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Field efficacy of flubendiamide 20WG against rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) and yellow stem borer, *Scirpophaga incertulas* (Walker) in basmati rice

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Abstract

Rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) and yellow stem borer, *Scirpophaga incertulas* (Walker) are the two major insect pests of rice causing considerable damage in India. Various strategies have been employed for managing these insect pests and insecticides as chemical control factors are the first line of defense. Thus, identification of new molecules with selective properties, novel mode of action, low toxicity to non-targets and environmental safety is required with a view of sustainable pest management. A number of novel insecticides have been registered for insect control in agriculture. A major advantage of these insecticides is that they act on insect biological processes and also have greater selectivity to target specific species. Therefore, flubendiamide 20 WG was evaluated at farmers' field in basmati rice during *Kharif*, 2020 to access its efficacy against rice leaf folder and yellow stem borer. Foliar spray of flubendiamide 20 WG @ 25 g a.i. ha^{-1} effectively reduced the infestation of rice leaf folder and yellow stem borer. Foliar application of flubendiamide 20 WG (25g a.i. ha^{-1}) did not cause any phyto toxicity symptoms on the crop. Average grain yield (37.14 q ha^{-1}) was observed in twice foliar application of flubendiamide 20 WG @ 25 gm a.i. ha^{-1} as compared to control (32.24 q ha^{-1}).

Keywords: Flubendiamide, phytotoxicity, rice leaf folder, yellow stem borer.

1. Introduction

Rice (*Oryza sativa* L.), is one of the staple foods for more than half of the world population and an important target to secure food security and livelihoods for millions of people. The productivity of rice in India is quite low (3.01 tons ha^{-1}) as compared to world average of 4.02 tons ha^{-1} (Anonymous, 2012). Among the various factors, insect pests cause serious losses in yield of rice in India. About 100 insect species are known to attack rice crop and 20 of them are consistently reported as major pests (Rahaman and Stout, 2019). Among these rice leaf folder, *Cnaphalocrocis medinalis* and yellow stem borer, *Scirpophaga incertulas* are the most important pests of rice in India. Rice leaf folder earlier considered as a minor pest has attained status of the major pest with the widespread adoption of high yielding rice varieties and accompanying changes in the cultural practices (Teng *et al.,* 1993). Larva fastens the edges of leaves together, fold them longitudinally and feed on the green matter from inside the folded leaf. Damaged leaves produce white streaks, become membranous and ultimately photosynthetic activity of the plant is reduced. Muhammad *et al.* (2012) reported that percentage of filled grains and grain yield varied significantly with rice leaf folder infestation levels. Yellow stem borer is the dominant species among the rice pests in India. Rice plants are most

prone to yellow stem borer infestation at tillering and flowering stages. If control measures are not adopted, yield loss may expect up to 87.66 per cent by this pest (Pallavi *et al.,* 2017). Stem borer larvae damage central whorl of the plants which then turn brownish and dries up resulting in "dead hearts". At reproductive stage, the damage is characterized by whitish, erect and chaffy panicles called, "white ears" (Muralidharan and Pasalu, 2006). Various strategies have been employed for managing these pests but insecticides as chemical control factors are first line of defense. In the last century, extensive use of persistent, broad spectrum and inexpensive pesticides in agriculture has led to severe concerns regarding public and environmental health. A number of novel insecticides have recently been registered for insect control in agriculture. A major advantage of these new insecticides is that they act on insect biological processes and also have greater selectivity to target specific species, so they may less likely to harm natural enemies when compared with the broader spectrum organophosphate, carbamate, neonicotinoid and pyrethroid insecticides. Flubendiamide (N^2-[1,1-dimethyl-2-methyl sulphonyl ethyl]-3-iodo-N^1-2-methyl-4-{1,2,2,2-tetrafluro-1-(trifluromethyl) ethyl} phenyl), a phthalic acid diamide insecticide, belongs to the benzene dicarboxamide group of insecticides. Unlike other conventional insecticides which target insect nervous system, flubendiamide is systemic and acts at receptors in insect muscles through the activation of ryanodine-sensitive intracellular calcium release channels (ryanodine receptors, RyR), causing immediate cessation of feeding (Tohnishi *et al.,* 2005). Flubendiamide 20WG is a registered insecticide by Central Insecticide Board & Registration Committee at a dose of 25g a.i./ha against rice leaf folder and yellow stem borer in rice. Keeping these points in view, present experiment was conducted to evaluate the efficacy of flubendiamide 20WG against rice leaf folder and yellow stem borer in basmati rice at farmers' field.

