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Research Article

Efficacy of selected synthetic insecticides against fall armyworm (*Spodoptera frugiperda*) on maize crop

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ABSTRACT

The Fall armyworm (*Spodoptera frugiperda* J.E. Smith) (Lepidoptera: Noctuidae), an invasive pest first reported in Pakistan in 2019, has since spread rapidly across major maize-growing regions, causing substantial yield losses and posing a serious threat to national food security. To assess effective chemical control options, field trials were conducted during autumn 2022 and 2023 to evaluate insecticides with different modes of action under natural infestation conditions. The experiments followed a randomized complete block design (RCBD) comprising eight treatments, including an untreated control, with three replications. Applications were made at the 5% crop damage and pest incidence was recorded pre-treatment and at three- and seven-days post-application. Results revealed that Magesta 165 ZC provided the highest and statistically significant ($P < 0.05$) reduction in FAW damage, followed by Famtro 24 SC and Rector Super 0.35 G. While, other treatments, Conceed 5 EC, Coragen 20 SC, Capture 0.4 G and Roxy 0.4 G also demonstrated significant but comparatively moderate efficacy. Higher pest suppression was positively correlated with increased grain yields relative to the control. Based on these findings, Magesta 165 ZC, Famtro 24 SC and Rector Super 0.35 G are recommended as promising components of an Integrated Pest Management (IPM) for *S. frugiperda* management in Pakistan.

Keywords: *Spodoptera frugiperda*; insecticides; toxicity assessment; IPM; maize crop.

INTRODUCTION

The fall arm yworm (*Spodoptera frugiperda* J.E. Smith) is a highly polyphagous, invasive lepidopteran pest that poses a severe threat to maize production worldwide (FAO, 2020). Since its first detection in Pakistan in 2019, *S. frugiperda* has dispersed rapidly across the country's maize-growing regions, producing episodic outbreaks and causing substantial yield reductions that imperil smallholder livelihoods and national food security (FAO, 2022; Saleem et al., 2024).

Chemical insecticides remain an important immediate-response tool for growers confronting heavy *S. frugiperda* infestations. However, indiscriminate and repetitive use of broad-spectrum pesticides has several drawbacks: disruption of natural enemies, environmental contamination, occupational health risks, and strong selection pressure for resistance (Gichere et al., 2022; Kumar et al., 2022). Recent regional studies report variable field performance among insecticide classes (e.g., diamides, avermectins) and emphasize the need for local efficacy data monitoring before recommending products for routine use.

Compounding the challenge, baseline and emerging resistance to commonly used active ingredients (including pyrethroids and other chemistries) has been documented in FAW populations, highlighting the urgency of rotating modes of action

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and integrating non-chemical tactics (Zaidi et al., 2024). Field evaluations that compare currently available synthetic insecticides under local agro-climatic and agronomic conditions are therefore critical to identify effective, selective options that can be integrated into sustainable IPM programs. Beyond chemical control, best-practice FAW management emphasizes monitoring (pheromone traps and scouting), decision thresholds, biological control agents, cultural measures (e.g., planting time, intercropping), and judicious, threshold-based insecticide use to reduce overall chemical dependence and delay resistance development (FAO, 2022; Tepa-Yotto et al., 2022). Locally relevant efficacy trials that relate pest suppression to yield outcomes, therefore inform both immediate control decisions and longer-term IPM adoption.

Accordingly, this study evaluates the field efficacy of selected synthetic insecticides with different modes of action against FAW on maize under natural infestation. The objective is to (i) quantify short-term reductions in foliar damage (ii) compare treatment effects on grain yield, and (iii) identify candidate chemistries suitable for incorporation into an IPM framework for *S. frugiperda* management in Pakistan's maize crop.

MATERIALS AND METHODS

Experimental Site and Crop Management

Field experiments were conducted during the main maize seasons (autumn) 2022 and 2023 at the experimental farm of Cereal Crops Research, Institute, Pirsabak, Nowshera, Pakistan. The soil at the trial site is classified as silt loam; baseline soil fertility was assessed prior to sowing. A commercial maize hybrid, Bilal was sown at the recommended spacing of 75 × 25 cm and managed according to local agronomic practices (CIMMYT, 2021). Standard crop husbandry was maintained uniformly across all plots except for pest management interventions.

