.323	-0.115	-0.246	0.019	0.083	0.245	0.162
6	Spiders	0.161	0.577*	0.474	0.648*	0.627*	0.018	-0.264	0.084
7	Mirid bug	-0.339	0.588*	0.769**	0.617*	-0.181	-0.453	-0.450	-0.603*

* – Significant at 0.05

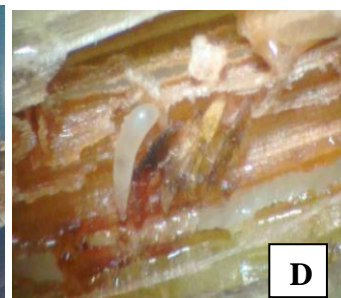
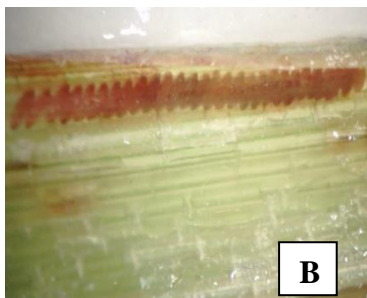
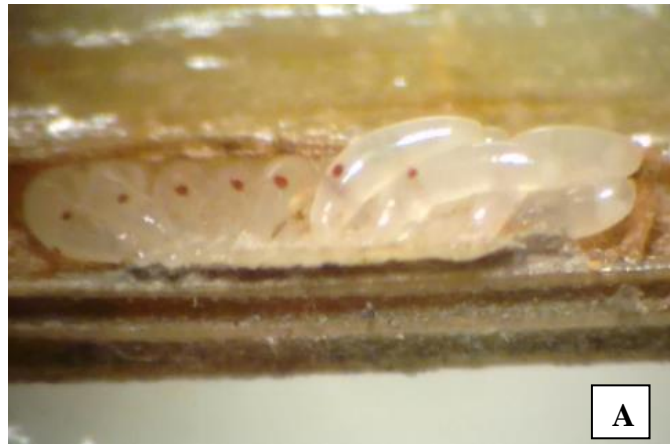
** – Significant at 0.01

4.1.3.6 Natural enemies

Among the predators spiders and mirid bugs were found abundant at ARS, Gangavathi. The data documented are presented in the Table 7.

Spiders population was noticed from 40 days old crop to maturity varying from 0.30 to 3.05 per hill (Table 7). Spider population increased gradually and attained peak at 60 days sown crop. It was maximum in transplanted unprotected condition (3.82/hill) followed by dry direct seeded unprotected condition (2.17 /hill) at 60 DAS. The spider count was very low in dry direct seeded (1.26 /hill) followed by transplanted (2.02/ hill) rice under protected condition at 60 DAS (Table 7).

Mirid bug activity started from last week of September and continued till crop harvest with a population varied from 0.1 to 1.0 per hill in dry direct seeded and 1.83 to 2.20/hill in rice ecosystems (Table 7). The populations of mirids reached peak in transplanted rice (8.92/hill) followed by dry direct seeded rice (0.72/hill) under unprotected condition at 60 DAS and 80 DAS respectively.



A) Healthy planthopper eggs
C) Parasitisation by *Oligosita*
E) Adult *Trichogramma*

B) Parasitisation by *Anagrus*
D) Parasitisation by *Gonatocerus*
F) Adult *Anagrus*

Plate 7. Natural enemies associated with planthoppers



Plate 8. Parasitoids emerged from the leaffolder pupa under laboratory condition (Unidentified)

4.1.4 Activity of pest and their natural enemies in relation to weather parameters under transplanted and dry direct seeded rice ecosystem

The dynamics of insect pests and natural enemies of paddy was assessed at ARS, Gangavathi during 2015-16 under DDSR and TPR ecosystem using popular rice variety JGL-6018. The activity of both pest and natural enemies were correlated with weather parameters and presented as below.

4.1.4.1 Activity of pest and their natural enemies in relation to weather parameters under transplanted unprotected condition

The results on the correlation studies made between paddy insect-pests and weather parameters are presented in the Table 8.

4.1.4.1.1 Brown planthopper

The correlation studies made between BPH incidence and microclimate observations revealed that activity of BPH had negative non-significant correlation with relative humidity (-0.328), while, it was significant positive relationship with temperature (0.631) and carbon dioxide (0.613). Similarly, when activity of BPH correlated with station observatory, it showed a significant positive relationship with maximum temperature (0.577) and positive non-significant correlation with minimum temperature (0.001). A non-significant negative correlation was noticed with rainfall (-0.319), morning relative humidity (-0.437) and evening relative humidity (-0.54) (Table 8).

4.1.4.1.2 Whitebacked planthopper

Activity of WBPH in relation to microclimate weather parameter revealed positive non-significant relationship with relative humidity (0.002) and significant positive relationship with temperature (0.594). The correlation with carbon dioxide (0.526) was positive but non-significant. Similarly, incidence of WBPH in relation to station observatory weather parameter exhibited significant positive relationship with maximum temperature (0.608) and non-significant positive relationship with minimum temperature (0.568), rainfall (0.150) and evening relative humidity (0.028). Further, population level showed negative but non-significant relationship with morning relative humidity (-0.393) (Table 8).

4.1.4.1.3 Green leafhopper

Correlation between GLH with microclimate weather factors revealed negative and non-significant association with relative humidity (-0.37). However, temperature found to be significantly positive correlated (0.594) while, carbon dioxide showed non-significant positive relationship. GLH population showed positive and significant correlation with maximum temperature (0.619) but a non-significant positive relationship with minimum temperature (0.568) and rainfall (0.150). Further statistically non-significant negative correlation was observed with morning (-0.143) and evening relative humidity (-0.058) (Table 8).

4.1.4.1.4 Yellow stem borer

Yellow stem borer incidence revealed positively non-significant relation with relative humidity (0.026). However, statistically significant but negative correlation was noticed with temperature (-0.609) and carbon dioxide (-0.585). Correlation between station observatory weather parameters with yellow stem borer was found to be significant negative relation with maximum temperature (-0.713) but non-significant negative relationship with minimum temperature (-0.417), rainfall (-0.169) and evening relative humidity (-0.157). It was found to be positively non-significant with morning relative humidity (0.460) (Table 8).

4.1.4.1.5 Leaffolder

Impact of microclimate weather factors on leaffolder incidence was presented in table 5 and the results revealed that relative humidity (0.224) had positive non-significant impact on incidence of leaffolder, whereas, negative non-significant correlation was observed with temperature (-0.323) and carbon dioxide (-0.115). Further, leaffolder incidence exhibited negatively non-significant relation with maximum temperature (-0.246). However, minimum temperature (0.019), rainfall (0.083), morning relative humidity (0.245) and evening relative humidity (0.162) were found to have positive non-significant relationship with leaffolder incidence (Table 8).

4.1.4.1.6 Spider

The relation between spider population and microclimate parameters were noticed and which exerted a positively non-significant correlation with relative humidity (0.161) and carbon dioxide (0.474) but statistically significant and positive relationship with temperature (0.577). Further spider population in relation to station observatory weather parameters was

found significant positive correlation with maximum temperature (0.648) and minimum temperature (0.627). However, non-significant positive correlation was noticed with rainfall (0.018) and evening relative humidity while non-significant negative correlation was observed with morning relative humidity (-0.264) (Table 8).

4.1.4.1.7 Mirid bug

Activity of predatory mirid bug in relation to microclimate weather parameter was assessed and presented in table 8. Correlation with relative humidity was found negative and non-significant (-0.339) however, significant positive relationship was noticed with temperature (0.617). Carbon dioxide (0.769) showed a significant positive correlation with activity of mirid bug population. The correlation between mirid bug and station observatory weather parameters revealed that maximum temperature (0.617), was significantly positive but non-significant while negative relationship was observed with minimum temperature (-0.181), rainfall (-0.453) and morning relative humidity (-0.450). There was significant negative correlation with evening relative humidity (-0.603) (Table 8).

4.1.4.2 Activity of pest and their natural enemies in relation to weather parameters under Transplanted protected condition

4.1.4.2.1 Brown planthopper

The correlation studies on BPH incidence and microclimate observations revealed non-significant negative relationship with relative humidity (-0.514) and significant positive relationship with carbon dioxide (0.613). However temperature (0.631) had non-significant positive correlation. Similarly, correlation between population of BPH and station observatory weather parameters exerted non-significant positive relationship with maximum temperature (0.422) and minimum temperature (0.27). A non-significant negative association was noticed with rainfall (-0.202), morning relative humidity (-0.286) and evening relative humidity (-0.377) (Table 9).

4.1.4.2.2 Whitebacked planthopper

The correlation studies between WBPH incidence and microclimate observations revealed the non-significant negative relationship with relative humidity (0.002) and non-significant positive relationship with temperature (0.491) and carbon dioxide (0.619). WBPH population level and station observatory weather parameters had shown non-significant

positive relationship with maximum temperature (0.433), minimum temperature (0.549), rainfall (0.150) and evening relative humidity (0.216). Further morning relative humidity (-0.216) was found non-significant negative correlation with WBPH incidence (Table 9).

4.1.4.2.3 Green leafhopper

The correlation between microclimate and GLH incidence revealed the non-significant negative relation with relative humidity (-0.577). However, both temperature (0.733) and carbon dioxide (0.675) had exhibited significant positive with GLH populations. Similarly GLH population and station observatory weather parameter correlation exerted significant positive relationship with maximum temperature (0.766) but non-significant positive association with minimum temperature (0.549). Whereas, non-significant negative correlation with rainfall (-0.0263), morning relative humidity (-0.557) and evening relative humidity (-0.209) (Table 9).

4.1.4.2.4 Yellow stem borer

The correlation between yellow stem borer incidence and microclimate weather observation showed non-significant positive relation with relative humidity (0.173) and significant negative correlation with temperature (-0.609). However, carbon dioxide (-0.585) exhibited negative non-significant relationship with yellow stem borer incidence. Similarly, yellow stem borer incidence with station observatory weather parameters exerted significant negative correlation with maximum temperature (-0.633) and minimum temperature (-0.695). Further, evening relative humidity (-0.259) and rainfall (-0.209) exhibited non-significant negative correlation. However, morning relative humidity (0.326) found to have non-significant positive (Table 9).

4.1.4.2.5 Leaffolder

The result revealed that non-significant positive correlation was noticed with relative humidity (0.173) but non-significant negative correlation was found with temperature (-0.317) and carbon dioxide (-0.072). Further correlation between leaffolder incidence with station weather parameters exhibited non-significant negative relationship with maximum temperature (-0.099). However, minimum temperature (0.238), rainfall (0.160), morning relative humidity (0.528) and evening relative humidity (0.319) were showed to be non-significant positive relationship with leaffolder incidence (Table 9).

Table 9. Correlation between paddy insect pests and their natural enemies with weather parameters in transplanted paddy ecosystem under protected condition during *kharif*, 2015-16

Sl. No.	Insect pests and its natural enemies	Micro climate weather parameters			Station observatory weather parameters				
		Relative humidity (%)	Temperature (°C)	CO ₂ (ppm)	Temperature (°C)		Rainfall (mm)	Morning RH (%)	Evening RH (%)
					Maximum	Minimum			
1	Brown planthopper	-0.514	0.374	0.590*	0.422	0.270	-0.202	-0.286	-0.377
2	White backed planthopper	-0.171	0.491	0.619	0.433	0.549	0.263	-0.216	0.216
3	Green leafhopper	-0.577	0.733**	0.675*	0.766**	0.387	-0.028	-0.557	-0.209
4	Yellow stem borer	0.173	-0.636*	-0.482	-0.633*	-0.695*	-0.209	0.326	-0.259
5	Leaffolder	0.317	-0.317	-0.072	-0.099	0.238	0.160	0.528	0.319
6	Spiders	0.121	0.383	0.241	0.416	0.709**	0.165	-0.074	0.366
7	Mirid bug	-0.466	0.656*	0.565	0.648*	0.208	-0.242	-0.405	-0.392

* – Significant at 0.05

** – Significant at 0.01

4.1.4.2.6 Spider

The correlation between microclimate weather parameters and spider population exhibited non-significant positive association with relative humidity, temperature and carbon dioxide (0.121, 0.383 and 0.474 respectively). Subsequently spider population with station weather parameters were found to have non-significant positive correlation with maximum temperature (0.416), rainfall (0.165) and evening relative humidity (0.366). However, significant positive association was noticed with minimum temperature (0.709), whereas, morning relative humidity (-0.074) found to be non-significant negative association (Table 9).

4.1.4.2.7 Mirid bug

The correlation between microclimate weather observations and predatory mired bug population showed non-significant negative relation with relative humidity (-0.466). Whereas, temperature (0.656) had significant positive association. However, carbon dioxide (0.769) exerted non-significant positive correlation with incidence of mired bug population. Similarly, influence of station weather parameter on activity of mirid bug exhibited significant positive relation with maximum temperature (0.648) and non-significant negative association with minimum temperature (-0.181), rainfall (-0.453), morning relative humidity (-0.074) and evening relative humidity (-0.392) (Table 9).

4.1.4.3 Activity of pest and their natural enemies in relation to weather parameters under dry direct seeded rice unprotected condition

4.1.4.3.1 Brown planthopper

Influence of microclimate on BPH incidence was assessed and revealed non-significant negative relationship with relative humidity (-0.520). However, significant positive relationship was noticed with temperature (0.662) and carbon dioxide (0.614). Similarly, association of BPH population and station weather parameters exerted a significant positive relationship with maximum temperature (0.719) but minimum temperature (0.27) had non-significant positive correlation, whereas a non-significant negative association with rainfall (-0.240), morning relative humidity (-0.588) and evening relative humidity (-0.448) (Table 10).

4.1.4.3.2 Whitebacked planthopper

The correlation studies on WBPH incidence and microclimate observations revealed non-significant negative association with relative humidity (-0.376) and significant positive relationship with temperature (0.628) and carbon dioxide (0.668). Similarly correlation between WBPH population level and station weather parameters showed significant positive relationship with maximum temperature (0.726). But non-significant positive correlation with minimum temperature (0.150). However morning relative humidity (-0.537), evening relative humidity (-0.531) and rainfall (-0.137) were found to have negative and non-significant relationship with WBPH population (Table 10).

4.1.4.3.3 Green leafhopper

The microclimate weather parameters on GLH population incidence exhibited non-significant negative correlation with relative humidity (-0.331) whereas, temperature showed non-significant positive correlation (0.628). However, carbon dioxide (0.668) was correlated significant positive with GLH populations. Similarly, correlation between GLH population and station weather parameters exerted a significant positive correlation with maximum temperature (0.766) but positive and non-significant association with minimum temperature (0.549). However, statistically non-significant and negative correlation with rainfall (-0.0263), morning relative humidity (-0.557) and evening relative humidity (-0.209) (Table 10).

4.1.4.3.4 Yellow stem borer

The correlation between yellow stem borer incidence and microclimate weather parameters had exhibited a non-significant positive relation with relative humidity (0.370) and carbon dioxide (0.700). Further statistically non-significant and negative correlation with temperature (-0.435). Similarly, yellow stem borer incidence and station weather parameters exerted a non-significant negative relation with maximum temperature and minimum temperature (-0.384 and -0.057 respectively). Further, non-significant positive correlation with morning relative humidity (0.333), evening relative humidity (0.158) rainfall (0.070) (Table 10).

Table 10. Correlation between paddy insect pests and their natural enemies with weather parameters in dry direct seeded rice ecosystem under unprotected condition during *kharif*, 2015-16

Sl. No.	Insect pests and its natural enemies	Micro climate weather parameters			Station observatory weather parameters				
		Relative humidity (%)	Temperature (°C)	CO ₂ (ppm)	Temperature (°C)		Rainfall (mm)	Morning RH (%)	Evening RH (%)
					Maximum	Minimum			
1	Brown planthopper	-0.520	0.662*	0.614*	0.719**	0.144	-0.240	-0.558	-0.448
2	White backed planthopper	-0.376	0.628*	0.668*	0.726**	0.150	-0.137	-0.537	-0.531
3	Green leafhopper	-0.331	0.476	0.726**	0.549	0.007	-0.459	-0.321	-0.571
4	Yellow stem borer	0.370	-0.435	0.700	-0.384	-0.057	0.070	0.333	0.158
5	Leaffolder	0.289	-0.460	0.248	-0.551*	-0.382	-0.089	0.448	-0.067
6	Spiders	-0.255	0.581*	0.624*	0.613*	0.193	-0.287	-0.329	-0.392
7	Mirid bug	-0.116	0.157	0.890**	0.192	-0.452	-0.387	-0.254	-0.571

* – Significant at 0.05

** – Significant at 0.01

4.1.4.3.5 Leaffolder

The correlation between microclimate weather parameters and leaffolder incidence were revealed that non-significant positive relationship with relative humidity and carbon dioxide (0.289 and 0.248 respectively). Whereas, non-significant negative correlation was showed with temperature (-0.460). Further maximum temperature (-0.551), minimum temperature (-0.382), rainfall (-0.089) and evening relative humidity (-0.067) of station weather parameters were showed significant negative impact on leaffolder incidence but morning relative humidity had revealed positive non-significant impact (0.448) (Table 10).

4.1.4.3.6 Spider

The microclimate weather and spider population level correlation studies exerted a non-significant negative relation with relative humidity (-0.255). However, temperature (0.383) and carbon dioxide (0.474) were showed to be significant positive correlation with spider population level. Further, significant positive correlation noticed with maximum temperature (0.613) of station weather parameters but non-significant positive correlation was observed with minimum temperature (0.193). Subsequently, the spider population level found to be non-significant negative association with morning relative humidity (-0.329) and evening relative humidity (-0.392) and rainfall (-0.089) (Table 10).

4.1.4.3.7 Mirid bug

The association between a predatory mirid bug population and microclimate parameters were studied and showed non-significant negative correlation with relative humidity (-0.116). Whereas, significant positive association noticed with carbon dioxide (0.890) but temperature exerted a non-significant positive correlation (0.157). Similarly, correlation between station weather parameters and mirid bug population level observed and found significant positive relation with maximum temperature (0.192). Further non-significant negative effect observed with minimum temperature (-0.452), rainfall (-0.387), morning relative humidity (-0.254) and evening relative humidity (-0.571) (Table 10).

4.1.4.4 Activity of pest and their natural enemies in relation to weather parameters under dry direct seeded rice protected condition

4.1.4.4.1 Brown planthopper

The correlation between BPH incidence and microclimate weather parameter revealed non-significant negative relationship with relative humidity (-0.285) and however significant positive relationship had obtained with temperature (0.586), but carbon dioxide (0.614) had showed to be non-significant positive relationship. Similarly, correlation between station observatory weather parameters and BPH population exerted non-significant positive relationship with maximum temperature (0.501) and minimum temperature (0.109). Whereas, a non-significant negative association was noticed with rainfall (-0.238), morning relative humidity (-0.258), evening relative humidity (-0.294) (Table 11).

4.1.4.4.2 Whitebacked planthopper

The correlation studies between microclimate observation and WBPH incidence revealed non-significant negative relationship with relative humidity (-0.263). Further non-significant positive relationship with temperature and carbon dioxide (0.568 and 0.466 respectively). Similarly, the relation between station observatory weather parameters and WBPH population level showed positive and non-significant relationship with maximum temperature (0.504) and minimum temperature (0.348). Subsequently non-significant negative correlation with morning relative humidity (-0.204), evening relative humidity (-0.189) and rainfall (-0.142) (Table 11).

4.1.4.4.3 Green leafhopper

The correlation studies between GLH population and microclimate parameters revealed non-significant negative correlation with relative humidity (-0.357) whereas, temperature (0.555) had non-significant positive relation, but the carbon dioxide (0.755) was correlated significant positive relation. Similarly, non-significant positive association was showed with maximum temperature (0.468) of station weather parameters. Further, non-significant negative correlation with minimum temperature, rainfall, morning relative humidity and evening relative humidity (-0.060, -0.472, -0.272, -0.612 respectively) (Table 11).

Table 11. Correlation between paddy insect pests and their natural enemies with weather parameters in dry direct seeded rice ecosystem under protected condition during *kharif*, 2015-16

Sl. No.	Insect pests and its natural enemies	Micro climate weather parameters			Station observatory weather parameters				
		Relative humidity (%)	Temperature (°C)	CO ₂ (ppm)	Temperature (°C)		Rainfall (mm)	Morning RH (%)	Evening RH (%)
					Maximum	Minimum			
1	Brown planthopper	-0.285	0.586*	0.544	0.501	0.109	-0.238	-0.258	-0.294
2	White backed planthopper	-0.263	0.568	0.466	0.504	0.348	-0.142	-0.204	-0.189
3	Green leafhopper	-0.357	0.555	0.755**	0.468	-0.060	-0.472	-0.272	-0.612
4	Yellow stem borer	0.433	-0.305	0.103	-0.233	0.119	0.133	0.254	0.248
5	Leaffolder	0.366	-0.265	0.129	-0.164	-0.080	0.103	0.177	0.183
6	Spiders	0.005	0.089	0.520	-0.296	-0.440	-0.290	0.292	-0.347
7	Mirid bug	-0.042	0.220	0.766**	0.159	-0.616*	-0.450	-0.277	-0.629*

* – Significant at 0.05

** – Significant at 0.01

4.1.4.4.4 Yellow stem borer

The correlation between microclimate weather parameters and yellow stem borer incidence exhibited non-significant positive relation with relative humidity and carbon dioxide (0.433 and 0.103 respectively). Further, non-significant negative correlation was found with temperature (-0.305). Similarly, with station observatory weather parameters exerted a non-significant negative relation with maximum temperature (-0.233). Further, non-significant positive correlation was noticed with minimum temperature (0.119), morning relative humidity (0.0254), evening relative humidity (0.248) and rainfall (0.133) (Table 11).

4.1.4.4.5 Leaffolder

The correlation studies between microclimate weather parameter and leaffolder incidence were revealed non-significant positive relationship with relative humidity and carbon dioxide (0.366 and 0.129 respectively). Whereas, non-significant negative association was showed with temperature (-0.265). Similarly, leaffolder incidence and station observations weather parameters exerted significant negative relationship with maximum temperature (-0.164), minimum temperature (-0.080) whereas, rainfall (0.103), morning relative humidity (0.177) and evening relative humidity (0.183) showed positive non-significant (Table 11).

4.1.4.4.6 Spider

The association between spider population and microclimate weather parameters exerted non-significant positive correlation with relative humidity and temperature and carbon dioxide (0.005, 0.89 and 0.520 respectively). Further, non-significant negative correlation was observed with maximum temperature, minimum temperature, rainfall and evening relative humidity (-0.296, -0.440, -0.292 and -0.347 respectively) of station observatory weather parameters. Further, morning relative humidity (0.292) was found to have non-significant positive relationship with spider population (Table 11).

4.1.4.4.7 Mirid bug

The association of microclimate weather parameters and of a predatory mirid bug population was studied and results revealed that non-significant negative correlation with relative humidity (-0.042). Whereas, non-significant positive association was noticed with temperature (0.89) but carbon dioxide (0.520) was found to have significant positive impact

with predatory bug population. Similarly relationship between predatory mirid bug population and station weather parameters exhibited non-significant positive relation with maximum temperature (0.192). Further significant negative impact was noticed with minimum temperature, evening relative humidity (-0.616 and -0.629 respectively). Rainfall (-0.450) was found to have non-significant negative impact with the predatory bug population (Table 11).

4.1.5 Correlation between insect pests of rice monitored through light trap and weather parameters during 2015-16

The results of the correlation studies made between paddy insect-pests and weather parameters are presented in the Table 15.

4.1.5.1 Planthopper

The population trend of BPH increased from 36th week onwards with peak trap catches of 3309 hoppers during 42nd standard week. Similarly, WBPH populations through light trap catches ranged from 31.25 to 3489.69 with peak activity during 42nd standard week (3489.69) and the population declined after second fortnight of October (Table 12).

It was evident from the data (Table 13) that the correlation studies made between BPH, WBPH and weather parameters revealed non-significant negative relationship with maximum temperature (-0.180 and -0.148 respectively), minimum temperature (-0.119 and -0.094 respectively) and total rainfall (-0.072 and -0.034 respectively). Further, the activity of planthopper exerted significant positive association with morning relative humidity (0.310 and 0.284 respectively) and evening relative humidity (0.304 and 0.312 respectively).

4.1.5.2 Green leafhopper

The activity of *Nephotettix virescens* and *Nephotettix nigropictus* were noticed with peak activity at 47th and 49th standard week. (108.00 and 157.71/trap/week respectively). Whereas, lowest population of 4.43 and 1.43/trap/week was recorded during 23rd standard week, respectively. Maximum population was noticed during the month of November (Table 12).

