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Research Article

Bioefficacy of Selected Biopesticides Against Fall Armyworm in Maize (*Zea Mays L.*) Agroecosystems



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ABSTRACT

Maize (*Zea mays L.*) is an important cereal crop widely cultivated for food, feed, and industrial purposes; however, its productivity is severely affected by fall armyworm (*Spodoptera frugiperda*), a destructive invasive pest. The present study was undertaken to evaluate the bioefficacy of selected microbial and botanical biopesticides against fall armyworm under field conditions. The experiment was conducted using a Randomized Block Design with five treatments and four replications. The treatments included *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae*, neem-based biopesticide (Azadirachtin), and an untreated control. Observations were recorded on larval population, leaf damage percentage, and grain yield. The results revealed significant differences among treatments. *Bacillus thuringiensis* recorded the lowest larval population (1.20 larvae/plant) and minimum leaf damage (12.5%), followed by *Beauveria bassiana* and *Metarhizium anisopliae*, while neem-based treatment showed moderate effectiveness. The highest grain yield (58.2 q/ha) was also obtained in *Bacillus thuringiensis*-treated plots compared to untreated control (34.7 q/ha). The reduction in pest infestation and crop damage was directly reflected in improved yield. The study concludes that microbial biopesticides, particularly *Bacillus thuringiensis*, are highly effective in managing fall armyworm and can be integrated with botanical pesticides for sustainable and eco-friendly pest management in maize agroecosystems.

1. Introduction

Maize (*Zea mays L.*) is one of the most widely cultivated cereal crops in the world and plays a vital role in global agriculture. It is used as food for humans, feed for livestock, and as a raw material for several industrial products (Sharma et al., 2021). In India, maize is grown in diverse agro-climatic regions and contributes significantly to agricultural productivity and rural livelihoods (ICAR, 2020). Despite its importance, maize cultivation is affected by numerous insect pests that attack the crop at different growth stages. Among these pests, fall armyworm (*Spodoptera frugiperda*) has recently emerged as one of the most destructive invasive pests of maize worldwide (Goergen et al., 2016). The pest was first reported in Africa in 2016 and later spread rapidly across Asia including India, causing severe damage to maize crops (Sharanabasappa et al., 2018). Fall armyworm larvae feed on maize leaves, whorls, tassels, and developing cobs, resulting in characteristic symptoms such as ragged leaves, shot holes, and accumulation of frass within the whorl. Severe infestations can lead to

significant yield losses if not properly managed (Prasanna et al., 2018).

The pest is highly polyphagous and capable of feeding on more than 80 plant species including maize, sorghum, rice, cotton, and several vegetable crops (Montezano et al., 2018). This wide host range enables the pest to survive across different cropping systems and facilitates rapid spread. This adaptability makes its management more challenging and often leads to increased dependence on chemical control methods. Farmers generally depend on chemical insecticides for the management of fall armyworm infestations. However, excessive and indiscriminate use of synthetic pesticides may result in environmental pollution, development of insecticide resistance, and negative impacts on beneficial organisms (Deshmukh et al., 2020).

Biopesticides derived from microorganisms and plant extracts have emerged as promising alternatives for sustainable pest management. Microbial agents such as *Bacillus thuringiensis* (Bt), *Beauveria bassiana*, and *Metarhizium anisopliae*

have been widely used in biological control programs against lepidopteran pests (Lacey et al., 2015). Bt produces toxic crystal proteins that disrupt the digestive system of insect larvae after ingestion, ultimately causing mortality (Bravo et al., 2011). Entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* infect insect hosts through the cuticle and proliferate inside the insect body, resulting in death due to fungal infection (Zimmermann, 2007). Botanical pesticides derived from neem (*Azadirachta indica*) also possess insecticidal, antifeedant, and growth-regulating properties that help reduce insect feeding and development (Isman, 2006). Considering the increasing threat of fall armyworm and the need for eco-friendly pest control methods, the present study was undertaken to evaluate the bioefficacy of selected biopesticides against fall armyworm in maize agroecosystems.

The present study was undertaken to evaluate the bioefficacy of selected biopesticides against fall armyworm in maize, to assess the reduction in larval population and leaf damage under different treatments, to compare the effectiveness of microbial and botanical biopesticides, and to identify eco-friendly pest management strategies for sustainable maize cultivation and depicted in Fig-1.

