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Efficacy of commonly used insecticides against shoot and fruit borer (*Earias vittella*) on pgpr treated okra plants

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Abstract

A field experiment was conducted at the Agricultural College and Research Institute, Killikulam, during Kharif 2021 to evaluate the efficacy of commonly used insecticides against *Earias vittella* on *Bacillus subtilis* Bbv57-treated okra plants. The study involved ten treatments, including PGPR (*B. subtilis* Bbv57) application alone and in combination with insecticides such as Spinetoram, Spinosad, and Emamectin Benzoate, along with an untreated control. Results demonstrated that foliar application of spinetoram 11.7 SC @ 450 ml/ha on *B. subtilis* Bbv57-treated plants was the most effective, achieving the lowest shoot damage (2.94% at 14 DAT) and fruit damage (4.79% pooled), alongside the highest fruit yield (19.31 t/ha) and benefit-cost ratio (BCR 1:2.56). Spinosad 45 SC @ 160 ml/ha also showed significant efficacy, reducing fruit damage and increasing yield (18.77 t/ha). The enhanced efficacy of insecticides reveals the potential of integrating PGPR with chemical insecticides to reduce pest infestation, minimize chemical pesticide use, and mitigate environmental risks.

Keywords: PGPR, insecticide, Pest, *Earias sp*., borer, okra, pest

Introduction

Okra, commonly referred to as lady's finger (*Abelmoschus esculentus* L. Moench), is an essential vegetable crop belonging to the Malvaceae family. It is widely cultivated in India and extensively grown as a commercial vegetable and garden crop across tropical and subtropical regions globally. Okra plays a pivotal role in meeting vegetable demand in India, contributing 62% to the global production (Rao *et al.*, 2019) [1]. The primary okra-producing countries include India, Turkey, Japan, Iran, Bangladesh, Malaysia, Thailand, Ethiopia, and Pakistan (Benjawan *et al.*, 2007; Qhureshi, 2007) [2]. Known for its high nutritional value, okra is a vital component of the human diet, offering carbohydrates, proteins, fats, vitamins (A, C, B6), folic acid, minerals (calcium, magnesium, potassium, iron, zinc, phosphorus), β-carotene, riboflavin, and fiber (Varmudy, 2011). Despite its nutritional and economic significance, okra production faces challenges, including poor seed quality, pest infestations, weed competition, inadequate plant density, improper fertilizer application, and limited space availability (Rahman, 2012). Among these, insect pests are a major limiting factor (Kumawat *et al.*, 2000; Bhatt and Sharma, 2018) [3, 4]. Key pests include the shoot and fruit borers (*Earias insulana* Boisd. and *Earias vittella* Fab.), the leafhopper (*Amrasca biguttula biguttula* Ishida), the leaf roller (*Sylepta derogata* Fab.), the whitefly (*Bemisia tabaci* Genn.), the aphid (*Aphis gossypii* Glover), and the mite (*Tetranychus cinnabarinus* Boisduval) (Kodandaram *et al.*, 2017) [5].

The shoot and fruit borers are oligophagous pests targeting tender shoots, flower buds, flowers, and young fruits, causing terminal shoot withering, flower bud drop, and fruit deformation, rendering them unsuitable for consumption. Yield losses due to *Earias* spp. range from 23% to 54% (Akolkar *et al.*, 2021) [6]. Farmers predominantly rely on chemical pesticides for pest management (Naranjo, 2001), a practice that, while effective and affordable, leads to environmental concerns, including pesticide residues, pest resistance, and resurgence (Ansari *et al.*, 2014; Maurya *et al.*, 2022) [7, 8]. On average, okra growers apply 10–12 pesticidal sprays per season to manage shoot and fruit borers, which result in high pesticide residues, since fruits are harvested at short intervals, posing risks to consumer health and the environment. Additionally, chemical resistance among pests elevates production costs and reduces profitability for farmers. Thus, adopting safer, biodegradable pesticides and minimizing pesticide usage has become crucial. Sustainable approaches, particularly Integrated Pest Management (IPM), are indispensable for ensuring a healthy environment. In recent years, various biological control methods (Arif *et al.*, 2018; Qasim *et al.*, 2018) [9, 10] and biopesticidal strategies (Shakeel *et al.*, 2019) [11] have been employed against major crop pests. Microbial-based solutions, particularly plant growth-promoting rhizobacteria (PGPR), have shown immense potential in agricultural systems (Kloepper, 1978; Harris, 2009).

