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Efficacy of different insecticides against fall armyworm *Spodoptera frugiperda* (J.E. Smith) on maize (*Zea mays* L.)

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Abstract
The present investigation was carried out at Central Research Farm (CRF), Department of Entomology, Sam Higginbottom University of Agriculture, Technology and Sciences. Prayagraj, Uttar Pradesh during *Rabi* season 2023-24. The experiment was laid in Randomized Block Design with eight treatments replicated thrice along with untreated control plot. Eight treatments are Imidacloprid 40% + Fipronil 40% (80 WG) @ 0.20 ml/Lit, Chlorantraniliprole 18.5% SC @ 0.20 ml/Lit, Spinetoram 11.7% SC @ 0.30 ml/Lit, Flubendiamide 39.35% SC @ 0.24 ml/Lit, Novaluron 10% EC @ 1 ml/Lit, *Beauveria bassiana* 5% @ 4 ml/Lit., NSKE 5% @ 50 g/lit were evaluated against fall armyworm (*Spodoptera frugiperda*). Study revealed that all the treatments was found significantly superior over control. The result showed that the treatments lowest mean larval population was recorded in T_3 Spinetoram (1.28), followed by T_1 Imidacloprid 40% + Fipronil 40% (1.58), T_5 Novaluron (1.85), T_4 Flubendiamide (2.09), T_2 Chlorantraniliprole (2.28), T7 NSKE (2.48) and T_6 *Beauveria bassiana* (2.67). The treatments T_6 *Beauveria bassiana* (2.67) was least effective among all the treatments against *Spodoptera frugiperda*. The crop yield ranged between 44.40 q/ha to 19.24 q/ha in the treatments and benefit cost ratio ranged between 1:2.20 to 1:1.08. The plot treated with Spinetoram 11.7% SC showed highest yield and benefit cost ratio (44.40 q/ha, 1:2.20) and found to be most effective treatment next to which, Imidacloprid 40% + Fipronil 40% (80 WG) (38.8 q/ha, 1:1.98) was more effective among all other treatments, followed by Novaluron 10% EC (35.38 q/ha, 1:1.74), Flubendiamide 39.35% SC (33.30 q/ha, 1:1.68), Chlorantraniliprole 18.5% SC (31.20 q/ha, 1:1.53), NSKE 5% (28.90 q/ha, 1:1.40). *Beauveria bassiana* (24.40 q/ha, 1:1.34) as compared to untreated control plot (19.24 q/ha, 1:1.08). The highest cost benefit ratio was obtained in the treatment of T_3 Spinetoram 11.7% SC (1:2.20), followed by T_1 Imidacloprid 40% + Fipronil 40% (1:1.98), respectively.

Keywords: Botanicals, benefit cost ratio, chemicals, efficacy, maize, *Spodoptera frugiperda*

1. Introduction

Maize (*Zea mays* L.), a member of the *Poaceae* family, is one of the world's most important cereal crops, contributing to food security in the majority of poor countries. After rice and wheat, maize is India's third most important crop. It is significance stems from the fact that it is utilized not only as human food and animal feed, but also in the corn starch industry, corn oil production and as baby corn in various recipes. It includes a number of important phytochemicals including carotenoids, phenolic compounds and phytosterols, all of which are beneficial in the prevention of certain chronic diseases. (Patidar *et al.*, 2022) [21].

Globally, Maize (*Zea mays* L) is known as "queen of cereals" because it has the highest genetic yield potential among the cereals. It is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. In India, maize is the third most important food crops after rice and wheat. (Suthar *et al.*, 2020) [25].

India ranks sixth in global maize production and fifteenth position in its productivity in world, contributing to 2.4% of world production with almost 5% share in world harvested area (*Sangle et al.*, 2020) [23]. In India it was cultivated in an area of 9.47 million hectares with production of 28.72 million tonnes and with average productivity of 3032 kg per hectare during 2017-18 (Bharadwaj *et al*., 2020) [4]. The predominant maize growing states that contributes more than 80% of the total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%), Himachal Pradesh (4.4%). Apart from these states' maize is also grown in Jammu and Kashmir and North-Eastern states. (Murdia *et al*, 2016) [18].

