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BIOEFFICACY OF INSECTICIDES AGAINST FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J.E. SMITH) IN MAIZE

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SUMMAERY

The present study was conducted during the *Kharif* season of 2024 at the Instructional Farm, Department of Entomology, MPKV, Rahuri to evaluate the bioefficacy of selected insecticides against the fall armyworm, *Spodoptera frugiperda*. Six treatments, Thiamethoxam + Lambda-cyhalothrin, Spinetoram, Chlorantraniliprole, Emamectin benzoate, Lufenuron + Emamectin benzoate and an untreated controlwere planned in a Randomized Block Design with four replications. Insecticides were applied three times at 10dayintervals after the pest population reached the economic threshold level. Among the evaluated insecticides, Spinetoram 11.7% SC recorded the lowest infestation (9.77%) and showed superior performance compared to the remaining treatmentswhich exhibited 12.52 to 46.04% infestation. Chlorantraniliprole 47.85% SC and Emamectin benzoate 5% SG were the next effective treatments. Spinetoram also resulted in the highest cob yield (8.41 t/ha) and the maximum incremental cost-benefit ratio (1:6.47). The findings identify Spinetoram as the most effective and economically viable insecticidal option for sustainable management of fall armyworm in maize.

Key words: Maize, Fall armyworm, spinetoram, chlorantraniliprole, emamectin benzoate, bioefficacy

Maize (*Zea mays* L.), a member of the Poaceae family. It is one of the world's most important cereal crops and ranks third after rice and wheat in global and Indian production. Introduced to India from Central America in the early 17thcentury. Maize has evolved into a multipurpose crop valued for human consumption, livestock feed and diverse industrial applications such as starch, oil, biofueland baby corn production. In India, nearly 15 million farmers cultivate maize across 97.9 lakh hectares, contributing substantially to food security, nutritional supplyand the agricultural economy. The crop accounts for nearly 9% of the national food basket and generates significant employment across cultivation, processing and allied sectors.

Despite its agronomic and economic significance, maize productivity is severely constrained by several abiotic and biotic stresses. Among the biotic factors, insect pests constitute a major limiting component with more than 130 species reported to infest maize at various growth stages. The fall armyworm, *Spodoptera frugiperda* (J.E. Smith), a highly polyphagous and migratory pest native to the Americas, has emerged as one of the most destructive invasive pests of maize. FAW was reported in India in 2018 and rapidly spread across major maizegrowing regions due to its high fecundity, long-distance dispersal, wide host range exceeding 350 plant species and remarkable adaptability (Suganthi *et al.*, 2022). In India, FAW has caused significant yield losses ranging from 20 to 34% with greater reductions documented under severe infestations. Many maize farmers in India rely on rainfed farming and therefore prefer low-cost insecticidesacross crops, making it essential to evaluate the performance of commonly used newer formulations against *Spodoptera frugiperda*. This made chemical management increasingly challenging. In this context, the present study was undertaken to assess the bioefficacy of selected insecticides for effective management of *S. frugiperda* in maize.

MATERIALS AND METHODS

During *Kharif*, 2024, the experiment was conducted using a Rajarshri variety of maize. The study used a randomized block design (RBD) with four replications and six treatments. The crop was grown using all agronomical practices recommended by the university. Selected insecticidal treatments were applied as foliar sprays against fall armyworm using a knapsack sprayer fitted with a hollow-cone nozzle. Three insecticidal applications were carried out at 10day intervals, initiated when plant infestation reached 10–20%.The required quantity of insecticide was first mixed in a small amount of water and then diluted to the final spray volume, ensuring uniform mixing. Spraying was carried out in the early morning, taking care to prevent drift between plots. The sprayer was washed thoroughly before changing treatments. Treatment efficacy was assessed based on the reduction in FAW infestation, recorded from 30 randomly selected plants per plot one day before spraying and at 3rd, 5th, 7th and 10th days after each spray. Plotwise yields were measured and converted to t/ha. The ICBR was computed considering plant-protection costs. Data on bioefficacy were analysed using RBD procedures as outlined by Panse and Sukhatme (1985) and treatment differences were tested at the 5% significance level using the critical difference (CD).