The results of the correlation studies between populations of green leafhopper (*N. virescens*) and weather factors revealed significant negative correlation with maximum temperature and minimum temperature (-0.449 and -0.444 respectively). Whereas, rainfall (-0.130) had non-significant negative correlation with GLH. However, it showed significant

Table 12. Light trap catches of insect pests of rice at ARS, Gangavathi during 2015-16

Standard week	Brown planthopper	White backed planthopper	Green leafhopper		Yellow stem borer moth	Leaf folder moth
			<i>Nephotettix virescens</i>	<i>Nephotettix nigropictus</i>		
1	99.71	85.00	45.14	42.29	11.43	15.43
2	92.57	68.14	32.71	29.43	5.71	12.43
3	102.25	88.58	48.43	38.86	6.00	9.57
4	108.25	101.2	22.43	15.43	4.57	6.29
5	111.43	155.69	19.29	13.43	4.43	7.29
6	203.43	120.36	18.71	16.00	7.14	5.71
7	317.71	299.65	22.29	15.57	4.57	4.71
8	320.5	367.57	26.00	16.71	11.43	13.86
9	319.8	417.14	35.67	26.71	10.57	15.14
10	559.43	541.14	27.29	21.86	8.14	24.00
11	634.00	598.86	45.29	28.29	15.43	31.14
12	706.86	676.00	42.57	29.14	17.71	32.57
13	620.00	560.29	34.86	21.00	34.57	36.86
14	810.00	784.43	38.29	21.71	57.86	38.71
15	853.86	609.85	31.29	21.00	92.28	53.43
16	890.36	681.25	30.14	24.29	82.43	41.86
17	895.68	699.25	18.86	13.57	85.29	37.71
18	890.25	701.23	16.00	9.71	66.00	25.14
19	891.24	640.2	10.29	7.57	49.43	17.00
20	555.57	347.57	7.57	10.71	46.00	5.43
21	590.23	370.58	9.00	5.57	29.72	1.71
22	253.47	258.96	4.71	3.43	10.43	2.29
23	194.00	147.25	4.43	1.43	8.15	2.00
24	166.39	120.36	13.71	8.14	9.14	1.43
25	109.71	113.29	8.43	2.57	4.58	0.86
26	116.71	87.29	12.86	7.14	2.28	2.43

Table 12. Contd.....

Standard week	Brown planthopper	White backed planthopper	Green leafhopper		Yellow stem borer moth	Leaf folder moth
			<i>Nephotettix virescens</i>	<i>Nephotettix nigropictus</i>		
27	58.29	59.86	12.29	11.14	2.00	1.57
28	20.14	31.29	4.86	2.57	1.28	0.86
29	23.71	31.25	5.43	2.71	1.42	1.29
30	60.25	37.86	5.43	3.00	6.00	1.43
31	50.25	83.00	6.57	4.14	6.29	0.71
32	40.25	103.57	17.00	10.29	4.58	1.43
33	50.25	147.71	9.86	6.71	6.57	1.43
34	116.00	109.14	15.29	7.86	10.57	2.86
35	191.29	195.71	15.71	9.86	5.00	2.14
36	180.25	323.14	16.86	11.43	5.86	3.57
37	447.29	782.25	29.71	22.14	12.72	5.43
38	1064.43	995.43	59.00	36.29	13.43	16.14
39	1721.14	1802.57	55.71	60.71	15.57	9.57
40	2580.86	2673.86	89.57	87.86	21.43	16.86
41	3305.00	3481.14	117.00	97.86	11.86	33.57
42	3309.56	3489.69	103.71	92.29	17.86	72.29
43	2985.57	3164.00	83.71	77.00	16.57	105.29
44	2736.14	1987.00	77.00	69.71	21.57	108.00
45	2611.29	1777.00	69.14	69.71	37.28	121.00
46	2398.71	1636.14	93.29	83.43	30.72	129.00
47	2208.57	1536.00	108.00	119.29	57.57	131.00
48	1855.71	1372.29	106.14	145.00	44.86	125.14
49	1401.14	1195.86	87.29	157.71	33.43	103.00
50	1322.5	1099.00	71.86	123.43	23.57	81.71
51	1021.25	780.71	55.71	58.57	9.00	55.14
52	722.29	560.00	15.14	12.71	11.72	25.00

Table 13. Correlation between insect pests of paddy trapped under light traps with weather parameters at ARS, Gangavathi during 2015-16

Weather parameter	Brown plant hopper	White backed planthopper	Green leafhopper		Yellow stem borer moth	Leaffolder moth
			<i>Nephotettix virescens</i>	<i>Nephotettix nigropictus</i>		
Maximum temperature (°C)	-0.180	-0.148	-0.449**	-0.444**	0.305*	-0.335*
Minimum temperature (°C)	-0.119	-0.094	-0.254	-0.262	-0.054	-0.250
Rainfall (mm)	-0.079	-0.034	-0.130	-0.128	0.218	-0.140
Morning relative humidity (%)	0.310*	0.284*	0.463**	0.487**	0.108	0.379**
Evening relative humidity (%)	0.304*	0.312*	0.388**	0.347*	-0.073	0.208

* – Significant at 0.05

** – Significant at 0.01

positive correlation with morning relative humidity and evening relative humidity (0.463 and 0.388 respectively) for the light trap catches of green leafhopper. Whereas, correlation between *N. nigropictus* and weather factors revealed that significant negative correlation with maximum temperature (-0.444) and non-significant negative correlation with minimum temperature (-0.262) and average rainfall (-0.128). Further, it showed significant positive correlation with morning relative humidity (-0.487) and evening relative humidity (0.347) (Table 13).

4.1.5.3 Yellow stem borer

Population of yellow stem borer (YSB) moth through light trap per week catches ranged from 1.27 to 92.28 during 2015-16. Moth catches under light trap were initiated from first week of March with 10/trap/week and showed increasing trend up to 15th standard week, but later declined after May month (Table 12).

It is evident from the data that maximum temperature had a significant positive correlation (0.305) on trap catches of yellow stem borer moths (Table 15). Whereas, minimum temperature and evening relative humidity (-0.054 and -0.073 respectively) had non-significant negative relationship on activity of yellow stem borer however, non-significant positive relationship was noticed with rainfall (0.218) and morning relative humidity (0.108) (Table 13).

4.1.5.4 Leaffolder

The population of leaffolder was found to have increasing trend from 42nd standard week with peak activity at 47th week. Over the year the population ranged from 0.71 to 131.00/trap/week moths during 31st and 47th meteorological standard week (Table 12).

Leaffolder population showed significant negative correlation with maximum temperature (-0.335) but non-significant negative relationship with minimum temperature (-0.250) and total rainfall (-0.140). However, significant positive correlation with morning relative humidity (0.463) and non-significant positive correlation with evening relative humidity (0.208) was noticed (Table 13).

4.1.6 Population dynamics of natural enemies of planthoppers in transplanted and dry direct seeded rice ecosystem

Some of the members of families including Drynidae, Mymaridae, Encyrtidae, Eulophidae, Pteromalidae, Scelionidae and Trichogrammatidae in Hymenopteran order are the important parasitoids of planthoppers. Among them *Anagrus* sp. belonging to family Mymaridae, *Oligosita* sp, Trichogrammatidae, followed by *Gonatocerus* sp belonging to Mymaridae are major parasitoids. Hence, dynamics of egg parasitoids were studied at TBP area under TPR and DDSR ecosystem and presented as below.

4.1.6.1 Per cent parasitisation recorded at 50 days after transplanting in transplanted and 50 days after sowing in dry direct seeded rice

Three species of hymenopteran egg parasitoids, *Anagrus* sp, *Oligosita* sp and *Gonatocerus* sp emerged from parasitized eggs reared under laboratory. The data in the Table 11 showed that overall per cent egg parasitisation was found to have significant less under DDSR unprotected condition (9.23%) compared to transplanted unprotected condition (21.56%) indicated by a significant t-value 2.32. Among the egg parasitoids, *Anagrus* sp. was found to be predominant parasitoid (77.42%) compared to other parasitoids viz., *Oligosita* (25.4%) and *Gonatocerus* (8.8%) at 50 DAT in transplanted unprotected condition. Similar, trend was noticed under unprotected DDSR system at 50 DAS, wherein, *Anagrus* accounted for 55.33 per cent egg parasitisation followed by *Oligosita* sp. (40%) and *Gonatocerus* (6.67%).

Significant difference between activity of egg parasitoids under transplanted and DDSR system was obtained only with *Anagrus* sp. (2.00). The activity of *Oligosita* and *Gonatocerus* did not differ significantly between DDSR and TPR system (Table 14).

4.1.6.2 Per cent parasitisation recorded at 70 days after transplanting in transplanted and 70 days after sowing in dry direct seeded rice

Significantly less egg parasitisation of 8.71 per cent was observed under DDSR unprotected condition compared to transplanted unprotected condition (22.20%). Among the egg parasitoids, *Anagrus* found to be predominant parasitoid accounting for 65.79 per cent of parasitisation of total parasitized eggs followed by *Oligosita* (27.63%) and *Gonatocera* (6.58%) under transplanted condition. Under DDSR unprotected condition

Anagrus sp. accounted for 58.33 per cent parasitisation compared to 33.33 per cent by *Oligosita* and 8.33 per cent by *Gonatocera* (Table 14).

Among parasitoid species, parasitisation due to *Anagrus* sp. differed significantly between transplanted and DDSR ecosystem, while rest of two species did not vary significantly.

4.1.6.3 Per cent parasitisation recorded at 90 days after transplanting in transplanted and 90 days after sowing in dry direct seeded rice

TPR registered more per cent egg parasitisation of 9.37 per cent than DDSR (6.26%), however both were statistically at par.

Activity of *Anagrus* sp. was found to be more accounting for 75.00 per cent of egg parasitisation of under TPR ecosystem and it was followed by *Oligosita* sp. (25.00%), while the activity of *Gonatocerus* sp. was nil. Similarly, under DDSR activity of *Anagrus* sp. was more accounting for 83.33 percent of parasitisation followed by *Oligosita* sp. (16.66%), while activity of *Gonatocerus* sp. was nil (Table 14).

Overall seasonal activity of natural enemies also depicted the similar trend. Seasonal mean egg parasitisation was significantly more in transplanted unprotected condition (17.71%) compared to DDSR unprotected condition (8.06%). Again significant variation was observed in the activity of *Anagrus* sp. which accounted for 72.73 per cent parasitisation of parasitized egg in TPR system compared to 64.99 per cent in DDSR system. This was followed by *Oligosita* but no significant variation was observed between TPR (29.99%) and DDSR (23.45%). Activity of *Gonatocerus* sp. was less in both TPR and DDSR (5.00 and 3.80% respectively) (Table 14).

4.2 To know the impact of left over crop residues on stem borer incidence for subsequent crop

Per cent damage caused by the stem borer emerged from left over crop residues was assessed for which the seven different treatments were formulated. The yield loss due to the damage caused by the stem borer is presented in the table 15.

Table 14. Dynamics of egg parasitoids of planthoppers in transplanted and dry direct seeded rice ecosystem at ARS, Gangavathi during 2015-16

Planting system	Parasitization by <i>Anagrus</i> (%)				Parasitization by <i>Oligosita</i> (%)				Parasitization by <i>Gonetocera</i> (%)				Total egg parasitisation (%)			
	50 DAS	70 DAS	90 DAS	Mean	50 DAS	70 DAS	90 DAS	Mean	50 DAS	70 DAS	90 DAS	Mean	50 DAS	70 DAS	90 DAS	Mean
Transplanted unprotected	77.42	65.79	75.00	72.73	17.74	27.63	25.00	23.45	4.84	6.58	0.00	3.80	21.56	22.20	9.37	17.71
Dry direct seeded rice unprotected	53.33	58.33	83.33	64.99	40.00	33.33	16.66	29.99	6.67	8.33	0.00	5.00	9.23	8.71	6.26	8.06
t- value	2.00*	2.34*	0.10	2.68**	0.91	1.81	-0.24	1.62	0.38	-0.21	-2.44	0.16	2.32*	2.27*	0.78	3.22**

DAS: Days after sowing/transplanting.

* – Significant at 5% level of significance ** – Significant at 1% level of significant

4.2.1 Dead heart per cent due to yellow stem borer at 30 days after sowing

Among the treatments chemical management showed lowest dead heart (0.13%) significantly superior to other treatments. The next best treatment was residue burning followed by tillage (0.47%). The highest per cent dead heart of damage 1.80 was recorded in zero tillage without nylon cage (open condition). The rest of the treatments *viz.*, zero tillage with normal time of sowing, zero tillage followed by 10 days late sowing, Recommended package of practice except plant protection and Burning of crop residues recorded 1.30, 1.40, 1.23 and 1.07 per cent dead heart, respectively (Table 15).

4.2.2 Dead heart per cent due to yellow stem borer at 60 days after sowing

The lowest per cent damage of dead heart (0.66%) was noticed in chemical management significantly superior to all the treatments and was followed by treatment residue burning followed by tillage with 2.27 per cent damage. Highest dead heart damage was recorded under the treatment zero tillage without nylon cage (open condition) (7.43%). The treatments zero tillage followed by 10 days late sowing and the treatment zero tillage with normal time of sowing also showed higher dead heart damage at par with the treatments of recommended package of practice except plant protection and the treatment burning of crop residues with 5.40, 4.93, 4.20 and 3.20 per cent dead heart respectively (Table 15).

4.2.3 Dead heart per cent due to yellow stem borer at 90 days after sowing

The treatment residue burning followed by tillage showed that a damage of 2.50. However, lowest per cent dead heart (0.93) was recorded in the treatment chemical management. Highest damage was observed in treatment zero tillage without nylon cage (open condition) (13.30) while the treatments zero tillage followed by 10 days late sowing, zero tillage with normal time of sowing, recommended package of practice

Table 15. Impact of left over crop residues on stem borer incidence for subsequent crop

Treatment	% Dead heart caused by yellow stem borer			Mean% DH	% DH reduction over control	% White ear	% WE reduction over control	Paddy yield (q/ha)
	30 DAS	60 DAS	90 DAS					
T ₁ : Zero tillage with normal time of sowing	1.30 (6.54) ^{cd}	4.93 (12.62) ^d	9.50 (17.92) ^d	5.24	30.22	7.73 (16.05) ^d	16.61	43.90. ^{bc}
T ₂ : Zero tillage followed by 10 days late sowing	1.40 (6.79) ^{cd}	5.40 (13.43) ^d	10.20 (18.40) ^{cd}	5.66	24.63	8.27 (16.60) ^d	10.78	40.23 ^{bc}
T ₃ : Recommended package of practice except plant protection	1.23 (6.24) ^c	4.20 (11.82) ^{cd}	6.30 (14.51) ^c	3.91	47.93	5.20 (13.18) ^c	43.90	44.56 ^{bc}
T ₄ : Residue burning followed by tillage	0.47 (3.80) ^b	2.27 (8.65) ^b	2.50 (9.07) ^b	1.74	76.83	2.63 (9.29) ^b	71.62	47.23 ^b
T ₅ : Burning of crop residues	1.07 (5.92) ^c	3.20 (10.51) ^{bc}	4.40 (12.08) ^{bc}	2.89	64.11	4.80 (12.65) ^c	48.22	44.66 ^{bc}
T ₆ : Zero tillage without nylon cage (open condition)	1.80 (7.71) ^d	7.43 (15.81) ^e	13.30 (21.37) ^e	7.51	-	9.27 (17.71) ^d	-	36.43 ^c
T ₇ : Chemical management#	0.13 (2.06) ^a	0.66 (3.62) ^a	0.93 (5.53) ^a	0.57	92.41	1.26 (6.43) ^a	86.40	59.56 ^a
S.Em±	0.5	0.7	1.0	-	-	0.8	-	1.0
CD @ 0.05	1.4	2.0	3.1	-	-	2.4	-	3.1
CV (%)	14.34	10.5	12.5	-	-	10.57	-	13.3

*Mean of 10 hills; DAS: Day after sowing, DH : Dead heart; WE : white ear

Chemical management includes profenophos 50 EC @ 500 g a.i. ha⁻¹ followed by flubendiamide 20 WG @ 35 g a.i. ha⁻¹

except plant protection and burning of crop residues showed 10.20, 9.5, 6.3 and 4.4 per cent dead heart, respectively (Table 15).

Among the different treatments which were evaluated for impact on damage after carryover of yellow stem borer, chemical management, residue burning followed by tillage, burning of crop residues and recommended package of practice except plant protection recorded 92.41, 76.83, 64.11 and 47.93 per cent reduction of dead hearts, respectively over the treatment zero tillage without nylon cage (open condition). Further, the treatments, zero tillage with normal time of sowing and zero tillage followed by 10 days late sowing recorded per cent reduction of 30.22 and 24.63 (Table 15).

4.2.4 Per cent white ear due to yellow stem borer before harvest of the crop

The treatment residue burning followed by tillage registered lowest per cent of white ear (2.63) compared to other treatment except chemical management. The treatment chemical management registered significantly lowest per cent white ear damage of 1.26 per cent. Significantly the highest incidence of white ear damage was noticed in the treatment zero tillage without nylon cage (open condition) 9.27 per cent (without nylon cage). The treatments, like zero tillage followed by 10 days late sowing, zero tillage with normal time of sowing, recommended package of practice except plant protection and burning of crop residues also showed higher white ear damage of 8.27, 7.73, 5.20 and 4.80 respectively and were found inferior to tillage followed by residue burning (Table 15).

Among the different treatments evaluated against carryover of YSB and its incidence on subsequent crop chemical management, residue burning followed by tillage, burning of crop residues, recommended package of practice except plant protection showed 86.40, 71.62, 48.22 and 43.90 per cent reduction of white ear, respectively over the treatment zero tillage without nylon cage (open condition). The treatment zero tillage with normal time of sowing and zero tillage followed by 10 days late sowing showed 16.61 and 10.78 per cent reduction of white ear respectively over zero tillage without nylon cage (open condition). This clearly indicates that burning followed by tillage was found to be superior treatment in reducing the YSB incidence (Table 15).

4.2.5 Yield loss due to yellow stem borer incidence

Significantly higher yield of 59.56 q ha⁻¹ was noticed in chemical management and next best was the treatment of residue burning followed by tillage with a yield of 47.23 q ha⁻¹. The lowest yield of 36.43 q ha⁻¹ was observed in zero tillage without nylon cage (open condition). The treatments burning of crop residues, recommended package of practice except plant protection, zero tillage with normal time of sowing and zero tillage followed by 10 days late sowing registered yields of 44.66, 44.56, 43.90 and 40.23 q ha⁻¹, respectively (Table 15).

4.3 To manage planthoppers by newer insecticides in dry direct seeded rice ecosystem

The results of the investigation on the bio-efficacy of novel insecticide molecules against planthopper conducted during *kharif* 2015-16 are presented here under.

4.3.1 Management of brown planthoppers through newer insecticides in dry direct seeded rice ecosystem

4.3.1.1 First spray

Prior to imposition of treatments population of BPH was uniform throughout the experiment and varied between 9.57 to 12.33 hoppers per hill. Hence it showed non-significant among the treatments (Table 16).

However, variation among the population was noticed at five days after treatment imposition. Treatment triflumezopyrim 106 SC @ 25 g a.i. /ha recorded significantly lower BPH population (2.23 hoppers/hill) which was followed by dinotefuran 20% SG @ 40 g a.i. /ha, pymetrozine 50% WG @ 200 g a.i. /ha and ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha, buprofezin 15% + acephate 35% WP @ 625 g a.i. /ha, acephate 50% + imidacloprid 1.8% WG @ 300 g a.i. /ha, buprofezin 25% SC @ 175 g a.i. /ha (4.53, 4.63, 5.07, 9.57, 10.07 and 10.50 hoppers/hill, respectively) but these treatments were at par. Highest population of BPH was noticed in untreated control (11.50 hoppers/hill) (Table 16).

At 10 days after spray (DAS), all treatments differed significantly with respect to the BPH population. Triflumezopyrim 106 SC @ 25 g a.i. /ha again proved its efficacy in keeping the BPH population significantly low (0.20 hoppers/hill). This treatment followed by dinotefuran 20% SG @ 40 g a.i. /ha, pymetrozine 50% WG @ 200 g a.i. /ha

Table 16. Bio efficacy of newer insecticides against brown planthopper under dry direct seeded rice ecosystem during *kharif* 2015-16

Sl. No	Treatment	g a.i/ ha	BPH / hill at 1 st spray				BPH / hill at 2 nd spray				Mean Before spray	Mean after spray
			1 DBS	5 DAS	10 DAS	15 DAS	1 DBS	5 DAS	10 DAS	15 DAS		
1	Pymetrozine 50% WG	200	11.97 (3.57) ^a	5.67 (2.57) ^{bc}	2.63 (1.90) ^{bc}	2.80 (1.94) ^{bc}	10.97 (3.42) ^a	8.63 (3.09) ^{abc}	3.63 (2.15) ^{bc}	4.00 (2.23) ^{bc}	11.47	4.56
2	Ethiprole + Imidacloprid 80% WG	100	9.73 (3.27) ^a	5.83 (2.59) ^{bc}	3.07 (2.01) ^{bcd}	3.23 (2.04) ^c	13.20 (3.66) ^a	9.40 (3.22) ^{bcd}	4.03 (2.24) ^{bcd}	4.33 (2.30) ^{bcd}	11.46	4.98
3	Dinotefuran 20% SG	40	11.97 (3.59) ^a	4.53 (2.30) ^b	2.03 (1.73) ^b	1.63 (1.62) ^{ab}	10.77 (3.41) ^a	7.70 (2.90) ^{ab}	3.30 (2.07) ^b	2.33 (1.81) ^b	11.37	3.58
4	Buprofezin 25% SC	175	10.50 (3.38) ^a	6.23 (2.69) ^{bc}	5.60 (2.56) ^{egf}	3.60 (2.14) ^{cd}	15.37 (4.04) ^a	11.60 (3.53) ^{cd}	5.87 (2.61) ^{cde}	4.73 (2.39) ^{de}	12.93	6.27
5	Buprofezin 15% + Acephate 35% WP	625	9.57 (3.25) ^a	5.87 (2.61) ^{bc}	4.23 (2.28) ^{cde}	3.37 (2.09) ^{cd}	14.83 (3.97) ^a	10.23 (3.32) ^{bcd}	5.30 (2.51) ^{cd}	4.43 (2.32) ^{bcd}	12.2	5.57
6	Acephate 50% + Imidacloprid 1.8% WG	300	10.07 (3.32) ^a	6.13 (2.67) ^{bc}	4.50 (2.34) ^{def}	3.40 (2.08) ^{cd}	15.83 (4.09) ^a	10.50 (3.39) ^{bcd}	5.57 (2.56) ^{cde}	4.50 (2.33) ^{cde}	12.95	5.76
7	Triflumezopyrim 106% SC	25	9.93 (3.31) ^a	2.23 (1.80) ^a	0.20 (1.09) ^a	0.93 (1.39) ^a	11.30 (3.49) ^a	5.47 (2.49) ^a	1.27 (1.50) ^a	0.90 (1.38) ^a	10.61	1.83
8	Flubendiamide 4% + Buprofezin 20% SC	96	12.33 (3.65) ^a	7.07 (2.81) ^c	5.30 (2.50) ^{egf}	3.67 (2.15) ^{cd}	12.80 (3.71) ^a	11.30 (3.50) ^{cd}	6.30 (2.69) ^{cde}	5.03 (2.43) ^{ef}	12.56	6.44
9	Fonicamid 50% WG	35	10.13 (3.33) ^a	7.60 (2.93) ^c	6.60 (2.74) ^{gf}	4.10 (2.24) ^{cd}	12.83 (3.69) ^a	12.23 (3.63) ^{cd}	7.60 (2.93) ^{de}	5.13 (2.44) ^{ef}	11.48	7.21
10	Acephate 75% SP	600	10.00 (3.31) ^a	7.87 (2.96) ^c	6.53 (2.73) ^{gf}	5.20 (2.46) ^{ed}	12.03 (3.61) ^a	12.53 (3.68) ^{cde}	7.57 (2.92) ^c	5.97 (2.63) ^{ef}	11.01	7.61
11	Imidacloprid 17.8% SL	22.25	9.73 (3.25) ^a	7.37 (2.86) ^c	7.43 (2.88) ^g	6.20 (2.67) ^e	15.47 (4.04) ^a	13.43 (3.77) ^{de}	8.40 (3.05) ^e	6.20 (2.68) ^f	12.60	8.17
12	Control	-	10.57 (3.36) ^a	11.50 (3.52) ^d	13.63 (3.82) ^h	14.00 (3.87) ^f	16.50 (4.16) ^a	17.00 (4.24) ^e	14.90 (3.96) ^f	13.67 (3.83) ^g	13.53	14.11
	S.Em ±	0.2	0.2	0.1	0.1	0.3	0.2	0.2	0.1			
	CD (@ = 0.05)	0.6	0.5	0.3	0.4	0.8	0.6	0.5	0.4	-		
	CV (%)	10.2	10.6	10.5	10.4	12.6	10.6	10.3	10.7			

DBS – Day before spraying; DAS – Days after spraying; NS – Non significant

Figures in the parenthesis are $\sqrt{x+1}$ transformed values. Means followed by the same alphabet in the column do not differ significantly by DMRT (0.05)

and ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha. (2.03, 2.63 and 3.07 hoppers/hill, respectively). Highest BPH population was recorded in untreated control (13.63 hoppers/hill) (Table 16).

