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Comparative efficacy of bio-pesticides and chemicals against fruit borer, *Helicoverpa armigera* (Hubner) on tomato, *Solanum lycopersicum* [Mill.] under field conditions

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Abstract
The fruit borer, *Helicoverpa armigera* (Lepidoptera: Noctuidae), is a highly destructive pest affecting tomatoes, presenting significant challenges for control due to its complex feeding behaviors. This study evaluates the effectiveness of biopesticides and chemical treatments in managing this pest. Eight different treatments were compared, with the lowest fruit borer infestation observed in the combination of Emamectin benzoate 5% SG and Indoxacarb 14.5% SC (11.36%) versus the untreated control (26.68%). Other effective treatments included Indoxacarb 14.5% SC alone (13.24%), Novaluron 10 EC combined with Indoxacarb 14.5% SC (13.56%), Beauveria bassiana combined with Indoxacarb 14.5% SC (13.70%), and Bacillus thuringiensis combined with Indoxacarb 14.5% SC (14.57%). Additionally, Novaluron 10 EC alone (15.03%) and Fipronil 5% SC (15.47%) were effective. The highest yield was achieved with Emamectin benzoate + Indoxacarb (207.39 q/ha), which also proved to be the most cost-effective treatment with a cost-benefit ratio of 1:10.90. The untreated control had the lowest cost-benefit ratio at 1:4.84.

Keywords: Bio-pesticides, *Helicoverpa armigera,* chemicals, cost-benefit ratio

Introduction

The tomato, *Solanum lycopersicum* (Miller), is a significant herbaceous crop from the Solanaceae family, commonly known as wolf apple, love apple, or Vilaayati baingan. It is versatile and can be consumed fresh in salads, curries, or as by-products such as chutney, pickle, soups, ketchup, sauce, powder, and purees (Manisha, C. and Kumar, A. 2022) [15]. Originating from the South American Andes, tomatoes are an essential part of a nutritious diet, rich in vitamins A and C, and often referred to as the "poor man's orange." They possess anti- cancer properties and serve as antioxidants; β-carotene helps prevent and neutralize free radical chain reactions, while ascorbic acid effectively scavenges superoxide, hydrogen peroxide, and other free radicals. Per 100 grams of ripe tomatoes contain Vitamin C (31.0 mg), Vitamin A (320 IU), Riboflavin (0.001 mg), Nicotinic acid (0.4 mg), and minerals such as Potassium (114.0 mg), Sulfur (24.0 mg), Chlorine (38.0 mg), Sodium (45.8 mg), Calcium (20.0 mg), Phosphorus (36.0 mg), Iron (1.8 mg), Magnesium (15.0 mg), and Copper (0.19 mg).

In India, tomatoes are grown over an area of 0.85 million hectares with a production of 20.82 million metric tons. The major tomato-producing states include Madhya Pradesh, Andhra Pradesh, Odisha, Karnataka, Bihar, Chhattisgarh, West Bengal, and Gujarat. In Uttar Pradesh, tomatoes cover an area of 23.05 thousand hectares, yielding 9.40 lakh metric tons (Horticulture Statistics Division, Department of Agriculture, Co-operation & Farmer's Welfare, 2023-24).

Helicoverpa armigera is a major pest causing significant yield losses in tomato crops. This pest has recently been recognized as a national threat due to its economic damage to various agricultural crops across India. *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is a highly polyphagous species impacting a wide range of crops, including cotton, soybeans, tobacco, chickpea, chilies, and pigeon pea. It is globally distributed and causes approximately one billion dollars' worth of damage annually in India alone.

Half of all insecticides used in India are targeted at this pest. In Tamil Nadu, fruit losses range from 40- 50%, while in Northern India, tomato fruit worm causes 30% fruit losses, with reported losses from this pest ranging from 5-55% in tomato-growing regions of India (Manisha, C. and Kumar, A. 2022) [15].

Materials and Methods

The current study aimed to evaluate the "Comparative efficacy of biopesticides and chemicals against the fruit borer, *Helicoverpa armigera* (Hubner), on tomato, *Solanum lycopersicum* (Mill.) under field conditions" during the *Rabi* season of 2023-24. The field experiment took place at the Central Research Farm, Department of Entomology, Sam Higginbottom University of Agriculture, Technology, and Sciences, Prayagraj. The experiment was arranged in a Randomized Block Design (RBD) with eight treatments and three replications, using a plot size of 2m x 1m. The tomato variety used was Sahoo. Two sprays were applied at fifteen-day intervals using a hand-operated sprayer during morning hours to prevent photo-oxidation of the chemicals. The treatments included Novaluron - 10 EC, Indoxacarb - 14.5% SC, Fipronil - 5% SC, Emamectin benzoate - 5% SG + Indoxacarb - 14.5% SC, Novaluron - 10 EC + Indoxacarb - 14.5% SC, *Beauveria bassiana* + Indoxacarb - 14.5% SC, *Bacillus thuringiensis* + Indoxacarb - 14.5% SC, and an untreated control.