Experimental Design and Treatments

The trial used a randomized complete block design (RCBD) with three replications, which is widely recommended for field entomological studies (Gomez & Gomez, 1984). Each block contained eight treatments: seven insecticidal treatments and one untreated control (Harrison et al., 2019). Treatments evaluated were: Magesta 165 ZC, Famtro 24 SC, Rector Super 0.35 G, Conceed 5 EC, Coragen 20 SC, Capture 0.4 G, and Roxy 0.4 G (Table 1). Insecticides were applied at manufacturer-recommended field rates (IRAC, 2022). Plot size was 5 m × 8 m (40 m²) with buffer zones to minimize drift.

Table 1. List of insecticides with trade name, active ingredient, formulation, dosage and mode of application.

S.No.	Insecticides	Active ingredient	Manufacturers	Formulations	Dose/Acre	Mode of application
1	Rector Super	Fipronil + Emamectin benzoate	Ag Pharma	0.35% G	08 Kgs	Whorl Application
2	Magesta	Chlorantraniliprole+Lambda-cyhalothrin	Sun Crop	165 ZC	90 ml	Foliar Spray
3	Famtro	Chlorantraniliprole+Thiamethoxam	Tara Imperial	24% SC	100 ml	Foliar Spray
4	Conceed	Emamectin Benzoate+Lufenuron	Ag Pharma	5% EC	250 ml	Foliar Spray
5	Capture	Chlorantraniliprole	Warble Private Limited	0.4% G	04 Kgs	Whorl Application
6	Roxy	Chlorantraniliprole	Rudolf Life Sciences	0.4% G	04 Kgs	Whorl Application
7	Coragen	Chlorantraniliprole	Syngenta	20% SC	50 ml	Foliar Spray

Treatments were applied when crop scouting indicated approximately 5% plant damage or early larval presence in the whorl, following IPM threshold guidelines (Prasanna et al., 2018). A single application was made per treatment in each season. Spray applications were performed using a knapsack sprayer calibrated to deliver 500 L ha^{-1} spray volume.

Ambient environmental data, daily temperature, relative humidity, and rainfall were obtained from the on-site meteorological station, as environmental factors can strongly influence pest pressure and insecticide performance (Early et al., 2018).

Pre-treatment data and observations at 3 and 7 days after spray were collected. Visual estimates of damaged plants per plot (10 plants/sub-plot) following established FAW damage scoring scales (Davis et al., 1992).

At physiological maturity, plots were harvested from a central area to avoid border effects. Grain yield was recorded, as recommended for maize yield trials (CIMMYT, 2021).

Statistical Analysis

Data were checked for normality and homogeneity of variance (Shapiro–Wilk and Levene's tests). Percentage data were arcsine-square-root transformed when necessary (Steel et al., 1997). ANOVA was used to test treatment effects, and means were separated by Duncan's Multiple Range Test (DMRT) or Tukey's HSD at α = 0.05 (Gomez & Gomez, 1984). Correlation analysis was used to relate FAW suppression with yield.

RESULTS AND DISCUSSION

The present study demonstrated that synthetic insecticides significantly suppressed fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), damage in maize under field conditions during both seasons 2022 and 2023 (Table 2 and 3). Each treatment is analyzed based on the percent damage reduction over check (control) and yield in kilograms per hectare (kgs/ha), following the application of the insecticides.

Table 2. Efficacy of new insecticides against Fall armyworm plant damage on maize crop under field condition during 2022.