RESULT AND DISCUSSION

Observations were systematically recorded oneday before sprayingand subsequently on the 3rd, 5th, 7th and 10th days after each spray. Following section presents a comprehensive discussion of the cumulative results derived from all three spray applications.

First spray

The first spray of insecticidal treatments resulted in a marked reduction in *Spodoptera frugiperda* infestation compared with the untreated control (Table 1). Initial observations confirmed uniform infestation levels across all plots. Spinetoram 11.7% SC consistently exhibited the highest efficacy, recording the lowest infestation on the 3rd (19.98%), 5th (10.29%), 7th (11.51%) and 10th (15.16%) days after treatment. Chlorantraniliprole 47.85% SC and Emamectin benzoate 5% SG were statistically at par and ranked next in effectiveness. Moderate suppression was achieved with Lufenuron 4% + Emamectin benzoate 1.5% EC and Thiamethoxam 12.6% ZC +

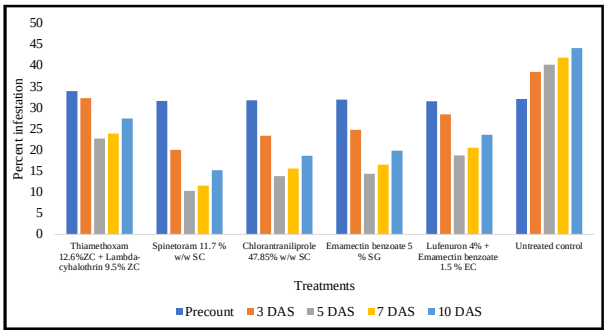

Fig. 1. Effect of different treatments on infestation of fall army worm on maize (First Spray).

TABLE 1
Effect of different treatments on infestation of fall army worm on maize
(First Spray)

Tr. No.	Treatment	Dose (g a.i./ha)	Per cent infestation of fall armyworm					
			Precount	3 DAS	5 DAS	7 DAS	10 DAS	Mean
T_1	Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC	27.50	33.89 (35.58)*	32.22 (34.57)	22.65 (28.41)	23.82 (29.20)	27.41 (31.56)	26.53 (33.76)
T_2	Spinetoram 11.7% w/w SC	30	31.54 (34.15)	19.98 (26.54)	10.29 (18.70)	11.51 (19.82)	15.16 (22.90)	14.23 (27.90)
T_3	Chlorantraniliprole 47.85% w/w SC	40	31.72 (34.26)	23.33 (28.87)	13.76 (21.76)	15.56 (23.22)	18.59 (25.52)	17.81 (29.85)0
T_4	Emamectin benzoate 5% SG	200	31.87 (34.25)	24.74 (29.81)	14.30 (22.15)	16.49 (23.93)	19.79 (26.39)	18.83 (30.33)
T_5	Lufenuron 4% + Emamectinbenzoate 1.5 % EC	(30+ 11.25)	31.47 (34.11)	28.39 (32.18)	18.66 (25.56)	20.50 (26.90)	23.57 (29.43)	22.78 (32.24)
T_6	Untreated control	-	32.01 (34.45)	38.43 (38.29)	40.13 (39.29)	41.81 (40.27)	44.06 (41.57)	41.11 (39.13)
	S.E.(m) ±	-	0.558	0.701	0.817	0.520	0.542	0.43
	CD @ 5 %	-	NS	2.14	2.50	1.59	1.66	1.28

*Figures in the parenthesis are arcsine transformed values, **DAS-Days After Spray.

Lambda-cyhalothrin 9.5% ZCwhile the untreated control consistently maintained the highest infestation levels. The mean infestation values further confirmed this trendwith Spinetoram recording the lowest overall infestation (14.23%) and the untreated control the highest (41.11%).

Second spray

The secondspray of insecticides significantly reduced *Spodoptera frugiperda* infestation compared to the untreated control (Table 2). By the third day after application, Spinetoram 11.7% SC exhibited the highest efficacy (10.61%), followed by Chlorantraniliprole 47.85% SC (13.14%) and Emamectin benzoate 5% SG (14.29%), while Lufenuron + Emamectin (18.16%) and Thiamethoxam + Lambda-cyhalothrin (21.36%) showed moderate suppression. Infestation further declined on the fifth and seventh dayswith Spinetoram maintaining the lowest levels (7.34% and 7.91%, respectively), whereas the untreated control consistently recorded the highest infestation (47.47% and 48.02%). On the tenth day after spraying, Treatment of Spinetoram remained most effective with infestation of 11.58%followed by Chlorantraniliprole (13.18%) and Emamectin benzoate (14.25%). The mean infestation across all observation periods was lowest in Spinetoramtreated plots (9.36%), followed by Chlorantraniliprole (11.82%) and Emamectin benzoate

