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Efficacy of bio-pesticides and botanicals in the management of Whitefly (*Bemisia tabaci* Genn.) and yield improvement in Black Gram (*Vigna mungo* L.)

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Abstract

A field experiment was conducted to evaluate the efficacy of bio-pesticides and botanical extracts against whitefly (*Bemisia tabaci* Genn.) in black gram (*Vigna mungo* L.). Nine treatments, including *Beauveria bassiana*, *Bacillus thuringiensis* var. *kurstaki*, neem oil, NSKE, *Verticillium lecanii*, Karanj oil, *Metarhizium anisopliae*, garlic extract, and an untreated control, were applied to assess their impact on pest suppression and yield performance. Significant differences were observed among treatments in reducing nymph populations and improving grain yield. *Beauveria bassiana* recorded the lowest mean nymph population (8.27) and highest grain yield (13.85 qt ha⁻¹), followed by *B. thuringiensis* (7.98; 12.89 qt ha⁻¹) and neem oil (8.03; 12.55 qt ha⁻¹). The untreated control exhibited the highest whitefly population (9.96) and the lowest yield (5.40 qt ha⁻¹). Overall, entomopathogenic fungi and neem-based botanicals demonstrated superior pest control and yield enhancement compared to other treatments. The findings confirm that eco-friendly bio-pesticides, particularly *Beauveria bassiana* and *Bacillus thuringiensis*, provide a sustainable alternative to chemical insecticides for effective whitefly management in black gram cultivation.

Keywords: Bio-pesticides, botanicals, whitefly, *Bemisia tabaci*, Black gram

1. Introduction

India is the world's largest producer and consumer of black gram (*Vigna mungo* L.), contributing nearly 28% to the global pulse basket and accounting for about 37% of the total global area under its cultivation. Black gram, also known as urd bean, is one of the most important multipurpose pulse crops in the country, grown over an estimated 4.11 million hectares with an annual production of 2.45 million tonnes and an average productivity of 596 kg ha⁻¹ (AICRP on MULLaRP, Annual Report, 2024–25) [2]. Its prominence in the Indian agricultural economy stems from its ability to thrive under diverse agro-climatic conditions, its short duration, and its versatile utility in food, fodder, and soil fertility enhancement.

In India, black gram is extensively cultivated across a wide range of states, including Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, and Tripura. Among these, Gujarat alone produces about 0.52 lakh tonnes of urd annually from approximately 0.84 lakh hectares, with an average yield of around 620 kg ha⁻¹. Black gram belongs to the Asiatic *Vigna* crop group and is cultivated in both spring and kharif seasons across the Indian subcontinent. Because of its short growth duration, it fits well into diverse cropping systems such as mixed cropping, intercropping, and sequential cropping. It is frequently intercropped with pigeon pea, maize, sorghum, cotton, and sugarcane, and is also grown as a green manure or fodder crop, further enhancing its economic significance.

The popularity of black gram is attributed not only to its role as a staple food pulse but also to its high nutritional value and industrial applications (Nene, 2006) [14]. Its seeds are rich in protein, essential amino acids, and minerals, making it a vital component of vegetarian diets in India. However, despite its economic and nutritional importance, the production and productivity of

black gram remain considerably low, primarily due to biotic and abiotic stresses. Among these, insect pests pose the most serious challenge, causing significant yield losses across different growth stages of the crop.

More than 60 insect species are known to attack black gram in India, and their damage can be devastating under favorable conditions (Reddy, 2015) ^[19]. Key insect pests include whitefly (*Bemisia tabaci*), thrips (*Thrips tabaci*), stink bug (*Coptosoma cribraria*), leafhopper (*Empoasca kerri*), defoliator (*Madurasia obscurella*), maruca pod borer (*Maruca vitrata*), pea butterfly (*Lampides boeticus*), tobacco caterpillar (*Spodoptera litura*), and gram pod borer (*Helicoverpa armigera*). These pests attack the crop at various growth stages, causing a wide range of damage symptoms, from defoliation and flower shedding to pod boring and seed damage, ultimately leading to significant yield reductions. For instance, whitefly (*B. tabaci*), one of the most destructive pests, feeds on plant sap, resulting in reduced plant vigor, premature defoliation, and flower drop. It also promotes the development of sooty mould by excreting honeydew, further impairing photosynthesis. Thrips cause silvery patches or streaks on leaves, reducing photosynthetic activity and creating entry points for secondary infections. Stink bugs suck sap from tender shoots, causing stunted growth, drying of vines, and flower abortion. Under different agro-climatic conditions, black gram has been reported to host more than 200 insect species from 48 families, spanning the orders Lepidoptera, Coleoptera, Thysanoptera, Diptera, Hemiptera, Hymenoptera, Isoptera, and Orthoptera, along with seven species of mites from the order Acarina (Naik *et al.*, 2019) ^[13].