2. Materials and Methods

Field efficacy of flubendiamide 20 WG against rice leaf folder, *Cnaphalocrocis medinalis* and yellow stem borer, *Scirpophaga incertulas* was tested at farmers' field at 10 multi-locations in Karnal, Kurukshetra and Kaithal districts using basmati rice (variety CSR 30) during *Kharif*, 2020. Test insecticide flubendiamide 20 WG was evaluated at 25g a.i. ha^{-1} and compared with untreated control. The crop was raised as per standard recommended package of practices of CCS Haryana Agricultural University, Hisar (Anonymous, 2019). However, tested insecticide for rice leaf folder and yellow stem borer were applied in treated plots. The rice seedlings were transplanted during *kharif*, 2020 at farmers' fields at 10 multi-locations with plot size of one acre per trial for treated and untreated control. Insecticide was sprayed twice in 500 liters of water per ha with a knapsack sprayer. First spray of insecticide was done at tillering stage at 30 days after transplanting (DAT) and second at panicle initiation stage (50 DAT) or when pest population crossed economic threshold level. Rice leaf folder and yellow stem borer infestation were recorded at 1 day before application of insecticide and at 5, 10 & 15 days after both sprays. For recording rice leaf folder damage, 10 hills were selected at random from each plot. For this, total number of leaves on 10 hills and damaged leaves (rolled leaves with live larvae) were 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. The yield was recorded separately from each plot and then converted into per hectare basis. Incremental cost: benefit ratio was calculated on basis of additional net income from insecticidal application and total cost of insecticide and its application. Data was analyzed on basis of average infestation of rice leaf folder and yellow stem borer at different intervals and decrease in pest population over untreated control.

Phytotoxic effects caused by flubendiamide 20 WG were also evaluated in the above-mentioned plots. Ten plants were randomly selected from each plot along with untreated control and examined at 5, 10 and 15 DAS for the phyto toxicity symptoms *viz.,* leaf tip burning, leaf chlorosis, vein clearing, leaf necrosis, leaf epinasty, leaf hyponasty, wilting, stunting and hyponasty on a scale of 0-10 (Ambarish *et al*., 2017).

Leaf injury scale for determining phyto toxicity in rice plants

Scale/score	Phyto toxicity (%)
0	No phytotoxicity
1	1-10
2	11-20
3	21-30
4	31-40
5	41-50
6	51-60
7	61-70
8	71-80
9	81-90
10	91-100

3. Results and Discussion

Data on rice leaf folder infestation recorded from 10 multi-location trials during *Kharif*, 2020 are presented in Tables 1-2. Results indicate that rice leaf folder infestation (rolled leaves with live larvae) from different locations was recorded on an average of 6.21% infested leaves (treated) and 6.27% (untreated control) before first insecticidal application indicating the uniform population in treated and untreated control plots. Rice leaf folder infestation at 5 days after application of flubendiamide 20% WG @ 25 g a.i. ha^{-1} at tillering stage (30 DAT) ranged from 0.71 to 1.06 % as compared to 6.07-6.91% infested leaves in untreated control (Table 1). Corresponding figures for mean infestation of rice leaf folder was 0.89 and 6.58% at 5 days after spray (DAS). Mean rice leaf folder infestation at 10 days after application of insecticide was recorded 1.00% as against 6.89% in untreated control. Pest population increased markedly at 15 days after application of insecticide and it was recorded 1.53% as compared to 7.33% in untreated control (Table 1). Per cent reduction in rice leaf folder infestation recorded from different locations ranged from 60.34 to 67.43% with mean of 64.39%. Similar trend was recorded in rice leaf folder infestation after second spray (Table 2). It was recorded 2.56% infested leaves as against 7.42% in untreated control before application of second spray. Minimum infestation (0.67%) was reported at 5 days after application of second spray as compared to 7.59% in untreated control. Infestation of rice leaf folder increased 10 days after application. Rice leaf folder infestation was recorded 1.18% infested leaves as compared to 7.99% in untreated control (Table 2). Mean per cent reduction over control was recoded 82.47%.

