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Bio-efficacy of chlorantraniliprole 0.4% GR against *Cnaphalocrocis medinalis* and *Scirpophaga incertulas* in rice (*Oryza sativa*)

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ABSTRACT

With the widespread adoption of high yielding rice (*Oryza sativa* L.) varieties and accompanying changes in the cultural practices, rice leaf folder [*Cnaphalocrocis medinalis* (Guenee)] and yellow stem borer [*Scirpophaga incertulas* (Walker)] has attained the status of major pests and influence the yield if proper timely management practices are not adopted. For effective management of these pests, identification of new molecules with novel mode of action, low toxicity to non-target insects and environmental safety is required for sustainable IPM. Chlorantraniliprole 0.4% GR (Ferterra 0.4% GR) is an anthranillic diamide insecticide in granular form for the control of lepidopterous pests in rice. A field experiment was conducted to evaluate the efficacy of chlorantraniliprole 0.4% GR (Ferterra 0.4% GR) against rice leaf folder and yellow stem borer during rainy (*kharif)* seasons 2017–19. The study revealed that broadcast application of chlorantraniliprole 0.4% GR @40 g a.i./ha at tillering stage was found effective and best insecticidal treatment in reducing rice leaf folder and yellow stem borer infestation with no phytotoxicity symptoms and increased grain yield. Chlorantraniliprole 0.4% GR @40 g a.i./ha was also safer to the natural enemies of the rice ecosystem. Post-harvest residual analysis of chlorantraniliprole 0.4% GR was found below the limit of quantification, i.e. 0.01 ppm in rice grains, soil, paddy straw and husk at recommended and double of the recommended dose indicating its safety to human, animals and environment.

Key words: Chlorantraniliprole, *Cnaphalocrocis medinalis*, Post-harvest residue, Rice, *Scirpophaga incertulas*

Rice (*Oryza sativa* L.) is a major staple food crop of about 65% of the world's population. It is a dominant cereal crop of India covering an area of 43.78 million hectares with production of 118.4 million tonnes and average yield of 27.05 q/ha (Anonymous 2021). Insect-pests are major constraints in enhancing rice productivity, besides diseases and weeds. Rice crop is attacked by more than 100 species of insect-pests and 20 are reported as major pests of economic importance (Basit and Bhattacharya 2001). Among the different insect pests associated with rice, rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) earlier considered as a minor pest has attained the status of major pest in India. Yellow stem borer, *Scirpophaga incertulas* (Walker) is also a destructive pest and is widely distributed insect has assumed the status of major pest which causes dead hearts at tillering stage and white ears at harvest stage, which can lead to complete failure of the crop. Avoidable losses due to leaf folder in rice were reported to be 37.9% in Kasturi Basmati variety (Chhavi *et al.* 2017) while avoidable losses by yellow stem borer were reported 40.81% (Pallavi *et al.* 2017).

Various strategies have been deployed for managing these pests and insecticides as chemical control factors are the first line of defense. For effective management of rice leaf folder and yellow stem borer, identification of new molecules with selective properties, novel mode of action is required for sustainable IPM. Chlorantraniliprole 0.4% GR is an anthranillic diamide insecticide in granular form for control of lepidopterous pests. Chlorantraniliprole opens muscular *calcium channels*, rapidly causing paralysis and ultimately death of sensitive species. Therefore, to break the plateau in rice production, sustainable management of insect pests through environmentally benign approaches has become necessary inexorable. Therefore, an experiment was conducted to evaluate the efficacy of chlorantraniliprole 0.4% GR (Ferterra 0.4% GR) against rice leaf folder, *Cnaphalocrocis medinalis* and yellow stem borer, *Scirpophaga incertulas* of rice under field conditions. Safety to natural enemies, phytotoxicity and residue studies were also evaluated.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of Regional Research Station, Karnal CCS Haryana

