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K Srinivas
Division of Entomology, Indian Council of Agriculture Research-Indian Agricultural Research Institute, New Delhi, India

M Raghuraman
Professor, Department of Entomology and Agricultural Zoology, Banaras Hindu University, Uttar Pradesh, India

Anil Kumar ST
Division of Entomology, Indian Council of Agriculture Research-Indian Agricultural Research Institute, New Delhi, India

Uday Kumar E
Division of Entomology, Indian Council of Agriculture Research-Indian Agricultural Research Institute, New Delhi, India

Corresponding Author:
K Srinivas
Division of Entomology, Indian Council of Agriculture Research-Indian Agricultural Research Institute, New Delhi, India

Management of paddy leaf folder, *Cnaphalocrocis medinalis* (Guenee) with novel molecules of pesticides

K Srinivas, M Raghuraman, Anil Kumar ST and Uday Kumar E

Abstract
The field experimental study was conducted during 2018-19 with a rice variety, Moti, to evaluate the bio-efficacy of the pyridine group insecticide, flonicamid 50% WG alongside a few major novel insecticides including chlorpyrifos 19% ME, imidacloprid 17.8 SL, thiamethoxam 25%WG, and fipronil 5% SC against rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) at BHU, Varanasi. it was discovered that chlorpyrifos and thiamethoxam were the most effective insecticides, causing 4.11% and 4.10% leaf damage, respectively. The rest of the insecticides, such as flonicamid @ 100g a.i/ha (5.97%), flonicamid @ 75g a.i/ha (6.41%), flonicamid @ 50g a.i/ha (6.85%), and fipronil (8.65%), were less effective in decreasing leaf folder damage. The plot treated with flonicamid @ 100g a.i/ha had the highest yield, with 31.25 percent, which might be due to its role in enhancing the plant vigour to tolerate pest damage, followed by flonicamid @ 75g a.i/ha (30.46 percent), fipronil (27.68 percent), flonicamid @ 50g a.i/ha (27.04 percent), chlorpyrifos (25.22 percent), imidacloprid (21.41 percent), and thiamethoxam (14.65 percent).

Keywords: Bio-efficacy, leaf folder, pyridine group, flonicamid, fipronil, chlorpyrifos

Introduction
Rice is the world's most significant staple food crop, with more than half of the world's population relying on it (FAO, 2004; Heinrichs *et al*., 2017) [1, 2]. More than 100 insect pests attack the rice crop, with 20 of them causing economic losses. Lepidopteron insects, such as the yellow stem borer, leaf folder, and case worm, are among those responsible for significant losses. Cnaphalocrocis medinalis (Guenee) (Pyralidae: Lepidoptera), the rice leaf folder, is the most damaging leaf-feeding insect pest. Under epidemic conditions, yield reductions of up to 80% are possible. The rice leaf folder was once a small rice pest, but it has now become a major pest for a variety of reasons. It causes serious issues in locations where higher nitrogen fertilizer levels have been applied. It causes 50-70 percent leaf loss and a 50 percent drop in rice output under ideal environmental conditions (Kushwaha and Singh, 1984) [3]. From October to January, there is a high prevalence of leaf folder. The larva folds the leaves by binding the edges, as well as the tip to the base, and feeds on them by being inside the leaf fold, causing chlorophyll to be lost and the leaves to change into white papery-like structures with longitudinal lines. Leaves dry up and shed away in severe situations of injury (Shrivastava *et al*, 1989) [4]. As a result, sufficient precautions should be taken to manage resistance by using pesticides with diverse modes of action in a reasonable and alternative manner. By considering the above circumstance, the current experimental investigation was undertaken to demonstrate the bio-efficacy of newer insecticides with diverse mechanisms of action against rice leaf folder.

Material and Methods
The experiment was conducted at Agricultural Research Farm, BHU, Varanasi, U.P. during 2018-19 to show the bio-efficacy of a few newer molecules *viz*., T_1= flonicamid 50% WG @ 50g a.i/ha; T_2= flonicamid 50% WG @ 75g a.i/ha; T_3 = flonicamid 50% WG @ 100g a.i/ha; T_4 = chlorpyrifos 19% ME @ 180g a.i/ha; T_5 = imidacloprid 17.8% SL @ 25g a.i/ha; T_6 = thiamethoxam 25% WG @ 25g a.i/ha; T_7 = fipronil 5% SC @ 75g a.i/ha, and T_8 = control against rice leaf folder in Moti variety of rice. It was grown in a Randomized Block Design with three replications and eight treatments. Transplanting was carried out with 25-day-old seedlings at a 20x15 cm spacing. To apply the treatments, a pneumatic hand sprayer with a spray fluid capacity of 500 l ha^{-1} was used. Soap powder @ 0.2 percent (200 g/100 lit) is added to the spray fluid for enhanced pesticide solution application on the crop (Anjarwalla *et al*.

