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Efficacy, Environmental Persistence of Chlorantraniliprole 50%w/w FS (625g/L) Seed Treatment Against Yellow Stem Borer, *Scirpophaga incertulas* Walker and its Safety to Natural Enemies in Direct Seeded Rice in Indo Gangetic Plain

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Abstract

The increasing popularity of direct seeded rice could be attributed to various benefits, including reduced labor costs, reduced water requirement, lower production cost, improved soil physical conditions and reduced methane emissions. Yellow stem borer, *Scirpophaga incertulas* Walkercauses considerable economic losses in India and is a dominant pest among the rice insect pests. The first line of defense against insect-pests is chemical control measures. However, because of the development of insecticide resistance, managing insect-pests has become more challenging. Some of the earlier recommended insecticides against *S. incertulas* in rice now has not effectively controlled this pest. Seed treatment is the most significant application mode for insecticides. Seed treatment requires much less pesticide than broadcast or spray, which also ensures no threats to human health or the environment. In this direction, a novel molecule *i.e.,* chlorantraniliprole 50%w/w FS (625g/L) in trade name of Lumivia as seed treatment was evaluated for the management of *S. incertulas* in direct seeded rice. The present research findings indicate that during the two study years, the most effective and best insecticidal treatment for minimizing *S. incertulas* damage proved to treat the seeds with chlorantraniliprole 50% FS @ 75 g a.i. ha^{-1} or 3.75 g a.i. kg^{-1} seed. This resulted increased grain yield in both experimental seasons. Seed treatment with chlorantraniliprole 50% FS did not cause any phytotoxicity symptoms in the rice crop even at a high dose of 180 g a.i. ha^{-1}. On a 0–10 scale, phytotoxicity was rated as 0, indicating the crop is completely safe. All doses of chlorantraniliprole 50% FS (67.5, 75.0, 82.5, and 90.0 g a.i. ha^{-1}) were also proven to be harmless for natural enemies, such as mirid bugs, coccinelid beetles and spiders. During the 2019 and 2020 crop seasons, the maximum grain yield (42.05 & 40.21 q ha^{-1}) was reported in the seed treatment with chlorantraniliprole 50% FS @ 90.0 g a.i ha^{-1}, which was comparable to 82.5 & 75.0 g a.i. ha^{-1}. The residues of chlorantraniliprole 50% FS @ 75.0 g a.i. ha^{-1} and 150 g a.i. ha^{-1} analyzed were below the quantification limit of 0.01 mg kg^{-1} in field soil, grain and paddy straw at harvest.

Keywords: Bio-efficacy, chlorantraniliprole, direct seeded rice, *kharif, Scirpophaga incertulas*

1. Introduction

Rice is an important staple food in India, cultivated over 46.28 million hectares producing 129.47 million tons annually (USDA, 2023). To keep up with the rising population, it is necessary to increase rice production by 1.0 million tonnes annually. Traditionally, rice is transplanted after puddling, a method that is labour-intensive, consumes large amounts of water and has negative impacts on soil health for subsequent wheat and other upland crops. Additionally, this conventional method contributes to methane emissions, adversely affecting the atmosphere (Dhakal *et al.,* 2013). The lowering of the water table, labour shortages and detrimental effects on soil health necessitate alternative cultivation methods to maintain rice productivity and conserve natural resources. Direct seeded rice can counter these issues and its cultivation is increasing.

Rice production faces limitations from both biotic and abiotic stresses, with insect pests causing significant economic losses. In India, rice yields are hindered by numerous biotic and abiotic factors, insect pests being a major contributor to economic losses, estimated at 27.9 percent (Mondal *et al.*, 2017). Rice crops are susceptible to attacks from approximately 100 insect species from sowing to maturity, with about 20 species consistently recognized as major pests of significant economic importance (Heinrichs *et al.*, 2017; Rahaman and Stout, 2019). Rice thrives in warm, humid climates that are particularly favorable for the survival and reproduction of lepidopteran pests such as yellow stem borer and leaf folder. In India, yellow stem borer, *Scirpophaga incertulas* Walker (Lepidoptera: Crambidae), is one of the most destructive pest, with rice plants being most vulnerable during the tillering and flowering stages. Without control measures, yield losses due to *S. incertulas* can range from 11.07 to 87.66 percent (Pallavi *et al.*, 2017). After emerging from the egg mass, *S. incertulas* larvae enter the tiller, feeding inside and damaging the central whorl, leading to "dead hearts." The affected tillers cease to grow and dry up.

