Cereal Research Communications 43(2), pp. 260–271 (2015)
DOI: 10.1556/CRC.2014.0034
First published online 4 February, 2015

Impact of Multiple Insect-Pest Incidence on Yield in Basmati Rice

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(Received 20 November 2013; Accepted 6 June 2014)

The experiments for determining the multiple insect-pest incidence on yield loss in basmati rice was conducted 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 Vs 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.

Keywords: basmati rice, leaf folder, planthopper, stem borer, yield loss

Introduction

Rice, *Oryza sativa* L., is the important cereal crop which is grown in 117 countries and is a staple food for people in 39 countries, which includes 2.70 billion people in Asia alone (Sardesai et al. 2001). Its productivity is severely affected by numerous biotic and abiotic factors. About 52% of the total global production of rice is lost annually owing to the damage caused by biotic factors, of which nearly 21% is attributed to the attack of insect pests (Brookes and Barfoot 2003). More than 100 species of insects are known as pests of this crop, out of which 20 are of major economic significance (Heong and Hardy 2009). The insect-pest damage in basmati rice especially from stem borers, yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae); white stem borer, *Scirpophaga innotata* (Walker) (Lepidoptera: Pyralidae) and pink stem borer, *Sesamia inferens* (Walker) (Lepidoptera: Noctuidae) is one of the major causes of poor productivity of rice in India (Muralidharan and Pasalu 2006). Rice plant is most prone to its infestation at the tillering and flowering stages. YSB has been reported to inflict 18–40% damage

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to the rice crop in different parts of India (Anonymous 2006). Rubia and Penning (1990) observed almost proportional yield reduction due to simulated whitehead damage. The rice leaf folder (RLF) *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera: Pyralidae) reported to cause the damage ranged from 18–58% depending on the stage of the crop (Ramasamy and Jaliecksono 1996). The losses caused by this pest to grain and straw yield were 63 and 76%, respectively (Patel et al. 1986). The infested rice plants were also predisposed to bacterial and fungal infection, sheath rot and difficulty in heading (Xiao 1990). Among sucking pests of rice, brown planthopper (BPH), *Nilaparvata lugens* (Stål) (Homoptera: Delphacidae) and whitebacked planthopper (WBPH), *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae) are important. Severe attack causes, "hopper burn" symptoms in the field (Horgan 2009). BPH has become an important pest of rice in North India (Krishnaiah and Lakshmi 2012). This pest has high degree of propensity for developing multiple insecticide resistance (Matsumura and Morimura 2010).

To achieve adequate and stable supplies of rice, it is important to study the damage and yield loss by rice pests and options for starting the appropriate pest management practices. Keeping this objective in mind, present studies were conducted to relate the different degree of pest incidence with yield loss under the complex of different insect-pest species in basmati rice.

Materials and Methods

Field experiments were conducted during wet seasons of 2011 and 2012 at Rice Research Area of Department of Plant Breeding and Genetics, Punjab Agricultural University (PAU), Ludhiana, Punjab positioned at 30º 54' North and 75º 48' East to study the effect of different pest damage levels at different crop stages on grain yield.

Raising of nursery bed

The basmati rice variety Punjab Basmati 2 was sown in well-prepared seed beds on 10 and 15 June during 2011 and 2012, respectively. The nursery was raised as per agronomic practices of PAU Package of Practices for *kharif* (summer) crops under unsprayed conditions (Anonymous 2013).

Transplanting

The 30 days old seedlings were transplanted at a rate of 2 seedlings hill^{-1} on 10 and 15 July during 2011 and 2012, respectively. Urea was applied at a rate of 0.09 tonne ha^{-1} in two equal splits one after 3 and other at 6 weeks after transplanting. This experiment was conducted under natural infestation and augmented infestation conditions under unsprayed conditions. Two meter alleys were left in between treatment plots of 25 m^2.