2016) [5]. Two sprayings were used in the evenings at 60 days (vegetative stage) and 90 days (reproductive stage) after transplantation, respectively. We counted the number of damaged and total leaves on 10 randomly selected hills in each plot. A leaf that has sustained more than 30% damage has been classified as damaged. For both the first and second sprays, the number of impacted tillers in 10 randomly selected hills was recorded during 1 Day Before Spraying (DBS), 1st, 3rd, 7th, 10th, and 14th Days After Spraying (DAS). The proportion of leaf damage was estimated using the formula below:

$$\%\ leaf\ damage = \frac{no.of\ damaged\ leaves}{total\ number\ of\ leaves} X100$$

Pesticidal Plants. World Agroforestry Centre (ICRAF), Nairobi, Keny

Statistical Analysis

The collected data were subjected to an ANOVA, and a comparison was done between the observed and tabulated F values at a 5% level of significance. CD calculated the meaningful difference between the treatments at a 5% level of significance (Gomez and Gomez, 1984) [6].

Results and Discussion

1st spraying: It was found that the% reduction of leaf folder damage over the control was highest in the plots treated with imidacloprid (31.98%) and the lowest in fipronil treated plot (23.87%) on 1st DAS. During the 3rd DAS and 7th DAS, it was reported that the% reduction of damage was highest in the plots treated with thiamethoxam (74.38% and 74.18% respectively), and the lowest in the fipronil treated plot (30.56% and 30.48% resp.). But, during the 10th DAS, 14th DAS, the damage reduction was more in chlorpyrifos (68.72%, 66.28% resp.), while fipronil was noticed with the lowest reduction of damage (28.85%, 6.13% resp.).

However, after the first spray, it was reported that chlorpyrifos and thiamethoxam were the most effective insecticides with a minimum of 4.27% leaf damage (Table 1). While the plots treated with imidacloprid, and fipronil showed 5.23% and 8.48% of leaf damage resp. Among the flonicamid treated plots *viz*, the damage in 100g a.i/ha with 6.63% was on par with 75g a.i/ha (6.84%) followed by flonicamid @ 50g a.i/ha (7.63%). It was also found that the mean% reduction of leaf folder damage over the control was highest in the plot treated with thiamethoxam (61.72%) and the lowest reduction of damage was noticed in the fipronil treated plot (23.38%).

2nd spraying

The plots treated with thiamethoxam during the 1st, 3rd, 7th, and 14th DAS showed the greatest reduction in leaf folder damage over the control, with damage reductions of 45.96%, 60.68%, 73.43%, and 64.12%, respectively. During the 10th DAS, chlorpyrifos was found to be effective against the leaf folder, with a maximum damage reduction of 61.79%. However, the fipronil-treated plot had the lowest damage reduction, with 25.02%, 9.22%, 33.59%, 25.10%, and 14.2% during the 1st, 3rd, 7th, 10th, and 14th DAS, respectively.

Table 1: Bio-efficacy of newer insecticides against *Cnaphalocrosis medinalis* after the first insecticidal spray during *Kharif* 2018-19

