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Efficacy of Various Insecticides against Leaf Folder *Cnaphalocrocis medinalis* (Guenee) in Rice and the Calculation of the Benefit-cost Ratio

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was conducted at Heera Puri research field, Institute of Agriculture and Natural Sciences, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur during *Kharif*, 2023. The relative effectiveness of six insecticides viz., Flubendiamide 39.35 % SC, Chlorpyriphos 20 EC, Acephate 95 SC, Chlorantraniliprole 18.5 SC, Fipronil 5 SC, Cartap hydrochloride 50% SP and

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Control. The study revealed that the treatment Flubendiamide 39.35% SC was found most effective followed by Chlorantraniliprole 18.5 SC, and Fipronil 5 SC whereas the highest infestation was recorded in the control plot. The significantly higher grain yield was obtained in Flubendiamide 39.35% SC treated plots which are followed by Chlorantraniliprole 18.5 SC, Fipronil 5 SC, Cartap hydrochloride 50% SP, Acephate 95 SC and Chlorpyriphos 20 EC. The highest increase in yield over control was reported in the plot treated with Flubendiamide 39.35% SC followed by Chlorantraniliprole 18.5 SC, Fipronil 5 SC, Cartap hydrochloride 50% SP, Acephate 95 SC, and Chlorpyriphos 20 EC. The economics of various treatments based on net profit and cost of plant protection revealed that. the highest cost: benefit ratio of Chlorpyriphos 20 EC was followed by Chlorantraniliprole 18.5 SC, followed by Acephate 95 SC, Fipronil 5 SC and the lowest benefit-cost ratio was reported in plots treated with Cartap hydrochloride 50% SP.

Keywords: Bio efficacy; rice; Oryza sativa; leaf folder; BC Ratio; Gorakhpur; Eastern Uttar Pradesh.

1. INTRODUCTION

"Rice, *Oryza sativa* L. is an important cereal crop of the world, known as the king of cereals, and forms the staple food crop for more than two-thirds of the population of India and more than 65 per cent of the world population" [1,2]. "The slogan "Rice is life" is the most important for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural households" [3,4]. "Decreases in rice yields have been attributed to several biotic and abiotic factors. Insects, mites, and nematode pests are the key biotic stresses limiting rice production in India" [5]. The annual yield loss due to insect pests in India varies from 21 to 51 per cent (Jaglan *et al.* [6], Singh and Dhaliwal, 1994), and in the world, it varies from 26 to 34 per cent [7]. About 1,000 species of invertebrate pests have been reported to infest rice in fields of which one dozen species cause significant economic losses in Asian countries [8] including the yellow stem borer, *Scirpophaga incertulas* (Walker), leaf folder, *Cnaphalocrocis medinalis* (Guenee), brown plant hopper, *Nilaparvata lugens* (Stal.), green leaf hopper, *Nephotettix virescens* (Distant) and Asian rice gall midge, *Orseolia oryzae* (Wood-Mason) [9]."The crop growth period between 30-60 days after transplanting was most vulnerable resulting in major yield losses (20- 68%) mainly due to stem borer, gall midge, leaf folder, and brown plant hopper. Beyond 60 days from transplanting, the crop damage is inflicted by stem borer and leaf folder causing 10 to 48% damage" [10]. "The rice leaf folder acquired the status of a major pest throughout the world's tropical and subtropical rice-growing countries in the last three decades" [11,12]. "The shift from minor to major pest status has been attributed to the adoption of new rice-growing practices that accompanied the introduction of high-yielding varieties" (Kulshreshtha *et al*., [13], Litsinger, 1989). "These practices included increased cropping intensity, irrigation and a high input of nitrogenous fertilizers and pesticides [14]. A large number of field trials, however, have shown that increasing nitrogenous fertilization usually leads to higher leaf folder injury levels" (Dale, 1994).