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Agricultural University, to evaluate the efficacy of chlorantraniliprole 0.4% GR (Ferterra 0.4% GR) against rice leaf folder and yellow stem borer during rainy (*Kharif*) season 2017 and 2018. Chlorantraniliprole 0.4% GR was tested at 4 doses, viz. 20 g, 30 g, 40 g and 50 g a.i./ha and compared with standard checks, monocrotophos 36 SL @179.86 ml a.i./ha (500 mlitre/ha formulation) for rice leaf folder, cartap hydrochloride 4 G @7.50 kg a.i./ha for yellow stem borer and untreated control. Seedlings of rice variety (CSR30) were transplanted on 25th July during *kharif,* 2017 and 30th July during *kharif*, 2018 laid out in randomized block design with 3 replications. The plot size was 6.0 m × 5.0 m at spacing of 20 cm × 15 cm. Individual plots were separated by bunds to prevent movement of water and insecticide from one plot to another. Granular insecticides were broadcasted by mixing in 25 kg sand/ha while monocrotophos 36 SL was sprayed in 500 liters of water/ha with knapsack sprayer. Single application was made for all the treatments at 30 days after transplanting (DAT) except cartap hydrochloride which was applied twice at 30 and 50 DAT as per recommendation in university package of practices (Anonymous 2019). Observations on rice leaf folder and yellow stem borer damage were recorded on 10 randomly selected hills in each plot at 30 DAT (before application of insecticide) and at 40, 50, 60, 70 DAT in each treatment. To calculate the mean per cent damage, data of four observations at 40, 50, 60 and 70 DAT was considered. For recording rice leaf folder damage, leaf damage from 10 hills selected at random in a replication from each plot was recorded and per cent leaf damage was worked out. For recording yellow stem borer damage, total number of plants and dead hearts were recorded from 10 hills selected at random at different intervals and per cent dead hearts were worked out. Similarly, white ears recorded from 10 hills selected at random at harvest and per cent white ear head damage was worked out. The yield was recorded separately from each plot and then converted on hectare basis.

Phytotoxicity of chlorantraniliprole 0.4% GR was evaluated in the experimental plots. Ten plants were randomly selected at 40, 50, 60 and 70 DAT from each treatment along with untreated control and examined for the phyto-toxicity symptoms, viz. leaf injury, vein clearing, leaf necrosis, leaf epinasty, yellowing, stunting and hyponasty on a scale of 0–10 (Ambarish *et al.* 2017). Safety of chlorantraniliprole 0.4% GR was evaluated with reference to the most abundantly found natural enemies of rice ecosystem. Population of natural enemies was recorded from each plot on 10 randomly selected plants at 40, 50, 60 and 70 DAT. For residue studies, experiment was laid out during *kharif,* 2019 crop season. The treatments included chlorantraniliprole 0.4% GR @40 gm a.i./ha (recommended dose), 80 gm a.i./ha (twice of recommended dose) and untreated control in randomized block design with 3 replications. The plot size for each treatment and untreated check was 6.0 m × 5.0 m. Rice (CSR 30) was transplanted on 20th July, 2019. Individual plots were separated by bunds to prevent movement of water and insecticide from one plot to another. The chemical was applied on 19th August, 2019. Samples of soil, leaves, husk and rice grains were collected at harvest i.e. on 24th October, 2019. Proper storage conditions for the samples were provided before residue analysis. Residues of chlorantraniliprole 0.4% GR at harvest of rice crop were analyzed using gas liquid chromatography (GLC) Shimadzu Model 2010 in residue analysis laboratory. Adaptive trials were also laid out at farmers' fields during *kharif,* 2019 at 6 multi-locations (3 districts) with plot size of half acre per trial for treated (chlorantraniliprole 0.4% GR @40 gm a.i./ha) and untreated control. Observations on rice leaf folder and yellow stem borer damage were recorded at 30 DAT (before application of insecticide) and 50 and 70 DAT. Grain yield per plot was also recorded and converted on hectare basis. The data were subjected to analysis of variance after necessary transformations (Gomez and Gomez 1984) and critical differences between the treatments were compared with untreated control. All the statistical functions were performed using SPSS version 23.0 (IBM Corp 2015).