The traditional insecticides such as cartap hydrochloride, acephate, chlorpyriphos, and monocrotophos have been ineffective in controlling *S. incertulas* in rice (Reddy *et al.*, 2019). There is a need to test new chemicals for managing this pest as a seed dresser due to reports of insect outbreaks and residue issues. Seed treatment is a highly effective method, requiring smaller quantities of pesticides compared to broadcasting or spraying, thus minimizing environmental risks and human health hazards. Seed treatment is crucial in Integrated Pest Management (IPM) for protecting crops against insect pests and diseases. Newer insecticides from the neonicotinoids and anthranilic diamides groups are important for seed treatment especially in direct seeded rice. Therefore, an effort was undertaken to study the efficacy of chlorantraniliprole 50% FS as a seed treatment for managing *S. incertulas* in direct seeded rice.

2. Material and Methods

2.1. Field Experiment

A field experiment was conducted at the research farm of CCS Haryana Agricultural University, Regional Research Station, Uchani, Karnal. The experimental site is situated at 76.99^{0}E Longitude, 29.69^{0}N Latitude, at an elevation of 243 meters above mean sea level with an average temperature of 28.0°C and an average annual rainfall of approximately 580 mm. The primary aim was to assess the effectiveness of chlorantraniliprole 50% w/w FS as a seed treatment for controlling yellow stem borer, *S. incertulas*, in direct-seeded rice during the *kharif* seasons of 2019 and 2020. The soil at the site is characterized as clay loam.The new insecticide, chlorantraniliprole 50% FS (Lumivia), was tested as seed treatment at four different doses: 67.5, 75.0, 82.5, and 90.0 g a.i. ha^{-1}. These treatments were compared with a standard check, cartap hydrochloride 4% GR (Caldan) and an untreated control (Table 1). Additionally, phyto-toxicity was also assessed at a higher dose of 180.0 g a.i. ha^{-1}.

Rice variety, PB 1121 was sown on June 18, 2019, during the *kharif* season of 2019 and on June 13, 2020, during the *kharif*season of 2020at the research farm. The experiment was designed using a randomized block design with four replications. Each treatment plot was sized 5.0 x 5.0 meters. For the seed treatment, the appropriate amount of chlorantraniliprole 50% FS was measured and mixed with water to prepare a 25 ml slurry for treating 1 kg of seeds. This slurry was thoroughly mixed with the seeds to ensure uniform coating and the treated seeds were then allowed to dry in the shade. Sowing was carried out following the trial layout. Cartap hydrochloride 4% GR was applied as broadcast at 30 days after sowing which served as

Table 1. Treatment details for evaluating the efficacy of chlorantraniliprole 50% w/w FS (625g/L) for control of yellow stem borer, S. incertulas in direct seeded rice during kharif, 2019 and 2020

Treatments	Treatment details	Dose g. a.i. ha^{-1}	Dose g. a.i. kg^{-1} seed
T1	Chlorantraniliprole 50% FS	67.5	3.38
T2	Chlorantraniliprole 50% FS	75.0	3.75
T3	Chlorantraniliprole 50% FS	82.5	4.13
T4	Chlorantraniliprole 50% FS	90.0	4.50
T5	Cartap hydrochloride 4% GR	750	-
T6	Untreated control	-	-
T7	*Chlorantraniliprole 50% FS	180.0	9.0

One litre of Chlorantraniliprole 50% w/w FS contains 625 g active ingredient on a weight by volume basis; Seed rate @ 20 kg/ha * Treatment T7 tested for phytotoxicity observation only.

the standard check, adhering to the package of practices from Chaudhary Charan Singh Haryana Agricultural University, Hisar. The crop was grown following the university's recommended practices (Anonymous, 2019). Insecticides for *S. incertulas* were applied according to the experiment's protocol. The crop was harvested on October 24, 2019 during *kharif* 2019 and on October 27, 2020 during *kharif* 2020.

2.2. Effect of chlorantraniliprole 50% FS seed treatment on germination

The observations were made at 10, 20, and 30 days after sowing in the aforementioned field experiment. The total number of seeds and germinated seeds were counted in a one-square-meter area at 10, 20, and 30 days after sowing for each treatment.