"Leaf folder infestation usually occurs during the late growth stages of rice crops. It inflicts the crop in vegetative and heading stages" (Prasad *et al*., 2004). "It damages the crop in its larval stage. Maximum damage to rice crops by the folder is caused by to reduction in the photosynthetic area of the flag leaf in the heading stage" Rajadurai *et al.* [15], Murugesan and Chelliah, 1983). "In severely affected the crop gives a scorched whitish appearance to infested plants and consequently drying of leaves" (Hajjar *et al.* [16], Kulshrestha, 1973). "Leaf folder damage can be observed at any stage of crop growth but is generally conspicuous during active tillering to the booting stage" (Khan *et al*., [17], Krishnaiah and Varma, 2011). "Each larva is capable of destroying several leaves by its feeding" [18]. A ten per cent increase in flag leaf damage by the leaf folder reduces grain yield by 0.13 g per tiller and reduces the number of filled grains by 4.5 per cent [19]. The peak incidence of rice leaf folder occurred in mid-September when the crop was at the panicle emergence stage [14]. High humidity and optimum temperature appeared to be important factors in increasing the population of the pest [20]. The application of high levels of nitrogen coupled with cloudy weather and low sunlight favors pest build-up. Empowering rice farmers to combat pests effectively, this research explores the best insecticide solutions to tackle the leaf folder menace. By uncovering the most efficient and budget-friendly options, we aim to boost crop yields and minimize financial losses for

agricultural communities. Through this study, we strive to cultivate a more sustainable future for rice production, where farmers thrive and the environment flourishes

2. MATERIALS AND METHODS

A field experiment was conducted in the Heera Puri research field, Deen Dayal Upadhyaya Gorakhpur University during the *kharif* 2023 in randomized block design (RBD) with 7 treatments including control replicated thrice. The insecticide treatments include T1: Flubendiamide 39.35 % SC, T2: Chlorpyriphos 20 EC, T3: Acephate 95 SC, T4: Chlorantraniliprole 18.5 SC, T5: Fipronil 5 SC @ 1.2 ml $^{-l,}$ T6: Cartap hydrochloride 50% SP, T7 Control. The variety Samba Mahsuri (BPT-5204) was grown in a plot size of 3x4 m with a spacing of 20x20 cm with a recommended package of practices excluding plant protection. Sprayings were given by using a hand compression knapsack high-volume sprayer during morning hours. The required spray fluid per plot is one liter. The plot in each treatment was sprayed with respective insecticides ensuring uniform coverage of insecticide. The treatments were imposed as and when the pest reached ETL. The data was recorded on the per cent leaf damage by leaf folder in 10 randomly selected hills from each plot recorded one day before the application of treatments and 2,7 and 10 DAS (Days After Spray). These percentages were transformed to the corresponding values and subjected to ANOVA and those mean values were compared by using the Least significant difference (LSD). The per cent reduction of leaf folder damage over control at each count was also calculated by using Abott's formula as given by Fleming and Retnakaran [21].