PGPR encompasses bacterial genera such as *Acinetobacter*, *Agrobacterium*, *Arthrobacter*, *Azotobacter*, *Azospirillum*, *Bacillus*, *Burkholderia*, *Bradyrhizobium*, *Frankia*, *Pseudomonas*, *Rhizobium*, *Serratia*, and *Thiobacillus* (Wani and Gopalakrishnan, 2019) [12]. These non-pathogenic rhizobacteria promote plant growth and induce systemic resistance (ISR) against fungal, bacterial, viral, insect, and nematode pests (Lugtenberg and Kamilova, 2009) [13].

PGPR enhances plant growth through multiple biochemical mechanisms, including the production of lipopolysaccharides, siderophores (iron-chelating molecules), phytohormones, scavengers of reactive oxygen species (ROS), volatile organic compounds (VOCs), nitrogen fixation, and phosphorus solubilization (Van Loon *et al.*, 1998; Persello-Cartieaux *et al.*, 2003; Ryu *et al.*, 2004) [14, 15, 16]. These below-ground interactions between PGPR and plants also influence above-ground herbivores, including sap-sucking and chewing insects, by altering plant abundance, nutritional quality, and host defenses (Hartley and Gange, 2009; Grunseich *et al.*, 2019) [17, 18]. Furthermore, the application of PGPR enhances crop growth and yield by improving nutrient uptake, stress tolerance, and plant defense mechanisms. Given the multifaceted benefits of PGPR, this study aims to evaluate the efficacy of commonly used insecticides against fruit borers in PGPR-treated okra plants.,

Materials and Methods

Field Experiment

Field experiment was conducted in randomized block design with ten treatments and three replications at Agricultural College and Research Institute, Killikulam farm during Kharif 2021 to study the efficacy of commonly used insecticides against borer pests of okra on PGPR treated plants. The field experiment comprised of following treatments:

Table 1

T_1	***Bacillus subtilis* Bbv57 (ST-SA)**
T_2	*Bacillus subtilis* Bbv57 (ST-SA) - *Bacillus thuringiensis* @ 1000 ml/ha
T_3	*Bacillus subtilis* Bbv57 (ST-SA) - Spinosad 45 SC @160 ml/ha
T_4	*Bacillus subtilis* Bbv57 (ST-SA) - Emamectin benzoate 5SG @ 250 g/ha
T_5	*Bacillus subtilis* Bbv57 (ST-SA) - Spinetoram 11.7 SC @ 450 ml/ha
T_6	*Bacillus thuringiensis* (Dipel® 8L) @ 1000 ml/ha
T_7	Spinosad 45 SC @ 160ml/ha
T_8	Emamectin benzoate 5SG @ 250g/ha
T_9	Spinetoram 11.7 SC @ 450 ml/ha
T_{10}	Untreated control

Okra F1 hybrid CoBh4 seeds were treated with talc formulation (containing $1x10^8$ cfu/g) of *B. subtilis* Bbv57 @ 10g/kg of seeds and sown in plots of size 6m x 5m. Soil application of *B. subtilis* Bbv57 was done before sowing @ 2.5 kg per hectare. Similarly, untreated plots were maintained to study the efficacy of insecticides without any seed treatment. The insecticides were applied on *B. subtilis* Bbv57 treated plots and untreated plots with high volume knapsack sprayer using solid cone nozzle. The talc formulations of *B. subtilis* Bbv57 was sourced from the Department of Plant Pathology at Tamil Nadu Agricultural University, Coimbatore. The crop was managed as per Tamil Nadu Agricultural University recommendations. Observations on borer pests before the application of insecticide and 3,7,10 and 14 days after treatment were recorded. The fruit yield was recorded at each harvest and pooled. Gross income, net income and benefit cost ratio (BCR) were worked out for each treatment.

Statistical Analysis

The data on per cent shoot and fruit damage were converted to angular values, while the population data were square root transformed. The yield data was analyzed without any transformation. The significance of difference between the treatments mean values were compared by using least significance difference (LSD) at 5 per cent probability.

Results and Discussion

The field experiment on the efficacy of PGPR on commonly used insecticides against *E. vittella* on okra showed that all the commercial insecticides significantly reduced the infestation of *E. vittella* on *B. subtilis* Bbv57 treated plants up to 14 DAT compared to the untreated control (Table 1). Among them application of spinetoram 11.7 SC @ 450 ml/ha significantly reduced the shoot damage and recorded nil shoot damage up to 10 DAT and 2.94% shoot damage at 14 DAT on *B. subtilis* Bbv57 treated okra plants. Foliar application of Emamectin Benzoate 5SG @ 250 g/ha on *B. subtilis* Bbv57 treated okra plants recorded 3.82 per cent shoot infestation on 14 DAT compared to 19.22 per cent shoot damage on untreated plants.

