academicJournals

Vol. 9(8), pp. 750-754, 20 February, 2014
DOI: 10.5897/AJAR2013.7054
ISSN 1991-637X ©2014 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Dinotefuran: A third generation neonicotinoid insecticide for management of rice brown planthopper

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Accepted 29 January, 2014

The field experiments were conducted for evaluation of Dinotefuran, a third generation neonicotinoid insecticide, against brown planthopper (BPH) in farmer's field at Sahebganj village (Block- Bhatar, Dist. – Burdwan), West Bengal, India during *kharif*, 2008-09 and 2009-10. Seven treatments contained four doses of dinotefuran at 15, 20, 25 and 30 g ai./ha, imidacloprid at 25 g ai./ha and acephate at 400 g ai./ha along with an untreated check were tested following randomised block design (RBD) with three replications. The crop was raised in plots (60 m^2) following recommended package of practices. Two successive sprays of selected insecticides were applied with knapsack sprayer at 15 days interval. Bio-efficacy of dinotefuran for controlling the rice brown planthopper in laboratory condition and the relative safety of the molecule to the major predators of brown planthopper in rice ecosystem was carried out in polycarbonate glasshouse. Results revealed that dinotefuran performed very good spectrum of action throughout the seasons against BPH population than the conventional acephate and commonly used neo-nicotenoids. Dinotefuran 20 SG was found quite effective against BPH at 25 g ai./ha and was also very safe to the important predators recorded to be present in rice field. LC_{50} value of dinotefuran as determined in the laboratory test at 24 h was 0.415 ppm.

Key words: Neonicotinoid, planthopper, dinotefuran.

INTRODUCTION

Rice (*Oryza sativa* L.) belonging to the Family Gramineae, is one of the most important food crops in the world and forms the staple diet of 2.7 billion people. Fletcher (1920) listed 35 species including 10 serious one feeding on paddy in India. Since the introduction of high yielding varieties, distinct changes have occurred in the insect pest complex of rice in India. Several species which once were considered minor pests are now considered as major. Examples are the brown planthopper, white backed planthopper, green leafhopper and leaf folders. Rice brown planthopper (BPH), *Nilaparvata lugens* (Stål) (= *Delphax oryzae*) belongs to the Family Delphacidae and Order Hemiptera, is probably the most important rice pest in Asia. This persuades composite plant responses with direct or indirect deleterious effects including reduction in the plant growth (root development, plant height and reproduction), wilting and leaf chlorosis. Collectively these symptoms are acknowledged as 'hopperburn'. The loss in grain yield ranges from 10% in moderately affected fields to 70% in those severely affected (Kulshreshtha, 1974).

Despite of the presence of substitutes to chemical control strategies, none is effective in controlling this plant hopper. Insecticide proves to be the only option where we can rely for emergency management of insect pest reaching on or beyond ETL. But the indiscriminate use of broad spectrum chemicals also reduces the biodiversity of natural enemies, lift the natural control,

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Tinduce outbreak of secondary pests and contaminate eco-system (Singh, 2000) resulted in resurgence of brown planthopper (Heinrichs and Mochida, 1984; Kenmore et al., 1984).

This has prompted the necessity of the introduction of the newer molecules that are safer, quickly degradable with known insecticidal alternatives. This will not only be feasible and effective for insect pest management, but also compatible with the natural enemies and environment. Dinotefuran is a new furanicotinyl insecticide which represents the third generation of neonicotinoid group. Dinotefuran, which was developed by Mitsui Chemicals, Inc., is not a mutagen, neurotoxin or reproductive toxin. It acts through contact and ingestion which results in the cessation of feeding and ultimately death shortly after. It appears that Dinotefuran acts as an agonist of insect nicotinic acetylcholine receptors, but it is postulated that Dinotefuran affects the nicotinic acetylcholine binding in a mode that differs from other neonicotinoid insecticides. Dinotefuran was reported to be highly active on a certain silverleaf whitefly strain which developed resistance against imidacloprid (Anonymous, 2011).

hus our following investigation was, therefore, formulated to find out the bio-efficacy of Dinotefuran in managing the rice brown planthopper in field condition as well as in laboratory condition. The relative safety of the molecule to the major predators of brown planthopper in rice ecosystem was also studied.