Treatments

The experiment was conducted with five treatments in a randomized block design with four replications each. The five treatments (T_1 to T_5) where, T_1 = Application of Confidor (imidacloprid 200 SL at a rate of 20 g a.i. ha^{-1}) at 25 and 40 days after transplanting (DAT) in vegetative stage; T_2 = Application of Padan (cartap hydrochloride 4 G at a rate of 1.00 kg a.i. ha^{-1}) (2011)/Thimet (phorate 10 G at a rate of 1.25 kg a.i. ha^{-1}) (2012) at 25 and 40 DAT; T_3 = Application of 200 kg urea ha^{-1} was done in two splits, one after 3 and other at 6 weeks after transplanting; T_4 = Augmentation by egg mass releases [pinning 1 egg mass of YSB per sq. m at vegetative stage (25 DAT) and booting stage]; T_5 = Untreated control.

Visual observations

The observations were recorded on 10 hills selected at random from each treatment replications. Stem borer damage was recorded at both vegetative (50 and 65 DAT) stage as deadheart damage and at reproductive stage as white ear damage. Larvae after emerging from egg mass enter the tiller to feed inside and damage the central whorl of plant which does not unfold, turn brownish and dries out. These affected tillers do not grow further, emit foul smell and can be easily pulled out called "dead heart". At reproductive stage, the damage is characterized by whitish, erect and chaffy panicles which are called, "white ears". At vegetative stage from each hill total tillers and dead hearts were recorded, while at reproductive stage panicle bearing tillers and white ears were recorded. The per cent dead heart and white ear damage was worked out based on this data. Similarly, leaf folder damage was recorded 50 and 65 DAT based on total leaves and number of damaged leaves (at least one-third of its area showing symptoms) on a hill. For counting the number of individuals of BPH and WBPH, each hill was tilted and tapped 2 or 3 times at the base and the planthoppers collected on water was counted. Grain yield at 14% water content on plot basis was recorded after harvesting/threshing the crop manually and expressed as q ha^{-1}.

Data analysis

The data pertaining to damage by leaf folder, stem borer and population counts of planthoppers were statistically analyzed with analysis of variance (ANOVA) using Minitab 15 software. The different treatment means were separated by least significant difference test (LSD) at $p = 0.05$ (Gomez and Gomez 1984). All the data were checked for normality before subjecting to analysis. Data lacking normality were transformed using arcsine and square root transformations. Multiple stepwise regression was performed by using forward selection method. In this procedure we start with no variable in the equation. The variables were checked one at a time and the most significant is added to the model at each stage. The procedure is terminated when all the independent variables having significant effect on the dependent variable Y is included in the regression equation.

Results

Wet season 2011

Stem borer damage

The dead heart (DH) damage caused by stem borer at vegetative stage varied significantly among the treatments both at 50 ($F = 121.93$; $df = 4, 12$; $p < 0.001$) and 65 ($F = 91.51$;

$df = 4, 12$; $p < 0.001$) DAT (Table 1). It varied from 1.04 to 10.64% among different treatments at 50 DAT. Least DH damage was observed in cartap hydrochloride treated plots (1.04%), while it significantly more in plots, where augmentation with egg masses was done (10.64%). Similar observations were recorded at 65 DAT (Table 1). Likewise trend in white ear (WE) damage ($F = 66.53$; $df = 4, 12$; $p < 0.001$) was observed among treatments (Table 1).

Leaf folder damage

The damaged leaves by leaf folder varied significantly ($F = 78.44$; $df = 4, 12$; $p < 0.001$) among different treatments (2.04–18.83%) at 50 DAT (Table 1). In cartap hydrochloride treated plots the damage was significantly lower (2.04%) than the plots where higher dose of nitrogen was applied (18.83%). The data recorded at 65 DAT also showed similar trend. Significantly less leaf damage ($F = 35.79$; $df = 4, 12$; $p < 0.001$) was recorded in insecticide treated plots (4.59%) than other treatments (Table 1).

Planthopper populations

The planthopper population varied significantly among the treatments both at 50 ($F = 63.57$; $df = 4, 12$; $p < 0.001$) and 65 ($F = 44.54$; $df = 4, 12$; $p < 0.001$) DAT (Table 1). Significantly lower population (3.59/hill) was noticed in imidacloprid treated plots than in the untreated control (9.93/hill) plots.