At 15 DAS also Triflumezopyrim 106 SC @ 25 g a.i. /ha was found to be superior and registered significantly lower BPH population (0.93 hoppers/hill) statistically at par with dinotefuran 20% SG @ 40 g a.i. /ha (1.63 hoppers/hill) followed by pymetrozine 50% WG @ 200 g a.i. /ha (2.80 hoppers/hill). Untreated control recorded significantly highest number of BPH population (14.07 hoppers/hill) (Table 16).

4.3.1.2 Second spray

At five days after spray all treatments differed significantly with respect to the BPH population. Significantly lower BPH population was observed in the treatment of triflumezopyrim 106 SC @ 25 g a.i. /ha (5.47 hoppers/hill) compared to untreated check (17.00 hoppers/hill). The next best treatments were dinotefuran 20% SG @ 40 g a.i. /ha, pymetrozine 50% WG @ 200 g a.i. /ha, ethiprole + imidacloprid 80 WG @ 100 g a.i. /ha, buprofezin 15% + acephate 35% WP @ 625 g a.i. /ha and acephate 50% + imidacloprid 1.8% WG @ 300 g a.i. /ha (7.70, 8.63, 9.40, 10.23 and 10.50 hoppers/hill, respectively) and they were on par. Dinotefuran 20% SG @ 40 g a.i. /ha was found at par with triflumezopyrim 106 SC (Table 16).

At 10 DAS the trend remained same, the treatment Triflumezopyrim 106 SC @ 25 g a.i. /ha was found to be statistically superior showing significantly lowest BPH population (1.27 hoppers/hill) followed by dinotefuran 20% SG @ 40 g a.i. /ha, pymetrozine 50% WG @ 200 g a.i. /ha and ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha (3.30, 3.63 and 4.03 hoppers/ hill, respectively) but these treatments were on par. Highest BPH population was noticed in untreated control (14.90 hoppers/ hill) (Table 16).

At 15 DAS also, same trend was noticed. Among the treatments, triflumezopyrim 106 SC @ 25 g a.i. /ha registered significantly lowest BPH population (1.07 hoppers/hill) and was followed by Dinotefuran 20% SG @ 40 g a.i. /ha, pymetrozine 50% WG @ 200 g a.i. /ha, ethiprole + imidacloprid 80 WG @ 100 g a.i. /ha and Buprofezin 15% + Acephate 35% WP @ 625 g a.i. /ha which recorded 2.33, 4.00, 4.33 and 4.43 hoppers per hill. Highest BPH population was noticed in untreated control (13.67 hoppers/hill) (Table 16).

Overall triflumezopyrim 106 SC @ 25 g a.i. /ha was found to be superior among treatment (1.83 hoppers/hill) compared to untreated check. The next best treatments were dinotefuran 20% SG @ 40 g a.i. /ha, pymetrozine 50% WG @ 200 g a.i. /ha, ethiprole + imidacloprid 80 WG @ 100 g a.i. /ha and buprofezin 15% + acephate 35% WP @ 625 g a.i. /ha (Table 16).

4.3.2 Management of whitebacked brown planthoppers through newer insecticides in dry direct seeded rice ecosystem

4.3.2.1 First spray

Population of WBPH was found uniform throughout experiment and did not varied significantly among the treatments.

However, significantly variation was noticed at five days after spray. Significantly lowest number (2.33 hoppers/hill) of hoppers was observed in the treatment triflumezopyrim 106 SC @ 25 g a.i. /ha but it was on par with dinotefuran 20% SG @ 40 g a.i. /ha, pymetrozine 50% WG @ 200 g a.i. /ha, ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha which recorded 4.50, 7.00 and 7.33 WBPH per hill. However, the highest WBPH population was noticed in untreated control (7.03 hoppers/hill) and it was on par with imidacloprid 17.8 SL @ 22.25 g a.i. /ha, acephate 75 SP @ 600 g a.i. /ha, flonicamid 50% EC @ 35 g a.i. /ha , flubendiamide + buprofezin 24% SC @ 96 g a.i. /ha (8.07, 8.05, 8.00 and 7.90 hoppers /hill) (Table 17).

At 10 DAS, triflumezopyrim 106 SC @ 25 g a.i. /ha registered significantly lowest WBPH population (0.13 hoppers/hill) and this was on par with dinotefuran 20% SG @ 40 g a.i. /ha, (0.97 hoppers/hill), followed by pymetrozine 50% WG @ 200 g a.i. /ha and ethiprole + imidacloprid 80 WG @ 100 g a.i. /ha (1.90 and 2.00 hoppers/hill, respectively). The next best was buprofezin 15% + acephate 35% WP @ 625 g a.i. /ha which recorded 2.03 hoppers per hill while, it was at par with acephate 50% + imidacloprid 1.8% WG @ 500 g ha⁻¹ and buprofezin 24 SC @ 175 g a.i. /ha (2.07 and 2.13 hoppers/hill). However, significantly highest population of WBPH was noticed in untreated check (11.50hoppers/hill) (Table 17).

At 15 DAS also, triflumezopyrim 106 SC @ 25 g a.i. /ha was noticed to be superior treatment with significantly lowest WBPH population (0.23 hoppers/hill) and followed by dinotefuran 20% SG @ 40 g a.i. /ha, Pymetrozine 50% WG @ 200 g a.i. /ha,

Table 17. Bio efficacy of newer insecticides against whitebacked planthopper under dry direct seeded rice ecosystem during *kharif* 2015-16

Sl. No.	Treatment	g a.i/ha	WBPH / hill at 1 st spray				WBPH / hill at 2 nd spray				Mean Before spray	Mean after spray
			1 DBS	5 DAS	10 DAS	15 DAS	1 DBS	5 DAS	10 DAS	15 DAS		
1	Pymetrozine 50% WG	200	8.53 (3.08) ^a	7.00 (2.82) ^{abc}	1.90 (1.70) ^{bc}	2.00 (1.73) ^{bc}	15.23 (4.03) ^a	14.17 (3.89) ^b	6.00 (2.62) ^{bc}	1.63 (1.62) ^b	11.88	5.45
2	Ethiprole + Imidacloprid 80% WG	100	7.77 (2.94) ^a	7.33 (2.85) ^{abc}	2.00 (1.72) ^{bc}	2.13 (1.76) ^{bc}	17.93 (4.33) ^a	14.20 (3.88) ^b	6.33 (2.64) ^c	1.60 (1.60) ^b	12.85	5.59
3	Dinotefuran 20% SG	40	8.03 (2.95) ^a	4.50 (2.34) ^{ab}	0.97 (1.39) ^{ab}	1.47 (1.56) ^b	16.37 (4.17) ^a	12.50 (3.66) ^b	3.40 (2.09) ^{ab}	1.33 (1.53) ^{ab}	12.20	4.02
4	Buprofezin 25% SC	175	7.97 (2.98) ^a	7.43 (2.89) ^{bcde}	2.13 (1.77) ^c	2.60 (1.89) ^{bcd}	16.67 (4.20) ^a	14.70 (3.94) ^b	7.27 (2.82) ^{cde}	2.37 (1.83) ^{bc}	12.32	6.08
5	Buprofezin 15% + Acephate 35% WP	625	9.03 (3.15) ^a	7.40 (2.88) ^{bcde}	2.03 (1.74) ^c	2.30 (1.81) ^{bc}	16.60 (4.19) ^a	14.27 (3.89) ^b	6.80 (2.75) ^{cd}	2.43 (1.85) ^{bcd}	12.81	4.75
6	Acephate 50% + Imidacloprid 1.8% WG	300	7.97 (2.99) ^a	7.43 (2.87) ^{abcd}	2.07 (1.74) ^c	2.40 (1.84) ^{bcd}	16.83 (4.22) ^a	14.47 (3.91) ^b	7.00 (2.78) ^{cd}	2.47 (1.86) ^{bcd}	12.40	5.97
7	Triflumezopyrim 106% SC	25	8.70 (3.11) ^a	2.33 (1.83) ^a	0.13 (1.06) ^a	0.23 (1.11) ^a	16.00 (4.05) ^a	7.03 (2.77) ^a	1.93 (1.71) ^a	0.53 (1.24) ^a	12.35	2.03
8	Flubendiamide 4% + Buprofezin 20% SC	96	8.03 (3.00) ^a	7.90 (2.97) ^{bcdef}	4.17 (2.27) ^d	3.03 (2.00) ^{cde}	18.53 (4.41) ^a	15.97 (4.12) ^b	9.70 (3.17) ^{de}	3.10 (2.02) ^{cde}	13.28	7.31
9	Fonicamid 50% WG	35	9.07 (3.14) ^a	8.00 (3.00) ^{cdef}	4.33 (2.29) ^d	3.30 (2.07) ^{cde}	17.97 (4.33) ^a	16.20 (4.15) ^b	10.00 (3.24) ^{de}	3.60 (2.14) ^{cde}	13.52	7.57
10	Acephate 75% SP	600	8.73 (3.12) ^a	8.05 (3.00) ^{def}	4.67 (2.37) ^d	3.80 (2.19) ^{de}	19.50 (4.52) ^a	18.00 (4.33) ^b	10.53 (3.31) ^e	3.80 (2.19) ^{de}	14.11	8.14
11	Imidacloprid 17.8% SL	22.25	8.33 (3.05) ^a	8.07 (3.00) ^{ef}	4.93 (2.42) ^d	4.23 (2.29) ^e	18.13 (4.36) ^a	18.14 (4.37) ^{bc}	10.67 (3.31) ^e	4.50 (2.34) ^e	13.23	8.42
12	Control		9.90 (3.29) ^a	10.70 (3.40) ^f	11.50 (3.54) ^e	13.17 (3.74) ^f	22.00 (4.76) ^a	25.07 (5.10) ^c	20.67 (4.64) ^f	16.67 (4.18) ^f	15.95	13.30
	S.Em ±	0.2	0.2	0.1	0.1	0.3	0.3	0.2	0.1			
	CD (@ = 0.05)	0.7	0.5	0.3	0.4	0.8	0.7	0.5	0.3	-		
	CV (%)	12.7	10.9	10.1	10.5	10.6	10.8	10.9	10.1			

DBS – Day before spraying; DAS – Days after spraying; NS – Non significant Figures in the parenthesis are $\sqrt{x+1}$ transformed values.

ethiprole+ imidacloprid 80 WG @ 100 g a.i. /ha, buprofezin 25% SC @ 175 g a.i. /ha, buprofezin 15% + acephate 35% WP @ 625 g a.i. /ha acephate 50% + imidacloprid 1.8% WG @ 300 g a.i. /ha, buprofezin 25% SC @ 96 g a.i. /ha (1.47, 2.00, 2.13, 2.30, 2.40 and 2.60 hoppers/hill, respectively) but these treatments are on par. However, significantly highest WBPH population was observed in untreated control (13.17 hoppers/ hill) (Table 17).

4.3.2.2 Second spray

At five day after spray, treatment triflumezopyrim 106 SC @ 25 g a.i. /ha proved to be superior by registering lowest WBPH population (1063 hoppers/hill) and significantly higher WBPH population was observed in untreated control (25.07 hoppers/hill) (Table 17).

Triflumezopyrim 106 SC @ 25 g a.i. /ha was found to be superior and registered significantly less WBPH population (1.93 hoppers/hill) at 10 day after spray. Dinotefuran 20% SG @ 40 g a.i. /ha was proved to be next best with lower WBPH populations (3.40 hoppers/hill) but it was at par with triflumezopyrim 106 SC. These were followed by pymetrozine 50% WG @ 200 g a.i. /ha, ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha, buprofezin15% + acephate 35% WP @ 625 g a.i. /ha, acephate 50% + imidacloprid 1.8% WG @ 300 g a.i. /ha, and buprofezin 25% SC @ 175 g a.i. /ha (6.00, 6.33, 6.80, 7.00 and 7.27 hoppers/hill respectively) registered significantly highest WBPH population (20.67 hoppers/hill) (Table 17).

Treatment triflumezopyrim 106 SC @ 237ml ha⁻¹ proved to be its efficacy even at 15 days after spray by registering significantly less WBPH population (0.53 hoppers/hill) and was statistically on par with dinotefuran 20% SG @ 40 g a.i. /ha (1.33 hoppers/hill). The next best treatments were ethiprole + imidacloprid 80 WG @ 100 g a.i. /ha, pymetrozine 50% WG @ 100 g a.i. /ha, buprofezin 25% SC @ 175 g a.i. /ha, buprofezin15% + acephate 35% WP @ 625 g a.i. /ha and acephate 50% + imidacloprid 1.8% WG @ 300 g a.i. /ha (1.60, 1.63, 2.37, 2.43 and 2.47 hoppers/hill, respectively). However, the significantly highest WBPH population was noticed in untreated control (16.67 hoppers/ hill) (Table 17).

Overall, triflumezopyrim 106 SC @ 25 g a.i. /ha was found to be superior among treatment (2.03 hoppers/hill) and compared to untreated check. The next best treatments

were dinotefuran 20% SG @ 40 g a.i. /ha, Pymetrozine 50% WG @ 200 g a.i. /ha, ethiprole + imidacloprid 80 WG @ 100 g a.i. /ha and buprofezin 15% + acephate 35% WP @ 625 g a.i. /ha (Table 17).

4.3.3 Grain yield (q ha⁻¹)

Grain yield was maximum in Triflumezopyrim 106 SC @ 25 g a.i. /ha with yield of 62.07 q ha⁻¹ followed by dinotefuran 20% SG @ 40 g a.i. /ha (56.26 q ha⁻¹). The next best treatments on par were pymetrozine 50% WG @ 200 g a.i. /ha and ethiprole + imidacloprid 80 WG @ 100 g a.i. /ha (55.00 and 53.16 q ha⁻¹ respectively). Buprofezin 15% + acephate 35% WP @ 625 g a.i. /ha, acephate 50% + imidacloprid 1.8% WG @ 300 g a.i. /ha and Buprofezin 25% SC @ 175 g a.i. /ha recorded 50.96, 48.66 and 46.00 q ha⁻¹ respectively and were on par. Flubendiamide + buprofezin 24% SC @ 96 g a.i. /ha, flonicamid 50% EC 35 g a.i. /ha and acephate 75 SP 600 g a.i. /ha were at par with each other and registered grain yield of 43.46, 41.06 and 39.2 q ha⁻¹ respectively. Imidacloprid 17.8 SL 22.25 g a.i. /ha lowest grain yield of 38.12 q ha⁻¹ but it was at par with flubendiamide + buprofezin 24% SC @ 96 g a.i. /ha, flonicamid 50% EC 35 g a.i. /ha and acephate 75 SP 600 g a.i. /ha. Significantly lowest yield of 24.53 q ha⁻¹ was obtained in untreated control (Table 18).

Table 18. Impact of new insecticides on grain yield during *kharif* 2015-16

Sl. No.	Treatment	g a.i/ha	Grain yield	
			(kg/plot)	(q/ha)
1	Pymetrozine 50% WG	200	13.75	55.00 ^{abc}
2	Ethiprole + Imidacloprid 80% WG	100	13.30	53.16 ^{abcd}
3	Dinotefuran 20% SG	40	14.07	56.26 ^{ab}
4	Buprofezin 25% SC	175	11.50	46.00 ^{cdefg}
5	Buprofezin 15% + Acephate 35% WP	625	12.74	50.96 ^{bcde}
6	Acephate 50% + Imidacloprid 1.8% WG	300	12.17	48.66 ^{bcdef}
7	Triflumezopyrim 106% SC	25	15.66	62.64 ^a
8	Flubendiamide 14% + Buprofezin 24% SC	96	10.87	43.46 ^{defg}
9	Flonicamid 50% WG	35	10.27	41.06 ^{efg}
10	Acephate 75% SP	600	9.80	39.2 ^{fg}
11	Imidacloprid 17.8% SL	22.25	9.53	38.12 ^g
12	Control	-	5.53	24.53 ^h
	S.Em±			3.5
	CD @ 0.05	-	-	10.2
	CV (%)	-	-	12.9

Means followed by the same alphabet in the column do not differ significantly by DMRT (0.05)

Discussion

V. DISCUSSION

Rice *Oryza sativa* L. is one of the important cereal staple food crop of world accounts for more than 65 per cent of world the population and known as king of cereals. Among the various constraints in low rice production, damage due to insect pest is substantial and needs regular attention. Among the several insect species recorded as pest of rice, about 20 have major significance in different rice growing regions of India. Among the insect pests, brown planthopper, whitebacked planthopper, yellow stem borer and leaffolder are considered to be major pests with diversified natural enemies complex predominant in Tungabhadra Project area of North Karnataka. There is a lack of information on pest status, natural enemy complex associated with influence of weather factors on their occurrence, effect of leftover stubbles in the field for yellow stem borer attack on subsequent crop and management of planthoppers in DDSR ecosystem. With this in view, present investigations were undertaken with the objectives *viz.*, (i) To document and compare the insect pests and natural enemies in dry direct seeded rice and transplanted rice ecosystem. (ii) To know the impact of left over crop residues on stem borer incidence for subsequent crop and (iii) To manage planthoppers by newer insecticides in dry direct seeded rice ecosystem. The results of the present investigation are discussed here under.

5.1 To document and compare the insect pests and natural enemies in dry direct seeded and transplanted rice ecosystem

5.1.1 Incidence of the insect pests and natural enemies in transplanted rice ecosystem through yellow pan trap

5.1.1.1 Transplanted rice ecosystem

Insect pests collected under yellow pan trap were leaffolder *Cnaphalocrosis medinalis*, yellow stem borer *Scirpophaga incertulas*, pink stem borer *Sesamia inferens* (Walker), rice hispa *Dicladispa armigera* (Olivier) rice skipper *Pelopidas mathias* Fabricius, green leafhopper *Nephotettix virescens* (Distant), *Exitianus* sp and unidentified Membracids. The natural enemies included members of the family Chalcididae (*Brachymeria* sp.), Braconidae, Trichogrammatidae, Pentatomidae, Miridae and Coccinellidae.

The present investigations are supported by different works on insect pests in the rice agro ecosystem. Jena *et al.* (2012) reported some of the major insect pests in rice production, which included yellow stem borer *S. incertulas*, leaffolder *C. medinalis*, whorl maggot *Hydrellia philippina* Ferino, rice hispa *D. armigera*, brown plant hopper *N. lugens*, whitebacked plant hopper *S. furcifera* and gundhi bug *L. acuta*. Similarly, Prasad (2010) reported spiders, Mirids, Staphylinids, Coccinellidae, Carabidae and Odonata as the natural enemies.

5.1.1.2 Dry direct seeded rice ecosystem

Insect pests noticed under DDSR ecosystem were leaffolder (*Cnaphalocrocis medinalis*), yellow stem borer (*Scirpophaga incertulas*), pink stem borer (*Sesamia inferens*), rice skipper *Pelopidas mathias* Fabricius, green leafhopper *Nephotettix virescens*, *Exitianus* sp. and unidentified membracidae. Group of natural enemies collected in yellow pan trap under DDSR consisted of (*Ooencyrtus* sp.) Encyrtidae, Braconidae, Coccinellidae, Miridae and Pentatomidae.

There are no earlier published report of insect pest and natural enemies documented under DDSR ecosystem in TBP area.

5.1.2 Documentation of natural enemies of planthopper and leaffolder reared under laboratory condition

In present study important natural enemies identified were *Anagrus*, *Gonetocera* and *Camptoptera* which were egg parasitoids of planthopper. One parasitoid emerged from leaffolder was Braconidae but was unidentified. Yasumatsu *et al.* (1975) reported *Anagrus optabilis*, *Gonatocera* sp. and *Polynema* sp. wasp were most important egg parasitoids of both rice leafhoppers and planthoppers. Similarly, Vijaykumar and Patil (2004) documented several predators and parasitoids in TBP area under TPR ecosystem, among them spiders and mirid bugs were major ones.

5.1.3 Studies on dynamics of insect-pests and natural enemies in dry direct seeded rice *vis-avis* transplanted rice

5.1.3.1 Brown planthopper

Brown planthopper incidence started from 40 days old crop and its peak population was reached on 60 days old crop in transplanted rice (26.13 hoppers/hill) followed by dry direct seeded rice under unprotected situation (7.75 hoppers/hill) (Fig. 1).

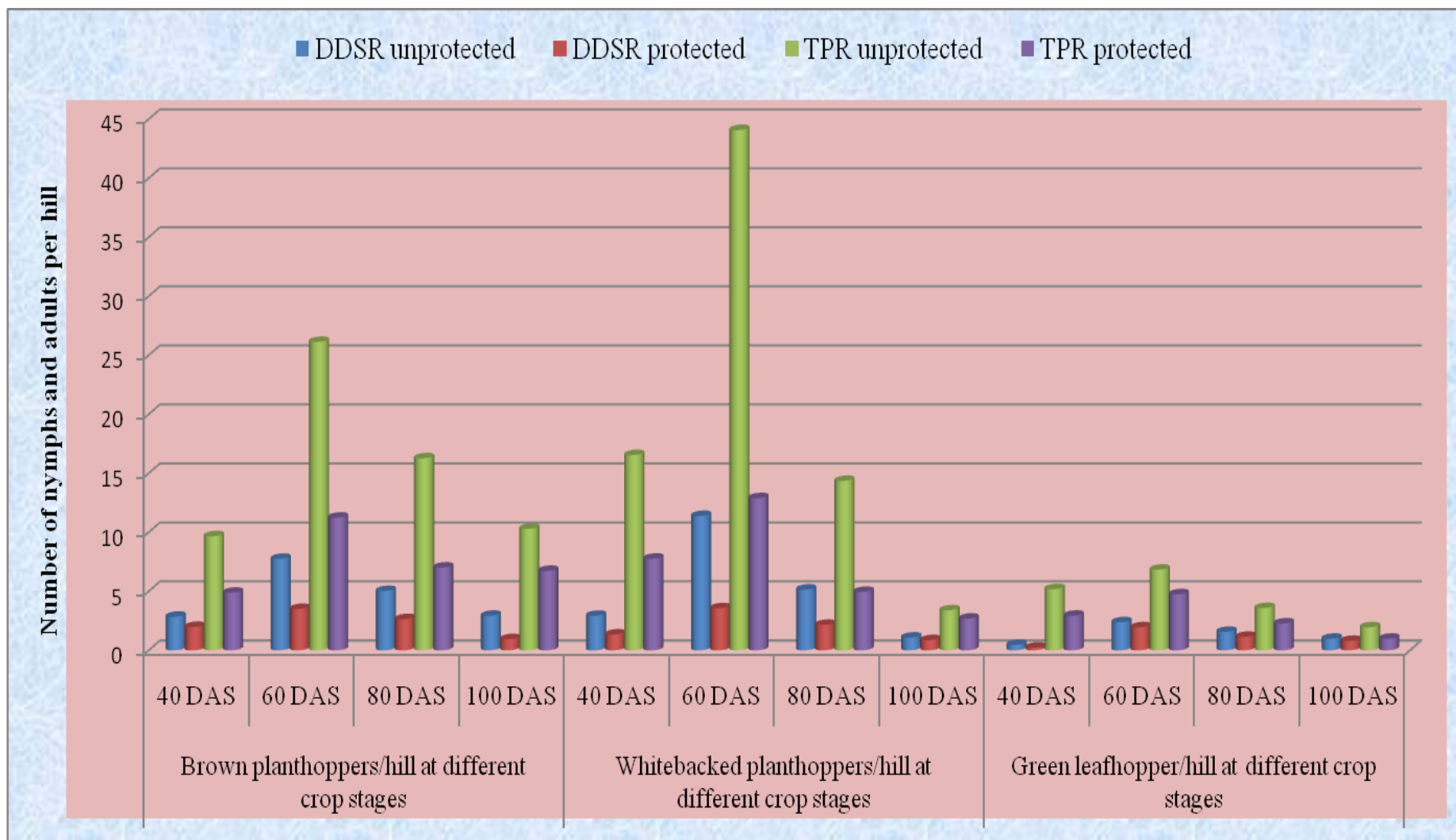


Fig. 1. Incidence of planthoppers and leafhoppers in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

These findings are in agreement with the report of Vijaykumar and Patil (2004) who found that peak incidence of BPH was observed in October-November.

