SEASONAL INCIDENCE AND MANAGEMENT OF RICE STEM BORERS (*Scirpophaga spp.*) ON RICE (*Oryza sativa* L.)

By

Sandeep Kumar

(J-14-M-362)

Thesis submitted to Faculty of Post graduate Studies
in partial fulfillment of the requirements
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MASTER OF SCIENCE IN AGRICULTURE

ENTOMOLOGY

Division of Entomology
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CERTIFICATE-I

This is to certify that the thesis entitled "SEASONAL INCIDENCE AND MANAGEMENT OF RICE STEM BORERS, *Scirpophaga spp.* ON RICE (*Oryza sativa* L.)" submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Entomology)** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is a record of bonafide research carried out by **Mr. Sandeep Kumar (Registration No. J-14-M-362)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of investigation have been duly acknowledged.

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Place: Jammu

Date: 12.01.2017

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ABSTARCT

Title of the Thesis	:	**SEASONAL INCIDENCE AND MANAGEMENT OF RICE STEM BORERS (*Scirpophaga spp.*) ON RICE (*Oryza sativa* L.)**
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Year of Award of degree	:	2017
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Study on Seasonal incidence and management of rice stem borers (*Scirpophaga spp.*) on rice (*Oryza sativa* L.) was carried out at Plant Pathology field, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha during *Kharif* 2015.

The observations on natural infestation of rice stem borers, *Scirpophaga* spp. on rice were recorded at weekly intervals starting from 27th SW to 46th SW during *kharif* 2015. The seasonal incidence of rice stem borers observed at experimental sites indicated that Yellow stem borer (YSB), *Scirpophaga incertulus* and white stem borer (WSB), *S. innotata* were found damaging and remain active on the crop during vegetative and reproductive stages of crop growth. Besides the insect pests, natural enemy fauna were also abundantly found in rice agro-ecosystem. The study revealed that different types of dragonfly, damselfly, coccinellids, spiders, robber fly, ground beetles were actively noticed in rice crops predating upon the stem borer adults population. Apart from predatory fauna, some parasitoids were also observed such as *Xanthopimpla* spp. *Tetrastichus* parasitoid, *Teleonomus* spp. on egg mass of rice stem borers.

During *kharif* 2015, mean number of Yellow stem borer (YSB) population on rice was observed to be increasing gradually till 38th SW recording a maximum of 11.33 larvae / 10 hills. While in case of white stem borer (WSB), *S. innotata*, the seasonal incidence of larval population was ranged from 1.0 to 14.67 larvae / 10 hills. The population WSB was observed to be peak larval number in 32nd SW with 11.00 larvae / 10 hills and 14.67 larvae / 10 hills during 38th SW. Thus, there was two peak of WSB larval population build-up observed during 32nd and 38th standard weeks on rice crop during 2015. The relationship between abiotic factors and incidence of YSB and WSB larval population when worked out during 2015, it was observed that YSB and WSB larval populations was found significantly correlated with morning relative humidity and rainfall, respectively. The maximum percentage damage of dead heart was noticed in 38th SW and remains observed just before the maturity of rice crop whereas, white ear was recorded on 35th SW with 2.92 per cent during *kharif* 2015. A weekly interval survey on white ear percentage due to stem borer revealed that the mean white ears were ranged from 2.92 to 14.58. The relationship between abiotic factors and percentage of dead hearts and white ears were found significantly correlated with morning relative humidity and rainfall, respectively. The overall impact of weather factors on the white ears was 74.10 per cent.

The maximum catches were recorded in 38th SW with 20.33, 27.33 and 14.67 adults population in light and pheromone traps, respectively. The perusal of data showed that more number of YSB adults was caught in light trap than the pheromone trap. The adult population fluctuated between 32nd to 38th standard weeks, exhibiting one 'V' shaped oscillations. Thus, there were two peaks of YSB adult trap catch population noticed during 33rd standard week (13.67) and 38th SW in light trap and 32nd SW (11.00) and 38th SW in pheromone traps, respectively. White stem borer (WSB) adults catches also showed the two peaks *viz*., in 32nd SW

between 32^{nd} to 38^{th} standard weeks, exhibiting one 'V' shaped oscillations. Thus, there were two peaks of YSB adult trap catch population noticed during 33^{rd} standard week (13.67) and 38^{th} SW in light trap and 32^{nd} SW (11.00) and 38^{th} SW in pheromone traps, respectively. White stem borer (WSB) adults catches also showed the two peaks *viz.*, in 32^{nd} SW (19.33) and in 38^{th} SW in light traps. The relationship between abiotic factors and rice stem borers (RSB) male adult population by light trap and YSB through pheromone trap catches showed that only pheromone trap catches of YSB was found significantly correlated with morning relative humidity and rainfall, respectively.

After 15^{th} days of 1^{st} spray, spinosad was found to be the best treatment in reducing the stem borer population on rice followed by novaluron (72.57 per cent) and cartap hydrochloride (62.38. per cent). In these results, spinosad is the most effective up to 15^{th} days and significantly different from other treatments at 5 per cent level of significance. Overall, spinosad and cartap hydrochloride were the most effective treatment after two sprays up to 15^{th} days in reducing the stem bore population and found to be significantly different from other treatments at 5 per cent level of significance. The descending order of performance of different treatments were found as follows- Spinosad> cartap hydrochloride> Thiodicarb> imidacloprid> Buprofezin + acephate> *Bacillus thuringiensis*> Novaluron> *Azadirachtin.*

Signature of Major Advisor

Signature of Student

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Introduction

Chapter-1

INTRODUCTION

Rice *(Oryza sativa* L.) is the lifeline of the human civilization. It is one of the important staple food of global importance for human consumption (Chaven and Kadam, 1989; Mathur *et al.,* 1999; Mishra, 2004). It has been estimated that half the world's population subsists wholly or partially on rice whereas, ninety per cent of the global rice grown and consumed in Asia. Tropics contribute 30% to the world's cereal production wherein, rice, wheat and maize and together comprise at least 75% of the world's grain production. Rice is the most important tropical crop grown on one third of all land cropped to cereals and it currently contributes 52% to all tropical cereal production because of its relatively high productivity per hectare.

Rice is exported to many countries accounting for above 20 per cent of global rice exports and plays an important role in national economy and significant role in livelihood of people. India is world's second largest rice producer and consumer next to China. Total area under rice in India is 44.1 million hectare with annual production of 105.5 million tonnes and productivity is 2.39 tonnes/ha (Anonymous, 2015). Rice is grown in almost all states but West Bengal and Tamil Nadu have the highest production whereas, the average yield per hectare is highest in Punjab. Rice productivity in the Jammu and Kashmir State is high (2.2 t/ha) compared to the national average productivity of about 1.9 t/ha. The total annual rice production in the state is about more than 0.59 mt (Annonymous, 2014).

In Jammu region, the cultivation of rice extends from Jammu plains with an elevation of 200 m to the mid and high hills extending up to 2300 m altitude and is grown on more than 32,000 hectares of area. Rice of Jammu region, particularly of R. S. Pura belt is known for growing the premium quality Basmati rice having a special aroma and quality. The business from basmati rice annually fetches more than 45 crores of rupees (http://www.rkmp.co.in). Adequate rainfall during growth period, suitable temperature during grain filling and enough sunshine hours provide highly favorable climatic conditions for the development of quality characteristics of rice. However, these conditions are also more conducive for the development and attack of insect pests (Singh *et al*., 2006). The crop is subjected to attack by more than 100 insect pest species and many of them causing economic losses to the crop.

The global losses due to various categories of pests vary with the crop, the geographical location and the weather. Total yield losses from different pests of all crops have been estimated to be US$ 500 billion worldwide. Insect pests have been one of the sources of high chronic or epidemic losses in production, usually in combination with other stresses (Litsinger *et al*., 2005). Despite the plant protection measures adopted to protect the principal crops, 42.1% of attainable production is lost due to attack by pests. However, if no control measures are used to protect the crops, the figure would be 69.8% (Oerke *et al.*, 1994; Oerke, 2006; Liebhold and Tobin, 2008). Besides direct losses, the costs involved for their control in the form of pesticides is manifold and has been estimated at US $10 billion annually (Sharma *et al.,* 2000).

Rice represents one of the highly diversified agro-ecosystem in the world wherein, there are some 800 insect pest species that have been recorded to feed on rice (Grist and Lever, 1969). Rice stem borers are probably the most serious group and usually 1- 4 species are important in any given area (Litsinger, 2009). In India, approximately 100 insect species feed on rice and 20 of these are considered to be major pests (Cramer, 1967; Pathak, 1968) of which Yellow stem borers (YSB), *Scirpopagha incertulas* Walker and *S. innotata* (Walker) (Lepidoptera: Pyralidae) (Sigsgaard, 2000) are considered as the most important and most destructive pest occurring throughout the country causing yield loss of about 10-60 per cent (Panda, *et al.*, 1976; Pathak and khan, 1994; Pasalu, *et al.*, 2005). The insect causes "Dead hearts" at tillering stage and "White ear head" at reproductive stage. Rubia-Sanchez *et al.*. (1997) reported that if more than 5 panicles destroyed, rice hills have felt about 80 % loss in yield.

Insect pests are the major constraints in getting the higher yields of rice crop have led to the indiscriminate and excessive use of pesticides which triggers several externalities such as like pest resistance, resurgence, elimination of natural enemy fauna, pesticides residues and environmental and human poisonings (Roger and Kurihara, 1988; Wilson and Tisdell, 2001; Tahir and Butt, 2009). IPM strategies for insect pests are based on using the best mix of all possible methods like biological, cultural and chemical control and genetic tactics provide a durable and sustainable rice production system (Kenmore *et al.*, 1985; Reissig *et al.*, 1986).

Keeping in view the export potential of rice, its cultivation in Jammu region offers a great potential for devising the integrated pest management approaches for insect pest management for getting the residue free produce. It is evident from the study conducted by Pimentel (1991) who revealed that the pesticide use could be reduced by 35-50 % without affecting crop yields or causing an appreciable increase in the price of food. In this context, alternative approaches of pest management are highly relevant as viable tool for sustainable production of rice. Therefore, the present investigation has been crafted with the following objectives:

1. To study the seasonal incidence of rice stem borers.
2. To study the monitoring of rice stem borers through pheromones traps
3. To evaluate the bio-efficacy of certain insecticide against rice stem borers

Review of Literature

Chapter-2

REVIEW OF LITERATURE

This chapter deals with the work done in the past emphasizing on the objectives decided for the present investigation. The major thrust has been given to the management of rice stem borers on *Oryza sativa L.* which comprises cultural, physical, mechanical, biological and eco-friendly insecticidal methods for the management of rice stem borers (*Scirpophaga* spp.). Efforts were made to cite some important and pertinent references on seasonal incidence of rice stem borers (RSB) and their natural enemy fauna in rice ecosystem, monitoring of borer adults population by light and pheromone traps and evaluation of bioefficacy of certain insecticides against rice stem borers (RSB).

There are more than seventy pest infesting rice crop in India and twenty are of regular occurrence (Pathak, 1975). The stem borer and brown plant hopper are the worst pests which can cause severe damage and yield loss to the rice crop in the later stage. Stem borers damage the rice plants from seedling to maturity, in all ecosystems. Of about 20 species of stem borers attacking rice in Asia, Yellow Stem borer (YSB), *Scirpophaga incertulas* is the most predominant one (Chaudhary *et al.*, 1984). The other stem borer species include the White stem borer, *S. innotata* (Walker), Striped stem borer, *Chilo suppressalis* (Walker), Dark headed borer (DHB), *C. polychrysus* and Pink stem borer (PSB), *Sesamia inferens*. The larvae of these borers cause dead hearts during vegetative stage resulting in loss of productive tillers and cause white ear damage at crop maturity phase resulting in chaffy grain. In India, the losses incurred by different insect pests are reported to the tune of 55.12 million rupees which in turn workout to 18.16 per cent of total losses. In India, Yellow stem borer, *S. incertulas* has assumed status as national pest and attacks the rice crop at all stages of its growth (Pasalu *et al.*, 2002). It causes dead hearts at active tillering stage and white ears at harvest stage, which can lead to complete failure of the crop (Karthikeyan and Purushothaman, 2000). The extent of damage caused by the yellow stem borer in rice ranges from 3 to 95 per cent (Ghose *et al.,*1960). Rice stem borers are of major economic significance causing 25-30% loss to rice crop (Lal, 1996; Senapati and Panda, 1999). Yellow stem borer (YSB), *S. incertulas* (Walk.) is the most predominant of these causing serious damage in rice including autumn (boro) rice (Misra *et al.*, 2005).

2.1 Seasonal incidences of rice stem borers, *Scirpophaga* spp.

Scirpophaga incertulas usually comprised more than 90% of the borers' population in rice and are most common pests in Asian countries and cause 5-10% annual damage (Pathak and khan, 1994). Rubia-Sanchez *et al.* (1997) reported that if more than 5 panicles destroyed rice hills can have as much as 80 % loss in yield.

Among several insects that feed on rice, stem borers are considered as the most important, particularly the Yellow stem borer (YSB) *S. incertulas* and White stem borer, *S. innotata* (Lepidoptera: Pyralidae) (Sigsgaard, 2000).

Dhaliwal and Arora (2006) conducted experiment for the study on incidence of rice stem borer in relation to meteorological parameters under different planting methods. The incidence of stem borer was negatively correlated with maximum temperature, minimum temperature, morning relative humidity and sunshine hours in both the planting methods in both the varieties during 2005; however it was positively correlated with evening relative humidity and rainfall. Step wise regression analysis was also conducted for both the years.

The r-value was highly significant during both the crop seasons. Growing degree days were accumulated during both the crop seasons and results revealed that the stem borer incidence was low when GDD accumulation was high and vice versa.

Adiroubane and Raja (2007) studied on the influence of weather parameters on the occurrence of Rice yellow stem borer, *Scirpophaga incertulas* (Walker) and revealed that high pest incidence during months of March (*Navarai–Rabi,2005*), August- September (*Kuruvai–Kharif, 2006*) and October- November (*Samba–Rabi,2006*). The favorable weather conditions for high stem borer incidence were 27.6 $^{\circ}$C, 30.1 $^{\circ}$C, 26.1°C as mean temperatures and relative humidity percent ranged between 95.6 and 65.7, 82.2 and 54.5, 95.3 and 82.8 pertaining to the *Navarai, Kuruvai* and *Samba* seasons, respectively.

