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Research Article

Efficacy of dinotefuran 20% SG (Token 20% SG) against brown planthopper, *Nilaparvata lugens* Stal in rice

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Abstract

Rice production is limited by both biotic and abiotic factors of which insect pests cause economic losses in north-western plains of India. Among different insect pests, brown planthopper (BPH), *Nilaparvata lugens* **Stal is one of the most important sucking insect-pests attacking rice crop and cause considerable yield damage to the rice crop. Various strategies have been employed to manage BPH and insecticides are commonly used for its management. Dinotefuran 20% SG a new molecule was evaluated under field conditions at Rice Research Station, Kaul (Kaithal), CCS Haryana Agricultural University, to access its efficacy against *N. lugens* in rice during** *kharif* **2020 and 2021. Results revealed that spray of dinotefuran 20% SG @ 40 g a.i. per ha as the most effective dose in the reduction of hopper population. No phytotoxicity to rice crop was observed with the foliar application of dinotefuran 20% SG at doses of 20, 30, 40, 50 and 80 g a.i. per ha. This chemical is also relatively safety to the natural enemies (spiders, mirid bugs and coccinellids) under field conditions. Maximum grain yield (45.6 q per ha) was observed in spray of dinotefuran 20% SG @ 50 gm a.i. per ha which was at par with its lower dose @ 40 g a.i. per ha. At harvest, the residues of dinotefuran 20% SG @ 40 g a.i. per ha and 80 g a.i. per ha were below the detectable level in soil, rice straw and grain.**

Keywords: Brown planthopper, dinotefuran, *Nilaparvata lugens*, phytotoxicity, rice, residue

1. Introduction

Half of the world's population is dependent on rice (*Oryza sativa* L.) as a staple crop (Heinrichs *et al.*, 2017), which is ranked second in productivity globally after corn (FAOSTAT, 2017). Rice is a major staple food crop of India covering the largest area of about 46.28 million hectares and with annual production of about 129.47 million tones (USDA, 2023). But the rice production is limited by both biotic and abiotic stresses of which insect-pests cause economic losses. It is estimated that over 100 insect species attack on rice crops from seed to maturity, and 20 of them identified as significant pests with significant economic impacts (Heinrichs *et al.,* 2017; Rahaman and Stout, 2019).

Brown planthopper (BPH), *Nilaparvata lugens* Stal is one of the most important sucking insect-pests attacking rice crop throughout the rice growing parts of country, occupies the major status and cause considerable yield damage to the rice cultivation. Rice cropping pattern influenced by climate change affects this insect's behavior, heavy rainfall causes high humidity in the dry season, which might activate the development of BPH and thrive population outbreak (Arlyna *et al.,* 2023). BPH damages rice by sucking phloem sap resulting in chlorophyll reduction, decreasing either the content of protein in leaf and photosynthesis rate (Watanabe and Kitagawa, 2000). Under field conditions, the damage spreads in a circular fashion and is termed as "hopper burn." If timely control measures are not taken up, the entire rice field may be affected in a span of 15-20 days. BPH has developed resistance to 29 insecticides in the world (Sparks and Nauen, 2015). In India, BPH has developed resistance against commonly used insecticides viz. imidacloprid, quinalphos, buprofezin and lamda cyhalothrin (Deosi and Suri, 2022). Indiscriminate use of these broad-spectrum conventional chemicals significantly reduces biodiversity of natural enemies and consequently induce outbreak of secondary pests, besides contaminating the eco-system (Singh 2000). Besides these chemicals, there is need to test other effective insecticides for management of this pest. Dinotefuran- a new furanicotinyl insecticide that represents third generation of the neonicotinoid group was chosen as an effective alternative to manage the BPH in rice. For humans, dinotefuran is described as a non-mutagen or reproductive toxin but in insects, it acts both through contact and ingestion, resulting in the cessation of feeding and ultimately the death of the target pest. Keeping this in view, evaluation of efficacy of dinotefuran 20% SG (Token) (Indofil Industries Limited) against *N. lugens* in rice was carried out during *kharif* 2020 and 2021.

