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Field Efficacy and Economics Certain Chemicals and Botanical against Fall Armyworm, [(*Spodoptera frugiperda* (J.E. smith.)] on Maize (*Zea mays*)

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Authors' contributions

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

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ABSTRACT

The current study evaluated the field efficacy of specific chemicals and botanicals against fall armyworm (Spodoptera frugiperda) on maize (Zea mays Linn.) during the Kharif season of 2023. It was carried out in a RBD with 3 replications and 8 treatments (seven insecticides and one control). Chlorantraniliprole 18.5% SC (3.25) > Spinosad 45 SC (3.46) was the study's most effective treatment. Lambda-cyhalothrin 5% EC + Chlorantraniliprole 18.5% SC (3.99) was the next best treatment, followed by Emamecttin benzoate 5% SG (4.16) > Lambda-cyhalothrin 5% EC (4.44) >

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Flubendiamid 39.35% SC (4.87) > Neem oil 1500 ppm (5.18), which was the least effective but still significantly better than the control. In comparison to the untreated Control plot (1:1.52), the most cost-effective treatment was Chlorantraniliprole 18.5% SC (1:2.96), followed by Spinosad 45 SC (1:2.82), Lambda-cyhalothrin 5% EC + Chlorantraniliprole 18.5% SC (1:2.65), Emamecttin benzoate 5% SG (1:2.53), Lambda-cyhalothrin 5% EC (1:2.36), Flubendiamide 39.35% SC (1:1.81), and Neem oil 1500 ppm (1:1.74).

Keywords: Spodoptera frugiperda; Chlorantraniliprole; Spinosad; neem oils.

1. INTRODUCTION

Maize (*Zea mays* L.) is a significant cereal crop cultivated worldwide for human consumption, animal feed, fodder, and industrial purposes. It is recognized for having the highest genetic yield potential among cereals. Globally, maize is often referred to as the "queen of cereals" due to its remarkable genetic yield potential. It is the "Miracle Crop" because of its high solar use efficienccy and the immense potential it holds for increased production [1].

India produces the sixth most maize worldwide and ranks fifteenth in terms of productivity; it contributes 2.4% of global production and over 5% of the world's harvested land. About 160 countries cultivate about 150 million hectares of maize, which demonstrates the great diversity of soil types, temperatures, biodiversity, and management techniques. India contributes 36% (782 million tonnes) of the world's grain production, or maize, making it a major player in the industry [2].

In specific reference to India, maize production was recorded at 31.51 million tonnes over an area of 9.9 million hectares in 2020-2021. During the kharif season of 2021-2022, maize production was estimated at 21.24 m tonnes (as per the first advance estimates) over an area of 8.15 million ha [1].

Maize cultivation in India, covering an area of 9.47 million hectares and producing 28.72 million tonnes with an average yield of 3032 kg per hectare in 2017-18, faces various pest challenges. Among the numerous pests attacking maize, stem borers, armyworms like Mythimna separata, and Helicoverpa armigera are notable. The fall armyworm, scientifically known as Spodoptera frugiperda, is particularly destructive and is now a major concern for maize cultivation in India. This invasive pest, known for its rapid spread and ability to feed on a wide range of host plants, poses a significant threat. Despite maize being susceptible to 141 insect pests, only a few are considered major in India, including shoot fly, stem borers, armyworms, and Helicoverpa armigera. The recent infestation of the fall armyworm has escalated the challenge for maize farmers due to its high mobility, reproductive rate, and ability to thrive on various host crops available year-round [3-6].

Additionally, it is said to seriously harm economically significant in the absence of any control measures, damage from this pest attack has the potential to lower corn grain output by up to 34% in Brazil and 20–50% in Africa, resulting in losses in maize yield of 8.3–20.6 million tons annually (Day et al., 2017).