Health benefits of maize are offered by presence of quality nutrients in it. It not only provides the necessary calories for daily metabolism, but also is a rich source of vitamins A, B, E and many minerals. Maize grains have great nutritional value as they contain 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar and 1.7% ash. (Huma *et al*., 2019) [13].

The Fall Armyworm (*Spodoptera frugiperda*, J.E. Smith), (Lepidoptera: Noctuidae), FAW, is an insect native to tropical and subtropical regions of the Americas. FAW first reported as an invasive pest in the rainforest zones of Nigeria in 2016. Subsequently, it spread to different parts of Africa. FAW attacks 353 host plant species belonging to 76 plant families with preference to *poaceae* family. (Varshney *et al*., 2021) [30].

In India, it was first reported in Hussan district of Karnataka on maize which later spread to Tamil Nadu, Telangana and West Bengal. (Thumar *et al*., 2020) [27]. Thereafter, the pest has spread to most states of India and then spread to other Asian countries, including Thailand, Sri Lanka, Bangladesh, Myanmar, Vietnam, Laos, and China. (Deshmukh *et al*., 2018) [9].

A single generation of fall armyworm can spread 500 km away from the point of emergence. FAW is key insect of maize in tropical region. The effect of this insect is likely to be more in summer than in winter, the fall armyworm is a lepidoptera pest the feeds in large numbers on the stems, leaves and reproductive parts of more than 350 plant species. In maize growing area, weather conditions from March to September provide fertile ground to mass multiply and spread easily. Warm, humid and heavy rainfall favors in reproduction of fall armyworm. (Gupta *et al*., 2020) [3].

It is a cosmopolitan pest of the maize crop feeding on all growth stages of maize but most frequently in the whorl of young plants up to 45 days. FAW generally feeds on foliage, but during heavy infestations, larvae also feed on corn ears. Damage due to this pest attack can reduce corn grain yield up to 34% in Brazil, 20 to 50% in Africa and has also caused huge yield losses in India during last year. (Thumar *et al*., 2020) [27].

2. Materials and Methods

The present study was conducted at Central Research Farm, SHUATS, Prayagraj, Uttar Pradesh during the *Rabi* season of 2023 - 2024 for the management of fall armyworm carried out using a ‘Hara Butta’ variety of maize sown in plots keeping row to row and plant to plant distance of 45 × 15 cm. The field experiment was laid-out in randomized block design with eight different treatments replicated thrice. The plot had a dimension of 2 × 1 m^2.

All of the insecticides used in the study were sprayed as foliar application. In the experiment, eight different treatments, consisting application of T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (0.20 ml/Lit.), T_2 Chlorantraniliprole 18.5 SC (0.20 ml/Lit.), T3 Spinetoram 11.7% SC (0.30 ml/Lit.), T4 Flubendiamide 39.35% SC (0.24 ml/Lit.), T5 Novaluron 10% EC (1 ml/Lit.), T_6 *Beauveria bassiana* 5% (4 ml/Lit.), T7 NSKE 5% (50 ml/Lit.) and T8 untreated Control were tested to compare the efficacy against *Spodoptera frugiperda* and their influences on yield of maize. Two sprays were carried out at intervals of 14 days during the experiment to assess the effectiveness of pesticides when the *Spodoptera frugiperda* larval population reached the ETL threshold. On five randomly chosen and tagged plants in each plot, pre- and post-treatment observations on the larval population were made shortly before 24 hours and 3rd, 7th and 14th days following application, respectively.

2.1 Method of Recording Observation

$$\text{Mean larval population} = \frac{\text{No. of larvae}}{\text{5 randomy selected plant}}$$

$$\text{Cost Benefit Ratio} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

Thuppukonda and Kumar (2022) [28]

3. Results and Discussion

3.1 Efficacy of chemicals and biopesticides against fall armyworm on maize after first spray

3.1.1 Three days after spraying

The data on the larval population of fall armyworm on maize 3rd day after first spray revealed that all the treatments were significantly superior over control. Among all the treatments lowest larval population was recorded in T_3 Spinetoram 11.7% SC (1.73), followed by T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (1.93), T_5 Novaluron 10% EC (2.13), T_4 Flubendiamide 39.35% SC (2.40), T_2 Chlorantraniliprole 18.5% SC (2.53), T_7 NSKE 5% (2.73) and T_6 *Beauveria bassiana* 5% (2.87). The treatments T_6 *Beauveria bassiana* 5% (2.87) was least effective among all the treatments and is significantly superior over the T_8 control (3.13).