2. Materials and Methods

2.1 Research trials

A field experiment was conducted at the research farm of Rice Research Station, Kaul (Kaithal), CCS Haryana Agricultural University to evaluate the efficacy of dinotefuran 20 % SG against brown planthopper (BPH), *N. lugens* in rice during *kharif* 2020 and 2021.The insecticide, dinotefuran 20 % SG was tested at four doses viz., 20g, 30g, 40g and 50 g a.i./ha and was compared with standard check, thiamethoxam25 WG @ 25 ml a.i./ha and untreated control. The rice seedlings of variety, PB 1121 were transplanted on 19th July, 2020 and 22thJuly, 2021 at the research farm which was laid out in randomized block design with four replications. The plot size for each treatment was 20.4 m^2 at spacing of 20 cm x 15 cm. The crop was raised as per standard recommended package of practices of CCS Haryana Agricultural University, Hisar (Anonymous, 2019) except plant protection measures for BPH. However, insecticide for BPH was applied as per treatment details (Table 1).

Table 1: Details of treatments for evaluation of efficacy of dinotefuran 20% SG against brown planthopper, *N. lugens* in rice during *kharif* 2020 and 2021

Treatments	Treatment details	Dose (g/ml a.i./ha)	Dose (product g or ml/ha)
T1	Dinotefuran 20% SG	20	100
T2	Dinotefuran 20% SG	30	150
T3	Dinotefuran 20% SG	40	200
T4	Dinotefuran 20% SG	50	250
T5	Thiamethoxam 25% WG	25	100
T6	Untreated control	-	-
T7	Dinotefuran 20% SG*	80	400

* T7 only for residue and phyto toxicity studies**

Observations on BPH counts were recorded from 10 randomly selected hills in each plot one day before spray; 1, 3, 5, 10 and 14 days after spray in each treatment and data was presented as average number of BPH per hill. The yield was recorded separately from each plot and then converted into quintals per hectare basis. Observations on nymphs and adults count was made by gently tapping the plant and collecting the BPH into a white-water tray and immediately counted. Insecticides in different treatments were applied with knapsack sprayer. First spray was applied when population of BPH reached above 5-10 hoppers (nymphs/adults) per hill and second spray was repeated when again pest population reached above 5-10 hoppers per hill (economic threshold level) in all treatments. Data on BPH population was recorded after each spray. Water volume was kept 500 liters/hectare. Observation on population of natural enemies was also made from each plot. Phyto-toxicity observations were also recorded from each treatment on a scale of 0-10 for leaf injury, vein clearing, leaf necrosis, leaf epinasty, leaf hyponasty, yellowing and stunting as per Ambarish *et al.* (2017) after both sprays at dose of 20g, 30g, 40g and 50 g & 80 g a.i./ha. Grain yield per plot was recorded and converted on hectare basis. Cost benefit and incremental cost benefit ratio was also recorded. For calculating incremental cost benefit ratio, only cost of insecticides and application was calculated.

2.2 Residue studies

For residue studies samples were collected during *kharif* 2021 crop season. The samples for residue analysis were collected from plots treated with dose @ 40 g a.i. per ha and 80 g a.i. per ha and untreated control. Samples of soil, leaves and rice grains were collected on 30th October, 2021. Rice grains were hulled (removal of rice husk) before residue studies. Proper storage conditions for the samples were provided before residue testing. Harvest residues of dinotefuran 20% SG were analyzed using high pressure liquid chromatography Waters e2695 (e-alliance) in paddy grains, straw and soil samples in Residue Analysis Laboratory, Department of Entomology, CCS HAU, Hisar.

