Uttar Pradesh Journal of Zoology

Volume 45, Issue 18, Page 514-524, 2024; Article no.UPJOZ.4061
ISSN: 0256-971X (P)

Efficacy of Newer Insecticides against Fall Armyworm, *Spodoptera frugiperda* on Maize

Shivangi Shahi [a], Saroj Chauhan [a++], Ritesh Kumar [a++*] and Jatin Kumar Singh [b#]

[a] Department of Entomology, Institute of Agriculture and Natural Sciences, Deen Dayal Upadhyaya Gorakhpur University Gorakhpur, Uttar Pradesh, Pin-273009, India.
[b] Department of Entomology, GBPUAT, Pantnagar, Pin-263145, Uttarakhand, India.

Authors' contributions

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

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i184468

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/4061

Original Research Article

Received: 08/07/2024
Accepted: 11/09/2024
Published: 16/09/2024

ABSTRACT

The effectiveness of various newer insecticides against fall armyworm was assessed. The different treatments were spray *viz.,* flubendiamide 39.35 % SC, chlorantraniliprole 18.5% SC, emamectin benzoate 5% SG, *Beauveria bassiana*, *Metarhizium anisopliae*, neem seed kernel extract, *Bacillus thuringiensis* and control. The overall mean of the two sprays revealed that the most effective treatment was chlorantraniliprole 18.5% SC recorded the lowest larval population followed by emamectin benzoate 5% SG, Flubendiamide 39.35 % SC, *Bacillus thuringiensis, Beauveria bassiana, Metarhizium anisopliae*, neem seed kernel extract. During the yield observation, it was observed that a significantly higher yield was obtained in chlorantraniliprole 18.5% SC treated plots

---

[++] *Assistant Professor;*
[#] *Ph.D. Scholar;*
**Corresponding author: Email: riteshskuast@gmail.com;*

***Cite as:** Shahi, Shivangi, Saroj Chauhan, Ritesh Kumar, and Jatin Kumar Singh. 2024. "Efficacy of Newer Insecticides Against Fall Armyworm, Spodoptera Frugiperda on Maize". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (18):514-24. https://doi.org/10.56557/upjoz/2024/v45i184468.*

which is followed by emamectin benzoate 5% SG, flubendiamide 39.35 % SC, *Bacillus thuringiensis, Beauveria bassiana, Metarhizium anisopliae* and NSKE 5 %. Maximum percentage increase in yield over control was obtained from chlorantraniliprole 18.5% SC treated plots which are followed by emamectin benzoate 5% SG, flubendiamide 39.35 % SC, *Bacillus thuringiensis, Beauveria bassiana, Metarhizium anisopliae* and NSKE 5 %. The economics of various treatments based on net profit and cost of plant protection revealed that the highest cost: benefit ratio was observed in plot treated with emamectin benzoate 5% SG followed by *Beauveria bassiana*, chlorantraniliprole 18.5% SC, *Bacillus thuringiensis*, NSKE, *Metarhizium anisopliae*, flubendiamide 39.35 % SC.

Keywords: Chlorantraniliprole 18.5% SC; efficacy; FAW; invasive pest; maize B:C ratio.

1. INTRODUCTION

The fall Armyworm, also known as S*podoptera frugiperda* is an invasive insect [1]. The grass family Poaceae includes the tribe Maydeae, which includes Maize. *Zea mays L.* "*Zea*" was derived from an ancient Greek word for food grass [2]. There are four species in the genus *Zea* with *Z. mays L*. being the most economically significant. *Z. mays* has 20 chromosomes or 2n = [3]. It Is also called the queen of cereals because of its inherent high genetic yield potentials and it is the third most significant cereal crop after wheat and rice in the world (Pratap and Kumar, [4]. Devi et al*.,* [5]. It originates in the Andean region of Central America [6]. It is grown in over 160 countries throughout the world in which the USA, China, Brazil, Mexico, France and India are the major producers [7]. In India, it is grown in a variety of habitats throughout the country Karnataka, Andhra Pradesh, Maharashtra, Bihar, Punjaband Haryana are the major producers. In India, maize is grown in three different seasons: *i.e. kharif*, *rabi* in Peninsular India and Biharand *spring* in northern India. Although it is typically grown during the *kharif* season, *rabi* maize has recently become a substantial part of India's overall maize production (Nirupma et al*.*, [8], Ramadhan et al*.,* [9]. In India maize was cultivated on 9.86 million hectares, which produced 31.51 million tonnes with a productivity of 3195 kg/hectare [10]. In Uttar Pradesh, around 63374 ha area is under maize production, with a productivity of 19.81 quintal ha^{-1}. Its relevance comes from the fact that, although 52% of the maize grown in India is used as animal feed, 23% of it is consumed by humans and the other 80% is used in various industrial applications [11]. 17% of the maize produced worldwide is utilized as food 22% as industrial feed and 61% as animal feed [12]. It was recorded in India in the month of *Kharif* in 2018 and caused havoc. From planting through harvest141 insect pests attack maize crops causing varied degrees of harm [13]. The current fall armyworm invasion in India puts the country's food security in danger and poses a significant obstacle for maize farmers. *S. frugiperda*, often known as the fall armyworm (FAW), is a destructive insect pest that is a member of the Noctuidae family in the lepidoptera order Abbas et al., [14], Sampat, [15]. An alien pest identified as the fall armyworm mostly attacks maize crops [16]. Around 80 species, especially rice, sorghum, beans and cotton are harmed by this polyphagous pest [17]. The larvae of FAW are found on young leaves, leaf whorls, tassels or cobs according to their growth stages [18]. Larvae typically eat a lot of foliage and occasionally destroy the growth of the plant [19]. As much as 34% of a yield drop in maize has been attributed to fall armyworm feeding [20]. Various approaches for insect pest management in maize are chemicals, botanicals and the use of resistant cultivars. The objective of this study is therefore to evaluate selected insecticides to manage, fall armyworm under field conditions to find the best insecticides for its management.