3. RESULTS AND DISCUSSION

The field bio-efficacy of certain insecticides against the leaf folder of rice during *Kharif* 2016 was assessed. The crop received two sprays during the crop period according to the ETL level of the pest population. The pretreatment data was recorded one day before spraying and the post-treatment data on the 3rd, 7^{th,} and 10th day after each spray. The mean reduction in the population was calculated for analysis. The pre-treatment observation showed that the percentage of leaf infestation varied from 14.46 to 14.58 per plant. This indicated that there were no significant variations across the treatments, suggesting that the pest infestation on the crop under study was relatively similar. The data presented in Table 1 and Fig. 1 revealed that three days after treatment, all the treatments were found significantly superior over the control (untreated) against leaf folder leaf infestation in rice. The treatment Flubendiamide 39.35% SC was found most effective with a minimum infestation of 7.36 per cent followed by Chlorantraniliprole 18.5 SC which registered 7.59 per cent infestation, Fipronil 5 SC (8.36 per cent), Cartap hydrochloride 50% SP (8.49 per cent), Acephate 95 SC (11.39 percent), Chlorpyriphos 20 EC (11.42 per cent) whereas the highest infestation was recorded in the control plot with 15.47 per cent infestation. The data presented in Table 1 and Fig.1 revealed that seven days after treatment, all the treatments were found significantly superior over the control (untreated) against leaf folder leaf infestation in rice. The treatment Flubendiamide 39.35 % SC was found most effective with a minimum infestation of 5.33 per cent followed by Chlorantraniliprole 18.5 SC which registered 6.53 per cent infestation, Fipronil 5 SC (7.08 per cent), Cartap hydrochloride 50% SP (7.76 per cent), Acephate 95 SC (8.39 per cent), Chlorpyriphos 20 EC (9.89 per cent) whereas the highest infestation was recorded in the control plot with 15.97 per cent infestation. The data presented in Table 1 and Fig. 1 revealed that ten days after treatment, all the treatments were found significantly superior over the control (untreated) against leaf folder leaf infestation in rice. The treatment Flubendiamide 39.35 % SC was found most effective with a minimum infestation of 4.45 percent followed by Chlorantraniliprole 18.5 SC which registered 5.26 percent infestation, Fipronil 5 SC @ 1.2 ml^{-l} (6.23 percent), Cartap hydrochloride 50% SP (6.91 percent), Acephate 95 SC (8.47 percent), Chlorpyriphos 20 EC (8.71 percent) whereas the highest infestation was recorded in the control plot with 22.15 percent infestation. The mean data presented in Table 3 and Fig. 3 revealed all the treatments were found significantly superior over the control (untreated) against leaf folder leaf infestation in rice. The treatment Flubendiamide 39.35 % SC was found most effective with a minimum infestation of 5.71 per cent followed by Chlorantraniliprole 18.5 SC which registered 6.46 per cent infestation, Fipronil 5 SC (7.22 per cent), Cartap hydrochloride 50% SP (7.72 per cent), Acephate 95 SC (9.42 per cent), Chlorpyriphos 20 EC (10.01 per cent) whereas the highest infestation was recorded in the control plot with 17.86 per cent infestation. The data presented in Table 2 and Fig. 2 revealed that three days after the second treatment, all the treatments were found

significantly superior over the control (untreated) against leaf folder leaf infestation in rice. The treatment Flubendiamide 39.35% SC was found most effective with a minimum infestation of 6.68 per cent followed by Chlorantraniliprole 18.5 SC which registered 9.72 per cent infestation, Fipronil 5 SC (10.44 per cent), Cartap hydrochloride 50% SP (10.65 per cent), Acephate 95 SC (11.55 per cent), Chlorpyriphos 20 EC (11.75 per cent) whereas the highest infestation was recorded in the control plot with 13.61 per cent infestation. The data presented in Table 2 and Fig. 2 revealed that seven days after treatment, all the treatments were found significantly superior over the control (untreated) against leaf folder leaf infestation in rice. The treatment Flubendiamide 39.35 % SC was found most effective with a minimum infestation of 4.97 per cent followed by Chlorantraniliprole 18.5 SC which registered 6.89 per cent infestation, Fipronil 5 SC (7.53 per cent), Cartap hydrochloride 50% SP (7.82 per cent), Acephate 95 SC (8.11 per cent), Chlorpyriphos 20 EC (9.85 per cent) whereas the highest infestation was recorded in the control plot with 14.53 per cent infestation. The data presented in Table 2 and Fig. 2 revealed that ten days after treatment, all the treatments were found significantly superior over the control (untreated) against leaf folder leaf infestation in rice. The treatment Flubendiamide 39.35% SC was found most effective with a minimum infestation of 3.51 per cent followed by Chlorantraniliprole 18.5 SC which registered 4.95 per cent infestation, Fipronil 5 SC (6.11 per cent), Cartap hydrochloride 50% SP (6.45 per cent), Acephate

