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Bio-efficacy of insecticides against yellow stem borer (*Scirpophaga incertulas* Walker) in rice (*O. sativa* L.) ecosystem of Varanasi region

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Abstract
An experimental trial was conducted during *Kharif* season of 2016-17 and 2017-18 at the Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi to evaluate the bio-efficacy of newer insecticides against yellow stem borer. The stem borer infestation varied from 3.85 to 7.85 per cent. Among the various insecticidal field evaluations against yellow stem borer, flubendiamide 20% WG @ 25 g a.i./ha was found best effective treatment against yellow stem borer recording overall mean per cent dead heart (DH) of 3.91 followed by Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha (4.23%), Lamda Cyhalothrin 5% EC @ 20 g a.i./ha (4.94%), Fipronil 5 % SC @ 50 g a../ha (5.24%) and Thiamethoxam 25% WG @ 25 g a.i./ha (5.73%) respectively during 2016-17. During 2017-18 again Flubendiamide 20% WG @ 25 g a.i./ha was found best effective recording overall mean per cent dead heart (DH) of 4.28 followed by Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha (4.93%), Fipronil 5 % SC @ 50 g a../ha (5.42%), Lamda Cyhalothrin 5% EC @ 20 g a.i./ha (5.55%) and Thiamethoxam 25% WG @ 25 g a.i./ha (5.93%), respectively. The highest main grain yield 5.10 t/ha during 2016-17 and 4.77 t/ha during 2017-18 was recorded from the plots treated with Flubendiamide 20% WG @ 25 g a.i./ha. While the lowest mean grain yield 3.38 and 3.00 t/ha was harvested from the plots treated with Neem (Azadiractin 0.15 % EC) @ 4 ml/liter during *Kharif* 2016-17 and 2017-18, respectively.

Keywords: Bio-efficacy, rice pest, yellow stem borer, flubendiamide

Introduction
Rice (*Oryza sativa* L.) is an important staple food crop for more than half of the world population that accounts for more than 50 per cent of the daily calorie intake (Khush, 2005) [8]. It supplies 52.76 per cent of total calories consumed by the population of South Asian countries such countries as Bangladesh, Cambodia, Indonesia, Myanmar and Vietnam and 30 per cent in India and China (Maclean *et al.*, 2002) [9]. It provides 27 per cent of nutritional energy and 20 per cent of proteins in the developing countries. This crop is cultivated in 114 countries which is the primary source of income and employment for more than 100 million households in Asia (FAO, 2004) [7]. It is also used as a stable food for more than two billion people in developing countries of Asia. About 162.75 million hectares were devoted to rice production worldwide producing 491.14 million tonnes with average productivity of 4.51 t/ha (Anonymous, 2018). India ranks second in rice production globally and occupies an area of 44.00 million hectares producing 111.00 million tonnes with the productivity of 3.78 t/ha (Anonymous, 2016). In Uttar Pradesh, 4.55 million hectares was occupied by rice in India producing 12.51 million tonnes with a productivity of 2.13 t/ha (Anonymous, 2016). Rice is menaced by several biotic and abiotic stresses. While in terms of insects more than more than 100 species of insects attacks on rice crop out of which twenty causes economic damage. In India, the yellow stem borer *Scirpophaga incertulas* (Walker) solely causes 2 to 20 per cent damage and 1.3 per cent loss observed with increase in every per cent of stem borer damage (Satpathi *et al.*, 2012) [11] and also caused 1 to 19 per cent yield loss in early planted rice crops and 38 to 80 per cent in late planted rice (Catinding and Heong, 2003) [3]. It is the most destructive insect pests of the rice crop and responsible for an annual yield loss of 10 to 15 per cent with local catastrophic outbreaks causing up to 60 per cent damage (Daryaei, 2005) [4]. It attacks the crop right from seedling stage till harvest and causes complete loss of affected tillers (Salim & Masih, 1987) [10]. Chemical control is still considered as the first line of defense in rice pest management. Application of various insecticidal formulations gives effective control of rice pests (Dash *et al.*, 1996) [5]. Hence, attempts were made to formulate the management practice of rice yellow stem borer using both granular and liquid formulations of such new molecules which may be of immense value for integration into the integrated pest management system.