Data on yellow stem borer is presented in Tables 3-4. Results indicate that yellow stem borer infestation from different locations ranged from 4.87 to 5.62 % dead heart (treated plots) and 5.19 to 5.72% dead heart (untreated plots) before first insecticidal application with mean infestation of 5.33% (treated) and 5.50% (untreated control). Yellow stem borer infestation at 5 days after application of flubendiamide 20% WG @ 25 g a.i. ha^{-1} at tillering stage (30 DAT) ranged from 2.02 to 2.34 % dead heart as compared to 5.21 to 6.81% in untreated control (Table 3). Corresponding figures for mean infestation was 2.18 and 5.86%. Average infestation of yellow stem borer at 10 days after application of insecticide was recorded 1.71% as against 6.09% in untreated control. Pest population increased markedly at 15 days after application of first spray and it was recorded 1.80% as compared to 6.21% in untreated control (Table 3). Per cent reduction in stem borer infestation recorded from different locations ranged from 50.44 to 57.45% with mean value of 56.11%. Similar trend was recorded in yellow stem borer infestation after second spray (Table 4). It was recorded 2.08 % dead heart before application of second spray as against 6.29 % in untreated control. Minimum infestation (1.67%) was reported at 5 days after application of second spray as compared to 6.45% in untreated control. Infestation of stem borer increased at 10 days after application. Yellow stem borer infestation was recorded 1.08% dead heart as compared to 6.56% in untreated control (Table 4). Trend was similar in yellow stem borer infestation after second spray based on the per cent reduction in dead hearts over

Table 1. Efficacy of flubendiamide 20% WG on infestation of rice leaf folder, *Cnaphalocrocis medinalis* in rice at farmers, field during kharif, 2020 (after first spray)

Locations	Village	District	Leaf damage (%) at 1 day before spray		Leaf damage (%) at 5 DAS		Leaf damage (%) at 10 DAS		Leaf damage (%) at 15 DAS		Decrease in rice leaf folder infestation over UC (%)
			T	UC	T	UC	T	UC	T	UC	
1	Pabla	Kaithal	6.21	6.16	0.94	6.43	1.12	6.57	1.72	6.65	61.29
2	Chandlana	Kaithal	5.85	5.76	0.81	6.12	0.94	6.30	1.29	6.45	63.91
3	Chuhar Majra	Kaithal	6.80	6.65	1.06	6.92	1.15	7.14	1.61	7.25	62.02
4	Dherdu	Kaithal	6.35	6.55	0.75	6.58	0.86	7.72	1.48	7.90	67.17
5	Khedarpur	Kaithal	5.28	5.40	0.93	6.46	0.99	6.82	1.47	7.94	67.43
6	Bir Amin	Kurukshetra	6.82	6.75	1.04	6.07	1.11	6.31	1.65	7.65	60.34
7	Khaspur	Kurukshetra	6.70	6.60	0.78	6.85	0.87	6.91	1.43	7.98	65.49
8	Mainmati	Karnal	5.65	6.43	0.86	6.73	0.95	6.85	1.39	6.92	67.14
9	Sultanpur	Karnal	5.82	5.72	1.05	6.91	1.12	7.04	1.72	7.20	63.86
10	Sultanpur	Karnal	6.62	6.70	0.71	6.74	0.84	7.20	1.58	7.38	65.20
	Average		6.21	6.27	0.89	6.58	1.00	6.89	1.53	7.33	64.39

DAS: days after spray; T: treated; UC: untreated control

Table 2. Efficacy of flubendiamide 20% WG on infestation of rice leaf folder, *Cnaphalocrocis medinalis* in rice at farmers, field during *Kharif*, 2020 (after second spray)

