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Comparative efficacy of biopesticides and selected chemicals against shoot and fruit borer, *Earias vittella* (Fabricius) on okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract
This field trial, which is entitled "Comparative efficacy of biopesticides and selected chemicals against shoot and fruit borer [*Earias vittella* (Fabricius)] on okra [*Abelmoschus esculentus* (L.) Moench]" was carried out at the Central Research Farm of Sam Higginbottom Universty of Agriculture, Technology and Sciences, Prayagraj. The experimental trial was conducted during the *Rabi* season of 2020-21 in Randomized Block Design (RBD) on three replications, okra cultivar i.e. Super green. Two applications of eight treatments viz., T_1 Neem oil (3 ml/L), T_2 Spinosad 45% SC (0.5 ml/L), T_3 Sixer plus (1.5 ml/L), T_4 *Metarhizium anisopliae* 1.0% WP (1×10^8 CFU/gm) (5 gm/L), T_5 Chlorantraniliprole 18.5% SC (0.3 ml/L), T_6 Cypermethrin 25% EC (2 ml/L), T_7 *Beauveria bassiana* 1.0% WP (1×10^9 CFU/gm) (5 gm/L) and T0 Control (Untreated). Among all the treatments minimum Percent shoot infestation, Percent fruit infestation, and Cost-benefit ratio were observed in T_5 Chlorantraniliprole 18.5% SC with (5.43%, 4.64% and 1:3.86) which was followed by T_2 Spinosad 45% SC (9.49%, 6.34 and 1:3.24), T_6 Cypermethrin 25% EC (10.86%, 8.72% and 1:2.90), T_3 Sixer plus (13.13%, 11.29% and 1:2.54), T_7 *Beauveria bassiana* 1.0% WP (14.56%, 13.82% and 1:2.00), T_1 Neem oil (17.20%, 15.63% and 1:1.89), T_4 *Metarhizium anisopliae* 1.0% WP (18.47%, 17.38% and 1:1.65) and T0 Control (Untreated) (22.19%, 26.99% and 1:1.53) respectively.

Keywords: Biopesticides, chlorantraniliprole, cypermethrin, efficacy, *Earias vittella*, okra

Introduction
Okra, *Abelmoschus esculentus* (L.) Moench is the most widely consumed vegetable in the Malvaceae family. Locally, it is referred to as lady's finger and Bhendi. In India, it's grown in the summer and the rainy season. As a summer crop and a winter crop, respectively, it is widely grown in Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, and North India (Gautam *et al.*, 2015) [19]. According to estimates, okra is grown on 1.26 million acres of land worldwide and produces 22.29 million tonnes of okra annually. The main nations that are experiencing growth in this regard are Saudi Arabia, Nigeria, Nigeria, Pakistan, Ghana, Egypt, Cameroon, and India. India is the world leader in okra production, producing 5784.0 thousand tonnes (72% of total output) annually over an area of 1148.0 thousand hectares, with productivity of 11.9 million tonnes per hectare. Although the crop is grown all over India, the state of Andhra Pradesh is the one that produces the most, producing roughly 1184.2 thousand tonnes of it annually from 78.90 thousand hectares, or 15 tonnes per ha. West Bengal comes in second place with 862.1 thousand tonnes from 74.00 thousand and a productivity of 11.70 tonnes per hectare. Okra yields and productivity in the Uttar Pradesh region are 12.19 hectares, 148.64 tonnes, or 12.2 metric tonnes per hectare. It is a significant cash crop that offers okra farmers a high rate of return. Okra, however, is also regarded as a haven for diseases and pests, so it needs extra care to combat them when and how they should be. The crop grows in two distinct stages: the fruiting stage and the vegetative stage. Twenty insect pests attack okra plants at different stages of growth. (Butani and Verma, 1976) [61]. Approximately 20 insect pests are said to be responsible for 65-100% of okra crop losses (Butani and Verma, 1976) [61]. The *Earias vittella* (Fabricius) shoot & fruit borer is the most harmful pest insect that affects okra. According to estimates, fruit borer and shoot damage ranged from 35 to 76 percent on average (Narke and Suryawanshi, 1987) [62].