RESULTS AND DISCUSSION

Bio-efficacy and safety of chlorantraniliprole 0.4% GR against rice leaf folder, Cnaphalocrocis medinalis *and yellow stem borer,* Scirpophaga incertulas: There were no significant differences in rice leaf folder and yellow stem borer infestation among treatments before insecticidal application during *kharif,* 2017 and 2018 indicating uniform population throughout the experiment (Table 1). During *kharif,* 2017, mean lowest leaf damage (2.19%) was observed by rice leaf folder with the application of chlorantraniliprole 0.4% GR @50 g a.i./ha and it was at par at lower dose i.e. 40 g a.i./ha (2.50%) which was followed by @30 g a.i./ha (4.09%), 20 g a.i./ha (4.39%), cartap hydrochloride (4% G) @750 g. a.i/ha (4.80%), monocrotophos 36% SL @179.86 ml a.i./ha (7.03%) and untreated control (11.22%). The untreated control exhibited highest leaf damage of 11.22% and significantly differed from all other treatments (Table 1). Chlorantraniliprole 0.4% GR applied at lower doses of 20 and 30 gm a.i./ha were significantly inferior than higher doses of chlorantraniliprole 0.4% GR (40 and 50 gm a.i./ha) but superior over control. Similar trend with regard to rice leaf folder infestation was recorded during *kharif,* 2018. Mean lowest leaf damage (1.74%) was observed in chlorantraniliprole 0.4% GR @50 g a.i./ha and it was at par with lower dose i.e. 40 g a.i./ha (2.07%). Mean decrease in damage by rice leaf folder (*kharif* 2017 and 2018) over control was observed maximum (81.38%) with the application of chlorantraniliprole 0.4% GR @50 g a.i./ha followed by with lower dose i.e., 40 g a.i./ha (78.36%) while it was observed minimum with the application of monocrotophos 36% SL @179.86 ml a.i./ha (36.29%). During *kharif* 2018, based on mean per cent dead hearts, order of efficacy in ascending order was as follows: chlorantraniliprole 0.4% GR @50 g a.i./ha (1.64)> 40 g a.i./ha (1.98) > cartap hydrochloride 4 GR @750 g a.i./ha (3.29) > chlorantraniliprole 0.4% GR @30 g a.i./ha (3.46) > chlorantraniliprole 0.4% GR @20 g a.i./ha (3.76) > monocrptophos 36 SL @179.86 ml a.i./ha (5.17). At

Table 1 Effect of chlorantraniliprole 0.4% GR on rice leaf folder and yellow stem borer infestation during *kharif* 2017 and 2018