Treatments	Formulation	Dose / Acre	(Pre-Treatment) Average % Plants Damage	(Post-treatment) Average % Plants Damage after		% Damage reduction over check		Kgs/ha
				3 Days	7 Days	3 Days	7 Days	
Rector Super (Fipronil + Emamectin benzoate)	0.35 G	08 Kgs	5.59±0.30 a	2.37±0.55 b	3.68±0.31 b	87.12 a	84.47 ab	10120 ab
Magesta (Chlorantraniliprole+ Lambda-cyhalothrin)	165 ZC	90 ml	5.09±0.24 a	2.26±0.49 b	3.61±0.52 b	87.34 a	84.55 ab	10233 a
Famtro (Chlorantraniliprole+ Thiamethoxam)	24 SC	100 ml	5.23±0.23 a	2.28±0.45 b	3.18±0.36 b	87.29 a	84.46 a	9817 ab
Conceed (Emamectin Benzoate+Lufenuron)	5 EC	250 ml	5.54±0.14 a	2.77±0.07 b	4.60±0.37 b	84.70 a	80.64 b	9792 ab
Capture (Chlorantraniliprole)	0.4 G	04 Kgs	5.81±0.18 a	2.90±0.09 b	4.36±0.13 b	83.97 a	81.59 b	9170 b
Roxy (Chlorantraniliprole)	0.4 G	04 Kgs	5.38±0.40 a	2.95±0.09 b	3.91±0.42 b	83.71 a	83.32 ab	9267 ab
Coragen (Chlorantraniliprole)	20 SC	50 ml	5.13±0.45 a	2.81±0.15 b	4.21±0.23 b	84.54 a	82.20 ab	9433 ab
Control	-----	-----	5.52±0.41 a	18.14±0.64 a	23.67±0.67 a	-----	-----	4324 c
LSD at 5%	-----	-----	0.9979	1.1776	1.4492	5.7981	4.6558	971.49

In column, means followed by common letters are not significantly different at (P ≤ 0.05) by Duncan's Multiple Range test DM.

Efficacy of Insecticides in 2022

The pre-treatment infestation of fall armyworm (FAW) across maize plots ranged between 5.09% (Magesta 165 ZC) and 5.81% (Capture 0.4 G), with no statistically significant differences among treatments (P > 0.05). This indicated that pest pressure was uniform across all plots before the application of insecticides (Table 2).

Three days after spraying, all insecticidal treatments significantly reduced FAW damage compared with the untreated control, which recorded 18.14% damaged plants. Among treatments, Magesta 165 ZC (2.26%), Rector Super 0.35 G (2.37%), and Famtro 24 SC (2.28%) were the most effective, achieving >87% damage reduction. Conceed 5 EC (2.77%), Capture 0.4 G (2.90%), Roxy 0.4 G (2.95%), and Coragen 20 SC (2.81%) also provided significant suppression but slightly lower reductions (83–85%).

Seven days after application, plant damage in the control plots further increased to 23.67%. In contrast, Magesta 165 ZC (3.61%), Rector Super 0.35 G (3.68%), and Famtro 24 SC (3.18%) maintained high levels of efficacy, with >84% reduction in damage relative to the control. Conceed 5 EC (4.60%), Capture 0.4 G (4.36%), Roxy 0.4 G (3.91%), and Coragen 20 SC (4.21%) remained statistically effective but showed comparatively moderate protection, with reductions between 80–83%.

Grain yield results reflected these efficacy trends. The untreated control yielded only 4,324 kg/ha, whereas insecticide-treated plots achieved significantly higher yields. Magesta 165 ZC produced the highest yield (10,233 kg/ha), followed closely by Rector Super 0.35 G (10,120 kg/ha) and Famtro 24 SC (9,817 kg/ha). Conceed 5 EC (9,792 kg/ha), Coragen 20 SC (9,433 kg/ha), and Roxy 0.4 G (9,267 kg/ha) were statistically at par but slightly lower. The lowest yield among treated plots was recorded with Capture 0.4 G (9,170 kg/ha).

Table 3. Efficacy of new insecticides against Fall armyworm plant damage on maize crop under field condition during 2023.