In certain Southeast Asian nations, the OSFB can harm okra fruit by up to 40-50percent, according to Srinivasan *et al.*, (1959) [63]. A fruit borer infestation affected 35percent of the harvestable okra fruit, according to Krishnaiah (1980) [64]. This pest was also found to have harmed 40-50% of the fruit in Madras (Srinivasan and Gowder, 1959) [63]. In both the kharif and summer seasons, the fruit borer Earias vittella attacks okra four to five weeks after germination. Attacked tender top shoots dry up, and blossoms, buds, and budding fruit drop off too soon. *Earias vittella* larvae penetrate the tips of young plants before entering the fruit. It is not safe for humans to consume the affected fruits. To control these pests, farmers use traditional insecticides like carbamates, organophosphate, and synthetic pyrethroids. However, the careless and insufficient application of synthetic pesticides causes many problems for the agroecosystem, including direct damage to fish, people, and beneficial insects. The only thing that has caused the insect pest to become resistant and disrupt the agroecosystem because of its effects on non-targets is the continuous application of systemic insecticides. Insect pest damage, pesticide use, and ecological balance have all been significantly reduced in numerous prior studies regarding the heavy usage of botanicals, biopesticides, and alternative insecticides that are less harmful to the environment in conjunction with IPM techniques for the ecologically sound control of insect pests on okra farms. With the following goals in mind, a study titled "Comparative efficacy of biopesticides and selected chemicals against shoot and fruit borer [*Earias vittella* (Fabricius)] on okra (*Abelmoschus esculentus* (L.) Moench)" was done. In particular, the investigation aimed to evaluate the efficacy of biopesticides with cypermethrin 25% EC and Chlorantraniliprole 18.5% SC against shoot and fruit borer of okra. As well as to evaluate the economics (Cost-benefit ratio) of treatments.

Materials and Methods

During the 2020-21 *Rabi* season, the experiment was carried out at the Central Research Farm of Sam Higginbottom University of Agriculture, Technology and Sciences in Naini, Prayagraj, Uttar Pradesh. The research field is located on the right side of Rewa Road at 25° 22' 15.888 North Latitude and 81°51' 31.4712 East Longitude, approximately 98 meters above mean sea level. Prayagraj experiences the typical subtropical climate of eastern Uttar Pradesh. Here are the summer and winter extremes. The highest temperature ever recorded in the summer was 47°C, & the lowest temperature ever recorded in the winter was 1.5°C. At the research farm, all the facilities required for crop cultivation were available. Three replications were used in the Randomized Block Design experiment. The same suggested agronomic practices for all the treatments, from sowing to harvesting, were used in the sowing process.

Method of recording observations and filed efficacy of treatments

Once the population level reached ETL, the spraying was completed. The observations were taken one day before spraying, 3, 7, and 14 days after spraying. The shoot damage assessment was computed and expressed as a percentage based on the number of damaged shoots and the total number of healthy shoots observed from five randomly selected plants per plot. To calculate the percentage of fruit damage at each picking, the total number of impacted fruits from each plot was counted.

Shoot and fruit Infestation

Each week, the total number of shoots and fruits on five randomly selected plants in each plot were counted. Additionally, the number of visually inspected and recorded infested shoots and fruits was also recorded. The following formula was used to determine the percentage of shoot and fruit infestation (Choudhury *et al.*, 2021) [12].

$$\text{Percent Shoot infestation} = \frac{\text{Number of infested shoots}}{\text{Number of total shoots}} \times 100$$

$$\text{Percent Fruit infestation} = \frac{\text{Number of infested fruits}}{\text{Number of total fruits}} \times 100$$

Table 1: Details of experiment

Season	*Rabi*
Crop	Okra
Design	Randomized Block Design (RBD)
Replication	03
Treatment	08
Plot size	2 mx 1 m
Total no of plots	24
Total length of area	20 m
Total width of area	5.8 m
Main irrigation channel	1 m
Sub-irrigation channel	0.5 m
Width of the bund	0.3 m
N:P:K	100:60:50kg/ha.
Net cultivated area	48 m^2
Soil	Sandy loam
Variety	Super green
Seed rate	10 kg/ha.
Spacing	45 × 30 cm
Row-to-row distance	45 cm
Plant-to-plant distance	30 cm
Farm yard manure	20 t/ha.
Total area	107.3 m^2

Table 2: Details of biopesticides and selected chemical insecticides used in the experiment

Sr. No.	Treatments	Insecticide names and Formulation	Group	Waiting period	Dosage (ml/gm/Liter)	Reference
1.	T_1	Neem oil	Botanical	07	3ml	Rakshith and Kumar (2016)
2.	T_2	Spinosad 45% SC	Spinosyns	03	0.5ml	Panbude *et al.*, (2019)
3.	T_3	Sixer plus	Organic molecule	01	1.5ml	Mahajan *et al.*, (2020) [67]
4.	T_4	*Metarhizium anisopliae* 1.0% WP (1×10^8 CFU/gm)	Biopesticide	02	5gm	Nalini and Kumar (2016) [65]
5.	T_5	Chlorantraniliprole 18.5% SC	Anthranilic diamide	05	0.3ml	Kumar *et al.*, (2017)
6.	T_6	Cypermethrin 25% EC	Synthetic Pyrethroid	03	2ml	Padwal and Kumar (2014)
7.	T_7	*Beauveria bassiana* 1.0% WP (1×10^9 CFU/gm)	Biopesticide	02	5gm	Sarkar *et al.*, (2015)
8.	T_0	Control (Untreated)	-	-	-	-