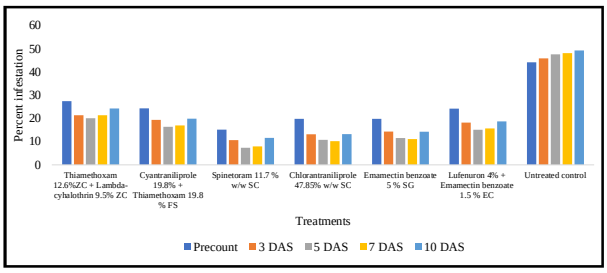

Fig. 2. Effect of different treatments on infestation of fall army worm on maize (Second Spray).

(12.80%), whereas the untreated control recorded the highest mean infestation (47.60%). These results confirm the superior and consistent efficacy of Spinetoram in controlling FAW under field conditions.

Third spray

The thirdspray of insecticides effectively suppressed *Spodoptera frugiperda* infestation compared to the untreated control (Table 3). By the third day after application, Spinetoram 11.7% SC recorded the lowest infestation (7.20%), followed by Chlorantraniliprole 47.85% SC (9.57%) and Emamectin benzoate 5% SG (10.45%), while Lufenuron + Emamectin (14.44%) and Thiamethoxam + Lambda-cyhalothrin (20.24 %) showed moderate control. The untreated control plot remained the most infested (51.41%). On the fifth and seventh days, Spinetoram continued to maintain superior efficacy

TABLE 2
Effect of different treatments on infestation of fall army worm on maize
(Second Spray)

Tr. No.	Treatment	Dose (g a.i./ha)	Per cent infestation of fall armyworm					
			Precount	3 DAS	5 DAS	7 DAS	10 DAS	Mean
T_1	Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC	27.50	27.41 (31.56) *	21.36 (27.50)	20.07 (25.88)	21.31 (27.48)	24.23 (29.48)	21.74 (32.16)
T_2	Spinetoram 11.7% w/w SC	30	15.16 (22.90)	10.61 (18.73)	7.34 (15.61)	7.91 (16.21)	11.58 (19.81)	9.36 (25.53)
T_3	Chlorantraniliprole 47.85% w/w SC	40	18.59 (25.52)	13.14 (21.22)	10.78 (19.16)	10.19 (18.59)	13.18 (21.24)	11.82 (27.45)
T_4	Emamectin benzoate 5% SG	200	19.79 (26.39)	14.29 (21.91)	11.54 (19.85)	11.11 (19.45)	14.25 (22.16)	12.80 (27.90)
T_5	Lufenuron 4 % + Emamectin benzoate 1.5% EC	(30+ 11.25)	23.57 (29.43)	18.16 (25.19)	15.08 (22.84)	15.68 (23.31)	18.66 (25.57)	16.89 (30.14)
T_6	Untreated control	-	44.06 (41.57)	45.75 (42.55)	47.47 (43.53)	48.02 (43.85)	49.16 (44.50)	47.60 (41.07)
	S.E.(m) ±	-	0.43	0.71	0.72	0.58	0.58	0.40
	C.D. @ 5 %	-	1.30	2.16	2.19	1.77	1.75	1.16

*Figures in the parenthesis are arcsine transformed values, **DAS- Days After Spray.

TABLE 3
Effect of different treatments on infestation of fall army worm on maize (ThirdSpray)