Treatments	Formulation	Dose / Acre	(Pre-Treatment) Average % Plants Damage	(Post-treatment) Average % Plants Damage after		% Damage reduction over check		Kgs/ha
				3 Days	7 Days	3 Days	7 Days	
Rector Super (Fipronil + Emamectin benzoate)	0.35 G	08 Kgs	7.52±0.86 a	1.84±0.38 b	3.32±0.65 b	86.47 a	81.17 a	10090 ab
Magesta (Chlorantraniliprole+ Lambda-cyhalothrin)	165 ZC	90 ml	7.96±0.51 a	1.85±0.41 b	3.25±0.38 b	86.57 a	81.50 a	10327 a
Famtro (Chlorantraniliprole+ Thiamethoxam)	24 SC	100 ml	8.83±0.64 a	1.87±0.50 b	3.22±0.34 b	86.54 a	81.63 a	10082 ab
Conceed (Emamectin Benzoate+Lufenuron)	5 EC	250ml	7.75±0.56 a	2.25±0.40 b	3.65±0.49 b	83.56 a	79.22 a	9894 ab
Capture (Chlorantraniliprole)	0.4 G	04 Kgs	8.75±0.30 a	2.32±0.50b	3.23±0.47b	82.92a	81.64 a	9617 ab
Roxy (Chlorantraniliprole)	0.4 G	04 Kgs	7.40±0.30 a	2.29±0.40 b	3.68±0.35 b	83.34 a	79.09 a	9413 b
Coragen (Chlorantraniliprole)	20 SC	50 ml	8.69±0.78 a	2.31±0.49 b	3.68±0.47 b	83.19 a	79.00 a	9446 b
Control	-----	-----	8.50±1.05 a	13.74±0.37a	17.53±0.27a	-----	-----	4177 c
LSD at 5%	-----	-----	-----	0.973	1.1792	9.7869	7.7874	781.41

In column, means followed by common letters are not significantly different at (P ≤ 0.05) by Duncan's Multiple Range test DM.

Efficacy of Insecticides in 2023

The pre-treatment infestation in 2023 was slightly higher than the previous year, ranging between 7.40% (Magesta 165 ZC) and 8.83% (Rector Super 0.35 G), though no significant differences were observed across treatments (P > 0.05) (Table 3).

Three days after application, all insecticides again significantly reduced FAW plant damage compared with the control (13.74%). The lowest damage was recorded in plots treated with Rector Super 0.35 G (1.84%), Magesta 165 ZC (1.85%), and Famtro 24 SC (1.87%), achieving >86% damage reduction. Conceed 5 EC (2.25%), Capture 0.4 G (2.32%), Roxy 0.4 G (2.29%), and Coragen 20 SC (2.31%) also reduced plant injury significantly, with reductions ranging from 82–84%.

Seven days after treatment, infestation in control plots increased to 17.53%. However, Magesta 165 ZC (3.25%), Famtro 24 SC (3.22%), and Rector Super 0.35 G (3.32%) continued to provide the highest suppression, maintaining

>81% damage reduction. The remaining insecticides provided effective but comparatively lower control, with reductions between 79–81%.

Grain yield data again followed the same trend. The control plots yielded only 4,177 kg/ha, significantly lower than all treated plots. Magesta 165 ZC (10,327 kg/ha) gave the highest yield, followed closely by Rector Super 0.35 G (10,090 kg/ha) and Famtro 24 SC (10,082 kg/ha). Conceed 5 EC (9,912 kg/ha), Coragen 20 SC (9,615 kg/ha), Roxy 0.4 G (9,488 kg/ha), and Capture 0.4 G (9,380 kg/ha) produced yields that were significantly higher than the control but slightly lower compared to the top-performing treatments.

Comparative Analysis Across Years

The results from both 2022 and 2023 clearly demonstrated the superior performance of Magesta 165 ZC, Rector Super 0.35 G, and Famtro 24 SC in suppressing FAW infestation and enhancing grain yield. These treatments consistently achieved >84% damage reduction and nearly doubled grain yield compared to the untreated control. Other insecticides such as Conceed 5 EC, Coragen 20 SC, Capture 0.4 G, and Roxy 0.4 G also provided effective control but were comparatively less efficient, particularly at seven days after treatment.

Interestingly, FAW pressure was higher in 2023 compared to 2022, as indicated by the higher pre-treatment infestation levels and control plot damage (13.74% and 17.53% in 2023 vs. 18.14% and 23.67% in 2022). Despite this, the top-performing insecticides maintained consistent efficacy, demonstrating their reliability under varying pest pressure.

Yield Response

Grain yield was strongly associated with FAW suppression. The three most effective insecticides (Magesta 165 ZC, Rector Super 0.35 G, and Famtro 24 SC) consistently produced yields >10,000 kg/ha in both years, compared to less than 4,500 kg/ha in untreated control plots. Yield advantages of 5,500–6,000 kg/ha were observed in treated plots, highlighting the economic importance of effective FAW management.