Note: The waiting period and treatment dosages were determined in accordance with the Ministry of Agriculture recommendations from the Government of India. Major use of pesticide: Registered under the Insecticide Act, 1968. As on January 31, 2020, and January 1, 2021

Cost Benefit Ratio

The gross return was computed by multiplying the entire yield by the market price of the produce. The cost of cultivation and treatment imposition was deducted from the gross returns to determine the net returns and cost benefit ratio using the following formula. The B:C ratio was estimated using a formula (Nalini and Kumar, 2016) [65].

$$\text{Cost benefit ratio} = \frac{\text{Gross returns}}{\text{Total cost of production}}$$

Statistical Analysis

The collected observations and data were analyzed statistically using Randomized Block Design (RBD) to determine their significance.

Results and Discussion

To assess the efficacy of biopesticides with cypermethrin 25% EC and chlorantraniliprole 18.5% SC against the shoot and fruit borer [*Earias vittella* (Fab.)] on okra: First spray: Percent shoot infestation.

Every treatment was found to be significantly better than the control, as indicated by Table 3, data on the percent shoot infestation on the third, seventh, and fourteenth post-spray. T_5 Chlorantraniliprole 18.5% SC (5.43%) had the lowest percent shoot infestation of okra shoot and fruit borer when compared to the untreated T0 control (22.19%). This was succeeded by T_2 Spinosad 45% SC (9.49%), T_6 Cypermethrin 25% EC (10.86%), T_3 Sixer plus (13.13%), T_7 *Beauveria bassiana* 1.0% WP (14.56%), T_1 Neem oil (17.20%), and T_4 *Metarhizium anisopliae* 1.0% WP (18.47%). Statistics showed that the treatments (T_2, T_6), (T_3, T_7), and (T_1, T_4) were comparable to one another

Second spray: Percent fruit infestation

Every treatment was discovered to be significantly better than the control, according to the data from Table 4, percent fruit infestation on the third, seventh, and fourteenth days following spraying. When compared to the untreated T0 control (26.99%), T_5 Chlorantraniliprole 18.5% SC (4.64%) had the least percent fruit infestation of okra shoot & fruit borer. This was succeeded by T_2 Spinosad 45percent SC (6.34%), T_6 Cypermethrin 25% EC (8.72%), T_3 Sixer plus (11.29%), T_7 *Beauveria bassiana* 1.0% WP (13.82%), T_1 Neem oil (15.63), and T_4 *Metarhizium anisopliae* 1.0% WP (17.38%).

The most successful treatment for okra shoot and fruit borer, *Earias vittella* (Fab.) infestation was discovered to be chlorantraniliprole 18.5% SC; as a result, this treatment is suggested for the control of this pest on okra. The first and second spray values are 5.43% and 4.64%, respectively. Kumar and Sharma (2014) and Kumar *et al.*, (2017) [34], who found that chlorantraniliprole 18.5% SC was the most successful course of action, corroborated these findings. The next successful treatment was Spinosad 45% SC, with efficacy values of 9.49% and 6.34% in the first and second sprays. Naidu & Kumar (2019) [66], Mahajan *et al.*, (2020) [67], & Singh *et al.*, (2020) [56] corroborated these results. According to reports, Spinosad 45% SC is the 2nd-most successful treatment available. In the first and second sprays, cypermethrin 25% EC has an efficacy of 10.86% and 8.72%. Research by Saran *et al.*, (2018) and Naidu and Kumar (2019) [66] corroborated these conclusions. The results of the first and second sprays of Sixer Plus, which was determined to be the next most effective treatment, are 13.13% and 11.29%. Reddy *et al.*, (2021) [46], and Gayathri and Kumar (2021) [20] corroborated these results. The next best treatment was *Beauveria bassiana* 1.0% WP (1×10^9 CFU/gm), for which 14.56% and 13.82% of the efficacy values were obtained. Studies by Sarkar *et al.*, (2015) and Kaveri and Kumar (2020) [28] corroborated these results. Neem oil proved to be the next successful treatment, with efficacy values of 17.20% and 15.63%. Pachole *et al.*, findings corroborated these conclusions (2017). With efficacy values of 18.47% and 17.38%, *Metarhizium anisopliae* 1.0% WP (1×10^8 CFU/gm) is the least effective treatment out of all of the treatments. The results of Chandravanshi *et al.*, (2019) [10] corroborated these conclusions.

