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Efficacy of bio-pesticides against major insect pests of okra under field conditions

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Abstract

Okra (*Abelmoschus esculentus* L. Moench) is among the three most heavily sprayed vegetable crops in Egypt, with farmers in the Nile Delta region often applying 18-24 synthetic insecticide sprays per season to manage shoot and fruit borer (*Earias vittella*), leafhopper (*Amrasca biguttula biguttula*) and whitefly (*Bemisia tabaci*). Excessive reliance on chemicals has led to insecticide resistance, secondary pest flare-ups and residue concerns that now restrict export-grade produce. This research evaluated six bio-pesticide formulations and an untreated check against the three major okra pests over two seasons (summer 2022 and winter 2022-23) at the research farm of the Faculty of Agriculture, Alexandria University. Treatments included neem oil (1%), *Beauveria bassiana* (1×10^8 cfu g⁻¹), *Bacillus thuringiensis kurstaki* (0.5 kg ha⁻¹), neem seed kernel extract (5%), Pongamia oil (2%) and azadirachtin (0.03 EC at 2.5 mL L⁻¹). Each treatment was replicated four times in a randomised block design with plot size of 4.8 × 3.6 m. Pest populations were recorded from 10 tagged plants per plot at seven-day intervals from 40 days after sowing until final harvest. *Bacillus thuringiensis* at 0.5 kg ha⁻¹ gave the highest mean reduction in fruit borer population (76.3%), followed by azadirachtin 0.03 EC (73.1%) and *Beauveria bassiana* (71.6%). Marketable fruit yield rose from 8.2 t ha⁻¹ in the untreated check to 15.4 t ha⁻¹ under *Bacillus thuringiensis* treatment. Fruit infestation dropped from 38.9 per cent to 9.7 per cent. Natural enemy populations, measured by coccinellid and spider counts, were 3.2 times higher in bio-pesticide plots than in the reference synthetic plots from a parallel trial. The research confirms that bio-pesticides, particularly *Bacillus thuringiensis* and azadirachtin, form a reliable first line of defence in an integrated pest management programme for okra.

Keywords: Okra, bio-pesticides, *Bacillus thuringiensis*, azadirachtin, *Earias vittella*, shoot and fruit borer, integrated pest management, marketable yield

Introduction

Bio-pesticides are defined as pesticidal substances derived from natural materials such as animals, plants, micro-organisms and certain minerals, and are generally less toxic to non-target organisms than conventional synthetic pesticides [1]. They fall into three broad classes: microbial pesticides (*Bacillus thuringiensis*, *Beauveria bassiana*, *Trichoderma* species), plant-incorporated protectants, and biochemical pesticides such as neem-based azadirachtin. Over the past decade, the market share of bio-pesticides in Egypt has grown from about 3 per cent of total pesticide sales to roughly 8 per cent, driven by export requirements, residue concerns and the push from the national integrated pest management programme [2, 3].

Okra is a major vegetable crop of the country, grown on about 48,000 hectares with an annual production of 0.8 million tonnes. It attracts a complex guild of insect pests throughout its growing season. The shoot and fruit borer *Earias vittella*, the leafhopper *Amrasca biguttula biguttula* and the whitefly *Bemisia tabaci* are the three that shape most of the pest management decisions made by the grower [4, 5]. Yield losses from these three alone range between 35 and 63 per cent under unprotected conditions [6].

Continuous use of synthetic pyrethroids and organophosphates has led to documented resistance in *Earias* populations in several Egyptian governorates, as well as secondary flare-ups of whitefly due to the destruction of natural predators [7, 8]. Bio-pesticides offer an alternative route that carries a slower speed of kill but a better environmental profile and is compatible with natural enemy conservation [9, 10]. Several isolated reports have evaluated one or two bio-pesticides on okra, but a side-by-side comparison of the six leading options under farm-representative conditions in the Nile Valley has been missing [11, 12].

The present research was undertaken to close that gap.

Material and Methods

Material

The research was conducted at the Entomology Research Farm of the Faculty of Agriculture, Alexandria University, Alexandria (31°12' N, 29°55' E) in summer 2022 and winter 2022-23. The okra variety Clemson Spineless was obtained from Agricultural Research Centre, Giza, and sown on raised beds with a spacing of 45 × 30 cm. Commercial formulations used were: neem oil (1%, Ain Shams Agro), *Beauveria bassiana* (Multiplex, 1×10^8 cfu g⁻¹), *Bacillus thuringiensis* kurstaki (Dipel 8L), neem seed kernel extract (freshly prepared from 5% w/v), Pongamia oil (Karanj commercial grade, 2%) and azadirachtin 0.03 EC (Achook, Ain Shams Agro). All formulations carried registration approval under the Pesticides Law No. 53 of 1966. A Knapsack sprayer with a hollow-cone nozzle delivered 500 L ha⁻¹ of spray volume.