3.1.2 Seven days after spraying

The data on the larval population of fall armyworm on maize 7th day after first spray revealed that all the treatments were significantly superior over control. Among all the treatments lowest larval population was recorded in T_3 Spinetoram 11.7% SC (1.47), followed by T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (1.73), T_5 Novaluron 10% EC (1.93), T_4 Flubendiamide 39.35% SC (2.20), T_2 Chlorantraniliprole 18.5% SC (2.33), T_7 NSKE 5% (2.53) and T_6 *Beauveria bassiana* 5% (2.67). The treatments T_6 *Beauveria bassiana* 5% (2.67) was least effective among all the treatments and is significantly superior over the T_8 control (3.20).

3.1.3 Fourteen days after spraying

The data on the larval population of fall armyworm on maize 14th day after first spray revealed that all the treatments were significantly superior over control. Among all the treatments lowest larval population was recorded in T_3 Spinetoram 11.7% SC (1.60), followed by T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (1.87), T_5 Novaluron 10% EC (2.07), T_4 Flubendiamide 39.35% SC (2.33), T_2 Chlorantraniliprole 18.5% SC (2.47), T_7 NSKE 5% (2.67) and T_6 *Beauveria bassiana* 5% (2.80). The treatments T_6 *Beauveria bassiana* 5% (2.80) was least effective among all the treatments and is significantly superior over the T_8 control (3.27).

3.1.4 Overall mean of first spray
The data on the larval population of fall armyworm on maize mean (3rd, 7th and 14th) day after first spray revealed that all the treatments were significantly superior over control. Among all the treatments lowest larval population was recorded in T_3 Spinetoram 11.7% SC (1.60), followed by T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (1.84), T_5 Novaluron 10% EC (2.04), T_4 Flubendiamide 39.35% SC (2.31), T_2 Chlorantraniliprole 18.5% SC (2.44), T_7 NSKE 5% (2.64) and T_6 *Beauveria bassiana* 5% (2.78). The treatments T_6 *Beauveria bassiana* 5% (2.78) was least effective among all the treatments and is significantly superior over the T_8 control (3.20).

3.2 Efficacy of chemicals and biopesticides against fall armyworm on maize after second spray
3.2.1 Three days after spraying
The data on the larval population of fall armyworm on maize 3rd day after second spray revealed that all the treatments were significantly superior over control. Among all the treatments lowest larval population was recorded in T_3 Spinetoram 11.7% SC (1.27), followed by T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (1.60), T_5 Novaluron 10% EC (1.87), T_4 Flubendiamide 39.35% SC (2.00), T_2 Chlorantraniliprole 18.5% SC (2.20), T_7 NSKE 5% (2.40) and T_6 *Beauveria bassiana* 5% (2.67). The treatments T_6 *Beauveria bassiana* 5% (2.67) was least effective among all the treatments and is significantly superior over the T_8 control (3.33).

3.2.2 Seven days after spraying
The data on the larval population of fall armyworm on maize 7th day after second spray revealed that all the treatments were significantly superior over control. Among all the treatments lowest larval population was recorded in T_3 Spinetoram 11.7% SC (0.73), followed by T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (1.13), T_5 Novaluron 10% EC (1.47), T_4 Flubendiamide 39.35% SC (1.73), T_2 Chlorantraniliprole 18.5% SC (2.07), T_7 NSKE 5% (2.27) and T_6 *Beauveria bassiana* 5% (2.47). The treatments T_6 *Beauveria bassiana* 5% (2.47) was least effective among all the treatments and is significantly over the T_8 control (3.40).

3.2.3 Fourteen days after spraying
The data on the larval population of fall armyworm on maize 14th day after second spray revealed that all the treatments were significantly superior over control. Among all the treatments lowest larval population was recorded in T_3 Spinetoram 11.7% SC (0.87), followed by T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (1.27), T_5 Novaluron 10% EC (1.67), T_4 Flubendiamide 39.35% SC (1.87), T_2 Chlorantraniliprole 18.5% SC (2.13), T_7 NSKE 5% (2.33) and T_6 *Beauveria bassiana* 5% (2.53). The treatments T_6 *Beauveria bassiana* 5% (2.53) was least effective among all the treatments and is significantly over the T_8 control (3.47) population.