5.1.3.2 Whitebacked planthopper

The incidence of whitebacked planthopper was noticed from 40 DAS and continued up to maturity (100 DAS). The population was found more in transplanted rice under unprotected condition (44.08 hoppers/hill) followed by dry direct seeded unprotected condition (11.38 hoppers/hill) at 60 DAS (Fig. 1). The present findings on the peak occurrence are in close conformity with the findings of Reddy *et al.* (1983).

5.1.3.3 Green leafhopper

The green leafhopper started appearing at 40 DAS of crop growth and attained peak at 60 DAS and remained there up to maturity (Fig. 1). Among the crop planting methods, the incidence level was comparatively high in transplanted rice under unprotected situation (6.83 hoppers/hill) followed by dry direct seeded rice under unprotected condition (2.38 hoppers/hill) at 60 DAS. The present findings are in conformation with those of Hegde and Nagappa (2011) and Anon. (2012) who reported that the leafhopper population was significantly higher in transplanted than aerobic methods.

Plant and leafhoppers population were comparatively more in transplanted rice than dry direct seeded rice mainly because of more humidity and less application of irrigation water coupled with less usage of chemical fertilizer, these two are the important cultural factors which favour sucking pests menace in transplanted rice ecosystem (Ashrith 2014). A few reports stated more planthoppers in transplanted rice fields than in dry direct seeded field (Anon., 2010).

5.1.3.4 Yellow stem borer

The maximum per cent dead heart was noticed in dry direct seeded rice under unprotected condition (6.22%) followed by transplanted rice under unprotected (3.80%) during the month of October at ARS, Gangavathi (Fig. 2). The per cent white ears was found high in dry direct seeded rice under unprotected condition (7.27%) compared to transplanted rice under unprotected condition (4.22%) prior to harvest of the crop (Fig. 3). Ayyanna and Hamidali (1970) reported that the yellow stem borer peak activity during

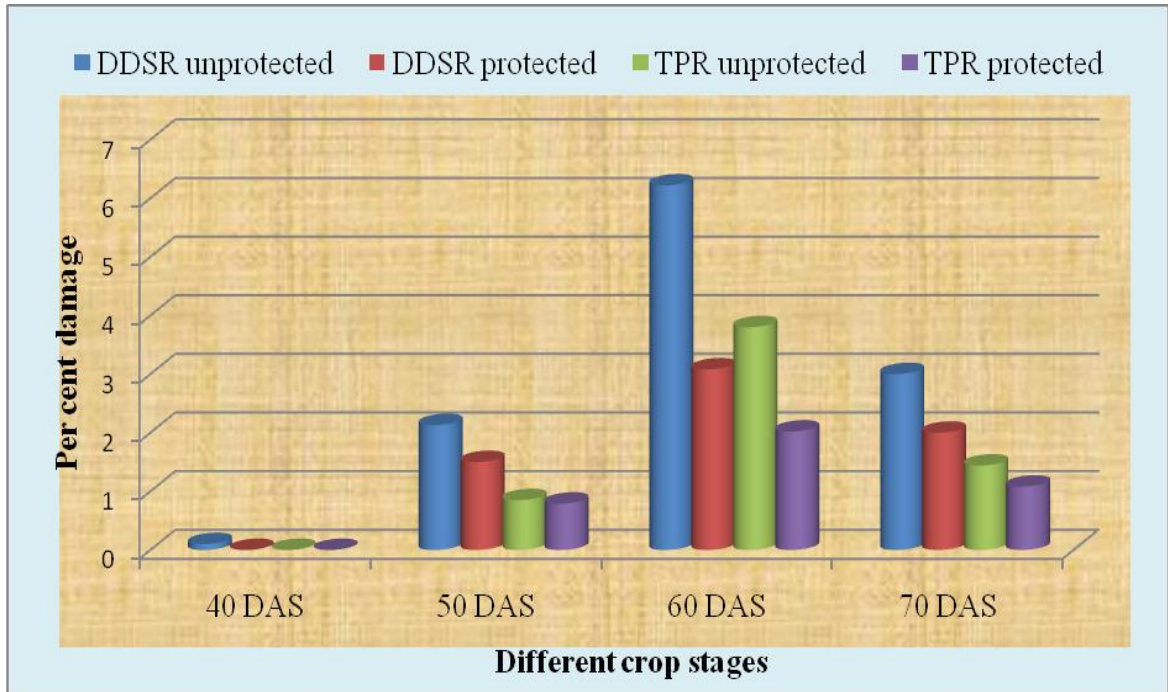


Fig. 2. Incidence of yellow stem borer (Dead heart) in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

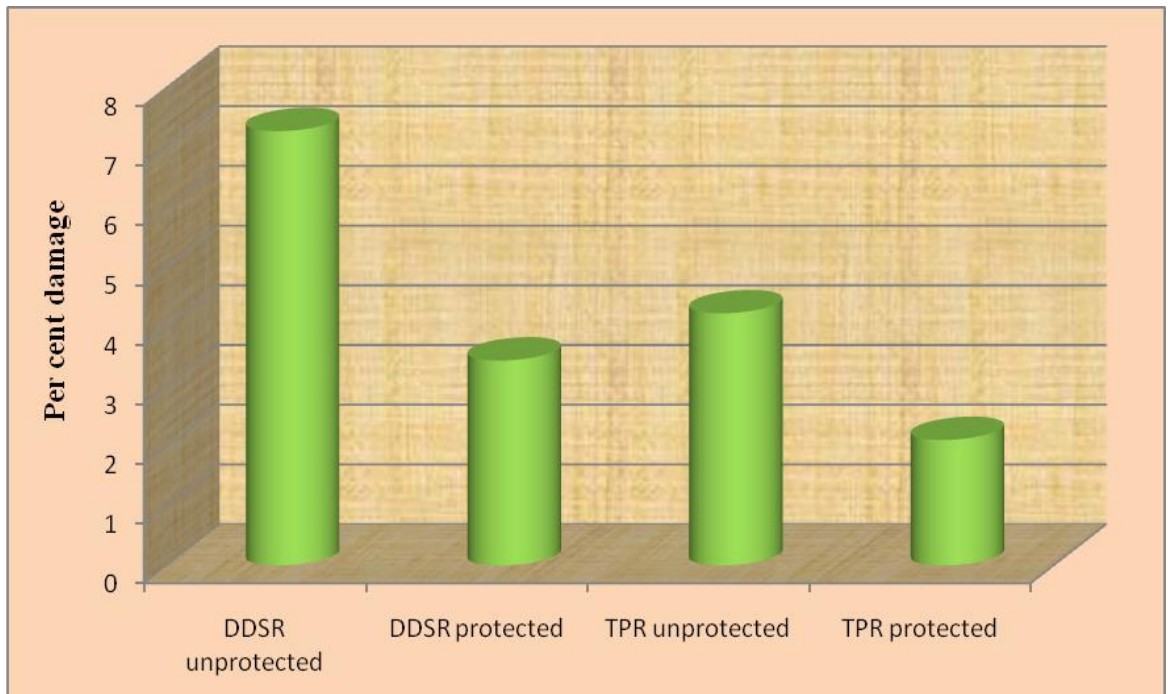


Fig. 3. Incidence of yellow stem borer (white ear) in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

first week of October. Kumar *et al.* (1995) reported that white ears were maximum during 41st standard week coinciding with flowering and ear head formation stage of crop. Similar findings were found by Anon. (2012) who reported that yellow stem borer damage was high in dry direct seeded rice as compared to normal transplanted method

Yellow stem borer incidence was comparatively higher in dry direct seeded rice than that of transplanted rice. These studies revealed that the larvae of *Scirpophaga* sp. usually overwinter at the basal part of rice stubbles in fallow (unploughed fields) wherein the stubbles are neither removed nor burnt. Because of this the population builds up easily and adds to that of subsequent crop. Hence, the ploughing or harrowing of fields immediately after harvest will be helpful in preventing the surviving populations as suggested by Saroj *et al.* (2005).

5.1.3.5 Leaf folder

Leaf folder damage was noticed during 50 days after sowing on the two rice planting methods. The per cent damage was more in (14.21%) unprotected dry direct seeded rice followed by unprotected transplanted rice (4.94%). The maximum incidence was noticed when crop was between 80 and 90 days after sowing (Fig. 4). The results of present study are in agreement with the findings of Kuligod (2009) who observed the leaf folder damage attained peak in October and November and decreased thereafter due to non-availability of fresh food for the pest at the flag end of the season. Anon. (2012) also reported that leaf folder damage was more in dry direct seeded rice than the transplanted rice.

5.1.3.6 Natural enemies

Spiders population was noticed from the second fortnight of September till the harvest of the crop. The spider population attained highest level in transplanted rice under unprotected condition (3.82 adults/hill) the reason for predominance of spider in transplanted rice was more prey population which increased the spider population (Fig. 5). The present findings on the activity of spiders are in agreement with the observation made by Okuma *et al.* (1978) reported that spider fauna was relatively poor in the early period of crop growth (July) and from August onwards, spider fauna became rich. However, Venkateshalu (1996) observed that most of the dominant species of spiders Lycosids and Tetragnathids were found throughout the crop growth period.

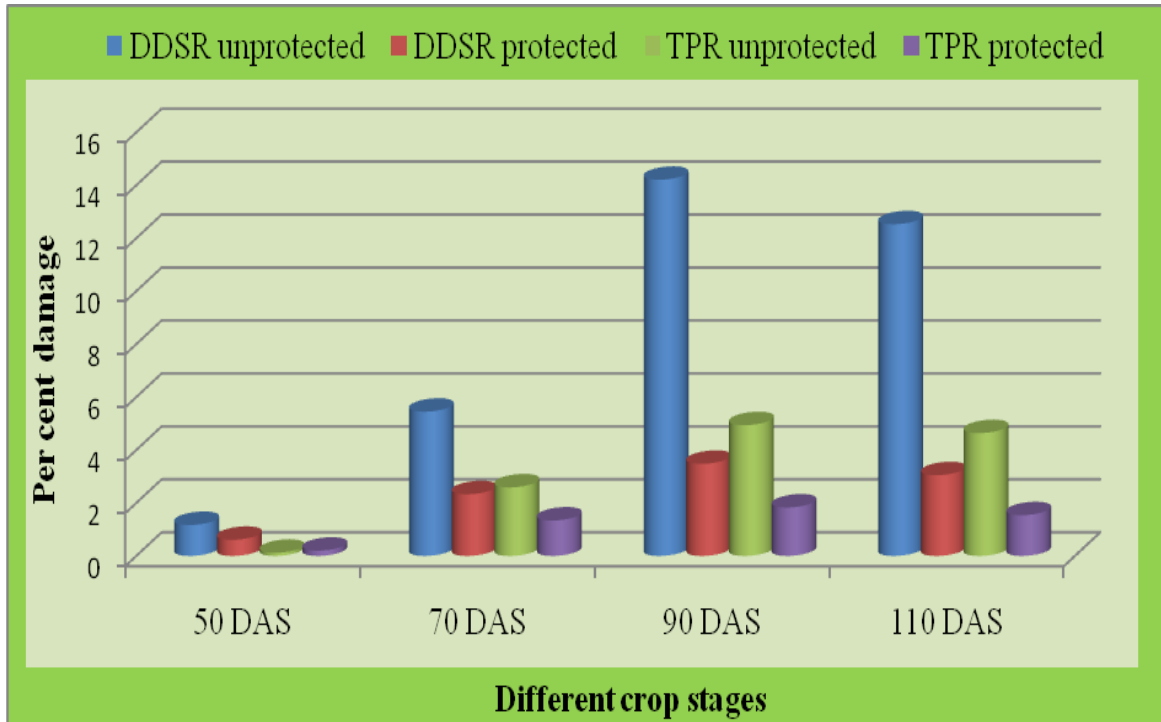


Fig. 4. Incidence of leaf folder in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

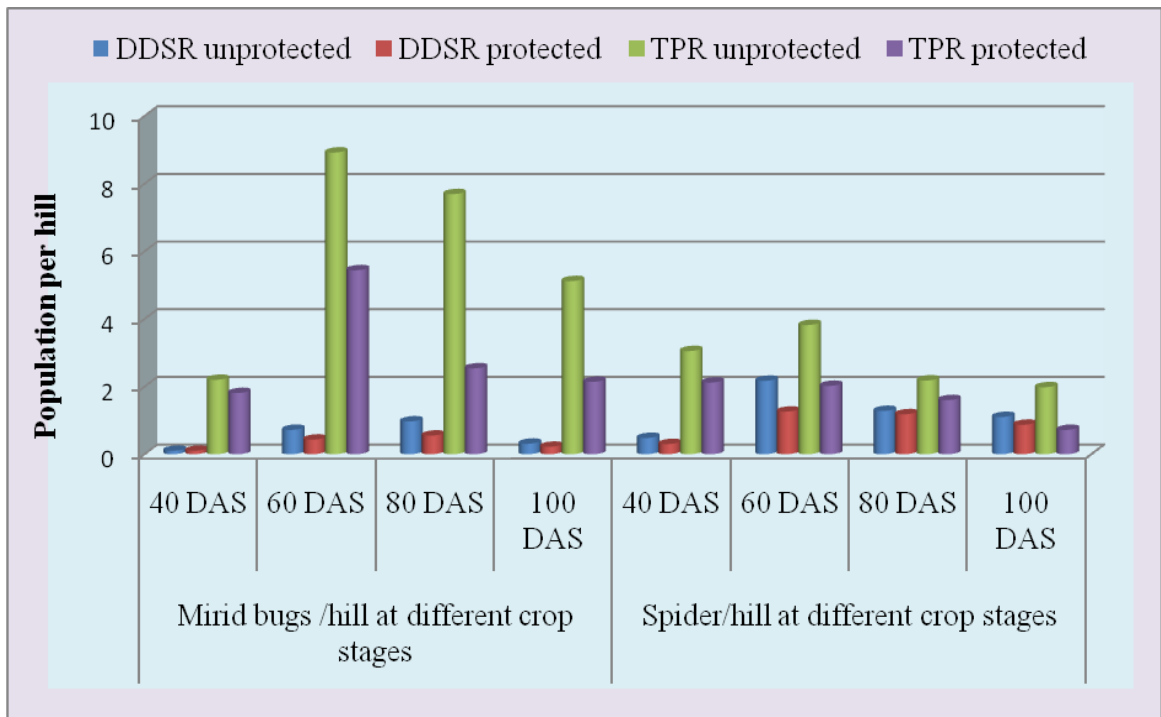


Fig. 5. Incidence of predators in dry direct seeded and transplanted rice ecosystem during *kharif* 2015-16

Occurrence of mirid bug started from 40 days old crop and continued till crop harvest. The populations of mirids reached peak in transplanted under unprotected condition (8.92 adult and nymph/hill) during October month. As a special reference to outbreak of BPH, the mirid population attained peak status during October as they are density dependent and host specific in nature. The present findings are in agreement with the report of Chill *et al.* (1979), however Mohan and Janarthanan (1985) reported uniform distribution of *C. lividipennis* during the rice crop season in Tamil Nadu.

5.1.4 Activity of pest and their natural enemies in relation to weather parameters under transplanted and dry direct seeded rice ecosystem

5.1.4.1 Activity of pest and their natural enemies in relation to weather parameters under transplanted unprotected condition

So far, none of the rice workers have made an attempt to investigate the influence of the various micro climate weather parameters on the incidence of insect pest and natural enemies in Tungabhadra command area and further no reports are available on impact of microclimate. Hence, present investigations had made attempt to correlate microclimate influence on activity of pest and natural enemies and were discussed as below.

5.1.4.1.1 Brown planthopper

The correlation studies on BPH incidence and microclimate weather observations revealed significantly positive relationship with temperature and carbon dioxide. This clearly indicated that temperature and carbon dioxide were one of the major factors responsible for increase in the population of BPH. The present findings are in line with Prasannakumar *et al.*, 2012 who also observed maximum number of brown planthopper population at elevated (570 ± 25 ppm) carbon dioxide level than ambient (380 ± 25) (Fig. 6).

Similarly, when activity of BPH correlated with station weather observatory, which exhibited a significantly positive relationship with maximum temperature and non-significant positive correlation with minimum temperature. A non-significant negative association was noticed with rainfall, morning relative humidity and evening relative humidity (Fig. 7). The present findings are in conformity reports of with Cheng *et al.* (1992), Krishnaiah *et al.* (2006) and Chaudhary *et al.* (2014) noticed positive correlation

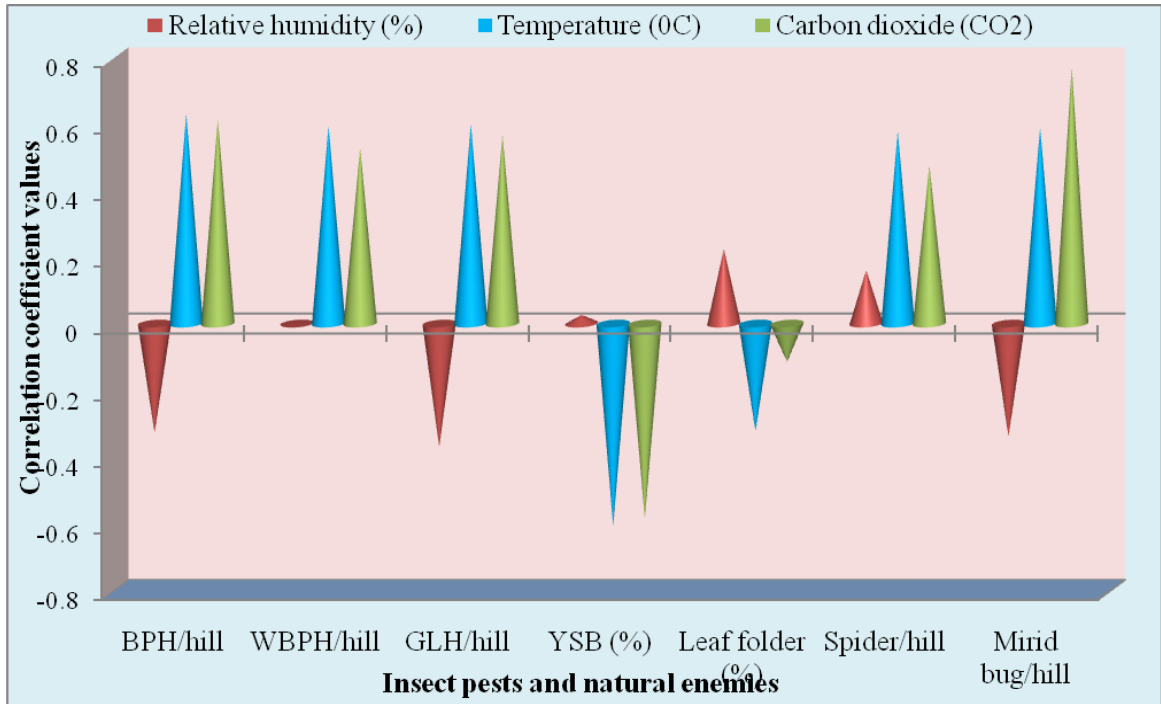


Fig. 6. Correlation between paddy insect pests and their natural enemies with micro climate weather observations in transplanted paddy ecosystem under unprotected condition during *kharif*, 2015-16

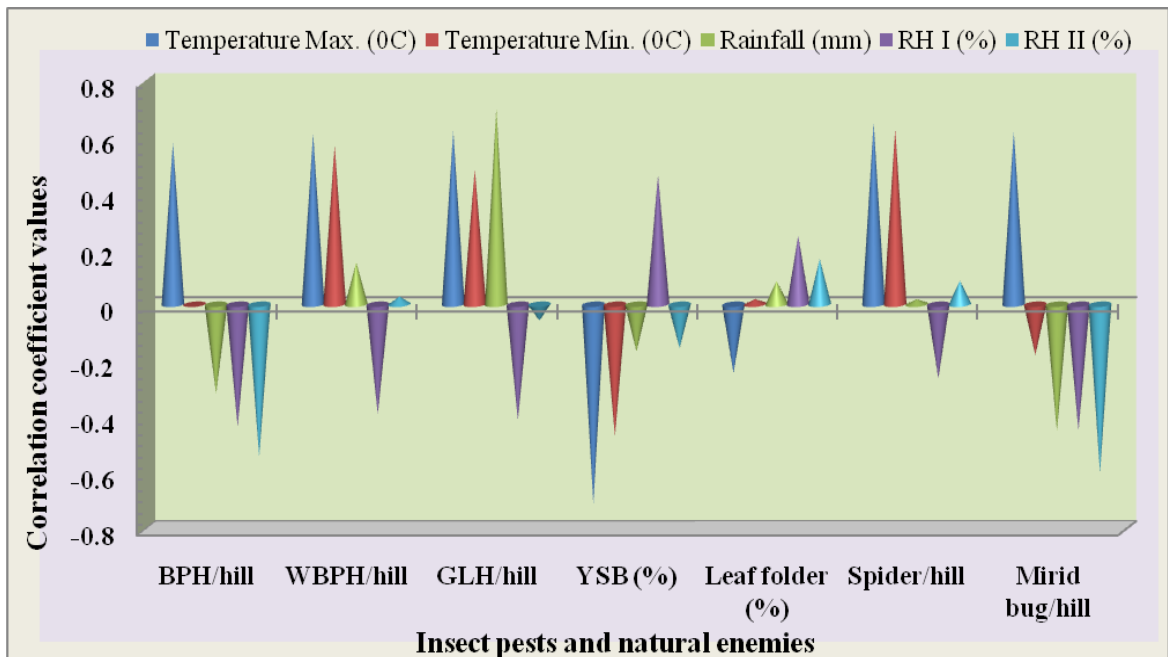


Fig. 7. Correlation between paddy insect pests and their natural enemies with station observatory weather parameters in transplanted paddy ecosystem under unprotected condition during *kharif*, 2015-16

between temperature and BPH. Prasannakumar and Subhash (2014) opined that temperature might be one of the major factor influenced for incidence of BPH and also temperature act as source of heat energy for insects take off flight during night. Jeyarani (2004) and Chaudhary *et al.* (2014) also observed a negative correlation between the incidence of the BPH and rainfall. Reddy *et al.* (1983) reported that relative humidity had a significant and effect on population of *N. lugens*.

On contradictory to present findings Prasad (2010) and Chaudhary *et al.* (2014) observed non-significant negative relationship with maximum and minimum temperature and positive association with relative humidity. (Nair *et al.*, 1980) who studies correlation studies and opined that the planthopper population was significantly influenced by climatic factors especially rainfall in association with high relative humidity and high temperatures. Contrary results in the present study to earlier work are may be due to change in climatic condition. In the present study period there was well distribution of rainfall during September month at that time humidity ranged between 68-80 per cent, meanwhile planthopper incidence was initiated. Further, last week of September there was heavy humidity ranged between 63-73% and evening relative humidity ranged between 45 to 89 per cent with maximum temperature 29 to 35 °C and minimum temperature of 22 to 24 °C was noticed. These conditions may be favourable for multiplication of hoppers. However, there was shower on September 26th, 2016 with a total rainfall of 38 mm. Afterwards there was decline in relative humidity but population of hoppers was found to be higher. Hence, higher relative humidity and temperature may be favourable for multiplication of hopper during October month though there was decline in relative humidity.

5.1.4.1.2 Whitebacked planthopper

Incidence of microclimate weather parameter on incidence of WBPH was assessed and results revealed non-significant positive relationship with relative humidity. However, significant positive relationship was observed with temperature, whereas, carbon dioxide showed non-significant positive association with WBPH population. (Fig. 6). Similarly, incidence of WBPH in relation to station observatory weather parameter exerted significant positive relationship with maximum temperature and non-significant positive relationship with minimum temperature, rainfall and evening relative humidity (Fig. 7). Present findings are in line with Satpathi *et al.* (2011) and Hafizal and Idris

(2014), who also noticed significant and positive relationship with temperature on growth and development of Delphacidae. On the contrary to present results Prasad (2010) noticed significant negative relationship with maximum and minimum temperature and positive association with relative humidity.