Treatments	Pre count 1 DBS	Mean% leaf damage of leaf folder after 1st spray					Mean
		1 DAS	3 DAS	7 DAS	10 DAS	14 DAS	
T_1	10.43* (18.8) **	8.16 (16.5)	7.14 (15.4)	7.29 (15.6)	7.45 (15.8)	8.10 (16.5)	7.63(16.0)
T_2	10.76 (19.1)	8.05 (16.4)	6.22 (14.4)	6.25 (14.4)	6.53 (14.7)	7.14 (15.4)	6.84 (15.1)
T_3	10.01 (18.4)	7.86 (16.2)	6.10 (14.2)	6.13 (14.3)	6.27 (14.4)	6.80 (15.1)	6.63 (14.9)
T_4	10.04 (18.4)	7.80 (16.2)	3.09 (10.1)	3.12 (10.1)	3.63 (10.9)	3.73 (11.1)	4.27 (11.9)
T_5	10.43 (18.8)	7.56 (15.9)	4.17 (11.7)	4.20 (11.8)	4.93 (12.8)	5.30 (13.3)	5.23 (13.2)
T_6	10.12 (18.5)	7.93 (16.3)	2.90 (9.8)	2.93 (9.8)	3.73 (11.1)	3.85 (11.3)	4.27 (11.9)
T_7	9.96 (18.3)	8.08 (16.5)	7.74 (16.1)	7.77 (16.1)	8.53 (16.9)	10.30 (18.7)	8.48 (16.9)
T_8	10.00 (18.4)	10.66 (19.0)	11.20 (19.5)	11.23 (19.5)	11.55 (19.8)	11.02 (19.3)	11.13 (19.4)
C.D @ 5%	NS	0.03	0.17	0.19	0.13	0.14	
SE(±m)	-	0.01	0.06	0.06	0.04	0.04	

* Mean of three replications, ** Figures in the parenthesis are ARC sine transformed values, DBS – the day before spraying, DAS - days after spraying, NS- non-significant

However, following the second spraying, it was discovered that chlorpyrifos and thiamethoxam were the most effective insecticides, causing 4.11% and 4.10% leaf damage, respectively (Table 2). The rest of the insecticides, such as flonicamid @ 100g a.i/ha (5.97%), flonicamid @ 75g a.i/ha (6.41%), flonicamid @ 50g a.i/ha (6.85%), and fipronil (8.65%), were less effective in decreasing leaf folder damage. It was also discovered that the plot treated with thiamethoxam (60.62%) had the greatest reduction in leaf folder damage in comparison to the control, whereas the plot treated with fipronil had the least reduction in damage (21.43%).

After the two insecticidal sprayings, thiamethoxam and chlorpyrifos were found to be the most effective in reducing the damage caused by the leaf folder and it was similar to the research findings of Sarao *et al.*, 2008 [7] & Bhavani, 2006 [8]. Plots treated with imidacloprid showed the mean value of 5.23%age of leaf damage and this result was in accordance with Seetharamu *et al.*, (2005) [9], and Wang *et al.*, (2008) [10] who reported that imidacloprid treated plots were subjected to less infestation of leaf folder. Remaining insecticides *viz*. flonicamid @ 100g ai/ha (6.63%), flonicamid @ 75g ai/ha (6.84%) (Mallikarjuna Jeer, 2014) [11], flonicamid @ 50g ai/ha (7.63%) and fipronil (8.48%) (Sarao *et al.*, 2008 [7] and Singh *et al*., 2010) [12] were less effective in reducing the damage incurred by the leaf folder in rice crop.

Table 2: Bio-efficacy of newer insecticides against *Cnaphalocrosis medinalis* after second insecticidal spray during *kharif* 2018-19

Treatments	Pre-count	Mean% leaf damage of leaf folder after 2nd spray					Mean
	1DBS	1DAS	3DAS	7DAS	10DAS	14DAS	
T_1	8.22* (16.6)**	6.14 (14.33)	6.68 (14.9)	6.48 (14.7)	6.72 (15.0)	8.24 (16.6)	7.08 (15.4)
T_2	8.13 (16.5)	5.90 (14.0)	6.32 (14.5)	6.12 (14.3)	6.38 (14.6)	7.34 (15.7)	6.70 (15.0)
T_3	8.01 (16.4)	5.80 (13.9)	5.78 (13.9)	5.48 (13.5)	5.90 (14.0)	6.90 (15.2)	6.31 (14.5)
T_4	7.19 (15.5)	6.16 (14.3)	3.50 (10.7)	3.42 (10.6)	3.60 (10.9)	3.90 (11.3)	4.63 (12.4)
T_5	8.14 (16.5)	6.11 (14.3)	4.54 (12.3)	4.34 (12.0)	4.70 (12.5)	6.10 (14.2)	5.65 (13.7)
T_6	9.16 (17.6)	5.93 (14.0)	3.68 (11.0)	3.15 (10.2)	4.93 (12.8)	4.30 (11.9)	5.19 (13.1)
T_7	9.03 (17.4)	8.11 (16.5)	8.38 (16.8)	7.76 (16.1)	8.86 (17.3)	10.13 (18.5)	8.71 (17.1)
T_8	9.10 (19.8)	10.90 (19.2)	9.31 (17.5)	11.78 (20.0)	11.92 (20.1)	11.90 (20.1)	10.82 (19.2)
C.D @ 5%	NS	0.06	2.53	0.18	0.13	0.16	
SE(±m)	-	0.02	0.82	0.06	0.04	0.05	