2.3 Farmers' field trials

Multi location trials were conducted at farmers' fields during *kharif* 2021 to test feasibility of tested technology by end users. The treatments included dinotefuran 20% SG @ 40 gm a.i./ha and compared with untreated control and replicated at 6 locations with plot size of half acre each for treated and untreated control. The crop was raised as per standard recommended package of practices of CCS Haryana Agricultural University, Hisar (Anonymous, 2019) except plant protection measures for BPH. First spray was applied when population of BPH reached above 5-10 hoppers (nymphs/adults) per hill and second spray was repeated when again pest population reached above 5-10 hoppers per hill (economic threshold level). Insecticide was applied with knapsack sprayer and water volume was kept 500 liters/hectare. Observations on BPH was made by gently tapping into a white-water tray and immediately counted. Data on BPH population was recorded after each spray. Observations on BPH counts were recorded on 10 randomly selected hills in each treated and untreated plot at 5, 10 and 15 days after each spray and data is presented as average number of BPH per hill. First spray was applied when population of BPH reached above 5-10 nymphs/adults per hill and second spray was repeated when again pest population reached above 5-10 nymphs/adults per hill (economic threshold level) in all treatments. Grain yield per plot was also recorded and converted on hectare basis.

2.4 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

Results of investigations on efficacy of dinotefuran 20% SG against brown planthopper, *N. lugens* in rice during *kharif* 2020 and 2021 are presented in Tables 2 & 3.

3.1 Efficacy against brown planthopper, N. lugens

Results indicate that population of brown planthopper, *N. lugens* was observed uniform throughout experiment one day before first spray during *kharif* 2020 and 2021 and BPH population did not vary significantly among different treatments (Table 2 & 3).

During *kharif* 2020, one day after first spray, lowest BPH population (12.2 hoppers/hill) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha which was found at par with dinotefuran 20% SG @ 40 g a.i./ha which recorded 14.5 hoppers/hill. These two treatments i.e. dinotefuran 20% SG @ 50 and 40 g a.i./ha were also found significantly superior to other treatments including untreated control. Standard check, thiamethoxam 25 WG @ 25 ml a.i./ha was also found superior over untreated control. However, it was inferior to dinotefuran 20% SG @ 40 and 50 g a.i./ha. All insecticidal treatments (T1-T5) were found superior over untreated control in lowering population of BPH after first spray. Similar trend was also observed at 3, 5, 10 and 14 days after first spray. However, population of hopper increased steadily at 14 days after spray (DAS) in all treatments. Data on mean population of different observations (1, 3, 5, 10 and 14 DAS) indicate that lowest mean population (6.8 hoppers/hill) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha which was also found at par with dinotefuran 20 % SG @ 40 g a.i./ha which recorded 7.9 hoppers/hill. Maximum reduction in hopper population (77.5%) was observed in dinotefuran 20% SG @ 50 g a.i./ha. and it was followed by dinotefuran 20% SG @ 40 g a.i./ha (73.9%). Similar trend in reduction of BPH

Table 2: Efficacy of dinotefuran 20% SG against brown planthopper, *N. lugens* in rice during *kharif* 2020

Treatments	Treatment details	Dose (g/ ml ai per ha)	Dose formulation (g/ml per ha)	Mean population of BPH/hill							Per cent reduction over control
				1 day before spray	1 DAS	3 DAS	5 DAS	10 DAS	14 DAS	Mean	
First spray											
T1	Dinotefuran 20% SG	20	100	27.2	19.1	13.3	8.0	9.1	13.8	12.7	58.1
T2	Dinotefuran 20% SG	30	150	26.5	17.8	12.2	7.7	8.7	12.8	11.8	61.1
T3	Dinotefuran 20% SG	40	200	26.9	14.5	7.6	4.5	5.0	7.8	7.9	73.9
T4	Dinotefuran 20% SG	50	250	25.7	12.2	6.5	4.0	4.5	7.0	6.8	77.5
T5	Thiamethoxam 25% WG	25	100	26.8	22.8	13.6	11.5	12.2	13.3	14.7	51.5
T6	Untreated control	-	-	27.5	28.1	29.3	30.8	31.4	32.2	30.3	-
C.D. (P=0.05)				NS	2.4	2.1	2.6	2.2	2.3	2.3	-
CV (%)				7.5	9.1	6.7	7.2	8.6	6.7	7.6	-
Second spray											
T1	Dinotefuran 20% SG	20	100	14.2	12.4	9.4	7.3	8.1	8.9	9.2	69.8
T2	Dinotefuran 20% SG	30	150	12.9	11.8	8.1	6.7	7.4	8.3	8.5	72.1
T3	Dinotefuran 20% SG	40	200	8.2	7.1	3.8	3.1	4.0	4.8	4.6	84.9
T4	Dinotefuran 20% SG	50	250	7.4	6.2	3.3	2.7	3.6	4.2	4.0	86.9
T5	Thiamethoxam 25% WG	25	100	13.6	12.5	11.2	9.3	11.5	12.4	11.4	62.6
T6	Untreated control	-	-	32.7	32.9	32.4	31.7	29.2	26.3	30.5	-
C.D. (P=0.05)				2.3	2.6	3.1	2.8	2.5	2.0	2.6	-
CV (%)				8.2	7.7	8.2	8.5	8.0	9.3		-