5.1.4.1.3 Green leafhopper

Incidence of GLH with microclimate observation were assessed and presented in the Fig. 6. There was a negative and non-significant effect of relative humidity. Correlation with temperature was found to be significantly positive. While, carbon dioxide effect was non-significant but positive. Similarly, population of GLH exhibited significant positive correlation with maximum temperature, and a non-significant positive association with minimum temperature and rainfall. There was a non-significant negative correlation noticed with morning and evening relative humidity (Fig. 7). These findings are in accordance with Khan and Mishra (2003) who found significant positive correlation between temperature and GLH population and reproduction of leafhopper had a close positive relationship with climate condition especially with the temperature but had no significant positive effect with humidity and Cicadelidae (Hafizal and Idris., 2014). On contrary to present results Vijaykumar (2002) observed non-significant positive correlation with rainfall, morning relative humidity and evening relative humidity and negative correlation with both maximum and minimum temperature with GLH activity.

5.1.4.1.4 Yellow stem borer

Influence of micro weather parameter on yellow stem borer revealed that relative humidity had a non-significant positive relation, while correlation with temperature and carbon dioxide was negative (Fig. 6). Similarly, correlation of station observatory weather parameters with yellow stem borer was assessed and found that morning relative humidity had non-significant positive association, while significant negative relation was noticed maximum temperature. Non-significant negative relation was observed with minimum temperature, rainfall and evening relative humidity was observed (Fig. 7). Kumar *et al.* (1995) and Vijaykumar (2002) also reported non-significant negative correlation with minimum temperature, and significant negative association with maximum temperature and non-significant positive effect with morning relative humidity. Present findings are also in support with Adiroubane and Raja (2007), Justin and Preetha (2013).

On contradictory to present results Somashekara and Javaregowda (2015) noticed positive relationship between minimum and maximum temperature and yellow stem borer light trap catches. This may be due to variations in the weather parameters in different locations and their influence on the activity of light trap catches that could not be correlated with field observation.

5.1.4.1.5 Leaffolder

Leaffolder incidence had a non-significant positive association with relative humidity, whereas, non-significant negative correlation was observed with temperature and carbon dioxide (Fig. 6). Further, station observatory weather parameters on leaffolder incidence were assessed and results revealed non-significant negative relation with maximum temperature. However, minimum temperature, rainfall, morning relative humidity and evening relative humidity were found to have a non-significant positive relationship with leaffolder incidence (Fig. 7). Present findings are in agreement with the reports of Bhaskar (1994) Vijaykumar (2002) and Prasad (2010). The present findings contrary to Kaul and Singh (1999) and Patel *et al.* (2011) recorded a significant positive correlation with average temperature.

5.1.4.1.6 Spider

The correlation of spider population was non-significant and positive effect with relative humidity and carbon dioxide but significant positive relationship with temperature. Spiders are general predators depends on general prey as they are density dependent factors (Fig. 6).

Further spider population in relation to station observatory weather parameter were revealed significant positive correlation with maximum temperature and minimum temperature. However, non-significant positive correlation was noticed with rainfall and evening relative humidity but non-significant negative effect was observed with morning relative humidity (Fig. 7). The findings are in accordance with the results of Vijaykumar (2002) and Prasad (2010) who were opined that both rainfall and evening relative humidity had positive correlation, while Khan and Mishra (2003) found significant positive correlation with temperature.

5.1.4.1.7 Mirid bug

Activity of predatory mirid bug in relation to microclimate weather parameter was assessed and results revealed that non-significant negative correlation was noticed with relative humidity. However, significant positive relationship was observed with temperature whereas, carbon dioxide exerted a significant positive correlation with activity of mirid bug population.

Similarly, the correlation between mirid bug and station observatory weather parameters revealed that maximum temperature was found to be significant positive correlation but minimum temperature, rainfall and morning relative humidity were non-significant negative impact whereas significant negative relation was recognised with evening relative humidity.

The present results are contradictory to the findings of Vijaykumar (2002) and Prasad (2010) who noticed non-significant negative correlation with maximum temperature but average rainfall, relative humidity and evening relative humidity were positive association with mirid bug activity. The contradictory results may be due to variation in location, season and intensity of prey. Further, mirid bugs are density dependent factors and favourable condition required for multiplication of prey (planthoppers) was maximum temperature and minimum temperature based on our present findings. Hence, prey and predator are closely related which may be support for the present findings.

5.1.4.2 Activity of pest and their natural enemies in relation to weather parameters under transplanted protected condition

5.1.4.2.1 Brown planthopper

The correlation studies on BPH incidence and microclimate weather observations revealed non-significant negative relationship with relative humidity and significant positive relationship with carbon dioxide. However, temperature had non-significant positive correlation. Present findings are in line with Prasannakumar *et al.* (2012) who reported maximum number of brown planthopper population at elevated (380 ± 25) carbon dioxide level than ambient (570 ± 25 ppm) and opined positive correlation between carbon dioxide and BPH activity (Fig. 8).

Similarly, correlation between population of BPH and station observatory parameters exerted non-significant positive relationship with maximum temperature and minimum temperature. Whereas, non-significant negative association was noticed with rainfall, morning relative humidity, evening relative humidity (Fig. 9). Present findings are in corroboration with Jeyarani (2004) and Chaudhary *et al.* (2014) who reported there is a negative correlation between the incidence of the BPH and rainfall. Reddy *et al.* (1983) and Chaudhary *et al.* (2014) also noticed negative correlation between relative humidity and population of BPH. Similarly, temperature had positive correlation with population of BPH as reported by Cheng *et al.* (1992), Krishnaiah *et al.* (2006), Chaudhary *et al.* (2014) and Prasannakumar and Subhash (2014).

On the contrary to present results, Prasad (2010) reported non-significantly negative relationship with maximum and minimum temperature and positive association with relative humidity. Variation in the result may be due to variation in location and climate.

5.1.4.2.2 Whitebacked planthopper

The correlation studies between WBPH incidence and microclimate observations noticed that relative humidity had non-significant negative relationship. Whereas, temperature and carbon dioxide had non-significant positive relationship with activity of WBPH (Fig. 8).

Similarly, WBPH population level and station observatory parameter showed non-significant positive relationship with maximum temperature, minimum temperature, rainfall and evening relative humidity. Further morning relative humidity was found to be non-significant negative relationship with WBPH incidence (Fig. 9). Similarly, Satpathi *et al.* (2011) and Hafizal and Idris (2014) opined that temperature had significant and positive relationships with development and growth of Delphacidae. Win *et al.* (2011) observed both the planthoppers population had positive correlation with rainfall.

On the contrary to present findings Prasad (2010) reported negative and significant relationship with maximum and minimum temperature and positive association with relative humidity. This may be due to variations in the weather parameters in different locations and their influence on the activity of pest population.

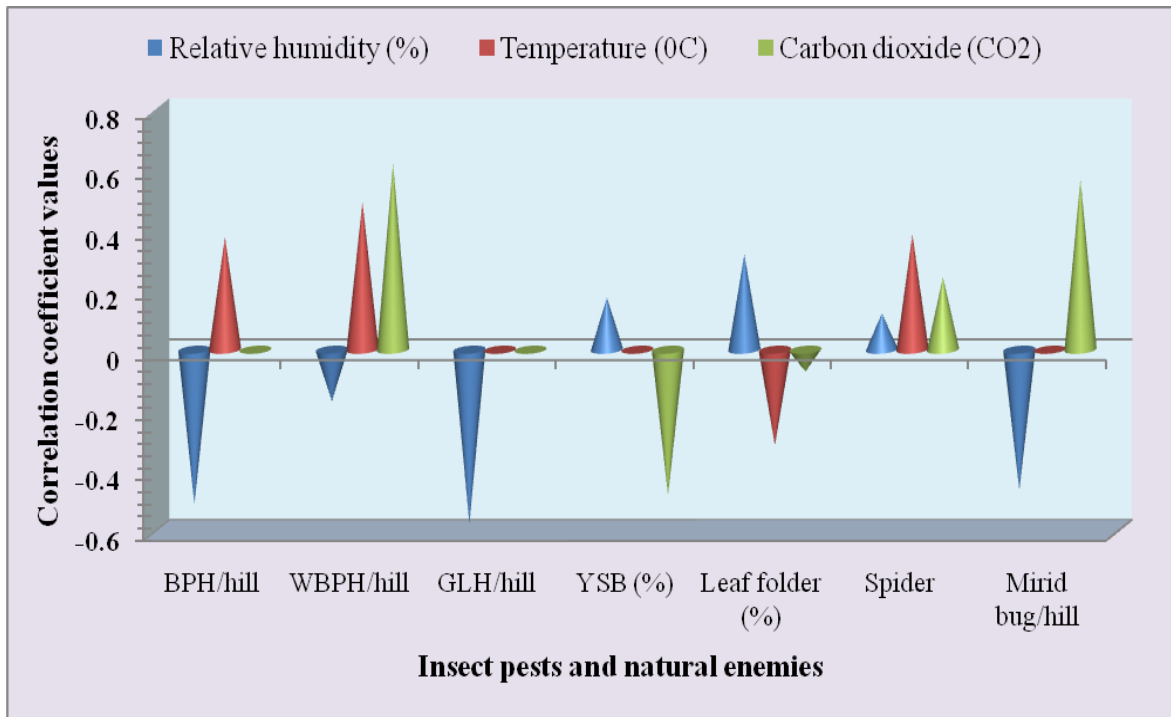


Fig. 8. Correlation between paddy insect pests and their natural enemies with micro climate weather observations in transplanted paddy ecosystem under protected condition during *kharif*, 2015-16

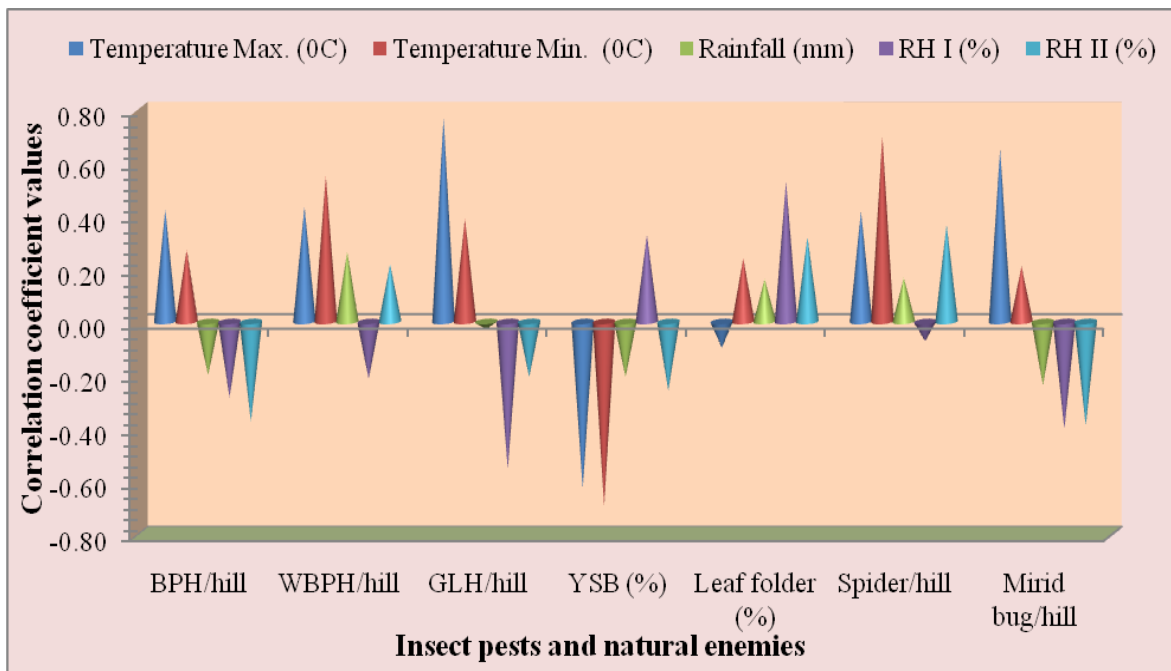


Fig. 9. Correlation between paddy insect pests and natural enemies with station observatory weather parameters under transplanted protected condition

5.1.4.2.3 Green leafhopper

The correlation between microclimate weather parameter and GLH incidence revealed the non-significant negative effect with relative humidity, whereas both temperature and carbon dioxide were noticed to be significant positive with GLH populations (Fig. 8).

Similarly, GLH population and station observatory weather parameter exerted significant positive relationship with maximum temperature but non-significant positive effect with minimum temperature, whereas non-significant negative correlation was noticed with rainfall, morning relative humidity and evening relative humidity (Fig. 9).

The present findings are supported by earlier work. Khan and Mishra (2003) who also noticed significant positive correlation with temperature and GLH population. Hafizal and Idris (2014) who also observed negative correlation between temperature and Cicadellidae. On contrary to present results Vijaykumar (2002) noticed non-significant positive correlation with rainfall, morning relative humidity evening relative humidity and negative correlation with both maximum and minimum temperature.

5.1.4.2.4 Yellow stem borer

The correlation between yellow stem borer incidence and microclimate observation was assessed and revealed that relative humidity had non-significant positive association and temperature was found to be significant negative correlation. However, carbon dioxide was observed to be negatively non-significant effect with yellow stem borer incidence (Fig. 8).

Similarly, yellow stem borer incidence with station observatory weather parameters exerted significant negative effect with maximum temperature and minimum temperature. Subsequently evening relative humidity and rainfall had exhibited non-significant negative correlation, but morning relative humidity was found to be non-significantly positive association (Fig. 9). These results are in confirmation with earlier worker Vijaykumar (2002) Adiroubane and Raja (2007) and Justin and Preetha (2013) who noticed non-significant negative correlation with minimum temperature, and significant negative correlation with maximum temperature but non-significant effect with morning relative humidity. Kumar *et al.* (1995) who also observed significant negative correlation between pest infestation and maximum temperature. It is clear from

the present study that rainfall had negative relation with stem borer incidence which is in agreement with Adiroubane and Raja (2007) and Justin and Preetha (2013). Somashekara and Javaregowda (2015) who noticed negative correlation between rainfall and light trap catches of YSB.

On contradictory to present results Somashekara and Javaregowda (2015) were observed minimum and maximum temperature had positive relationship with yellow stem borer light trap catches but morning relative humidity was positively correlated. This may be due to variations in the weather parameters in different locations and their influence on the activity of pest population. Further, there was variation in light trap catches and field incidence. Here present study was carried out in field condition.

5.1.4.2.5 Leaffolder

The relation between microclimate observatory observations and leaffolder incidence was assessed. The result revealed that non-significant positive correlation was noticed with relative humidity, whereas, non-significant negative correlation was found with temperature and carbon dioxide (Fig. 8).

Further correlation between leaffolder incidence with station observatory weather parameters exhibited non-significant negative effect with maximum temperature. However, minimum temperature, rainfall, morning relative humidity and evening relative humidity were found to be non-significant positive relationship with leaffolder incidence (Fig. 9). Present findings are in close agreement with the reports of Bhaskar (1994), Vijaykumar (2002) and Prasad (2010) who reported non-significant negative correlation with maximum and minimum temperature.

5.1.4.2.6 Spider

The correlation between microclimate weather parameters and spider population exhibited non-significant positive impact with relative humidity, temperature and carbon dioxide (Fig. 8).

Further, population of spider with station weather parameters were showed non-significant positive correlation with maximum temperature, rainfall and evening relative humidity. However, significant positive association was noticed with minimum temperature. Whereas, morning relative humidity was found to be non-significant negative relation (Fig. 9).

Present results are in conformity with the results of Vijaykumar (2002); Khan and Mishra (2003) and Prasad (2010). But on contradictory Vijaykumar (2002) also mentioned morning relative humidity was found to be positively correlated with spider population.

5.1.4.2.7 Mirid bug

The correlation between microclimate weather observations and predatory mirid bug population was revealed that non-significant negative relation with relative humidity, whereas, significant positive association was noticed with temperature. However, carbon dioxide exerted non-significant positive correlation with incidence of mirid bug population in micro climate.

Influence of station weather parameters on activity of mirid bug was exhibited significant positive correlation with maximum temperature and non-significant negative effect with minimum temperature, rainfall, morning relative humidity and evening relative humidity. The results are contradictory to the findings of Vijaykumar (2010) who reported negative and non-significant correlation with maximum temperature and had positive correlation with average rainfall, relative humidity and evening relative humidity. The variation in the result may be due to implementation of trail. The present trail was conducted under protected condition where application of insecticide hindered activity of mirid bug which leads to drawn inappropriate conclusion.

5.1.4.3 Activity of pest and their natural enemies in relation to weather parameters under dry direct seeded rice unprotected condition.

5.1.4.3.1 Brown planthopper

Influence of microclimate weather on BPH incidence was assessed and revealed that relative humidity had non-significantly negative relationship but had significant positive relationship temperature and carbon dioxide. In present study, microclimate weather had a significance impact on incidence of planthopper. Temperature and carbon dioxide were main important factor which influenced positively to incidence of BPH. The present findings on impact of carbon dioxide was in confirmative with the earlier work Prasannakumar *et al.*, 2012 who noticed maximum number of BPH at elevated (380 ± 25) carbon dioxide level than ambient (570 ± 25 ppm) (Fig. 10).

Association of BPH population and station weather parameters exerted significant positive relationship with maximum temperature but minimum temperature had non-significant positive correlation, whereas, a non-significant negative association was found with rainfall, morning relative humidity, evening relative humidity (Fig. 11).

Similarly, influence of weather parameters on BPH are in confirmation with reports of Reddy *et al.* (1983), Cheng *et al.* (1992), Jeyarani (2004), Krishnaiah *et al.* (2006), Sachan *et al.* (2006), Chaudhary *et al.* (2014) and (Prasannakumar and Subhash., 2014) and these findings are in confirmation with present findings.

5.1.4.3.2 Whitebacked planthopper

The correlation studies on WBPH incidence and microclimate weather observations revealed that relative humidity had non-significant negative relationship with WBPH and temperature and carbon dioxide had significant positive relationship. In present study microclimate weather parameter like temperature and carbon dioxide had showed positive influence on activity of WBPH. This indicates has increased temperature and carbon dioxide, there was increase in WBPH population. However, there was no evidence to support this fact. But further, these factors need to ascertain to confirm the facts (Fig. 10).

Similarly, correlation between WBPH population level and station weather parameters was assessed and results showed significant positive relationship with maximum temperature and non-significant positive correlation with minimum temperature. However, morning relative humidity, evening relative humidity and rainfall were found to be negative and non-significant relationship with WBPH population (Fig. 11).

These findings are in support with Narayansamy *et al.* (1979), Khan and Mishra (2003), Prasad (2010), Satpathi *et al.* (2011) and Hafizal and Idris (2014) and who reported positive correlation with relative humidity. The present findings are disagree with the reports of Win *et al.* (2011) observed positive relationship between rainfall and WBPH population. Mancharan and Jayaraj (1979) reported non-significant relationship between BPH population and maximum temperature, relative humidity and rainfall. Variation in the present result may be due to variation in location and climate.

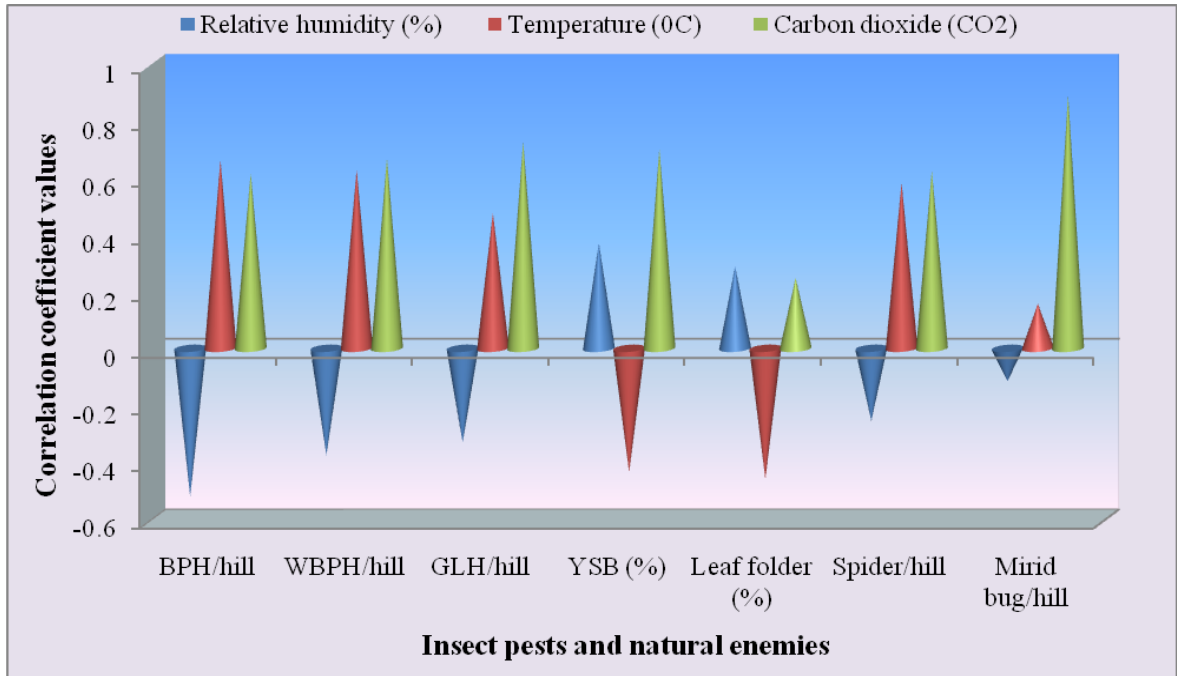


Fig. 10. Correlation between paddy insect pests and natural enemies with micro climate weather observations in dry direct seeded rice ecosystem under unprotected condition during *kharif*, 2015-16

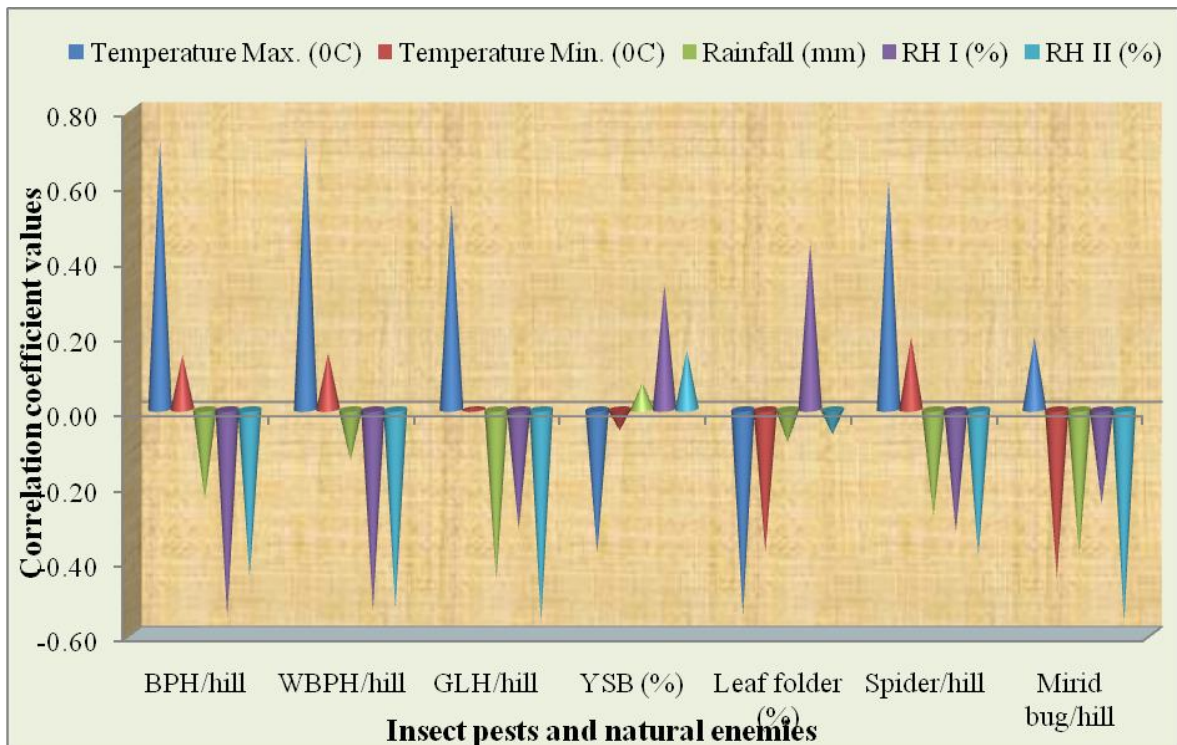


Fig. 11. Correlation between paddy insect pests and natural enemies with station observatory weather parameters in dry direct seeded rice ecosystem under unprotected condition during *kharif*, 2015-16

5.1.4.3.3 Green leafhopper

The microclimate weather parameters on GLH population exhibited non-significant negative effect with relative humidity. Whereas, temperature was had non-significant positive correlation. However, carbon dioxide was correlated significant positive with GLH populations (Fig. 10). It clearly indicates that as increase in carbon dioxide level population of GLH also increases. No work has been done to be ascertain under open top chamber condition.