Due to their numerous inhibitory effects on insect physiology and behavior, biopesticides are useful in the management of insect pests. They provide the greatest substitute for chemical insecticides when controlling fall armyworms in maize. They are readily available locally, reasonably priced, biodegradable, and simple to handle. They are restoring the ecosystem's equilibrium. As organic farming gains ground,

2. MATERIALS AND METHODS

This study was carried out in the Kharif season of 2023 at the Department of Entomology's experimental research plot at the SHUATS. It used a RBD with eight treatments and three replications, utilizing Komal seeds of the variety. The plot measured 2 m by 1 m and was spaced 60 cm apart by 20 cm. The recomended package of practices was followed, with the exception of plant protection. The experimental site's soil was medium high and well-drained [7-9].

By randomly selecting five plants from each treatment and checking for the presence of larvae one day before and three, seven, and fourteen days after each insecticide application, the population of the pest was assessed. The overcontrol of the larval population against the autumn armyworm.

2.1 Data Collection

2.1.1 Larval population

The number of maize fall armyworm larvae and the injured plants were observed one day prior to spraying and again on the third, seventh, and fourteenth day following the application of insecticidal treatment. Five plants will be chosen at random from each plot to record the observation. The grain yield per plot was measured during harvest and translated to Q/ha for comparative purposes. The following formula is used to convert the results into a percentage of plant damage.

$$\text{Mean larval population} = \frac{\text{Number of larvae}}{\text{5 randomly plant selected}}$$

2.1.2 Economics

The gross returns and net returns for each treatment were computed using the yield data. The market price of the produce was multiplied by the total yield to determine the gross returns. The benefit-cost ratio (BCR), which was used to compare the effectiveness of various treatments, is the ratio of gross return to cultivation costs. This ratio will be worked for each therapy. The following formula was used to get the benfit cost ratio.

$$Gross\ return = Marketable\ yield \times Market\ price$$

$$Net\ return = Gross\ return - Total\ cost$$

$$B{:}C\ Ratio = \frac{Gross\ returns}{Total\ Cost}$$

3. RESULTS AND DISCUSSION

All treatments are effective, with the exception of the untreated control, according to data on the mean (3rd, 7th, and 14th DAS) population of Spodoptera frugiperda following the initial spray. The lowest population was seen in Chlorantraniliprole @ 18.5% EC (4.4) out of all the treatments. The least effective but still significantly better than the control group included Spinosad 45 SC (4.63), Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (4.95), Emamecttin benzoate @ 5% SG (5.1), Lambda cyhalothrin @ 2.5% EC (5.23), Flubendiamid 39.35% EC (5.23), and Neem oil 1500 ppm (5.8) [10,11].

Data on the Spodoptera frugiperda population on the second spray showed that all of the treatments outperformed the control by a substantial margin. For all treatments combined, the value of chlorantraniliprole at 18.5% EC (2.09). The least effective but still significantly better than the control group included Spinosad 45 SC (2.29), Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (3.02), Emamecttin benzoate @ 5% SG (3.22), Lambda cyhalothrrin @ 2.5% EC (3.64), Flubendamide 39.35% EC (4.27), and Neem oil 1500 ppm (4.55) [12,13].

The differences in yields between the various treatments were noteworthy. Chlorantraniliprole at 18.5% EC (51.52 q/ha) had the maximum yield. In comparison to the control plot (22.26 q/ha), Spinosad 45 SC (45.40 q/ha) was found to be the next best treatment, followed by Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (46 q/ha), Emamectin benzoate @ 5% SG (40 q/ha), Lambda cyhalothrin @ 2.5% EC (37 q/ha), Flubendiamide 39.35% EC (35.18 q/ha), and Neem oil 1500 ppm (28.82 q/ha) [14].

An intriguing outcome was obtained when the cost-benefit ratio was calculated. The most effective and cost-effective treatment among those examined was chlorantraniliprole @ 18.5% EC (1:2.96). In comparison to the control plot (1:1.52), Spinosad 45 SC (1:2.82) was found to be the next best treatment, followed by Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (1:2.60), Emamecttin benzoate @ 5% SG (1:2.53), Lambda cyhalothrin @ 2.5% EC (1:2.36), Flubendiamide 39.35% EC (1:1.81), and Neem oil 1500 ppm (1:1.74) (Table 3).