Yield

Yield varied significantly among different treatments ($F = 182.65$; $df = 4, 12$; $p < 0.001$) (Fig. 1). Highest yield of 39.74 q ha^{-1} was recorded in cartap hydrochloride treated plots followed by imidacloprid treated plots (30.94 q ha^{-1}). A yield of 27.01 q ha^{-1} was observed in plots, where no protection was done. However, significantly low yield was recorded in plots (24.15 q ha^{-1}), where augmented release of egg masses was done, it was on a par with plots (24.92 q ha^{-1}), where, higher nitrogen dose was applied (Fig.1).

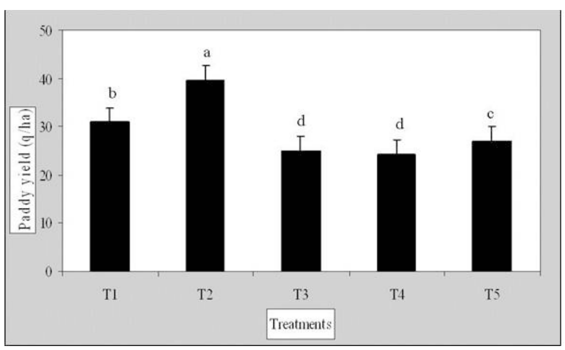

Figure 1. Grain yield in different treatments during wet season 2011. Bars sharing common letter(s) in each histogram do not differ statistically as per LSD test; 2011 ($F = 182.65$; $df = 4, 12$; $p < 0.001$); T_1 – Application of imidacloprid; T_2 – Application of cartap hydrochloride; T_3 – Application of higher dose of nitrogen; T_4 – Augmentation by releases of YSB egg mass; T_5 – Untreated control

Table 1. Incidence of insect-pests in different treatment during wet season 2011

T. No.	Treatments	Stem borer incidence (%)			Leaf folder damaged leaves (%)		Plant hoppers (no./hill)	
		Vegetative stage (dead hearts)		Maturity stage (white ears)				
		50 DAT	65 DAT	Preharvest	50 DAT	65 DAT	50 DAT	65 DAT
T_1	Application of imidacloprid 20 g a.i. ha^{-1} at 25 and 40 DAT	3.39 ± 0.27^{b}	5.33 ± 0.79^{b}	4.09 ± 0.32^{b}	13.33 ± 1.07^{bc}	12.55 ± 1.86^{b}	2.77 ± 0.32^{a}	3.84 ± 0.26^{a}
T_2	Application of cartap hydrochloride 4 G 1 kg a.i. ha^{-1} at 25 and 40 DAT	1.04 ± 0.01^{a}	1.22 ± 0.47^{a}	1.96 ± 0.30^{a}	2.04 ± 0.25^{a}	4.59 ± 0.29^{a}	3.59 ± 0.25^{a}	3.91 ± 0.39^{a}
T_3	Application of 200 kg µrea ha^{-1}	6.49 ± 0.33^{d}	6.46 ± 0.71^{b}	6.46 ± 0.35^{c}	18.83 ± 0.84^{d}	20.87 ± 0.85^{d}	14.83 ± 1.48^{c}	19.45 ± 1.00^{c}
T_4	Augmentation by releases of egg mass at 25 DAT and panicle initiation/ booting stage	10.64 ± 0.70^{e}	11.10 ± 1.82^{c}	10.62 ± 0.53^{d}	12.92 ± 1.21^{b}	18.03 ± 1.84^{cd}	9.07 ± 0.56^{b}	7.20 ± 1.03^{b}
T_5	No protection in nursery and main field (untreated control)	4.65 ± 0.37^{c}	5.56 ± 0.47^{b}	5.83 ± 0.30^{c}	16.20 ± 1.07^{cd}	16.24 ± 0.26^{c}	9.93 ± 0.32^{b}	8.13 ± 1.16^{b}
SEM±		0.44	0.49	0.50	0.78	0.97	0.11	0.14
p value at $df_{4, 12}$		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Note: Values within a column followed by same superscript letters did not differ significantly as per LSD test

Wet season 2012

Stem borer damage

The DH damage varied significantly (1.17–9.12%) among different treatments (F = 60.07; df = 4, 12; p < 0.001) at 50 DAT (Table 2). The damage was significantly low (1.17%) in phorate application plots. Whereas, intermediate damage was observed in imidacloprid treated and untreated control plots (Table 2). Next higher DH damage was observed in higher nitrogen dose treated plots (5.83%) and where augmented release of egg masses was done. Similar trend was observed at 65 DAT among different treatments (F = 76.71; df = 4, 12; p < 0.001) (Table 2). The WE damage recorded one week before harvesting varied significantly among treatments (F = 122.25; df = 4, 12; p < 0.001) (Table 2). The damage was significantly low in phorate (2.19%) treated plots. Highest WE damage (13.78%) was observed in the augmentative releases of egg masses plots.