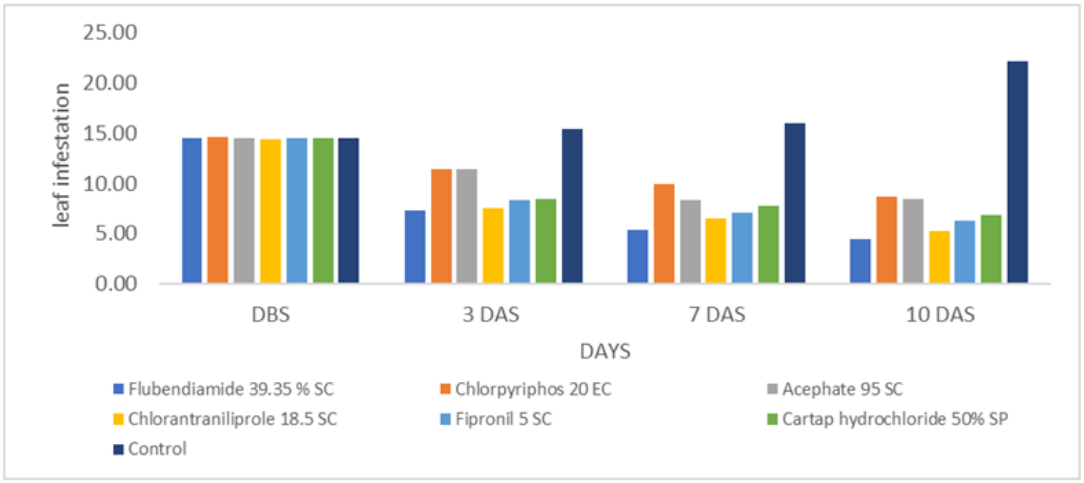

Fig. 1. Effect of various treatments on leaf infestation of rice leaf folder after the first spray

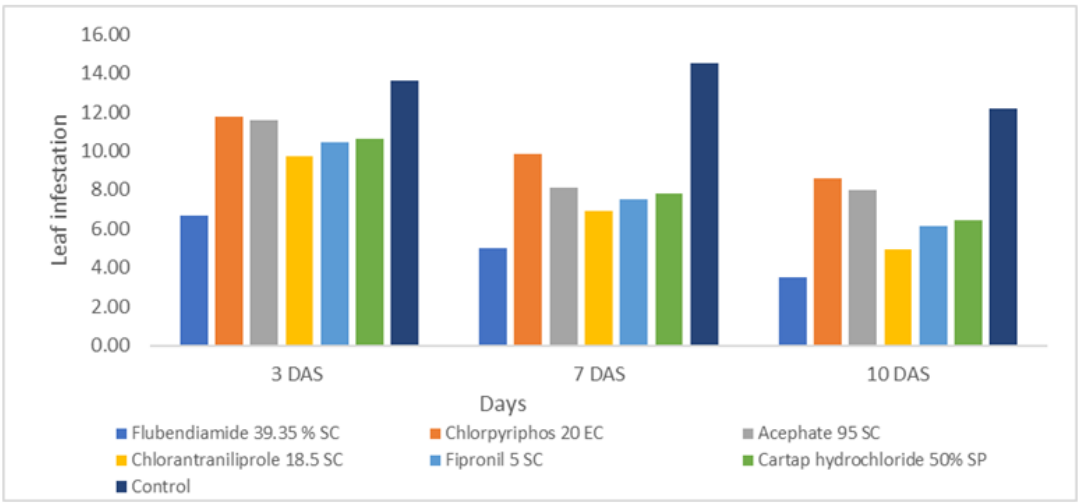

Fig. 2. Effect of various treatments on leaf infestation of rice leaf folder after the second spray