3.1 Discussion

In the present research work lowest percent of maize fall armyworm population was recorded in T2 Chlorantraniliprole @18.5% EC (3.25%) had the lowest percentage of maize fall armyworm population in the current study. Similar conclusions were reached by Baurtet al. (2017), Triboni et al. (2019), and Viteri et al. [15] who found that the most successful treatment was T2 Chlorantraniliprole @ 18.5%EC, which resulted in the lowest population of fall armyworms (Spodoptera frugiperda) ever recorded [16,17]. The most successful treatment for decreasing the S. frugiperda population was T1 Spinosad 45% SC (3.46), which is consistent with the results of Belay et al. (2012), Sharma et al. (2018), and Rebeca et al. (2018).

Table 1. Efficacy of certain chemicals and biopesticides against larval population of *Spodoptera frugiperda* on maize after (1st spray)

		Number of larva *Spodoptera frugiperda* /five plants				
Treatments no.	**Treatments**	**1 DBS**	**3rd DAS**	**7th DAS**	**14th DAS**	**Overall mean**
T1	Spinosad 45 SC	5.93	4.6	3.8	4.2	4.63
T2	Chlorantraniliprole 18.5%SC	5.86	4.26	3.46	4	4.40
T3	Emamectin benzoate 5%SG	6.33	5.06	4.33	4.66	5.10
T4	Lambda-cyhalothrrin 5%EC + Chlorantraniliprol 18.5%SC	5.8	4.8	4.73	4.46	4.95
T5	Flubendiamide 39.35%SC	5.8	5.6	5.13	5.33	5.47
T6	Lambda-cyhalothrin 5%EC	6.13	5.26	4.53	5	5.23
T7	Neem oil 1500ppm	5.93	6.2	5.4	5.66	5.80
T_0	Control	6	6.26	6.6	5.77	6.16
F- test		NS	S	S	S	S
S. Ed (±)			0.22	0.18	0.16	0.21
C.D.(P=0.05)			0.46	0.390	0.347	0.367