2. MATERIALS AND METHODS

A field experiment was conducted at the entomology research field, Deeksha Bhawan, Institute of Agriculture and Natural Science, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur during *Kharif*- 2023. The variety Sartaj was used for this experiment. Seven treatments: - flubendiamide 39.35 SC, chlorantroniuprole 18.5% SC, emamectin benzoate 5% SG, *Beauveria bassiana* (1x10^9 cfu/g), *Metarhizium anisopliae* (1x10^9 cfu/g), Neem seed kernel extract, *Bacillus thuringiensis* (2x10^9 cfu/g) were evaluated. Randomized Block Design with three replications along with an untreated check (control plot) in a plot size of 3m×3m with a spacing of 60 x 20 cm was followed. Seeds were sown directly to the soil during the last week of July and the crop was raised following all the agronomical practices. The first spray of insecticides was made on the ETL and subsequent spray was given at 15-day intervals for recording observations five plants were randomly selected and tagged from the whole experimental plot. The observation on number of larvae per plant. The observation was made prior to 24 hours of the first spray as well as 3,7 and 10 days after each spray. The recorded observation on the mean larval population was subjected to the RBD (Randomized Block Design) by using 'OPSTAT' software and data was subjected to log transformation to know the treatment variations for significance. Picking-wise fruit yield were recorded at each picking from each plot. The periodical data on a number of larvae were subjected to analysis of variance (ANOVA) after transforming them to square root.

The mean larval population of fall armyworm was calculated as follows.

Mean Larval Population = Number of larvae / Five randomly selected plants

Per cent increase in yield over control calculated using the following formula.

Per cent increase in yield = Yield in treatment−Yield in control / Yield in control * 100

The benefit-cost ratio was calculated using the following formula

B: C ratio = Net benefit over control / Total cost of protection

3. RESULTS AND DISCUSSION

Seven treatments were evaluated for their efficacy against fall armyworm based on number of larvae and fruit yield. The different treatments were sprayed *viz.,* flubendiamide 39.35 SC, chlorantroniuprole 18.5% SC, emamectin benzoate 5% SG, *Beauveria bassiana* ($1x10^9$ cfu/g), *Metarhizium anisopliae* ($1x10^9$ cfu/g), neem seed kernel extract, *Bacillus thuringiensis* ($2x10^9$ cfu/g) and control plot. Pretreatment observation was recorded a day before treatment and there after 3, 7 and 10 days of spraying. In pre-treatment observation, the larval population of fall armyworm ranged from 1.46 to 1.55 per plant, which revealed no significant differences among different treatments, indicating more or less similar pest infestation on the crop under investigation. Data revealed that three days after application of the first spray, the plot treated with chlorantraniliprole 18.5% SC recorded the lowest larval population (1.22 larvae/ plant) followed by emamectin benzoate 5% SG (1.27 larvae/plant), flubendiamide 39.35% SC (1.29 per plant), *B. thuringiensis* (1.34 larvae/ plant), *B. bassiana* (1.36 larvae/ plant), *M. anisopliae* (1.39 larvae/plant) and neem seed kernel extract (1.41 larvae/ plant). As compared to the control plot (1.97 larvae/ plant) neem seed kernel extract was found statically at par with *M. anisopliae* (Table 1 & Fig. 1). At seven days after the first spray, chlorantraniliprole 18.5% SC recorded the lowest larval population (0.82 larvae/ plant) followed by emamectin benzoate 5% SG (0.87 larvae/ plant), flubendiamide 39.35% SC (0.93 larvae/plant), *B.bassiana* (1.14 larvae/ plant), *M. anisopliae* (1.21 larvae/ plant), *B. thuringiensis* (1.25 larvae/plant), neem seed kernel extract (1.36 larvae/ plant) and control plot (2.02 larvae/plant) (Table 1& Fig. 1). The least number of larvae were recorded in plots treated after ten days of spray were chlorantraniliprole 18.5% SC (0.97 larvae/ plant) application followed by emamectin benzoate 5% SG (1.07 larvae/ plant) flubendiamide 39.35% SC (1.11 larvae/plant), *B. thuringiensis* (1.18 larvae/plant), *B. bassiana* (1.21 larvae/plant), *M. anisopliae* (1.26 larvae/ plant), neem seed kernel extract (1.38 larvae/ plant) and control plot (2.08 larvae/ plant). (Table 1 & Fig. 1). The mean data of the first spray revealed that the lowest number of larvae were recorded in plots treated with chlorantraniliprole 18.5% SC recorded the lowest larval population (1.00 larvae/ plant) followed by emamectin benzoate 5% SG (1.07 larvae/plant), flubendiamide 39.35% SC (1.11 larvae/ plant), *B. thuringiensis* (1.18 larvae/ plant), *B. bassiana* (1.21 larvae/ plant), *M. anisopliae* (1.26 larvae/ plant), neem seed kernel extract (1.38 larvae/ plant) and control plot (2.02 larvae/ plant). (Table 1). The data revealed that three days after second spray, the plot treated with chlorantraniliprole 18.5% SC recorded the lowest larval population (1.32 larvae/plant) followed by emamectin benzoate 5% SG (1.38 larvae/ plant), flubendiamide 39.35% SC (1.48 larvae/ plant), *B. thuringiensis* (1.56 larvae/ plant), *B. bassiana* (1.63 larvae/plant), *M. anisopliae* (1.66 larvae/ plant), neem seed kernel extract (1.78 larvae/ plant) and control plot recorded the highest number of larvae (2.31 larvae/ plant) (Table 1 & Fig. 2). After seven days of second spray, the plot treated with chlorantraniliprole 18.5% SC recorded lowest number of larval population (1.03 larvae/ plant) followed by emamectin benzoate 5% SG (1.11 larvae/ plant), flubendiamide 39.35% SC (1.19 larvae/plant), *B.*

