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Efficacy of Insecticides in Managing Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) on Maize Crop Under Natural Field Condition

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Abstract

The fall armyworm (Spodoptera frugiperda J.E. Smith) is a polyphagous and voracious insect pest that causes significant damage to maize crops in Nepal. Nepalese farmers often resort to expensive insecticides to manage this pest, substantially increasing the cost of maize production. This study aimed to evaluate various insecticides to identify options that are cost-effective, readily available, and affordable for farmers. Insecticides with different modes of action were tested for their effectiveness in controlling fall armyworm larvae through foliar spray applications 15 days after sowing under natural field conditions at the National Maize Research Program, Chitwan, Nepal, during the winter seasons of 2022 and 2023. The study revealed that all treatments significantly reduced plant damage and increased grain yield compared to the untreated control ($p < 0.005$). Spinosad 45% EC at 0.3 ml/liter of water demonstrated the lowest foliar damage (4.5%), followed by flubendiamide 480 SC at 1 ml/3 liters of water (20.9%) and thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC at 0.5 ml/liter of water (28.2%), compared to the untreated control (88.9%). Similarly, the highest grain yield (9.79 t/ha) was obtained with spinosad, followed by flubendiamide 480 SC (8.95 t/ha) and thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC (8.46 t/ha), compared to the untreated control (1.76 t/ha). Lambda-cyhalothrin 5% EC at 2 ml/liter of water also performed well (7.5 t/ha). Although MP AP3 Grease at 0.15 grams/whorl and thiamethoxam 25% WG at 0.5 g/liter of water were the least effective among the treatments they were still significantly superior to the untreated control. A negative correlation was observed between the mean damage score, mean foliar damage percent and grain yield.

Keywords: *Maize, Fall armyworm, Damage, Insecticides, Spinosad*

INTRODUCTION

Maize (*Zea mays L.*) is a major cereal crop in Nepal, widely cultivated in the hills, mountains, and Terai regions. It serves as both a staple food and an important feed for livestock, playing a vital role in the country's food security and agricultural economy. According to the Ministry of Agriculture and Livestock Development [18], maize is grown on a total area of 940,256 hectares, with an annual production of 2,976,490 metric tons and an average yield of 3.16 metric tons per hectare. Various factors affect maize yield, with insect pests emerging as a significant challenge in recent years. Among these, the fall armyworm (*Spodoptera frugiperda* J.E. Smith) (Lepidoptera: Noctuidae) has become a major invasive pest of economic importance, primarily infesting maize. Its invasion in Nepal was first reported in the Nawalpur district [4], and it has since spread to other parts of the country. The pest attacks maize throughout the year under favorable environmental conditions, targeting the crop at all stages of growth seedling to harvest and feeding on all parts of the plant except the roots. [10] estimated maize production losses due to fall armyworm at USD 2.481 to 6.187 million per annum. This polyphagous pest feeds on more than 350 plant species [19] and causes significant yield losses in economically important crops such as maize, cotton, soybean, and beans [21], [7]. Yield losses in maize due to fall armyworm infestation can reach as high as 30% reported by [2], 32% by [16] and 33% by [3]. There is a difficulty in the management of *Spodoptera frugiperda* because it has a wide host range and, high fecundity rate, with multiple generations within a year [8].

In Nepal, chemical control measures are predominantly used to manage fall armyworm infestations. Effective insecticides for its control include chlorantraniliprole, spinosad, spinetoram, and novaluron. However, these products are often expensive and unaffordable for many farmers. Frequent application of insecticides can also lead to the rapid development of resistance, as observed in other regions [13]. These insecticides are not immune to resistance development. [20] reported resistance in fall armyworms to chlorantraniliprole (160-fold), spinetoram (14-fold), and spinosad (8-fold). Consequently, the continuous exploration of new insecticides is essential for the effective management of fall armyworms. This study aims to evaluate selected cost-effective and economically viable synthetic insecticides currently available in the market to support Nepalese farmers in combating fall armyworm infestations.

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MATERIALS AND METHODS

Experimental site and Design

This experiment was conducted in the research field of the National Maize Research Program (NMRP), Rampur, Chitwan, Nepal during winter seasons of 2022 and 2023. The research location has latitude 27º 40' N, longitude 84º 19' E, and 228 meter above sea level. Six insecticides including untreated control were studied in RCB design with 4 times replication. The maize variety (Rampur hybrid-10) was sown at row to row and plant to plant with a spacing of 60x25 cm in a plot size of 8 rows of five-meter length. All the crop-raising practices including cultural practices, fertilizer application and weed management were followed as per recommendation of NMRP, Rampur, Chitwan. The first spray was given at 15 days after seed sowing as foliar application except for the control, whereas the second and third application was done at 15 days intervals after the first spray.