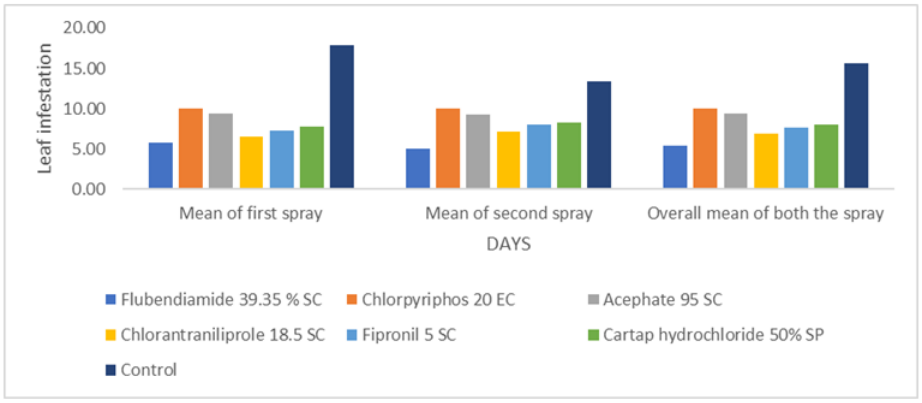

Fig. 3. Mean data of first spray, second spray, and overall mean of both the spray

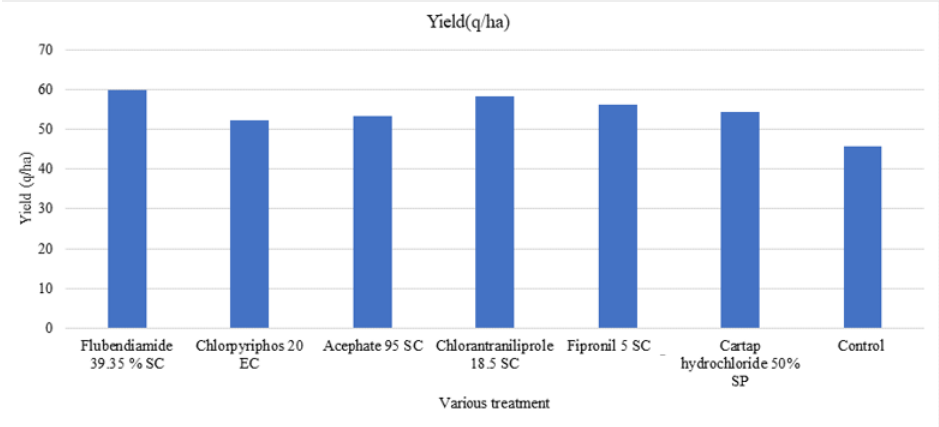

Fig. 4. Impact of various treatments on Yield (q/ha)

95 SC (8.01 per cent), Chlorpyriphos 20 EC (8.56 per cent) whereas the highest infestation was recorded in the control plot with 12.16 per cent infestation. The mean data presented in Table 3 and Fig. 3, revealed all the treatments were found significantly superior over the control (untreated) against leaf folder leaf infestation in rice. The treatment Flubendiamide 39.35 % SC was found most effective with a minimum infestation of 5.05 per cent followed by Chlorantraniliprole 18.5 SC which registered 7.19 per cent infestation, Fipronil 5 SC (8.03 per cent), Cartap hydrochloride 50% SP (8.31 per cent), Acephate 95 SC (9.22 per cent), Chlorpyriphos 20 EC (10.05 per cent) whereas the highest infestation was recorded in the control plot with 13.43 per cent infestation. The overall mean data of both the sprays revealed that the treatment Flubendiamide 39.35 % SC was found most effective with a minimum infestation of 5.38 per cent followed by Chlorantraniliprole 18.5 SC which registered 6.82 per cent infestation, Fipronil 5 SC (7.63 per cent), Cartap hydrochloride 50% SP (8.01 per cent), Acephate 95 SC (9.32 per cent), Chlorpyriphos 20 EC (10.03 per cent) whereas the highest infestation was recorded in the control plot with 15.65 per cent infestation. The superiority of flubendiamide conformed with the findings of Raju *et al.*, 2018, who reported a 3.69 per cent reduction in population. Similarly, Misra (2008) reported a 69.65 per cent reduction in the population over control and a lower leaf folder incidence (1.43 %) with flubendiamide @ 25g a.i/ha 10 days after spray. Similarly, Sekh et al. (2007) also recorded that the number of leaf folder-damaged leaves was reduced with flubendiamide @ 24 and 30 g a.i/ha (1.66 and 0.7/ hill). Javaregowda and Krishna Naik (2005) stated that flubendiamide @ 25 and 50 g a.i/ha was effective against leaf folder with 0.61 and 0.44 leaf folder damaged leaves per hill at 7 days after spray, respectively. The cumulative yield data revealed that the grain production gradually increased when the rice leaf folder was treated with different insecticides and marketable grain yield ranged from 52.24 to