2.3. Efficacy of chlorantraniliprole 50% FS seed treatment against S. incertulas in rice

Observation on the incidence of *S. incertulas* was recorded by selecting 20 randomly selected hills per replicate from each plot and counting the number of dead hearts and healthy tillers at 30, 40, 50, 60, and 70 days after sowing. From the 20 randomly chosen hills, the total number of plants and dead heart occurrences were counted, and the proportion of dead hearts was subsequently calculated (Sarao and Kaur, 2014).

2.4. Effect of chlorantraniliprole 50% FS on phytotoxicity

Phytotoxic effects of chlorantraniliprole 50% FS were recorded for all treatments (T1-T7) including the untreated control at 10, 20, 30, 40, 50, 60, and 70 days after sowing. One hundred plants were randomly selected from each treatment and replication. On a scale of 0 to 10, phytotoxicity symptoms such as leaf injury, vein clearing, leaf necrosis, leaf epinasty, yellowing, stunting, and hyponasty were recorded as per the method described by Ambarish *et al.* (2017).

2.5. Safety of chlorantraniliprole 50% FS to natural enemies

The safety of chlorantraniliprole 50% FS was assessed by observing its impact on the natural enemies that are prevalent in the rice ecosystem including mirid bugs, coccinellids, and spiders. Ten randomly chosen hills were examined in order to record observations of the population of these natural enemies from each plot at 30, 40, 50, 60, and 70 days after sowing during the *kharif* seasons of 2019 and 2020.

2.6. Grain yield analysis and economic evaluation

The crop was harvested on October 24, 2019 and October 20, 2020. Post-harvest, winnowing was conducted to separate the chaff and debris from the grains. The grain yield for each plot was recorded in kilograms, and subsequently converted to quintals per hectare. Additionally, incremental cost-benefit ratio for each treatment and replication were calculated.

2.7. Residue studies and farmers' field trials

chlorantraniliprole 50% w/w FS (625 g/L) was registered by the Central Insecticide Board & Registration Committee during 2020 (Anonymous, 2020). Following its registration, farmers' field trials were conducted to evaluate the technology's suitability by end users. For farmers' field trials, treatments included chlorantraniliprole 50% FS at 75g

a.i. ha^{-1} (3.75 g a.i. kg^{-1} seed) compared with an untreated control. Six multi-location trials were conducted with a plot size of 0.4 ha at each location for both treated and untreated control. The crop was grown in accordance with the standard recommended practices provided by CCS Haryana Agricultural University, Hisar, with the exception of plant protection measures for *S. incertulas*. Observations on *S. incertulas* were recorded at 30, 60 and 90 days after sowing. From 100 randomly chosen hills, the total number of plants and dead hearts were counted at different intervals to find out per cent incidence. Further, the grain yield per plot was recorded and converted to a per-hectare basis.

Residue trials were also carried out to ensure the chemical's safety for the environment and consumers. The experiment was conducted at RRS, Karnal during the *kharif* 2023 season, including treatments of chlorantraniliprole 50% FS at 75 g a.i. ha^{-1} and 150 g a.i. ha^{-1} (double the dose), which is 3.75 and 7.50 g a.i. kg^{-1} seed, respectively, along with an untreated control. The experiment was laid out in a randomized block design with three replications. The plot size for each treatment and untreated check was 6.0 x 5.0 meters and rice variety, PB 1121 was sown on June 20, 2023. Individual plots were separated with bunds to control water flow and prevent flow of insecticides between plots. On October 18, 2023, samples of soil, leaves/straw, and rice grains were collected and properly stored for subsequent residue analysis. Residue analysis of chlorantraniliprole 50% w/w FS was performed using gas liquid chromatography (GLC) Shimadzu Model 2010 in the Residue lab of the Department of Entomology, CCS HAU, Hisar as per method given by Hilger, 2021.

2.8. Statistical analysis

Critical differences among the treatments were analyzed using an ANOVA technique, following the guidelines suggested by Gomez and Gomez (1984). Tukey's significant difference (HSD) tests for paired comparisons were used to compare the treatment means at a 5% probability level. Version 23.0 of SPSS was used for all statistical operations (IBM Corp 2015).

3. Results and Discussion

3.1. Effect of chlorantraniliprole 50% FS on seed germination

The results on effect of chlorantraniliprole 50% FS on seed germination is presented in Table 2. During *kharif*, 2019, seed germination ranged from 86.2 to 87.5% in different treatments including untreated control and showed a non-significant effect on seed germination. Similar results were reported during second year of study (*kharif,* 2020). Results obtained during *kharif*, 2020 indicated that seed germination ranged from 87.0 to 88.6% in different treatments including untreated control and showed a non-significant effect on seed germination. Therefore, no adverse effect of chlorantraniliprole 50% FS on seed germination was observed at all doses tested and even at dose @180 g a.i. ha^{-1} (Table 2).