Treatment	Dose (g or ml a.i./ha)	Per cent leaf folder damage before application		**Per cent leaf folder damage after application		Pooled mean	Mean per cent reduction over control	Per cent dead heart by stem borer before application		**Per cent dead heart by stem borer after application		Pooled mean	Mean per cent reduction over control	Per cent white ear by stem borer	
		2017	2018	2017	2018			2017	2018	2017	2018			2017	2018
Chlorantraniliprole	20	3.89 (11.37)*	4.09 (11.65)*	4.39 (12.06)*	3.98 (11.48)*	4.19 (11.77)*	60.40	4.12 (11.69)*	3.65 (11.01)*	3.76 (11.14)*	3.93 (11.36)*	3.85 (11.25)*	42.62	3.46 (10.70)*	3.86 (11.33)*
Chlorantraniliprole	30	4.19 (11.80)	4.02 (11.55)	4.09 (11.63)	3.58 (10.87)	3.84 (11.25)	63.71	4.36 (12.05)	3.69 (11.04)	3.46 (10.66)	3.40 (10.57)	3.43 (10.62)	48.88	3.23 (10.34)	3.32 (10.49)
Chlorantraniliprole	40	4.21 (11.83)	3.95 (11.43)	2.50 (9.04)	2.07 (8.20)	2.29 (8.62)	78.36	4.46 (12.19)	3.92 (11.39)	1.98 (8.03)	1.63 (7.29)	1.81 (7.66)	73.03	1.63 (7.33)	1.68 (7.44)
Chlorantraniliprole	50	3.81 (11.24)	4.16 (11.75)	2.19 (8.39)	1.74 (7.47)	1.97 (7.93)	81.38	4.49 (12.22)	3.47 (10.73)	1.64 (7.28)	1.40 (6.73)	1.52 (7.01)	77.35	1.43 (6.83)	1.69 (7.47)
Cartap hydrochloride	750	3.80 (11.23)	4.30 (11.96)	4.80 (12.62)	4.01 (11.54)	4.41 (12.08)	58.32	4.13 (11.69)	4.01 (11.52)	3.29 (10.39)	2.94 (9.81)	3.12 (10.10)	53.50	2.88 (9.77)	3.24 (10.36)
Monocrotophos	179.86	4.37 (12.07)	4.05 (11.61)	7.03 (15.09)	6.44 (14.40)	6.74 (14.75)	36.29	4.06 (11.60)	3.37 (10.57)	5.17 (12.94)	4.64 (12.29)	4.91 (12.62)	26.83	5.27 (13.25)	5.07 (13.00)
Untreated control	-	4.25 (11.88)	3.91 (11.40)	11.22 (19.44)	9.93 (18.23)	10.58 (18.84)		4.39 (12.09)	3.69 (11.05)	7.11 (15.42)	6.31 (14.50)	6.71 (14.96)		7.21 (15.57)	7.26 (15.63)
CD (P=0.05)		(NS)	(NS)	(1.30)	(1.44)	(1.37)		(NS)	(NS)	(1.20)	(1.21)	(1.21)		(1.11)	(0.96)
CV (%)		(3.73)	(4.12)	(5.63)	(6.74)	(6.19)		(4.02)	(7.18)	(6.21)	(6.57)	(6.39)		(5.83)	(4.94)

*Figures in parentheses are angular transformed values; **Mean of four observations (40, 50, 60 & 70 days after transplanting).

Table 2 Effect of chlorantraniliprole 0.4% GR on population of natural enemies, yield, cost benefit ratio and incremental cost benefit ratio in rice during *kharif* 2017 and 2018

Treatment	Dose (g or ml a.i./ha)	**Mean number of natural enemies/10 hills						Yield attributes					
		2017			2018			2017			2018		
		Spiders	Mirid bugs	Coccinellids	Spiders	Mirid bugs	Coccinellids	Yield (q/ha)	Cost benefit ratio	ICBR	Yield (q/ha)	Cost benefit ratio	ICBR
Chlorantraniliprole	20	1.67 (1.63)*	0.87 (1.37)*	0.80 (1.34)*	1.93 (1.71)*	0.73 (1.32)*	0.67 (1.29)*	28.22	1.96	6.22	30.00	2.02	4.28
Chlorantraniliprole	30	1.60 (1.61)	0.80 (1.34)	0.87 (1.36)	1.80 ((1.67)	0.80 (1.34)	0.73 (1.32)	29.67	1.98	7.18	31.00	2.08	5.19
Chlorantraniliprole	40	1.47 (1.57)	1.03 (1.42)	0.80 (1.34)	1.80 (1.67)	0.80 (1.34)	0.73 (1.32)	33.55	2.40	11.22	34.89	2.35	10.76
Chlorantraniliprole	50	1.53 (1.59)	1.07 (1.44)	0.87 (1.36)	1.93 (1.71)	0.87 (1.37)	0.67 (1.29)	34.22	2.28	10.24	36.00	2.41	10.50
Cartap hydrochloride	750	1.73 (1.65)	1.00 (1.41)	0.87 (1.37)	1.87 (1.69)	0.87 (1.36)	0.67 (1.29)	31.56	2.07	3.35	32.67	2.16	2.58
Monocrotophos	179.86	1.40 (1.55)	0.87 (1.37)	0.73 (1.32)	1.93 (1.71)	0.80 (1.34)	0.67 (1.29)	27.11	1.83	7.66	28.89	1.96	3.10
Untreated control	-	1.73 (1.65)	1.13 (1.46)	0.87 (1.36)	1.87 (1.69)	0.87 (1.36)	0.73 (1.32)	25.22	1.71		28.11	1.92	
CD (P=0.05)		(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	3.45			2.74		
CV (%)		(3.92)	(5.64)	(5.72)	(2.55)	(4.60)	(4.42)	6.37			4.82		

*Figures in parenthesis are square root transformations; **Average of four observations (40, 50, 60 & 70 days after transplanting); ICBR, Incremental cost: benefit ratio.