Similarly, correlation between GLH population and station weather parameters exerted a significant positive correlation with maximum temperature but positive and non-significant effect with minimum temperature. However, statistically non-significant and negative correlation was found with rainfall, morning relative humidity and evening relative humidity. Present findings are in line with the reports of Khan and Mishra (2003).

5.1.4.3.4 Yellow stem borer

The correlation between yellow stem borer incidence and microclimate parameters was exhibited non-significant positive relation with relative humidity and carbon dioxide. Further Statistically non-significant and negative correlation was noticed with temperature (Fig. 10).

Similarly, yellow stem borer incidence and station weather parameters exerted a non-significantly negative relation with maximum temperature and minimum temperature. Further non-significant positive correlation was noticed with morning relative humidity, evening relative humidity and rainfall (Fig. 11).

The present results in corroborate with results of earlier worker Kumar *et al.* (1995), Vijaykumar (2002), Adiroubane and Raja (2007), Justin and Preetha (2013) were also noticed positive correlation with relative humidity and negative correlation with maximum temperature and rainfall with incidence of stem borer.

On contradictory to present results Vijaykumar (2002) observed minimum temperature and maximum temperature were negatively correlated with yellow stem borer incidence. This may be due to variations in the weather parameters of the locations and their influence on the activity of pest population.

5.1.4.3.5 Leaffolder

It is clearly evident from the Figure 10, carbon dioxide and relative humidity had non-significant positive relationship with incidence of leaffolder whereas, temperature had showed non-significant negative relation. It indicates both microclimate weather parameter like carbon dioxide and relative humidity had positive impact on incidence of leaffolder. However, no evidences are available to support the fact.

Further, maximum temperatures, minimum temperature, rainfall, evening relative humidity of station weather parameters were showed significant negative impact on leaffolder incidence. But morning relative humidity had non-significant positive impact (Fig. 11). The present findings are supported the results of Vanitha (2012) who also reported a significant positive correlation with the morning relative humidity, afternoon relative humidity but the maximum temperature had negatively association with leaffolder incidence. Bhatnagar and Saxena (1999), Bhaskar (1994) Vijaykumar (2002), Prasad (2010) and Chakraborty and Deb (2011) were also in confirmative with present findings

Present results were contradicted by Kaul and Singh (1999) and Patel *et al.* (2011) who recorded a significant positive correlation with average temperature. This variation might be due to the variations in the climatological condition of the location.

5.1.4.3.6 Spider

The correlation between microclimate weather and spider population study exerted a non-significant negative relation with relative humidity whereas, temperature and carbon dioxide had significant positive effect with spider population level (Fig. 10).

Further, maximum temperature of station weather parameters had significant positive associated with spider but non-significant positive effect was noticed with minimum temperature. Subsequently the spider population level found to be non-significantly negative association with morning relative humidity and evening relative humidity and rainfall. Results are agree with the results of Vijaykumar (2002) and Prasad (2010) who reported the both rainfall and evening relative humidity were found to be positively correlated. Also Khan and Mishra (2003) revealed significant positive correlation with temperature.

5.1.4.3.7 Mirid bug

The association between a predatory mirid bug population and microclimate parameters were observed and found non-significantly negative correlation with relative humidity, whereas, significant positive association was noticed with carbon dioxide but temperature exerted a non-significant positive correlation. As observed in planthoppers here also carbon dioxide exhibited positive relation with mirid bug. Moreover these are density dependent factors, influence of microclimate is need to be ascertain. No evidence available to support the present study.

Similarly, correlation between station weather parameters and mirid bug population level was found significant positive relation with maximum temperature. Further, non-significantly negative effect was observed with minimum temperature, rainfall, morning and evening relative humidity. Present results are contradicted with the reports of Vijaykumar (2002) and Prasad (2010) who reported positive correlation with morning relative humidity and evening relative humidity.

5.1.4.4 Activity of pest and their natural enemies in relation to weather parameters under dry direct seeded rice protected condition

5.1.4.4.1 Brown planthopper

The correlation between BPH incidence and microclimate weather parameter revealed non-significantly negative relationship with relative humidity and however temperature had significant positive relationship, but carbon dioxide had non-significant positive relationship (Fig. 12). Similarly, Prasannakumar *et al.* (2012) who also reported maximum number of brown planthopper population at elevated (380 ± 25) carbon dioxide level than ambient (570 ± 25 ppm). Similarly, correlation between station observatory weather parameters and BPH population exerted non-significant positive relationship with maximum temperature and minimum temperature, whereas, a non-significant negative association was noticed with rainfall, morning relative humidity, evening relative humidity (Fig. 13). The present findings are in accordance with Reddy *et al.* (1983), Cheng *et al.* (1992), Krishnaiah *et al.* (2006), Sachan *et al.* (2006), Prasannakumar and Subhash, (2014). On contradictory to present findings, Prasad (2010) revealed negative association with maximum and minimum temperature, positive relationship with morning and evening relative humidity. This may be due to variations in the weather parameters in different locations and their influence on the activity of pest population.

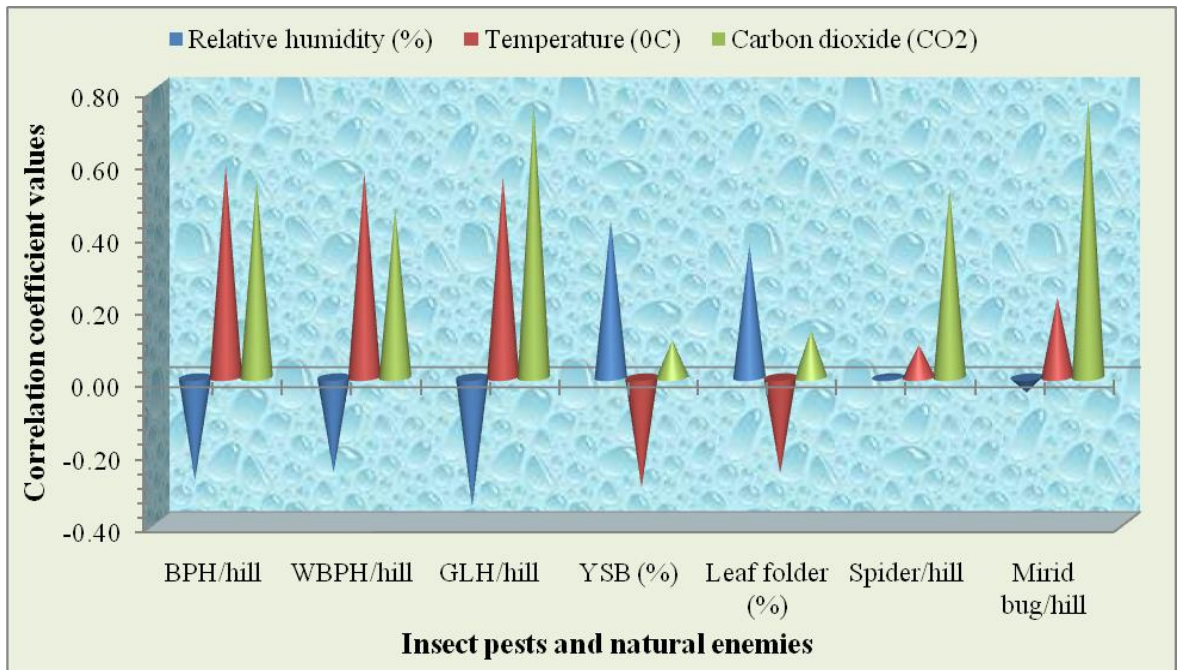


Fig. 12. Correlation between paddy insect pests and natural enemies with micro climate weather observations in dry direct seeded rice ecosystem under protected condition during *kharif*, 2015-16

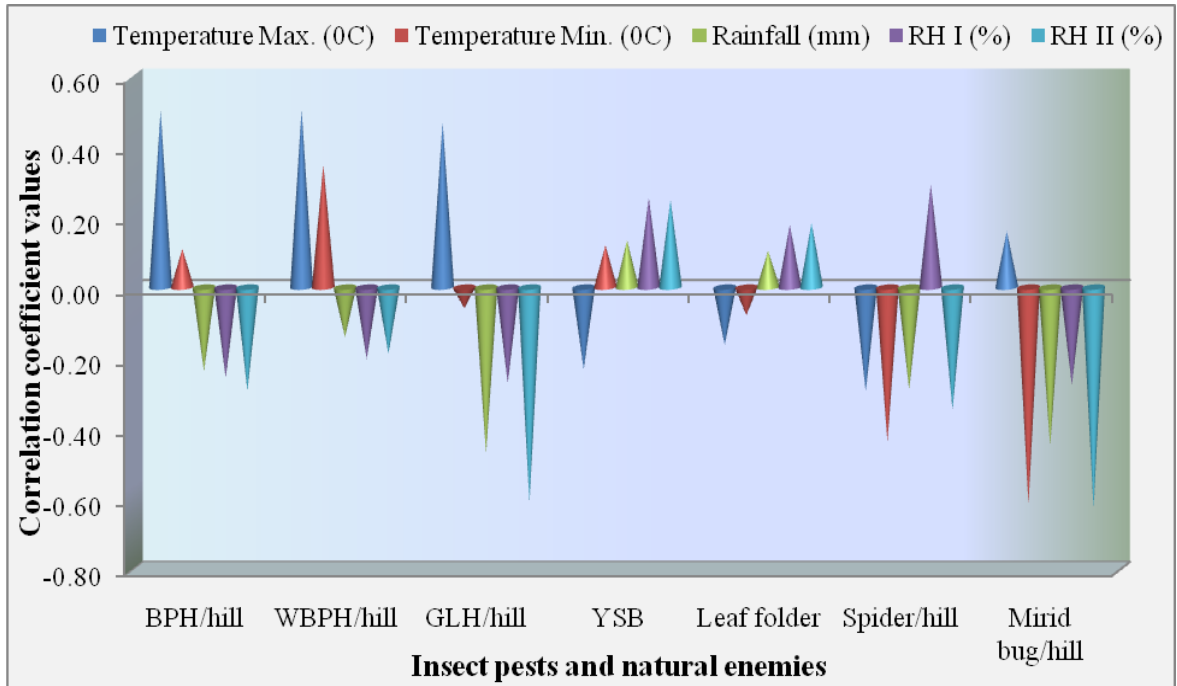


Fig. 13. Correlation between paddy insect pests and natural enemies with station observatory weather parameters in dry direct seeded rice ecosystem under protected condition during *kharif*, 2015-16

5.1.4.4.2 Whitebacked planthopper

The correlation studies between microclimate weather observation and WBPH incidence revealed non-significantly negative relationship with relative humidity. Further, temperature and carbon dioxide had non-significant positive relationship. Similarly, the relation between station weather parameter observations and WBPH population level was showed non-significant positive relationship with maximum temperature and minimum temperature. Further, non-significantly negative correlation was noticed with morning relative humidity, evening relative humidity and rainfall (Fig. 13). The present findings are in close association with the result of Khan and Mishra (2003), Satpathi *et al.* (2011) and Hafizal and Idris (2014). Whereas, present results were disagree with the reports of Narayansamy *et al.* (1979) who reported positive correlation of relative humidity with planthopper. Mancharan and Jayaraj (1979) reported non-significant relationship between *N. lugens* population and maximum temperature, relative humidity and rainfall. Similarly, Win *et al.* (2011) who observed both the planthoppers population was found positively correlated with rainfall. Srinivasa (1984) who reported significant negative correlation between trap catches and maximum temperature. Difference in results may be due to variation and location and also variation in planthoppers population due to application of pesticide.

5.1.4.4.3 Green leafhopper

The correlation studies between GLH population level and microclimate parameters revealed the non-significantly negative correlation with relative humidity. Whereas temperature was found to be non-significant positively relation, but the carbon dioxide had correlated significant positive relation (Fig 12).

Similarly, non-significant positive association was noticed with maximum temperature of station weather parameters. Further, non-significant negative effect was noticed with minimum temperature, rainfall, morning relative humidity and evening relative humidity. Present findings are in line with the reports of Khan and Mishra (2003) who noticed negative correlation of GLH population with relative humidity and but temperature had positive correlation (Fig 13).

5.1.4.4 Yellow stem borer

The correlation between microclimate weather parameters and yellow stem borer incidence exhibited non-significant positive effect with relative humidity and carbon dioxide but, non-significant negative correlation was observed with temperature (Fig 12).

Similarly, station weather parameters also exerted a non-significantly negative effect with maximum temperature. Further, non-significant positive correlation was noticed with minimum temperature, morning relative humidity, evening relative humidity and rainfall (Fig. 13). Similar kinds of results were obtained by results of Kumar *et al.* (1995), Vijaykumar (2002), Adiroubane and Raja (2007) and Justin and Preetha (2013).

Further, reports of Somashekara and Javaregowda (2015) were contradictory to present findings which may due to the variation may be due to variation in location, climate, and variation in incidence of YSB in field and light trap catches.

5.1.4.5 Leaffolder

The correlation studies between microclimate weather parameter and leaffolder incidence were revealed non-significant positive effect with relative humidity and carbon dioxide, whereas, temperature had non-significant negative association. This clearly indicates that carbon dioxide and relative humidity were had positive influence on activity of leaffolder. No evidences are available to support the fact (Fig. 12).

Similarly, leaffolder incidence and station observatory weather parameters exhibited significant negative effect with maximum temperature and minimum temperature. whereas, rainfall, morning relative humidity and evening relative humidity showed positively non-significant effect (Fig. 13). Present findings are in accordance with the results of Bhaskar (1994), Bhatnagar and Saxena (1999), Vijaykumar (2002), Vanitha (2012), and Prasad (2010) who reported non-significant negative correlation with maximum and minimum temperature.

Further, Chakraborty and Deb (2011) reported a significant positive association of leaffolder population with the maximum relative humidity and rainfall. Likewise, they also reported a significant negative association of the minimum relative humidity and

sunshine hour with the leaffolder damage found contrary to present results. This variation might be due to the variations in the climatological condition of the location.

5.1.4.4.6 Spider

The association between spider population and microclimate weather parameters exerted non-significant positive effect with relative humidity and temperature and carbon dioxide. Influence of these micro weather parameters on spider population needs to be ascertain under control condition. Since no literature are available to support the findings (Fig. 12).

Further, non-significant negative correlation was observed with maximum temperature, minimum temperature, rainfall and evening relative humidity of station weather parameters. Further, morning relative humidity was found to be non-significant positive effect with spider population (Fig. 13).

The present findings are in line with the results of Vijaykumar (2002) and Prasad (2010) who reported the both rainfall and evening relative humidity had positively correlation but on contrary minimum temperature and maximum temperature were found negative correlation with spider activity. Also Khan and Mishra (2003) found that significant positive correlation with temperature.

5.1.4.4.7 Mirid bug

The association of microclimate weather parameters and predatory mirid bug population were ascertained and results revealed that relative humidity was found to be non-significant negative correlation but temperature was found non-significant positive association. However, carbon dioxide had significant positive impact on predatory mirid bug population (Fig. 12).

Similarly, relationship between predatory mirid bug population level and station weather observations was assessed and revealed that maximum temperature had non-significant positive association but significant negative effect was observed with minimum temperature, evening relative humidity. However, rainfall had negatively non-significant association with the predatory bug population (Fig. 13). Present findings are contrary with the findings of Prasad (2010) who reported positive correlation with minimum temperature morning relative humidity, evening relative humidity and rainfall.

5.1.5 Correlation between insect-pests of rice monitored through light trap and weather parameters during 2015

Population dynamics of insect pests of rice was assessed through light trap catches. The peak activity of BPH was noticed at 42nd standard week and activity was less during 28th standard week which indicated that BPH menace was more in *kharif* season compared to other seasons. Similarly, populations of WBPH dynamics was assessed through light trap catches which ranged from 31.25 to 3489.69 hoppers/trap/week with peak activity at 42nd standard week (3489.69) and the population declined at 44th standard week which indicated that WBPH was noticed to be preferred early stage of the crop (Fig. 14). The present findings are in accordance with the reports of Vijaykumar and Patil (2004) and Ashrith (2014) who observed peak incidence of planthoppers in the month of October-November.

Correlation studies observed on activity planthoppers (BPH and WBPH) with weather parameter result showed that negative relationship was obtained with maximum temperature, minimum temperature and rainfall, whereas, morning and evening relative humidity were showed significant positive correlation. High humidity probably favours planthopper multiplication because planthoppers are highly adapted to the humid climate (Fig. 16). The present findings are in agreement with the reports of Narayansamy *et al.* (1979) who also reported positive correlation with relative humidity. Barwal and Rao (1986) who were also noticed negative relationship between BPH and minimum temperature. Mancharan and Jayaraj (1979) also reported non-significant relationship between WBPH populations and maximum temperature. Gupta (1981) reported negative correlation between trap catches and rainfall. While, on contradictory to the present findings Ashrith (2014) who noticed maximum temperature and minimum temperature were found to be positive relationship with light trap catches of planthopper. Guruprasad *et al.* (2014) recorded minimum temperature, evening relative humidity and morning relative humidity showed significant positive correlation with the activity of WBPH.

Likewise, population of *N. virescens* and *N. nigropictus* were noticed peak at 47th and 49th standard week 108.00 and 157.71 per/trap/week, respectively, maximum population was noticed during the month of November (Fig 16). The present findings are inline with the reports of Guruprasad *et al.* (2014) who noticed peak incidence of GLH in the months of October and November.

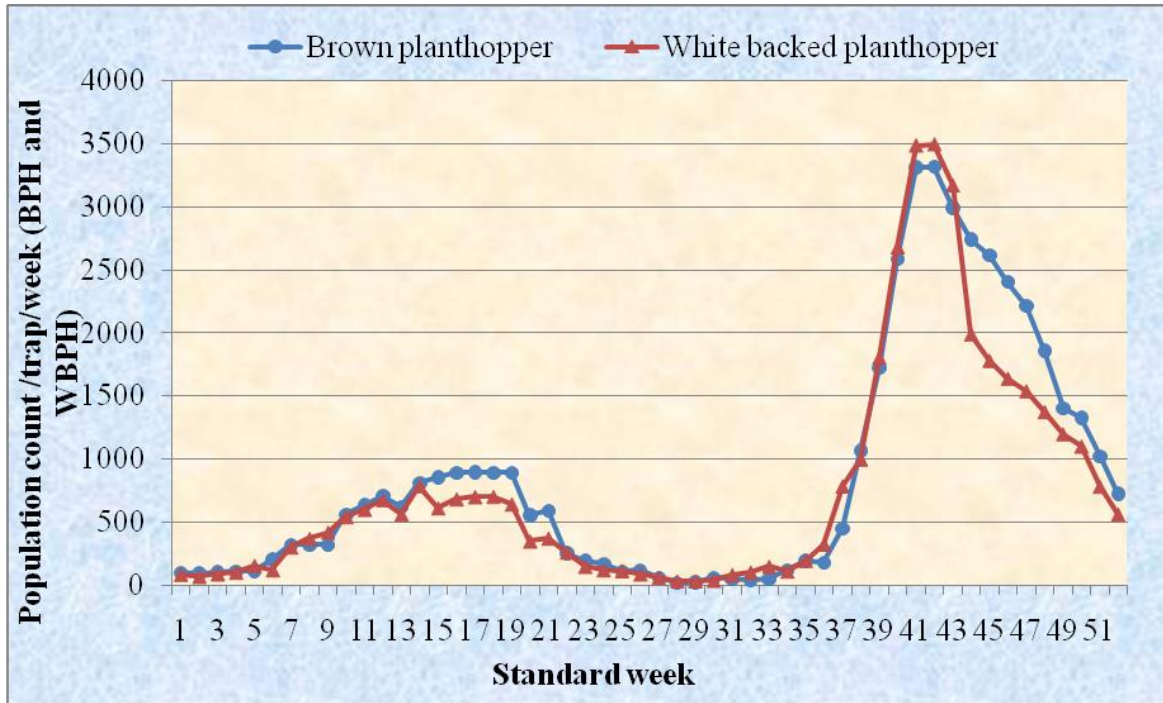


Fig. 14. Light trap catches of Brown planthopper and Whitebacked planthopper at ARS, Gangavathi, during 2015-16

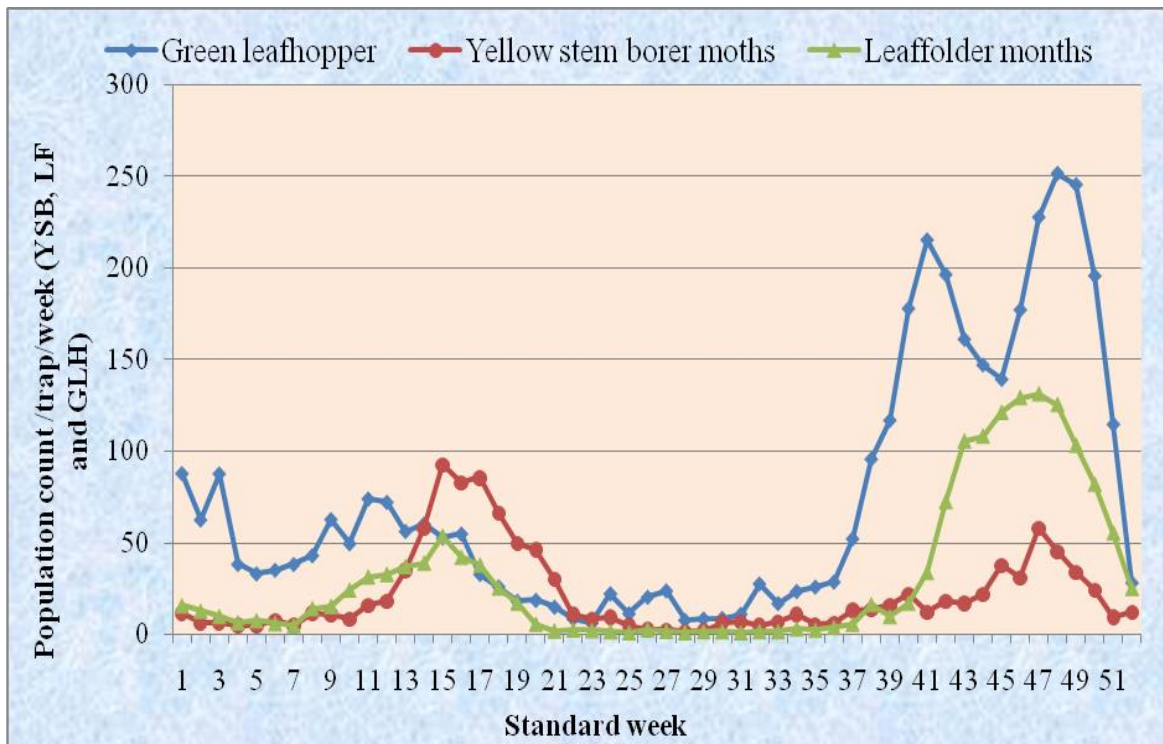


Fig. 15. Light trap catches of Green leafhopper, Yellow stem borer and Leaffolder at ARS, Gangavathi, during 2015-16

Activities of green leafhopper incidence correlated with weather factors which revealed that significant negative correlation was noticed with maximum temperature but non-significantly negative relationship was observed with minimum temperature and average rainfall. However, significant positive correlation with morning and evening relative humidity. The main reason may be humid climate which might have influenced the activity and multiplication of leafhoppers (Fig. 15). The present findings are supported with the report of Ashrith (2014) and Shamim *et al.* (2009) who reported that non-significantly negative association with GLH with maximum temperature, minimum temperature and rainfall. Vijaykumar (2002) who also reported non-significant positive correlation with both morning relative humidity and evening relative humidity.