thuringiensis (1.47 larvae/plant), *B. bassiana* (1.54 larvae/plant), *M. anisopliae* (1.59 larvae/ plant), neem seed kernel extract (1.61 larvae/ plant) and control plot recorded highest number of larvae (2.28 larvae/plant). Neem seed kernel extract was found statically at par with *B. bassiana* and *M. anisopliae* (Table 1 & Fig. 2). After ten days of the second spray, the lowest larval population were recorded in plots treated with chlorantraniliprole 18.5% SC (1.21 larvae/ plant) followed by emamectin benzoate 5% SG (1.27 larvae/plant), flubendiamide 39.35% SC (1.31 larvae/ plant), *B. thuringiensis* (1.53 larvae/ plant), *B. bassiana* (1.59 larvae/ plant), *M. anisopliae* (1.65 larvae/ plant), neem seed kernel extract (1.69 larvae/plant) and control plot recorded highest number of larvae (2.21 larvae/plant). Neem seed kernel extract was found statically at par with *M. anisopliae* (Table 1 & Fig. 2). The mean data of the second spray revealed that the most effective treatment was chlorantraniliprole 18.5% SC recorded the lowest larval population (1.19 larvae/plant) followed by emamectin benzoate 5% SG (1.25 larvae/ plant), flubendiamide 39.35% SC (1.33 larvae/plant), *B. thuringiensis* (1.52 larvae/plant), *B. bassiana* (1.59 larvae/ plant), *M. anisopliae* (1.63 larvae/plant), neem seed kernel extract (1.69 larvae/plant) and control plot recorded the highest number of larvae (2.27 larvae/plant). (Table 1). The overall mean of two sprays revealed that the most effective treatment was chlorantraniliprole 18.5% SC recorded the lowest larval population (1.22 larvae/plant) followed by emamectin benzoate 5% SG (1.16 larvae/plant), flubendiamide 39.35% SC (1.22 larvae/plant), *B.thuringiensis* (1.39 larvae/ plant), *B. bassiana* (1.41 larvae/plant), *M. anisopliae* (1.46 larvae/plant), neem seed kernel extract (1.54 larvae/plant) and control plot recorded the highest number of larvae (2.15 larvae/plant). (Table 1).

Thus, it is clear from the results that chlorantraniliprole 18.5% SC was found most effective insecticide treatment among all pesticides for controlling the fall armyworm, as it was recorded the lowest number of larvae (1.10 larvae/plant). The second-best treatment was emamectin benzoate 5% SG (1.16 larvae/plant) followed by flubendiamide 39.35% SC (1.22 larvae/plant). Neem seed kernel extract was recorded least effective treatment (1.54 larvae/plant). Present findings clearly state that the best efficacy of chlorantraniliprole against fall armyworm in maize. The present findings are in accordance with Hardke et al. 2011 reported that chlorantraniliprole is highly effective in bioassay against S. *frugiperda* in the laboratory as well as effective in controlling the pest in sorghum. He also reported emamectin benzoate 5% SG as the second most effective insecticide based on observed treatments. Belay et al. [21] studied the effect of different insecticides for the management of fall armyworm larvae using a direct spray over third-instar larvae. More than 80% mortality was observed in chlorantraniliprole. Sisay et al., [22] also found chlorantraniliprole effective in reducing foliar damage of maize compared to the control in the greenhouse experiment. Bajracharya et al., [23] reported chlorantraniliprole and emamectin benzoate were effective for *S. frugiperda* in maize. Deshmukh et al*.,* [24] revealed that the effective insecticides were chlorantraniliprole 18.5 SC, followed by emamectin benzoate 5 SG. chlorantraniliprole and emamectin benzoate are suitable as one of the components of Integrated Pest Management of fall armyworms in India.