Locations	Village	District	Leaf infestation (%) at 1 day before spray		Leaf infestation (%) at 5 DAS		Leaf infestation (%) at 10 DAS		Leaf infestation (%) at 15 DAS		Decrease in rice leaf folder infestation over untreated control (%)
			T	UC	T	UC	T	UC	T	UC	
1	Pabla	Kaithal	2.23	6.71	0.57	6.81	0.84	6.96	1.06	7.10	82.96
2	Chandlana	Kaithal	2.48	6.50	0.62	6.54	0.80	6.75	1.16	7.23	81.27
3	Chuhar Majra	Kaithal	2.72	7.42	0.72	7.59	0.87	.7.82	1.09	7.93	82.44
4	Dherdu	Kaithal	2.68	7.93	0.53	8.00	0.94	8.15	1.14	8.20	83.61
5	Khedarpur	Kaithal	2.38	7.98	0.64	8.02	1.11	8.20	1.37	8.30	83.08
6	Bir Amin	Kurukshetra	2.76	7.75	0.97	7.81	1.21	7.89	1.26	8.18	80.40
7	Khaspur	Kurukshetra	2.69	8.00	0.63	8.16	0.92	8.23	1.17	8.49	83.55
8	Mainmati	Karnal	2.27	6.99	0.74	7.42	1.06	7.87	1.23	8.05	82.53
9	Sultanpur	Karnal	2.64	7.75	0.69	7.82	1.21	7.97	1.31	8.20	81.57
10	Sultanpur	Karnal	2.78	7.21	0.56	7.70	0.84	7.82	0.98	8.17	83.30
	Average		2.56	7.42	0.67	7.59	0.98	7.77	1.18	7.99	82.47

DAS: days after spray; T: treated; UC: untreated control

Table 3. Efficacy of flubendiamide 20% WG on infestation of yellow stem borer, *Scirpophaga incertulas* in rice at farmers, field during *Kharif*, 2020 (after first spray)

Locations	Village	District	Dead heart (%) at 1 day before spray		Dead heart (%) at 5 DAS		Dead heart (%) at 10 DAS		Dead heart (%) at 15 DAS		Decrease in yellow stem borer infestation over untreated control (%)
			T	UC	T	UC	T	UC	T	UC	
1	Pabla	Kaithal	5.62	5.72	2.14	6.81	1.82	6.90	1.92	6.94	56.38
2	Chandlana	Kaithal	5.45	5.54	2.15	5.91	2.07	6.72	2.10	6.80	52.86
3	Chuhar Majra	Kaithal	5.38	5.57	2.20	5.94	2.10	6.20	2.22	6.30	50.44
4	Dherdu	Kaithal	5.30	5.43	2.02	5.80	1.56	6.15	1.72	6.27	55.18
5	Khedarpur	Kaithal	5.46	5.61	2.34	5.74	1.70	5.83	1.76	5.92	51.26
6	Bir Amin	Kurukshetra	5.35	5.68	2.25	6.21	1.42	6.34	1.52	6.54	57.45
7	Khaspur	Kurukshetra	5.38	5.53	2.11	5.67	1.28	5.84	1.41	6.01	55.84
8	Mainmati	Karnal	5.49	5.67	2.27	5.95	1.73	6.04	1.82	6.08	52.36
9	Sultanpur	Karnal	5.04	5.26	2.17	5.38	1.65	5.44	1.69	5.58	51.29
10	Sultanpur	Karnal	4.87	5.19	2.18	5.23	1.75	5.46	1.81	5.64	50.70
	Average		5.33	5.50	2.18	5.86	1.71	6.09	1.80	6.21	56.11

DAS: days after spray; T: treated; UC: untreated control

Table 4. Efficacy of flubendiamide 20% WG on infestation of yellow stem borer, *Scirpophaga incertulas* in rice at farmers, field during *Kharif*, 2020 (after second spray)