To evaluate the economics of treatments (Cost Benefit ratio)

According to Table 5, each treatment had a noteworthy yield. T_5 Chlorantraniliprole 18.5% SC (101.58 q/ha) yielded the highest, compared to untreated T0 control (38.09 q/ha), T_2 Spinosad 45% SC (85.18q/ha), T_6 Cypermethrin 25% EC (74.28 q/ha), T_3 Sixer plus (66.24q/ha), T_7 *Beauveria bassiana* 1.0% WP (51.45q/ha.), T_1 Neem oil

(48.74q/ha.), and T_4 *Metarhizium anisopliae* 1.0% WP (42.51q/ha.). Calculating the cost-benefit ratio produced an interesting result. T_5 Chlorantraniliprole 18.5% SC (1:3.86) was the most successful and cost-effective treatment of those that were examined. T_2 Spinosad 45% SC (1:3.24), T_6 Cypermethrin 25% EC (1:2.90), T_3 Sixer plus (1:2.54), T_7 *Beauveria bassiana* 1.0% WP (1:2.00), T_1 Neem oil (1:1.89), and T_4 *Metarhizium anisopliae* 1.0% WP (1:1.65) was the least expensive treatment when compared to the untreated T0 control (1:1.53) that was examined.

According to reports from Kumar *et al.*, (2017), Naidu and Kumar (2019) [66], and others, Chlorantraniliprole 18.5% SC had the greatest possible cost-benefit ratio (1:3.86). These findings were corroborated by the fact that the product had higher yields. Spinosad 45% SC yielded the second effective benefit-cost ratio (1:3.24), which was corroborated by Chowdary *et al.*, (2010) [13] and similar findings reported by Naidu and Kumar (2019) [66]. The next effective benefit-cost ratio (1:2.90) for cypermethrin 25% EC was found, and Padwal and Kumar (2014) as well as Naidu and Kumar (2019) [66] supported this finding. Sixer Plus cost-benefit ratio (1:2.54) was found, and Reddy *et al.*, (2021) [46] findings were corroborated. *Beauveria bassiana* 1.0% WP (1×10^9 CFU/gm) had a cost-benefit ratio of 1:2.00, which was confirmed by Kaveri and Kumar (2020) [28] and Singh *et al.*, (2020) [56]. All the treatments, the cost-benefit ratios for Neem oil (1:1.89) and *Metarhizium anisopliae* 1.0% WP (1×10^8 CFU/gm) (1:1.65) were the lowest. Pachole *et al.*, (2017) [68] and Chandravanshi *et al.*, (2019) [10] corroborated these results.

Table 3: Efficacy of biopesticides with Cypermethrin 25% EC and Chlorantraniliprole 18.5% SC against shoot and fruit borer of okra, First spray: Percent shoot infestation

Treatments		Percent shoot infestation of *Earias vittella* (Fab.)				
		1 DBS	After spray			
			3 DAS	7 DAS	14 DAS	Mean
T_1	Neem oil	21.72 (27.77)*	17.57 (24.73)*	15.36 (22.91)*	18.67 (25.55)*	17.20 (24.48)*
T_2	Spinosad 45% SC	25.83 (30.22)*	9.89 (18.30)*	7.32 (15.70)*	11.28 (19.61)*	9.49 (17.88)*
T_3	Sixer plus	25.85 (30.52)*	13.35 (21.42)*	11.41 (19.68)*	14.64 (22.49)*	13.13 (21.22)*
T_4	*Metarhizium anisopliae* 1.0% WP	26.96 (31.16)*	18.89 (25.76)*	16.83 (24.22)*	19.71 (26.35)*	18.47 (25.44)*
T_5	Chlorantraniliprole18.5% SC	17.36 (24.62)*	5.70 (13.62)*	3.62 (10.96)*	6.98 (15.21)*	5.43 (13.36)*
T_6	Cypermethrin 25% EC	23.26 (28.80)*	11.54 (19.86)*	8.78 (17.23)*	12.26 (20.49)*	10.86 (19.19)*
T_7	*Beauveria bassiana* 1.0% WP	23.06 (28.53)*	15.25 (22.91)*	12.09 (20.17)*	16.38 (23.81)*	14.56 (22.39)*
T_0	Control (Untreated)	17.79 (24.95)*	21.22 (27.43)*	22.22 (28.12)*	23.15 (28.75)*	22.19 (28.10)*
Overall Mean		22.72	14.17	12.20	15.38	13.91
F- test		NS	S	S	S	S
S. Ed. (±)		15.27	3.38	5.50	2.79	0.46
C. D. (P = 0.05)		-	3.22	4.11	2.92	1.19

* Arcsine-transformed values are indicated by figures in parenthesis.
DAS = Day After Spraying; DBS = Day Before Spraying.