Tr. No.	Treatment	Dose (g a.i./ha)	Per cent infestation of fall armyworm					
			Precount	3 DAS	5 DAS	7 DAS	10 DAS	Mean
T_1	Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC	27.50	24.23 (29.48)*	20.24 (26.71)	17.28 (24.51)	19.07 (25.85)	22.66 (28.38)	19.81 (31.27)
T_2	Spinetoram 11.7% w/w SC	30	11.58 (19.81)	07.20 (15.53)	04.21 (11.81)	04.78 (11.00)	06.64 (14.92)	5.70 (22.36)
T_3	Chlorantraniliprole 47.85% w/w SC	40	13.18 (21.34)	9.57 (18.31)	06.57 (14.82)	05.98 (14.12)	09.58 (18.00)	7.92 (24.52)
T_4	Emamectin benzoate 5% SG	200	14.25 (22.16)	10.45 (18.84)	06.59 (14.87)	06.04 (14.20)	10.42 (18.78)	8.37 (24.85)
T_5	Lufenuron 4% + Emamectin benzoate 1.5% EC	(30+ 11.25)	18.66 (25.57)	14.44 (22.28)	11.10 (19.42)	12.61 (20.75)	16.39 (24.36)	13.63 (28.26)
T_6	Untreated control	-	49.16 (44.50)	51.41 (45.79)	51.98 (46.11)	52.55 (46.45)	53.67 (47.09)	52.40 (42.68)
	S.E.(m) ±	-	0.58	0.54	0.60	0.75	0.80	0.47
	CD @ 5 %	-	1.75	1.67	1.83	2.31	2.45	1.38

*Figures in the parenthesis are arcsine transformed values, **DAS-Days After Spray.

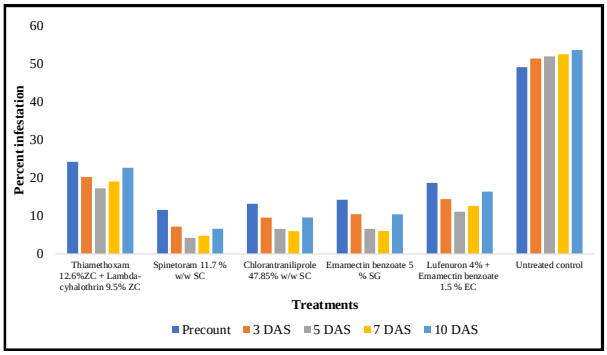

Fig. 3. Effect of different treatments on infestation of fall armyworm on maize (Third Spray).

(4.21% and 4.78%, respectively) with Chlorantraniliprole and Emamectin benzoate showing comparable effectiveness, whereas untreated plots recorded more than 50% infestation. By the tenth day, Spinetoram (6.64%) remained the most effective treatment, followed by Chlorantraniliprole (9.58%) and Emamectin benzoate (10.42%). Maximum percent infestation was observed in untreated plot (53.67%).

Cumulative effect of three sprays

The cumulative percent infestation of *Spodoptera frugiperda* across three insecticidal applications is presented in Table 4. All insecticidal treatments significantly suppressed fall armyworm infestation compared to the untreated control which recorded the highest infestation (47.03%). Spinetoram 11.7% SC proved most effective, recording the lowest cumulative infestation (9.76%). Chlorantraniliprole 47.85% SC (12.51%) and Emamectin benzoate 5% SG (13.33%) were statistically at par and ranked next in efficacy. Moderate suppression was observed with Lufenuron 4% + Emamectin benzoate 1.5% EC (17.76%), whereas Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC exhibited relatively higher infestation (22.69%).

These findings are consistent with earlier reports. Bharadwaj *et al.* (2020) identified Spinetoram 11.7% SC at 0.011% as the most effective treatment against *S. frugiperda*, followed by Emamectin benzoate 5% WG at 0.02%. Similarly, Deshmukh *et al.* (2020) reported Spinetoram 11.7% SC, Chlorantraniliprole 18.5% SC, Emamectin benzoate 5% SG, Flubendiamide 480 SC, Indoxacarb 14.5% SC, Lambda-cyhalothrin 5% ECand Novaluron 10% EC as potent insecticidal options against fall armyworm. Bade *et al.* (2017) also demonstrated that Spinetoram 12 SC (0.01%) was most effective in reducing fruit borer incidencefollowed by Spinosad 45 SC (0.01%) and Emamectin benzoate 5 SG (0.001%). These results validate the consistent efficacy of Spinetoram in field conditions and support its recommendation for integrated management of FAW in maize.

