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MANAGEMENT OF FALL ARMYWORM, *Spodoptera frugiperda* (J. E. SMITH) BY SEQUENTIAL APPLICATION OF INSECTICIDES IN MAIZE

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ABSTRACT

A field experiment was conducted during *Rabi* 2023–24 at the College of Agriculture, Hassan, to evaluate different sequences of biopesticides and insecticides for the management of fall armyworm, *Spodoptera frugiperda* (J. E. Smith) in maize. The experiment was laid out in a Randomized Block Design with three replications using maize variety MAH 14-5. Observations for larval population was recorded one day before the treatment and at 1, 3, 7 and 14 days after each spray. Significant differences were observed among the treatment sequences. Emamectin benzoate 5 SG @ 0.40 g/l - Chlorantraniliprole 18.5% SC @ 0.40 ml/l recorded the lowest larval population of 0.13 larva par plant at the end of second spray and the highest reduction over control, followed by *Metarhizium rileyi* 1×10^8 CFU @ 5 g/l - Spinetoram 11.7% w/w SC @ 0.50 ml/l which recorded 0.18 larva par plant. The remaining treatment sequences were comparatively less effective in suppressing fall armyworm infestation. The results demonstrated that sequential application of effective biopesticides and insecticides can successfully manage fall armyworm in maize. Among the sequences tested, Emamectin benzoate 5 SG @ 0.40 g/l - Chlorantraniliprole 18.5% SC @ 0.40ml/l and *Metarhizium rileyi* 1×10^8 CFU @ 5 g/l - Spinetoram 11.7% w/w SC @ 0.50 ml/l emerged as the most promising treatments for sustainable fall armyworm management.

***Keywords* :** Maize, Fall armyworm, *Spodoptera frugiperda*, Management, Sequential application.

Introduction

Maize (*Zea mays* L.), a member of the grass family (Poaceae), is the world's third most important cereal crop after rice and wheat and contributes over 5% of global dietary energy. Known as the "Queen of Cereals," it is valued for its high yield potential, genetic diversity, and adaptability across diverse agro-ecological regions (Azerefegne *et al*., 2002).

However, maize production is increasingly threatened by the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), a highly destructive pest that attacks over 350 plant species, including maize and sorghum. Poor FAW management can cause annual maize yield losses of 8.3–20.6 million tonnes, equivalent to 21–53% of total production (Day *et al*., 2017). Native to the Americas, FAW spread to Africa in 2016 and was first reported in India in Karnataka during 2018, from where it rapidly expanded to other regions of India and several Asian countries (Goergen *et al*., 2016; Sharanabasappa *et al.*, 2018; Ganiger *et al*., 2018).

FAW larvae attack maize at all growth stages, with the most severe damage during the vegetative phase. Early instars feed on leaf tissue, causing "window-pane" or skeletonized damage, while later instars create larger holes, ragged margins, and frass-filled whorls. The pest also harms silks and tassels, disrupting pollination, and feeds on developing kernels, leading to grain loss and increased disease susceptibility. Maize around 15 days after emergence is most vulnerable (Aditya and Singh, 2019).

Managing fall armyworm is most effective using an integrated approach combining biopesticides and chemical insecticides. Biopesticides, from natural sources like microbes and plants, are eco-friendly but act slowly, while chemical insecticides provide rapid control but risk resistance and environmental harm if overused. Sequential use of both ensures effective pest suppression, delays resistance, protects beneficial organisms, and supports sustainable maize production.

Materials and Methods

The field experiment was conducted at College of Agriculture, Hassan during *Rabi* 2023-24. The variety MAH 14-5 was sown in a Randomized Block Design with three replications with plot size of 2m ×3m. The crop was raised as per recommended package of practices. The first spray of insecticides was done after the infestation of the pest on 20 days old crop and second spray was done after 15 days of the first spray .The pre-treatment observation of damage by fall armyworm was recorded one day before spraying and the post-treatment observations was taken at one, three, seven and fourteen days after spraying on five randomly selected plants per plot. The observations were recorded for number of larvae per plant.