* Mean of three replications, ** Figures in the parenthesis are ARC sine transformed values, DBS – the day before spraying, DAS - days after spraying, NS- non-significant.

Table 3: Overall efficacies of newer insecticides against *Cnaphalocrosis medinalis* after two insecticidal sprays during *Kharif* 2018-19

Treatments	Dosage (g a.i. / ha)	% Leaf damage of leaf folder		Overall mean
		1st spray	2nd spray	
Flonicamid 50% WG	50	7.63 (16.04)	7.08 (15.4)	7.24 (15.6)
Flonicamid 50% WG	75	6.84 (15.16)	6.70 (15.0)	6.62 (14.9)
Flonicamid 50% WG	100	6.63 (14.92)	6.31 (14.5)	6.31 (14.5)
Chlorpyrifos 19% ME	180	4.27 (11.93)	4.63 (12.4)	4.19 (11.8)
Imidacloprid 17.8 SL	25	5.23 (13.22)	5.65 (13.7)	5.19 (13.1)
Thiamethoxam 25% WG	25	4.27 (11.93)	5.19 (13.1)	4.33 (12.0)
Fipronil 5% SC	75	8.48 (16.93)	8.71 (17.1)	8.57 (17.0)
Control	-	11.13 (19.49)	10.82 (19.2)	11.15 (19.5)

* Mean of two sprayings, ** Figures in the parenthesis are ARC sine transformed values

Impact of insecticidal treatments on yield

Insecticides were sprayed to lessen the damage caused by major insect pests of rice, which had an indirect effect on rice productivity. Among the insecticides used, flonicamid @ 100g a.i/ha produced the highest paddy yield, with 44.81 q/ha, followed by flonicamid @ 75g a.i/ha with 44.54 q/ha (Table 4) (Seni and Naik, 2017)[13]. Remaining insecticides *viz* fipronil @ 43.59 q/ha, flonicamid with 43.37 q/ha, chlorpyrifos @ 42.75 q/ha, imidacloprid @ 41.45 q/ha, and thiamethoxam @ 39.14 q/ha were also effective in improving the yield of rice when compared to the yield of control @ 34.14 q/ha. The plot treated with flonicamid @ 100g a.i/ha had the highest yield, with 31.25 percent, followed by flonicamid @ 75g a.i/ha (30.46 percent), fipronil (27.68 percent), flonicamid @ 50g a.i/ha (27.04 percent), chlorpyrifos (25.22 percent), imidacloprid (21.41 percent), and thiamethoxam (14.65 percent).

Table 4: Impact of newer insecticides on yield of rice during *Kharif* 2018-19

SI	Treatments	Dose (g a.i/ha)	Yield (quintals/ha)	% Increase over control
1	Flonicamid 50% WG	50	43.37	27.04
2	Flonicamid 50% WG	75	44.54	30.46
3	Flonicamid 50% WG	100	44.81	31.25
4	Chlorpyrifos 19% ME	180	42.75	25.22
5	Imidacloprid 17.8 SL	25	41.45	21.41
6	Thiamethoxam 25% WG	25	39.14	14.65
7	Fipronil 5% SC	75	43.59	27.68
8	Control	0	34.14	27.04
C.D @ 5%			-	-
SE(±m)			-	-

Conclusion

Chlorpyrifos 19% ME was determined to be the most efficient pesticide against leaf folder, followed by thiamethoxam 25% WG and fipronil, which was the least effective. Because flonicamid may play a function in boosting plant development and preserving vigour, the yield was higher in flonicamid treated plots than in chlorpyrifos treated plots (Jiang *et al*., 2020) [14]. To avoid the development of resistance in the leaf folder, chlorpyrifos is recommended, but flonicamid is particularly efficient against the sucking pests of paddy,

despite the increased yield in the crop infested with leaf folder.

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