3.1 Yield Parameter

The cumulative yield data revealed that the fruit production gradually increased when fall armyworms were treated with different insecticides and marketable maize cob yield ranged from 47.02 to 53.26 q / ha. In contrast to the control plot, which produced the lowest fruit yield of 41.21 q / ha. The significantly higher cob yield (53.26 q / ha) was obtained in chlorantraniliprole 18.5% SC treated plots which is followed by emamectin benzoate 5% SG (52.41 q / ha), flubendiamide 39.35% SC (51.53 q / ha), *B. thuringiensis* (49.44 q / ha), *B. bassiana* (47.91 q per ha), *M. anisopliae* (47.02 q / ha) and NSKE 5% (46.05 q / ha) (Table 2 & Fig. 3). Maximum percentage increase in yield over control was obtained from chlorantraniliprole 18.5% SC (22.62%) treated plots which are followed by emamectin benzoate 5% SG (21.37%), flubendiamide 39.35% SC (20.03%), *B. thuringiensis* (16.65%), *B. bassiana* (13.98%), *M. anisopliae* (12.26%) and NSKE 5% (10.51%) (Table 3). The economics of various treatments based on net profit and cost of plant protection (Table 3) revealed that the highest cost: benefit ratio emamectin benzoate 5% SG (1:10.26) followed by *B. bassiana* (1:10.03), chlorantraniliprole 18.5% SC (1:8.34), *B. thuringiensis* (1:7.09), Neem seed kernel extract (1:5.13), *M. anisopliae* (1:3.58), flubendiamide 39.35% SC (1:3.31). The highest B:C ratio of emamectin benzoate 5% SG may be due to its low price and dose concentration [25].

Table 1. Observation of larval population of *S. frugiperda* after application of treatments.

Treatment no.	Treatment	Dose g a.i. ha^{-1}	Mean larval population per plant									
			Before spray	1st Spray			Mean of first spray	2nd Spray			Mean of second spray	Overall mean of both spray
				3 DAS	7 DAS	10 DAS		3 DAS	7 DAS	10 DAS		
1	Flubendiamide 39.35% SC	250	1.51 (1.58)	1.29 (1.51)	0.93 (1.39)	1.11 (1.45)	1.11	1.48 (1.57)	1.19 (1.48)	1.31 (1.52)	1.33	1.22
2	Chlorantraniliprole 18.5% SC	150	1.48 (1.57)	1.22 (1.49)	0.82 (1.34)	0.97 (1.40)	1.00	1.32 (1.50)	1.03 (1.42)	1.21 (1.48)	1.19	1.10
3	Emamectin benzoate 5% SG	250	1.55 (1.59)	1.27 (1.50)	0.87 (1.36)	1.07 (1.43)	1.07	1.38 (1.54)	1.11 (1.45)	1.27 (1.50)	1.25	1.16
4	*Beauveria bassiana*	1500	1.46 (1.56)	1.36 (1.53)	1.14 (1.46)	1.21 (1.48)	1.24	1.63 (1.62)	1.54 (1.59)	1.59 (1.60)	1.59	1.41
5	*Metarhizium anisopliae*	2500	1.47 (1.57)	1.39 (1.54)	1.21 (1.48)	1.26 (1.50)	1.29	1.66 (1.63)	1.59 (1.60)	1.65 (1.62)	1.63	1.46
6	Neem seed kernel extract (NSKE)	25000	1.49 (1.57)	1.41 (1.55)	1.36 (1.53)	1.38 (1.54)	1.38	1.78 (1.68)	1.61 (1.61)	1.69 (1.63)	1.69	1.54
7	*Bacillus thuringiensis*	1000	1.52 (1.58)	1.34 (1.53)	1.25 (1.49)	1.18 (1.47)	1.26	1.56 (1.60)	1.47 (1.57)	1.53 (1.59)	1.52	1.39
8	Control plot	-	1.47 (1.57)	1.97 (1.72)	2.02 (1.73)	2.08 (1.75)	2.02	2.31 (1.81)	2.28 (1.81)	2.21 (1.79)	2.27	2.15
	Sem±		**0.006**	**0.008**	**0.019**	**0.016**	**-**	**0.008**	**0.013**	**0.011**	**-**	**-**
	CD (5%)		**NA**	**0.025**	**0.057**	**0.05**	**-**	**0.025**	**0.039**	**0.035**	**-**	**-**