Table 1: Treatment details

Tr. No.	Treatment	Dosage
T1	*Beauveria bassiana* 1×10^8CFU - Chlorantraniliprole18.5% SC	5 g/l - 0.40ml/l
T2	*Metarhizium anisopliae* 1×10^8CFU - Emamectin benzoate 5 SG	5 g/l - 0.40g/l
T3	Neem seed kernel extract 5% -Thiodicarb 75% WP	50 ml/l - 0.70g/l
T4	*Metarhizium rileyi* 1×10^8 CFU -Spinetoram 11.7% w/w SC	5 g/l - 0.50ml/l
T5	*Bacillus thuringiensis* var. *Kurstaki* - Spinosad 45% SC	2 g/l - 0.30ml/l
T6	Emamectin benzoate 5 SG - Chlorantraniliprole 18.5% SC	0.40g/l - 0.40ml/l
T7	Untreated control	-

The mean data obtained for the larval population was processed by angular transformation (√Vx + 0.5). The data from each treatment was subjected for ANOVA (Gomez and Gomez, 1984; Hosmand, 1988) and means was separated by Tukey's HSD (Tukey, 1965) for interpretation.

Results and Discussion

First spray: The pre-treatment observations revealed a uniform distribution of fall armyworm larvae across treatments, with no significant differences in larval population. At 7 days after application, Emamectin benzoate 5 SG @ 0.40 g/l recorded the lowest larval population, followed by Metarhizium rileyi 1×10^8 CFU @ 5 g/l, Bacillus thuringiensis var. kurstaki @ 2 g/l, Beauveria bassiana 1×10^8 CFU @ 5 g/l, neem seed kernel extract 5% @ 50 ml/l, and Metarhizium anisopliae 1×10^8 CFU @ 5 g/l (Table 2). At 14 days after the first spray, Emamectin benzoate 5 SG @ 0.40 g/l remained the most effective treatment with the lowest larval population, followed by Metarhizium rileyi 1 × 10^8 CFU @ 5 g/l, Bacillus thuringiensis var. kurstaki @ 2 g/l, neem seed kernel extract 5% @ 50 ml/l, Beauveria bassiana 1×10^8 CFU @ 5 g/l, and Metarhizium anisopliae 1 × 10^8 CFU @ 5 g/l, which was the least effective (Table 2).

The reduction in larval population over untreated control ranged from 37.03 to 59.25 per cent. Emamectin benzoate 5 SG @ 0.40 g/l recorded the highest reduction, followed by *Metarhizium rileyi* 1 × 10^8 CFU @ 5 g/l, *Bacillus thuringiensis* var. *kurstaki* @ 2 g/l, *Beauveria bassiana* 1 × 10^8 CFU @ 5 g/l, neem seed kernel extract 5% @ 50 ml/l, and *Metarhizium anisopliae* 1 × 10^8 CFU @ 5 g/l. Overall, Emamectin benzoate 5 SG @ 0.40 g/l proved to be the most effective treatment against fall armyworm larvae (Table 2).

Second spray: The second spray of insecticides was taken 15 days after the first spray. Among all the treatments tested at 3 DAS a significant and lower larval population was observed from the treatments having the spray of Emamectin benzoate 5 SG @ 0.40 g/l - Chlorantraniliprole 18.5% SC @ 0.40 ml/l and Metarhizium rileyi 1×108 CFU @ 5 g/l - Spinetoram 11.7% w/w SC @ 0.50ml/l recording 0.13 and 0.20 larva per plant which are on par with each other (Table 3). Similarly at 7DAS a significant and least larval population was observed in Emamectin benzoate 5 SG @ 0.40g/l - Chlorantraniliprole 18.5% SC @ 0.40ml/l where the larval population was nill i.e., it has recorded 0.00 larva per plant. This was followed by Metarhizium rileyi 1×108 CFU @ 5 g/l - Spinetoram 11.7% w/w SC @ 0.50ml/l and Beauveria bassiana 1×108 CFU @ 5 g/l - Chlorantraniliprole18.5% SC @ 0.40ml/l where both the treatments have recorded 0.6 larva per plant (Table 3).

The same trend was observed at 14^{th} day after second spray where Emamectin benzoate 5 SG @ 0.25g/l - Chlorantraniliprole 18.5% SC @ 0.40 ml/l, *Metarhizium rileyi* 1×10^8 CFU @ 5 g/l - Spinetoram 11.7% w/w SC @ 0.50ml/l and *Beauveria bassiana* 1×10^8 CFU @ 5 g/l - Chlorantraniliprole18.5% SC @ 0.40ml/l recorded least larval population of 0.00 larva per plant and found most effective in managing the fall army worm larval population when compared to other treatments (Table 3).