Among these pests, whitefly (*Bemisia tabaci*) is particularly notorious because of its rapid reproductive cycle and ability to transmit plant viruses. Its life cycle includes egg, four nymphal instars, and adult stages, which can be completed in as little as 2–3 weeks under optimal conditions, allowing for explosive population growth. Eggs are laid on the underside of leaves, especially those with a hairy surface, and hatch into mobile first-instar “crawler” nymphs that settle on the leaf surface to feed. Subsequent nymphal stages become progressively immobile while continuing to suck plant sap, causing chlorosis, reduced photosynthetic efficiency, and overall plant debilitation.

Management of insect pests in black gram is challenging due to their diversity and overlapping occurrence. Farmers commonly rely on chemical insecticides, which provide quick results but leave behind persistent toxic residues, posing risks to human health, non-target organisms, and the environment. Moreover, the repeated use of synthetic chemicals leads to resistance development and increases the cost of production, making it uneconomical for small and marginal farmers. In contrast, botanical pesticides such as neem-based formulations offer a promising eco-friendly alternative. They are generally safer, cost-effective, and biodegradable, with minimal persistence in the environment, thereby reducing the risk of long-term contamination and ecological imbalance.

The economic importance of black gram and the heavy losses caused by insect pests, especially whitefly, there is an urgent need to explore sustainable pest management strategies that

integrate botanicals, resistant cultivars, and other eco-friendly approaches. Such integrated approaches will not only ensure environmental safety but also enhance the profitability and productivity of black gram cultivation, supporting the livelihoods of millions of smallholder farmers in India. The present research is therefore of great significance as it aims to generate scientific insights and practical solutions for reducing pest pressure through safer and more sustainable methods. By addressing the limitations of chemical control and evaluating alternative management strategies, this study will contribute to improving crop resilience, ensuring food security, and promoting environmentally responsible agriculture.

2. Materials and Methods

2.1 Experimental site and climate

A field experiment was conducted during the kharif season of 2024–25 at the Organic Research Farm, Kargua Ji (25°27' N, 78°36' E; 178.36 m above mean sea level), Institute of Agricultural Sciences, Bundelkhand University, Jhansi, Uttar Pradesh, India. The region has a dry sub-humid, semi-arid climate with an annual rainfall of 1200–1400 mm. The maximum temperature during summer reaches ~45 °C and the minimum during winter falls to ~10 °C. Weekly meteorological data on temperature, rainfall, and relative humidity were recorded throughout the cropping period and used for correlation analyses.

2.2 Experimental design and crop details

The experiment was laid out in a Randomized Block Design (RBD) with nine treatments replicated thrice, comprising a total of 27 plots. Each net plot measured 1.80 × 1.80 m, with 45 cm row spacing and 15 cm plant spacing. The black gram (*Vigna mungo* L.) variety PU-31 was sown on 4 August 2024 in a field of 19 × 9.2 m.

2.3 Field preparation and cultural practices

The field was prepared by tractor-drawn cultivation followed by two cross-harrowings. Well-decomposed farmyard manure (FYM) @ 25 t ha⁻¹ was incorporated before final planking to improve soil fertility and tilth. Recommended organic crop management practices were followed. A pre-sowing irrigation was applied, and subsequent irrigations were given as per crop requirement. Weeding was done at 15–20 day intervals to maintain a weed-free condition.

2.4 Treatments and application

Nine treatments comprising different botanicals and entomopathogenic formulations were tested for their efficacy against whitefly (*Bemisia tabaci* Genn.). Details are presented in Table 1. Neem seed kernel extract (NSKE) and garlic bulb extract were prepared locally, while other formulations were procured from commercial sources. Sprays were initiated when the whitefly population reached the economic threshold level (ETL) of 6–7 adults per leaf. Applications were made using a hand sprayer, ensuring uniform coverage of foliage.