Table 1. Treatment details

Treatment	Trade name	Active ingredient	Formulation	WHO Class	Dose
T_1	Adrol	MP AP3 Grease			0.15gram/whorl
T_2	Fame 480	Flubendiamide	39.3% SC	II	1ml/3 liter of water
T_3	Agent Plus	Lamda-cyhalthrin	5% EC	II	2ml/liter of water
T_4	Tracer	Spinosad	45% SC	III	0.3ml/liter of water
T_5	Thilaz	Thiamethoxam + Lamda-cyhalothrin	22.1% ZC	II	0.5ml/liter of water
T_6	Vextar	Thiamethoxam	25% WG	III	0.5g/liter of water
T_7	Untreated Control	-	-	-	-

SC=suspension concentrate, EC=emulsifiable concentrate, WDG=water dispersible granule, ZC=Zeon Capsule Suspension, II=moderately hazardous, III=slightly hazardous

Data to be taken

In each treatment, the middle four rows were sampled for leaf and ear injury measurements. Leaf and ear damage were scored through visual observation using the scoring scale of 1–9 reported by [9] (Table 2). Field data were collected three days after each treatment application. The same sample plants were examined in each plot at harvest, and ear damage was measured using the rating scale developed by [9].

Table 2. Fall armyworm damage scoring scale (1-9)

Scale	Description	Host reaction
1	No visible leaf feeding damage	Highly resistant (RH)
2	Few pin holes on older leaves	Resistant (R)
3	Several shot-holes injury on a few leaves	Resistant (R)
4	Several shot-hole injuries common on several leaves or small lesions	Moderately resistant (MR)
5	Elongated lesions (> 2 cm long) on a few leaves	Moderately resistant (MR)
6	Elongated lesions on several leaves	Susceptible (S)
7	Several leaves with elongated lesions or tattering	Susceptible (S)
8	Most leaves with elongated lesions or severe tattering	Highly susceptible (HS)
9	Plant dying as a result of foliar damage	Highly susceptible (HS)

Yield-attributing traits, namely cob length and cob diameter, were measured using a Vernier caliper. Grain yield was calculated at 15% moisture using the formula provided below [24].

$$\text{Grain yield (t/ha)} = \frac{\text{Field weight (kg/plot)} \times \text{selling \%} \times 10\ (100 - \text{Moisture \%})}{\text{Net plot area } (m^2) \times 85}$$

The data were entered into Microsoft Excel 2016, and GENSTAT (18th edition) was used for data analysis. The comparison of treatment means for significant differences was conducted at a 0.05 probability level [12]. Correlation analysis with weather parameters was also performed. Climate and weather can significantly influence the growth, development, and distribution of insects. Weather data for the experimental period were recorded from the weather station at the National Maize Research Program, Rampur, and are presented in Figure 1.

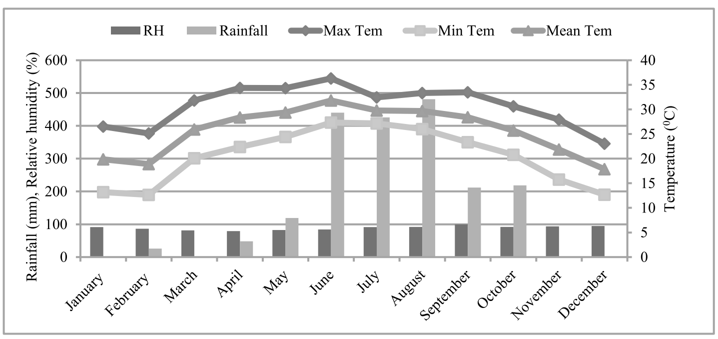

Figure 1: Meteorological data during experimental period (2022 and 2023) at Rampur, Chitwan, Nepal

Weather parameters

Climate and weather can significantly influence the growth, development, and distribution of insects. Weather parameters were recorded during the experimental period from the weather station established at the National Maize Research Program, as presented below in Figure 1.

RESULT

Statistical analysis revealed that all treatments were significantly different from the untreated control ($p < 0.05$) in terms of plant damage and grain yield. However, no significant differences were observed in cob length, cob diameter, and thousand-grain weight (Tables 3 and 4).