At the end of second spray per cent reduction of larval population among all the treatments varied from 95 to 65 percent . The highest per cent reduction was seen in the treatments having Emamectin benzoate 5 SG @ 0.40 g/l - Chlorantraniliprole 18.5% SC @

0.40 ml/l, *Metarhizium rileyi* 1×10^8 CFU @ 5 g/l - Spinetoram 11.7% w/w SC @ 0.50ml/l and *Beauveria bassiana* 1×10^8 CFU @ 5 g/l - Chlorantraniliprole 18.5% SC @ 0.40 ml/l with a reduction of 95 per cent larval population. The least per cent reduction was seen in the treatment Neem seed kernel extract 5% 50 ml/l - Thiodicarb 75% WP @ 0.70g/l having a per cent reduction of 65 per cent and found least effective among all the treatments (Table 3).

The findings in respect to larval population management of fall army worm with biopesticides was in concurrent with Dhobi *et al*., 2020, where *Nomuraea rileyi* showed 1.81 larva / 10 plant followed by *Bacillus thuringiensis* var. *kurstaki* showing 2.03 larvae /10 plants. The findings in respect to chemical insecticides were in confirmation with the findings of Karki *et al*., 2023 as they reported that the treatment with Chlorantraniliprole 18.5% SC showed least infestation of FAW and the highest yield was obtained from the treatment Emamectin Benzoate 5% SG (72 t / ha).

Deshmukh *et al.* (2020) also found that efficacy testing for insecticides applied to crops planted in June and September of 2018 showed that Chlorantraniliprole 18.5 SC was the most effective, followed by Emamectin Benzoate 5 SG. These insecticides not only proved more effective than the control but also resulted in higher grain yields.

Similarly, Shinde *et al.* (2021) reported that whorl application of *Nomuraea rileyi* was most effective for management of fall armyworm. Similarly, Thumar *et al.* (2020) also observed that Spinetoram 11.7 SC, 0.117 %, Emamectin benzoate 5 SG, 0.0025 %, Chlorantraniliprole 18.5 EC, 0.006 % and Thiodicarb 75 WP, 0.11 % were found more effective in checking the larval population of fall armyworm.

Supremacy of Emamectin benzoate was proved by Babendreier *et al.,* (2020) who reported that emamectin benzoate might be more preferable than some of the older broad-spectrum ones against *S. frugiperda* at 0.167 per cent which demonstrated the significant reduction in larval number over other treatments and increased the yield. Similar results were obtained in the present investigation. Emamectin benzoate 5 SG @ 0.4g/L and Chlorantraniliprole 18.5 SC @ 0.4 ml/L being a novel insecticide known with translaminar activity proved to be effective against lepidopteran pests. Sharanabasappa *et al.,* (2020) also reported similar results indicating the efficacy of Emamectin benzoate 5 SG @ 0.4g/L against fall armyworm followed by Chlorantraniliprole 18.5 SC @ 0.5 ml/L in maize which recorded significantly higher larval mortality with LC50 values of 0.0051 and 0.0159, respectively under laboratory conditions. Also in field conditions, Chlorantraniliprole 18.5 SC (62.33 q/ha) and Emamectin benzoate 5 SG (61.80 q/ha) produced a higher grainyield

Table 2 : Efficacy of sequential application on fall army worm larval population (I spray), *Rabi* 2023-24.

Tr. No.	Treatment	Dosage	Mean no. of larvae per plant after first spray					Mean st of 1 spray	% R o C
			1DBS	1DAS	3DAS	7DAS	14DAS		
T1	*Beauveria bassiana* 1×10^8 CFU Chlorantraniliprole18.5% SC	5 g/l - 0.40ml/l	1.27	1.27 (1.33)^a	1.07 (1.25)^{ab}	1.00 (1.22)^b	0.73 (1.11)^{bc}	1.06 c (1.25)	44.44
T2	*Metarhizium anisopliae* 1×10^8 CFU - Emamectin benzoate 5 SG	5 g/l- 0.40g/l	1.33	1.27 (1.33)^a	1.20 (1.3)^{ab}	1.13 (1.28)^{ab}	0.93 (1.2)^b	1.17 b (1.29)	37.03
T3	Neem seed kernel extract 5% - Thiodicarb 75% WP	50 ml/ - 0.70g/l	1.40	1.27 (1.33)^a	1.13 (1.28)^{ab}	1.07 (1.25)^{ab}	0.73 (1.11)^{bc}	1.12 b (1.27)	40.74
T4	*Metarhizium rileyi* 1×10^8 CFU - Spinetoram 11.7% w/w SC	5 g/l - 0.50ml/l	1.40	1.13 (1.28)^a	0.93 (1.2)^b	0.87 (1.17)^b	0.53 (1.02)^{bc}	1.00 d (1.22)	51.85
T5	*Bacillus thuringiensis* var. *Kurstaki* - Spinosad 45% SC	2 g/l - 0.30ml/l	1.20	1.13 (1.28)^a	1.00 (1.22)^{ab}	0.93 (1.2)^b	0.60 (1.05)^{bc}	1.00 d (1.22)	48.14
T6	Emamectin benzoate 5 SG - Chlorantraniliprole 18.5% SC	0.40g/l- 0.40ml/l	1.27	1.27 (1.33)^a	0.87 (1.15)^b	0.73 (1.09)^b	0.40 (0.94)^c	0.90 e (1.19)	59.25
T7	Untreated control	-	1.27	1.33 (1.35)^a	1.80 (1.52)^a	1.80 (1.52)^a	1.66 (1.47)^a	1.57 a (1.44)	0
SEm+			NS	0.03	0.06	0.06	0.04	0.02	
CD@p=0.05				0.12	0.19	0.18	0.12	0.13	
CV (%)				7.89	8.74	8.39	9.23	9.67	