The present study demonstrated that synthetic insecticides significantly suppressed fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), damage in maize under field conditions during both 2022 and 2023. Among the treatments evaluated, Magesta 165 ZC, Rector Super 0.35 G, and Famtro 24 SC consistently provided the highest efficacy, achieving more than 84% reduction in plant damage and significantly improving grain yield. Other treatments, including Conceed 5 EC, Coragen 20 SC, Capture 0.4 G, and Roxy 0.4 G, also showed substantial effectiveness but were comparatively less consistent across assessment intervals.

The superior efficacy of Magesta 165 ZC and Famtro 24 SC may be attributed to their dual-active ingredient formulations combining diamides (chlorantraniliprole) with lambda-cyhalothrin and thiamethoxam, which provide both immediate larvicidal action and residual activity. Diamides have been widely reported as highly effective against FAW due to their unique mode of action targeting ryanodine receptors, leading to uncontrolled calcium release and muscle paralysis (Hardke et al., 2022; IRAC, 2022). Similar findings were reported in Africa and Asia, where chlorantraniliprole-based products significantly reduced FAW infestations and increased maize yields (Rwomushana et al., 2018; Sharanabasappa et al., 2021).

The consistent performance of Rector Super 0.35 G (fipronil + emamectin benzoate) also highlights the importance of combination products. Fipronil, a GABA-gated chloride channel blocker, and emamectin benzoate, a chloride channel activator, act synergistically to disrupt neural function and feeding behavior in larvae (Hruska, 2019). These results align with recent reports from India and sub-Saharan Africa, where emamectin and fipronil formulations significantly suppressed FAW populations under field conditions (Khan et al., 2022; Prasanna et al., 2021).

Although all tested insecticides significantly outperformed the control, moderate efficacy of Conceed 5 EC, Capture 0.4 G, Roxy 0.4 G, and Coragen 20 SC after seven days indicate potential limitations in persistence or residual activity. This finding is consistent with studies reporting that single-active formulations, particularly those relying solely on chlorantraniliprole, may require repeated applications under high pest pressure (Bateman et al., 2018; CABI, 2022).

Yield data strongly correlated with pest suppression. The three top-performing insecticides consistently achieved >10,000 kg/ha grain yield, nearly doubling production compared with untreated controls. This highlights the critical role of timely and effective FAW management in safeguarding maize productivity, especially in regions where smallholder farmers face severe yield losses of up to 60–70% without intervention (Day et al., 2017; Kumela et al., 2019).

Despite the effectiveness of synthetic insecticides, reliance solely on chemical control is unsustainable. Intensive insecticide use may accelerate the development of resistance, as has already been documented in several FAW populations globally (Gutierrez-Moreno et al., 2021). Therefore, these results underscore the need to integrate effective insecticides, such as Magesta 165 ZC, Rector Super 0.35 G, and Famtro 24 SC, within broader Integrated Pest

Management (IPM) frameworks. Such strategies should include cultural practices, biological control agents, and regular resistance monitoring to prolong the efficacy of available chemistries and minimize environmental risks (Prasanna et al., 2022; IRAC, 2022).

CONCLUSION

The study confirmed that fall armyworm poses a serious threat to maize in Pakistan, but effective suppression is possible with selected insecticides. Among the tested products, Magesta 165 ZC, Rector Super 0.35 G, and Famtro 24 SC consistently provided the highest reduction in plant damage and the greatest yield gains across both years. Other insecticides were effective but comparatively less consistent. These results suggest that the top-performing products can serve as reliable tools within Integrated Pest Management (IPM) programs, though their long-term use should be balanced with resistance management and complementary control strategies.

AUTHOR'S CONTRIBUTION

M. Nawaz and Irfanullah khan designed and supervised the Trial, M. Nawaz and M. Waqas conducted the research Trial, S.A. Khan and S. Jan provided the research material to conduct the research trial, I. A. Khalil, M. Khalid analyzed the data, M. Nawaz wrote the research Paper, I. B Amin review the research paper. All authors read and approved to submit the research paper to the journal.

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There was no external funding agency for research trials.

AVAILABILITY OF DATA AND MATERIAL

All data generated or analyzed in this study are presented within this article in the form of tables.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

I, the undersigned, consent to the publication of my identifiable information.

CONFLICT OF INTERESTS

The authors declare there is no conflict of interest.

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