Among the treatments, Spinosad 45% SC was the most effective, achieving the lowest damage score (1.1) and plant damage percentage (5.2%) due to fall armyworm, followed by Flubendiamide 480 SC (19.7%) and Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC (31.7%), based on visual observations, compared to the untreated control (84.0%). Similarly, the highest grain yield (9.36 mt/ha) was recorded in the Spinosad 45% SC-treated plot, followed by plots treated with Flubendiamide 480 SC (8.49 mt/ha) and Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC (8.07 mt/ha), as compared to the untreated control (6.54 mt/ha). While MP AP3Grease and Thiamethoxam 25% WG were the least effective among the treatments, they were still significantly superior to the untreated control.

Table 3. Effect of different treatments on reduction of plant damage incidence by fall armyworm in maize at NMRP, Rampur during winter season, 2022

Name of Treatment	Damage score (0-9 scale)			Plant Damage (%)		
	KHS (25 DAS)	BTS (40 DAS)	MS	KHS (25 DAS)	BTS (25 DAS)	MDP
MP AP3Grease	4.5^{c}	5.8^{d}	5.1^{d}	60.6^{d}	59.2^{d}	59.9^{e}
Flubendiamide 480 SC	3.0^{b}	2.8^{b}	2.9^{b}	25.5^{b}	14.0^{ab}	19.7^{b}
Lambda-cyhalothrin 5% EC	4.0^{c}	2.8^{b}	3.4^{b}	53^{cd}	13.6^{ab}	33.3^{cd}
Spinosad 45% SC	2.0^{a}	0.3^{a}	1.1^{a}	9.0^{a}	1.3^{a}	5.2^{a}
Thiamethoxam 12.6%+ Lambda-cyhalothrin 9.5% ZC	3.8^{bc}	3.3^{b}	3.5^{b}	41.4^{c}	22.0^{b}	31.7^{c}
Thiamethoxam 25%WG	4.0^{c}	4.5^{c}	4.3^{c}	48.1^{cd}	39.9^{c}	44.0^{d}
Control (without application)	6.0^{d}	6.5^{d}	6.3^{e}	87.5^{e}	80.5^{e}	84.0^{f}
Grand mean	3.89	3.68	3.786	46.5	32.9	39.7
CV, %	13.6	16.7	11.5	20.9	26.5	18.3
P value	**	**	**	**	**	**
LSD	0.789	0.912	0.645	14.44	12.96	10.81

*KHS=knee high stage, BST=before tasseling stage, DAS=days after seed sowing, MDP=mean damage percent, CV=coefficient of variance, LSD=least standard deviation, **=highly significant, Mean in a column followed by the same letters are not significantly different at P=0.05.*

Table 4. Effect of different treatments on grain yield and yield attributing traits at NMRP, Rampur during winter season 2022

Name of Treatment	Cob diameter (cm)	Cob length (cm)	1000 grain weight (gm)	Grain yield (mt/ha)	Increase in yield over untreated check (%)
MP AP3Grease	4.2	16.9	338	7.35^{c}	11.0
Flubendiamide 480 SC	4.2	17.2	359	8.49^{b}	23.0
Lambda- cyhalothrin 5% EC	4.2	17.3	323	8.03^{bc}	18.6
Spinosad 45% SC	4.0	16.9	348	9.36^{a}	30.1
Thiamethoxam 12.6%+ Lambda-cyhalothrin 9.5% ZC	4.2	16.0	326	8.07^{bc}	19.0
Thiamethoxam 25%WG	4.3	17.9	341	7.94^{bc}	17.6
Control (without application)	4.1	16.2	320	6.54^{d}	
Grand mean	4.2	16.9	336.4	7.97	
CV, %	5	7.5	8.1	5.8	
P value	ns	ns	ns	**	
LSD	-	-	-	0.687	

*cm=centimeter, gm=gram, mt=metric ton, ha=hectare, CV=coefficient of variance, LSD=least significant difference, ns=non significant, **=highly significant, Mean in a column followed by the same letters are not significantly different at P=0.05.*

In second year experiment, statistical analysis showed that all treatments were significantly different as compared to untreated control ($p<0.05$) in the case of plant damage and grain yield measurement but non-significant results were found in cob length, cob diameter, and thousand-grain weight (Table 5 and 6). The lower plant infestation (3.8%) due to fall armyworm was found in spinosad 45% SC treated plot followed by flubendiamide 480 SC (22.1%) and thiamethoxam 12.6%+ lambda-cyhalothrin 9.5%ZC (24.7%) in visual observation as compared to untreated control (93.9%). Similarly, the highest grain yield (10.23 mt/ha) was found in spinosad 45% SC treated plot followed by flubendiamide 480 SC treated plot (9.39 mt/ha) and Lamda-cyhalothrin 5% EC (8.85 mt/ha) as compared to untreated control (6.78 mt/ha). MP AP3 Grease was found least effective among the treatments but was significantly superior to untreated control.