Observations on the percentage of fruit damage caused by the tomato fruit borer were recorded on five randomly selected plants in each replication, including unsprayed controls. Pre- and post-treatment observations were taken on the 3rd, 7th, and 14th days after each spray. The percentage of fruit borer damage in field conditions was calculated relative to the control.

The data were averaged and subjected to appropriate transformations. After analysis, the data were tabulated according to the objectives for result interpretation. The standard procedures in agricultural statistics provided by Gomez and Gomez (1984) [24] were followed throughout. Data interpretation utilized the critical difference value calculated at a 0.05 probability level, with significance expressed at this same level.

Results and Discussions

The data on the percent infestation of the fruit borer observed on the 3rd, 7th, and 14th days after the first spray indicated that all treatments were significantly more effective than the control. Among the treatments, the lowest infestation rate was recorded with Emamectin benzoate + Indoxacarb (14.60%), followed by Indoxacarb (15.83%), Novaluron + Indoxacarb (16.48%), *Beauveria bassiana* + Indoxacarb (16.98%), *Bacillus thuringiensis* + Indoxacarb (17.40%), Novaluron (17.93%), and Fipronil (18.22%). These were all significantly superior to the control (23.03%). The treatments (Fipronil, Novaluron, *Bacillus thuringiensis* + Indoxacarb, *Beauveria bassiana* + Indoxacarb), (Novaluron + Indoxacarb, Indoxacarb), and (Emamectin benzoate + Indoxacarb) were found to be statistically at par with each other.

The data on percent infestation on the 3rd, 7th, and 14th days after the second spray also showed that all treatments were significantly more effective than the control. Emamectin benzoate + Indoxacarb again had the lowest infestation rate (11.03%), followed by Indoxacarb (12.67%), Novaluron + Indoxacarb (13.14%), *Beauveria bassiana* + Indoxacarb (13.51%), *Bacillus thuringiensis* + Indoxacarb (14.28%), Novaluron (14.84%), and Fipronil (15.47%). These were all significantly better than the control (26.96%). The treatments (Fipronil, Novaluron, *Bacillus thuringiensis* + Indoxacarb), (*Beauveria bassiana* + Indoxacarb, Novaluron + Indoxacarb), and (Indoxacarb, Emamectin benzoate + Indoxacarb) were statistically similar to each other.

Overall, the data revealed that all treatments significantly outperformed the control after both the first and second sprays. The lowest infestation across both sprays was recorded with Emamectin benzoate + Indoxacarb (12.81%), followed by Indoxacarb (14.25%), Novaluron + Indoxacarb (14.76%), *Beauveria bassiana* + Indoxacarb (15.24%), *Bacillus thuringiensis* + Indoxacarb (15.84%), Novaluron (16.39%), and Fipronil (16.84%), all of which were significantly better than the control (26.50%). The treatments (Fipronil, Novaluron), (*Bacillus thuringiensis* + Indoxacarb, Beauveria *bassiana* + Indoxacarb), and (Novaluron + Indoxacarb, Indoxacarb, Emamectin benzoate + Indoxacarb) were statistically at par with each other.

The highest yield was achieved with Emamectin benzoate + Indoxacarb (207.39 q/ha), followed by Indoxacarb (190.34 q/ha), Novaluron + Indoxacarb (178.95 q/ha), *Beauveria bassiana* + Indoxacarb (158.54 q/ha), *Bacillus thuringiensis* + Indoxacarb (152.75 q/ha), Novaluron (145.14 q/ha), Fipronil (118.65 q/ha), and the untreated control, which had the lowest yield (83.25 q/ha).

In terms of cost-benefit ratio, the most economical treatment was Emamectin benzoate + Indoxacarb (1:10.90), followed by Indoxacarb (1:10.32), Novaluron + Indoxacarb (1:9.48), *Beauveria bassiana* + Indoxacarb (1:8.53), *Bacillus thuringiensis* + Indoxacarb (1:8.04), Novaluron (1:7.94), and Fipronil (1:6.54). The untreated control had the lowest cost-benefit ratio (1:4.84).

Table 1: Comparative efficacy of Bio-pesticides and chemicals on percentage of fruit damage of *Helicoverpa armigera* (Hubner) on Tomato