Pujari *et al.* (2008) studied the relative abundance of different stem borer in Jorhat, Assam and revealed that larval population of *Scirpophaga innota* was 43.39, 41.96 and 35.43 per cent of the total borer population at all tillering, maximum tillering and at heading stages of the crop, respectively during the *Ahu* season, while in *Sali* season the corresponding percentage was 44.73, 41.48 and 37.50. The population of *S. innota* as hibernating larvae was 34.40 percent. Moth population of *S. innota* constituted 73.31 and 72.84 percent of the total borer complex during *Ahu* and *Sali* seasons, respectively. Pink borers, *S. inferens* was the least abundant species during both the *Ahu* and *Sali* seasons.

Padmavathi *et al.* (2009) revealed the results about the Influence of SRI method of rice cultivation on insect pest incidence and arthropod diversity. Field experiments were conducted in dry and wet seasons in 2005 and 2006 to assess the insect pest scenario in system of rice intensification (SRI) and conventional methods and also impact of SRI on arthropod diversity. Yellow stem borer damage was high at all stages of crop growth period and its damage (dead hearts) at maximum tillering stage was low in cv. Shanti grown under

SRI (7.0%) as compared to conventional method (11.4%). At reproductive stage, the damage (white ear heads) was high in SRI (28.3%) than conventional method (21.2%). Total abundance 263.34 and species richness 20.34 was high in SRI as compared to conventional method. Among various guilds, natural enemies were found more in SRI than conventional method of rice cultivation.

Pathak *et al.* (2012) conducted the experiment for the study on prevalence of insect pests, natural enemies and diseases in SRI (System of Rice Intensification) of Rice cultivation in North East Region. Two rice varieties *viz*. Deku (local variety) and CAU R-1(improved variety) were transplanted under system of rice intensification (SRI) and traditional system of cultivation. The pooled results of two cropping seasons revealed prevalence of stem borer was significantly lower in SRI system, mean damage of 6.8 and 7.5 % (dead heart) and 17.8 and 15.7 (white ear head) was recorded in CAU R-1 and Deku, respectively, as against a higher incidence of 11.7 (dead heart) and 12.5 % (white ear-head) in Deku and 10.7 and 14.4 (dead heart) and17.8 % (white ear head) in CAU R-1 while at reproductive phase, there was no significant difference. The prevalence of blue beetle, case worm, leaf folder and gundhi bug/m^2 were lower in SRI as compared to traditional system. The occurrence of natural enemies like dragon flies and wolf spiders was higher in SRI while damsel flies and ladybird beetles population was lower in SRI in comparison to the traditional system. However, there was no significant difference in grain yield between the two systems of cultivation.

Sarwar (2012) determined the effects of host plant resistance in early, medium and late sown varieties of rice [2 non aromatic IR8 (P) and Sharshar, and 2 aromatic Basmati-370 (P) and Mehak] against the incidence of rice stem borers. Treatments comprised the crop sown on 3 different dates at the fortnightly intervals starting from the last week of June till the end of July to note the rate of stem borer's infestation. Rice yellow stem borer *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae), was the most important insect pest of rice, attacking all stages of the crop causing substantial losses in early, medium and late-sown crops, and degree of stem borer infestation depended upon the planting time. The pest incidence was the least on early sown crop as compared to medium and late sown crops. Similarly, the highest yield was obtained in early sown crop, and the crop sown after this date showed drastic reductions in yield. Among different varieties tested, Sharshar showed best results in holding least pest infestation and increased grain yield approached by, IR8 (P), Mehak and Basmati-370 (P). Hence, use of tolerant rice varieties and their early sowing under agro climatic conditions of this region was recommended to protect the crop from borer's invasion.

Justin *et al.* (2013) studied the seasonal incidence of rice yellow stem borer, *Scirpophaga incertulas,* (Walker) at the Agricultural Research station, Tamil Nadu Agricultural University. The incidence was assessed by observing the damage symptoms *viz.,* dead heart at the vegetative stage (tillering) and white ear at the maturity stage. This studies revealed that the infestation was found during August-September and December-February, reaching the peak in January-February, and without any infestation in other months.

Ho *et al*. (2013) surveyed the incidence of yellow rice stem borer (YRSB), *Scirpophaga incertulas* (Walker) in 2011 and 2012 at main rice growing district of Haiphong Province, Vietnam and revealed that YRSB is one of the most serious pests of rice in Southeast Asia. They further showed that the densities of YRSB larvae and pupae were very low in main rice-cropping times, *i.e.,* late spring and middle summer seasons. In fact, the percentages of dead hearts and white heads were low. However, in middle summer, the density of YRSB and the percentage of damaged stems were higher than those in late spring rice.

Kakde and Patel (2014) studied the seasonal incidence of rice stem borer (*Scirpophaga incertulas* walker) in relation to conventional and SRI Methods of planting and its correlation with weather parameters and indicated non-significant results in conventional and SRI methods. The results of both methods indicated that the weather parameter had less influence on the activity of yellow stem borer damage as well as no difference found among both type of planting, which justified that the stem borer activity concealed with plant phenology.

Nayak (2014) tested the performance of nine released varieties of Nuziveedy Seed Pvt. Ltd. against *S. incertulas, O. oryzae, C.medinalis* and *H. phillippin* and compared with two check, *i.e.,* Lalat and Kanak during kharif, 2012 in RBD with four replications. Stem borer infestation data revealed that a significant difference with respect to white ear head at the reproductive stage among the test varities. Lowest WEH incidence was recorded in the test variety NP-210 (0.51%) followed by the check variety Kanak (0.56 %). The performance of tested high yielding verities NP-209 (2.01 %) and NP-360 (2.69%) were better compared to check variety Lalat 6.15% against stem borer. The incidence of WEH was highest in the tested verities NP-124-8 (11.41%) and NP-3114 (10.08). Significantly highest yield was recorded in the test variety NP-256 (62.13 q/ha) followed by NP-210 (59.80 q/ha).

Randhawa and Aulakh (2014) conducted the experiment for study of effect of different nitrogen level and varieties on the incidence of leaf folder and stem borer of Basmati rice. The highest incidence of rice leaf folder *Cnaphalocrocis medinalis* (Guenee) and stem borer, *Scirpophaga incertulas* (walker) was recorded from the basmati variety

Punjab Bas-2. The incidence of leaf folder and stem borer increase with increase in nitrogen level.

Justin and Preetha (2015) conducted study on influence of dates of sowing on the incidence of yellow stem borer, *Scirpophaga incertulas* (walker) on rice. The stem borer incidence was less in the kharif season than in the Rabi season. The stem borer damage was nil or less in early sown crops as compared to late sown crops. Similarly, the yield was maximum in the early sown crop. The plant infestation in *Rabi* season ranged from 0.8 to 7.0 per cent (Dead heart) and 2.7 to 7.3 per cent (White ear). The highest per cent of dead heart and white ear were observed in October 26 sown crops. The yellow stem borer infestation was lower in the crops sown during September. The grain yield of rice varied with sowing dates as well as yellow stem borer infestation. In both seasons, early sown crops did not suffered from yellow stem borer infestation, and resulted in higher yields. On the other hand late sown crop showed drastic reduction in grain yield.

Anitha *et al.* (2016) studied seasonal dynamics and relative abundance of egg parasitoids of yellow stem borer, *Scirpophaga incertulas* in rice for three years (kharif seasons of 2010-2012). The yellow stem borer is a key pest in rice and integrated pest management tactics for its management involve conservation of its natural enemies, viz. three hymenopteran egg parasitoids, *Tetrastichus schoenobii* Ferriere, *Telenomus dignus* (Gahan) and *Trichogramma japonicum* Ashmead. The seasonal dynamics of the parasitoids and variations in natural parasitisation caused by each revealed that egg parasitisation started in 37th SMW and attained a peak (98.4%) by the 39th SMW. In the initial weeks, it was dominated mainly by *T. dignus* followed by *T. japonicum* and *T. schoenobii*. However, after the 39th SMW, *T. schoenobii* took over and recorded highest parasitization consistently till the end of the study (44th SMW). The number of egg masses parasitized by a single genus were higher (63.9%) compared to those parasitized by more than one genus (36.1%). Maximum parasitisation, by *T. schoenobii*, *T. dignus* and *T. japonicum* were found to be 54.5, 47.1 and 27.3 per cent, respectively. Among egg masses parasitized by more than one genus, *T. schoenobii* and *T. dignus* together parasitized a maximum of 35.3 per cent egg masses. *T. schoenobii, T. dignus* and *T. japonicum* together parasitized a maximum of 7.7 per cent egg masses. Correlating parasitoid populations with weather factors revealed that among the three parasitoids, only *T. japonicum* was found to be significantly influenced by weather factors, while *T. schoenobii* and *T. dignus* were not.

Singh *et al*. (2016) revealed that rice crop is infested by many insect-pests which play a significant role in rice production. Insect-pests infest all parts of the plant at all growth stages, and a few transmit viral diseases such as leafhoppers and plant hoppers. In rice ecosystem some defender viz., dragon fly, spiders and praying mentis were also noticed. They further observed that the leaf folder and stem borer were found to be at significance level while Insect-pests as gall midge, gundhi bug, rice hispa, green leaf hopper, brown plant hopper, grasshopper etc. were also found at Rice field. Besides insect pests several diseases were noticed like root-rot, brown rot, and sheath blight. The increasing concern for environmental safety and global demands for pesticide residue free food evoked keen interest in pest control through eco-friendly methods.

2.2. Monitoring of rice stem borers adult population through traps

Pathak (1968) indicated that the more females than males in light trap catches but the sex ratio differed in different seasons in light trap catches. Scarcity of infestation in general and sex related phototropism of this species renders it difficult to conclude on the variation of sex ratio in light trap.

Singh (1970) recorded observations on 23 species of economic importance at Jabalpur for two years and mentioned that, light trap can play a significant role in pest surveillance and forecasting the pest population in different crops.

Zafar and Chaudhary (1979) recorded that the moth populations of white and yellow borers were alarming from the last two weeks of August through September, because meteorological conditions. After the monsoon rains, the temperature favours earlier moth emergence. If temperature remains mild because of a later or prolonged monsoon, the number of moths remains critical until the first two weeks of October. That is especially true for *T. incertulas* which seems to be favoured by mild humid conditions.

Manjunath (1982) indicated the seasonal appearance and population fluctuations of yellow stern borer *Scirpophaga incertulas* Walker from 1976 to 1979. Moth emergence was similar in all the years. There were three peaks of emergence each year, a low peak in February (winter generation), a moderate peak in May (summer generation) and a high peak in November (Kharif generation).

Verma et al. (1982) have observed that none of the weather factors studied *viz*. temperature, humidity and rainfall had any significant effect on the flight activity of *Heliothis armigera*. Hence, the size of the trap catch in relation to its ambient population remained unaffected by these factors.

Litsinger et al. (1986) report maximum number of YSB collected in the light trap near harvest probably represent on emigrant dispersal flight in response to crop senescence and dry field. This pest does not aestivate during the dry season but re-colonizes from tracts of irrigated rice 10 km away. Low number of YSB was collected in the light trap throughout the year.

The effect of trap type, trap height, position in the crop and age of the lure on trap catch were optimized by Ganeswara Rao and Krishnaiah (1995).

Sawant *et al.* (1995) observed in Maharashtra, where farmers do not apply insecticides for *S. incertulas* control, larval damage estimates were significantly less in the pheromone-treated plots than the farmers' practice plots and this was reflected in a 60% increase in yield. They further revealed that the maximum dead heart and white head damage recorded in the pheromone-treated plots (2.8 and 15.7%) and the farmers' practice plots (7.0 and 20.9%) were not significantly different from Warangal. Surveys of farmers showed that in Medchal 92% of small holders applied insecticide at least once per season while in Warangal over 60% applied insecticide on two or more occasions confirming that mating disruption was at least as efficacious insecticides in the control of *S. incertulas*.

Cork and Hall (1998) reviewed on application of pheromones for crop pest management in the Indian Sub-continent. The female sex pheromone of the main insect pest of rice in India and Bangladesh, the yellow stem borer, *Scirpophaga incertulas* was identified by Cork using insects from the Philippines.

Rai *et al.* (2002) conducted the study on influence of weather factors on light trap catches of yellow stem borer in kharif season. Peak occurrence of yellow stem borer (*Scirpophaga incertulas*) (Walker) on rice (*Oryza sativa*) was noted during the first fortnight of October during the 26 years of study. The period of peak occurrence of YSB coincide with the ranges of favorable environmental factors during the kharif seasons. The influence of weather factors such as maximum relative humidity and Sunshine hours on YSB population catches in light trap showed positive correlation as well as coefficient of determination was 71 per cent. The effect of temperature on catches could not show any specific influence. Rainfall showed the negative influence on the catches of YSB.

Oo *et al.* (2003) investigated the seasonal appearance of the yellow stem borer (YSB), *Scirpophaga incertulas* Walker (Lepidoptera; Pyralidae) caught in light trap in different seasons from 1998 to 2000. A light trap was set up and only one peak population was observed in May 1998. In June and July 1999, the number of moths caught in light trap was also high in numbers. The peak population was also recorded in August 2000. The results suggested that availability of suitable food plant was at least partially responsible for the population increase of the YSB. Illumination of full moon, distances between the food source and trap located, and weather condition such as temperature and rainfall were considered as important factors influencing the fluctuation of YSB moths caught in the light trap.

Prakash *et al.* (2007) reviewed the studies on management of insect pests in field and stored rice by pheromone traps. Monitoring, mass trapping and mating disruption in rice stem borers have been established after the field trials in India. They suggested that for monitoring, three sleeve traps baited with rubber dispenser (impregnated with pheromone @ 5mg/dispenser) should be installed at inter trap distance of 60 m in a triangular pattern in rice field of about one acre. For mass trapping 20 traps/ha found to be optimum for yellow stem borer. Single application of slow-release pheromone formulations was used to control the pyralid, *Scirpophaga incertulas* using mating disruption in two trials on rice. The formulations exhibited pseudo-zero order release rates with field life of 70 and 90 days.