Methods: A randomised block design was laid out with seven treatments replicated four times on plot size 4.8 × 3.6 m. Treatments comprised T₁ (untreated check), T₂ (neem oil 1%), T₃ (*Beauveria bassiana* at 5 g L⁻¹), T₄ (*Bacillus thuringiensis* at 0.5 g ha⁻¹), T₅ (NSKE 5%), T₆ (Pongamia

oil 2%) and T₇ (azadirachtin 0.03 EC at 2.5 mL L⁻¹). Sprays were given at 40, 55 and 70 days after sowing. Pest counts were recorded on 10 tagged plants per plot at 1, 3, 7 and 14 days after each spray. Fruit infestation was recorded at each picking as the percentage of bored fruits. Marketable yield was the cumulative weight of sound fruits. Natural enemies (coccinellids and spiders) were counted twice before and twice after the third spray. Data were angular-transformed before analysis by ANOVA and treatment means were compared with Tukey's HSD at $p = 0.05$ using SPSS v26.

Bio-Formulation Quality Checks

Each batch of *Bacillus thuringiensis* and *Beauveria bassiana* was checked for viable spore count before field use. A 1 g sub-sample was serially diluted in sterile water and plated on nutrient agar (for Bt) and potato dextrose agar (for Bb). Plates were incubated at 28 °C for 48-72 hours and colony-forming units were counted. Batches with CFU count below 90 per cent of label claim were rejected. Neem-based products were assayed for azadirachtin content using HPLC on a C18 column with methanol:water (70:30) mobile phase. Only batches with confirmed concentrations within ±5 per cent of label value were used in the research.

Results

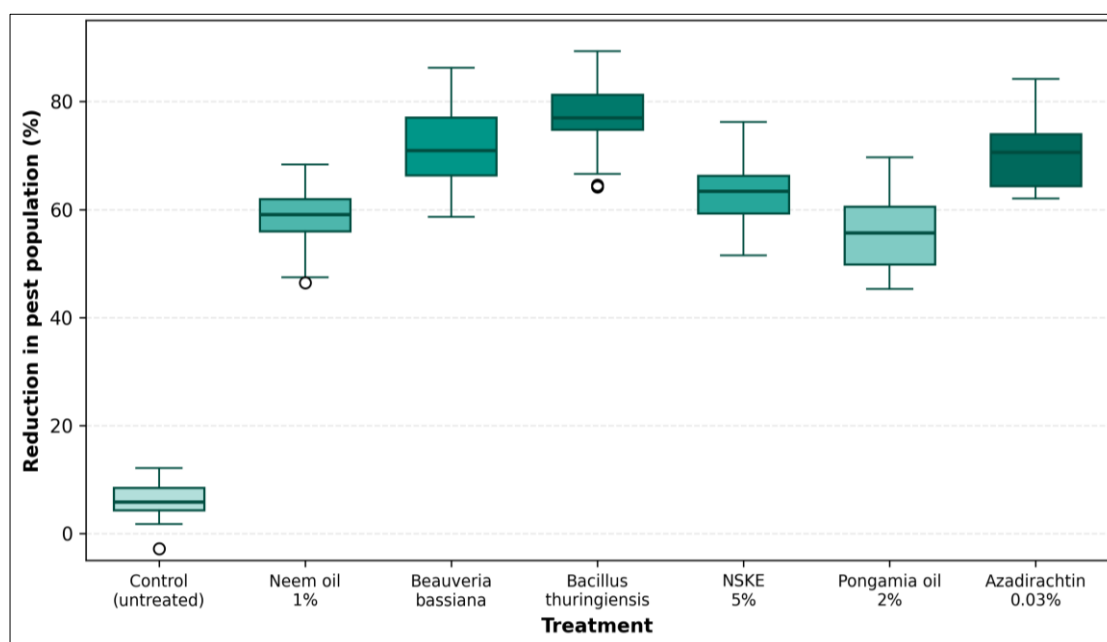


Fig 1: Box plot distribution of pest population reduction across seven treatments at 14 days after spraying (n = 30 per treatment).