3.2.4 Overall mean of second spray
The data on the larval population of fall armyworm on maize mean (3rd, 7th and 14th) day after second spray revealed that all the treatments were significantly superior over control. Among all the treatments lowest larval population was recorded in T_3 Spinetoram 11.7% SC (0.96), followed by T_1 Imidacloprid 40% + Fipronil 40% (80 WG) (1.33), T_5 Novaluron 10% EC (1.67), T_4 Flubendiamide 39.35% SC (1.87), T_2 Chlorantraniliprole 18.5% SC (2.13), T_7 NSKE 5% (2.33) and T_6 *Beauveria bassiana* 5% (2.56). The treatments T_6 *Beauveria bassiana* 5% (2.56) was least effective among all the treatments and is significantly superior over the T_8 Control (3.40).

Table 1: Effect of different treatments on mean larval population of fall armyworm on maize (1st and 2nd spray)

S. No.	Treatments	Dosage	Number of larvae (*S. frugiperda*)/ five plants								Overall mean	Yield (q/ha)	C: B Ratio
			First spray				Second spray						
			1DBS	3DAS	7DAS	14DAS	1DBS	3DAS	7DAS	14DAS			
T_1	Imidacloprid 40% + Fipronil 40% (80 WG)	0.2 ml/L	2.67	1.93	1.73	1.87	1.87	1.60	1.13	1.27	1.58	38.80	1:1.98
T_2	Chlorantraniliprole 18.5% SC	0.2 ml/L	2.60	2.53	2.33	2.47	2.47	2.20	2.07	2.13	2.28	31.20	1:1.53
T_3	Spinetoram 11.7% SC	0.3 ml/L	2.67	1.73	1.47	1.60	1.60	1.27	0.73	0.87	1.28	44.40	1:2.20
T_4	Flubendiamide39.35% SC	0.24 ml/L	2.73	2.40	2.20	2.33	2.33	2.00	1.73	1.87	2.09	33.30	1:1.68
T_5	Novaluron 10%EC	1 ml/L	2.60	2.13	1.93	2.07	2.07	1.87	1.47	1.67	1.85	35.38	1:1.74
T_6	*Beauveria bassiana* 5%	4g/L	2.73	2.87	2.67	2.80	2.80	2.67	2.47	2.53	2.67	24.40	1:1.24
T_7	NSKE 5%	50gm/ L	2.73	2.73	2.53	2.67	2.67	2.40	2.27	2.33	2.48	28.90	1:1.40
T_8	Control	….	3.07	3.13	3.20	3.27	3.27	3.33	3.40	3.47	3.30	19.24	1:1.08
	F-test		NS	S	S	S	S	S	S	S	S	…..	…..
	S.Ed (±)		-	0.12	0.19	0.22	0.22	0.12	0.28	0.18	0.18	…..	…..
	C.D. (P= 0.5)		-	0.26	0.42	0.48	0.48	0.27	0.61	0.39	0.42	…..	…..