Kumar *et al.* (2009) conducted experiments on seasonal abundance of *Scirpophaga incertulas* Walker and *Helicoverpa armigera* Hubner based on pheromone trap catches during 2005-07. During the year 2006-07 number *S. incertulas* moth catches was higher than 2005-06 and the most favorable period was observed from 36th to 42nd standard week.

Mishra and Sharma (2011) monitored the yellow stem borer, *Scirpophaga incertulas* Walker through light and pheromone traps and revealed that yellow stem borer moth catches in light and pheromone traps were comparatively higher during Kharif season 2008 than 2007 in both type of traps.

Akhter *et al*. (2015) revealed the results from light trap catches of some major rice insect pests in association with prevailing environmental factors. They further showed that that the insect trap was recorded higher within specific range of temperature i.e., from 18 to 35°C and shows significant relationship in case of White and Yellow Stem Borers. Maximum traps were observed during April where average temperature was 30-33°C, considering it optimal temperature for insect catch by light traps. However, in case of Pink Stem Borer, insect trap was found to occur below 32°C during all winter season.

Kumar *et al.* (2015) showed the population dynamics and management of yellow stem borer (*Scirpophaga incertulas* Walker) with insect sex-pheromone trap at Rajendra Agricultural University, Pusa. They recorded the pest activity started from 30th standard week and continued upto 41st standard week. The peak population of stem borer recorded twice in 34th and 37th standard week, respectively. Thereafter, its population declined and finally no population was recorded. Correlation between weather parameters and the population of male yellow stem borer moth revealed that maximum temperature (°C), minimum temperature (°C), relative humidity (%) at 7 hr, relative humidity (%) at 14 hrs, rainfall (mm) and evaporation (mm) were positively correlated to the tune of 0.273, 0.453, 0.075, 0.478, 0.339 and 0.122, respectively whereas, sunshine (hr) was found to be negatively correlated (-0.453).

Baehaki *et al*. (2016) carried out a study on light traps abilities of mercury (ML-160 watt) BSE models and solar cell light traps (CFL-20 watt) to capture rice pests in West Java.

The Results showed that abilities of light trap of mercury (ML-160 watt) BSE-G3, BSE-G4, and BSE-Giant models were higher capture of pests compared to the light trap of solar cell (CFL-20 Watt). The rice pests that caught on the light trap with higher power capacity at 160 watt and light intensity at 3150 lm were higher than in the lower power capacity at 20 watt and low light intensity between 1200-1250 lm. In the other hand, number of pests that caught in mercury lamp were higher than CFL. Pests were caught in the light traps of mercury (ML-160 watt) BSE-G3 and BSE-G4 models with the top of the funnel collector pests are 60 cm in diameter less than the pest was caught the light traps of mercury (ML-160 watt) BSE-Giant with the top of the funnel collector pests is 100 cm in diameter.

2.3 Management of rice stem borers

Lal (2006) conducted a trial on novel use of cartap hydrochloride 4G against stem borers for two consecutive kharif seasons during 2001 and 2002 and showed that rice stem borers, *Scirpophaga incertulas*, *Scirpophaga innotata* and *Sesamia inferens* pose a serious threat to scented rice in Haryana, India. Cartap hydrochloride 4G at 1.0 and 0.75 kg a.i./ha were applied at 30, 50; 30, 70; 50, 70 and 30, 50 and 70 days after transplanting (DAT) and were compared with monocrotophos 36 WSC at 0.45 kg a.i/ha applied at 30, 50 and 70 DAT. Cartap hydrochloride at 1.0 and 0.75 kg a.i./ha applied at 30, 50 and 70 DAT proved most effective in managing the incidence of stem borers and realizing higher rice grain yield. Two applications of cartap hydrochloride at 30, 50 and 30, 70 DAT were equally effective to three applications of monocrotophos in managing the incidence of stem borers and realizing higher yield. The effect of cartap hydrochloride was observed more than 30 days when applied at 30 DAT and observation recorded up to 70 days. All the treatments increased yield over the control. The cost:benefit ratio was highest in monocrotophos (1:8.68), followed by cartap hydrochloride at 0.75 kg a.i./ha broadcasted at 30 and 50 DAT (1:7.64), but lowest in cartap hydrochloride at 1.0 and 0.75 kg a.i./ha applied at 50 and 70 DAT (1:2.80).

Baruah *et al.* (2008) reported the bio-efficacy of Carbosulfan 20EC against Rice Stem Borer, *Scirpophaga incertulas* and their studies revealed that the increase in infestation at seven days after application over one day before application were found to be 2.59, 1.90, 0.14, 1.07, and 5.73% in the plots treated with carbosulfan 250, 300, 350 g *a.i.* per hectare, chlorpyriphos @ 250 g *a.i.* per hectare and untreated control, respectively, in 2005. Likewise in 2006, the increase in infestation was found to be 4.75, 2.75, 1.37, 1.52, 8.32 % in carbosulfan 250, 300, 350 g *a.i.* per hectare, chlorpyriphos @ 250 g *a.i.* per hectare and untreated control respectively. All the treatment was found to be significantly superior over untreated control in respect of increase of infestation but among them no significant difference was observed.

Kaur and Brar (2008) evaluated the different doses of *Trichogramma* species were against leaf folder and stem borer on Basmati rice in farmers' field. Seven releases of *Trichogramma chilonis* Ishii and *T. japonicum* Ashmead each @ 100000, 125000 and 150000 hectare^{-1} at weekly interval starting at 30 DAT (days after transplanting) were made. All the three doses were effective for the control of leaf folder and stem borer and also helped to increase the parasitization and yield. Thus the lower dose (100000 ha^{-1}) of both the parasitoids can be used for the control of two pests. The incidence of leaf folder was significantly lower in the plots where cartap hydrochloride 4G @ 25 kg ha^{-1} was applied three times. The releases of egg parasitoids at all the doses were equally and significantly better than control.

Prakash *et al.* (2008) studied about the future of botanical pesticides in rice, wheat, pulses and vegetables pest management. Botanical pesticides are the important alternatives to minimize or replace the use of synthetic pesticides as they possess an array of properties including toxicity to the pest, repellency, anti-feedance, insect growth regulatory activities against pests of agricultural importance. In fact botanical pesticides are in use in Indian agriculture for over a century to minimize losses caused by pests and diseases. They suggested that botanical pesticides must be used because these have many advantages over synthetic pesticides.

Karthikeyan *et al.* (2010) compared the 3 rice IPM modules (IPM I, IPM II and IPM III) with farmers' practices to validate and popularize the IPM modules in rice during 2006-07 to 2008-2009 at Kerala. The results revealed that IPM- III comprised alternate spraying with neem-based formulation and newer safe insecticide (Cartap hydrochloride and Spinosad) coupled with release of egg parasitoids against leaf folder and monitoring of stem borer (3.88% dead heart, 1.95% white ear), whorl maggot (4.10% damaged leaves), and leaf folder (2.73% damaged leaves). Stem borer incidence was reduced by 61.6% in IPM-III module as compared with farmers’ practices.

Chakroboraty (2011) studied the efficacy of some bio-rational pesticide formulation for the management of yellow stem borer *Scirpophaga incertulas* walker in the paddy field, cultivar *Swarna Mashuri* (MTV 7029) and least damage was noted for monocrotophos 36 WSC. This was followed by carbofuran 3G, nimbecidine-2.5%, neem seed kernel extract (NSKE) – 5%, Mahua oil – 2 %. In consideration of yield increase over control, maximum efficacy was registered for monocrotophos respectively followed carbofuran, nimbecidine, *B. thuringiensis,* NSKE, NLE, mahua oil, neem oil, KSKE, *V. negundo* and plant mixture in descending order. Significant differences in the number of effective tillers/m^2, panicle/m^2 leaf area index and dry matter production/m^2 in consideration of different treatment formulation was noted. But plant height, panicle length, and 1000 seed grain weight differed insignificantly.

Kulagod *et al.* (2011) evaluated the insecticides and bio-rationals against yellow stem borer and leaf folder on rice crop. A field experiment was conducted during kharif 2008. The experiment was laid outin a randomized block design with eleven treatments and threereplications. The variety MTU-1001 was sown during the monthof June 2008. Fipronil 5 FS @2.5 ml, indoxacarb 14.5 SC @ 0.5 ml, thiodicarb 75 WP @1 g, *Bacillus thuringiensis* @ 1 g, novaluron 10EC, cartap 50 SP, spinosad 45 SC, chlorpyriphos 20 EC, Flubendiamide 480 SC @0.2 ml/L of water and untreated check for comparison. The observations were recorded by following standard method for stem borer and leaf folder (Anon., 2007).The bio-rational treatment, cartap hydrochloride harvested highest grain yield, was at par with fipronil and flubendiamide. The untreated check recorded lowest yield.

Chakraborty (2012) evaluated the efficacy of the integrated pest management (IPM) system against the yellow stem borer on rice (cv. Swarna Mashuri) during the kharif seasons of 2003-07 at West Bengal, India. The treatments consisted of an IPM module (seed treatment with Bavistin [carbendazim], transplanting in early July at a spacing of 15 × 15 cm, split application of 6.5 t decomposed cow dung and 100 kg urea/ha at the vegetative and early ripening stages, installation of pheromone traps, release of *Trichogramma*, retention of some weedy bunds for natural enemies, light trapping, application of ethofenprox [etofenprox], incorporation of tender neem [*Azadirachta indica*] branches in the field, arrangement of perching places such as bamboo sticks for insect predatory birds, wetting and drying at 7-day intervals from 60 days after transplanting, and application of monocrotophos 36 EC based on the economic threshold level) and farmer acute practice (seed treatment with Bavistin; non-specific pest monitoring in the nursery and main fields; need-based application of ethofenprox, monocrotophos and phorate; foliar application of chlorpyrifos 20 EC at 30, 60 and 80 days after transplanting; split application of 160 kg urea/ha at the vegetative and early ripening stages; and restricted clean cultivation). The IPM module resulted in lower dead heart and white head incidence, higher populations of spiders and beetles, higher grain and fodder yields, and higher returns and cost benefit ratios.

Gupta and Das (2012) evaluated the effectiveness of some integrated pest management modules against major insect pests of rice during kharif of 2010. In Odisha, the major insect pests invading the rice and causing severe loss in rice production are yellow stem borer (*Scirpophaga incertulas*), leaf folder (*Cnaphalocrocis medinalis*), whorl maggot (*Hydrellia philippina*), hispa (*Dicladispa armigera*), brown plant hopper (*Nilaparvata lugens*), white-backed plant hopper (*Sogatella furcifera*), and gundhi bug (*Leptocorisa acuta*). Treatments were: chemical based module IPM1 (Application of carbofuran 36 at 1.0 kg ai/ha); Non-chemical based module IPM2 (Installation of yellow stem borer (YSB) pheromone traps 5 mg lure at 20/ha + field release of *Trichogramma japonicum* 1,00,000 parasitized *Corcyva* eggs/ha at 30 and 45 DAT); chemical + Non-chemical based module, IPM3 (Application of carbofuran 3G 1.0kg a.i/ha at 20 DAT + installation of YSB pheromone traps 5mg lure at 20/ ha + release of *Trichogramma chilonis* at 1,00,000 parasitized *Corcyva* eggs at 30 and 45 DAT); and farmers practices IPM4 (Application of monocrotophos 36 WSC at O.5Kg ai/ha at 50 and 65 DAT). Results revealed that IPM3 resulted in the lower incidence of stem borer (03.38% dead heart and 11.50% white ear head), whorl maggot (11.84% damaged leaves), leaf folder (04.20% damaged leaves) hispa (0l.66% damaged leaves), gundhi bug (01.74/m2), white backed plant hopper (8.7

hoppers/clump), brown plant hopper (7.45 hoppers/clump), caseworm (1.26% damaged leaves) and produced the highest grain yield (08.92 t/ha) with cost: benefit ratio (1:3.08).

Mishra *et al.* (2012) revealed the results about from their experiments on efficacy of insecticides against rice yellow stem borer, *Scirpophaga incertulas* (Walker) on Basmati rice. Field experiments were carried out during wet seasons of 2007 and 2008 to test the efficacy of various insecticides along with check against yellow stem borer, *Scirpophaga incertulas* (Walker) with rice variety Pusa Basmati-1. Out of seven insecticides tested, fipronil 5SC @ 50g *a.i.*ha^{-1}superior to over other insecticides, which results the lowest incidence of yellow stem borer with highest grainsyield followed by Cartap hydrochloride 50SP @ 300g *a.i.*ha^{-1} and Cartap hydrochloride 4G @ 750g *a.i.*ha^{-1}.However remaining insecticides were also found significantly superior over the control (check). Based oneconomics of the insecticides, Cartap hydrochloride 50SP proved most economical than others with highestcost: benefit ratio (1:8.97) followed by fipronil 5SC (1:6.22) and Cartap hydrochloride 4G (1:5.54) againstlowest in Indoxacarb 14.5 SC @ 75g *a.i.*ha^{-1} (1:2.89).

Pandey and Choubey (2012) studied the management of yellow stem borer, *Scirpophaga incertulas* in "rice" at the Research Farm, Jaunpur (UP) during Kharif, 2004. All the treatments were found to be effective in reducing the incidence of *S. incertulas*. The treatments, carbofuran, imidacloprid 25 g ai/ha, imidacloprid 40 g ai/ha and biolap were found most effective as these treatments registered comparatively low incidence of *S. incertulas*. The release of bioagent, *T. japonicum* 50000 eggs/ha was found effective in reducing the incidence of *S. incertulas* which was observed to be superior over some of the treatments namely Nimbecidene.

Ho *et al.* (2013) examined the efficacy of removing yellow rice stem borer (YRSB) egg masses and spraying with three insecticides. Efficacy of controlling measures was then evaluated with 11 treatments consisting of egg mass removal and insecticide applications. The results demonstrated that all measures provided better control of YRSB than the control. However, different measures resulted in different percentages of white heads. Efficacy of two newly used insecticides Virtako 40 WG and Prevathon 5 SC was highest when applied twice. The efficacy was followed by removal of egg mass twice, spraying Virtako 40 WG once or Prevathon 5 SC once with and without removal of egg mass and spraying Regent 800 WG. A combination of removing egg masses and spraying Regent 800 WG once provided a better result than spraying Regent 800 WG twice.