Table 2. Effect of chlorantraniliprole 50% FS seed treatment on germination in direct seeded rice during *kharif*, 2019 and 2020

Treatments	Treatment details	Dose g. a.i. ha^{-1}	Dose g. a.i. kg^{-1} seed	Germination (%)*		
				2019	2020	Mean
T1	Chlorantraniliprole 50% FS	67.5	3.38	86.9	88.2	87.5
T2	Chlorantraniliprole 50% FS	75.0	3.75	87.1	88.0	87.5
T3	Chlorantraniliprole 50% FS	82.5	4.13	86.7	87.2	86.9
T4	Chlorantraniliprole 50% FS	90.0	4.50	86.2	87.0	86.6
T5	Cartap hydrochloride 4% GR	750	-	87.2	88.4	87.8
T6	Untreated control	-	-	87.3	88.6	87.9
T7	Chlorantraniliprole 50% FS	180.0	9.00	87.5	87.0	87.2
C.D. (P=0.05)				NS	NS	NS
CV (%)				4.28	5.73	5.00

Mean of three observations (10, 20 & 30 days after sowing)

Despite this, there is limited literature on the efficacy of chlorantraniliprole 50% FS when used as a seed treatment for control of *S. incertulas*, its safety to natural enemies, and its residual impact in direct-seeded rice. However, efforts

have been made to discuss efficacy of other insecticides as seed treatment. Observations recorded in the present studies reveal that no adverse effect on seed germination was recorded at all doses of chlorantraniliprole 50% FS. Similar were reported from China by Yong-Qiang *et al.* (2022) in an experiment under laboratory conditions that germination and emergence of rice were not affected by treatment of seeds with chlorantraniliprole concentrations of 150 ml/hm^2 or 120 ml/hm^2. Reports of Singh *et al.* (2023) who reported that insecticide belonging to the same chemistry tetraniliprole 480FS @ 6.0 g a.i. kg^{-1} have no significant effect on germination and vigor of plants partially support present investigations.

3.2 Efficacy of chlorantraniliprole 50% FS against S. incertulas

Four different doses of chlorantraniliprole 50% FS (67.5, 75.0, 82.5, and 90 g a.i. ha^{-1}) were tested as seed treatments to evaluate their effectiveness against *S. incertulas* in direct-seeded rice (variety PB 1121). Results showed that up to 30 days after sowing, no incidence of *S. incertulas* was observed in both years of the study (Tables 3-4).

In the *kharif* season of 2019, at 40 days after sowing, the lowest incidence of *S. incertulas* (1.77% dead heart) was observed in the treatment with 90 g a.i. ha^{-1} of chlorantraniliprole 50% FS. This was statistically similar to the lower doses of 82.5 g a.i. ha^{-1}and 75 g a.i. ha^{-1}, which had 1.84% and 2.01% dead heart, respectively (Table 3). At 50 days after sowing, the minimum dead hearts were recorded in the plots treated with 90 g a.i. ha^{-1} (2.40% dead heart), followed by 82.5 g a.i. ha^{-1} (2.52%) and 75 g a.i. ha^{-1} (2.79%). These treatments were statistically similar. A comparable trend was reported at 60 and 70 days after sowing, with the 90 g a.i. ha^{-1} treatment consistently showing the least damage, and the lower doses (82.5 and 75 g a.i. ha^{-1}) being statistically comparable. Alltested doses of chlorantraniliprole 50% FS were significantly superior to untreated control. The mean incidence of *S. incertulas* (40, 50, 60, and 70 days after sowing) was lowest (2.98% dead heart) at dose of 90 g a.i. ha^{-1}, but this was statistically at par with 82.5 g a.i. ha^{-1}(3.14%) and 75 g a.i. ha^{-1} (3.35%) treatments (Table 3).