METHODOLOGY

Field experiment

Field experiment on the evaluation of Dinotefuran for BPH was conducted in farmer's field at Sahebganj village (Block- Bhatar, Dist. - Burdwan, West Bengal, India during *kharif*, 2008-09 and 2009-10 with seven treatments replicated thrice following randomised block design (RBD). Seven treatments contained four doses of dinotefuran at 15, 20, 25 and 30 g ai./ha, imidacloprid at 25 g ai./ha and acephate at 400 g ai./ha along with an untreated check. The crop was raised in plots (60 m^2) following recommended package of practices and maintaining a spacing of 20 cm × 15 cm which was left for natural infestation of desired pest. Two successive sprays of selected insecticides were conducted with pneumatic knapsack sprayer at 15 days interval. Spray volume was used at the rate of 500 L/ha. *Visual sampling* method was found to be most fitting for counting the brown planthopper population in the experiment. Five hills across the plot were randomly selected and hit several times with hands to take the count of nymphs and adults that fall on the standing water. Observation was taken at one day before and on one, seven and 15 days after each spray. The various natural enemies found to be associated with BPH in the field condition among which mirid bugs and spiders were found to be the most plentiful. The wolf spider, *Pardosa pseudoannulata* was noted to be predominant in the plots. Mean population of mirid bugs and spiders per hill up to 15 days was recorded after each spray and number of brown planthopper/mirid bug was calculated due to the greater potentiality of mirid bug to suppress the population of BPH in the field condition. Population of mirid bug was observed to vary with the population of BPH. Necessary statistical transformation and calculation has been followed accordingly.

Laboratory experiment

Laboratory experiment was carried out in polycarbonate glasshouse at Directorate of Research at Kalyani, Nadia, West Bengal during the year 2009-10.

Collection and rearing of test insect

Field collected insects were used to start the initial population of the brown planthopper (BPH). Ten days old seedlings of rice (MTU-7029) were planted in plastic pots (14 cm diameter and 15 cm height). To maintain a standing water condition pots were then placed in trays full of water. 30 to 40 days old plants were ideal for feeding and oviposition of hoppers in the cages. Separate cages were maintained for oviposition and rearing of the hoppers. All along the experiment temperature of 30±5°C and RH 70±20% was maintained. Periodic examination of the cages for the presence of predators and prompt removal of these were necessary for maintaining the population.

Bioassay

Bioassay study following 'spraying on the plant and insect release' was found most suitable in the laboratory condition as the method was quite effective in giving maximum kill on consistent basis. Five seedlings of rice variety MTU-7029 ageing 30 to 40 days were planted in each plastic pot and put into plastic trays full of water to maintain standing water condition. Hand atomiser was used to spray the plants with fixed volume of dinotefuran of different concentrations. One untreated check was maintained which was sprayed with water only. Cylindrical mylar cages (10 cm dia. and 50 cm ht.) were used to cover the plants. One to two day(s) old brachypterous adults of uniform size were collected with mouth aspirator from rearing cage and released them into the mylar cage. Insects reared for more than two generations were taken for bioassay study. On an average 20 insects were released per mylar cage and the open end was covered with cloth. Insect mortality was observed at different time intervals after exposure to treated plants. Number of dead insects was recorded at 24, 48 and 72 h of exposure. The mortality data of test species were converted to percentage-mortality by using the formula:

$$\text{Percentage of mortality} = \frac{\text{Number of dead insects}}{\text{Number of treated insects}} \times 100$$

The data were subjected to Probit analysis after correcting the mortality in the untreated check by Abbott's formula (Abbott, 1925):

$$P = \frac{P_1 - C}{100 - C} \times 100$$

Where, P = Percentage of corrected mortality; P_1 = Percentage of observed mortality; C = Percentage of mortality in control). The Probit analysis was done by the method adopted by Finney (1971) for the estimation of median lethal concentration (LC_{50}).

RESULTS AND DISCUSSION

Insecticides were tested under field condition on the

Table 1. Effect of insecticides against *Nilaparvatalugens* during *kharif*, 2008-2009 and 2009-2010.