Table 5. Effect of different treatments on reduction of plant damage incidence by fall armyworm in maize at NMRP, Rampur during winter season, 2023

Name of treatments	Damage (%)			Mean Score (1-9 scale)
	KHS (25 DAS)	BST (45 DAS)	Mean damage	
MP AP3 Grease	89.1^{f}	56.2^{c}	72.6^{c}	6.1^{d}
Flubendiamide 480 SC	18.2^{b}	25.9^{b}	22.1^{b}	2.5^{b}
Lambda- cyhalothrin 5% EC	33.1^{c}	32.9^{b}	33.0^{b}	3.5^{c}
Spinosad 45% SC (Tracer)	4.1^{a}	3.6^{a}	3.8^{a}	1.1^{a}
Thiamethoxam 12.6%+ Lambda-cyhalothrin 9.5% ZC	25.5^{c}	23.9^{b}	24.7^{b}	3.3^{c}
Thiamethoxam 25%WG	78.9^{e}	58.1^{c}	68.5^{c}	5.6^{d}
Control (without application)	98.6^{g}	89.2^{d}	93.9^{d}	7.4^{d}
Grand mean	49.7	41.4	45.5	4.3
CV, %	8.7	32.6	15.8	10.7
P value	**	**	**	**
LSD	6.443	20.06	10.66	0.6683

*KHS=knee high stage, BST=before tasseling stage, DAS=days after seed sowing, CV=coefficient of variance, LSD=least standard deviation, **=highly significant, Mean in a column followed by the same letters are not significantly different at P=0.05.*

Table 6. Effect of different treatments on grain yield and yield attributing traits at NMRP, Rampur during winter season 2023

Name of Treatments	Cob diameter (cm)	Cob length (cm)	1000 grain weight (gm)	Grain yield (mt/ha)	Increase in yield over untreated check (%)
MP AP3Grease	17.3	4.2	477	7.63cd	11.1
Flubendiamide 480 SC	16.9	4.1	498	9.39ab	27.8
Lambda-cyhalothrin 5% EC	17.6	4.2	556	8.79b	22.9
Spinosad 45% SC	17.6	4.1	470	10.23a	33.7
Thiamethoxam 12.6%+ Lambda-cyhalothrin 9.5% ZC	17.7	4.2	476	8.85b	23.4
Thiamethoxam 25%WG	18.1	4.2	390	8.28bc	18.1
Control (without application)	16.5	4.1	480	6.78d	
Grand mean	17.4	4.1	478	8.567	
CV, %	5.2	2.8	22.2	5.3	
P value	ns	ns	ns	**	
LSD	1.343	0.1716	-	0.6684	

*cm=centimeter, gm=gram, mt=metric ton, ha=hectare, CV=coefficient of variance, LSD=least significant difference, ns=non significant, **=highly significant, Mean in a column followed by the same letters are not significantly different at P=0.05.*

Similarly, pooled analysis results indicated that all the treatments were significantly different from the untreated control ($p < 0.05$) in terms of plant damage and grain yield measurement. However, no significant differences were observed in cob length, cob diameter, and thousand-grain weight in the interaction between year and treatments (Tables 7 and 8). Visual observations showed the lowest plant infestation due to fall armyworm (4.5%) in the spinosad 45% SC-treated plot, followed by flubendiamide 480 SC (20.9%) and thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC (28.2%), compared to the untreated control (88.9%).

Similarly, the highest grain yield (9.79 mt/ha) was recorded in the spinosad 45% SC-treated plot, followed by flubendiamide 480 SC (8.95 mt/ha), thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC (8.46 mt/ha), and lambda-cyhalothrin 5% EC (8.41 mt/ha), as compared to the untreated control (6.65 mt/ha). MP AP3 Grease was found to be the least effective among the treatments but was still significantly superior to the untreated control.