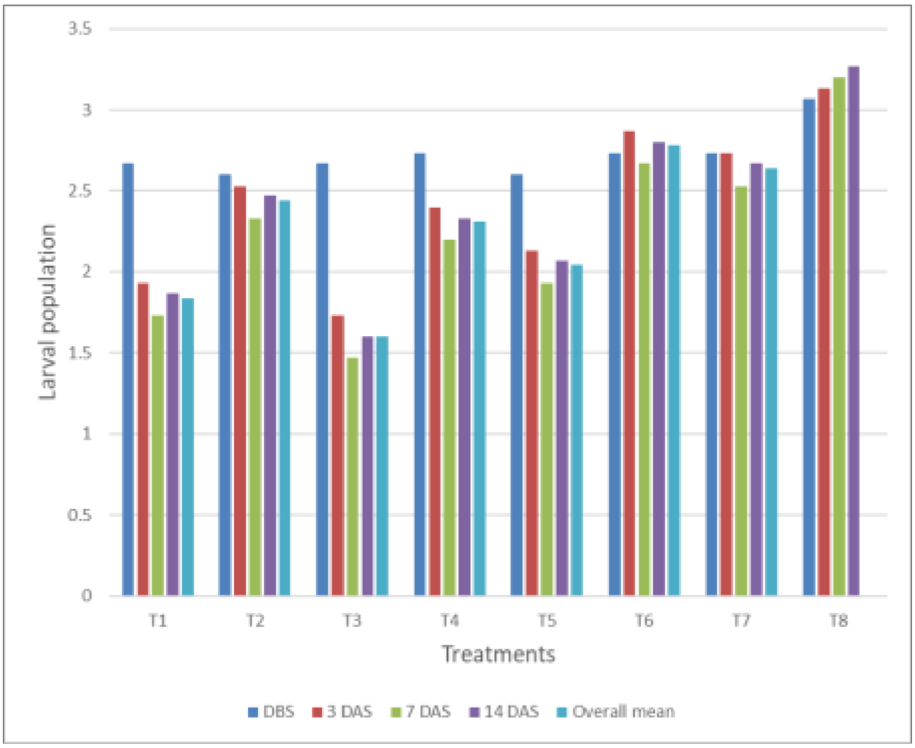

Fig 1: Effect of different treatment on mean larval population of fall armyworm after 1st spray

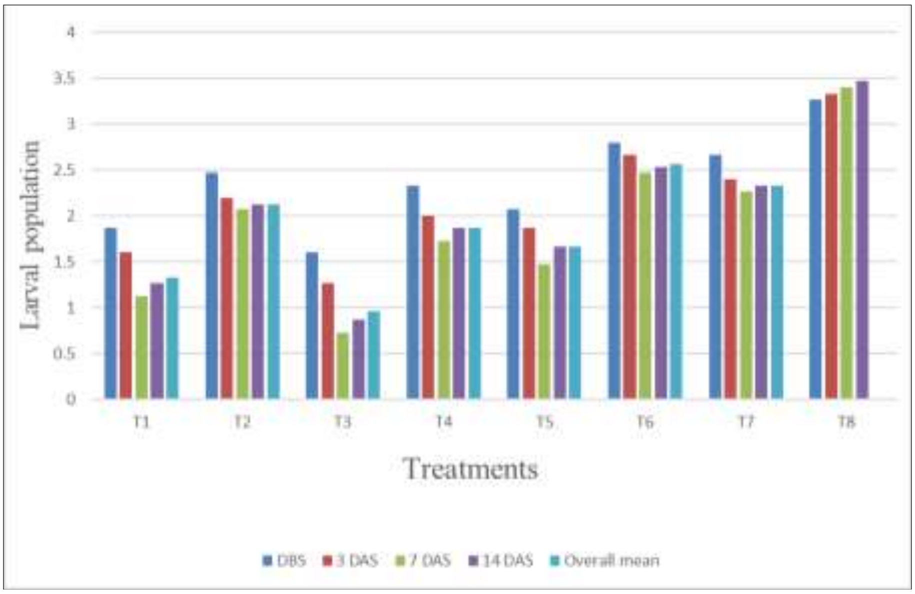

Fig 2: Effect of different treatments on mean larval population of fall armyworm after 2nd spray

4. Discussion

In the experiment. Eight different treatments were used *viz.* T_1 Imidacloprid 40% + Fipronil 40% (80 WG), T_2 Chlorantraniprole 18.5% SC, T_3 Spinetoram 11.7% SC, T_4 Flubendamide 39.3% SC5, T_5 Novaluron 10% EC, T_6 *Beauveria bassiana* 5% WP, T_7 NSKE 5% and T_8 untreated control, were evaluated against fall armyworm (*Spodoptera frugiperda*).