Table 1: Bio-pesticide treatments and dosages applied against *Bemisia tabaci* in black gram

Treatment code	Technical name	Formulation	Concentration/ rate	Source
T ₁	NSKE	Crude extract	5%	Plant product
T ₂	Neem oil	Crude extract	5%	Multiplex Agro Pvt. Ltd.
T ₃	<i>Beauveria bassiana</i>	1×10 ⁸ CFU	5 ml L ⁻¹ water	Agrizone
T ₄	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	5×10 ⁸ CFU	2.5 ml L ⁻¹ water	Katyayni Organic
T ₅	<i>Verticillium lecanii</i>	2×10 ⁸ CFU	2.5 ml L ⁻¹ water	Katyayni Organic
T ₆	Karanj oil	Crude extract	2.5 ml L ⁻¹ water	Multiplex Agro Pvt. Ltd.
T ₇	Garlic bulb extract	45% SC	0.5%	Plant product
T ₈	<i>Metarhizium anisopliae</i>	–	2.5 g L ⁻¹ water	Katyayni
T ₉	Water control	–	–	–

2.5 Observation and data collection

The population of whitefly and other sucking pests (thrips, leafhoppers, aphids) was recorded weekly from sowing to harvest. Five plants per plot were randomly selected and tagged for regular observation. Whitefly adults and nymphs were counted from three leaves per plant (top, middle, and bottom canopy). After each spray, observations were taken at 3, 7, and 14 days after spraying (DAS) to assess population reduction. Pod damage was calculated as:

$$\text{Percent pod damage} = \frac{\text{No. of infested pods}}{\text{Total No. of pods observed}} \times 100$$

Pod yield - Pod yield was recorded plot-wise at final harvest and expressed in $q\ ha^{-1}$.

2.6 Statistical analysis

Data on pest population, pod damage, and yield were subjected to analysis of variance (ANOVA) following the RBD procedure of Gomez and Gomez (1984). Treatment means were compared using the F-test, and critical differences (CD) were calculated at 5% probability level.

3. Results

The results of the field experiment revealed significant differences among the treatments in reducing the whitefly (*Bemisia tabaci* Genn.) population and minimizing pod damage in black gram. All bio-pesticides and botanical extracts performed better than the untreated control, with notable variation in their effectiveness over different observation periods (3, 7, and 14 days after spray). The treatments also influenced yield parameters, indicating a positive correlation between effective pest management and higher pod yield.

3.1 Observation of Instar population before spraying of treatments (pre –treatment observation)

The data collected before the spray was shown that in every replication the mean population of the instar of the *Bemisia tabaci* found the equal in all treatment and damage also found in

equal manner as the data revealed in table 2 showed the mean population of the larvae was 9.76, 10.12, 9.81, 9.29, 10.07, 9.63, 10.02, 9.57, 8.88 in treatments T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈, T₉, respectively.

3.1.1. Observation of nymph population after 3 days from the first spray of treatments

The data described in table 2 and fig 1 revealed that the comparative study between the all treatment found effective significantly and but the most effective that control the nymph population of insect was T₁ neem oil (8.87) followed by T₃ *Bt.* (9.00) and T₄ *Verticillium laccani* (9.03), and other treatment showed T₈ *Beauveria bassiana* (9.09) T₅ *Metarhizium anisopole* (9.20), T₇ Karanj oil (8.93) T₆ NSKE (9.42) and T₉ garlic bulb extract (9.45) mean population of the nymph and in uncontrolled plot T₉ showed highest mean nymph population 9.74.

3.1.2 Observation of nymph population after 7 days from the first spray of treatments

The observation after seven days from first spray of treatment was found the best effective treatment to control the nymph population was T₁ neem oil (7.95) and second best treatment was T₃ *Bt.* (8.04) followed by T₈ *Beauveria bassiana* (8.34) and T₄ *Verticillium laccani* (8.51) and rest of all treatment showed T₆ NSKE (9.06), T₅ *Metarhizium anisopole* (9.06), T₈ garlic bulb extract (9.21) with comparative to uncontrolled plot T₉ (9.8) showed highest nymph population which were described in table 2 and fig 1.

3.1.3 Observation of nymph population after 14 days from the first spray of treatments

The data collected after the 14 days from spray found that the result was same as the previous observation and the best treatment to control the nymph population of insect was found T₃ *Bt.* (6.92) followed by T₁ neem oil (7.28) and T₈ *Beauveria bassiana* (7.37) and rest of all treatments also showed significant result as 7.59, 7.83, 8.07, 8.14, 8.43 mean nymph population per plant found in following treatments T₄, T₆, T₇, T₅, T₂ respectively described in table 2 and fig 1.