Leaf folder damage

The per cent of leaf folder damaged leaves varied significantly among the treatments at 50 (F = 5.99; df = 4, 12; p = 0.007) DAT (Table 2). The damaged leaves were significantly more (16.47%) in the higher nitrogen dose application plots. In all other treatments damaged leaves varied from 12.40–13.05% which were on a par with each other (Table 2). Similar, trend was observed for leaf folder damage at 65 DAT (F = 3.96; df = 4, 12; p = 0.029) (Table 2).

Planthopper population

The planthopper population varied significantly among the treatments both at 50 (F = 51.36; df = 4, 12; p < 0.001) and 65 (F = 132.36; df = 4, 12; p < 0.001) DAT (Table 2). Significantly low population (0.40–1.85/hill) was recorded in imidacloprid treated plots, while, significantly more population (2.33–6.70/hill) was observed in higher nitrogen application plots on both the observation dates (Table 2).

Yield

The paddy yield varied significantly among the treatments (F = 21.08; df = 4, 12; p < 0.001), it was highest to lowest in the order of phorate, imidacloprid, untreated control, application of higher dose of nitrogen and plots with augmented egg mass releases (Fig. 2).

Correlation and regression analysis of yield vs pest incidence

Wet season 2011

The data on incidence of stem borer, leaf folder and planthopper population recorded at different crop growth stages in different treatments were correlated with the grain yield (Table 3). DH damage both at 50 (r = –0.834, p < 0.001) and 65 (r = –0.848, p < 0.001) DAT as well as WE at maturity (r = –0.822, p < 0.001) had a negative and significant impact on the grain yield. Likewise, leaf folder damaged leaves also showed a negative and significant impact both at 50 (r = –0.863, p < 0.001) and 65 (r = –0.900, p < 0.001) DAT.

Table 2. Incidence of rice insect-pests in different treatment during wet season 2012

T. No.	Treatments	Stem borer incidence (%) – Vegetative stage (dead hearts)		Stem borer incidence (%) – Maturity stage (white ears)	Leaf folder damaged leaves (%)		Plant hoppers (no./hill)	
		50 DAT	65 DAT	Preharvest	50 DAT	65 DAT	50 DAT	65 DAT
T_1	Application of imidacloprid 20 g a.i. ha at 25 and 40 DAT	4.38±0.38[b]	5.65±0.47[b]	9.01±0.56[b]	12.43±0.64[a]	14.40±0.93[a]	0.40±0.04[a]	1.85±0.05[a]
T_2	Application of phorate 10 G 1.25 kg a.i. ha^{-1} at 25 and 40 DAT	1.17±0.24[a]	1.88±0.36[a]	2.19±0.31[a]	13.05±0.92[a]	15.54±1.09[a]	1.23±0.14[b]	4.73±0.13[b]
T_3	Application of 200 kg urea ha^{-1}	5.83±0.45[c]	6.12±0.14[b]	10.02±0.52[b]	16.47±0.32[b]	18.26±0.95[b]	2.33±0.12[c]	6.70±0.24[c]
T_4	Augmentation by releases of egg mass at 25 DAT and panicle initiation/ booting stage	9.12±0.45[d]	10.11±0.30[c]	13.78±0.67[c]	12.40±0.55[a]	14.50±0.64[a]	1.23±0.11[b]	4.70±0.25[b]
T_5	No protection in nursery and main field (untreated control)	4.48±0.40[b]	5.58±0.52[b]	9.19±0.21[b]	12.60±0.47[a]	14.51±0.55[a]	1.28±0.15[b]	4.78±0.17[b]
SEM±		0.44	0.53	0.44	0.45	0.58	0.64	0.03
p value at $df_{4,12}$		<0.001	<0.001	<0.001	<0.001	0.007	0.029	<0.001