Table 2: Efficacy of commonly used insecticides against *E. vittella* on PGPR treated okra – shoot damage during Kharif 2021

S.No.	**Treatments**	**Per cent shoot damage***				
		PTC	**3 DAT**	**7 DAT**	**10 DAT**	**14 DAT**
T_1	*Bacillus subtilis* Bbv57 (ST-SA)	2.41 (8.93)	0.00 (0.00) ^{a}	3.88 (11.36) ^{d}	10.56 (18.96) ^{d}	16.44 (23.92) ^{de}
T_2	*Bacillus subtilis* Bbv57 (ST-SA) - *Bacillus thuringiensis* (Dipel® 8L) @ 1000 ml/ha	1.85 (7.82)	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	0.84 (5.26) ^{bc}	6.11 (14.31) ^{bc}
T_3	*Bacillus subtilis* Bbv57 (ST-SA) - Spinosad 45 SC @ 160ml/ha	2.02 (8.17)	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	4.35 (12.04) ^{ab}
T_4	*Bacillus subtilis* Bbv57 (ST-SA) - Emamectin benzoate 5SG @ 250 g/ha	1.98 (8.09)	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	3.82 (11.27) ^{ab}
T_5	*Bacillus subtilis* Bbv57 (ST-SA) - Spinetoram 11.7 SC @ 450 ml/ha	2.06 (8.25)	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	2.94 (9.87) ^{a}
T_6	*Bacillus thuringiensis* (Dipel® 8L) @ 1000ml/ha	2.55 (9.19)	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	1.36 (6.7) ^{c}	8.11 (16.54) ^{cd}
T_7	Spinosad 45 SC @ 160 ml/ha	2.37 (8.86)	0.00 (0.00) ^{a}	0.00 (0.00) ^{a}	0.39 (3.58) ^{b}	4.49 (12.23) ^{ab}

T8	Emamectin benzoate 5SG @ 250 g/ha	2.66 (9.39)	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.95 (5.59)^{bc}	3.91 (11.4)^{ab}
T9	Spinetoram 11.7 SC @ 450 ml/ha	1.87 (7.86)	0.00 (0.00)^{a}	0.00 (0.00)^{a}	0.46 (3.89)^{bc}	3.14 (10.21)^{a}
T10	Untreated control	2.74 (9.32)	8.69 (16.78)^{c}	11.96 (19.82)^{e}	15.33 (22.59)^{e}	19.22 (25.51)^{e}
CD (P = 0.05)		NS	2.49**	2.96**	3.35**	3.86**

DAE – Days after treatment PTC – Pre-treatment count
*Mean of three replications
Figures in parentheses are arc-sine transformed values.
In a column, means followed by common letters are not significantly different by LSD (P=0.05)

Application of insecticides on PGPR treated plants significantly reduced the fruit damage caused by *E. vittella* up to 14 DAT (Table 2). Among the treatments, application of spinetoram 11.7 SC @ 450 ml/ha on *B. subtilis* Bbv57 treated plants recorded 8.12 and 11.02 per cent fruit damage on 10 DAT and 14 DAT respectively whereas spinetoram 11.7 SC @ 450 ml/ha on untreated plants registered 9.09 and 12.66 per cent fruit damage on 10 DAT and 14 DAT respectively. The untreated plants recorded 22.77 and 24.41 per cent fruit damage on 10 DAT and 14 DAT respectively. The pooled per cent fruit damage recorded with spinetoram 11.7 SC application on *B. subtilis* Bbv57 treated plants was low (4.79%) compared to the untreated control (21.61%). Application of Spinosad 45 SC @ 160 ml/ha on *B. subtilis* Bbv 57 treated plants registered 6.52% pooled fruit damage.