Locations	Village	District	Dead heart (%) at 1 day before spray		Dead heart (%) at 5 DAS		Dead heart (%) at 10 DAS		Dead heart (%) at 15 DAS		Decrease in yellow stem borer infestation over untreated control (%)
			T	UC	T	UC	T	UC	T	UC	
1	Pabla	Kaithal	2.21	7.12	1.65	7.21	1.06	7.30	1.21	7.36	78.85
2	Chandlana	Kaithal	2.26	6.84	1.52	6.94	1.11	6.98	1.18	7.12	78.23
3	Chuhar Majra	Kaithal	2.31	6.34	1.68	6.56	1.13	6.76	1.23	6.86	76.06
4	Dherdu	Kaithal	1.94	6.31	1.70	6.54	1.12	6.65	1.24	6.75	77.14
5	Khedarpur	Kaithal	1.92	5.98	1.66	6.14	1.05	6.45	1.16	6.64	77.03
6	Bir Amin	Kurukshetra	1.87	6.59	1.55	6.71	1.12	6.85	1.19	6.98	78.88
7	Khaspur	Kurukshetra	1.91	6.20	1.81	6.35	1.04	6.40	1.25	6.55	76.43
8	Mainmati	Karnal	2.15	6.11	1.77	6.30	1.03	6.34	1.16	6.46	75.76
9	Sultanpur	Karnal	2.08	5.65	1.67	5.91	1.02	5.95	1.21	6.01	74.57
10	Sultanpur	Karnal	2.10	5.72	1.68	5.80	1.15	5.91	1.23	6.08	73.80
	Average		2.08	6.29	1.67	6.45	1.08	6.56	1.21	6.68	76.68

DAS: days after spray; T: treated; UC: untreated control

Table 5. Efficacy of flubendiamide 20% WG on yield of rice, cost benefit ratio and incremental cost benefit ratio at farmers, field during *Kharif*, 2020

Locations	Village	District	Cost of insecticides for two sprays/ha (Rs.)	Labour cost for two sprays/ha (Rs.)	Total cost/ ha (Rs.)	Yield (q/ha) T	Yield (q/ha) UC	Increase in yield over UC (%)	Additional yield (q/ ha)	Market rate rice grain (Rs./q)	Additional gross income/ ha (Rs.)	Additional net income/ha (Rs.)	Incremental Cost benefit ratio
1	Pabla	Kaithal	1160	1250	2410	37.65	32.46	13.78	5.19	4482	23262	20852	1: 8.65
2	Chandlana	Kaithal	1160	1250	2410	36.35	33.40	8.12	2.95	4265	12582	10172	1: 4.22
3	Chuhar Majra	Kaithal	1160	1250	2410	36.85	31.75	13.84	5.10	4350	22185	19775	1: 8.20
4	Dherdu	Kaithal	1160	1250	2410	37.49	31.48	16.03	6.01	4295	25813	23403	1: 9.71
5	Khedarpur	Kaithal	1160	1250	2410	37.85	32.08	15.24	5.77	4287	24736	22326	1: 9.26
6	Bir Amin	Kurukshetra	1160	1250	2410	38.20	31.83	16.68	6.37	4124	26270	23860	1: 9.90
7	Khaspur	Kurukshetra	1160	1250	2410	35.46	31.24	11.90	4.22	4263	17990	15580	1: 6.46
8	Mainmati	Karnal	1160	1250	2410	36.20	32.60	9.94	3.60	4370	15732	13322	1:5.53
9	Sultanpur	Karnal	1160	1250	2410	37.45	31.86	14.93	5.59	4280	23925	21515	1: 893
10	Sultanpur	Karnal	1160	1250	2410	37.89	33.72	11.00	4.17	4420	18431	16021	1: 6.65
Mean			1160	1250	2410	37.14	32.24	13.15	4.90	4314	21093	18683	1: 7.75

T: treated; UC: untreated control; market rate of flubendiamide 20% WG: Rs. 5800/kg; labour cost for spray: Rs. 625/ha for one spray

the untreated control as in first spray (Table 4). Mean per cent reduction over control was recoded 76.68%.