Sarao and Kaur (2013) studied about the efficacy of Ferterra 0.4% GR (chlorantraniliprole) against stemborers and leaf-folder insect-pests of basmati rice.Field experiments were conducted during three kharif seasons from 2009 to 2011. Four doses of ferterra 0.4% GR (chlorantraniliprole) a new chemistry @ 20, 30, 40 and 50 g *a.i.*per ha and standard check Cartap hydrochloride 4 G @ 1 1000 g *a.i.*per ha was tested against stem borers and leaf-folder infesting basmati rice. Over the years, dead heart in all the Ferterra doses and standard check (1.01-1.80 %) were at par 70 DAT, whereas, at 80 DAT doses @ 40, 50 and standard check were at par (1.04-1.13 %) but significantly better than lower doses and untreated control. Similarly, over the years, Ferterra doses @ 40 and 50 g *a.i.* per ha was significantly better than control in reducing white ear incidence, whereas, at 30 g *a.i.* per ha and standard check intermediately reduced the white ears incidence. Leaf folder infestation at all the Ferterra doses were at par with standard check 70 DAT (2.69-3.87 %), whereas, 80 DAT, Ferterra doses @ 30, 40, 50 and standard check were at par (2.95-3.49 %) but significantly better than lower dose and untreated control. Over the years the cost: benefit ratio was maximum (1: 23.67) in the Ferterra @ 40 g a.i. ha dose followed by 50 g *a.i.* per ha dose.

Anitha and Parimala (2014) studied the comparative reaction of four rice varieties *viz*., to stem borer infestation when cultivated under BIPM and farmers' practices in *kharif* seasons of 2009-10 and 2010-11 at Rajendranagar, Hyderabad, India. Analysis of two-year results showed that BIPM treated plots recorded significantly lesser dead hearts and white ears in all the four varieties compared to the plots grown using farmers' practices. Among the different varieties in BIPM and Farmers' module, there was no significant difference among the different varieties with respect to dead hearts, white ears and yield. Study of the extent of parasitisation of stem borer egg masses collected from the fields revealed that higher number (88.6%) of completely parasitized egg masses were recorded in BIPM plots compared to FP plots (55.45%). *Tetrastichus*, *Telenomus* and *Trichogramma* were found to be the dominating species. *Tetrastichus* was the single dominant species in 89.1% of the completely parasitized egg masses, *Telenomus* to an extent of 7.2% and *Trichogramma* upto 3.7%.

Chatterjee and Mondal (2014) studied the performance of some biorational insecticides against yellow stem borer, *Scirpophaga incertulas* Walker in *Boro* rice at Rice Research Station, West Bengal during the year 2009-10 to 2011-12. Nine treatments viz. *Beauveria bassiana* (Panther BB) @ 4 g/l, *Beauveria bassiana* (Myco-Jaal) @ 4 ml/l, *Metarhizium anisopliae* (Nodule Testing Laboratory, BCKV) @ 2 g/l, *Bacillus thuringiensis*(Panther BT) @ 1.5 g/l, *Bacillus thuringiensis*(Nodule Testing Laboratory, BCKV) @ 1.5 g/l, Azadirachtin 10,000 ppm @ 1 ml/l, Spinosad 45%SC @ 2 ml/15 l, Phosphamidon 40% EC @ 1.5ml/l of water and untreated control (Water Spray) were laid out in randomized block design with three replications. The observations on per cent of dead heart and white ear head along with yield of the crop in different treatments were recorded. Spinosad 45%SC proved most effective in managing the insect population as lowest DH%

and WE% were observed in all the crop growing seasons. Result on pooled analyses revealed that 80.27% and 67.10% reduction of dead heart and white ear head were achieved over the control by two sprayings of Spinosad 45%SC which resulted in 69.96% increase of yield over the control. Apart from Spinosad 45%SC, Phosphamidon 40% EC also proved better in reducing the dead heart and white ear head as well as in per cent increase of yield over the control.

Chormule *et al*. (2014) evaluated the efficacy of granular insecticides, *viz.*, cartap hydrochloride 4G, fipronil 0.3G, ferterra 0.4G carbofuran 3G, lasenta 80 WG, Phorate 10G, and chlorpyriphos 10G against yellow stem borer, *Scirpophaga incertulas* infesting rice. Among the evaluated granular insecticide molecules lasenta 80 WG @ 250 g a.i./ha proved to be most effective against *S. incertulas* by recording lowest dead hearts 3.17 per cent after first application and 5.12 per cent after second application. This treatment ultimately recorded highest of 43.30 q/ha yield of rice. The next best treatment in order of their effectiveness were ferterra 0.4 G @ 30 g a.i./ha, fipronil 0.3G @ 7.5 g a.i./ ha, cartap hydrochloride 4 G @ 750 g a.i./ha, chlorpyriphos 10 G @ 1 kg a.i./ha, carbofuran 10 G @ 750 g a.i./ha and phorate 10 G 750 g a.i./ha .

Prasad *et al.* (2014) evaluated certain new insecticide against yellow stem borer, *S. incertulas* on semi deep water rice. Altogether, 9 treatments including 5 insecticides, viz. buprofezin 25 SC @ 700 ml ha^{-1}, acephate 95 SG @ 592 g ha^{-1}, acephate 75 SP @ 667 g ha^{-1}, dinetofuran 20 SG @ 200 g ha^{-1}, flubendiamide 20 WDG @ 175 g ha^{-1}; 2 combination of insecticides, viz. flubendiamide (4%) + buprofezin (20%) 24 SC @ 875 ml ha^{-1}, buprofezin (20%) + acephate (50%) 70 WP @ 900 g ha^{-1} besides insecticidal check monocrotophos 36 SL @ 1390 ml ha^{-1} and untreated control. The stem borer infestation, i.e. white ears varied from 2.24 to 10.90 % over the *kharif* seasons. The results on stem borer infestation and yield indicated that all the insecticidal treatments were significantly superior to untreated control. The results clearly indicated that 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} with 3.50, 4.15 and 4.40average YSB infestation; and 18.00, 16.37 and 16.27 q ha^{-1} average grain yields, respectively, were effective against YSB on semi deep water rice. The insecticidal check monocrotophos 36 SL @ 1390 g ha^{-1} was superior with 5.54% average stemborer infestation and 13.42 q ha^{-1} average grain yield to untreated control with 9.69 % average stem borer infestation and 10.87 q ha^{-1} average grain yield.

Rath *et al*. (2014) evaluated eleven insecticides including a new insecticide sulfoxaflor 24SC and standard insecticide monocrotophos 36SL in the field against yellow stem borer and rice gundhi bug during wet season of 2011 and 2012. Plots treated with imidacloprid 17.8 SL @ 500 g a.i. ha^{-1} recorded lowest (3.6%) dead heart (DH), 3.6% white ear head (WEH), 6.5% grain damage due to gundhi bug and highest grain yield i.e., 5.18 t ha^{-1} in cv Jaya followed by sulfoxaflor 24 SC @ 90 g a.i. ha^{-1} (4.61 t ha^{-1}), thiamethoxam 25WG@ 25 g a.i. ha^{-1} (4.58 t ha^{-1}) and triazophos 40EC @ 450 g a.i. ha^{-1} (4.56 t ha^{-1}) during 2011. Similar trend was also observed in 2012. During both the years, all the insecticides significantly reduced stem borer and gundhi bug damage over control. The standard insecticide monocrotophos 36SL@500 g a.i. ha^{-1} was found superior to the new insecticide sulfoxaflor 24SC at lower dose i.e. 75 g a.i. ha^{-1} against yellow stem borer and gundhi bug damage.

Shitiri *et al.* (2014) conducted study on effect of cultivars and botanicals on the incidence of major insect pests in lowland rice. Field experiment was conducted during the wet season of 2011 using Split Plot Design to study on the effect of cultivars and botanicals on the incidence of major insect pests in lowland rice. A rice variety, Ranjit and two rice cultivars, Miraclerice and Jalukie special were selected and three major pests were taken into account for the study. Among the botanical treatments, *Litseacitrate* seed extract was found to give effective control against the three pests almost at par with Monocrotophos. Crude stem extract of *Costus speciosus* and seed extract of *Chenopodium ambrosioides* were also found to be effective in reducing the pests.

Vennila *et al*. (2014) tested eight foliar insecticides in which fipronil was found to be most effective in reducing survival of moth, oviposition and larval hatching of yellow stem borer, *Scirpophaga incertulas* (Wlk) followed by cartap hydrochloride, chlorantraniliprole, spinosad, flubendiamide, emamectin benzoate, chlorpyriphos and monocrotophos in the order of their efficacy. All the treatments were more effective in seedling stage compared to tillering stage in greenhouse condition.

Sarao *et al*. (2015) determined the multiple insect-pest incidence on yield loss in basmati rice for two crop seasons. Five treatments were viz. application of imidacloprid in vegetative stage; application of granular insecticide in vegetative stage; application of higher dose of Urea; augmentive releases of yellow stem borer egg mass at vegetative and booting stage; untreated control. During both the years, the correlation between grain yield and dead heart, leaf folder damage and planthopper population at 50 and 65 DAT and white ear at maturity was negative. The analysis of variance of regression analysis of yield V/s damage levels at different crop growth stages during both the years revealed a significant linear relationship. The yield loss was highly related to incidence of stem borer and leaf folder damage at 50 and 65 DAT during both the years. For integrated pest management, effective monitoring of stem borer and leaf folder from 50 to 65 DAT is required, which appeared as a critical crop growth stage. The farmers should remain cautious during this period to prevent yield loss.

Bhandari *et al*. (2016) determined the comparative efficacy of some promising chemical insecticides against rice stem borer and brown plant hopper pests of rice and reported that XL-0.3-GR (Imidacloprid 0.3% G R) is safe against the natural enemies. Farmers can use XL-0.3-GR (Imidacloprid 0.3% G R) @ 15 kg/ha to control rice stem borer and BPH in rice crop. Further, they observed that XL-0.3-GR (Imidacloprid 0.3% G R) @ 15kg/ha and phorate 10G @ 10 kg/ha were found statically at par in reducing percent dead heart and white ear head in rice crop. XL-0.3-GR (Imidacloprid 0.3% G R) @ 15kg/ha were found statistically at par in yield when compared with phorate 10G @ 10 kg/ha. There was no phytotoxicity effect (rating 0) of any doses of XL-0.3-GR (Imidacloprid 0.3% G R) including 60.0 kg/ha on rice crop.

Kaur *et al*. (2016) highlighted about the severe incidence of insect-pests particularly stem borer on paddy during kharif season in Punjab, has become a limiting factor in successful cultivation. Crop sown during the month of May and transplanted in the month of June following all the recommended practices was selected for the study. Efficacy of Mortar 75 SG @ 170 gram/acre was compared with the existing recommended insecticides (Durasban 20 EC and Coroban 20 EC (@ 1 liter/acre)) along with untreated plot. The results revealed that the new molecule was at par in the management of paddy stem borer with the Dursban and Coroban in both of the districts. Number of dead hearts recorded before spray was above economic threshold level at all the locations, while after five days, ten days and after fifteen days a reduction was recorded. Similar trend was observed in the per cent white ear head produced (0.18-0.23% as compared to 11.03% in Patiala and 1.25-2.00 per cent as compared to 8.75 per cent in Jalandhar). Significantly higher crop yield was observed in treated plots as compared to the untreated ones.

Material and Methods

Chapter-3

MATERIALS AND METHODS

The materials employed and methodology adopted during the course of experimentation to study various objectives for the development of an effective pest management programme, the information regarding seasonal incidence of rice stem borers (RSB) and management through trap devices and certain insecticides are of prime importance in effective management programme for the rice cultivator in Jammu region. The technical programme includes:

3.1 Details of the experiments

3.1.1 Location and site of the experimental plots for studying seasonal incidence

The site located at the research farm (Plant Pathology) of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha was selected for laying out the experimental field trial (Plate-1). The plot size of 5×5 m was selected to study the seasonal incidence of rice stem borers, adult trap catches population and natural enemies prevalent in rice ecosystem during *kharif* 2015. The plot size was 3×2 m for evaluating the efficacy of certain insecticides against of rice stem borer (RSB). The meteorological data for the period of experimentation was obtained from the Agro-meteorological observatory, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha.

3.1.2 Layout of the Experiment

Crop	:	Rice (*Oryza sativa* L.)
Design	:	Randomised Block Design (RBD)

Plate-1

Lay-out of the experimental field at SKUAST-J Chatha Farm

(A) Experimental View of lay-out at Chatha Farm SKUAST-J during *Kharif* 2015

(B) Experimental View of lay-out with details

(C)Field ploughing by tractors at Chatha Farm

(D) Rice nursery at Plant pathology field

(E) Rice crop in vegetative stage

(F) Monitoring of insect pest incidence at Chatha Farm

Spacing	:	4 seedlings transplanted per hill
Replications	:	3
Crop Variety	:	Basmati-370

3.1.3 Cultural Operations

Cultural operations were done according to the package of practices (2012) SKUAST-Jammu.

3.1.4 Harvesting

The crop was harvested at the time of grains maturity and left in the field for some days for threshing.

3.1 Seasonal incidences of rice stem borers, *Scirpophaga* spp.

The experiment was conducted at Research Farm, Chatha, SKUAST-J to record the seasonal incidence of rice stem borers. In every observation, 10 hills were selected randomly and tagged. The population of stem borers were recorded at weekly intervals during morning hours and mean population were calculated accordingly. The incidence was assessed by observing the damage symptoms *viz.*, dead hearts at vegetative stage and white ear at reproductive stage. The per cent incidence was calculated by following formula which given by Heinrichs *et al.*, 1985-

$$\text{Per cent incidence} = \left(\frac{\text{Number of dead hearts or white ears}}{\text{Total number of tiler or panicle}}\right) \times 100$$

The data obtained during the course of investigation on rice stem borers and adult trap catches were correlated with the weather factors. Simple correlations were calculated between weekly mean number of major insect pests recorded and abiotic factors.