Table 3: Efficacy of commonly used insecticides against *E. vittella* on PGPR treated okra – fruit damage during Kharif 2021

S.No.	**Treatments**	**Per cent fruit damage***					**Pooled per cent fruit damage**
		PTC	**3 DAT**	**7 DAT**	**10 DAT**	**14 DAT**	
T1	Bacillus subtilisBbv57 (ST-SA)	17.12 (24.44)	3.52 (10.81)^{b}	12.44 (20.65)^{c}	15.95 (23.54)^{d}	19.22 (26)^{bc}	12.78 (20.95)^{c}
T2	*Bacillus subtilis* Bbv57 (ST-SA) - Bacillus thuringiensis (Dipel® 8L) @ 1000 ml/ha	18.59 (25.54)	0.00 (0.00)^{a}	1.33 (6.62)^{a}	13.28 (21.37)^{bcd}	16.11 (23.66)^{ab}	9.17 (17.62)^{bc}
T3	*Bacillus subtilis* Bbv57 (ST-SA) - Spinosad 45 SC @ 160ml/ha	19.02 (25.86)	0.00 (0.00)^{a}	0.00 (0.00)^{a}	9.57 (18.02)^{ab}	13.41 (21.48)^{ab}	6.52 (14.8)^{ab}
T4	*Bacillus subtilis* Bbv57 (ST-SA) - Emamectin benzoate 5SG @ 250 g/ha	18.21 (25.26)	0.00 (0.00)^{a}	0.00 (0.00)^{a}	10.63 (19.03)^{abc}	14.23 (22.16)^{ab}	6.77 (15.08)^{ab}
T5	*Bacillus subtilis* Bbv57 (ST-SA) - Spinetoram 11.7 SC @ 450 ml/ha	17.66 (24.85)	0.00 (0.00)^{a}	0.00 (0.00)^{a}	8.12 (16.55)^{a}	11.02 (19.39)^{a}	4.79 (12.63)^{a}
T6	Bacillus thuringiensis (Dipel® 8L) @ 1000ml/ha	18.82 (25.71)	0.00 (0.00)^{a}	2.14 (8.41)^{b}	14.66 (22.51)^{cd}	18.74 (25.65)^{bc}	10.53 (18.93)^{bc}
T7	Spinosad 45 SC @ 160ml/ha	18.14 (25.21)	0.00 (0.00)^{a}	0.00 (0.00)^{a}	11.73 (20.03)^{abcd}	14.71 (22.55)^{ab}	8.33 (16.77)^{abc}
T8	Emamectin benzoate 5SG @ 250g/ha	17.91 (25.03)	0.00 (0.00)^{a}	0.00 (0.00)^{a}	13.11 (21.23)^{bcd}	16.08 (23.64)^{ab}	8.86 (17.31)^{bc}
T9	Spinetoram 11.7 SC @ 450 ml/ha	18.31 (25.33)	0.00 (0.00)^{a}	0.00 (0.00)^{a}	9.09 (17.55)^{ab}	12.66 (20.84)^{a}	6.91 (15.24)^{ab}
T10	Untreated control	18.33 (24.87)	19.11 (25.43)^{c}	20.14 (26.5)^{d}	22.77 (27.99)^{e}	24.41 (29.10)^{c}	21.61 (27.2)^{d}
CD (P = 0.05)		ns	3.90**	1.96**	4.41**	4.61**	4.24**

DAT – Days after treatment PTC – Pre-treatment count
*Mean of three replications
Figures in parentheses are arc-sine transformed values.
In a column, means followed by common letters are not significantly different by LSD (P=0.05)

Among the treatments, application of spinetoram 11.7 SC @ 450 ml/ha recorded the highest fruit yield (19.31 tonnes/ha) on *B. subtilis* Bbv57 treated plants. Spinosad 45 SC @ 160 ml/ha on PGPR treated plants recorded fruit yield as 18.77 tonnes/ha and the untreated plants registered the lowest fruit yield (14.85 tonnes/ha) in. The BCR was more (1:2.56) for spinetoram 11.7 SC treatment on *B. subtilis* Bbv57 treated plants whereas the BCR was 1:1.89 for untreated plants (Table 3).

Table 4: Efficacy of insecticides against *E. vittella* on PGPR treated plants - yield and economics

S.No.	**Treatments**	**Yield (t/ha)**	**Cost of cultivation (₹)**	**Gross income (₹)**	**Net income (₹)**	**BCR**
T1	*Bacillus subtilis* Bbv57 (ST-SA)	16.11^{d}	94554	289980	195426	1:2.07
T2	*Bacillus subtilis* Bbv57 (ST-SA) - *Bacillus thuringiensis* (Dipel® 8L) @ 1000 ml/ha	18.36^{abc}	98404	330480	232076	1:2.36
T3	*Bacillus subtilis* Bbv57 (ST-SA) - Spinosad 45 SC @ 160 ml/ha	18.77^{ab}	95793	337860	242067	1:2.53
T4	*Bacillus subtilis* Bbv57 (ST-SA) - Emamectin benzoate 5SG @ 250 g/ha	18.45^{abc}	95054	332100	237046	1:2.49
T5	*Bacillus subtilis* Bbv57 (ST-SA) - Spinetoram 11.7 SC @ 450 ml/ha	19.31^{a}	97554	347580	250026	1:2.56
T6	*Bacillus thuringiensis* (Dipel® 8L) @ 1000ml/ha	17.68^{bc}	93150	318240	225090	1:2.42
T7	Spinosad 45 SC @ 160ml/ha	17.88^{bc}	93789	321840	228051	1:2.43