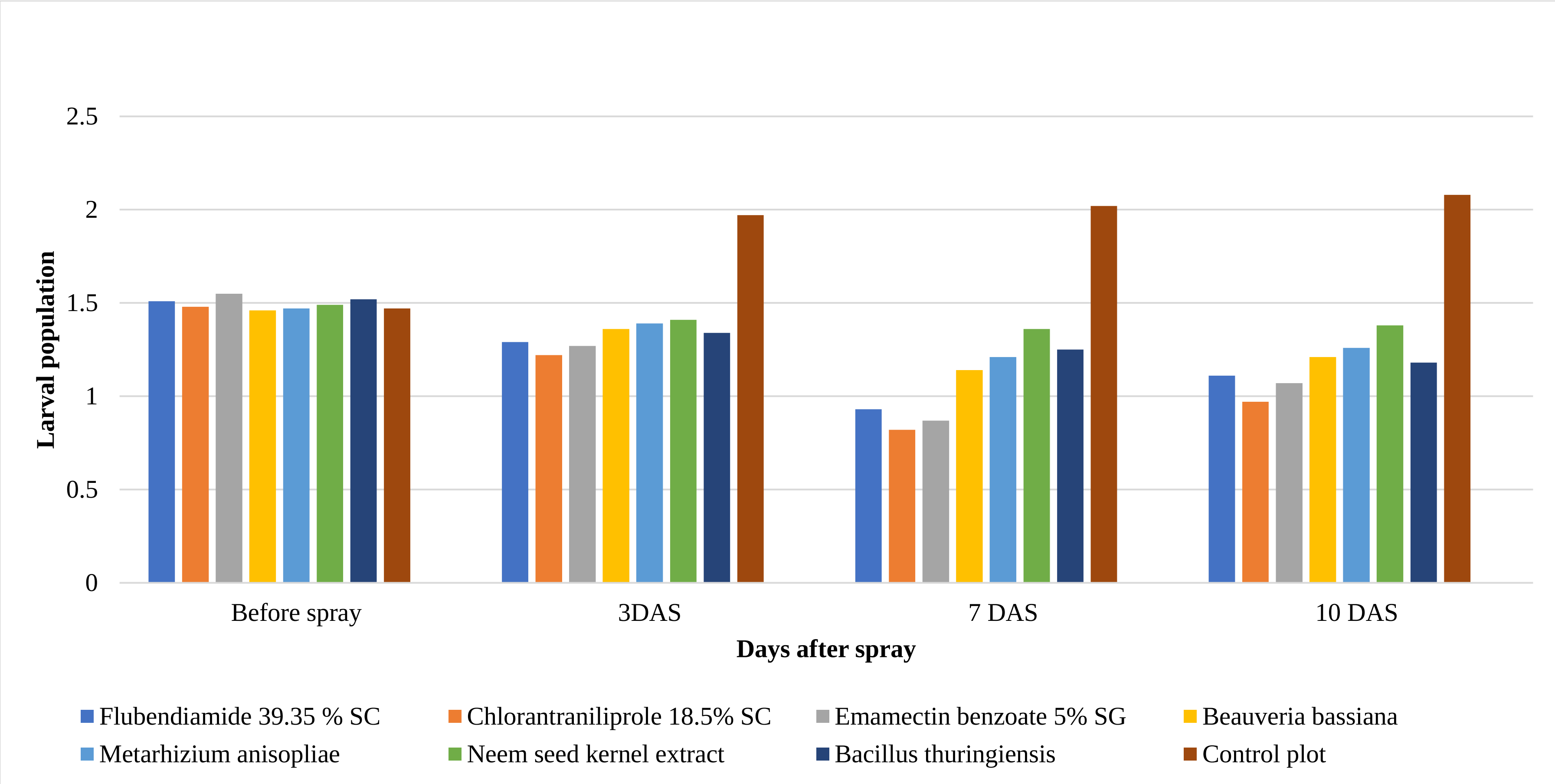

Fig. 1. Impact of various insecticides against fall armyworm in maize after first spray