Treatment	Dose g ai/ha	PT	1DAS	7DAS	15DAS	Mean after 1st spray	1DAS	7DAS	15DAS	Mean after 2nd spray	Overall mean	Yield (q/ha)
Dinotefuran 20 SG	15	29.17 (1.48)^{a}	17.33 1.26)^{c}	15.34(1.21)^{b}	21.00(1.34)^{bc}	17.89	12.34 (1.13)^{c}	12.67(1.14)^{c}	19.83(1.32)^{c}	14.95	16.42	39.15
Dinotefuran 20 SG	20	28.34 (1.47)^{a}	12.67(1.14)^{b}	11.17(1.09)^{b}	15.34(1.21)^{b}	13.06	8.17(0.96)^{c}	7.34(0.92)^{b}	11.67(1.10)^{b}	9.06	11.06	42. 83
Dinotefuran 20 SG	25	31.00(1.51)^{a}	9.33(1.01)^{a}	5.00(0.78)^{a}	7.50(0.93)^{a}	7.28	1.00(0.30)^{a}	0.67(0.22)^{a}	2.33(0.52)^{a}	1.33	4.31	51.34
Dinotefuran 20 SG	30	28.00(1.46)^{a}	9.33(1.01)^{a}	3.33(0.64)^{a}	4.67(0.75)^{a}	5.78	0.67(0.22)^{a}	0.67(0.22)^{a}	1.33(0.37)^{a}	0.89	3.33	51.50
Imidacloprid 17.8 SL	25	30.67(1.50)	9.83(1.03)^{a}	5.50(0.81)^{a}	14.67(1.20)^{b}	10.00	3.33(0.64)^{b}	5.17(0.79)^{b}	10.50(1.06)^{b}	6.33	8.17	45.85
Acephate 75 WP	400	30.34(1.50)	16.67(1.25)^{c}	14.17(1.18)^{b}	24.00(1.40)^{c}	18.28	14.50(1.19)^{c}	15.67(1.22)^{c}	22.17(1.36)^{c}	17.44	17.86	38.15
Control	-	30.34(1.50)	30.67(1.50)^{d}	42.67(1.64)^{c}	57.17(1.76)^{d}	43.50	60.00(1.79)^{d}	81.00(1.91)^{d}	72.17(1.86)^{d}	71.06	57.28	25.40

Values in the parenthesis are $\log_{10}(x+1)$ transformed values; Means followed by a common letter in a column are not significantly different from each other by DMRT; DAS= days after spraying, PT= pretreatment count.

basis of number of BPH per hill, changes in the population of natural enemies and finally the yield. It is clear from the result (Table 1) that the brown planthopper population did not vary significantly among the treatments before the application of insecticides. At 1 day after spraying the dinotefuran at 30 and 25 g ai./ha recorded lowest number of BPH per hill followed by imidacloprid. Upto 15 days after 1st spray dinotefuran at 30 and 25 g ai./ha maintained the population of brown planthopper under normal limit. Same trend was noticed after 2nd spray also. Population of brown planthopper considerably reduced after 1 day of spraying and continued even after 7 days. Lowest population was recorded in dinotefuran at 30 and 25 g ai./ha which are statistically at par throughout the observation. Dinotefuran at 25 and 30 g ai./ha were recorded as the best treatments over imidacloprid and acephate.

Effect of insecticides on natural enemies associated with brown planthopper

Population of natural enemies was found to be moderate to good in both seasons. Mirid bug and wolf spider were more abundant. Population of mired bug was found to be highly dependent on the availability of brown planthopper for preying. This is known as the density dependent nature of mirid bug. Number of mirid bug was higher with more availability of panthopper and vice-versa in untreated plots. Spider population was observed to be independent of planthopper population.

It is evident from the Table 2 that mean number of mirid bug per hill after 15 days of first spray was comparatively low in all insecticide treated plots than the untreated control. A predator favourable low BPH and mirid bug ratio was maintained in case of dinetofuan treated plots that implied its safety to mirid bug. Same trend was noticed after 2nd spray also. Table 2 showed that up to 15 days after both the sprays there was no significant effect of insecticides on the mean number of spider population.

Dose-mortality response and LC_{50} value of sulfoxaflor against brown planthopper

Table 3 shows that LC_{50} value of dinotefuran at 24 h was 0.415 ppm against laboratory reared BPH. LC_{50} value of dinotefuran steadily declined up to 72 h of exposure.

In our overall findings, we found that dinotefuran performed very good spectrum of action throughout the seasons against BPH population than the conventional acephate and commonly used neonicotenoid imidacloprid. Dinotefuran showed quick knock down in action and restrained to build up the population of BPH up to harvesting stage. Among the traditional neonicotinoids, imidacloprid showed lower efficacy than dinotefuran. Neonicotinoid insecticides belong to a new insecticide class which act as competitive inhibitor of nicotinic acetylcholine receptors in the central nervous system. Their systemic property and long residual activity make them ideal insecticides against sucking pests. Dinotefuran is a new furanicotinyl insecticide which represents the third generation of neonicotinoid group. Dinotefuran was developed by Mitsui Chemicals. Dinotefuran was granted Organophosphorus Alternative and Reduced Risk Status by the EPA. Dinotefuran acts through contact and ingestion and results in the cessation of feeding within several hours of contact and death shortly after. It does not inhibit cholinesterase or interfere with