Materials and Methods

The field experiments have been conducted in a randomized block design with three replications during Kharif 2016-17 and 2017-18. The plot size was 5×4 m^2 with 1 m replication border and 0.5 m treatment border between the plots. The experimental plots have been separated by raising bund of about 0.5 m height all around each plot. Submergence rice variety used in the present study was Swarna sub-1 of 145 to 150 days duration. Twenty five days old seedlings were transplanted at a spacing of 20×15 cm during second and last week of July for both the seasons of 2016 and 2017. Agronomic practices were adopted during the course of study. The treatments *viz.,* Carbofuran 3% G @ 750 g a.i./ha, Thiamethoxam 25% WG @ 25 g a.i./ha, Fipronil 5 % SC @ 50 g a.i./ha, Pymetrozine 50% WG @ 7.5 g a.i./ha, Lamda-Cyhalothrin 5% EC @ 20 g a.i./ha, Neem (Azadirachtin) 0.15 % EC @ 4 ml/litre, Flubendiamide 20% WG @ 25 g a.i./ha, Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha, Acetamiprid 20 % SP @ 35 g a.i./ha, Dinotefuran 20% SG @ 40 g a.i./ha and untreated control. The observations were recorded from randomly selected 10 hills in each treatment plot. Observations were taken one day prior to insecticidal application and on 1^{st}, 3^{rd}, 7^{th} and 14^{th} days after application. The per cent incidence (Dead hearts/White ears) was calculated as follows:

$$\text{Per cent Incidence} = \frac{\text{Number of dead hearts/white ears}}{\text{Total number of tillers/panicles}} \times 100$$

Yield record

Plot wise Harvesting was done on November 11^{th}, 2016 and November 27^{th}, 2017. Grain yield and threshing observations were taken after one week harvest. The yield per plot subjected to respective treatments was extrapolated to quintals per hectare. The yield data in each treatment was recorded separately and subjected to statistical analysis to test the significance of mean yield variation in different treatments. The per cent increase in yield over control in various treatments was calculated by using the following formula.

$$\text{\% increase of yield in treatment over control} = \frac{\text{Yield in treatment - Yield in control}}{\text{Yield in control}} \times 100$$

Result and Discussion

The overall mean data of two sprays on the incidence of *S. incertulas* showed in Table 1 and 2 and Figures 1 and 2 revealed that the mean dead heart (DH) incidence significantly differed among the treatments throughout the experimental periods of *Kharif* season of 2016-17 2017-18, respectively. The untreated control plot recorded 10.21 per cent (2016) and 12.14 per cent (2017). Treatment with Flubendiamide 20% WG @ 25 g a.i./ha was found to be best effective with lowest DH incidence of 3.91% followed by Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha, Lamda-Cyhalothrin 5% EC @ 20 g a.i./ha, Fipronil 5 % SC @ 50 g a.i./ha, Thiamethoxam 25% WG @ 25 g a.i./ha, Dinotefuran 20% SG @ 40 g a.i./ha, Acetamiprid 20 SP @ 35 g a.i./ha, Pymetrozine 50% WG @ 7.5 g a.i./ha, Carbofuran 3% G @ 75 g a.i./ha and Neem (Azadirachtin) 0.15 % EC @ 4 ml/litre with overall mean of 4.23, 4.94, 5.24, 5.73, 6.02, 6.14, 6.38, 7.01, 7.35 per cent as against 10.21% in the untreated control during *Kharif* 2016, respectively.

Table 1: Effect of insecticidal treatments against S. incertulas in rice ecosystem during *Kharif* 2016-17.