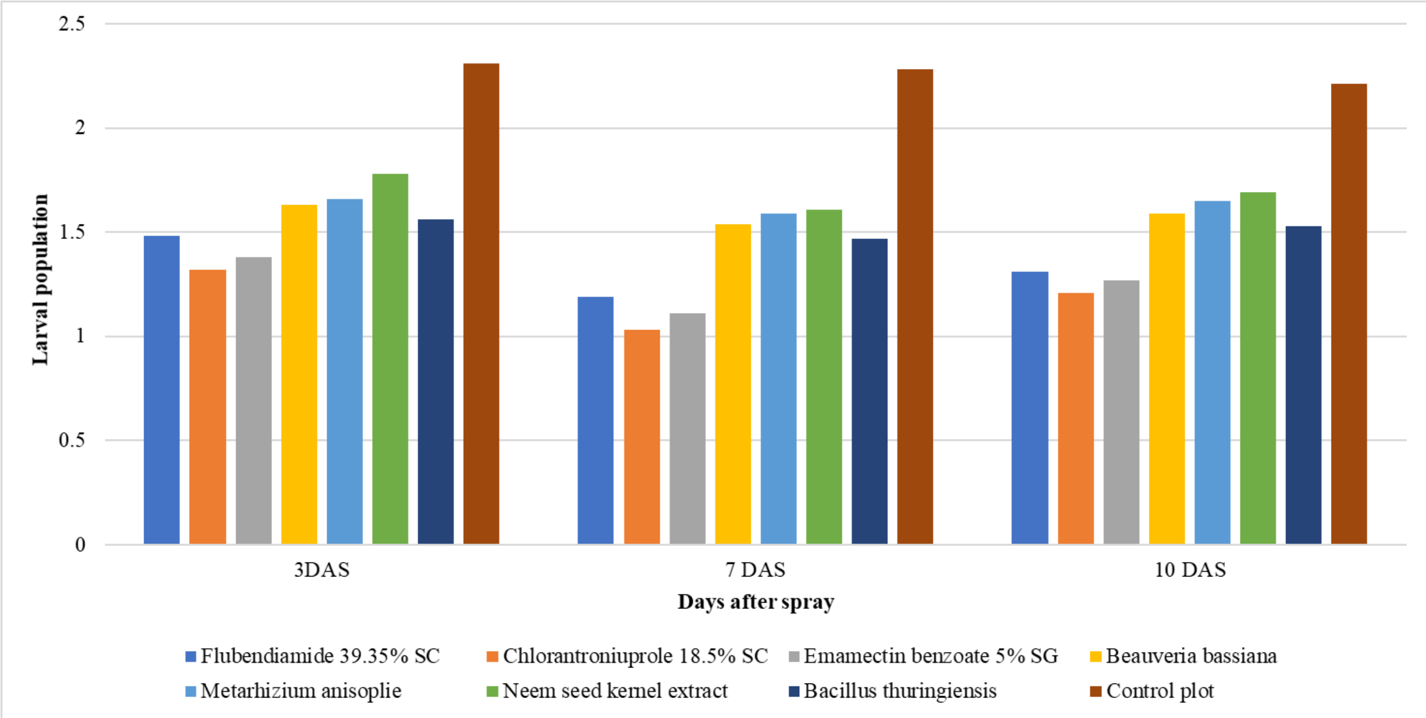

Fig. 2. Impact of various insecticides against fall armyworm in maize after second spray

Table 2. Influence of various insecticide treatments on maize yield and increase in yield (%) compared to control

S.N.	Treatments	Yield (q/ha)	Increase in yield (%) over control
1	Flubendiamide 39.35% SC	51.53	20.03
2	Chlorantraniliprole 18.5% SC	53.26	22.62
3	Emamectin benzoate 5% SG	52.41	21.37
4	*Beauveria bassiana*	47.91	13.98
5	*Metarhizium anisopliae*	47.02	12.36
6	Neem seed kernel extract	46.05	10.51
7	*Bacillus thuringiensis*	49.44	16.65
8	Control plot	41.21	0.00