Table 3. Efficacy of chlorantraniliprole 50% FS seed treatment against yellow stem borer, *Scirpophaga incertulas* in direct seeded rice during *kharif*, 2019

Treatments	Treatment details	Dose g. a.i. ha^{-1}	Dose g. a.i. kg^{-1} seed	Dead heart (%)					
				30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Mean dead heart (%)
T1	Chlorantraniliprole 50% FS	67.5	3.38	0	3.52	4.43	5.25	6.42	4.90
T2	Chlorantraniliprole 50% FS	75.0	3.75	0	2.01	2.79	3.68	4.94	3.35
T3	Chlorantraniliprole 50% FS	82.5	4.13	0	1.84	2.52	3.43	4.76	3.14
T4	Chlorantraniliprole 50% FS	90.0	4.50	0	1.77	2.40	3.29	4.48	2.98
T5	Cartap hydrochloride 4% GR	750	-	0	2.32	3.77	4.94	6.62	4.41
T6	Untreated control	-	-	0	5.36	6.21	7.28	8.08	6.73
C.D.(P=0.05)				-	1.02	1.46	1.34	1.25	1.27
CV (%)				-	7.42	6.36	7.43	6.46	6.92

DAS: Days after sowing

The second year of the study (*kharif* 2020) yielded similar results. All doses of chlorantraniliprole 50% FS were significantly superior to the untreated control (Table 4). At 40 days after sowing, the lowest dead heart incidence (2.26%) was recorded at dose of 90 g a.i. ha^{-1} treatment, which was statistically comparable to 82.5 g a.i. ha^{-1} (2.37%) and 75 g a.i. ha^{-1} (2.59%) treatments (Table 4). At 50 days after sowing, the lowest dead heart was observed at dose of 90 g a.i. ha^{-1} plots (3.04%) which was at par with dose of 82.5 g a.i. ha^{-1} (3.12%) and 75 g a.i. ha^{-1} (3.31%). The same trend persisted at 60 and 70 days after sowing, with the 90 g a.i. ha^{-1} treatment showing the least damage, and the

lower doses remaining statistically comparable. The mean incidence (40, 50, 60, and 70 days after sowing) was lowest (3.51% dead heart) at dose of 90 g a.i. ha^{-1} treatment which was found statistically similar to 82.5 g a.i. ha^{-1} (3.60%) and 75 g a.i. ha^{-1} (3.78%) treatments (Table 4).

Table 4. Efficacy of chlorantraniliprole 50% FS seed treatment against yellow stem borer, *Scirpophaga incertulas* in direct seeded rice during *kharif*, 2020

Treatments	Treatment details	Dose g. a.i. ha^{-1}	Dose g. a.i. kg^{-1} seed	Dead heart (%)					
				30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Mean dead heart (%)
T1	Chlorantraniliprole 50% FS	67.5	3.38	0	4.08	4.76	5.45	6.57	5.21
T2	Chlorantraniliprole 50% FS	75.0	3.75	0	2.59	3.31	4.15	5.06	3.78
T3	Chlorantraniliprole 50% FS	82.5	4.13	0	2.37	3.12	3.99	4.94	3.60
T4	Chlorantraniliprole 50% FS	90.0	4.50	0	2.26	3.04	3.89	4.86	3.51
T5	Cartap hydrochloride 4% GR	750	-	0	2.92	4.27	5.09	6.82	4.77
T6	Untreated control	-	-	0	5.82	6.63	7.04	8.31	6.95
C.D.(P=0.05)				-	1.21	1.30	1.18	1.27	1.24
CV (%)				-	5.94	7.24	5.67	7.49	6.58

DAS: Days after sowing

The results of present investigations revealed that seed treatment with chlorantraniliprole 50% FS at four different dosages effectively controlled *S. incertulas* as compared to untreated control. Among the tested dosages, the treatment at 90 g a.i. ha^{-1} dose showed superior performance, although it was statistically comparable to the lower doses of 82.5 g a.i. $ha^{-1}$and 75 g a.i. ha^{-1}. These findings are consistent with Rani *et al.* (2020), who reported that chlorantraniliprole 625g/L FS at 90 g a.i. ha^{-1}achieved the highest reduction in stem borer incidence (76.71%) during the *kharif* season. Patil *et al.* (2023) also support our results, showing that chlorantraniliprole at 75 g a.i. ha^{-1} as a seed treatment provided significantly better control of *S. incertulas*, with reduced dead heart percentage recorded at various intervals. In contrast, Villagas *et al.* (2019) found that reduced rates of chlorantraniliprole were effective against the rice water weevil (*Lissorhoptrus oryzophilus*) and fall armyworm (*Spodoptera frugiperda*), which provides partial support to the current study.