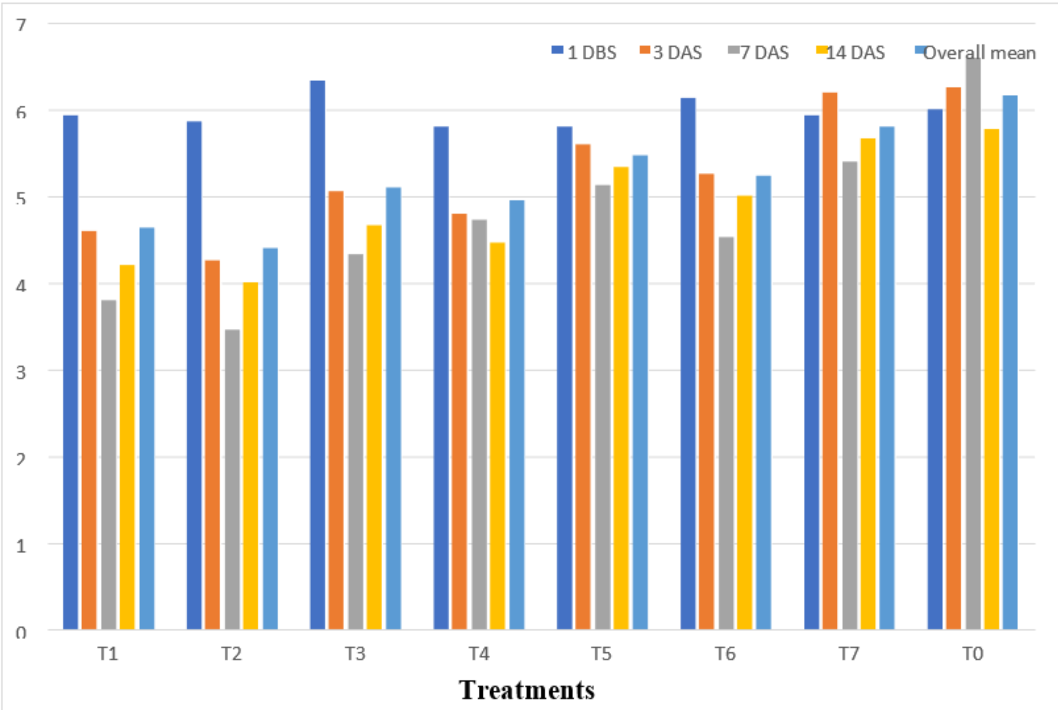

Fig. 1. Effect of different treatment on maize fall armyworm, *Spodoptera frugiperda* after first spray (Larval population)

An intriguing outcome was obtained when the cost-benefit ratio was calculated. T2 Chlorantraniliprole @ 18.5% EC (1:2.96) was the most effective and cost-effective treatment out of all the ones that were investigated. Next best treatment, as compared to control plot (1:1.52), was T1 Spinosad 45 SC (1:2.82), followed by T4 Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (1:2.60), T3 Emamectin benzoate @ 5% SG (1:2.53), T6 Lambda cyhalothrin @ 2.5% EC (1:2.36), T5 Flubendiamide 39.35% EC (1:1.81), and T7 Neem oil 1500 ppm (1:1.74).

Table 2. Efficacy of certain chemicals and biopesticides against larval population of *Spodoptera frugiperda* on maize after (2nd spray)

		Number of larva *Spodoptera frugiperda* /five plants			
No. of t.	**Treatments**	**3rd DAS**	**7th DAS**	**14th DAS**	**Overall mean**
T1	Spinosad 45 SC	2.86	1.8	2.2	2.29
T2	Chlorantraniliprole 18.5%SC	2.8	1.6	1.86	2.09
T3	Emamectin benzoate 5%SG	3.73	2.73	3.2	3.22
T4	Lambda-cyhalothrrin 5%EC + Chlorantraniliprol 18.5%SC	3.53	2.53	3	3.02
T5	Flubendiamide 39.35%SC	4.6	4	4.2	4.27
T6	Lambda-cyhalothrin 5%EC	4.13	3.26	3.53	3.64
T7	Neem oil 1500ppm	4.93	4.26	4.46	4.55
T0	Control	7	7.13	7.33	7.15
F- test		S	S	S	S
S. Ed (±)		1.03	1.22	0.19	1.17
C.D.(P=0.05)		0.398	0.366	0.413	0.406