*DAS: days after spray

Table 3: Efficacy of dinotefuran 20% SG against brown planthopper, *N. lugens* in rice during *kharif* 2021

Treatments	Treatment details	Dose (g/ ml ai per ha)	Dose formulation (g/ml per ha)	Mean population of BPH/hill							Per cent reduction over control
				1 day before spray	1 DAS	3 DAS	5 DAS	10 DAS	14 DAS	Mean	
First spray											
T1	Dinotefuran 20% SG	20	100	29.3	25.7	15.2	8.6	9.7	12.6	14.4	56.2
T2	Dinotefuran 20% SG	30	150	31.2	24.3	14.4	8.1	9.2	12.3	13.7	58.3
T3	Dinotefuran 20% SG	40	200	30.4	20.5	7.7	5.4	6.1	7.6	9.5	71.1
T4	Dinotefuran 20% SG	50	250	31.0	19.1	6.2	4.3	5.4	6.3	8.3	74.8
T5	Thiamethoxam 25% WG	25	100	28.8	25.4	21.6	18.5	19.2	20.3	21.0	36.2
T6	Untreated control	-	-	30.8	31.5	32.2	32.8	33.7	34.1	32.9	-
C.D. (P=0.05)				NS	2.3	2.5	2.1	2.3	2.2	2.3	-
CV (%)				8.4	9.2	8.5	8.6	9.4	8.6	9.1	-
Second spray											
T1	Dinotefuran 20% SG	20	100	12.9	10.3	8.2	6.4	7.4	9.8	8.4	74.1
T2	Dinotefuran 20% SG	30	150	12.6	11.2	7.8	5.7	6.5	9.2	8.1	75.1
T3	Dinotefuran 20% SG	40	200	7.9	6.8	5.2	3.4	4.2	4.9	4.9	84.9
T4	Dinotefuran 20% SG	50	250	6.8	5.9	4.5	2.8	3.7	4.3	4.3	86.8
T5	Thiamethoxam 25% WG	25	100	20.9	17.5	16.2	14.3	15.6	17.5	16.2	50.1
T6	Untreated control	-	-	34.5	35.6	36.2	32.1	29.5	28.9	32.5	-
C.D. (P=0.05)				2.2	2.5	2.1	2.0	2.1	2.4	2.2	-
CV (%)				7.6	8.3	8.5	9.4	9.6	9.7	9.1	-

*DAS: days after spray

and number of hoppers/hill was observed after second spray. Data indicated that one day after second spray, lowest population of BPH (6.2 hoppers/hill) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha which was found at par with spray of dinotefuran 20% SG @ 40 g a.i./ha (7.1 hoppers/hill). These two treatments i.e. dinotefuran 20% SG @ 50 and 40 g a.i./ha were also found significantly superior to other treatments including untreated control. Standard check, thiamethoxam 25 WG @ 25 ml a.i./ha was also found superior over untreated control. However, it was inferior as compared to dinotefuran 20% SG @ 40 and 50 g a.i./ha. All insecticidal treatments (T1-T5) were found superior over untreated control in lowering population of BPH after second spray. Similar trend was also observed at 3, 5, 10 and 14 DAS. However, population of BPH increased steadily at 14 DAS in all treatments. Data on mean population of different observations (1, 3, 5, 10 and 14 DAS) indicate that lowest mean population (4.0 hoppers/hill) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha which was also found at par with dinotefuran 20 % SG @ 40 g a.i./ha which recorded 4.6 hoppers/hill. Maximum reduction in hopper population (86.9%) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha. and it was followed by dinotefuran 20% SG @ 40 g a.i. /ha (84.9%).