Marketable yield of maize cobs

Marketable maize cob yield was significantly influenced by insecticidal treatments. Spinetoram 11.7%

TABLE 4
Cumulative effects of different treatments on infestation of fall army worm on maize

Tr. No.	Treatment	Dose (g a.i./ha)	Per cent infestation of fall armyworm				Percent reduction over untreated control
			I spray	II spray	III spray	Mean	
T_1	Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC	27.50	26.53 (33.76)*	21.74 (32.16)	19.81 (31.27)	22.69	51.75
T_2	Spinetoram 11.7% w/w SC	30	14.23 (27.90)	9.36 (25.53)	5.70 (22.36)	9.76	79.24
T_3	Chlorantraniliprole 47.85% w/w SC	40	17.81 (29.85)	11.82 (27.45)	7.92 (24.52)	12.51	73.39
T_4	Emamectin benzoate 5% SG	200	18.83 (30.33)	12.80 (27.90)	8.37 (24.85)	13.33	71.65
T_5	Lufenuron 4 % + Emamectin benzoate 1.5% EC	(30+ 11.25)	22.78 (32.24)	16.89 (30.14)	13.63 (28.26)	17.76	62.23
T_6	Untreated control	-	41.11 (39.13)	47.60 (41.07)	52.40 (42.68)	47.03	
	S.E.(m) ±	-	0.43	0.40	0.47	0.43	
	C.D. @ 5 %	-	1.28	1.16	1.38	1.27	

*Figures in the parenthesis are arcsin transformed value.

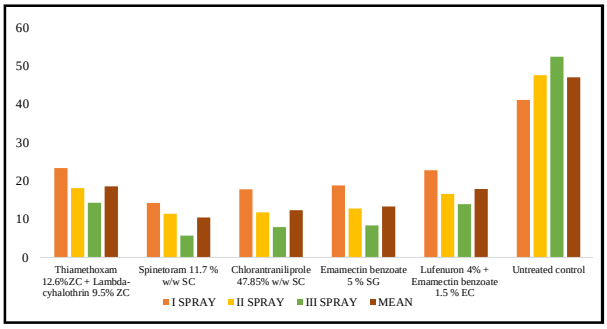

Fig. 4. Cumulative effects of various treatments on infestation of fall army worm on maize.

SC produced the highest yield (10.10 kg/plot) representing 65.57% increase over the untreated control and significantly outperforming all other treatments. Chlorantraniliprole 47.85% SC (9.10 kg/plot) representing 49.18% increase over a untreated control and Emamectin benzoate 5% SG (8.66 kg/plot) representing 41.96% increaseover the untreated control were next in effectiveness, followed by Lufenuron + Emamectin (7.46 kg/plot). The descending order of treatment efficacy based on marketable yield was: Spinetoram > Chlorantraniliprole >Emamectin benzoate > Lufenuron + Emamectin> Thiamethoxam + Lambda-cyhalothrin > untreated control. These results align with Sharma *et al.* (2023), who reported significantly higher maize yields under Spinosad and Spinetoram treatments, highlighting the superior role of Spinosyn based insecticides in enhancing both yield and crop protection against fall armyworm.

Incremental cost benefit ration (ICBR)

Economic analysis of the insecticidal treatments revealed significant variation in cost, net returns, and incremental cost-benefit ratio (ICBR). The cost of plant protection ranged from Rs. 1246 to Rs. 3551/ha with Lufenuron + Emamectin being the most expensive and Thiamethoxam + Lambda-cyhalothrin the least. Spinetoram 11.7% SC produced the highest net return (Rs. 14,025/ha) and superior ICBR (1:6.47), followed by Chlorantraniliprole 47.85% SC and Emamectin benzoate 5% SG with ICBR 1:2.32 and 1:1.44, respectively. Thiamethoxam + Lambda-cyhalothrin showed moderate profitability, whereas Lufenuron + Emamectin recorded the lowest net return (Rs. 1129/ha) and minimal cost-benefit ratio (1:1.03). These results highlight Spinetoram as the most economically viable treatment for FAW management in maizecombining high efficacy with maximum profitability.

CONCLUSION

Spinetoram 11.7% w/w SC @ 30 g a.i./ha was identified and displayed the highest level of treatment for the control of fall armyworm achieving 79.24 per cent reduction in infestation per plot compared to the untreated control. Apart from this, the treatment recorded the topmost cobs production of 84.1 q/ha along with the maximum incremental

cost-benefit ratio (ICBR) of 1:6.47, indicating its superior economic efficiency over the other treatments.

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