3.3. Phytotoxicity of chlorantraniliprole 50% FSon rice plants

Phytotoxicity symptoms were monitored across all treatments including the untreated control (T1-T7). No signs of phytotoxicity, such as chlorosis, wilting, vein clearing, necrosis, epinasty, or hyponasty, were observed in rice plants at any chlorantraniliprole 50% FS dose, including the highest dose of 180g a.i. ha^{-1}. Consequently, none of the tested doses of chlorantraniliprole 50% FS caused any phytotoxic effects on the rice crop. This absence of phytotoxicity is corroborated by Rani *et al.* (2020), who found no phytotoxic effects of chlorantraniliprole 50% FS at 90 and 180 g a.i. ha^{-1} through out the crop season.

3.4. Safety of chlorantraniliprole 50% FS to natural enemies in the rice ecosystem

The experimental plots were observed to support natural enemies such as mirid bugs, coccinellid beetles and spiders in the rice ecosystem during the period of the study (Table 5). The results revealed that the populations of natural enemies in plots treated with different doses of chlorantraniliprole 50% FS, including the standard check, were statistically similar to those in the untreated control (Table 5). Although there was a marginal reduction in the number of natural enemies in the plots treated with insecticides as compared to the untreated control, however, chlorantraniliprole 50% FS demonstrated safety for natural enemies and the rice crop across all tested doses. The application of chlorantraniliprole 50% FS as a seed treatment did not adversely affect the natural enemy populations within the rice ecosystem.

The presence of natural enemies in rice ecosystem have contributed to increase in yield of rice by decreasing damage caused by insects. However, the use of harmful broad-spectrum insecticides has negatively impacted spider populations, reducing their predation capabilities (Rhoades and Stoddart, 2021). The current study indicates that seed treatment with chlorantraniliprole 50% FS at various dosages and a standard check, did not adversely affect the populations of natural enemies such as mirid bugs, coccinellid beetles, and spiders. This finding is supported by Rani *et al.* (2020), who also reported no adverse effects of chlorantraniliprole on natural enemies during the *kharif* and *rabi* seasons of 2019-2020. The results of Singh *et al.* (2023) who also revealed that no harmful effects of tetraniliprole 480 FS on spiders partially support the present studies.

Table 5. Effect of chlorantraniliprole 50% FS seed treatment on population of natural enemies in rice during *kharif*, 2019 and 2020

Treatments	Treatment details	Dose g. a.i. ha^{-1}	Dose g. a.i. kg^{-1} seed	*Mean number of natural enemies/10 hills					
				2019			2020		
				Mirid bugs	Coccinellids	Spiders	Mirid bugs	Coccinellids	Spiders
T1	Chlorantraniliprole 50% FS	67.5	3.38	1.17	0.98	2.01	1.26	0.86	1.78
T2	Chlorantraniliprole 50% FS	75.0	3.75	1.06	0.87	1.92	1.21	0.82	1.71
T3	Chlorantraniliprole 50% FS	82.5	4.13	1.03	0.84	1.84	1.17	0.79	1.68
T4	Chlorantraniliprole 50% FS	90.0	4.50	1.01	0.81	1.80	1.17	0.72	1.64
T5	Cartap hydrochloride 4% GR	750	-	0.98	0.82	1.68	1.14	0.69	1.61
T6	Untreated control	-	-	1.20	0.80	2.05	1.30	0.91	1.81
C.D.(P=0.05)				NS	NS	NS	NS	NS	NS
CV (%)				6.14	5.49	5.29	6.28	5.39	5.17

*Average of five observations at 30, 40, 50, 60 &70 DAS

3.5. Economics of chlorantraniliprole 50% FSin relation to grain yield and incremental cost-benefit ratio

The economic analysis in relation to grain yield data from the *kharif* seasons of 2019 and 2020 demonstrated a significantly higher yield in plots treated with chlorantraniliprole 50% FS as compared to untreated control (Table 6). In *kharif* season of 2019, the highest average yield was observed in plots treated with chlorantraniliprole 50% FS at a rate of 90.0 g a.i. ha^{-1}, yielding 42.05 q ha^{-1}. This yield was statistically comparable to the yields from plots treated with lower doses of chlorantraniliprole 50% FS, specifically 82.5 g a.i. ha^{-1} (41.85 q/ha^{-1}) and 75.0 g a.i. ha^{-1} (41.60 q ha^{-1}). Similar yield trends were recorded in *kharif* season of 2020. The highest average yield during *kharif* 2020 was 40.21 q ha^{-1} in plots treated with 90.0 g a.i. ha^{-1} and it was again statistically at par to the yields from the 82.5 g a.i. ha^{-1} (39.62 q ha^{-1}) and 75.0 g a.i. ha^{-1} (39.43 q ha^{-1}) treatments. A pooled analysis of the two years' data reinforced the finding of significantly higher yields in chlorantraniliprole 50% FS treated plots compared to the untreated control. The yield data revealed that all doses of chlorantraniliprole 50% FS and the standard check were significantly superior over the untreated control (Table 6). Regarding the Incremental Cost-Benefit Ratio (ICBR), the results from the *kharif* season of 2019 indicated that plots treated with chlorantraniliprole 50% FS at 90.0 g a.i. ha^{-1} achieved the highest ICBR of 15.52. This value was statistically similar to the ICBRs from plots treated with 82.5 g a.i.ha^{-1} (14.99) and 75.0 g a.i. ha^{-1} (14.32). In the *kharif* season of 2020, the highest ICBR was again recorded in plots treated with 90.0 g a.i. ha^{-1} (18.25), with statistically at par ICBRs