Table 2. Effect of insecticides on natural enemies associated with *Nilaparvatalugens* during *kharif*, 2008-09 and 2009-10

Treatment	Pretreatment			15 days after 1st spray				15 days after 2nd spray			
	BPH/hill	MB/hill	BPH/MB	Mean no. BPH/hill	Mean no. MB/hill	BPH/MB	Mean no. Spider/hill	Mean no. BPH/hill	Mean no. MB/hill	BPH/MB	Mean no. Spider/hill
Dinotefuran 20 SG	29.17	3.00 (1.87)^{a}	9.72	17.89	2.33 (1.68)^{a}	7.68	3.00 (1.87)^{a}	14.95	2.33 (1.68)^{b}	6.42	3.33 (1.96)^{a}
Dinotefuran 20 SG	28.34	2.92 (1.85)^{a}	9.71	13.06	1.67 (1.47)^{a}	7.82	3.00 (1.87)^{a}	9.06	1.33 (1.35)^{c}	6.81	3.00 (1.87)^{a}
Dinotefuran 20 SG	31.00	3.13 (1.91)^{a}	9.90	7.28	1.00 (1.22)^{b}	7.28	2.67 (1.78)^{a}	1.33	0.33 (0.91)d	4.03	3.00 (1.87)^{a}
Dinotefuran 20 SG	28.00	3.00 (1.87)^{a}	9.33	5.78	0.67(1.08)^{bc}	8.63	2.67 (1.78)^{a}	0.89	0.33 (0.91)d	2.70	2.67 (1.78)^{a}
Imidacloprid 17.8 SL	30.67	3.32 (1.95)^{a}	9.25	10.00	0.49 (0.99)^{c}	18.24	3.67 (2.04)^{a}	6.33	0.38 (0.94)d	16.51	3.00 (1.87)^{a}
Acephate 75 WP	30.34	2.87 (1.84)^{a}	10.56	18.28	0.83 (1.15)^{b}	22.02	4.00 (2.12)^{a}	17.44	0.95 (1.20)^{c}	18.38	3.67 (2.04)^{a}
Control	30.34	2.83 (1.83)^{a}	10.71	43.50	2.91 (1.85)^{a}	10.57	4.00 (2.12)^{a}	71.06	7.07 (2.75)^{a}	10.05	3.67 (2.04)^{a}

Values in the parenthesis are √(x+0.5) transformed values, Means followed by a common letter in a column are not significantly different from each other by DMRT; DAS= days after spraying.

Table 3. LC50 values of sulfoxaflor at different interval against laboratory reared Nilaparvatalugens.

Treatments (h)	df	Heterogeneity (χ^2)	Regression equation (y=)	LC_{50} (ppm)	Fuducial limit
24	3	3.266	5.817 + 2.139x	0.415	0.345-0.484
48	3	2.664	6.474 + 2.706x	0.285	0.234-0.332
72	3	2.189	6.811 + 2.573x	0.198	0.143-0.244

sodium channels. Therefore, its mode of action is different from those of organophosphate, carbamate, and pyrethroid compounds. It appears that dinotefuran acts as an agonist of insect nicotinic acetylcholine receptors, but it is postulated that dinotefuran affects the nicotinic acetylcholine binding in a mode that differs from other neonicotinoid insecticides. It is reported that dinotefuran was highly active on a certain silverleaf whitefly strain which developed resistance against imidacloprid (Anonymous, 2011). In the present study, dinotefuran was found to be quite safe to nymphs and adults of mirid bug (*C. lividipennis*). In all observations favourable ratio of BPH and mirid bug was noted after dinotefuran treatments which indicated that these insecticides were safe to the population of mirid bug. Dinotefuran is not a mutagen, neurotoxin or reproductive toxin. Spider population did not exhibit appreciable differences among the treatments in the experiment, corroborated by Krishnaiah et al. (2003) and Vijayaraghavan and Regupathy (2006). Fukuda et al. (2007) indorsed the good efficacy of dinotefuran against *Nilaparvata lugens*. Dinotefuran 20 SG at 30 and 40 g ai./ha was proved to be effective against brown planthopper at 35 locations in India during 2009 (Anonymous, 2010).

Conclusion

It is evident from the present investigation that dinotefuran 20 SG is effective against *Nilaparvata lugens* at 25 g ai./ha and is very safe to the important predators recorded in rice field.

ACKNOWLEDGEMENT

The authors are grateful to the Department of Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

and Indofil Industries Limited for provision of facilities.

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