Treatments	Dose (g a.i./ha)	Mean per cent DH per 10 hills												
		First spray						Second spray						Overall mean
		1 DBS	1 DAS	3 DAS	7 DAS	14 DAS	Mean	1 DBS	1 DAS	3 DAS	7 DAS	14 DAS	Mean	
Acetamiprid 20 SP	35	6.32* (14.55)**	6.17 (14.38)	5.52 (13.57)	5.71 (13.82)	6.79 (15.10)	6.05 (14.24)	7.00 (15.33)	6.43 (14.69)	5.28 (13.27)	5.85 (13.98)	7.31 (15.69)	6.22 (14.41)	6.14 (14.33)
Carbofuran 3% G	750	7.12 (15.47)	6.61 (14.90)	6.47 (14.72)	6.93 (15.26)	7.60 (16.00)	6.90 (15.22)	7.51 (15.90)	7.10 (15.28)	5.92 (14.06)	7.39 (15.77)	8.07 (16.50)	7.12 (15.44)	7.01 (15.33)
Chlorantraniliprole 18.5 % SC	30	5.31 (13.32)	4.64 (12.44)	3.45 (10.70)	4.10 (11.68)	4.95 (12.85)	4.31 (11.96)	5.21 (13.18)	4.95 (12.84)	3.26 (10.41)	4.06 (11.58)	4.36 (12.04)	4.15 (11.72)	4.23 (11.84)
Dinotefuran 20% SG	40	6.52 (14.79)	6.34 (14.58)	4.94 (12.82)	5.65 (13.75)	6.63 (14.92)	5.89 (14.02)	6.40 (14.64)	6.28 (14.51)	5.00 (12.90)	6.10 (14.29)	7.22 (15.59)	6.15 (14.32)	6.02 (14.17)
Fipronil 5 % SC	50	6.80 (15.11)	5.58 (13.66)	4.32 (12.00)	4.70 (12.52)	5.93 (14.10)	5.13 (13.07)	5.91 (14.06)	5.67 (13.76)	4.42 (12.13)	4.89 (12.76)	6.40 (14.65)	5.34 (13.32)	5.24 (13.20)
Flubendiamide 20% WG	25	5.09 (13.03)	4.32 (12.00)	3.17 (10.25)	3.77 (11.19)	4.63 (12.43)	3.97 (11.46)	5.64 (13.73)	4.73 (12.55)	3.11 (10.15)	3.64 (10.99)	3.95 (11.45)	3.85 (11.28)	3.91 (11.37)
Lamda Cyhalothrin 5% EC	20	6.04 (14.22)	5.11 (13.07)	3.87 (11.35)	4.22 (11.85)	5.37 (13.37)	4.64 (11.91)	5.40 (13.43)	5.18 (13.14)	3.96 (11.46)	5.73 (13.85)	5.85 (14.00)	5.18 (13.11)	4.94 (12.51)
Neem (Azadiractin 0.15 % EC)	4 ml/lit.	7.41 (15.79)	7.08 (15.43)	6.64 (14.92)	7.35 (15.73)	8.26 (16.70)	7.33 (15.69)	8.10 (16.52)	7.52 (15.92)	6.45 (14.70)	6.79 (15.10)	8.70 (17.15)	7.36 (15.72)	7.35 (15.71)
Pymetrozine 50% WG	7.5	6.49 (14.75)	6.30 (14.54)	5.91 (14.06)	6.33 (14.57)	6.95 (15.28)	6.37 (14.61)	7.35 (15.72)	6.53 (14.81)	5.37 (13.40)	6.18 (14.40)	7.47 (15.85)	6.39 (14.61)	6.38 (14.61)
Thiamethoxam 25% WG	25	6.30 (14.54)	6.08 (14.27)	4.78 (12.63)	5.21 (13.20)	6.53 (14.80)	5.65 (13.72)	6.12 (14.31)	6.17 (14.38)	4.89 (12.77)	5.21 (13.18)	6.96 (15.30)	5.81 (13.91)	5.73 (13.82)
Control	Water spray	6.59 (14.86)	7.69 (16.09)	7.82 (16.25)	8.67 (17.12)	9.70 (18.15)	8.47 (16.90)	9.90 (18.32)	10.40 (18.80)	11.31 (19.64)	12.48 (20.69)	13.64 (21.66)	11.95 (20.20)	10.21 (18.55)
C.D. (0.05%)	--	--	0.57	0.60	0.63	0.67	--	--	0.60	0.63	0.65	0.61	--	--
SE (m)±	--	--	0.20	0.20	0.21	0.22	--	--	0.20	0.21	0.21	0.20	--	--

*Mean of three replications, **Figures in the parenthesis are Angular transformed values, DBS- Days before spray DAS- Days after spray

Table 2: Effect of insecticidal treatments against *S. incertulas* in rice ecosystem during *Kharif* 2017-18.