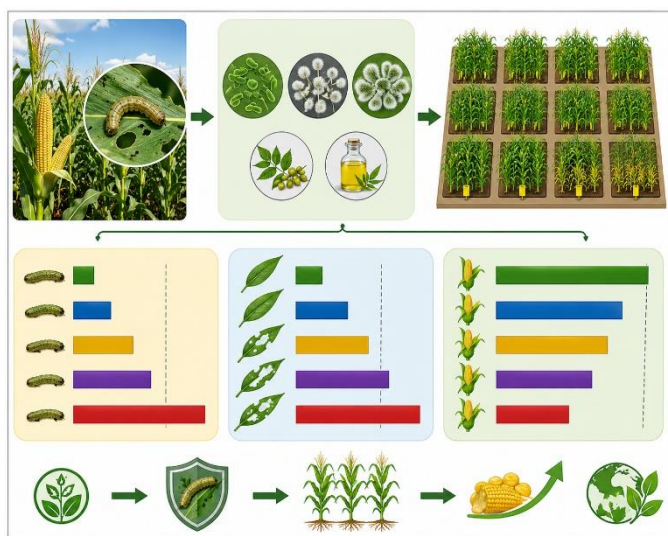


Figure-1. Graphical abstract

Materials and Methods

2.1. Study Area:

The field experiment was conducted during the maize growing season under typical tropical agro-climatic conditions favorable for maize cultivation and fall armyworm development. The region is characterized by moderate temperature (25–35°C), relative humidity of 60–80%, and seasonal rainfall, which are conducive for rapid multiplication of *Spodoptera frugiperda* (Prasanna et al., 2018; Montezano et al., 2018). The soil of the experimental field was red sandy loam with good drainage and moderate fertility, suitable for maize production (ICAR, 2020).

2.2. Experimental Design:

The experiment was laid out in a Randomized Block Design (RBD) with five treatments and four replications. Each plot was of uniform size, and treatments were randomly assigned within each replication to minimize experimental bias. Buffer zones were maintained between plots to avoid spray drift and cross-

contamination. This experimental design ensured reliable comparison among treatments and reduced experimental error (Gomez and Gomez, 1984).

2.3. Treatments:

The following treatments were evaluated: *Bacillus thuringiensis* (Bt) formulation, *Beauveria bassiana* formulation, *Metarhizium anisopliae* formulation, neem-based biopesticide (*Azadirachtin*), and an untreated control. These biopesticides were selected based on their proven efficacy against lepidopteran pests and eco-friendly nature, and to address the objective of comparing microbial and botanical biopesticides under field conditions (Lacey et al., 2015; Isman, 2006).

2.4. Crop Establishment and Maintenance:

A locally recommended hybrid maize variety was sown following standard agronomic practices. Uniform spacing, irrigation, fertilization, and weed management were maintained across all treatments to eliminate confounding effects. No synthetic insecticides were applied during the experimental period to ensure unbiased evaluation of the treatments (FAO, 2019).

Application of Treatments: Biopesticides were applied as foliar sprays using a knapsack sprayer at recommended dosages. The first application was made at the early stage of infestation when initial symptoms such as leaf scraping and shot holes appeared. Subsequent applications were carried out at 7–10-day intervals depending on pest incidence (Deshmukh et al., 2020). Sprays were applied during early morning or late evening hours to enhance microbial survival and efficacy. Proper coverage of the plant canopy, especially the whorl region, was ensured since it serves as the primary feeding site for larvae (Prasanna et al., 2018).

2.5. Data Collection:

Data were recorded at regular intervals from randomly selected plants in each plot, including larval population per plant, leaf damage assessed using a standard visual rating scale, plant growth parameters such as plant height and vigor, and grain yield, which was harvested and converted into yield per hectare (Sharanabasappa et al., 2018; Davis et al., 1992).

2.6. Statistical Analysis:

The data collected were subjected to analysis of variance (ANOVA) to determine the statistical significance of treatment effects. Mean comparisons were performed at a 5% level of significance. Percentage data were transformed where necessary. Statistical procedures were followed as described by Gomez and Gomez (1984), ensuring accuracy and reliability of the results.

2. Results and Discussion

The results obtained from the present investigation clearly demonstrated the effectiveness of selected biopesticides in managing fall armyworm infestation in maize agroecosystems. Significant variations were observed among the treatments with respect to larval population, extent of leaf damage, and grain yield. The application of microbial and botanical biopesticides resulted in considerable suppression of pest incidence compared to the untreated control, thereby contributing to improved crop performance. These variations

among treatments reflect differences in their mode of action, speed of effectiveness, and persistence under field conditions. The detailed results and their implications for pest management are discussed below.

3.1. Effect of Biopesticides on Larval Population:

The application of different biopesticides resulted in a significant reduction in the larval population of fall armyworm compared to the untreated control. The mean larval population recorded across treatments is presented in Table 1. Among all treatments, *Bacillus thuringiensis* showed the lowest larval population, followed by *Beauveria bassiana* and *Metarhizium anisopliae*. Neem-based treatment showed moderate suppression, whereas the untreated control recorded the highest larval population.

The superior performance of *Bacillus thuringiensis* can be attributed to its rapid toxic action through Cry proteins, which disrupt the insect midgut leading to mortality (Bravo et al., 2011). Similar reductions in larval population were reported by Sharanabasappa et al. (2018) and Deshmukh et al. (2020). The comparatively slower action of entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* is due to their infection-based mode of action, which requires suitable environmental conditions (Zimmermann, 2007; Lacey et al., 2015). Neem-based formulations exhibited moderate reduction due to their antifeedant and growth regulatory properties (Isman, 2006; Sisay et al., 2019).