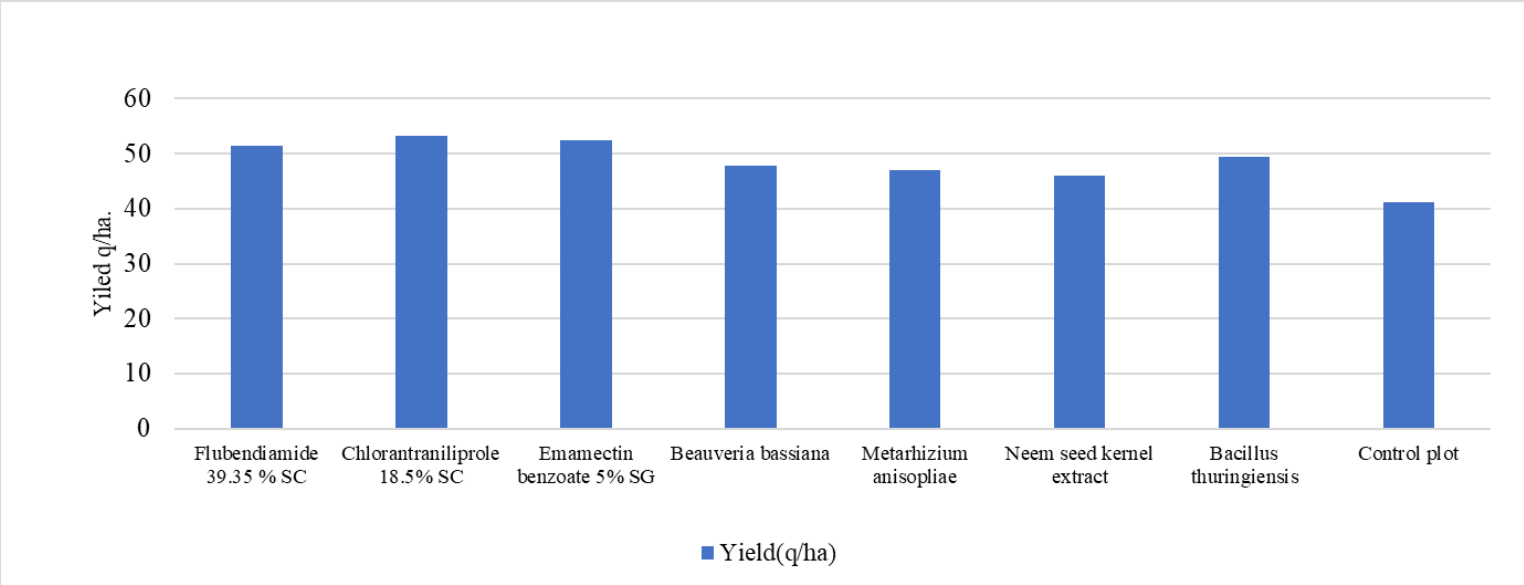

Fig. 3. Impact of various treatments on Yield(q/ha)

Table 3. Economics of different insecticides against fall armyworm

S.No.	Treatments	Yield (q/ha)	Insecticide Cost	Total cost of Plant Protection	Gross Income	Net Income	Benefit over control	B:C
1	Flubendiamide 39.35% SC	51.53	4110	5010	107697.7	102687.7	16558.8	1:3.31
2	Chlorantraniliprole 18.5% SC	53.26	1795	2695	111313.4	108618.4	22489.5	1:8.34
3	Emamectin benzoate 5% SG	52.41	1073	1973	109536.9	107563.9	21435	1:10.86
4	*Beauveria bassiana*	47.91	369	1269	100131.9	98862.9	12734	1:10.03
5	*Metarhizium anisopliae*	47.02	1750	2650	98271.8	95621.8	9492.9	1:3.58
6	Neem seed kernel extract	46.05	750	1650	96244.5	94594.5	8465.6	1:5.13
7	*Bacillus thuringiensis*	49.44	1080	1980	103329.6	101349.6	15220.7	1:7.69
8	Control plot	41.21	-	-	86128.9	86128.9	-	-

Labour cost per day = 350 ₹ per labour (2 labour required for spraying in one hectare per day), Spraying machine cost =100 ₹ per day. Local mandi of price of maize @ 2090 ₹ per quintal

Table 4. Price of different insecticide used in the experiment

Insecticide	Price per litre/kg	Insecticide	Price per litre
Flubendiamide 39.35% SC	16410 ₹ per litre	*Metarhizium anisopliae*	700 ₹ per litre
Chlorantraniliprole 18.5% SC	11368 ₹ per litre	Neem seed kernel extract	30 ₹ per litre
Emamectin benzoate 5% SG	4292 ₹ per kg	*Bacillus thuringiensis*	1080 ₹ per litre
Beauveria bassiana	246 ₹ per litre	-	-

4. CONCLUSION

The overall mean of two spray revealed that the most effective treatment was chlorantraniliprole 18.5% SC recorded the lowest larval population (1.22 per plant) followed by emamectin benzoate 5% SG (1.16 per plant), flubendiamide 39.35% SC (1.22 per plant), *B. thuringiensis* (1.39 per plant), *B. bassiana* (1.41 per plant), *M. anisopliae* (1.46 per plant), neem seed kernel extract (1.54 per plant) and control plot recorded the highest number of larvae (2.15 per plant). During the yield observation, it was observed that the significantly higher cob yield (53.26 q / ha) was obtained in chlorantraniliprole 18.5% SC treated plots which is followed by emamectin benzoate 5% SG (52.41 q per ha), flubendiamide 39.35% SC (51.53 q per ha), *B. thuringiensis* (49.44 q per ha), *B. bassiana* (47.91 q per ha), *M. anisopliae* (47.02 q per ha) and NSKE 5% (46.05 q per ha). Maximum percentage increase in yield over control was obtained from chlorantraniliprole 18.5% SC (22.62%) treated plots which are followed by emamectin benzoate 5% SG (21.37%), flubendiamide 39.35% SC (20.03%), *B. thuringiensis* (16.65%), *B. bassiana* (13.98%), *M. anisopliae* (12.26%) and NSKE 5% (10.51%). The economics of various treatments based on net profit and cost of plant protection revealed that. the highest cost: benefit ratio emamectin benzoate 5% SG (10.86) followed by *B. bassiana* (10.03), chlorantraniliprole 18.5% SC (8.34), *B. thuringiensis* (7.09), neem seed kernel extract (5.13), *M. anisopliae* (3.58), flubendiamide 39.35% SC (3.31).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare 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.