Table 1. Efficacy of different treatments against leaf folder leaf infestation in rice 1st spray during *Kharif*, 2023

S.no	Treatment	Dose	Percentage infestation of leaf folder in rice			
			Before one day of spray	**After 3days of spray**	**After 7 days of spray**	**After 10 days of spray**
T1	Flubendiamide 39.35 % SC	0.20 ml/l	14.52 (3.93)	7.36 (2.89)	5.33 (2.51)	4.45 (2.33)
T2	Chlorpyriphos 20 EC	5%	14.58 (3.94)	11.42 (3.52)	9.89 (3.29)	8.71 (3.11)
T3	Acephate 95 SC	0.5g/l	14.52 (3.93)	11.39 (3.53)	8.39 (3.06)	8.47 (3.077)
T4	Chlorantraniliprole 18.5 SC	3%	14.46 (3.93)	7.59 (2.93)	6.53 (2.74)	5.26 (2.50)
T5	Fipronil 5 SC	5ml/l	14.48 (3.93)	8.36 (3.06)	7.08 (2.84)	6.23 (2.68)
T6	Cartap hydrochloride 50% SP	0.4g/l	14.55 (3.93)	8.49 (3.08)	7.76 (2.96)	6.91 (2.81)
T7	Control	Water	14.56 (3.94)	15.47 (4.05)	15.97 (4.11)	22.15 (4.81)
	SE +-		**0.004**	**0.005**	**0.006**	**0.006**
	C.D.9P=0.05)		**NA**	**0.016**	**0.017**	**0.019**

Table 2. Efficacy of different insecticides against leaf folder leaf infestation in rice 2nd spray

S.no	Treatments	Percentage infestation of leaf folder in rice		
		3 days after the spray	**7 days after the spray**	**10 days after the spray**
T1	Flubendiamide 39.35 % SC	6.68 (2.77)	4.97 (2.44)	3.51 (2.12)
T2	Chlorpyriphos 20 EC	11.75 (3.57)	9.85 (3.29)	8.56 (3.09)
T3	Acephate 95 SC	11.55 (3.54)	8.11 (3.018)	8.01 (3.02)
T4	Chlorantraniliprole 18.5 SC	9.72 (3.27)	6.89 (2.809)	4.95 (2.43)
T5	Fipronil 5 SC	10.44 (3.83)	7.53 (2.921)	6.11 (2.66)
T6	Cartap hydrochloride 50% SP	10.65 (3.41)	7.82 (2.970)	6.45 (2.72)
T7	Control	13.61 (3.82)	14.53 (3.940)	12.16 (3.62)
	SE +-	**0.006**	**0.007**	**0.005**
	C.D.9P=0.05)	0.020	0.023	0.015

Table 3. Efficacy of different insecticides against leaf folder leaf infestation

S. No	Treatment	Dose	1st spray mean	2nd spray mean	Overall mean
T1	Flubendiamide 39.35 % SC	0.20 ml/l	5.71	5.05	5.38
T2	Chlorpyriphos 20 EC	5%	10.01	10.05	10.03
T3	Acephate 95 SC	0.5g/l	9.42	9.22	9.32
T4	Chlorantraniliprole 18.5 SC	3%	6.46	7.19	6.82
T5	Fipronil 5 SC	5ml/l	7.22	8.03	7.63
T6	Cartap hydrochloride 50% SP	0.4g/l	7.72	8.31	8.01
T7	Control	Water	17.86	13.43	15.65

Table 4. Influence of various insecticide treatments on rice yield and increase in yield (%) compared to control