3.2 Monitoring of rice stem borers adult population through traps

One light traps with 100 watt ordinary bulb and two funnel type polythene sleeve plastic pheromone traps were installed at Research farm, Chatha, SKUAST-J for monitoring the RSB adults population. In pheromones traps, *Scirpolure* (3 mg) was fixed and replaced regularly at 14 day interval. The traps height was maintained at 30 cm above the crop canopy throughout the experimental period. The observation was taken by collecting and counting the daily catches of RSB moths in light traps and pheromone traps (male) during morning hours throughout season on weekly basis.

3.3. Management of rice stem borers

Field experiments were conducted at Chatha farm, SKUAST-J during 2015 in order to evaluate the bio-efficacy of certain insecticides, the rice crop was raised and categorized with 9 different treatments with three replications on rice. The experiment was laid out in RBD (Randomized Block Design) with three replications. Details of the different treatments tested in the present study along with doses/concentrations are presented in table 1.

Table 1: List if treatment with doses /concentration used in the present investigation

Treatments No.	Treatments	Dose/concentration
T1	Imidacloprid	0.3 ml/L
T2	Buprofezin + acephate 70 WP	900 g
T3	*Bacillus thuringiensis*	1g/L
T4	Novaluron 10 EC	0.1 ml/L
T5	Thiodicarb 75 WP	1 g/L
T6	Azadirachtin 5000 ppm	3ml/L
T7	Cartap Hydrochloride 50 SP	1g/L
T8	Spinosad 45 SC	0.2 ml/L
T9	Water (Check)	-

For controlling the Rice Stem Borer, spraying was initiated coinciding with their peak population. The crop was sprayed twice at 15 days interval. Five hills were selected randomly from each plot. Observations were recorded on insect pests count before spray and after 1, 3, 7 and 14 days of spray. The comparative efficacy and economics of the treatments were worked out accordingly.

Statistical analysis

The per cent reduction of insect population was assessed by the modified Abbott's formula (Fleming and Retnakaran, 1985)

$$\text{Percent reduction in population over control} = 1 - \left(\frac{A \times C}{B \times D}\right) \times 100$$

Where,

A	=	Post treatment population in treatment
B	=	Pre-treatment population in treatment
C	=	Pre-treatment population in control
D	=	Post treatment population in control

The data recorded during *kharif* 2015 regarding the population of stem borer at each spray were subjected to square root transformation. These transformed values were statistically analyzed to obtain the Critical Difference (CD), so that the efficacy of different treatments against the target pests could be compared to each other and their relative efficacy could be adjudged.

Chapter-4

Results

Chapter-4

RESULTS

In the present investigation an effort was made to understand the incidence of rice stem borer in relation to abiotic factors, monitoring of adult borer population through pheromone and light traps, activity of predatory and parasitoid fauna, and bio-efficacy of certain insecticides on rice, (*Oryza sativa* L.). The results obtained are presented under following sub-heads:

4.1. Seasonal incidences of rice stem borers, *Scirpophaga* spp. on rice

The result on the seasonal incidence of the rice stem borers, *Scirpophaga* spp. on rice are given below:

4.1.1 Seasonal incidences of larval population of rice stem borers

The observations on natural infestation of rice stem borers, *Scirpophaga* spp. on rice were recorded at weekly intervals starting from 27^{th} SW to 46^{th} SW during *kharif* 2015. The seasonal incidence of rice stem borers observed at experimental sites indicated that Yellow stem borer (YSB), *S. incertulus* and White stem borer (WSB), *S. innotata* were found damaging and remain active on the crop during vegetative and reproductive stages of crop growth (Plate 2 & 3). The correlation studies indicated that abiotic factors such as weather parameters played a cumulative role in population build-up of these insect pests on rice. The pest incidence data of borer insect pests were correlated with the weather data obtained from Meteorology section SKUAST-Jammu, Chatha. Besides the insect pests, natural enemy fauna were also abundantly found in rice agro-ecosystem. The study revealed that different

Plate-2

Rice stem borers

(A) Egg mass of rice stem borer

(B) Yellow stem borer adult

(C) White stem borer borer adults

(D) Dead hearts caused by borers

(E) White ears or chaffy grains caused by borers

(F) Damaged stem by borer

Plate-3

Rice crop with traps installation

(A) Pheromone traps for rice stem borer, *S. incertulus* adult catches

(B) Field view with pheromone traps

(C) Monitoring of trap catcjes

(D) Light trap installed in rice field

(E) Light trap catches

(F) Heavy catches in light trap

types of dragonfly, damselfly, coccinellids, spiders, robber fly, ground beetles were actively noticed in rice crops predating upon the stem borer adults population. Different types of spiders fauna were also actively noticed who devours various types of insects in rice crop. Apart from predatory fauna, some parasitoids were also observed such as *Xanthopimpla* sppp. *Tetrastichus* parasitoid, teleonomus spp. on egg mass of rice stem borers (Plate 4).

During *kharif* 2015, mean number of Yellow stem borer (YSB) population on rice ranged from 0.67 to 11.33. Infestation was first observed nearly 30 days after transplanting i.e., from 27th standard week with an initial population of 0.67 larvae/10 hills. The population was observed to be increasing gradually till 38th SW recording a maximum of 11.33 larvae / 10 hills. The larval population of YSB then decreased till 46th standard week on the same crop up to 3.67 larvae / 10 hills. The mean weekly temperature and relative humidity during the period were recorded to be 31.25°C and 65 per cent, respectively.

While in case of white stem borer (WSB), *S. innotata*, the seasonal incidence of larval population was ranged from 1.0 to 14.67 larvae / 10 hills. The population WSB was quite fluctuating due to fluctuation in mean weekly maximum and minimum temperature, morning and evening relative humidity and rainfall. The population was observed to be peak larval number in 32nd SW with 11.00 larvae / 10 hills and 14.67 larvae / 10 hills during 38th SW. Thus, there was two peak of WSB larval population build-up observed during 32nd and 38th standard weeks on rice crop during 2015. During this period, the maximum temperature, minimum temperature, morning humidity, evening humidity and rainfall were observed to be 32.5°C, 25°C, 91, 73 per cent, and 101.6 mm, and 32.0°C, 21.2°C, 86.0, 61.0 per cent, and 107.6 respectively. The results indicated that the WSB population was comparatively more than YSB on rice crops of Jammu region (Table 2, Fig.1).

Table 2: Seasonal Incidence of rice stem borer, *Scirpophaga incertulus* larvae/10 hills basis during *Kharif* 2015

Standard Weeks (SW)	Yellow stem borer (YSB)	White stem borer (WSB)	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
			Maximum	Minimum	Morning	Evening	
27	0.67	1.00	36.5	26	75	55	31.8
28	6.00	7.33	33.5	24	85	64	146.9
29	5.33	5.33	33.5	26.4	83	71	102.6
30	7.00	8.00	34.5	24.9	84	62	126.2
31	2.00	3.00	33.4	25.5	82	67	15.8
32	9.33	11.00	32.5	25	91	73	101.6
33	3.33	4.67	34.5	25.9	78	63	19
34	6.33	8.00	34	24.7	84	69	38.4
35	3.00	4.00	35.2	24.9	75	55	0
36	6.00	8.33	34.6	22.6	78	53	28.8
37	4.33	4.67	35.1	23.6	80	53	0
38	11.33	14.67	32	21.2	86	61	107.6
39	7.33	7.33	32	19.7	87	56	0
40	4.33	4.00	33	18.4	84	48	0
41	5.33	5.00	31.9	20.6	85	51	0
42	7.00	7.67	30.2	16.7	85	44	19
43	5.33	5.67	27.6	14.2	83	68	14.4
44	6.33	7.67	27	13.8	90	81	3
45	5.00	8.00	25.2	11.6	93	91	0.8
46	3.67	3.33	26.7	10.6	92	47	0

Fig. 1: Seasonal incidence of rice stem borers in relation to abiotic factors during *Kharif* 2015

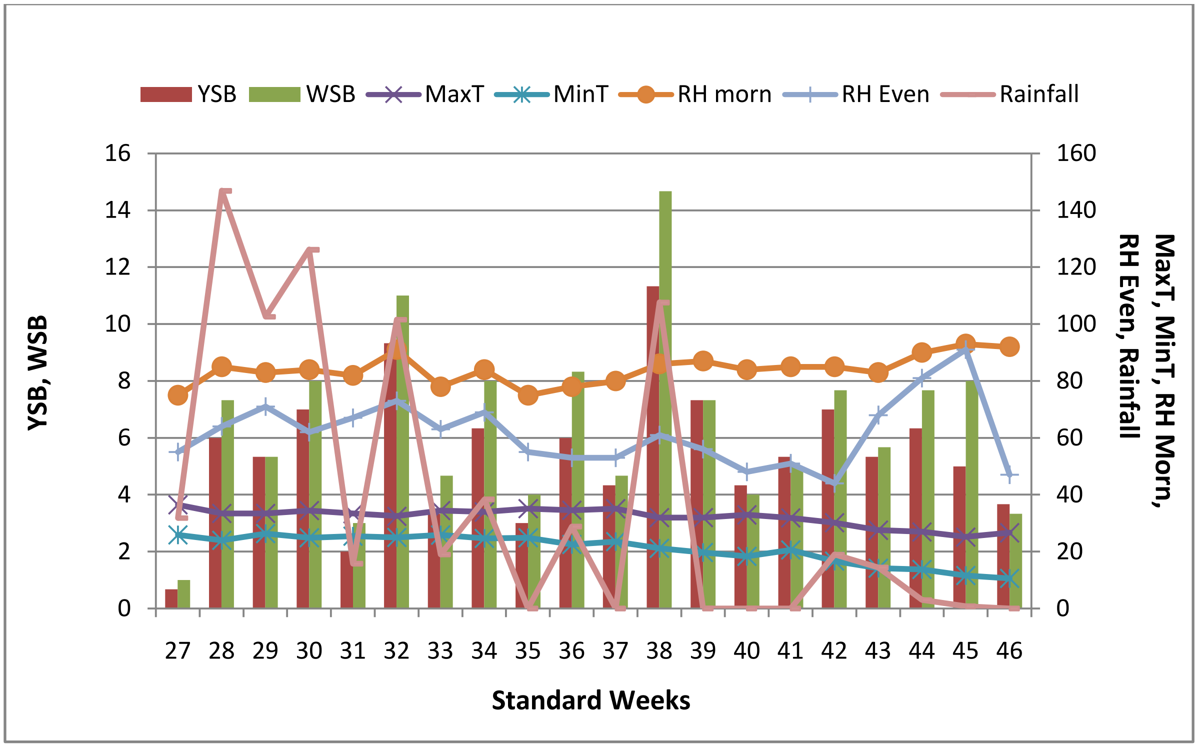
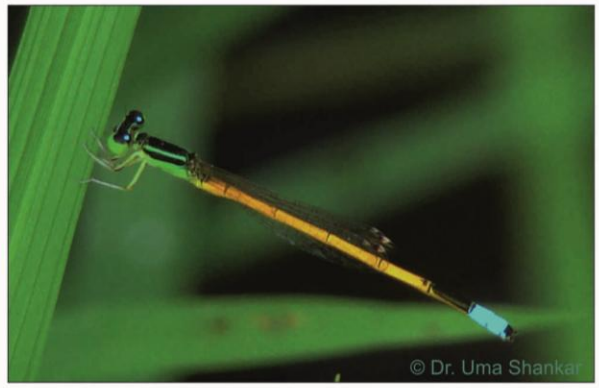


Plate-4

Natural enemy fauna in rice ecosystem

(A) Dragonfly predator

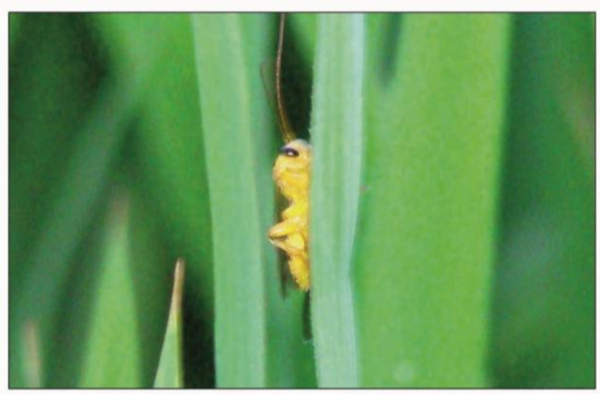


(B) Damselfly predating upon borer adults


(C) *Oxyopes* spider predating on larvae


(D) Spiders


(E) *Tetrastichus sp.* parasitoid


(F) *Xanthopimpla* parasitoid

Correlation Studies

The relationship between mean maximum and minimum temperature, mean morning and evening relative humidity, rainfall and incidence of YSB and WSB larval population when worked out during 2015, it was observed that YSB and WSB larval populations was found significantly correlated with morning relative humidity and rainfall, respectively (Table 3).

The linear regression equations for YSB larval population was calculated to be Y= – 21.902 + 0.024 X1+ 0.274 X2 – 0.018 X3 – 0.095 X4 +0.205 X5. The multiple determination (R^2) values was worked out to be 0.304 which indicated that the overall impact of weather factors on population build up of YSB larval population was 30.4 per cent. While in case of WSB, the overall impact of weather factors on the WSB larval populations was 23.5 % (Table 4).