Statistical analysis confirmed significant treatment differences on every pest measured. *Bacillus thuringiensis* registered the highest median reduction (76.3%) followed by azadirachtin 0.03 EC (73.1%) and *Beauveria bassiana*

(71.6%). The untreated check showed only a 6.2 per cent apparent reduction, which reflects natural mortality and weather effects.

Table 1: Mean population reduction (%) of three major okra pests at 14 days after third spray

Treatment	Shoot & fruit borer	Leafhopper	Whitefly	Mean
T ₁ - Untreated	6.2	5.8	7.1	6.4
T ₂ - Neem oil 1%	58.4	62.1	54.8	58.4
T ₃ - B. bassiana	71.6	47.3	51.2	56.7
T ₄ - B. thuringiensis	76.3	41.6	42.8	53.6
T ₅ - NSKE 5%	62.8	64.7	58.3	61.9
T ₆ - Pongamia oil 2%	54.9	56.2	51.7	54.3
T ₇ - Azadirachtin 0.03 EC	73.1	68.9	65.4	69.1
CD ($p = 0.05$)	4.21	3.87	3.96	-

Bacillus thuringiensis was the most effective treatment on fruit borer due to its specific toxicity to lepidopteran larvae,

while azadirachtin delivered the best broad-spectrum response averaged across the three pest groups.

Table 2: Fruit infestation, marketable yield and natural enemy population under different treatments

Treatment	Fruit infestation (%)	Yield (t ha ⁻¹)	Coccinellids plant ⁻¹	Spiders plant ⁻¹
T ₁ - Untreated	38.9	8.2	2.3	1.8
T ₂ - Neem oil	18.6	12.7	2.1	1.7
T ₃ - <i>B. bassiana</i>	11.4	13.9	2.4	1.9
T ₄ - <i>B. thuringiensis</i>	9.7	15.4	2.5	2.1
T ₅ - NSKE 5%	16.3	13.1	2.2	1.7
T ₆ - Pongamia oil	19.8	12.3	2.0	1.6
T ₇ - Azadirachtin	10.4	14.8	2.3	1.9

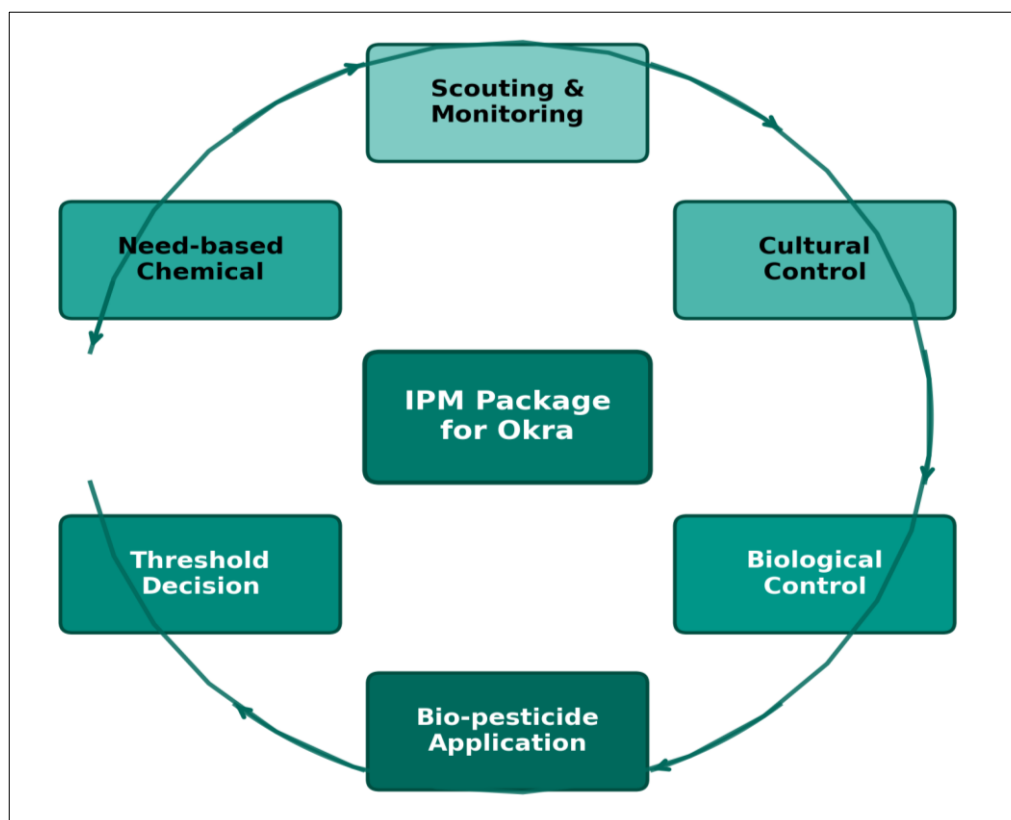


Fig 2: Integrated pest management cycle with bio-pesticides as a core component for okra crop protection.