Table 7. Effect of chemical insecticides on reduction of plant damage by fall armyworm in maize at NMRP, Rampur in combined analysis, during 2022 and 2023

Name of treatments	Mean Score (1-9 scale)			Damage (%)		
	KHS (25 DAS)	BST (45 DAS)	Mean damage	KHS (25 DAS)	BST (45 DAS)	Mean damage
MP AP3Grease	5.75f	5.5c	5.6e	74.8f	57.7c	66.3e
Flubendiamide 480 SC	2.62b	2.8b	2.7b	21.8b	20.0b	20.9b
Lambda-cyhalothrin 5% EC	3.9d	3.0b	3.4c	43.1d	23.2b	33.2c
Spinosad 45% SC	1.6a	0.6a	1.1a	6.6a	2.5a	4.5a
Thiamethoxam 12.6%+ Lambda-cyhalothrin 9.5% ZC	3.3c	3.5b	3.4d	33.5c	23.0b	28.2c
Thiamethoxam 25%WG	5.0c	4.9c	4.9f	63.5e	49.0c	56.3d
Control (without application)	6.9g	6.8d	6.8g	93.1g	84.8d	88.9f
Grand mean	4.1	3.86	4.0	48.1	37.2	42.61
Treatment	**	**	**	**	**	**
Year	*	ns	**	ns	*	*
Treatment x Year	**	ns	**	**	ns	*
CV, %	12.7	19.7	10.8	16.2	29.4	16.7
LSD	0.752	1.086	0.618	11.11	15.64	10.202

*KHS=knee high stage, BST=before tasseling stage, DAS=days after seed sowing, CV=coefficient of variance, LSD=least standard deviation, **=highly significant, *=Significant, ns=non significant, Mean in a column followed by the same letters are not significantly different at P=0.05.*

Table 8. Effect of chemical insecticides on grain yield and yield attributing traits of maize in pooled analysis during winter 2022 and 2023

Name of Treatments	Cob diameter (cm)	Cob length (cm)	1000 grain weight (gm)	Grain yield (mt/ha)	Increase in yield over untreated check (%)
MP AP3Grease	4.2	17.1	408.0	7.49cd	11.2
Flubendiamide 480 SC	4.1	17.1	428.0	8.95ab	25.7
Lambda-cyhalothrin 5% EC	4.2	17.5	440.0	8.41bc	20.9
Spinosad 45% SC	4.1	17.3	409.0	9.79a	32.1
Thiamethoxam 12.6%+ Lambda-cyhalothrin 9.5% ZC	4.2	16.8	401.0	8.46bc	21.4
Thiamethoxam 25%WG	4.2	18.0	366.0	8.11bc	18.0
Control (without application)	4.1	16.4	400.0	6.65d	
Grand mean	4.2	17.2	407.0	8.3	
Treatment	ns	ns	ns	**	
Year	ns	ns	*	*	
Treatment x Year	ns	ns	ns	ns	
CV, %	4.10	6.3	19.0	7.8	
LSD	0.241	1.55	110.7	0.9232	

*cm=centimeter, ha=hectare, LSD=least significant difference, ns=non significant, *=significant, **=highly significant, Mean in a column followed by the same letters are not significantly different at P=0.05.*

Correlation among the parameters

The correlation coefficients of various growth and yield attributes, namely cob length, cob diameter, thousand grain weight, and grain yield, with the mean damage score and mean foliar damage percent caused by fall armyworm, are presented in Table 9. A positive correlation was found between cob diameter, cob length, mean damage score, and mean foliar damage percent. In contrast, a negative correlation was observed between the mean damage score, mean foliar damage, and grain yield.

Table 9: Correlation coefficient of growth and yield parameters with foliar damage

Parameters	Cob length (cm)	Cob diameter (cm)	1000 grain weight (gm)	Mean Score (no.)	Mean Damage (%)	Grain yield (kg/ha)
Cob length (cm)	-					
Cob diameter (cm)	0.578*	-				
Thousand grain weight (gm)	0.079	0.275	-			
Mean Score (no.)	-0.143	0.110	-0.188	-		
Mean Damage (%)	-0.125	0.109	-0.146	0.988**	-	
Grain yield (kg/ha)	0.225	-0.018	0.123	-0.873**	-0.856**	

*cm=centimeter, gm=gram, kg=kilo gram, ha=hectare, *=significant, **= highly significant*

DISCUSSION

In the present study, all market-available insecticides tested were found to be toxic to fall armyworm, effectively reducing infestation and significantly enhancing grain yield compared to the untreated control. A significant difference was observed among the treatments in terms of percentage damage and grain yield in treated plots. The minimum plant and cob damage, along with higher grain yields, was recorded for spinosad 45% SC, followed by flubendiamide 480 SC, thiamethoxam 12.6%+lambda-cyhalothrin 9.5% ZC, and lambda-cyhalothrin, respectively.