ACKNOWLEDGEMENTS

I am thankful to the director professors and whole staff of IANS for providing support and materials during the period of the investigations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kumar RM, Gadratagi BG, Paramesh V, Kumar P, Madivalar Y, Narayanappa N, et al. Sustainable management of invasive fall armyworm, *Spodoptera frugiperda*. Agronomy. 2022; 12(9):2150.
2. Rao IU. Origin and Introduction of Crop Plants, Cereals and Pulses; 2007.
3. Hossain F, Muthusamy V, Bhat JS, Jha SK, Zunjare R, Das A, et al. Maize. In: Broadening the genetic base of grain cereals. 2016;67-88.
4. Pratap A, Kumar J. Alien Gene Transfer in Crop Plants, Volume 2. Springer-Verlag New York; 2016.
5. Devi V, Bhushan B, Gupta M, Sethi M, Kaur C, Singh AV, et al. Genetic and molecular understanding for the development of methionine-rich maize: a holistic approach. Frontiers in Plant Science. 2023;14:1249230.
6. Bonavia D, Grobman A. Andean maize: Its origins and domestication. In: Foraging and farming Routledge. 2014; 456-470.
7. Chaudhary DP, Kumar S, Langyan S, editors. Maize: nutrition dynamics and novel uses. New Delhi: Springer India. 2014;3.
8. Nirupma SR, Rajendran RA, Shekhar M, Jat SL, Kumar R, Kuma RS. Rabi Maize Opportunities Challenges. Directorate of Maize Research, New Delhi, India. 2012;9-32.
9. Ramadhan AJ, Tiwari AK, Kumar B, Supriya S, Mishra H, Gautam S, et al. Comparative Economics of Maize Crop in Kharif and Rabi Season. In: BIO Web of Conferences EDP Sciences. 2024;97: 00134.
10. Anonymous. Agricultural Statistics at a Glance. Directorate of Economics & Statistics, Ministry of Agriculture & Farmers Welfare, Department of Agriculture & Farmers Welfare, Government of India; 2021.
11. Kumar R, Bhardwaj A, Singh LP, Singh G. Environmental and economical assessment of maize cultivation in Northern India. Process Integration and Optimization for Sustainability. 2024;8 (1):165-179.
12. Mandal S, Singh VK, Chaudhary D, Kaur A, Kumar R, Panwar A. and Kaushik, P. From Grain to Gain: Revolutionizing Maize Nutrition; 2023.
13. Reddy YVR, Trivedi S. Maize Production Technology. Academic Press. 2008;0-192.
14. Abbas A, Ullah F, Hafeez M, Han X, Dara MZN, Gul H, and Zhao. Biological control

of fall armyworm, *Spodoptera frugiperda*. Agronomy. 2022;12(11):2704.
15. Sampat MPK. Eco-friendly management of fall armyworm, *Spodoptera frugiperda* (JE SMITH) in maize [Doctoral dissertation]. Mahatma Phule Krishi Vidyapeeth; 2024.
16. Andrews KL. The whorlworm, *Spodoptera frugiperda*. Central America and neighboring areas. Florida Entomologist. 1980;63(4):456-467.
17. Day R, Abrahams P, Bateman M, Beale T, Clottey V, Cock M, et al. Fall armyworm: impacts and implications for Africa. Outlooks on Pest Management. 2017;28(5):196-201.
18. Acharya S, Kaphle S, Upadhayay J, Pokhrel A, Paudel S. Damaging nature of fall armyworm and its management practices in maize: A review. Tropical Agrobiodiversity. 2020;1:82-85.
19. Hodgson EW, Dean AN, Rice ME. Recognizing feeding injury to corn ears in the United States. Journal of Integrated Pest Management. 2024;15(1):18.
20. Yaméogo IS, Latévi K, Ouattara D, Agboyi LK, Dabiré RA, Zallé S.Kenis, M., Gnankine, O and Nacro, S. Level of damage and yield losses associated with the fall armyworm (*Spodoptera frugiperda*) on maize (*Zea mays*), millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*) on station in Burkina Faso. Crop Protection. 2024;106743.
21. Belay DK, Huckaba RM, Foster JE. Susceptibility of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), at Santaisabel, Puerto Rico to different insecticides. J Florida Entomologist. 2012;95(2):262-268.
22. Sisay B, Tefera T, Wakgari M, Ayalew G, Mendesil E. The efficacy of selected synthetic insecticides and botanicals against fall armyworm, *Spodoptera frugiperda*, in maize. Insects. 2019;10(2):45.
23. Bajracharya ASR, Bhat B, Sharma P. Field efficacy of selected insecticides against fall armyworm, *Spodoptera frugiperda* (JE Smith) in maize. Journal of Plant Protection Society. 2020;6:127-133.
24. Deshmukh S, Pavithra HB, Kalleshwaraswamy CM, Shivanna BK, Maruthi MS, Mota-Sanchez D. Field efficacy of insecticides for management of invasive fall armyworm, *Spodoptera frugiperda* (JE Smith) (*Lepidoptera: Noctuidae*) on maize in India. Florida Entomologist. 2020; 103(2):221-227.
25. Hardke JT, Temple JH, Leonard BR, Jackson RE. Laboratory toxicity and field efficacy of selected insecticides against fall armyworm (*Lepidoptera: Noctuidae*). Florida Entomologist. 2011;94(2):272 -278.

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/4061