DAT – Days after transplanting; Data were transformed before analysis and original values are given; Figures within a column followed by same superscript letters did not differ significantly as per LSD test

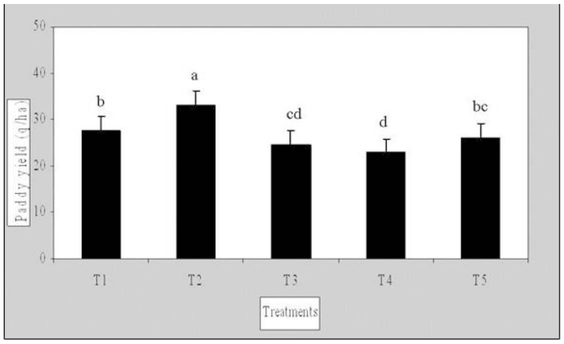

Figure 2. Grain yield in different treatments during wet season 2012. Bars sharing common letter(s) in each histogram do not differ statistically as per LSD test (F = 21.08; df = 4, 12; p < 0.001); T_1 – Application of imidacloprid; T_2 – Application of phorate; T_3 – Application of higher dose of nitrogen; T_4 – Augmentation by releases of YSB egg mass; T_5 – Untreated control

Table 3. Correlation analysis of yield vs damage levels/numbers at different crop growth stages during wet seasons 2011 and 2012

Insect damage/numbers	Correlation coefficient *(r)*	
	2011	2012
Dead hearts at 50 DAT	–0.834**	–0.816**
Dead hearts at 65 DAT	–0.848**	–0.885**
White ears at pre-harvest	–0.822**	–0.912**
Damaged leaves at 50 DAT	–0.863**	–0.155
Damaged leaves at 65 DAT	–0.900**	$–0.777^{\$}$
Population at 50 DAT	–0.702**	–0.259
Population at 65 DAT	–0.553**	–0.235

** significant at 1%; $^{\$}$ significant at 10%

The correlation between paddy yield and planthopper population was also significantly negative at 50 (r = –0.702, p < 0.001) and 65 (r = –0.553, p < 0.001) DAT. Further analysis of variance of regression analysis of yield Vs damage levels at different crop growth stages during wet season 2011 revealed that a significant linear relationship exist (Table 4). The stepwise multiple regression studies revealed that leaf folder damage at 50 and 65 DAT and dead heart incidence at 50 DAT had a negative and significant impact on grain yield which in-concert accounted for 97.2 per cent variation in yield during 2011 (F = 76.17, n = 20, p < 0.0001) (Table 5).

Wet season 2012

The correlation between grain yield and stem borer damage in terms of DH at 50 (r = –0.816, p < 0.001) and 65 DAT (r = –0.885, p < 0.001) and WE at maturity (r = –0.912, p < 0.001) was found to be negative and significant. The correlation between leaf folder damage and yield was negative and non-significant at 50 DAT (r = –0.155, p = 0.514), while,

Table 4. Analysis of variance (ANOVA) w.r.t. regression analysis of yield vs damage levels/numbers at different crop growth stages during wet seasons 2011 and 2012

Year	Source of variation	*df*	SS	MS	*F* value	*P* value
2011	Regression	7	656.595	93.799	76.17	0.0001
	Residual error	12	14.778	1.231		
	Total	19	671.373			
2012	Regression	7	262.464	37.495	16.74	0.0001
	Residual error	12	26.883	2.240		
	Total	19	289.347			

Table 5. Stepwise regression analysis for yield and insect-pests damage at different crop growth stages during wet seasons 2011 and 2012

Year	Regression equations	R^2
2011	$Y = 42.79 – 0.379^{**}LF_1 – 0.265^{**}LF_2 – 0.810^{**} DH_2$	0.972
2012	$Y = 36.88 – 0.345^{\$}LF_2 – 0.742^{\$}DH_2 – 0.894^{**}WE$	0.881

** significant at 1%; $^{\$}$ significant at 10%; DH_2 – dead hearts at 65 DAT; WE – white ears at preharvest; LF_1 – leaf folder damage at 50 DAT; LF_2 – leaf folder damage at 65 DAT

at 65 DAT (r = –0.777, p = 0.056) it was significant (Table 3). The correlation between planthopper population and yield was negative and non-significant. The analysis of variance of regression analysis of yield Vs damage levels during 2012 at different crop growth stages revealed the same pattern as in the previous year (Table 4). The stepwise multiple regression analysis revealed that white ear damage at preharvest, leaf folder and DH damage at 65 DAT accounted for variability in the grain yield with R^2 value of 0.88 (F = 16.74, n = 20, p < 0.0001) (Table 5).