Treatments	Dose (g a.i./ha)	Mean per cent DH per 10 hills														
		First spray						Second spray						Overall mean	Grain yield (t/ha)	
		1 DBS	1 DAS	3 DAS	7 DAS	14 DAS	Mean	1 DBS	1 DAS	3 DAS	7 DAS	14 DAS	Mean		2016	2017
Acetamiprid 20 SP	35	7.35* (15.73)**	6.80 (15.11)	5.78 (13.90)	6.25 (14.47)	6.79 (15.09)	6.40 (14.64)	6.88 (15.19)	5.22 (13.21)	4.80 (12.65)	7.06 (15.40)	7.77 (16.17)	6.21 (14.35)	6.31 (14.50)	4.20	3.96
Carbofuran 3% G	750	7.92 (16.33)	7.60 (16.00)	6.53 (14.79)	7.23 (15.59)	8.10 (16.52)	7.36 (15.72)	8.41 (16.85)	6.16 (14.37)	5.65 (13.74)	8.24 (16.67)	8.81 (17.25)	7.21 (15.50)	7.29 (15.61)	3.62	3.33
Chlorantraniliprole 18.5 % SC	30	5.91 (14.06)	5.00 (12.90)	3.85 (11.30)	4.61 (12.39)	4.68 (12.48)	5.15 (12.26)	5.60 (13.68)	4.61 (12.39)	3.57 (10.87)	5.06 (12.99)	5.59 (13.68)	4.71 (12.48)	4.93 (12.37)	4.80	4.50
Dinotefuran 20% SG	40	7.51 (15.91)	6.90 (15.23)	5.39 (13.40)	5.75 (13.86)	5.63 (13.73)	5.92 (14.05)	6.52 (14.78)	5.69 (13.80)	5.18 (13.14)	7.63 (16.02)	7.90 (16.31)	6.60 (14.82)	6.26 (14.44)	4.00	3.77
Fipronil 5 % SC	50	6.21 (14.42)	6.06 (14.25)	4.86 (12.73)	5.01 (12.90)	6.05 (14.24)	5.49 (13.53)	5.18 (14.03)	5.17 (13.14)	4.36 (12.05)	5.56 (13.63)	6.27 (14.49)	5.34 (13.33)	5.42 (13.43)	3.77	3.52
Flubendiamide 20% WG	25	5.19 (13.16)	4.78 (12.61)	3.50 (10.77)	4.21 (11.83)	4.51 (12.25)	4.22 (11.86)	5.40 (13.42)	4.33 (12.00)	3.20 (10.29)	4.65 (12.44)	5.15 (13.11)	4.33 (11.96)	4.28 (11.91)	5.10	4.77
Lamda Cyhalothrin 5% EC	20	5.65 (13.74)	5.51 (13.58)	3.34 (12.01)	4.76 (12.59)	5.84 (13.98)	5.86 (13.04)	5.81 (13.94)	4.74 (12.57)	3.96 (11.46)	6.08 (14.28)	6.14 (14.33)	5.23 (13.16)	5.55 (13.10)	3.45	3.13
Neem (Azadiractin 0.15 % EC)	4 ml/lit.	8.21 (16.65)	7.98 (16.40)	6.96 (15.28)	7.75 (16.15)	8.70 (17.14)	7.85 (16.27)	6.70 (15.00)	5.81 (13.95)	5.85 (13.99)	8.74 (17.18)	9.51 (17.95)	7.48 (15.77)	7.67 (16.02)	3.38	3.00
Pymetrozine 50% WG	7.5	7.41 (15.80)	7.00 (15.35)	5.93 (14.08)	6.61 (14.90)	7.40 (15.77)	6.77 (15.02)	7.58 (15.97)	5.60 (13.67)	5.19 (13.16)	6.61 (14.88)	7.75 (16.15)	6.28 (14.46)	6.53 (14.74)	4.60	4.36
Thiamethoxam 25% WG	25	6.84 (15.15)	6.61 (14.90)	5.46 (13.51)	5.59 (13.68)	6.18 (14.40)	5.96 (14.22)	6.35 (14.59)	5.55 (13.61)	5.05 (12.98)	6.20 (14.42)	6.79 (15.10)	5.90 (14.03)	5.93 (14.13)	4.37	4.13
Control	Water spray	7.51 (15.89)	8.28 (16.71)	9.45 (19.89)	10.40 (18.80)	11.51 (19.82)	10.10 (18.80)	11.71 (20.00)	12.48 (20.67)	13.55 (21.59)	14.41 (22.30)	16.26 (23.77)	14.17 (22.08)	12.14 (20.44)	3.05	2.69
C.D. (0.05%)	--		0.64	0.69	0.55	0.73	--		0.54	0.57	0.63	0.56	--	--	--	--
SE (m)±	--		0.21	0.23	0.18	0.24	--		0.18	0.19	0.21	0.19	--	--	--	--