* Mean of five plants; DBS - Day Before Spray; DAS - Days After Spray; % R o C - Per cent Reduction over Control
Figure in parenthesis indicate √x +0.5 transformed values. Values in the column followed by common letters are non-significant at p=0.05 as per Tukey's HSD (Tukey, 1953).

Table 3 : Efficacy of sequential application on fall army worm larval population (II spray), *Rabi* 2023-24

Tr. No.	Treatment	Dosage	Mean no. of larvae per plant after second spray				Mean of 2nd spray	% R oC
			1DAS	3DAS	7DAS	14DAS		
T1	*Beauveria bassiana* 1×10^8 CFU Chlorantraniliprole18.5% SC	5 g/l - 0.40ml/l	0.53 (1.02)^b	0.33 (0.91)^{bcd}	0.06 (0.75)^c	0.00 (0.71)^d	0.23 c (0.86)	95
T2	*Metarhizium anisopliae* 1×10^8 CFU - Emamectin benzoate 5 SG	5 g/l-0.40g/l	0.73 (1.11)^b	0.66 (1.08)^b	0.46 (0.98)^b	0.40 (0.95)^b	0.56 b (1.03)	70
T3	Neem seed kernel extract 5% - Thiodicarb 75% WP	50 ml/l - 0.70g/l	0.66 (1.07)^b	0.60 (1.05)^b	0.40 (0.95)^b	0.33 (0.91)^b	0.50 b (1.00)	65
T4	*Metarhizium rileyi* 1×10^8 CFU - Spinetoram 11.7% w/w SC	5 g/l - 0.50ml/l	0.46 (0.98)^b	0.20 (0.84)^c	0.06 (0.75)^c	0.00 (0.71)^c	0.18 c (0.83)	95
T5	*Bacillus thuringiensis* var. *Kurstaki* - Spinosad 45% SC	2 g/l - 0.30ml/l	0.60 (1.05)^b	0.46 (0.98)^{bc}	0.26 (0.87)^{bc}	0.13 (0.79)^{cd}	0.36 c (0.93)	80
T6	Emamectin benzoate 5 SG - Chlorantraniliprole 18.5% SC	0.40g/l-0.40ml/l	0.33 (0.91)^b	0.13 (0.79)^c	0.00 (0.71)^c	0.00 (0.71)^c	0.13 d (0.80)	95
T7	Untreated control	-	1.53 (1.42)^a	1.46 (1.4)^a	1.33 (1.35)^a	1.20 (1.3)^a	1.38 a (1.37)	0
SEm+			0.05	0.03	0.04	0.02	0.02	
CD@p=0.05			0.16	0.11	0.13	0.08	0.12	
CV(%)			7.86	10.67	9.67	8.34	9.78	

* Mean of five plants ; DBS - Day Before Spray ; DAS-Days After Spray ; % R o C - Per cent Reduction over Control
Figure in parenthesis indicate √x +0.5 transformed values. Values in the column followed by common letters are non-significant at p=0.05 as per Tukey's HSD (Tukey, 1953).

Conclusion

Among the different sequence of insecticides tested for management of fall armyworm during *Rabi* 2023-24 the treatment Emamectin benzoate 5 SG @ 0.40g/l - Chlorantraniliprole 18.5% SC @ 0.40ml/l recorded the least larval population of 0.52 larva per plant compared to others followed by *Metarhizium rileyi* 1×10^8 CFU @ 5 g/l - Spinetoram 11.7% w/w SC @ 0.50ml/l with a least larval population of 0.59 larva per plant. These two sequences of chemicals were found most effective in managing the fall army worm in maize.

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