Population of YSB moth through light trap per week catches was noticed with peak incidence of 92.28moths/trap/week during 15th meteorological standard week which indicating that YSB menace was more in *summer* compared *kharif* season (Fig. 15). The present findings are in accordance with the reports of Ishhaque and Rahman (1983), Guruprasad *et al.* (2014) and Ashrith (2014) noticed peak incidence of YSB in second fortnight of April. On contrary to the present reports Somashekar and Javaregowda (2015) who recorded peak incidence of YSB in 34 -38th standard week. This may be due to variation in the weather parameters and their influences on the activity of pest population.

Light trap catches of yellow stem borer moth (both males and females) when correlated with major weather parameters revealed that only maximum temperature showed significant positive influences whereas, minimum temperature was found to be negatively correlated. Main reason for this significant effect is because this pest prefers high temperature for multiplication hence, its incidence is more in the summer season (Fig. 16). The present findings are in conformation with the report made by Rao and Padhi (1988) who reported significant correlation between pest infestations with maximum temperature. Nandihalli *et al.* (1990) reported the positive correlation with trap catches and average maximum temperature and also average morning relative humidity. On contrary to present results Somashekar and Javaregowda (2015) who noticed positive correlation between minimum temperature and light trap catches of yellow stem borer at Uttara Kannada district.

The peak trap catches of leaffolder was noticed at 47th week and was remained maximum throughout the November month (Fig. 15). The present findings are in supported with earlier report of Guruprasad *et al.* (2014) and Ashrith (2014).

Correlation studies made between leaffolder moth population and weather parameters showed significant negative correlation with maximum temperature and non-significant negative correlation with minimum temperatures and rainfall. Further, morning relative humidity showed a significant positive association but non-significant positive correlation was noticed with evening relative humidity (Fig. 16). These findings are in close relationship with the report of Bhaskar (1994) who reported non-significant negative correlation with maximum and minimum temperature, non-significant positive correlation with relative humidity. Also, Guruprasad *et al.*, (2014) and Chakraborty and Deb (2011) who also reported similar kind of result on humidity and temperature. On contradictory to present findings Guruprasad *et al.* (2014) who observed significant positive relationship with minimum temperature and leaffolder trap catches.

5.1.6 Population dynamics of natural enemies of planthoppers in transplanted and dry direct seeded rice ecosystem

Dynamics of egg parasitoids of planthoppers were assessed by rearing of field infested eggs of unprotected condition under laboratory. Results of dynamics of natural enemies are discussed as below.

From the Fig. 17 it is clear that activity of egg parasitoid was more at 50 and 70 DAT under DDSR and TPR cultivation system (9.23 and 22.02% respectively). However, activity was declined as pest incidence was reduced which was at 90 DAT. This indicates that activities of natural enemies of planthopper are density dependant. When incidence of planthopper was more the activity of parasitoids was also more but as incidence declined activity also declined. However, significantly maximum per cent of egg parasitisation by all parasitoid was noticed in TPR system (17.17%) compared to DDSR (8.06) at all stages of crop growth. Among the three species, *Anagrus* was found to be predominant species accounting for 64.99 and 72.73 per cent in DDSR and TPR respectively compared to other two species irrespective of systems. This was followed by *Oligosita* which accounting for 29.99 and 23.45 per cent in DDSR and TPR respectively and the least per cent parasitisation was observed with *Gonetocera*.

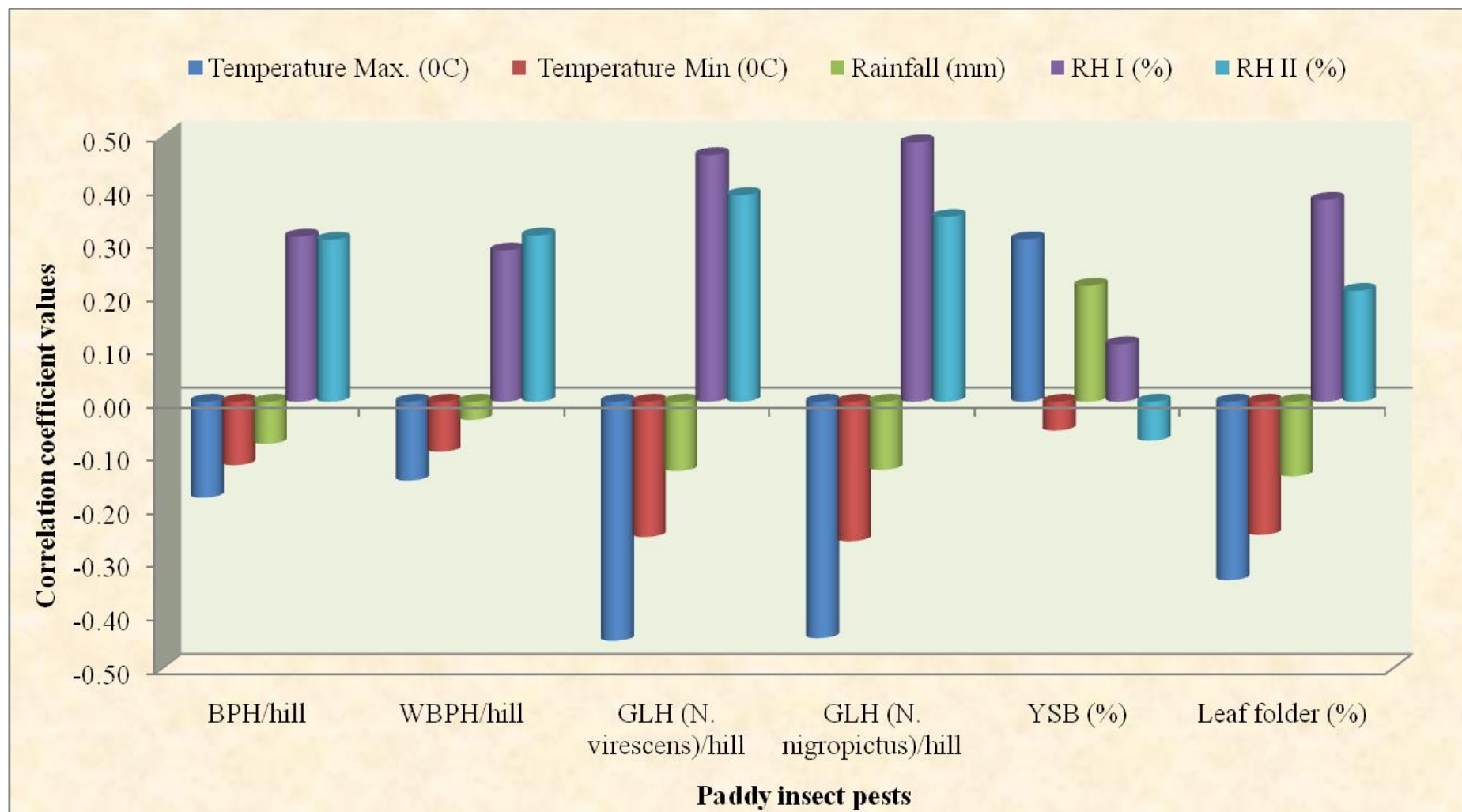


Fig. 16. Correlation between insect pests of paddy trapped under light traps with weather parameters at ARS, Gangavathi during 2015-16

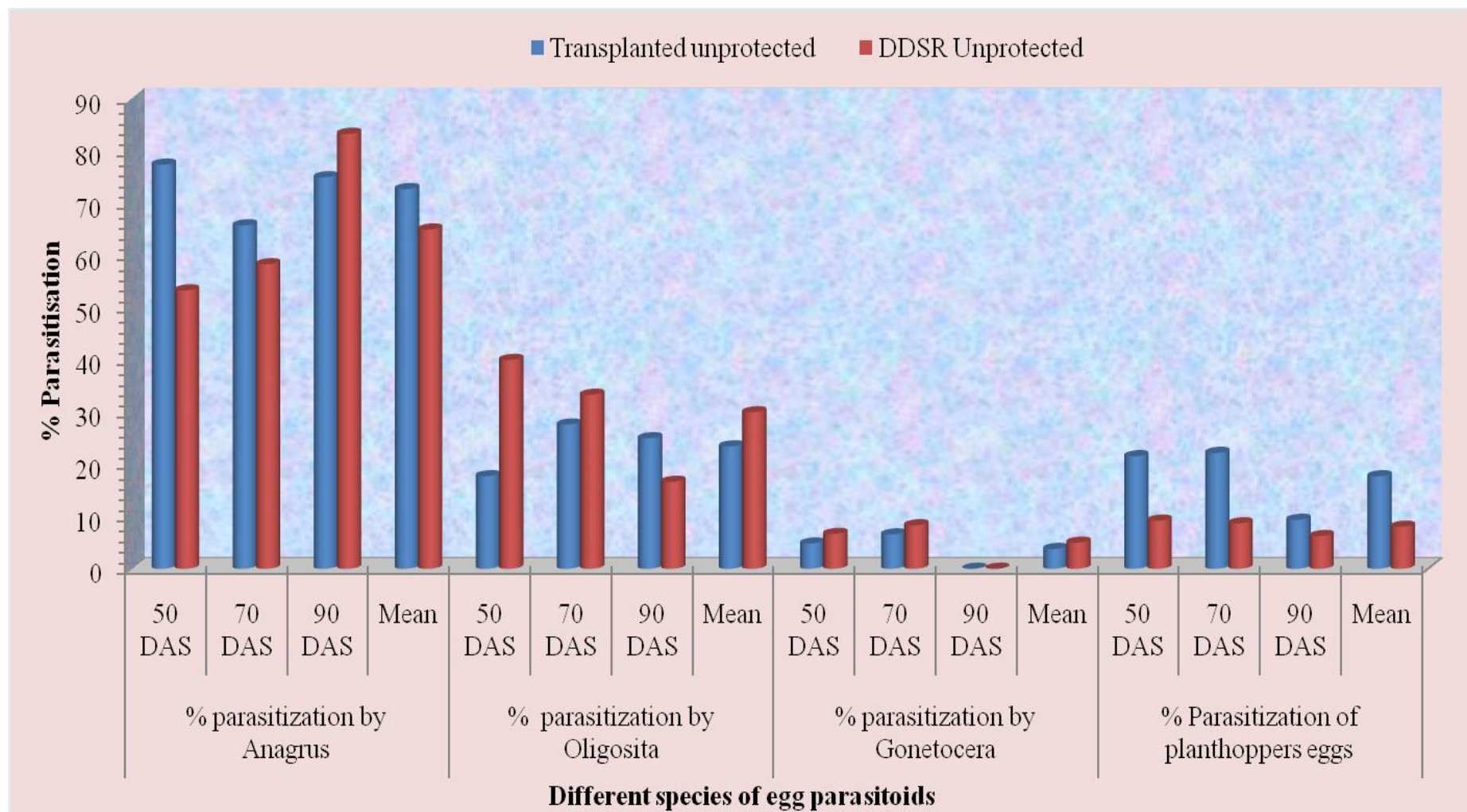


Fig. 17. Dynamics of egg parasitoids of planthoppers in transplanted and dry direct seeded rice ecosystem at ARS, Gangavathi during 2015-16

In the present findings, per cent egg parasitisation was found to be less compared to TPR. This because parasitoids are density dependent factor as report of earlier work (Anon., 2010). However, DDSR registered less number of planthoppers infestation compared to TPR as observed by Ashrith (2014). Hence, less infestation of planthoppers results less number of parasitisation. Further, *Anagrus* was predominant species among the parasitoids. The results of present findings are in confirmation with the reports made by Yasumatsu *et al.* (1975) who reported *A. optabilis*, *Gonetocerus* sp. *Polynema* sp. wasps were most important egg parasitoids of both rice leafhoppers and planthoppers in Thailand. Otake (1996), Kuno and Hokyo (1970) and Lin (1974) also found to be *Anagrus* sp. was the most dominant among the other parasitoids of egg.

Anon., 2013 recorded egg parasitisation of 37.5 per cent on BPH eggs in Ecological engineering plots of which *Anagrus* was dominant species with 66-70% parasitisation at Gangavathi (Karnataka, India).

5.2 To know the impact of left over crop residues on stem borer incidence for subsequent crop

The results on effectiveness of different treatments on left over crop residues on stem borer damage incidence for subsequent crop was evaluated and results revealed that the treatment residue burning followed by tillage was found to be superior treatment by registering significantly less per cent of 1.74 and 2.63 per cent dead heart and white ear damage, respectively (Fig. 18) but was statistically inferior to the chemical management. The chemical management treatment recorded significantly lowest percentage of dead heart and white ear damage (0.57 and 1.26, respectively). The next best treatments were burning of crop residues and recommended package of practice except plant protection which recorded moderate per cent of dead heart and white ear (2.89 & 4.80 and 3.91 & 5.20%, respectively). However, the treatment zero tillage with normal time of sowing (5.24% DH and 7.73% WE) and zero tillage followed by 10 days late sowing (5.66% DH and 8.27% WE) registered higher stem borer incidence. Significantly higher incidence was found in the treatment zero tillage without nylon cage (open condition) (7.51% DH and 9.27% WE) and was statistically inferior to all the treatments.

Among the different treatments which were evaluated against carryover of yellow stem chemical management, residue burning followed by tillage, burning of crop residues

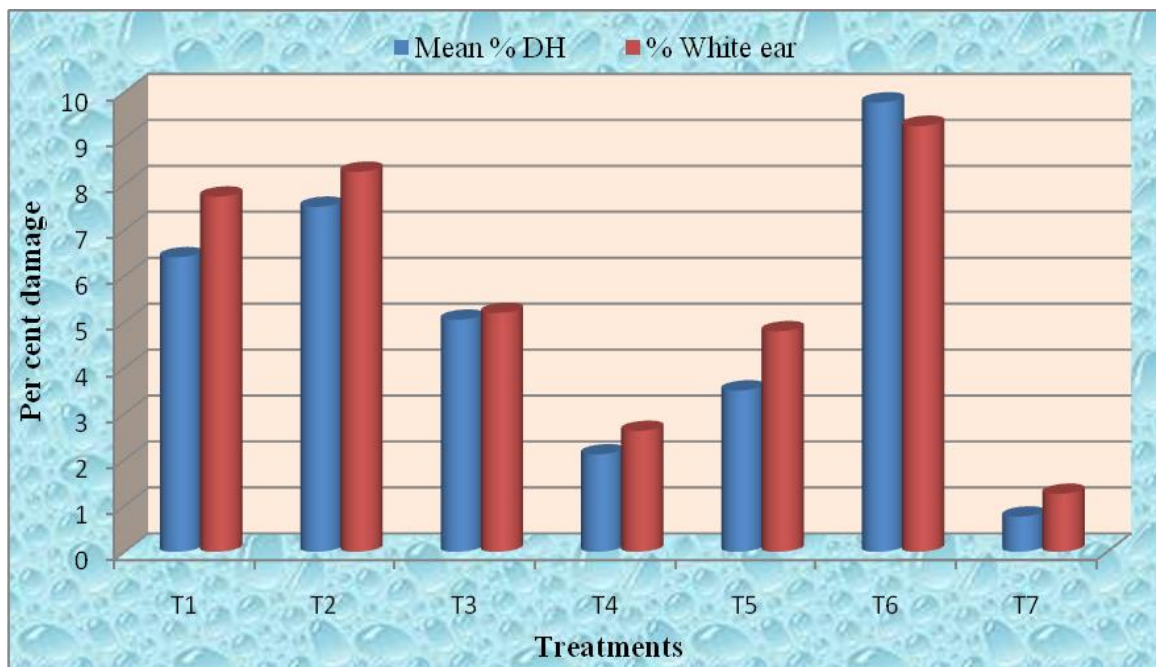


Fig. 18. Impact of left over crop residues on stem borer incidence for subsequent crop

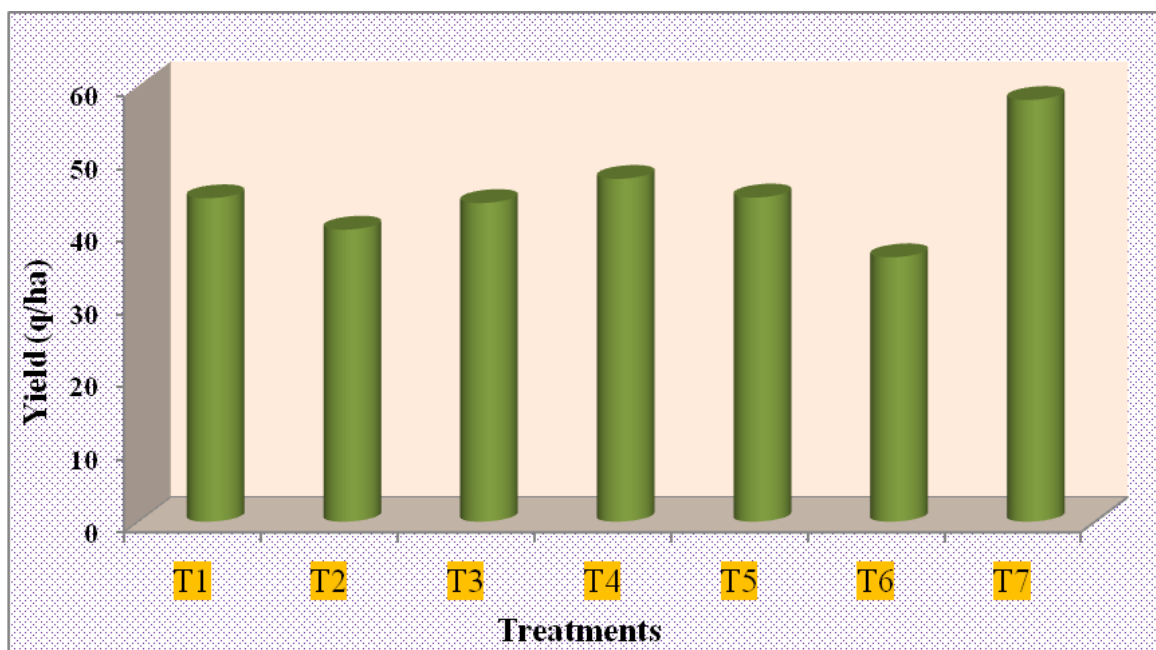


Fig. 19. Impact assessment of carryover yellow stem borer incidence on yield of subsequent crop

and recommended package of practice except plant protection recorded 92.41, 76.83, 64.11 and 47.93 per cent reduction of dead heart over untreated control, respectively. Similarly, among the different treatments which were evaluated against the carryover of yellow stem and incidence on subsequent crop includes chemical management, residue burning followed by tillage, burning of crop residues and recommended package of practice except plant protection recorded 86.40, 71.62, 48.22 and 43.90 per cent reduction of white ear over untreated control, respectively (Fig. 18).

Significantly higher grain yield of 58.10 q ha⁻¹ was recorded in the treatment chemical management and was followed by 47.23 q ha⁻¹ in residue burning followed by tillage. These treatments were followed by burning of crop residues, recommended package of practice except plant protection, zero tillage with normal time of sowing and zero tillage followed by 10 days late sowing recorded higher yield of 44.66, 44.56, 43.90 and 40.23 found on par with each other. All these treatment were found differed significantly with the treatment zero tillage without nylon cage (open condition) (36.43 q ha⁻¹) (Fig. 20).

Carryover of stem borer incidence for subsequent crop is due to overwintering larvae and pupation in basal part of rice stubble. Hence, tillage practices can greatly influence the survival of the pest and damage on the subsequent sown crop. Present experimental results were in confirmation with the findings of Unithan and Gebre (1989); Rehman *et al.* (2002); Saroj *et al.* (2005) and Ramzan *et al.* (2007) who reported that stem borers incidence remained comparatively higher in zero-tillage sown fields than those of conventional transplanted rice which in turn emerges from the stubbles after hibernation or completion of pupal period and attacks on the subsequent crops. Ashrith *et al.* (2015) studied on carryover of stem borers in DDSR and transplanted rice on subsequent crop reported that tillage practices and crop rotation will greatly influence on survival of stem borers. This was the reason in present study highest damage was registered in the treatment zero tillage without nylon cage (open condition).

The best cultural practice found to reduce the stem borer incidence was burning and tillage which could reduce the incidence up to 78.32% of dead heart and 71.62% of white ear. This factor is attributed to earlier worker Jiang *et al.* (2011) who found that burning the fields after harvesting appeared to be most effective and could kill 84.5% of remaining borers in high stubbles of super rice. This is because borers in super rice reside

LEGEND

Treatment details

- T₁ : Pymetrozine 50 WG @ 200 g a.i. /ha
- T₂ : Ethiprole + Imidacloprid 80 WG @ 100 g a.i. /ha
- T₃ : Dinotefuran 20 SG @ 40 g a.i. /ha
- T₄ : Buprofezin 25 SC @ 25 g a.i. /ha
- T₅ : Buprofezin 15 + Acephate 35 WP @ 625 g a.i. /ha
- T₆ : Acephate 50 + Imidacloprid 1.8 WG @ 300 g a.i. /ha
- T₇ : Triflumezopyrim 106 SC @ 25 g a.i. /ha
- T₈ : Flubendiamide 14 + Buprofezin 24 SC @ 96 g a.i. /ha
- T₉ : Flonicamid 50 WG @ 35 g a.i. /ha
- T₁₀ : Acephate 75 SP @ 600 g a.i. /ha
- T₁₁ : Imidacloprid 17.8 SL @ 22.25 g a.i. /ha
- T₁₂ : Control

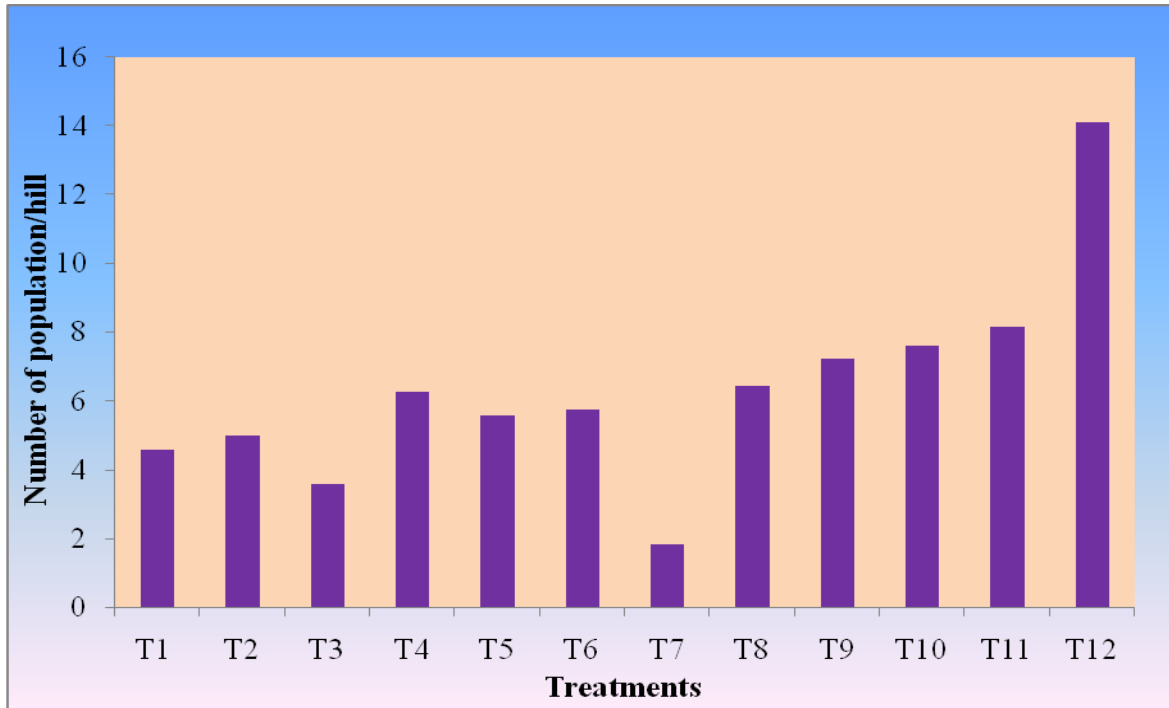


Fig. 20. Bio efficacy of newer insecticides against brown planthopper under dry direct seeded rice ecosystem during *kharif* 2015-16

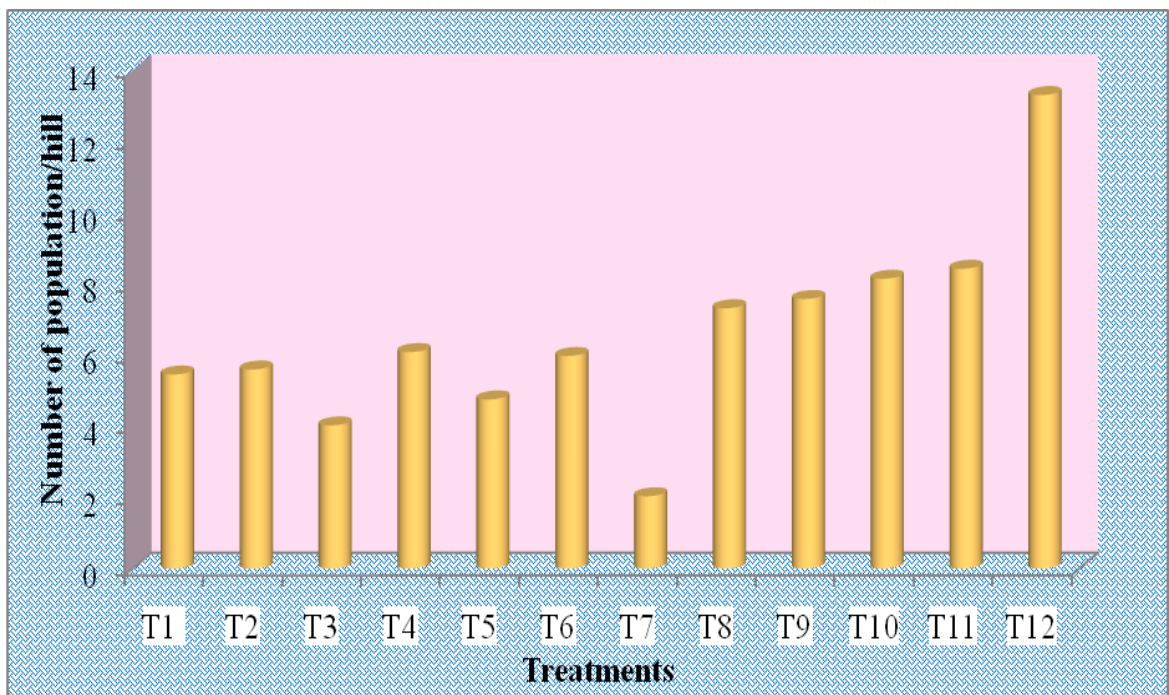


Fig. 21. Bio efficacy of newer insecticides against whitebacked planthopper under dry direct seeded rice ecosystem during *kharif* 2015-16

higher up the rice stems and these tall stubbles were easier to burn effectively. Similarly, Soomro *et al.* (2013) who registered lower number of larvae and pupae with higher mortality under ploughed rice field than with un-ploughed field. Hence burning and tillage practices could be better resort to manage the stem borers but it is forbidden practice for ecological reason. However, based on the present findings, an efficient way to manage stem borers without resources to insecticides can be summarised as burning followed by tillage, tillage and burning which can reduce the borers efficiently but that could be practice in high endemic area for ecological concern

Prasad *et al.* (2014) in which they clearly indicated the effectiveness of chemical insecticides like Acephate 75 SP @ 667 g ha⁻¹, followed by the combination of Flubendiamide (4%) + Buprofezin (20%) 24 SC @ 875 ml ha⁻¹ and Flubendiamide 20 WDG @ 175 g ha⁻¹. Whereas, the incidence of lower dead heart 3.50 %, 4.15 %, 4.40% and with a higher yield of 18.00, 16.37 and 16.27 q ha⁻¹ respectively.