Discussion

A large proportion of the potential yield of the rice plant is lost to insect pests which generally causes 21% yield loss (Brookes and Barfoot 2003). In our present study results revealed that one per cent increase in DH damage by stem borer in 2011 at 65 DAT caused 0.81% decrease in the yield. Similarly one per cent increase in leaf folder damage at 50 and 65 DAT ultimately caused 0.37 and 0.26% decrease in yield, respectively (Table 5). The 97.2% of the variation in yield loss was explained by the above-stated factors. More or less similar trend was also observed in 2012. However during 2012 crop season, WE damage has significantly contributed for yield loss whereas, it was non-significant during 2011. This is due to the fact that WE damage in various treatments during the year 2012 has varied from 11.73 to 120.29% more than the previous year damage.

The increase in nitrogen fertilization leads to higher injury levels, increased larval survival rate, leaf area consumed, pupal weight, moth longevity, fecundity and preference of oviposition (Muralidharan and Pasalu 2006; Sarao and Mahal 2008a). These studies were in corroboration to our findings where we submitted that the stem borer damage was more in higher nitrogen dose plots. Ramzan et al. (2007) indicated that stem borer incidence increases with the increase of nitrogen fertilizer dose. Likewise, Chakraborty (2011), reported that the incidence of DH and WE was 176% and 207% higher than the control field when it was fertilized by 140 kg N ha^{-1}. However, he observed insignificant variation of grain amylose and protein content, total phenol and ortho-dihydroxy phenol amount under different fertilizer treatments, while the plant moisture content increased with the increase in N fertilizer dose. Planthopper population responded positively to nitrogen fertilizer (Lu et al. 2004; Lu et al. 2005), and it act as a major cause of BPH outbreak (Bottrell and Schoenly 2012).

In case of leaf folder our studies reported that RLF damage increased in higher N dose application plots. These studies are in consent with other scientists work. Pandey (2003) opined that the luxuriant growth of the crop due to higher N application attracts more RLF for shelter and oviposition. Similarly, Padmavathi et al. (2013) reported that RLF damage resulted in 57% reduction in chlorophyll. Larval density of more than 3 larvae $hill^{-1}$ at maximum tillering stage resulted up to 20% unfilled grains and 28–57% reduction in PS II activity. In the same line, Ge et al. (2013) submitted that development duration for RLF larvae and number of eggs laid increased but development duration of pupae, pupation rate or adult emergence did not influence with increasing nitrogen level. While, the development duration for adults decreased with increased fertilizer level. Likewise, Kulagod et al. (2011) observed that the higher dose of nitrogen increases DH (6.57%), WE (14.57%), RLF damaged leaves (13.79%) and green leafhoppers (15.52/hill) than other fertilizer doses and combinations.

The efficacy of insecticides for the management of stem borer, leaf folder and planthopper population in the present study at different a.i.s confirms to the findings of Karthikeyan et al. (2008), who submitted that leaf folder population was effectively controlled by the phosphamidon granules. Likewise, Singh et al. (2009) also informed the effectiveness of fipronil, chlorpyriphos and cartap hydrochloride granules against stem borers. Similar results were also reported by other scientists (Sarao and Mahal 2008b; Dhawan et al. 2010; Sarao et al. 2012; Kumar et al. 2013) regarding the efficacy of insecticides in managing the rice insect pests. Selvaraj et al. (2012) determined single species (stem borers, leaf folder and planthoppers) as well as multi-species economic injury level for rice insect pests. The single species injury level of leaf folder and stem borer ranged from 2.9–6.4% folded leaves and 1.9–3.0% WE, respectively. The joint incidence combinations showed that although each pest was below economic injury level, the combination of both pests inflicted economic damage.

During both the years, correlation between grain yield and pest incidence, namely dead heart and leaf folder damage at 50 and 65 DAT was negative. Similar trend was followed in case of white ears at maturity. 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.

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