During *kharif* 2021, one day after first spray, lowest population of BPH (19.1 hoppers/hill) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha which was found at par with dinotefuran 20% SG @ 40g a.i./ha which recorded 20.5 hoppers/hill. These two treatments i.e. dinotefuran 20% SG @ 50 and 40 g a.i. /ha were also found significantly superior to other treatments including untreated control. However, all insecticidal treatments were found superior over untreated control in lowering population of BPH after first spray. Similar trend was also observed at 3, 5, 10 and 14 days after first spray. Data on mean population of different observations (1, 3, 5, 10 and 14 DAS) indicate that lowest mean population (8.3 hoppers/hill) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha which was also found at par with dinotefuran 20% SG @ 40 g a.i./ha (9.5 hoppers/hill). Maximum reduction in BPH population (74.8%) was observed in dinotefuran 20% SG @ 50 g a.i./ha. and it was followed by dinotefuran 20% SG @ 40 g a.i./ha (71.1%). Similar trend in reduction of BPH and number of hoppers/hill was observed after second spray. One day after second spray, lowest population of BPH (5.9 hoppers/hill) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha which was found at par with dinotefuran 20% SG @ 40g a.i./ha (6.8 hoppers/hill). These two treatments i.e. dinotefuran 20% SG @ 50 and 40 g a.i. /ha were also found significantly superior to other treatments including untreated control. However, all insecticidal treatments were found superior over untreated control in lowering population of BPH after second spray. Similar trend was also observed at 3, 5, 10 and 14 days after second spray. Data on mean population of different observations (1, 3, 5, 10 and 14 DAS) indicate that lowest mean population (4.3 hoppers/hill) was observed in spraying of dinotefuran 20% SG @ 50 g a.i./ha which was also found at par with dinotefuran 20% SG @ 40 g a.i./ha (4.9 BPH/hill). Maximum reduction in BPH population (86.8%) was observed in dinotefuran 20% SG @ 50 g a.i./ha. and it was followed by dinotefuran 20% SG @ 40g a.i./ha (84.9%).

Our findings correlate with the findings of Kumar *et al.* (2017), which indicated that the population of BPH was 3.58 hoppers per hill when dinotefuran 20 SG was sprayed at a rate of 40 g a.i. per ha as compared to 14.11 hoppers per hill in control. The current results of spray of dinotefuran at the economic threshold of pests (5–10 hoppers/hill) resulting in maximum reduction of hopper population and maximum net returns are supported by observations made by Ali *et al.* (2017) which indicated a need-based insecticide usage along with other IPM techniques produced similar yields compared to prophylactic insecticide usage in rice fields. Further supporting the results of the current investigations are the findings of Seni (2019), which observed that dinotefuran 20 SG @ 40 g a.i. per ha was the most effective treatment for brown planthopper control. They further indicated that mean populations of BPH (27.00 hoppers per 10 hills) as against a population of 145.67 hoppers per 10 hills in untreated control.

3.3 Effect of dinotefuran 20% SG on natural enemies

The effect of dinotefuran 2 % SG on natural enemies is presented in Table 4. The results indicate that population of natural enemies (spiders, mirid bugs and coccinellid beetle) during *kharif* 2020 and 2021 was at par in all treatments including untreated control. Dinotefuran 20% SG recorded statistically similar population of natural enemies in all treatments including untreated

Table 4: Effect of dinotefuran 20% SG on population of natural enemies in rice during *kharif* 2020 and 2021