Our results indicated that there was no difference in terms of leaf damage and dead hearts before insecticidal applications against rice leaf folder and yellow stem borer in rice. After both the applications, flubendiamide 20 WG @ 25 g a.i. ha^{-1} markedly reduced leaf and stem damage as compared to untreated control. Similar results were observed by Hurali *et al.* (2019) who reported that flubendiamide 0.7 GR @ 100 g a.i. ha^{-1} gave maximum per cent reduction over control in case of dead hearts (85.68 & 85.48) in rice during *Kharif,* 2015 and 2016, respectively. Similarly, highest efficacy of flubendiamide against rice insect pests (rice leaf folder and yellow stem borer) was observed by Reddy *et al.* (2019) and Randhawa *et al.* (2018). Arulkumar *et al.* (2019) investigated effect of foliar spray of flubendiamide 20 WG on infestation of yellow stem borer infestation in rice. They reported infestation of yellow stem borer to be 6.48% dead heart after two sprays of flubendiamide 20 WG @ 25 g a.i. ha^{-1} as against 19.81% in untreated control. Studies of Zala and Sipai (2021) who reported that application of flubendiamide 20 WG @ 25 g a.i. ha^{-1} recorded 12.51% leaf damage infestation of *C. medinalis* as against 28.21% in untreated control also support present investigations. Seni (2019) made studies on spray of novel insecticide, Rynaxypyr 20 SC @ 150 ml ha^{-1} and reported that yellow stem borer infestation was recorded 3.63% (dead heart) in treated plots as compared to 8.66% in control partially support present investigations.

No phyto toxicity symptoms *viz.,* leaf tip burning, leaf chlorosis, vein clearing, leaf necrosis, leaf epinasty, leaf hyponasty, wilting, stunting and hyponasty were inflicted by flubendiamide 20 WG @ 25 g a.i. ha^{-1} on the rice crop during *kharif,* 2020. Similarly, Sudhanan *et al.* (2017) did not observe any phyto toxicity symptom of flubendiamide 20 WG @ 50, 100 and 200 g a.i. ha^{-1}in sugarcane crop partially support present investigations.

Average grain yield (37.14 q/ha) was observed from different multi-location trials in twice application of flubendiamide 20 WG @ 25 gm a.i. ha^{-1} as compared to untreated control (32.24 q/ha). Average per cent increase in yield over untreated control at 10 locations was recorded to be 13.15% (Table 5). Incremental cost benefit ratio in flubendiamide 20 WG @ 25 g a.i. ha^{-1} was recorded to be 1: 7.75 (Table 5). Results of Zala and Sipai

(2021) who recorded rice yield of 54.01 q ha^{-1} in two sprays of flubendiamide 20 WG @ 25 gm a.i. ha^{-1} as compared to 34.33 q ha^{-1} in untreated control support present findings. Similarly, in a fungicide and insecticide compatibility experiment, Biswas (2012) found that flubendiamide 480 SC increased the rice grain yield by 3875 kg ha^{-1}. Ghoghari *et al.* (2019) conducted experiment for control of yellow stem borer in rice and exhibited that flubendiamide 20 WG @ 2.5 g per 10 liters of water gave maximum yield 67.59 qha^{-1}) as compared to the other treatments. Hurali *et al.* (2019) showed that flubendiamide 0.7% GR @ 100 g a.i. ha^{-1} gave maximum grain yield of rice *i.e.,* 66.29 and 69.14 q ha^{-1} during *Kharif,* 2015 and 2016, respectively. Literature is silent with regard to ICBR in rice. However, Sridhar and Sharma (2015) investigated that application of flubendiamide 20 WG @ 60 g a.i. ha^{-1} was found most effective with better incremental cost benefit ratio as compared to the check insecticides in soybean crop.

4. Conclusion

The results of present investigations on evaluation of efficacy of flubendiamide 20% WG against rice leaf folder and yellow stem borer in basmati rice concluded that spray of flubendiamide 20 WG @ 25 g a.i. ha^{-1} in 500 litre water ha^{-1} first at the tillering stage (30 DAT) and second at panicle initiation stage (50 DAT) or when pests crosses ETL was found as an effective insecticidal treatment in reducing infestation of both pests drastically with no phyto toxicity symptoms and increased grain yield.

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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 both authors (MSJ & OPC).

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