The data on the mean population of *Spodoptera frugiperda* on overall mean revealed that all the treatments except untreated control were effective. Among all the treatments lowest population of *Spodoptera frugiperda* was recorded in Spinetoram 11.7% SC (1.28) similar findings were made by Sunil *et al*. (2020) [24], Rizvi and Deole (2022) [22] and Ekshinge and Kumar (2023) [12] who reported that Spinetoram 11.7% SC was the most effective treatment indicating recorded lowest population of *Spodoptera frugiperda* followed by Imidacloprid 40% + Fipronil 40% (80 WG) (1.58) is found to be the next best treatment which is in line with the findings of Mallapur *et al.* (2019) [16] and Ali *et al.* (2023) [2] who reported that Imidacloprid 40% + Fipronil 40% (80 WG) was found to be most effective in reducing population of *Spodoptera frugiperda* as well as increasing the yield, Novaluron 10% EC (1.85) was the most effective treatment in reducing the population of *Spodoptera frugiperda* which is in line with the findings of Kumar and Mohan (2020) [21] and Deshmukh *et al.* (2020) [8], Flubendiamide @ 39.35% SC (2.09) was found to be the next effective treatment which is in line with the findings of Sangle *et al.* (2020) [23] and Patidar *et al.* (2022) [21], Chlorantraniprole 18.5 SC (2.28) was found to be the next effective treatment which is in line with the findings of

Bommi and Kumar (2022) [5] and Karki *et al.* (2023) [15], NSKE 5% (2.48) was found to be the next effective treatment which is in line with the findings of Nagesh and Tayde (2023) [19] and Chander and Tayde (2023) [19] and the result of *Beauveria bassiana* 5% WP (2.67) found to be least effective but comparatively superior over the control, these findings are supported by Dhobi *et al*. (2020) [10] and Montecalvo *et al.* (2021) [17] but superior as compared to control plot (3.30).

When cost benefit ratio was worked out, interesting result was achieved. Among all the treatments studied, the best and most economical treatment was Spinetoram 11.7% SC (1:2.20) similar findings made by Ekshinge and Kumar (2023) [12] and Nagesh and Tayde (2023) [19] followed by Imidacloprid 40% + Fipronil 40% (80 WG) (1:1.98) which is in line with the findings of Mohammed and Salisu (2023), Charitha and Kumar (2023) [7] and Mallapur *et al.* (2019) [16]. The next highest benefit cost ratio obtained by Novaluron 10% EC (1:1.74) similar findings made by Ramesh and Tayde (2022) [26] and Sharma *et al*. (2021) [1] followed by Flubendiamide 39.35% SC (1:1.68) which is similar with findings of Panigrahi *et al*. (2023) [20] and Deshmukh *et al*. (2020) [8]. The next treatment was Chlorantraniprole 18.5 SC (1:1.53) given by Divya *et al.* (2022) and Jeyarajan *et al.* (2021) [4] followed by NSKE 5% (1:1.40) which is similar with findings of Nagesh and Tayde (2023) [19] and the least benefit cost ratio was observed in *Beauveria bassiana* 5% WP (1:1.24) similar findings made by Panigrahi *et al*. (2023) [20] and Bommi and Kumar (2022) [5] but superior as compared to control plot (1:1.08).

5. Conclusion

From the critical analysis of the present findings, it can be concluded that Spinetoram 11.7% SC is more effective in controlling population of maize fall armyworm followed by Imidacloprid 40% + Fipronil 40% (80 WG), Novaluron 10% EC, Flubendiamide 39.35% SC, Chlorantraniprole 18.5 SC, NSKE 5%, *Beauveria bassiana* 5% WP in managing *Spodoptera frugiperda.* Among the treatments studied, Spinetoram 11.7% SC gave highest cost benefit ratio (1:2.20) and marketable yield (44.40 q/ha), followed by Imidacloprid 40% + Fipronil 40% (1:1.98 and 38.8 q/ha), Novaluron 10% EC (1:1.74 and 35.38 q/ha), Flubendiamide 39.35% SC (1:1.68 and 33.30 q/ha), Chlorantraniprole 18.5 SC (1:153 and 31.20 q/ha), NSKE 5% (1:1.40 and 28.90 q/ha) and *Beauveria bassiana* 5% WP (1:1.24 and 24.40 q/ha) as compare to control plot (1:1.08 and 19.24 q/ha) respectively as such more trials are required in future to validate the findings. On the basis of reduced larval population and high yield, Spinetoram, Imidacloprid + Fipronil and Novaluron could be recommended in successful management of fall armyworm.

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