The last resort for the management of stem borer in incidence was chemical practice. So present study in accordance with Devi and Singh (2016) who recorded the lowest per cent of dead heart and white ear in treatment of flubendiamide 39.35 SC @ 24 g a.i. ha⁻¹ was found quite effective against YSB by recording mean per cent dead heart (DH) and white ear (WE) of 3.48 and 1.32, respectively and recorded significantly higher grain yield.

5.2.1 Yield loss due to stem borer damage

The effect of different treatments on incidence of yellow stem borer on subsequent crop was mainly reflected on yield and noticed that among all the treatments chemical management was superior in suppressing the damage and found significantly higher yield of 59.56 q/ha followed by the treatment residue burning followed by tillage (47.23 q ha⁻¹). The next best treatments were burning of crop residues, recommended package of practice except plant protection, zero tillage with normal time of sowing and zero tillage followed by 10 days late sowing registered comparatively lowest yield of 44.66, 44.56, 43.90 and 40.23 q ha⁻¹, respectively but were at par with above mentioned treatments, whereas, lowest yield of 36.43 q ha⁻¹ was observed in the treatment zero tillage without nylon cage (open condition) (Fig. 19). Devi and Singh (2016) on Flubendiamide 39.35 SC @ 24 g a.i. ha⁻¹ noticed highest yield of 60.3 and 60.2 quintals per hectare in 2013 and 2014, respectively.

5.3 To manage planthoppers by newer insecticides in dry direct seeded rice ecosystem

Insecticides have been first line of defence against insect pest attacking rice on account of their effectiveness easy application and immediate results. Therefore, evaluation of new insecticide molecules is an important exercise of the rice entomologist and the present findings are discussed hereunder.

5.3.1 Management of brown planthopper through newer insecticides in dry direct seeded rice ecosystem

In the present study four new insecticides were found to be superior in suppressing the brown planthoppers population as compared to the recommended insecticides. Those novel insecticides include triflumezopyrim 106 SC @ 25 g a.i. /ha, dinotefuran 20% SG @ 40 g a.i. /ha, pymetrozine 50% WG @ 200 g a.i. /ha and ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha excelled over all other new synthetic insecticides.

The data on bio-efficacy of different chemicals evaluated against BPH and results of overall season and mean data consistently revealed that the lowest population of BPH was observed in triflumezopyrim 106SC @ 25 g a.i. /ha (1.83 hoppers/hill), followed by dinotefuran 20 SG @ 200g ha⁻¹ (3.58 hoppers/hill). The next best treatment was pymetrozine 50% WG @ 200 g a.i. /ha and ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha which recorded 4.56 and 4.98 hoppers per hill, respectively. Whereas, buprofezin15% + acephate 35% WP @ 625 g a.i. /ha and acephate 50% + imidaclopride 1.8% WG 300 g a.i. /ha registered moderate population per hill (5.57 and 5.76) respectively. All treated chemicals were superior over control (14.11 populations/hill) (Fig. 20). However, untreated control recorded highest population of 14.11 hoppers/hill.

Earlier Hegde and Nidagundi (2009) reported that buprofezin 25 SC at 1ml per/lit was the best treatment in suppressing the planthoppers population. Chaudhary *et al.* (2014) who also evaluated the superiority of different dozes of buprofezin15 + acephate 35% and reported that buprofezin 15 % + acephate 35% @ 1500 ml/ha significantly suppressed the population of BPH to 3.89 per 5 hills and increased yield of rice (57%) over untreated control. Similarly, Ghosh *et al.* (2014) that dinotefuran @ 25 g a.i./ ha performed well against BPH population than the conventional acephate and commonly used neo-nicotenoids.

Similarly, triflumezopyrim 106 SC was found to be best treatment and was followed by dinotefuran @ 25 g a.i. /ha at in Warangal and Maruthuru and Gangavathi (Anon., 2015). Cordova *et al.* (2016) also reported that triflumezopyrim provided good control of brown planthopper.

5.3.2 Management of whitebacked planthopper through newer insecticides in dry direct seeded rice ecosystem

Overall seasonal mean data on bio efficacy of different insecticides revealed that, Triflumezopyrim 106 SC @ 25 g a.i. /ha was found to be superior treatment by registering lowest population of WBPH (2.03 hoppers/hill) and was followed by dinotefuran 20% SG @ 40 g a.i. /ha (4.02). The next best treatment was pymetrozine 50% WG @ 200 g a.i. /ha and ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha @ recorded 5.45 and 5.59 hoppers per hill, respectively. Further, buprofezin 15% + acephate 35% WP @ 625 g a.i. /ha and Acephate 50% + Imidaclopride 1.8% WG 300 g a.i. /ha were recorded 4.75 and 5.97 hoppers per hill, respectively. Untreated control (13.30 hoppers/hill) registered highest population of WBPH (Fig. 21).

Mishra (2008) founded that application of new molecule Ethiprole 10 SC @ 50 g a.i./ha and clothianidine 50 WG @ 25 g a.i./ha were effective in selectively suppressing the WBPH population compared to conventional insecticides like triazophos and phasphomidon. Muralibhaskaran *et al.* (2009) observed 89.4 and 87.56 per cent reduction in population of WBPH after application of pymetrozine 50 WG (Chess 50 WG) @ 400 and 350 g/ha, respectively.

5.3.3 Grain yield ($q\ ha^{-1}$)

The efficacy of newer molecules also reflected on yield and among all the treatments Triflumezopyrim 106 SC @ 25 g a.i/ha was superior in suppressing the population and showing significantly higher yield of 62.64 q/ha followed by Dinotefuran 20% SG @ 40 g a.i. /ha ($56.26\ q\ ha^{-1}$) on par with each other. The next best treatments at par were pymetrozine 50% WG @ 200 g a.i. /ha and ethiprole + imidacloprid 80% WG @ 100 g a.i. /ha (55.00 and $53.16\ q\ ha^{-1}$ respectively) (Fig. 22).

Muralibhaskaran *et al.* (2009) on pymetrozine 50 WG and Mishra (2009) on flonicamid 50 WG were also noticed positive impact of new molecule on yield. Hegde

LEGEND

Treatment details

- T₁ : Pymetrozine 50 WG @ 200 g a.i. /ha
- T₂ : Ethiprole + Imidacloprid 80% WG @ 100 g a.i. /ha
- T₃ : Dinotefuran 20 SG @ 40 g a.i. /ha
- T₄ : Buprofezin 25 SC @ 25 g a.i. /ha
- T₅ : Buprofezin 15 + Acephate 35 WP @ 625 g a.i. /ha
- T₆ : Acephate 50 + Imidacloprid 1.8 WG @ 300 g a.i. /ha
- T₇ : Triflumezopyrim 106 SC @ 25 g a.i. /ha
- T₈ : Flubendiamide 14 + Buprofezin 24 SC @ 96 g a.i. /ha
- T₉ : Flonicamid 50 WG @ 35 g a.i. /ha
- T₁₀ : Acephate 75 SP @ 600 g a.i. /ha
- T₁₁ : Imidacloprid 17.8 SL @ 22.25 g a.i. /ha
- T₁₂ : Control

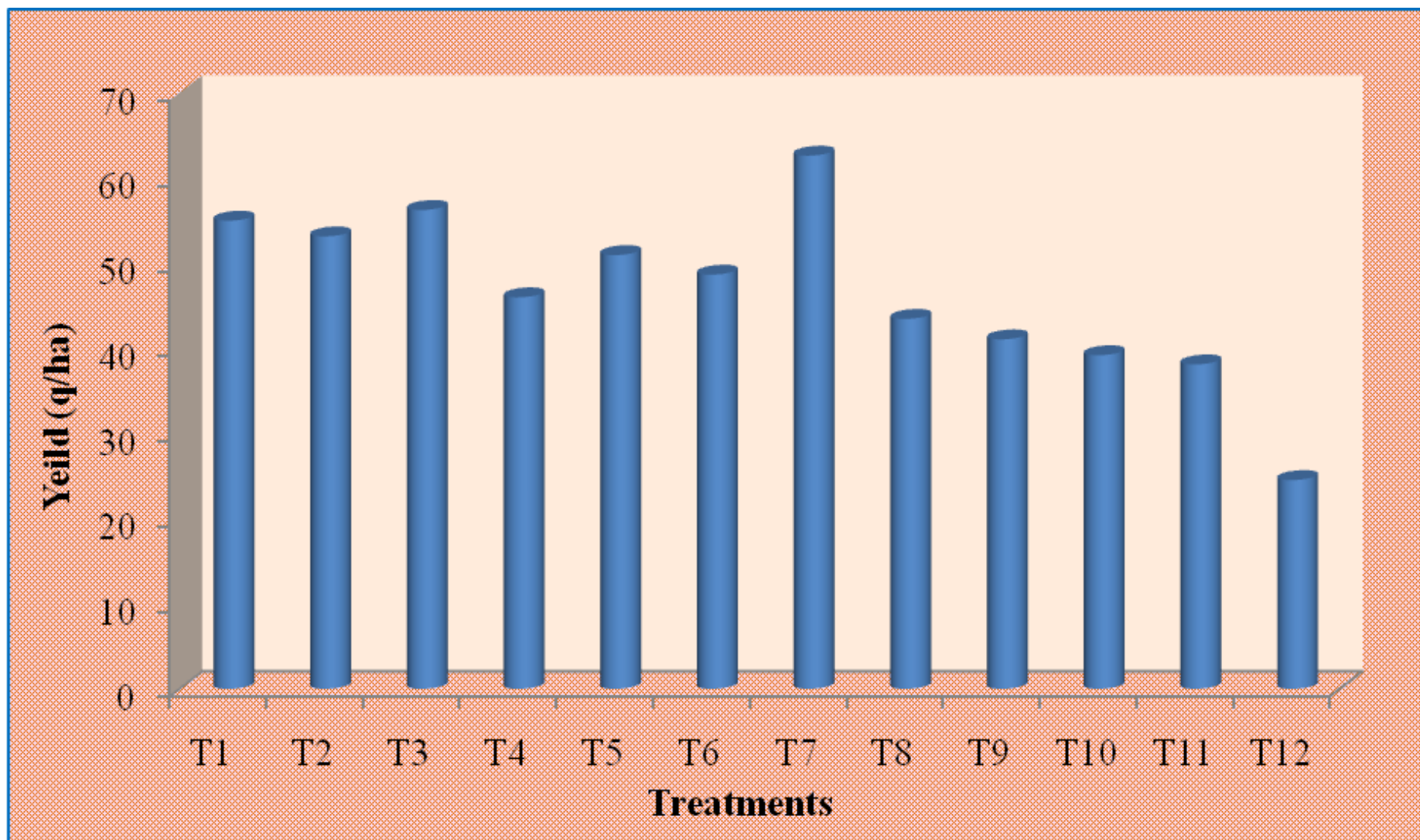


Fig. 22. Impact of new insecticides on grain yield during *kharif* 2015-16

and Nidagundi (2009) recorded highest yield in treatment Buprofezin 25 SC @ 1 ml /l. (Anon., 2015) also registered highest yield in triflumezopyrim 106 SC.

FUTURE LINE OF WORK

1. Species diversity of planthoppers and stem borers and their natural enemy complex has to be studied
2. Impact of microclimate weather parameter on pest and natural enemies dynamics has to be addressed in depth
3. Life table studies for planthopper and stem borer under DDSR needs to be studied

Summary and Conclusions

VI. SUMMARY AND CONCLUSIONS

The present investigation on the documentation of pest and natural enemies in DSR and TPR, impact of microclimate and station weather parameters, carryover and incidence of yellow stem borer on subsequent crop, chemical management aspects of rice planthoppers (Delphacidae) (Lepidoptera : Pyralidae) were conducted at Agriculture Research Station, Gangavathi during *kharif* 2015 and the results are summarised hereunder.

Documentation of insect pest and natural enemies of paddy was carried out in DSR and TPR system through yellow pan trap catches nine insect pests, 6 natural enemies including 3 predators, 3 parasitoids and an unidentified spider were recorded in transplanted condition. Whereas, 8 insect pests and 5 natural enemies which included 3 predators and 2 parasitoids were noticed in DSR system.

Planthoppers occurrence started from last week of September and the peak population was noticed during the month of October in transplanted (26.16 and 44.08/hill of BPH and WBPH respectively) rice under unprotected situation followed by dry direct seeded (7.75 and 11.38 of BPH and WBPH/hill) rice condition. Green leafhopper was active throughout the crop growth period and population level was comparatively high in transplanted (6.83/hill) than dry direct seeded (2.38/hill) rice under unprotected situation.

Stem borer incidence started from last week of October and maximum per cent of dead heart and white ear was recorded (14.21 and 12.53%) during second fortnights of October and November respectively in dry direct seeded rice under unprotected situation. Leaffolder damage commenced during first fortnight of October and peak leaffolder damage (14.21%) was observed during last week of November in dry direct seeded rice under unprotected situation.

Spiders were noticed throughout the cropping period and populations were recorded from 40 days old crop up to maturity. Highest level of population occurred in transplanted unprotected condition (3.82/hill) followed by dry direct seeded unprotected condition (2.17/hill). Mirid bugs *Cyrtorhinus levidpennis* started appearing during last week of September and populations of mirids reached peak in transplanted (8.92/hill)

followed by dry direct seeded (0.92/hill) rice under unprotected condition at 60 and 80 days old crop respectively.

Correlation between incidence of paddy insect-pests and natural enemies and weather parameters under unprotected transplanted condition revealed that temperature (microclimate) and maximum temperature (station weather parameters) had significantly positive relationship with BPH, WBPH, GLH, spider and negatively significant with yellow stem borer. Further, carbon dioxide (microclimate) was found to be positively correlated with BPH and mirid bug but significantly negative association was noticed with yellow stem borer. Further, Minimum temperature exerted significantly positive relation with spider but same abiotic factor had reciprocal relationship with respect to mirid bug. Rainfall had positive and non-significant correlation with white backed planthopper, green leafhopper, leaf folder and spider. Under transplanted protected condition and results revealed that temperature had significantly positive correlation with GLH and mirid bug but negative correlation with yellow stem borer. Further, carbon dioxide had significantly positive effect on BPH and GLH. Likewise maximum temperature showed significantly positive correlation with GLH and mirid bug. Positively significant relation was found also between minimum temperature and spider while minimum temperature had reciprocal association with yellow stem borer. Rain fall had non-significant positive correlation with white backed planthopper, green leafhopper, leaf folder and spider.

Also correlation studies between paddy insect-pests and natural enemies with weather parameters under DSR unprotected condition revealed that micro weather parameter like temperature had significantly positive association with BPH, WBPH and spider. BPH, WBPH, GLH, spider and mirid bug exhibited a significantly positive relationship with carbon dioxide of micro weather parameter. Subsequently maximum temperature showed significantly positive correlation with BPH, WBPH and spider but reciprocal association was found with leaf folder. Similarly, under DSR protected condition temperature had a significantly positive relationship with BPH. GLH and mirid bug exhibited significantly positive association with carbon dioxide. Minimum temperature and evening relative humidity showed negatively significant correlation with mirid bug.

Assessment of paddy pest dynamics through light trap catches revealed that yellow stem borer had significantly positive correlation with maximum temperature but same factor had reciprocal association with leaffolder and GLH. Similarly, morning relative humidity had significantly positive relationship with BPH, WBPH, GLH and leaffolder. Further, evening relative humidity had showed significantly positive association with BPH, WBPH and GLH.

Dynamics of egg parasitoids of planthoppers were assessed by rearing of field infested eggs of unprotected condition under laboratory. Significantly higher egg parasitization by all parasitoid was noticed in TPR conditions compared to DSR at all stages of crop growth. Among the egg parasitoid species observed *Anagrus* was found to be predominant species compared to *Oligosita* and *Gonatocerus*.

However, an efficient way to manage stem borers without resort for insecticides application can be summarised as burning followed by tillage, burning and tillage practices are effective tool in reducing the hibernating larvae of yellow stem borer and its further carryover but that could practice in high endemic area for ecological concern. Anyhow chemical spray with insecticides was given significantly better control of stem borer.

Management of planthoppers under DSR ecosystem through novel insecticide is practical and easily approachable to farming community. Among the various novel insecticides evaluated for the management of rice planthoppers, triflumezopyrim 106 SC @ 25 g a.i. /ha was found very effective in reducing hoppers population and there by resulting the higher yield of 62.64 q ha⁻¹ and was followed by dinotefuran 20% SG @ 40 g a.i. /ha and pymetrozine 50% WG @ 200 g a.i. /ha.

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Appendices

APPENDIX – I

Station observatory weather parameters 2015, ARS, Gangavathi

ISD weeks	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum		Morning	Evening
1	29.93	19.29	0.00	65.14	41.89
2	27.93	13.86	0.00	45.43	29.00
3	29.00	16.00	0.00	61.11	32.89
4	29.21	16.29	0.00	63.57	32.64
5	29.43	16.71	0.00	66.95	33.64
6	30.50	15.50	0.00	56.83	29.19
7	32.57	16.07	0.00	49.94	27.00
8	32.57	16.43	0.00	53.14	27.60
9	32.53	18.86	0.00	53.73	35.57
10	32.86	20.86	2.80	61.66	39.41
11	34.36	19.71	0.00	54.23	29.64
12	36.64	21.00	0.00	57.06	30.84
13	35.93	21.43	0.00	57.21	33.71
14	36.50	21.80	0.00	46.00	28.46
15	33.57	17.86	42.20	69.46	38.40
16	35.64	22.00	0.00	61.26	33.37
17	36.29	22.86	45.70	64.56	33.04
18	38.00	22.43	0.00	47.40	28.13
19	38.29	25.29	1.00	48.07	23.83
20	36.71	24.29	16.3	55.26	34.34
21	39.00	25.29	0.5	51.91	25.40
22	37.43	24.43	23.1	55.57	28.41
23	35.86	21.71	0.00	51.19	28.57
24	34.14	24.29	0.00	54.43	39.06
25	32.21	56.00	5.20	60.46	46.43
26	33.07	23.57	1.00	57.13	38.13
27	34.50	23.71	0.00	53.97	35.00
28	34.43	23.57	3.50	57.66	34.80
29	34.21	23.71	0.00	54.26	33.84

Contd.....

ISD weeks	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum		Morning	Evening
30	34.04	23.64	0.00	56.46	36.24
31	33.10	23.43	2.5	64.50	49.31
32	32.86	23.71	3.00	62.99	47.54
33	32.79	24.00	5.8	64.50	47.13
34	31.57	23.71	0.00	63.47	56.81
35	32.29	23.43	20.6	65.31	49.77
36	31.71	22.86	60.1	71.41	46.77
37	31.29	22.57	53.8	75.67	57.33
38	31.14	22.71	26.7	72.53	53.73
39	32.43	23.00	38.00	67.39	56.50
40	31.57	22.86	0.00	70.81	56.17
41	33.00	22.86	0.00	62.13	44.67
42	33.36	21.29	0.00	56.63	37.93
43	32.07	18.86	0.00	59.63	37.37
44	30.57	21.14	0.00	67.91	50.19
45	30.86	20.00	0.00	61.80	40.24
46	29.00	18.86	0.00	69.26	46.10
47	27.43	20.71	5.60	80.43	63.01
48	29.57	18.43	0.00	69.26	47.80
49	30.71	17.57	6.60	75.04	41.64
50	32.36	17.14	0.00	61.87	32.74
51	33.00	17.14	0.00	56.60	28.43
52	30.29	15.14	0.00	49.89	28.33

**STUDIES ON INCIDENCE OF INSECT PESTS AND NATURAL ENEMIES OF
DIRECT SEEDED RICE VIS-A VIS TRANSPLANTED RICE AND MANAGEMENT
OF PLANTHOPPERS**

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2016

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ABSTRACT

Studies on the incidence of insect-pests and natural enemies in direct seeded and transplanted rice and management of planthoppers were carried out at Agricultural Research Station, Gangavathi during 2015-16. Totally nine insect pests and seven natural enemies were identified and documented under TPR and DSR. Incidence of BPH, WBPH, GLH and natural enemies were comparatively high in unprotected condition of transplanted rice than direct seeded rice and the peak population was noticed in second fortnight of October. Whereas, stem borer complex and leaffolder was more after second fortnight of November and during last week of November respectively and comparatively more incidence was registered under direct seeded rice than transplanted rice. Correlation studies made between sucking pests and natural enemies with various abiotic factors revealed positive relationship with temperature, maximum temperature and carbon dioxide. Whereas, yellow stem borer and leaffolder were observed positive correlation with relative humidity, morning and evening relative humidity. Dynamics of egg parasitoids of planthoppers were assessed and observed maximum per cent of egg parasitization by all parasitoid were noticed in TPR conditions compared to DSR and among them *Anagrus* sp. predominant. However, an efficient way to manage stem borers without resort for insecticides application can be summarised as burning followed by tillage of crop residue is an effective tool in reducing the hibernating larvae of yellow stem borer and its further carryover. Among the various novel insecticidal approaches evaluated in the management of rice planthoppers triflumezopyrim 106 SC @ 25 g a.i. /ha was found very effective in reducing hoppers population and there by resulting the higher yield.