Treatments	Dosage	1st Spray					2nd Spray				Overall Mean	Yield (q/ha)	B:C Ratio
		1 DBS	3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean			
T_1- Novaluron (10 EC)	75 ml/ha	21.01	18.05	17.73	18.03	17.93	15.71	14.09	14.72	14.84	16.39	145.14	1:7.94
T_2- Indoxacarb (14.5 SC)	60 gm/ha	17.76	17.03	14.76	15.71	15.83	13.18	12.18	12.65	12.67	14.25	190.34	1:10.32
T_3- Fipronil (5 SC)	50 gm/ha	19.48	18.33	18.18	18.14	18.22	16.64	14.65	15.10	15.47	16.84	118.65	1:6.54
T_4- Emamectin benzoate (5 SG) + Indoxacarb (14.5 SC)	220 mg/ha + 60 gm/ha	18.52	15.58	13.82	14.39	14.60	12.31	9.95	10.83	11.03	12.81	207.39	1:10.90
T_5- Novaluron (10EC) + Indoxacarb (14.5 SC)	80 gm/ha	19.11	17.38	15.62	16.45	16.48	13.74	12.59	13.10	13.14	14.76	178.95	1:9.48
T_6- *Beauveria bassiana* + Indoxacarb (14.5 SC)	400 gm/ha + 60 gm/ha	19.57	17.60	16.42	16.93	16.98	14.54	12.71	13.26	13.51	15.24	158.54	1:8.53
T_7- *Bacillus thuringiensis* + Indoxacarb (14.5 SC)	750 gm/ha + 60 gm/ha	18.75	17.94	17.03	17.22	17.40	14.82	13.70	14.32	14.28	15.84	152.75	1:8.04
T_8- Control	--	20.09	21.56	22.24	25.28	23.03	26.85	26.97	27.07	26.96	26.50	83.25	1:4.84
F- test		NS	S	S	S	S	S	S	S	S	S		
S. Ed. (±)		2.31	0.74	0.52	0.46	0.36	0.36	0.34	0.45	0.08	4.56		
C. D. (P = 0.05)		3.23	2.20	1.84	1.74	1.53	1.53	1.48	1.72	0.71	6.00		

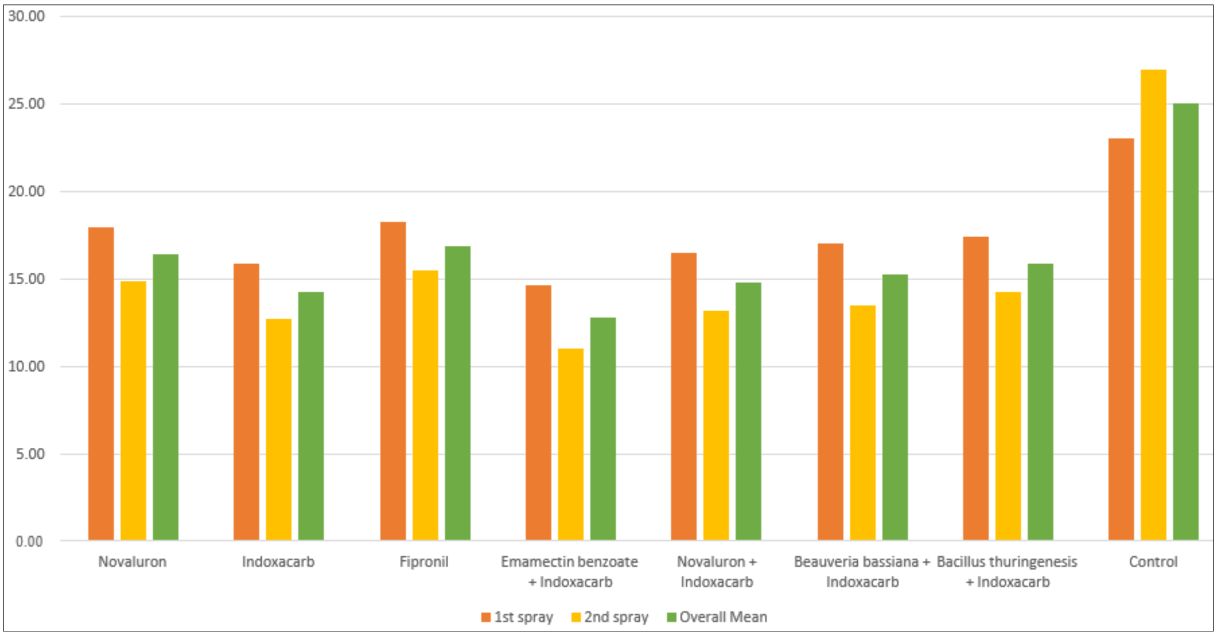

Fig 1: Comparative efficacy of Bio-pesticides and chemicals against fruit borer, *Helicoverpa armigera* (Hubner) after first and second spray

Conclusion

The results of this study indicate that Emamectin benzoate 5% SG + Indoxacarb 14.5% SC and Indoxacarb 14.5% SC are the most effective treatments against the tomato fruit borer (*Helicoverpa armigera*), leading to the highest yields and the best cost-benefit ratios compared to other treatments. Novaluron 10% EC + Indoxacarb 14.5% SC, *Beauveria bassiana* + Indoxacarb 14.5% SC, and *Bacillus thuringiensis* + Indoxacarb 14.5% SC demonstrated moderate effectiveness. Novaluron 10% EC and Fipronil 5% SC were found to be the least effective in controlling *Helicoverpa armigera*. Therefore, it is recommended that these effective insecticides be rotated within Integrated Pest Management (IPM) programs to prevent issues such as insecticidal resistance and pest resurgence. Integrating botanicals into IPM strategies is also advisable to reduce the indiscriminate use of chemical pesticides, thus minimizing environmental pollution and safeguarding beneficial insects.

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