4.1.2 Seasonal incidence of percentage dead hearts and white ears

The initial appearance of dead heat caused stem borer was observed during 27th standard week with 1.56 per cent. The maximum percentage damage of dead heart was noticed in 38th SW and remains observed just before the maturity of rice crop. The corresponding maximum and minimum temperature, morning and evening relative humidity and rainfall was recorded to be 32.0°C, 21.2°C, 86, 61 per cent and 107.6 mm during 38th SW. Thereafter, the dead heart percentage fluctuating in the field condition and minimum dead heart was recorded in 46th SW with 5.21 per cent (Table 5, Fig. 2). Like the dead heart, white ear was recorded on 35th SW with 2.92 per cent during *kharif* 2015. A weekly interval survey on white ear percentage due to stem borer revealed that the mean white ears were ranged from 2.92 to 14.58. The population was quite fluctuating and observed to be low up to 43rd SW when the mean weekly maximum and minimum temperature, morning and

Table 3. Correlation coefficient of stem borers on *kharif* rice 2015

S. No.	Insect Pests	Temperature (C^o)		Relative Humidity (%)		Rainfall (mm)
		Maximum	Minimum	Morning	Evening	
1	Yellow stem borer	–0.195	–0.099	0.506*	0.159	0.498*
2	White stem borer	–0.187	–0.066	0.450*	0.309	0.504*

* $p < 0.05$

Table 4. Regression equation and coefficient of determination (R^2) of YSB and WSB in relation to abotic factors on rice during 2015

S. No.	Insect pests	Regression equation	Coefficient of determination (R^2)	Coefficient of variation (%)
1	Yellow stem borer (YSB)	Y= –21.902 +0.024 X1 0.274 X2 –0.018 X3 –0.095 X4 0.205 X5	0.304	30.4
2	White stem borer (WSB)	Y= –27.821 +0.031X1+0.248 X2 +0.047 X3 –0.277 X4– 0.472X5	0.235	23.5

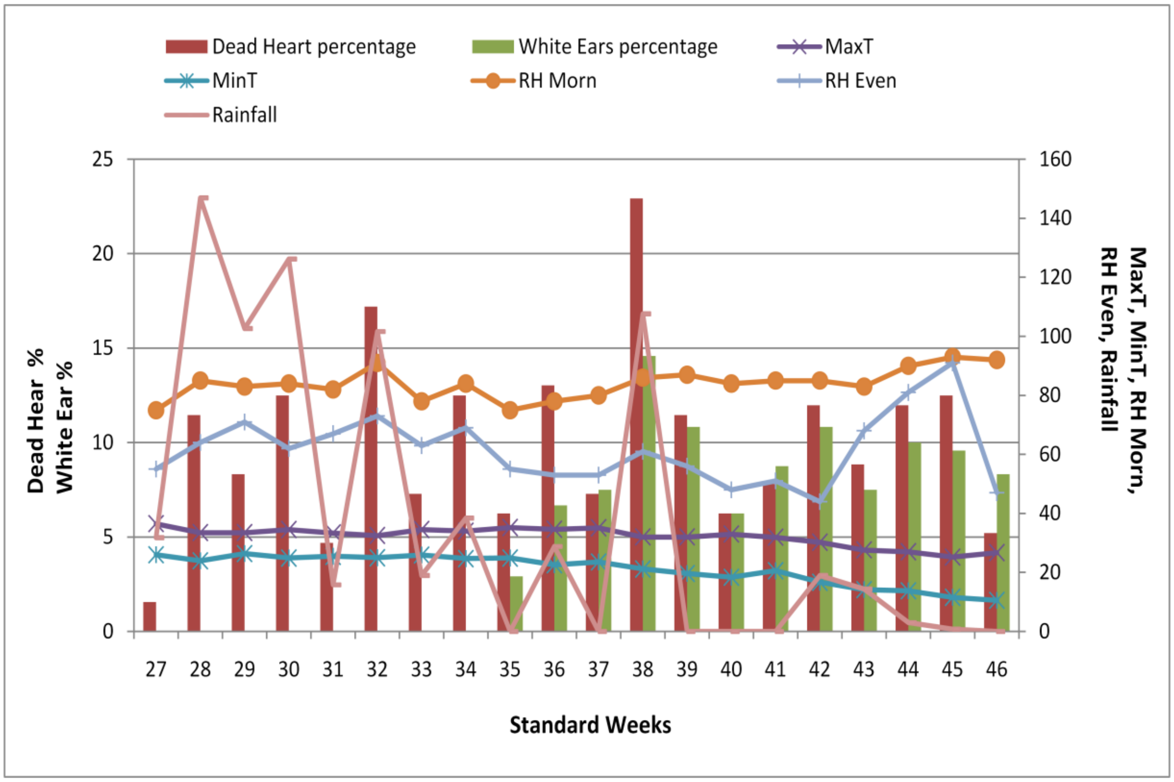
Where,

Y = Constant, X1 = Temperature (Maximum), X2 = Temperature (Minimum), X3 = Relative Humidity (Morning), X4 = Relative Humidity (Evening), X5 = Rainfall

Table 5: Percentage of dead hearts and white ears (per/10 hills) by the stem borers (*Scirpophaga* spp.) on rice during *kharif* 2015

Standard Weeks (SW)	Dead heart (%)	White ears (%)	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
			Maximum	Minimum	Morning	Evening	
27	1.56	0.0	36.5	26	75	55	31.8
28	11.46	0.0	33.5	24	85	64	146.9
29	8.33	0.0	33.5	26.4	83	71	102.6
30	12.50	0.0	34.5	24.9	84	62	126.2
31	4.69	0.0	33.4	25.5	82	67	15.8
32	17.19	0.0	32.5	25	91	73	101.6
33	7.29	0.0	34.5	25.9	78	63	19
34	12.50	0.0	34	24.7	84	69	38.4
35	6.25	2.92	35.2	24.9	75	55	0
36	13.02	6.67	34.6	22.6	78	53	28.8
37	7.29	7.50	35.1	23.6	80	53	0
38	22.92	14.58	32	21.2	86	61	107.6
39	11.46	10.83	32	19.7	87	56	0
40	6.25	6.25	33	18.4	84	48	0
41	7.81	8.75	31.9	20.6	85	51	0
42	11.98	10.83	30.2	16.7	85	44	19
43	8.85	7.50	27.6	14.2	83	68	14.4
44	11.98	10.00	27	13.8	90	81	3
45	12.50	9.58	25.2	11.6	93	91	0.8
46	5.21	8.33	26.7	10.6	92	47	0

Fig. 2: Dead hearts and white ears percentage in relation to abiotic factors



evening relative humidity and rainfall were observed to be 27.6°C, 14.2 °C, 83.0, 68 per cent and 14.4 mm, respectively. However, the white ear percentage decreased up to 7.50 by 43rd standard week, the white ear symptoms were recorded up to the harvest of crop up to 436th SW (Table 5, Fig. 2).

Correlation Studies

The relationship between abiotic factors and percentage of dead hearts and white ears (per/10 hills) by the stem borers (*Scirpophaga* spp.) when worked out on rice during *kharif* 2015, it was observed that percentage of dead hearts and white ears were found significantly correlated with morning relative humidity and rainfall, respectively (table 6). Whereas, the dead hearts and white ears were found negatively correlated and non-significant with maximum and minimum temperature.

The linear regression equations for dead hearts was calculated to be Y= –43.569 0+.049 X1 +0.388 X2 +0.073 X3 –0.433 X4 +0.739 X5. The multiple determination (R^2) values was worked out to be 0.235 which indicated that the overall impact of weather factors on dead hearts was 23.50 per cent. The regression equation was calculated to be Y= –25.538+ 0.048 X1+ 0.536 X2 – 0.048 X3+ 0.731 X4 – 0.725 X5 in case of white ears. The Coefficient of determination for white ear was calculated to be 0.741 and overall impact of weather factors on the white ears was 74.10 per cent (Table 7, Fig. 2).

4.2 . Monitoring of Rice stem borers adult population of YSB and WSB through traps

The data on incidence of rice stem borers (RSB) male adult population by light trap and YSB through pheromone trap catches showed that initial moth catch (YSB and WSB) in light trap was observed in 27th standard week with 1.67 mean number of adults whereas, 0.67 mean number of YSB adults in pheromone trap. As the environmental variables showed the gradually increasing and a little bit fluctuating trend, the maximum catches were

Table 6. Correlation coefficient of percentage of dead hearts and white ears (per/10 hills) by the stem borers (*Scirpophaga* spp.) on rice during *kharif* 2015

S. No.	Insect Pests	Temperature (C^o)		Relative Humidity (%)		Rainfall (mm)
		Maximum	Minimum	Morning	Evening	
1	**Dead hearts percentage**	–0.187	–0.066	0.451*	0.309	0.505*
2	**White ears percentage**	–0.356	–0.269	0.602*	0.204	0.621*

* $p < 0.05$

Table 7. Regression equation and coefficient of determination (R^2) of dead hearts and white ears by the stem borers in relation to abotic factors during 2015

S. No.	Insect pests	Regression equation	Coefficient of determination (R^2)	Coefficient of variation (%)
1	**Dead hearts**	Y= –43.569 0+.049 X1 +0.388 X2 +0.073 X3 –0.433 X4 +0.739 X5	0.235	23.5
2	**White ears**	Y= –25.538+ 0.048 X1+ 0.536 X2 – 0.048 X3+ 0.731 X4 – 0.725 X5	0.741	74.1

Where,

Y = Constant, X1 = Temperature (Maximum), X2 = Temperature (Minimum), X3 = Relative Humidity (Morning), X4 = Relative Humidity (Evening), X5 = Rainfall

recorded in 38th SW with 20.33, 27.33 and 14.67 adults population in light and pheromone traps, respectively. The perusal of data showed that more number of YSB adults were caught in light trap than the pheromone trap. A little more higher catches of WSB in light trap was indicated that the incidence of white stem borer (WSB) population was found to be more pronounced in Jammu region. The mean weekly maximum and minimum temperature, morning and evening relative humidity and rainfall were observed to be 21.2°C, 32.0 °C, 86.0, 61 per cent and 107.6 mm, respectively. The moth activity was observed in light and pheromone traps up to the harvest of crop i.e., 46th standard week. The adult population fluctuated between 32nd to 38th standard weeks, exhibiting one 'V' shaped oscillations. Thereafter, a sharp decline was noticed up to the harvest of crop during 46th SW ranging from 2.33 to 3.33 mean numbers of moths trap in light and pheromone trap, respectively. Thus, there were two peaks of YSB adult trap catch population noticed during 33rd standard week (13.67) and 38th SW in light trap and 32nd SW (11.00) and 38th SW in pheromone traps, respectively. White stem borer (WSB) adults catches also showed the two peaks *viz*., in 32nd SW (19.33) and in 38th SW in light traps (Table 8, Fig. 3).

Correlation Studies

The relationship between abiotic factors and rice stem borers (RSB) male adult population by light trap and YSB through pheromone trap catches showed that only pheromone trap catches of YSB was found significantly correlated with morning relative humidity and rainfall, respectively (Table 9). Whereas, the trap catches in light trap were found to non-significant with the abiotic factors *i.e*., maximum and minimum temperature, morning and evening relative humidity and rainfall.

The linear regression equations for light trap catches for YSB and WSB were calculated to be Y= –43.427 – 0.008X1+ 0.475X2+ 0.002X3 + 0.304X4+ 0.169X5 and Y= –

Table 8. Light trap and pheromone trap catches of yellow stem borer (YSB) and white stem borer (WSB) on rice during *kharif* 2015

Standard Weeks (SW)	Mean No. of YSB in Light Trap	Mean No. of WSB in Light Trap	Mean No. of YSB in Pheromone Trap	Meteorological observations				
				Temperature (^{o}C)		Relative humidity (%)		Rainfall (mm)
				Maximum	Minimum	Morning	Evening	
27	1.67	1.67	0.67	26	36.5	75	55	31.8
28	3.33	8.67	7.33	24	33.5	85	64	146.9
29	6.33	6.33	5.33	26.4	33.5	83	71	102.6
30	7.67	11.33	8.00	24.9	34.5	84	62	126.2
31	8.67	4.67	3.00	25.5	33.4	82	67	15.8
32	11.67	19.33	11.00	25	32.5	91	73	101.6
33	13.67	10.67	4.67	25.9	34.5	78	63	19
34	9.00	21.00	8.00	24.7	34	84	69	38.4
35	4.00	11.67	4.00	24.9	35.2	75	55	0
36	8.33	16.33	8.33	22.6	34.6	78	53	28.8
37	4.67	14.67	4.67	23.6	35.1	80	53	0
38	20.33	27.33	14.67	21.2	32	86	61	107.6
39	14.33	16.67	7.33	19.7	32	87	56	0
40	10.00	10.67	4.00	18.4	33	84	48	0
41	6.33	9.33	5.00	20.6	31.9	85	51	0
42	7.67	11.67	7.67	16.7	30.2	85	44	19
43	5.67	6.00	5.67	14.2	27.6	83	68	14.4
44	7.67	8.33	7.67	13.8	27	90	81	3
45	8.00	6.00	8.00	11.6	25.2	93	91	0.8
46	3.33	2.33	3.33	10.6	26.7	92	47	0

Table 9. Correlation coefficient of mean umber of YSB and WSB in different types of traps during 2015

S. N.	Trap catches	Rainfall	Relative Humidity		Temperature	
			Morning	Evening	Minimum	Maximum
1	Mean No. of YSB in Light Trap	0.155	0.225	0.129	0.064	–0.012
2	Mean No. of WSB in Light Trap	0.282	0.047	–0.048	0.266	0.264
3	Mean No. of YSB in Pheromone Trap	0.500*	0.456*	0.309	-0.070	–0.193

* $p < 0.05$

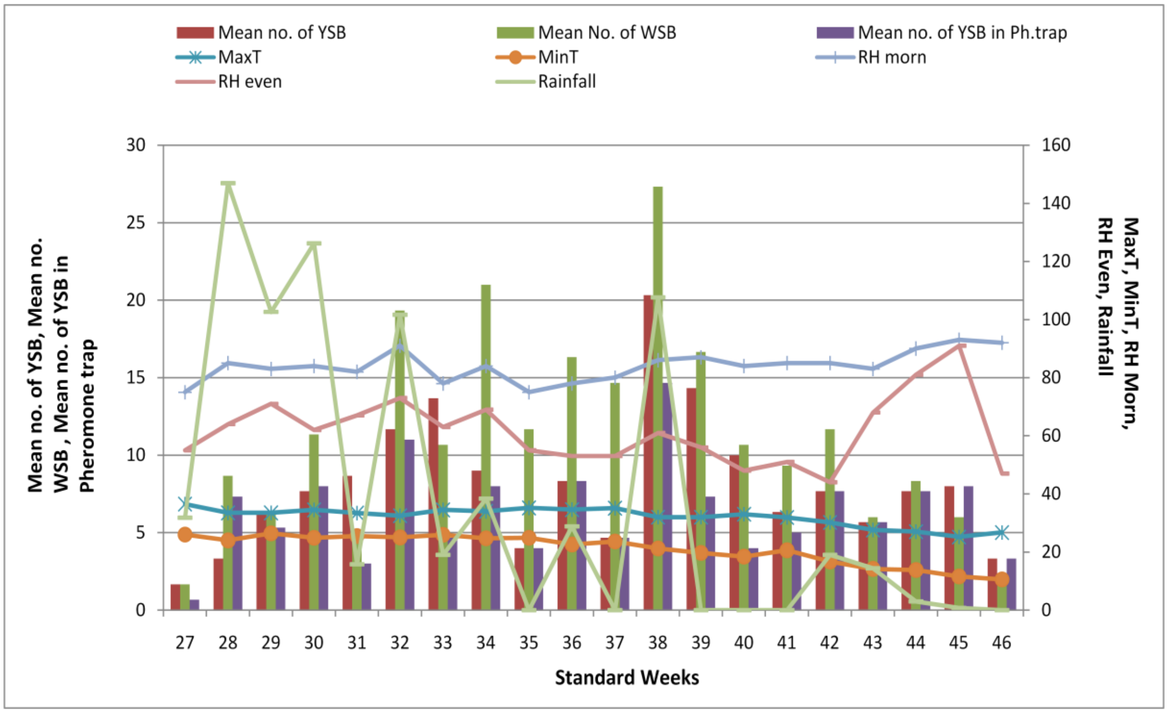
Table 10. Regression equation and coefficient of determination (R^2) of Light trap and pheromone Trap catches of YSB and WSB on Rice