Table 1. Effect of Biopesticides on Larval Population of Fall Armyworm.

Treatment	Larvae/Plant (Mean ± SE)
<i>Bacillus thuringiensis</i>	1.20 ± 0.15
<i>Beauveria bassiana</i>	1.85 ± 0.18
<i>Metarhizium anisopliae</i>	2.10 ± 0.20
Neem (Azadirachtin)	2.75 ± 0.25
Control	4.90 ± 0.30
SE(d)	0.12
CD (P=0.05)	0.35

3.2. Effect on Leaf Damage:

Corresponding to the reduction in larval population, a significant decrease in leaf damage was observed in all treated plots compared to the untreated control. The extent of leaf damage under different treatments is presented in Table 2. The lowest leaf damage percentage was recorded in *Bacillus thuringiensis*-treated plots, followed by fungal biopesticides, while neem-based treatment showed moderate effectiveness.

Table 2. Effect of Biopesticides on Leaf Damage (%)

Treatment	Leaf Damage (%) (Mean ± SE)
<i>Bacillus thuringiensis</i>	12.5 ± 1.2
<i>Beauveria bassiana</i>	18.3 ± 1.5
<i>Metarhizium anisopliae</i>	20.6 ± 1.7
Neem (Azadirachtin)	26.8 ± 2.0
Control	48.5 ± 2.5
SE(d)	1.05
CD (P=0.05)	3.12

The reduction in leaf damage is directly associated with decreased feeding activity and larval population. Bt-treated plants showed minimal symptoms due to rapid cessation of

feeding. Similar findings were reported by Prasanna et al. (2018). Entomopathogenic fungi reduced damage gradually by infecting larvae (Lacey et al., 2015; Gujjeti et al., 2014), while neem formulations reduced feeding through antifeedant action (Isman, 2006; Sisay et al., 2019; Al-Masri et al., 2024).

3.3. Effect on Grain Yield:

The reduction in pest infestation and leaf damage was reflected in grain yield. Grain yield differed significantly among treatments as presented in Table 3. The highest grain yield was recorded in *Bacillus thuringiensis*-treated plots, followed by *Beauveria bassiana* and *Metarhizium anisopliae*. Neem-based treatments also improved yield compared to control.

The increase in grain yield is directly related to effective pest suppression and reduced crop damage. Bt-treated plots maintained higher photosynthetic efficiency due to lower leaf damage. Similar yield improvements have been reported by Goergen et al. (2016); Garrapu et al., (2017) and Day et al. (2017). Untreated plots showed reduced yield due to continuous pest damage affecting plant growth and grain development.

Table 3. Effect of Biopesticides on Grain Yield

Treatment	Grain Yield (q/ha) (Mean ± SE)
<i>Bacillus thuringiensis</i>	58.2 ± 2.1
<i>Beauveria bassiana</i>	52.6 ± 2.3
<i>Metarhizium anisopliae</i>	49.8 ± 2.5
Neem (Azadirachtin)	45.3 ± 2.8
Control	34.7 ± 3.0
SE(d)	1.85
CD (P=0.05)	5.40

3.4. Comparative Performance of Biopesticides:

The comparative analysis of treatments clearly indicated that *Bacillus thuringiensis* was the most effective biopesticide across all parameters studied, followed by *Beauveria bassiana* and *Metarhizium anisopliae*. Neem-based formulations provided moderate control but were less effective compared to microbial agents. These differences are mainly due to variation in mode of action and persistence of the biopesticides under field conditions (Bravo et al., 2011; Vega et al., 2009; Isman, 2006).

3.5. Implications for Sustainable Pest Management:

The present findings emphasize the importance of biopesticides in sustainable agriculture. The integration of microbial and botanical biopesticides can significantly reduce reliance on chemical insecticides while maintaining crop productivity. Biopesticides are biodegradable, target-specific, and safe to beneficial organisms. Their incorporation into Integrated Pest Management (IPM) programs is strongly recommended for long-term pest suppression and environmental safety (FAO, 2019; Sisay et al., 2019). Thus, adoption of biopesticide-based strategies can play a crucial role in sustainable maize agroecosystems.

3. Conclusion

The present study demonstrated that selected biopesticides are effective in managing fall armyworm infestation in maize agroecosystems. Among the tested treatments, *Bacillus thuringiensis* showed the highest bioefficacy followed by *Beauveria bassiana* and *Metarhizium anisopliae*. Neem-based

botanical pesticides also provided moderate control of the pest. The integration of microbial and botanical biopesticides into pest management programs can reduce dependence on chemical pesticides and promote sustainable maize cultivation.

Competing interests:

The authors declare that they have no competing interests

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