Table 3 Efficacy of chlorantraniliprole 0.4% GR @ 40 gm a.i./ha on incidence of rice leaf folder, yellow stem borer, cost benefit ratio and incremental cost benefit ratio and yield of rice at farmers, field during *kharif* 2019

Location	Village	District	Variety	*Decrease in leaf folder incidence over untreated control (%)	*Decrease in yellow stem borer incidence over untreated control (%)	Yield (q/ha)		Increase in yield over untreated control (%)	Cost: benefit ratio		Incremental cost benefit ratio
						Treated	Untreated		Treated	Untreated control	
1	Rindal	Karnal	PR 126	73.9	67.2	80.7	71.4	13.03	2.49	2.27	5.89
2	Indergarh	Karnal	CSR 30	73.0	68.0	36.4	31.6	15.18	2.35	2.11	6.52
3	Bubka	Yamunanagar	CSR 30	72.5	69.1	35.2	29.5	19.32	2.27	1.97	7.93
4	Samalkha	Kurukshetra	PR 126	73.9	73.2	77.4	67.1	15.35	2.39	2.14	6.63
5	Kaul	Kaithal	CSR 30	69.0	62.9	35.7	30.3	17.82	2.30	1.93	7.46
6	Chandlana	Kaithal	CSR 30	70.7	68.4	37.8	32.4	16.67	2.44	2.16	7.46
Average				72.2	68.0	50.5	43.7	16.23	2.37	2.10	6.98

*Average of two observations (50 & 70 days after transplanting)

maturity, white ear infestation (%) was also recorded that was reduced after the application of chlorantraniliprole 0.4% GR at all tested doses and other insecticidal applications. Similar trend with regard to yellow stem borer infestation was recorded during *kharif* 2018 (Table 1). The mean lowest dead heart (1.40%) was observed with the application of chlorantraniliprole 0.4% GR @50 g a.i./ha and it was at par at lower dose i.e., 40 g a.i./ha (1.63%). Chlorantraniliprole 0.4% GR @50 and 40 g a.i./ha were at par with each other (Table 1). Mean decrease in dead heart by yellow stem borer (*kharif* 2017 and 2018) over control was observed maximum (77.35%) with the application of chlorantraniliprole 0.4% GR @50 g a.i./ha and it was followed by lower dose i.e. 40 g a.i./ha (73.03%) while it was observed minimum with the application of monocrotophos 36% SL @179.86 ml a.i./ha (26.83%). Although literature is scanty on systematic study on efficacy of chlorantraniliprole 0.4% GR against rice leaf folder and yellow stem borer but present findings are supported by Chormule *et al.* (2014) who also reported that chlorantraniliprole 0.4% GR was best for reducing the infestation of yellow stem borer. Present findings are also supported by Sarao and Kaur (2014) who reported that chlorantraniliprole 0.4% G @30, 40 and 50 g a.i./ha was found effective against stem borer and leaf folder in basmati rice.

Spiders, mirid bugs and coccinellid beetles were the most abundant natural enemies of the rice ecosystem. Chlorantraniliprole 0.4% GR at all the tested doses was recorded at par in terms of population of natural enemies as compared to the untreated control during both years of study (Table 2). Therefore, all doses of chlorantraniliprole 0.4% GR were safe to natural enemies. The present finding is in accordance with Shanwei *et al.* (2009) who reported chlorantraniliprole 20 SC @40 g a. i./ha as highly safe to the beneficial predatory coccinellids and spiders in the rice ecosystem. Similarly, Jafar *et al.* (2013) also reported that chlorantraniliprole was safer to the natural enemies of rice insect pests. Results indicated absence of phyto-toxicity symptoms, viz. leaf injury, vein clearing, leaf necrosis, leaf epinasty, leaf hyponasty, yellowing and stunting at all the tested doses of chlorantraniliprole 0.4% GR in rice crop. Literature is silent regarding the effect of chlorantraniliprole 0.4% GR on phytotoxicity in rice.