Spinosad and flubendiamide were the most effective insecticides against fall armyworms. Spinosad, which contains spinosyns derived from the soil bacterium *Saccharopolyspora spinosa*, acts uniquely by targeting nicotinic acetylcholine receptors (nAChRs) in insects [1]. Flubendiamide, a member of the diamide class, exhibits excellent larvicidal activity through contact and ingestion modes of action against lepidopteran pests [15]. These unique modes of action not only enhance their effectiveness but also delay resistance development, provide longer-lasting effects, and make them suitable for integrated pest management (IPM) strategies. Supporting this, [14] found that chlorantraniliprole (0.101 kg ai/ha), flubendiamide (0.098 kg ai/ha), and novaluron (0.088 kg ai/ha) significantly reduced infestation levels in sorghum 7 days after treatment. Similarly, [6] reported that spinosad was found to be the most effective in managing fall armyworm incidence in maize crops under natural conditions in the Nepalese context.

The effectiveness of spinosad, flubendiamide, thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC, lambda-cyhalothrin, and thiamethoxam 25% WG against fall armyworm in this study aligns with findings from other researchers. Researchers reported that spinosad 45% SC achieved the highest maize grain yields, followed by emamectin benzoate 5% SG, chlorantraniliprole 18.5% SC, flubendiamide 39.35% SC, and thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC [23]. In contrast, plots treated with lambda-cyhalothrin 5% EC recorded the lowest grain yields. Similarly, [11] noted that lambda-cyhalothrin reduced insect infestation in only 40% of treated whorls.

These results are consistent with findings by [25], who reported maximum yields in chlorantraniliprole 18.5% SC and flubendiamide 480 SC-treated plots (5.12 t/ha and 4.98 t/ha, respectively) compared to untreated control plots (2.93 t/ha). Thus, insecticides such as spinosad 45% SC, flubendiamide 480 SC (0.3 ml/l), and thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC (0.5 ml/l) were effective in reducing fall armyworm infestation and increasing yield compared to untreated control. Additionally, [22] reported the highest grain yields with emamectin benzoate 5% SG (4.25 t/ha), followed by chlorantraniliprole 18.5% SC (4.01 t/ha), flubendiamide 39.35% SC (3.85 t/ha), and Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC (3.76 t/ha), compared to water spray (2.41 t/ha). The reduction in fall armyworm infestation through effective insecticide application correlated with increased maize grain yields, aligning with [26], who reported higher yields in fields treated with spinosad and spinetoram. [14] also noted significantly higher larval mortality (90.6–100%) three days after treatment with chlorantraniliprole, lambda-cyhalothrin, spinetoram, and flubendiamide.

Among the treatments, MP3 Grease (0.15 g/whorl) and thiamethoxam 25% WG (0.5 g/l) recorded the lowest grain yields (7.49 t/ha and 8.11 t/ha, respectively), though these were still significantly higher than the untreated control (6.65 t/ha). However, [17] reported no crop damage when MP3 Grease (0.15 g) was applied to the maize whorl or a drooping leaf tip in contact with soil, suggesting that the observed discrepancy might result from restricted larval movement on treated plants. In this experiment, a negative correlation was found between foliar damage, damage score, and grain yield. These results are in line with the findings of [5], who reported a highly significant negative relationship between foliar damage caused by fall armyworm and all the measured parameters.

CONCLUSION

The present study concludes that insecticides containing active ingredients such as spinosad 45% SC, flubendiamide 480 SC, and thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC were effective in managing fall armyworm when applied three times at 10-day intervals, starting 15 days after seed sowing. A total grain yield increase of 32.1% was observed in the spinosad-treated plot, followed by flubendiamide (25.7%). However, less effective protection (11.2% yield increase) was observed in the MP3 grease-treated plot. Further research is required to assess the potential of MP3 grease for reducing pest populations at the field level. Additionally, future studies should explore the field-level potential of these insecticides and MP3 grease, ensuring their long-term sustainability and environmental safety, and evaluate the compatibility of these treatments within an integrated pest management (IPM) framework.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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