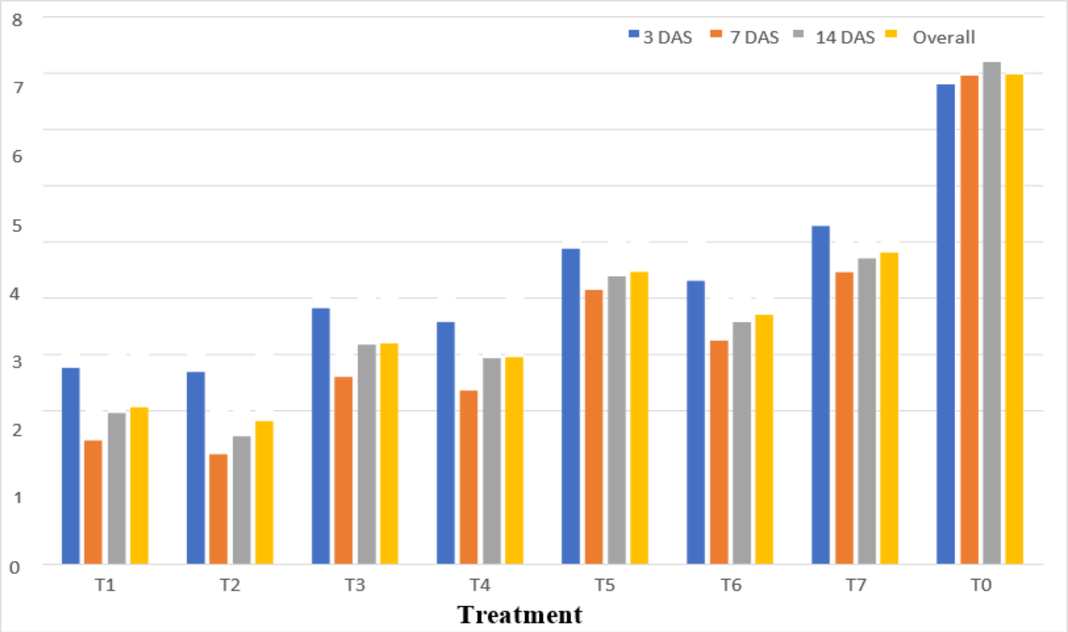

Fig. 2. Effect of different treatment on maize fall armyworm, *Spodoptera frugiperda* after second spray (Larval population)

Table 3. Economics of cultivation

S. N	Treatments	Yield (q/ha)	Cost of yield / (₹)	Total cost of yield (₹)	Common cost (₹)	Treatment cost (₹)	Net Return (₹)	Total cost (₹)	C:B ratio
T_1	Spinosad 45 SC	45.40	1800	81720	26222	2737	52761	28959	1:2.82
T_2	Chlorantraniliprole 18.5%SC	51.52	1800	92736	26222	5040	61474	31262	1:2.96
T_3	Emamectin benzoate 5%SG	40	1800	72000	26222	2236	43542	28458	1:2.53
T_4	Lambda-cyhalothrrin 5%EC + Chlorantraniliprol 18.5%SC	46	1800	82800	26222	5525	51053	31747	1:2.60
T_5	Flubendiamide 39.35%SC	35.18	1800	63324	26222	8645	28457	34867	1:1.81
T_6	Lambda- cyhalothrin 5%EC	37	1800	66600	26222	1885	38493	28107	1:2.36
T_7	Neem oil 1500ppm	28.82	1800	51876	26222	3500	22154	29722	1:1.74
T_0	Control	22.26	1800	40068	26222	_	13846	26222	1:1.52

4. CONCLUSION

Based on an examination of current research, several pesticides and plants have been found to be effective in the field in combating autumn armyworms, or Spodoptera frugiperda, on zea maize (Linn.). T2 chlorantraniliprole @ 18.5% EC is more effective than T1 Spinosad @ 45% SC, T4 Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC, T3 Emamectin benzoate @ 5% SG, T6 Lambda cyhalothrin @ 2.5% EC, T5 Flubendiamide @ 480% SC, and T7 Neem oil 1500 ppm in managing Spodoptera frugiperda, it can be concluded. Treatment T2 Chlorantraniliprole @ 18.5% EC (1:2.96 and 51.52 q/ha) was one of the ones examined. In comparison to the control plot (1:1.52 and 22.26 q/ha.), T1 Spinosad 45 SC (1:2.82 and 45.40 q/ha.) was found to be the next best treatment, followed by T4 Lambda cyhalothrin @ 2.5% EC + Chlorantraniliprole @ 18.5% EC (1:2.60 and 46 q/ha.), T3 Emamectin benzoate @ 5% SG (1:2.53 and 40 q/ha.), T6 Lambda cyhalothrin @ 2.5% EC (1:2.36 and 37 q/ha.), T5 Flubendiamide 39.35% EC (1:1.81 and 35.18 q/ha), and T7 Neem oil 1500 ppm (1:1.74 and 28.82 q/ha.). Therefore, additional studies will be needed in the future to confirm the results.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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