*Mean of three replications, **Figures in the parenthesis are Angular transformed values, DBS- Days before spray DAS- Days after spray

Similar trend was observed in *Kharif* 2017, Treatment with Flubendiamide 20% WG @ 25 g a.i./ha was also found to be best effective with lowest DH incidence of 4.28% followed by Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha, Fipronil 5 % SC @ 50 g a.i./ha, Lamda- Cyhalothrin 5% EC @ 20 g a.i./ha, Thiamethoxam 25% WG @ 25 g a.i./ha, Dinotefuran 20% SG @ 40 g a.i./ha, Acetamiprid 20 SP @ 35 g a.i./ha, Pymetrozine 50% WG @ 7.5 g a.i./ha, Carbofuran 3% G @ 75 g a.i./ha and Neem (Azadirachtin) 0.15 % EC @ 4 ml/litre with overall mean of 4.93, 5.42, 5.55, 5.93, 6.26, 6.31, 6.53, 7.29 and 7.67 per cent respectively. Similar results were obtained by Devi and Singh (2016) [6] who reported that the Flubendiamide 39.35 SC @ 24 g a.i./ha was best effective followed by Fipronil 80 WG @ 40 g a.i./ha. The present findings are also agreement with the result of Sekh *et al.*, (2007) [12] who reported that Flubendiamide 480 SC @ 24 and 30 g a.i./ha provided effective control against yellow stem borer. However in the present study, the Flubendiamide 20% WG @ 25 g a.i./ha was most effective against yellow stem borer in low land rice crop. The order of efficacy of each treatment along with the test of significance is depicted below: Flubendiamide 20% WG < Chlorantraniliprole 18.5% SC < Lambda-cyhalothrin 5% EC < Fipronil 5% SC < Thiamethoxam 25% WG < Dinotefuran 20% SG < Acetamiprid 20% SP < Pymetrozine 50% WG < Carbofuran 3% G, Neem (Azadiractin 0.15% EC) <, respectively.

The insecticides employed to reduce insect damage helped to increase the yield of the crop by significantly eliminating the pest population. Hence, the impact of newer insecticides on rice yield was also studied. All the insecticidal treatments gave good results when compared with control. The plot treated with Flubendiamide 20% WG @ 25 gai./ha was observed to be best and gave yield of 5.10 and 4.77 t/ha followed by Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha with yield of 4.80 and 4.50 t/ha during *Kharif* 2016 and 2017. The remaining treatments of yield were at par with each other. Thus on the basis of present finding, it may be concluded that Flubendiamide 20% WG @ 25 g a.i./ha was found best effective against yellow stem borer followed by Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha. The yield was found to be high in Flubendiamide 20% WG @ 25 gai./ha followed by Chlorantraniliprole 18.5 % SC @ 30 gai./ha treated plot. However, all the insecticidal treatments recorded significantly lower dead hearts incidence than the untreated control.

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