from the 82.5 g a.i. ha^{-1} (16.41) and 75.0 g a.i. ha^{-1} (15.81) treatments. Results of Rani *et al.* (2020) who reported that among various treatments evaluated, the highest yield was recorded in chlorantraniliprole 50% FS@ 90 g a.i. ha^{-1} with 45.8 q ha^{-1} as against lowest yield with 27.5 q ha^{-1} in untreated control during *kharif*, 2019 support present studies. Singh *et al.* (2023) also reported that the damage caused by insect pests are reduced by use of tetraniliprole 480 FS as seed treatment, the yield of the crop is thereby increased partially support present investigations.

Table 6. Effect chlorantraniliprole 50% FS seed treatment on yield of direct seeded rice during *kharif*, 2019 and 2020

Treatments	Treatment details	Dose g. a.i. ha^{-1}	Dose g. a.i. kg^{-1} seed	Yield ha^{-1}			Incremental cost benefit ratio		
				2019	2020	Mean	2019	2020	Mean
T1	Chlorantraniliprole 50% FS	67.5	3.38	39.04	37.02	38.03	7.49	8.28	7.89
T2	Chlorantraniliprole 50% FS	75.0	3.75	41.60	39.43	40.51	14.32	15.81	15.07
T3	Chlorantraniliprole 50% FS	82.5	4.13	41.85	39.62	40.73	14.99	16.41	15.70
T4	Chlorantraniliprole 50% FS	90.0	4.50	42.05	40.21	41.13	15.52	18.25	16.89
T5	Cartap hydrochloride 4% GR	750	-	38.90	36.78	37.84	4.56	4.82	4.69
T6	Untreated control	-	-	36.23	34.37	35.30	-	-	-
C.D. (P = 0.05)				2.31	2.20	2.25	2.32	2.54	2.43
CV (%)				6.84	7.69	7.26	7.86	7.18	7.52

Market rate of insecticides: chlorantraniliprole 50% FS Rs. 12.0/ml (formulation), Cartap hydrochloride 4% GR @ Rs.120/kg (formulation), Price of paddy grain: Rs. 3840/q (2019), Rs. 4500/q (2020)

3.6. Residue Studies

Analysis of samples collected at harvest showed that residues of chlorantraniliprole 50% FS were below detectable limit (0.1 µg/g) in paddy grains, straw and soil samples from treatments at 75.0 g a.i. ha^{-1} and 150.0 g a.i. ha^{-1} and in untreated control. Residue analysis was done at Limit of Detection (LOD): 0.005 µg/g and Limit of Quantification (LOQ): 0.01 µg/g. Literature concerning residual effect of chlorantraniliprole 50% FS in rice against rice insect-pests is scanty.

3.7. Farmers' Field Trials

Results obtained from six multi-location trials carried out in *kharif* 2023 season are presented in Table 7. Seed treatment with chlorantraniliprole 50% w/w FS@ 75 g a.i. ha^{-1} resulted in reduction in *S. incertulas* incidence and increase of yield over the untreated control. Reduction in *S. incertulas* incidence over untreated control was recorded 48.9 per cent. Average grain yield was 47.56 q ha^{-1} in chlorantraniliprole 50% FS@ 75 g a.i. ha^{-1} as compared to 42.88 q ha^{-1} in the untreated control. Average increase in yield over the untreated control was 10.92 per cent and the mean incremental cost brenefit ratio was found to be 9.91 in treated plots. No phyto toxic effects of chlorantraniliprole 50% FS @ 75 g a.i. ha^{-1} in the form of necrosis, injury to leaf tips or leaf surface, wilting of leaves or epinasty or hyponasty were observed from the multi-location trials. The data from the multi-location adaptive trials during *kharif* 2023 clearly show that seed treatment with chlorantraniliprole 50% FS at 75 g a.i. ha^{-1} not only reduced *S. incertulas* incidence but also increased grain yield as compared to untreated control. Results on incremental cost benefit ratio (ICBR) indicated that mean ICBR (13.25) was obtained in seed treatment with chlorantraniliprole 50% FS@ 75 g a.i. ha^{-1}. Patil *et al.* (2023) supported these results, showing that chlorantraniliprole at 75 g a.i. ha^{-1} as a seed treatment provided significant control of *S. incertulas*, with reduced per cent dead heart recorded at various intervals.