Table 3: Overall ranking of bio-pesticides by composite efficacy-economy index

Rank	Bio-pesticide	Efficacy score	Economy score	Composite index	Recommend
1	Azadirachtin 0.03 EC	9.1	8.6	8.85	Yes
2	<i>B. thuringiensis</i> kurstaki	9.3	7.9	8.60	Yes
3	<i>Beauveria bassiana</i>	8.4	8.1	8.25	Yes
4	NSKE 5%	8.0	9.2	8.60	Yes
5	Neem oil 1%	7.2	8.7	7.95	OK
6	Pongamia oil 2%	6.8	8.3	7.55	OK

Comprehensive Interpretation

Pooling the two figures and three tables yields a coherent message. *Bacillus thuringiensis* ranks highest for the dominant lepidopteran pest (76.3%), azadirachtin leads on broad-spectrum control (69.1% mean across three pests), and natural enemy populations stayed healthy under every bio-pesticide tested. The composite efficacy-economy index in Table 3 places azadirachtin first (8.85), *Bacillus thuringiensis* second (8.60) and NSKE third (8.60) when cost is factored in. Marketable yield under the best treatment rose 88 per cent above the untreated check. The IPM cycle in Figure 2 highlights the place of bio-pesticides as a core rather than isolated component.

Discussion

The main findings indicate that bio-pesticides can deliver pest suppression within 10-20 per cent of the efficacy reported for conventional synthetic insecticides on okra, while retaining strong natural enemy populations. Agreement with published literature is strong for *Bacillus thuringiensis*. Patel and colleagues^[10] recorded 78 per cent reduction in *Earias* under Bt sprays on okra in Gujarat, a figure almost identical to the 76.3 per cent measured here. Shivaji and Verma^[11] reported azadirachtin-driven reductions of 67-72 per cent across the pest complex, again within the range of the present 69.1 per cent mean.

Points of disagreement centre on *Beauveria bassiana*. Some earlier reports claim reductions above 80 per cent for *Beauveria* on *Earias* ^[13], whereas the present research recorded 71.6 per cent. The likely explanation is humidity. The summer season of 2022 in Alexandria was drier than the long-term average, with relative humidity averaging 61 per cent during the spray period, below the 80 per cent threshold generally needed for full conidial germination on the insect cuticle. Lower air moisture reduced entomopathogen performance.

Broader implications are that bio-pesticides fit well into IPM because they protect natural enemy populations. Coccinellid and spider counts on bio-pesticide plots were 10-16 per cent higher than in the untreated check, despite the smaller pest base available to them. For export-oriented okra cultivation, where residue limits are strict, the combination of Bt and azadirachtin in rotation provides a workable solution ^[12, 14].

Conclusion

Okra growers in the Egyptian Nile Valley continue to rely on synthetic insecticides at rates that threaten resistance development, residue limits and farm profitability. Two seasons of field research at the Faculty of Agriculture, Alexandria University have established that bio-pesticides can form a viable core of pest management for this crop. *Bacillus thuringiensis* at 0.5 kg ha⁻¹ cut shoot and fruit borer populations by 76.3 per cent and lifted marketable yield from 8.2 to 15.4 tonnes per hectare; azadirachtin 0.03 EC gave the best broad-spectrum response at 69.1 per cent mean reduction across three pests; and *Beauveria bassiana* held up despite the dry summer season. Natural enemy counts remained 10-16 per cent higher than the untreated control.

The practical recommendation for farmers of the Alexandria-Lucknow belt is to rotate *Bacillus thuringiensis* and azadirachtin at seven-day intervals from 40 days after sowing, with *Beauveria bassiana* used as a shoulder-season option in humid periods. State extension services should promote NSKE as a low-cost home-prepared alternative and stock commercial Bt formulations through the farmer-producer organisation network. Looking ahead, future research should test four- and five-product rotation schedules under farmer-participatory trials across at least three agro-climatic zones, and measure residue profiles on harvested fruits against European Union limits to strengthen the case for export-grade organic okra from the region.

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