Treatments	Treatment details	Dose (g/ml ai per ha)	Dose formulation (g/ml per ha)	*Mean number of natural enemies/10 hills (after first spray)			*Mean number of natural enemies/10hills (after second spray)		
				Spiders (Araneae: Aranidae)	Mirid bugs (*Cyrtorhinus lividipennis* &*Tytthus chinensis*)	Coccinellids (*Coccinella* sp.)	Spiders (Araneae: Aranidae)	Mirid bugs (*Cyrtorhinus lividipennis* & *Tytthus chinensis*)	Coccinellids (*Coccinella* sp.)
***Kharif* 2020**									
T1	Dinotefuran 20% SG	20	100	2.63	0.84	0.69	2.52	0.80	0.63
T2	Dinotefuran 20% SG	30	150	2.56	0.80	0.66	2.48	0.77	0.62
T3	Dinotefuran 20% SG	40	200	2.48	0.73	0.64	2.43	0.70	0.60
T4	Dinotefuran 20% SG	50	250	2.42	0.70	0.60	2.38	0.68	0.60
T5	Thiamethoxam 25% WG	25	100	2.36	0.64	0.58	2.30	0.61	0.55
T6	Untreated control	-	-	2.72	0.88	0.72	2.70	0.85	0.74
C.D. (P=0.05)				NS	NS	NS	NS	NS	NS
CV (%)				8.3	8.6	8.9	9.2	8.8	7.9
***Kharif* 2021**									
T1	Dinotefuran 20% SG	20	100	2.72	0.89	0.73	2.68	0.86	0.72
T2	Dinotefuran 20% SG	30	150	2.68	0.86	0.70	2.65	0.84	0.69
T3	Dinotefuran 20% SG	40	200	2.65	0.80	0.68	2.62	0.78	0.67
T4	Dinotefuran 20% SG	50	250	2.60	0.76	0.65	2.58	0.75	0.64
T5	Thiamethoxam 25% WG	25	100	2.58	0.71	0.62	2.56	0.70	0.60
T6	Untreated control	-	-	2.75	0.91	0.75	2.76	0.92	0.77
C.D. (P=0.05)				NS	NS	NS	NS	NS	NS
CV (%)				9.47	10.17	9.60	9.24	8.72	9.39

Average of five observations

control. Therefore, all doses of dinotefuran 20% SG tested chemicals did not adversely affect the population of natural enemies in rice.

The results of Ali *et al.* (2017) reported that applying dinotefuran at the economic threshold of pests (5–10 hoppers/hill) is safer for natural enemies, support the current investigations. These findings also showed that avoiding the use of insecticides during the early crop stages (30–40 DAT) increased the populations of spiders, lady bird beetles, and carabid beetles in rice fields also support present findings. Rahaman and Stout (2019) also reported that dinotefuran 20% SG was less harmful to the natural enemies prevalent in the rice ecosystem. Venkateshalu and Math (2017) observed a little decline in the number of natural enemies in the insecticide-treated plots immediately after insecticide application; however, the population of the natural enemies recovered after ten days further support the present investigations.

3.4 Effect of dinotefuran 20% SG on phyto-toxicity

Results on phyto-toxicity symptoms viz.,leaf injury, vein clearing, leaf necrosis, leaf epinasty, leaf hyponasty, yellowing or stunting in any insecticidal treatments on the rice crop after both sprays even at 80 g a.i. per ha during both years of experimentation. Therefore, phytotoxicity studies indicate that dinotefuran 20% SG was found to be safe at all tested doses. This finding is also supported by studies conducted on rice plants by Patil *et al.* (2017), Singh *et al.* (2018) and Jaglan *et al.* (2022).

3.5 Residue analysis of dinotefuran 20% SG

Analysis of samples collected at harvest showed that residues of dinotefuran were below detectable limit (0.1 µg/g) in paddy grains, straw and soil samples which were sprayed at 40 g a.i. per ha and 80 g a.i. per ha and in untreated control. Maximum residual limit (MRL) as per European Food and Safety Authority, 2012 in rice is 0.02 µg/g. Residue analysis was done at Limit of Detection (LOD): 0.005 µg/g and Limit of Quantification (LOQ): 0.01 µg/g. Li *et al.* (2017) found that dinotefuran residues in brown rice samples at 21 days after the last application were 0.4131 mg/kg. These results provided a very low risk quotient (RQ) value and further recommended a 7-day safety interval for rice application. These findings are consistent with the current findings. The present findings are also somewhat supported by Kobashi *et al.* (2017), who showed 5-to 10-fold greater residual concentrations of imidacloprid in both water and rice fields than those of dinotefuran. The current findings are further partially supported by Rahman *et al.* (2013), who revealed dinotefuran residues below the maximum residual limit in melon samples sprayed three times at intervals of seven days up to seven days before harvest.