T_8	Emamectin benzoate 5SG @ 250 g/ha	17.36^{c}	93175	312480	219305	1:2.35
T_9	Spinetoram 11.7 SC @ 450 ml/ha	17.98^{bc}	95550	323640	228090	1:2.39
T_{10}	Untreated control	14.85^{e}	92550	267300	174750	1:1.89
CD (P = 0.05)		1.18^{**}				

*Mean of three replications Okra fruits sold @ ₹18 per kg

In a column, means followed by common letters are not significantly different by LSD (P=0.05)

The experiments under field conditions and biochemical analysis of plant samples showed that *B. subtilis* Bbv57 was significantly more effective than all other PGPR in reducing the incidence of major pests of okra during Rabi 2020 and Summer 2021. All the commonly used insecticides against sucking pests of okra reduced the aphid and leafhopper population up to 14 DAT on *B. subtilis* Bbv57 treated and untreated okra plants. The present findings are in line with Reddy and Gowdar (2006) [19] and Kanna *et al.* (2007) [20] who showed that acetamiprid 20 SP @ 20g a.i/ha significantly reduced the population of sucking pests in okra. However, the efficacy of insecticides persisted more in *B. subtilis* Bbv57 treated plants when compared with untreated plants.

Similarly, all the insecticides used for the management of fruit borers effectively reduced the infestation on shoot and fruit by *E. vittella* on okra plants treated with *B. subtilis* Bbv57 and untreated plants. Among them, spinetoram 11.7 SC significantly reduced the *E. vittella* infestation up to 14 DAT on *B. subtilis* Bbv57 treated plants than the untreated plants. *B. subtilis* treated okra plants sprayed with spinetoram 11.7 SC had less shoot damage and fruit damage among all the treatments. Muthukrishnan *et al.* (2013) [21] reported that application of spinetoram @ 45 g a.i./ha thrice at 15 days interval resulted in significant reduction in the population of *H. armigera* and increased the fruit yield of okra.

The prolonged efficacy of chemical insecticides against the insect pests on *B. subtilis* Bbv57 treated plants may be due to the increased levels of biochemicals which might have reduced the feeding preference and affected the physiology of insect pests on okra. The present findings are in line with the reports of Myresiotis *et al.* (2015) [22] where *B. subtilis* strain FZB24 significantly enhanced the root uptake of thiamethoxam in corn, *Zea mays* L. thereby reduced the usage of chemical insecticides.

Conclusion

The field experiment conclusively demonstrated that the integration of *Bacillus subtilis* Bbv57 with commonly used insecticides significantly reduced the infestation of *Earias vittella* on okra plants, showcasing superior pest management compared to untreated control plots. Among the treatments, foliar application of spinetoram 11.7 SC @ 450 ml/ha on *B. subtilis* Bbv57-treated plants emerged as the most effective, achieving the lowest shoot damage and fruit, and the highest fruit yield. The economic analysis revealed that spinetoram application on *B. subtilis* Bbv57-treated plants yielded the highest benefit-cost ratio, affirming its economic feasibility for large-scale implementation. The enhanced efficacy of insecticides on PGPR-treated plants can be attributed to the induction of systemic resistance and biochemical changes by *B. subtilis* Bbv57, including increased production of secondary metabolites and defense enzymes, which not only deterred pest feeding but also improved overall plant health and resilience. Furthermore, the combined approach of PGPR and insecticides reduced reliance on chemical pesticides, minimized environmental contamination, and offered a sustainable pest management strategy. In conclusion, integrating *Bacillus subtilis* Bbv57 with chemical insecticides provides a scientifically robust, economically viable, and environmentally sustainable approach to managing fruit borers in okra. This method not only enhances pest control efficacy but also contributes to increased crop productivity and quality, paving the way for sustainable intensification in modern agriculture.

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 the writing or editing of this manuscript.

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Competing Interests

Authors have declared that no competing interests exist.

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