Conclusion

Most popular and easy approach of insect-pests management by the farmers is spray of insecticides and this practice has infinite demerits majorly being environmental pollution and insecticide resistance. One of the best approaches of insect-pest management concluded in our experiment is seed treatment which focuses on use of minimal dose of insecticides for maximum control of insects-pests. It can be inferred from results of present investigations that chlorantraniliprole 50% FS@ 90 g a.i. ha^{-1} exhibited the highest efficacy, though it was statistically comparable to the lower dosages of 82.5 g a.i. ha^{-1} and 75 g a.i. ha^{-1} in managing *S. incertulas* and

Table 7. Efficacy of chlorantraniliprole50% FS@ 75 g a.i./ha (3.75 g a.i. kg^{-1} seed) on the incidence of yellow stem borer, *Scirpophagaincertulas* and yield at farmers' field trials during *kharif* 2023

Location	Village	District	Variety	Dead heart damage (%) at 30 DAS		Dead heart damage (%) at 60 DAS		Decrease in yellow stem borer incidence over untreated (%)	Dead heart/white year damage (%) 90 DAS		Decrease in yellow stem borer incidence over untreated (%)	Yield (q/ha)		Increase in yield over untreated control (%)	Incremental cost benefit ratio
				Treated	Untreated	Treated	Untreated		Treated	Untreated		Treated	Untreated		
I	Gudha	Kurukshetra	PB 1509	0	0.15	4.17	7.38	43.5	6.27	10.22	38.6	46.25	41.65	11.04	13.17
II	Sambhi	Karnal	PB 1121	0	0.24	4.11	8.26	50.2	7.18	10.52	31.7	46.50	41.45	12.18	14.29
III	Sehjanpur	Karnal	PB 1121	0	0.18	4.04	8.14	50.4	7.12	9.47	24.8	47.75	43.10	10.79	13.16
IV	Gagsina	Karnal	PB 1718	0	0	3.42	7.11	51.9	8.46	10.65	20.3	47.30	42.20	12.08	14.43
V	UrlanaKhurd	Panipat	PB 1121	0	0	4.16	8.18	49.1	8.20	11.73	30.1	48.60	44.10	10.20	12.73
VI	Urlana Kalan	Panipat	PB 1121	0	0	4.25	8.27	48.6	6.62	9.87	32.9	48.95	44.80	9.26	11.74
		Average		0	0.09	4.02	7.89	48.9	7.31	10.41	29.7	47.56	42.88	10.92	13.25

Market rate of insecticides: chlorantraniliprole50% FS Rs. 12.0/ml (formulation), Price of paddy grain: Rs. 4075/q *DAS: Days after sowing

resulted in a significant increase in yield compared to untreated control. The results from the adaptive trials conducted across six different locations on farmers' fields also further corroborate these findings. Chlorantraniliprole 50% FS@ 75 g a.i. ha^{-1} (3.75 g a.i. kg^{-1} seed) was also safer to the natural enemies of the rice ecosystem with no detectable harmful residues at harvest time. The current study affirm that seed treatment with chlorantraniliprole 50% FS is a viable and environmentally friendly pest management strategy. Therefore, chlorantraniliprole 50% w/w FS (625g/L) @ 75 g a.i. ha^{-1} (3.75 g a.i. kg^{-1} of seed) is recommended as an effective and sustainable seed treatment option for controlling *S. incertulas* in direct seeded rice. This approach offers a promising alternative towards achieving sustainable pest management.

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Authors' Contribution

Designing of experiment, lay out, data collection, analysis and preparation of manuscript by authors (MSJ, OPC, C, SA & RK)

Conflict of Interest

Authors declare that they do not have any conflict of interest.

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NA

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No

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