Table 4: Efficacy of biopesticides with Cypermethrin 25% EC and Chlorantraniliprole 18.5% SC against shoot and fruit borer of okra, Second spray: Percent fruit infestation

Treatments		Percent fruit infestation of *Earias vittella* (Fab.)				
		1 DBS	After spray			
			3 DAS	7 DAS	14 DAS	Mean
T_1	Neem oil	22.11 (28.03)*	15.79 (23.41)*	14.35 (22.26)*	16.76 (24.16)*	15.63 (23.28)*
T_2	Spinosad 45% SC	21.45 (27.58)*	6.45 (14.71)*	4.96 (12.28)*	7.61 (15.99)*	6.34 (14.53)*
T_3	Sixer plus	23.24 (28.79)*	11.69 (19.98)*	9.55 (17.98)*	12.64 (20.80)*	11.29 (19.60)*
T_4	*Metarhizium anisopliae* 1.0% WP	20.44 (26.87)*	17.45 (24.68)*	16.14 (23.69)*	18.55 (25.49)*	17.38 (24.63)*
T_5	Chlorantraniliprole 18.5% SC	22.41 (28.24)*	4.99 (12.88)*	3.11 (10.10)*	5.82 (13.94)*	4.64 (12.34)*
T_6	Cypermethrin 25% EC	21.14 (29.42)*	9.34 (17.77)*	6.68 (14.97)*	10.14 (18.56)*	8.72 (17.11)*
T_7	*Beauveria bassiana* 1.0% WP	21.21 (27.41)*	14.07 (22.02)*	12.57 (20.76)*	14.83 (22.63)*	13.82 (21.81)*
T_0	Control (Untreated)	24.17 (29.44)*	25.70 (30.46)*	26.86 (31.21)*	28.43 (32.22)*	26.99 (31.30)*
Overall Mean		22.02	13.18	11.77	14.34	13.10
F-test		NS	S	S	S	S
S.Ed.(±)		2.40	0.57	0.68	1.40	0.33
C.D.(P=0.05)		-	1.33	1.45	2.07	1.01

* Arcsine-transformed values are indicated by figures in parenthesis.
DAS = Day After Spraying; DBS = Day Before Spraying.

Table 5: Economics of cultivation (Cost-benefit ratio)

Tr. No.	Treatment	Yield (q/ha)	Cost of yield (Rs/q)	Total Cost of Yield (Rs/ha)	Common Cost (Rs/ha)	Treatment Cost (Rs/ha)	Total cost (Rs/ha)	C: B Ratio
T_1	Neem oil	48.74	2200	107228	54720	1750	56470	1:1.89
T_2	Spinosad 45% SC	85.18	2200	187396	54720	2975	57695	1:3.24
T_3	Sixer plus	66.24	2200	145728	54720	2500	57220	1:2.54
T_4	*Metarhizium anisopliae* 1.0% WP	42.51	2200	93522	54720	1625	56345	1:1.65
T_5	Chlorantraniliprole 18.5% SC	101.58	2200	223476	54720	3100	57820	1:3.86
T_6	Cypermethrin 25% EC	74.28	2200	163416	54720	1450	56170	1:2.90
T_7	*Beauveria bassiana* 1.0% WP	51.45	2200	113190	54720	1700	56420	1:2.00
T_0	Control (Untreated)	38.09	2200	83798	54720	-	54720	1:1.53

Conclusion

Following a critical evaluation of the available results, T_5 Chlorantraniliprole 18.5% SC was discovered to be the best and best possible care for controlling okra shoot & fruit borer, which was followed by T_2 Spinosad 45% SC, T_6 Cypermethrin 25% EC, T_3 Sixer plus, T_7 *Beauveria bassiana* 1.0% WP (1×10^9 CFU/gm), T_1 Neem oil and T_4 *Metarhizium anisopliae* 1.0% WP (1×10^8 CFU/gm) was found to be least effective compared to T0 control (untreated). To guarantee that the biopesticides also work better against the okra shoot & fruit borer, *Erias vittella* (Fab.), further research and studies may be suggested. Developing suitable integrated pest management strategies against this pest may benefit from the application of the recommended dosages of chemical insecticides and bio pesticides.

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