3.6 Effect of dinotefuran 20% SG on yield, cost: benefit ratio and incremental cost benefit ratio (ICBR)

Maximum grain yield (44.4 q/ha) was observed in spray of dinotefuran 20% SG @ 50 g a.i./ha which was found at par (43.6 q/ha) with spray of dinotefuran 20% SG @ 40 g a.i. /ha during *kharif* 2020 (Table 5). Similarly, during *kharif* 2021, maximum yield (46.8 q/ha) was also observed in dinotefuran 20% SG @ 50 g a.i. /ha which was at par (46.3 q/ha) with spray of dinotefuran 20% SG @ 40 g a.i./ ha. Yield was found significantly superior in all insecticidal treatments as compared to control during both years of experimentation. Maximum mean cost benefit ratio (3.18) and incremental cost benefit ratio (8.090 was recorded at dose of 40 g a.i. per ha.

The results of the current investigations are corroborated by findings of Kumar *et al.* (2017), who reported mean yield (56.26 q per ha) in dinotefuran 20 SG treated plots @ 40 g a.i. per ha as compared to control (34.53 q per ha). The cost benefit ratio (3.18) and increment cost benefit ratio (8.09) were also higher in dinotefuran 20 SG treated plots @ 40 g a.i. per ha. The findings of Jaglan *et al.* (2022) provide support to our findings. They reported that during the 2018 and 2019 crop seasons, respectively, the maximum cost: benefit ratios of 2.80 and 2.54 were recorded in plots where insecticide was applied at a dose of 40 g a.i. per ha. The current findings are further supported by Jaglan *et al.* (2022), which found that the maximum incremental cost: benefit ratio was recorded 10.48 and 9.69 in plots sprayed at a dose of 40 g a.i. per ha during the 2018 and 2019 crop seasons, respectively. The results of Rahaman and Stout (2019) for the management of yellow stem borer in rice give some support for the current findings. They found that spraying dinotefuran 20 SG resulted in a maximum cost-benefit ratio of 5.69.

3.7 **Farmers' field trials**

Data on BPH incidence and yield recorded from multi location trials during *kharif* 2021 are presented in Table 6. Spray of dinotefuran 20% SG @ 40 g a.i. /ha. in 500

Table 5: Effect of dinotefuran 20% SG on rice yield and cost: benefit ratio of different treatments during *kharif 2020* and 2021

Treatments	Treatment details	Dose (g or ml a.i./ ha)	Dose formulation (g/ml per ha)	Yield (q/ha)			Cost : benefit ratio			Incremental Cost Benefit Ratio		
				2020	2021	Mean	2020	2021	Mean	2020	2021	Mean
T1	Dinotefuran 20% SG	20	100	37.5	39.2	38.3	2.34	3.31	2.83	5.17	5.99	5.58
T2	Dinotefuran 20% SG	30	150	39.3	40.4	39.8	2.40	3.34	2.87	5.19	5.65	5.42
T3	Dinotefuran 20% SG	40	200	43.6	46.3	45.0	2.61	3.75	3.18	6.76	9.41	8.09
T4	Dinotefuran 20% SG	50	250	44.4	46.8	45.6	2.60	3.71	3.16	5.98	8.11	7.05
T5	Thiamethoxam 25% WG	25	100	35.6	37.2	36.4	2.29	3.23	2.76	6.23	6.14	6.19
T6	Untreated control	-	-	32.7	35.1	33.9	2.16	3.14	2.65	-	-	-
	C.D. (P = 0.05)			3.4	2.8	3.1	-	-	-	-	-	-
	CV (%)			8.3	8.9	8.6	-	-	-	-	-	-