S. No.	Insect pests	Regression equation	Coefficient of determination (R^2)	Coefficient of variation (%)
1	Mean No. of YSB in Light Trap	Y= –43.427 – 0.008X1+ 0.475X2+ 0.002X3 + 0.304X4+ 0.169X5	0.177	17.7
2	Mean No. of WSB in Light Trap	Y= –131.810 + 0.008X1+ 0.837X2 + 0.058X3 – 0.598X4 +2.534X5	0.026	02.6
3	Mean No. of YSB in Pheromone Trap	Y= –27.688+ 0.031X1+ 0.253X2 +.0045X3 –0.262X4+ 0.448X5	0.233	23.3

Where,

Y = Constant, X1 = Temperature (Maximum), X2 = Temperature (Minimum), X3 = Relative Humidity (Morning), X4 = Relative Humidity (Evening), X5 = Rainfall

Fig. 3: Light trap and pheromone Trap catches of YSB and WSB on rice during *kharif* 2015



131.810 + 0.008X1+ 0.837X2 + 0.058X3 – 0.598X4 +2.534X5, respectively. The multiple determination (R^2) values was worked out to be 0.233 for YSB in pheromone trap and overall impact of weather factors on the YSB in pheromone trap was 23.3 per cent (Table 10). The perusal of data showed that the weather factor could not play be an important for light trap catches of YSB and WSB adult population.

4.3 Management of rice stem borers

4.3.1 Bio-efficacy of certain insecticide against rice stem borers

First Spray

The pre-treatment population of rice stem borer ranged from 3.33 to 6.33 per 10 hills in different treatments during 1st spray. However, one day after application of various treatments, cartap hydrochloride was the most effective treatment in causing 55.82 per cent population reduction which was followed by Buprofezin + acephate (51.17) treated plots. Whereas, the plots treated with Spinosad and *Bacillus thuringiensis*, the reduction was 48.66 and 37.85 per cent, respectively. *Azadirachtin* was the least effective, resulting in only 26.65 per cent reduction (Table 11).

After three days of first spray, the best effect was observed in Buprofezin + acephate which reduced the stem borer population by 79.10 per cent. This was followed by the treatment of Imidacloprid in different plots, causing a reduction of 77.30 per cent. Application of spinosad resulted in 72.37 per cent reduction while in case of cartap hydrochloride (69.74 per cent reduction); application of novaluron resulted in 66.90 per cent reduction whereas, *Bacillus thuringiensis* caused a suppression of 66.55 per cent over control. *Azadirachtin was* the least effective, giving a reduction of 48.19 per cent.

After seventh days after 1st spray, the maximum reduction of stem borer was observed in the application of *Bacillus thuringiensis* (84.21 %). This was followed by

Table 11.Efficacy of different insecticides (First spray) against Rice Stem Borers, *Scirpophaga spp.* on rice during *Kharif* 2015

Sr. No	Treatment	Dose	1DBS	1DAS	% tage Reduction	3DAS	% tage Reduction	7 DAS	% tage Reduction	15 DAS	% tage Reduction	Overall % reduction	Rank
1	Imidacloprid	0.3 ml/L	7.00 (0.102)	5.33 (0.065)	35.73	2.00 (0.169)	77.30	1.67 (0.106)	82.14	5.00 (0.118)	52.97	62.03	4
2	Buprofezin + acephate 70 WP	900 g	6.33 (0.268)	3.67 (0.213)	51.17	1.67 (0.106)	79.10	2.33 (0.089)	72.37	5.67 (0.228)	41.09	60.93	5
3	*Bacillus thuringiensis*	1g/L	6.33 (0.161)	4.67 (0.137)	37.85	2.67 (0.168)	66.55	1.33 (0.106)	84.21	4.33 (0.150)	54.95	60.89	6
4	Novaluron 10 EC	0.1 ml/L	8.00 (0.096)	7.00 (0.102)	26.19	3.33 (0.168)	66.90	2.67 (0.089)	75.00	3.33 (0.209)	72.57	60.16	7
5	Thiodicarb 75 WP	1 g/L	6.67 (0.255)	5.67 (0.276)	28.30	3.00 (0.146)	64.25	2.33 (0.195)	73.75	4.00 (0.130)	60.50	64.50	3
6	Azadirachtin 5000 ppm	3ml/L	7.67 (0.153)	6.67 (0.163)	26.65	5.00 (0.118)	48.19	2.67 (0.089)	73.91	4.67 (0.071)	59.92	52.16	8
7	Cartap Hydrochloride 50 SP	1g/L	7.00 (0.102)	3.67 (0.079)	55.82	2.67 (0.089)	69.74	1.67 (0.106)	82.14	4.00 (0.130)	62.38	67.52	2
8	Spinosad 45 SC	0.2 ml/L	7.67 (0.057)	4.67 (0.191)	48.66	2.67 (0.244)	72.37	2.33 (0.195)	77.17	1.67 (0.106)	85.69	70.97	1
9	Water (Check)	-	9.00 (0.091)	10.67 (0.049)	-	11.33 (0.175)	-	12.00 (0.161)	-	13.67 (0.116)			
C.D.		**-**	**N.S.**	**0.413**		**0.429**		**0.341**		**0.393**			
S.E. (m)±			**0.141**	**0.136**		**0.142**		**0.113**		**0.130**			

Figures in parenthesis are square root √X+1 trasformed values
DBS=Days before Spray, DAS=Days after spray

application of cartap hydrochloride and imidacloprid which was at par with each other in various plots (82.14 %), spinosad (77.17 %), novaluron (75.00 %) and *Azadirachtin* (73.91 %).

After 15th days of 1st spray, spinosad was found to be the best treatment in reducing the stem borer population on rice followed by novaluron (72.57 per cent) and cartap hydrochloride (62.38. per cent). In these results, spinosad is the most effective up to 15th days and significantly different from other treatments at 5 per cent level of significance (table 11). The descending order of performance of different treatments were found as follows-

Spinosad> cartap hydrochloride> Thiodicarb> imidacloprid> Buprofezin + acephate> *Bacillus thuringiensis*> Novaluron> *Azadirachtin.*

Second Spray

One day after the second spray the highest population reduction was observed in thiodicarb treated plots, which caused a reduction of 40.96 per cent, followed by *Azadirachtin* which resulted in 35.12 per cent reduction over control. The application of Bacillus and novaluron in various plots caused 33.73 per cent reduction stem borer population and found to be *at par*. Buprofezin + acephate was the least effective causing a reduction of 23.32 per cent (Table 12).

Third day after second spray, Spinosad was the most effective insecticide, causing 73.52 per cent reduction, followed by imidacloprid with 69.45 per cent, and thiodicarb with 68.23 per cent. *Bacillus* and cartap hydrochloride with 60.28 per cent reduction were found to be at par in reducing the stem borer population. While, Buprofezin + acephate was the least effective and gave a reduction of only 42.23 per cent.

Table 12.Efficacy of different insecticides (Second Spray) against Rice Stem Borers, *Scirpophaga spp.* on rice during *Kharif* 2015

Sr. No	Treatment	Dose	1DBS	1DAS	% tage reduction	3DAS	% tage reduction	7 DAS	% tage reduction	15 DAS	% tage reduction	Overall % reduction	Rank
1	Imidacloprid	0.3 ml/L	4.33 (0.189)	3.67 (0.271)	28.63	1.67 (0.106)	69.45	1.67 (0.106)	71.15	2.33 (0.089)	64.55	58.44	4
2	Buprofezin + acephate 70 WP	900 g	3.67 (0.079)	3.33 (0.168)	23.32	2.67 (0.168)	42.23	1.00 (0.212)	79.55	0.67 (0.138)	88.03	58.28	5
3	*Bacillus thuringiensis*	1g/L	4.67 (0.071)	3.67 (0.079)	33.73	2.33 (0.089)	60.28	1.33 (0.106)	78.57	3.00 (0.146)	57.68	57.47	6
4	Novaluron 10 EC	0.1 ml/L	4.67 (0.191)	3.67 (0.079)	33.73	3.33 (0.209)	43.26	2.67 (0.089)	57.14	2.33 (0.089)	67.08	50.30	7
5	Thiodicarb 75 WP	1 g/L	3.33 (0.209)	2.33 (0.239)	40.96	1.33 (0.290)	68.23	1.00 (0.212)	77.50	2.67 (0.168)	47.33	58.50	3
6	Azadirachtin 5000 ppm	3ml/L	4.33 (0.189)	3.33 (0.209)	35.12	3.00 (0.146)	45.01	2.33 (0.195)	59.62	2.67 (0.089)	59.48	49.30	8
7	Cartap Hydrochloride 50 SP	1g/L	5.33 (0.251)	4.33 (0.189)	31.47	2.67 (0.089)	60.28	2.33 (0.089)	67.19	1.33 (0.244)	83.54	60.62	2
8	Spinosad 45 SC	0.2 ml/L	5.00 (0.118)	4.00 (0.130)	32.52	1.67 (0.106)	73.52	1.33 (0.106)	80.00	3.00 (0.146)	60.50	61.63	1
9	Water (Check)	-	6.33 (0.126)	7.33 (0.151)	-	8.00 (0.194)	-	10.00 (0.087)	-	10.67 (0.173)			
C.D.		**-**	**N.S.**	**0.497**		**0.434**		**0.366**		**0.481**			
S.E. (m)±		**-**	**0.149**	**0.164**		**0.144**		**0.121**		**0.159**			

Figures in parenthesis are square root √X+1 trasformed values
DBS=Days before Spray, DAS=Days after spray

At 7 days after second spray, the maximum population reduction of stem borer was achieved due to spinosad treatment (80.00%) followed by Buprofezin + acephate (79.55 %). *Bacillus* caused a reduction of 78.57 per cent, while application of thiodicarb and imidacloprid resulted in 77.50 and 71.15 per cent reduction, respectively. Novaluron was found to be least effective, giving a reduction of only 57.14 per cent at 7th day during second spray. Among the biopesticides *Azadirachtin* gave 59.62 per cent reduction in stem borer population. At 15 days after second spray, Buprofezin + acephate (88.03) was found to be the best treatment in reducing the stem borer population on basmati rice followed by cartap hydrochloride (83.54 per cent) and novaluron (67.08 per cent).

Overall, spinosad and cartap hydrochloride were the most effective treatment after two sprays up to 15th days in reducing the stem bore population and found to be significantly different from other treatments at 5 per cent level of significance (table 12). The descending order of performance of different treatments were found as follows-

Spinosad> cartap hydrochloride> Thiodicarb> imidacloprid> Buprofezin + acephate> *Bacillus thuringiensis*> Novaluron> *Azadirachtin.*

Discussion

Chapter-5

DISCUSSION

The present investigation was carried out with an objective to study the incidence of rice stem borer in relation to abiotic factors, monitoring of adult borer population through pheromone and light traps, activity of predatory and parasitoid fauna and bio-efficacy of certain insecticides on rice, (*Oryza sativa* L.). The results obtained in this study on seasonal incidence and management of stem borers are discussed as under:

5.1. Seasonal incidences of rice stem borers, *Scirpophaga* spp. on rice

The observations on natural infestation of rice stem borers, *Scirpophaga* spp. on rice were recorded at weekly intervals starting from 27^{th} SW to 46^{th} SW during *kharif* 2015. The seasonal incidence of rice stem borers observed at experimental sites indicated that Yellow stem borer (YSB), *S. incertulus* and white stem borer (WSB), *S. innotata* were found damaging and remain active on the crop during vegetative and reproductive stages of crop growth. Besides the insect pests, natural enemy fauna were also abundantly found in rice agro-ecosystem. The study revealed that different types of dragonfly, damselfly, coccinellids, spiders, robber fly, ground beetles were actively noticed in rice crops predating upon the stem borer adults population. Different types of spiders fauna were also actively noticed who devours various types of insects in rice crop. Apart from predatory fauna, some parasitoids were also observed such as *Xanthopimpla* spp. *Tetrastichus* parasitoid, *Teleonomus* spp. on egg mass of rice stem borers.

The present results are in agreement with the results observed by Anitha *et al.* (2016) who studied seasonal dynamics and relative abundance of three hymenopteran egg parasitoids, *Tetrastichus schoenobii*, *Telenomus dignus* and *Trichogramma japonicum* of yellow stem borer, *Scirpophaga incertulas* in rice. The present findings are in conformity with Gangwar et al. (2015), Singh *et al*. (2016) who recorded some defender *viz.* dragon fly, spiders and praying mentis also were noticed in controlling the pest population.