During *kharif,* 2017, maximum grain yield (34.22 q/ha) was observed in chlorantraniliprole 0.4% GR @50 gm a.i./ha which was at par with 40 gm a.i./ha (Table 2). Maximum cost: benefit ratio (1: 2.40) was recorded in case of chlorantraniliprole 0.4% GR (@ 40 gm a.i./ha. Incremental cost benefit ratio was also recorded maximum (1: 11.22) in chlorantraniliprole 0.4% GR @ 40 gm a.i./ha. Similarly, during *kharif* 2018, maximum grain yield (36.00 q/ha) was observed in chlorantraniliprole 0.4% GR @50 gm a.i./ha which was at par with chlorantraniliprole 0.4% GR @ 40 gm a.i./ha (34.89 q/ha). Maximum cost benefit ratio (1:2.35) was recorded in application of chlorantraniliprole 0.4% GR @40 gm a.i./ha. Incremental cost benefit ratio was also recorded maximum (1: 10.76) in chlorantraniliprole 0.4% GR @40 gm a.i./ha (Table 2). The present findings are in accordance with that of Sarao and Kaur (2014) who reported that Ferterra 0.4% GR was effective in the management of rice stem borers and leaf folder in basmati rice and gave the highest yield (40.53 q/ha) at a dose of 50 g a.i./ha which was at par with 40 g a.i./ha. Rana and Singh (2017) studied that chlorantraniliprole 18.5% SC was found most effective with the highest pooled yield of 44.58 q/ha and also give partial support to the present investigations.

Post-harvest residual estimation of chlorantraniliprole 0.4% GR in rice: Post-harvest residual analysis of chlorantraniliprole 0.4% GR was found below the limit of quantification i.e. 0.01 ppm in rice grains, soil, paddy straw and husk in a single application of recommended (40 gm a.i./ha) and twice of the recommended dose (80 gm a.i./ha) indicating its safety up to twice of the recommended dose for human, animals and environment. Zhang *et al.* (2012) and Mack *et al.* (2015) reported that residues of chlorantraniliprole on brown rice were lower than the maximum residue limit and support present findings.

Farmer's field trials: Results revealed that application of chlorantraniliprole 0.4% GR @40 gm a.i./ha resulted in reduction in leaf folder and yellow stem borer incidence and increase of yield over the untreated control. Mean decrease in damage by rice leaf folder was observed 72.2% while decrease in yellow stem borer damage was recorded 68.0% in comparison to untreated control (Table 3). Mean grain yield was 50.5 q/ha in chlorantraniliprole 0.4% GR @40 gm a.i./ha as compared to 43.7 q/ha in the untreated control (Table 3). Increase in yield over untreated control was recorded as 16.23%. However, mean value of cost: benefit ratio (1:2.37) was recorded in the application of chlorantraniliprole 0.4% GR @40 gm a.i./ha. as compared to the untreated control (1: 2.10). Mean incremental cost benefit ratio was recorded (1: 6.98) in chlorantraniliprole 0.4% GR @40 gm a.i./ha. Present findings are supported by Sarao and Kaur (2014) who reported that chlorantraniliprole 0.4% G @30, 40 and 50 g a.i./ha was found effective against stem borer and leaf folder in basmati rice at farmers' field.

From the present investigations, it is concluded that single broadcast application of chlorantraniliprole 0.4% GR @40 g a.i./ha at tillering stage was found effective and best insecticidal treatment in reducing rice leaf folder and yellow stem borer infestation with no phytotoxicity symptoms and increased grain yield. Chlorantraniliprole 0.4% GR @40 g a.i./ha was also found safer to the natural enemies of the rice ecosystem. Post-harvest residual analysis of chlorantraniliprole 0.4% GR was found below the limit of quantification i.e. 0.01 ppm in rice grains, soil, paddy straw and husk at recommended and double of the recommended dose indicating its safety for human, animals and the environment.

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