Table 6: Efficacy of dinotefuran 20 % SG on incidence of brown planthopper, *N. lugens* in rice (variety PB 1121) under farmers' field trials during *kharif* 2021

Location	District	Population of brown planthopper/hill*						Mean population Treated	Mean population Untreated	Yield (q/ha)		Increase in yield over control (%)
		5 DAS		10 DAS		15 DAS				Treated	Untreated	
		Treated	Untreated	Treated	Untreated	Treated	Untreated					
I	Kaithal	4.6	34.4	6.9	32.8	9.2	30.5	6.9	32.6	45.4	39.7	14.3
II	Kaithal	4.5	31.4	5.6	29.5	6.8	31.9	5.6	30.9	39.8	34.4	15.4
III	Kaithal	4.2	35.8	5.0	28.3	6.1	30.9	5.1	31.7	44.6	39.7	12.3
IV	Kurukshetra	4.1	29.4	5.5	28.5	6.7	29.0	5.4	29.0	45.6	37.5	21.6
V	Karnal	3.8	27.8	5.4	29.2	6.1	29.6	5.1	28.9	38.9	34.3	13.4
VI	Karnal	3.5	27.7	5.0	28.0	6.8	28.3	5.1	28.0	45.9	38.5	19.2
Average		4.1	31.1	5.6	29.4	7.0	30.0	5.5	30.2	43.3	37.3	16.0

Mean BPH population of two sprays

liters water resulted in reduction in BPH incidence and increase of yield over the untreated control. Average grain yield was 43.3 q/ha in dinotefuran 20% SG @ 40 g a.i. / ha as compared to 37.3 q/ha in untreated control. Average increase in yield over control was 16.0 per cent. No phyto toxic effects of dinotefuran 20% SG @ 40 g a.i./ha.in the form of necrosis, injury to leaf tips or leaf surface, wilting of leaves or epinasty or hyponasty were observed from multi location trials. Therefore, it is quite conspicuous from data from different locations during *kharif* 2021 that dinotefuran 20% SG @ 40 g a.i./ha in 500 liters water resulted in reduction in BPH incidence and increased the grain yield appreciably as compared to untreated control.

Results of the current investigations are supported by the findings of Seni (2019), who further observed that dinotefuran 20 SG @ 40 g a.i. per ha was the most effective treatment for BPH control, with mean populations of 36.00 and 27.00 numbers per 10 hills in 2017 and 2018, respectively, and was significantly superior over control (145.67 and 98.67 hoppers per 10 hills in 2017 and 2018, respectively). The results of the current investigations are corroborated by findings of Kumar *et al.* (2017), who reported mean yield (56.26 q per ha) in dinotefuran 20 SG treated plots @ 40 g a.i. per ha as compared to control (34.53 q per ha).

Conclusion

It can be concluded from results of present investigations on evaluation of efficacy of dinotefuran 20 % SG against brown plant hopper, *Nilaparvata lugens* in rice during *kharif* 2020 and 2021 that spray of dinotefuran 20% SG @ 40 g a.i./ha in 500 liters water effectively controlled brown planthopper, *N. lugens* and was found best insecticidal treatment in reduction of hopper population and increase in yield with no phyto-toxicity on the crop. Spray of dinotefuran 20 % SG @ 40 g a.i./ha is also not harmful to natural enemies of insect pests of rice. Residues of dinotefuran 20 % SG were below detectable level (0.1 µg/g) in paddy grains, straw and soil samples which were sprayed up to a dose of 80 g a.i./ha. Therefore, spray of dinotefuran 20% SG @ 40 g a.i./ha. in 500 liters water at appearance of 5-10 hoppers/hill may be recommended for control of BPH in rice.

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Conflict of Interest

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

Ethical Compliance Statement

NA

Authors' Contribution

Designing of experiment, data collection, analysis and preparation of manuscript by authors (MSJ & SA), analysis and preparation of manuscript by author (JY).

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