During *kharif* 2015, mean number of Yellow stem borer (YSB) population on rice was observed to be increasing gradually till 38th SW recording a maximum of 11.33 larvae / 10 hills. While in case of white stem borer (WSB), *S. innotata,* the seasonal incidence of larval population was ranged from 1.0 to 14.67 larvae / 10 hills. The population WSB was quite fluctuating due to fluctuation in mean weekly maximum and minimum temperature, morning and evening relative humidity and rainfall. The population was observed to be peak larval number in 32nd SW with 11.00 larvae / 10 hills and 14.67 larvae / 10 hills during 38th SW. Thus, there was two peak of WSB larval population build-up observed during 32nd and 38th standard weeks on rice crop during 2015.

Correlation Studies

The relationship between abiotic factors and incidence of YSB and WSB larval population when worked out during 2015, it was observed that YSB and WSB larval populations was found significantly correlated with morning relative humidity and rainfall, respectively. The linear regression equations for YSB larval population was calculated to be $Y= –21.902 + 0.024 X1+ 0.274 X2 – 0.018 X3 – 0.095 X4 +0.205 X5$. The multiple determination (R^2) values was worked out to be 0.304 which indicated that the overall impact of weather factors on population build up of YSB larval population was 30.4 per cent. While in case of WSB, the overall impact of weather factors on the WSB larval populations was 23.5 per cent.

These findings were in supportive with those reported from India by Pathak, 1975; Chaudhary *et al.*, 1984; Karthikeyan and Purushothaman, 2000; Sigsgaard, 2000; Pasalu *et al.*, 2002; Misra *et al.*, 2005; Ho *et al.*, 2013). While studying the seasonal incidence of this pest Pasalu *et al.*, 2002 reported that yellow Stem borer (YSB), *Scirpophaga incertulas* is the most predominant one and has assumed the status of national pest and attacks the rice crop at all stages of its growth. The present results are also in line with the study conducted by Adiroubane and Raja (2007) who recorded the influence of weather parameters on the occurrence of Rice yellow stem borer, *Scirpophaga incertulas* and revealed that high pest incidence during August- September month (Justin *et al.*, 2013).

However, the results obtained by Dhaliwal *et al.* (2006) were differed from the present findings who recorded the incidence of stem borer was negatively correlated with maximum temperature, minimum temperature, morning relative humidity and sunshine hours in both the planting methods during 2005; however it was positively correlated with evening relative humidity and rainfall.

5.1.2 Seasonal incidence of percentage dead hearts and white ears

The maximum percentage damage of dead heart was noticed in 38th SW and remains observed just before the maturity of rice crop. Thereafter, the dead heart percentage fluctuating in the field condition and minimum dead heart was recorded in 46th SW with 5.21 per cent. Like the dead heart, white ear was recorded on 35th SW with 2.92 per cent during *kharif* 2015. A weekly interval survey on white ear percentage due to stem borer revealed that the mean white ears were ranged from 2.92 to 14.58.

Correlation Studies

The relationship between abiotic factors and percentage of dead hearts and white ears were found significantly correlated with morning relative humidity and rainfall, respectively. Whereas, the dead hearts and white ears were found negatively correlated and non-significant with maximum and minimum temperature. The multiple determination (R^2) values were worked out to be 0.235 which indicated that the overall impact of weather factors on dead hearts was 23.50 per cent. The regression equation was calculated to be Y= –25.538+ 0.048 X1+ 0.536 X2 – 0.048 X3+ 0.731 X4 – 0.725 X5 in case of white ears. The Coefficient of determination for white ear was calculated to be 0.741 and overall impact of weather factors on the white ears was 74.10 per cent.

The results obtained by Justin *et al.* (2013) are in conformity with the present findings who assessed the incidence by observing the damage symptoms *viz.,* dead heart at the vegetative stage (tillering) and white ear at the maturity stage. Whereas, the results obtained by Justin and Preetha (2015) deferred from the present findings who reported that the highest per cent of dead heart and white ear were observed in October 26 sown crops.

5.2 . Monitoring of Rice stem borers adult population of YSB and WSB through traps

The maximum catches were recorded in 38th SW with 20.33, 27.33 and 14.67 adults population in light and pheromone traps, respectively. The perusal of data showed that more number of YSB adults was caught in light trap than the pheromone trap. The adult population fluctuated between 32nd to 38th standard weeks, exhibiting one 'V' shaped oscillations. Thereafter, a sharp decline was noticed up to the harvest of crop during 46th SW ranging from 2.33 to 3.33 mean numbers of moths trap in light and pheromone trap, respectively. Thus, there were two peaks of YSB adult trap catch population noticed during 33rd standard week (13.67) and 38th SW in light trap and 32nd SW (11.00) and 38th SW in pheromone traps, respectively. White stem borer (WSB) adults catches also showed the two peaks *viz*., in 32nd SW (19.33) and in 38th SW in light traps.

Correlation Studies

The relationship between abiotic factors and rice stem borers (RSB) male adult population by light trap and YSB through pheromone trap catches showed that only pheromone trap catches of YSB was found significantly correlated with morning relative humidity and rainfall, respectively. The multiple determination (R^2) values was worked out to be 0.233 for YSB in pheromone trap and overall impact of weather factors on the YSB in pheromone trap was 23.3 per cent.

The findings of the present study also draw support from the observations made by Sawant *et al.* (1995) who assessed that the larval damage estimates were significantly less in the pheromone-treated plots and dead heart and white head damage recorded in the pheromone-treated plots (2.8 and 15.7%) was less than the farmers' practice plots (7.0 and 20.9%). Oo *et al.* (2003) also supported the results of current findings and showed that the number of yellow stem borer (YSB), *Scirpophaga incertulas* moths caught in light trap was also high in numbers recorded in August month. Prakash *et al.* (2007) reviewed the studies on management of insect pests in field by pheromone traps and suggested that for monitoring, three sleeve traps baited with rubber dispenser (impregnated with pheromone @ 5mg/dispenser) and for mass trapping 20 traps/ha found to be optimum for yellow stem borer. Maximum traps were at average temperature of 30-33°C for insect catch by light traps. The results obtained by Kumar *et al.* (2009) was in conformity to the present findings who *Scirpophaga incertulas* moth catches was higher from 36th to 42nd standard week.

5.3 Management of rice stem borers

5.3.1 Bio-efficacy of certain insecticide against rice stem borers

After 15^{th} days of 1^{st} spray, Spinosad was found to be the best treatment in reducing the stem borer population on rice followed by Novaluron (72.57 per cent) and Cartap hydrochloride (62.38. per cent). In these results, Spinosad is the most effective up to 15^{th} days and significantly different from other treatments at 5 per cent level of significance. Overall, Spinosad and Cartap hydrochloride were the most effective treatment after two sprays up to 15^{th} days in reducing the stem bore population and found to be significantly different from other treatments at 5 per cent level of significance. The descending order of performance of different treatments were found as follows- Spinosad> Cartap hydrochloride> Thiodicarb> Imidacloprid> Buprofezin + Acephate> *Bacillus thuringiensis*> Novaluron> *Azadirachtin.*

The present findings are in conformity with the results obtained by Lal (2006) who recorded the effect of Cartap hydrochloride was observed more than 30 days when applied at 30 DAT and observation recorded up to 70 days and the cost:benefit ratio was highest in Monocrotophos (1:8.68), followed by cartap hydrochloride. Chakroboraty (2011) also studied the efficacy of some bio-rational pesticide formulation for the management of yellow stem borer *S. incertulas* in the paddy field like Nimbecidine, Neem seed kernel extract (NSKE) and Mahua oil. The present results were in conformity with Kulagod *et al.* (2011) who evaluated the insecticides and bio-rationals like Fipronil 5 FS, Indoxacarb 14.5 SC, Thiodicarb 75 WP, *Bacillus thuringiensis,* novaluron 10EC, Cartap 50 SP, Spinosad 45 SC, Chlorpyriphos 20 EC, Flubendiamide 480 SC against yellow stem borer . Mishra *et al.* (2012) also supportive to the present findings and revealed that fipronil 5SC @ 50g *a.i.*ha^{-1} was superior to over other insecticides, which results the lowest incidence of Yellow stem borer with highest grains yield followed by Cartap hydrochloride 50SP @ 300g *a.i.*ha^{-1} and Cartap hydrochloride 4G @ 750g *a.i.*ha^{-1}. Prasad *et al.* (2014) also evaluated certain new insecticide against yellow stem borer, *S. incertulas* who confirmed that all the insecticidal treatments were significantly superior to untreated control. The results clearly indicated that 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} with 3.50, 4.15 and 4.40 average YSB infestation; and 18.00, 16.37 and 16.27 q ha^{-1} average grain yields, respectively.

Chapter-6

Summary and Conclusion

Chapter-7

SUMMARY AND CONCLUSION

The thesis embodies the results of experimentation made on "Seasonal incidence and management of rice stem borers (*Scirpophaga spp.*) on rice (*Oryza sativa* L.)" carried out during cropping season of *kharif* 2015. The broad objectives of present studies were as follows:

1. To study the seasonal incidence of rice stem borers.
2. To study the monitoring of rice stem borers through pheromones traps
3. To evaluate the bio-efficacy of certain insecticide against rice stem borers

The observations on natural infestation of rice stem borers, *Scirpophaga* spp. on rice were recorded at weekly intervals starting from 27th SW to 46th SW during *kharif* 2015. The seasonal incidence of rice stem borers observed at experimental sites indicated that Yellow stem borer (YSB), *Scirpophaga incertulus* and white stem borer (WSB), *S. innotata* were found damaging and remain active on the crop during vegetative and reproductive stages of crop growth. Besides the insect pests, natural enemy fauna were also abundantly found in rice agro-ecosystem. The study revealed that different types of dragonfly, damselfly, coccinellids, spiders, robber fly, ground beetles were actively noticed in rice crops predating upon the stem borer adults population. Apart from predatory fauna, some parasitoids were also observed such as *Xanthopimpla* spp. *Tetrastichus* parasitoid, *Teleonomus* spp. on egg mass of rice stem borers.

During *kharif* 2015, mean number of Yellow stem borer (YSB) population on rice was observed to be increasing gradually till 38th SW recording a maximum of 11.33 larvae / 10 hills. While in case of white stem borer (WSB), *S. innotata,* the seasonal incidence of larval population was ranged from 1.0 to 14.67 larvae / 10 hills. The population WSB was observed to be peak larval number in 32nd SW with 11.00 larvae / 10 hills and 14.67 larvae / 10 hills during 38th SW. Thus, there was two peak of WSB larval population build-up observed during 32nd and 38th standard weeks on rice crop during 2015. The relationship between abiotic factors and incidence of YSB and WSB larval population when worked out during 2015, it was observed that YSB and WSB larval populations was found significantly correlated with morning relative humidity and rainfall, respectively. The overall impact of weather factors on population build up of YSB larval population was 30.4 per cent. While in case of WSB, the overall impact of weather factors on the WSB larval populations was 23.5 per cent.

The maximum percentage damage of dead heart was noticed in 38th SW and remains observed just before the maturity of rice crop whereas, white ear was recorded on 35th SW with 2.92 per cent during *kharif* 2015. A weekly interval survey on white ear percentage due to stem borer revealed that the mean white ears were ranged from 2.92 to 14.58. The relationship between abiotic factors and percentage of dead hearts and white ears were found significantly correlated with morning relative humidity and rainfall, respectively. The overall impact of weather factors on the white ears was 74.10 per cent.

The maximum catches were recorded in 38th SW with 20.33, 27.33 and 14.67 adults population in light and pheromone traps, respectively. The perusal of data showed that more number of YSB adults was caught in light trap than the pheromone trap. The adult population fluctuated between 32^{nd} to 38^{th} standard weeks, exhibiting one ‘V’ shaped oscillations. Thus, there were two peaks of YSB adult trap catch population noticed during 33^{rd} standard week (13.67) and 38^{th} SW in light trap and 32^{nd} SW (11.00) and 38^{th} SW in pheromone traps, respectively. White stem borer (WSB) adults catches also showed the two peaks *viz*., in 32^{nd} SW (19.33) and in 38^{th} SW in light traps. The relationship between abiotic factors and rice stem borers (RSB) male adult population by light trap and YSB through pheromone trap catches showed that only pheromone trap catches of YSB was found significantly correlated with morning relative humidity and rainfall, respectively.

After 15^{th} days of 1^{st} spray, spinosad was found to be the best treatment in reducing the stem borer population on rice followed by novaluron (72.57 per cent) and cartap hydrochloride (62.38. per cent). In these results, spinosad is the most effective up to 15^{th} days and significantly different from other treatments at 5 per cent level of significance. Overall, spinosad and cartap hydrochloride were the most effective treatment after two sprays up to 15^{th} days in reducing the stem bore population and found to be significantly different from other treatments at 5 per cent level of significance. The descending order of performance of different treatments were found as follows- Spinosad> Cartap hydrochloride> Thiodicarb> Imidacloprid> Buprofezin + Acephate> *Bacillus thuringiensis*> Novaluron> *Azadirachtin.*

The conclusion drawn during present investigation is summarized below:

- Basmati rice is an important staple crop grown commercially in and around Jammu region. The crop recorded a huge pressure of insect pests especially rice stem borer as the major pest of economic significance which requires suitable intervention for the successful cultivation of this crops.

- The seasonal incidence of stem borers during *kharif* 2015 provides holistic information about the seasonal incidence and impact of abiotic factors on the population build up of the above pest. On the basis of information generated, we are enable to forecast the timely intervention for the management of stem borers population on rice.
- Apart of insect pests, a large number of natural enemy fauna like predatory fauna and parasitoids are also present in rice crop ecosystem which mitigates the population of stem borer population.
- Among the different treatments evaluated, Spinosad and Cartap hydrochloride were the most effective treatments after two sprays up to 15th days in reducing the stem borer population and found to be significantly different from other treatments at 5 per cent level of significance. The descending order of performance of different treatments were found as follows- Spinosad> Cartap hydrochloride> Thiodicarb> Imidacloprid> Buprofezin + Acephate> *Bacillus thuringiensis*> Novaluron> *Azadirachtin.*

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CERTIFICATE-IV

Certified that all the necessary corrections as suggested by the external examiner and the Advisory Committee have been duly incorporated in the thesis entitled **"SEASONAL INCIDENCE AND MANAGEMENT OF RICE STEM BORERS, *Scirpophaga spp.* ON RICE (*Oryza sativa* L.)"** submitted by **Mr. Sandeep Kumar,** Registration No. **J-14-M-362.**

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