Number	Treatment	Yield	Increase in percentage over control
T 1	Flubendiamide 39.35 % SC	59.87	31.41
T 2	Chlorpyriphos 20 EC	52.24	14.66
T 3	Acephate 95 SC	53.21	16.79
T 4	Chlorantraniliprole 18.5 SC	58.12	27.57
T 5	Fipronil 5 SC	56.21	23.38
T 6	Cartap hydrochloride 50% SP	54.26	19.10
T 7	Control	45.56	0.00

Table 5. Economics of different insecticides against rice leaf folder

S.No.	Treatment	Yield (q/ha)	Insecticide Cost	Total cost of Plant Protection	Gross Income	Net Income	Benefit over control	B: C ratio
1	Flubendiamide 39.35 % SC	59.87	4110	5010	125128.3	120118.3	24897.9	4.97
2	Chlorpyriphos 20 EC	52.24	398	1298	109181.6	107883.6	12663.2	9.76
3	Acephate 95 SC	53.21	1057	1957	111208.9	109251.9	14031.5	7.17
4	Chlorantraniliprole 18.5 SC	58.12	1795	2695	121470.8	118775.8	23555.4	8.74
5	Fipronil 5 SC	56.21	2000	2900	117478.9	114578.9	19358.5	6.68
6	Cartap hydrochloride 50% SP	54.26	1625	2525	113403.4	110878.4	15658	6.20
7	Control	45.56			95220.4	95220.4		

59.87 q per ha. in contrast to the untreated plot, which produced the lowest fruit yield of 45.56 q per ha. The significantly higher grain yield (59.87 q per ha) was obtained in Flubendiamide 39.35 % SC treated plots which are followed by Chlorantraniliprole 18.5 SC (58.12 q per ha), Fipronil 5 SC (56.21 q per ha), Cartap hydrochloride 50% SP (54.26 q per ha), Acephate 95 SC (53.21 q per ha) and Chlorpyriphos 20 EC (52.24 q per ha) (Table 4 & Fig. 4). The increase in yield percentage over control ranged between 14.66 to 31.41 [22,23]. The highest increase in yield over control was reported in plot treated with Flubendiamide 39.35 % SC (31.41) followed by Chlorantraniliprole 18.5 SC (27.57), Fipronil 5 SC (23.38), Cartap hydrochloride 50% SP (19.10), Acephate 95 SC (16.79) and Chlorpyriphos 20 EC (14.66) (Table 4). The economics of various treatments based on net profit and cost of plant protection (Table 5) revealed that. the highest cost: benefit ratio is Chlorpyriphos 20 EC (9.76) followed by Chlorantraniliprole 18.5 SC (8.74), followed by Acephate 95 SC (7.17), Fipronil 5 SC (6.68) and the lowest benefit-cost ratio was reported in plots treated with Cartap hydrochloride 50% SP (6.20). The highest B: C ratio of Chlorpyriphos 20 EC may be due to its low price and dose concentration [24,25].

4. CONCLUSION

The study investigated the field bio-efficacy of various insecticides against the leaf folder pest in rice during the Kharif season of 2016. Flubendiamide 39.35% SC emerged as the most effective treatment, followed by Chlorantraniliprole 18.5 SC, Fipronil 5 SC, Cartap hydrochloride 50% SP, Acephate 95 SC, and Chlorpyriphos 20 EC. These treatments significantly reduced leaf folder infestation compared to the control plot, with the mean reduction in leaf folder population ranging from 5.38% to 15.65% across treatments. Consequently, Flubendiamide 39.35% SC resulted in the highest grain yield (59.87 q/ha), followed by other treatments, with the increase in yield percentage over control ranging from 14.66% to 31.41%. The economic analysis revealed that Chlorpyriphos 20 EC had the highest cost-benefit ratio (9.76), followed by other treatments. Overall, Flubendiamide 39.35% SC proved to be a viable option for managing leaf folders in rice crops, offering effective pest control and higher grain yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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