Table 2: Effect of bio-pesticides and botanicals against damage caused by white fly (*Bemisia tabaci* Genn.) in black gram after first spray of treatments

T. No	Treatments	Mean nymph population			
		Before spray	3 DAS	7 DAS	14DAS
T ₁	Neem oil	9.76	8.87	7.95	7.28
T ₂	Karanj oil	10.12	9.45	9.21	8.43
T ₃	<i>Bacillus thuringiensis</i> var. Kurstaki	9.81	9.00	8.04	6.92
T ₄	<i>Metarhizium anisopole</i>	9.29	9.03	8.51	7.59
T ₅	Garlic bulb extract	10.07	9.20	9.06	8.14
T ₆	NSKE	9.63	9.42	9.06	7.83
T ₇	<i>Verticillium lessani</i>	10.02	8.93	8.88	8.07
T ₈	<i>Beauveria bassiana</i>	9.57	9.09	8.34	7.37
T ₉	Water control	8.88	9.74	9.85	10.29
SEM±		0.33	0.29	0.25	0.13
C.D (P=0.05)		NS	NS	NS	0.40

3.2. Post treatment observation of nymph population after second spray of treatments against white fly (*Bemisia tabaci* Genn.)

3.2.1 Observation of nymph population after 3 days from the second spray of treatments

The collected and observation showed that mean nymph population of *Bemisia tabaci* Genn. found the best treatment was

T₃ *Bt.* (5.65) and second effective treatment was T₈ *Beauveria bassiana* (5.99) followed by T₁ neem oil (6.12) and T₄ *Verticillium laccani* (6.35) remain treatments showed T₆ NSKE (6.80), T₇ Karanj oil (7.09), T₅ *Metarhizium anisopole* (7.11) and T₂ garlic bulb extract (7.15) mean population of larvae and highest population was found in uncontrolled plot 10.69 larvae per plant.

3.2.2 Observation of nymph population after 7 days from the second spray of treatments

The data which described in table no. 3 and fig no 2 that revealed that the minimum mean larvae population with the application of T₃ *Bt*. (4.81) followed by T₈ *Beauveria bassiana* (5.04) and T₁ neem oil (5.11) rest of all treatment also give significantly effective with 5.16, 5.40, 5.55, 5.63, 6.70 mean nymph population per plant in T₄ *Verticillium laccani*, T₇ Karanj oil, T₆ NSKE, T₅ *Metarhizium anisopole*, T₂ garlic bulb extract treatments respectively.

3.2.3 Observation of nymph population after 14 days from the second spray of treatments

The data which described in table no. 3 and fig no 2 revealed that the mean nymph population found minimum with the application of T₃ *Bt*. that showed 3.00 larva per plant and followed by T₈ *Beauveria bassiana* that showed 3.26 larvae of insect. The treatment T₁ neem oil also found significant effective with 3.38 mean nymph population followed by T₄ *Verticillium laccani* (3.42), T₆ NSKE (4.29), T₇ karanj oil (4.32), T₅ *Metarhizium anisopole* (4.48) and T₂ garlic bulb extract (4.93) mean nymph per plant. And the highest nymph population was found in uncontrolled plot with 11.14 mean nymph populations.

Table 3: Effect of bio-pesticides and botanicals against damage caused by white fly (*Bemisia tabaci* Genn.) in black gram after second spray of treatments

T. No	Treatments	Mean nymph population			
		Before	3DAS	7DAS	14 DAS
T ₁	Neem oil	7.58	6.12	5.11	3.38
T ₂	Garlic extract	8.56	7.15	6.70	4.93
T ₃	<i>Bacillus thuringiensis</i> var. Kurstaki	7.11	5.65	4.81	3.00
T ₄	<i>Verticillium laccani</i>	8.10	6.35	5.16	3.42
T ₅	<i>Metarhizium anisopole</i>	8.50	7.11	5.63	4.48
T ₆	NSKE	8.58	6.80	5.55	4.29
T ₇	Karanj oil	8.05	7.09	5.40	4.32
T ₈	<i>Bauvaria bassiana</i>	7.54	5.99	5.04	3.26
T ₉	Water control	10.52	10.69	11.00	11.14
	SEm±	0.13	0.11	0.12	0.15
	C.D (P=0.05)	0.40	0.36	0.39	0.44

3.3 Effect of nymph population on yield

The graph presents a comparative analysis of the mean nymph population and grain yield (q/ha) under different bio-pesticide and botanical treatments. Among the treatments, *Beauveria bassiana* (T₈) recorded the highest grain yield (13.85 q/ha) with a comparatively low mean nymph population (8.27), indicating superior efficacy in whitefly suppression and positive impact on yield. This was followed by *Bacillus thuringiensis* var. kurstaki (T₃) and Neem oil (T₁), which yielded 12.89 q/ha and 12.55

q/ha, respectively, along with lower nymph populations (7.98 and 8.03). Conversely, the untreated control (T₉) recorded the highest nymph population (9.96) and the lowest yield (5.40 q/ha), highlighting the damaging effect of whitefly infestation in the absence of control measures. While among the Garlic extract (T₂) showed the least effectiveness among the treatments, resulting in a low yield of 7.30 q/ha despite moderate nymph suppression.

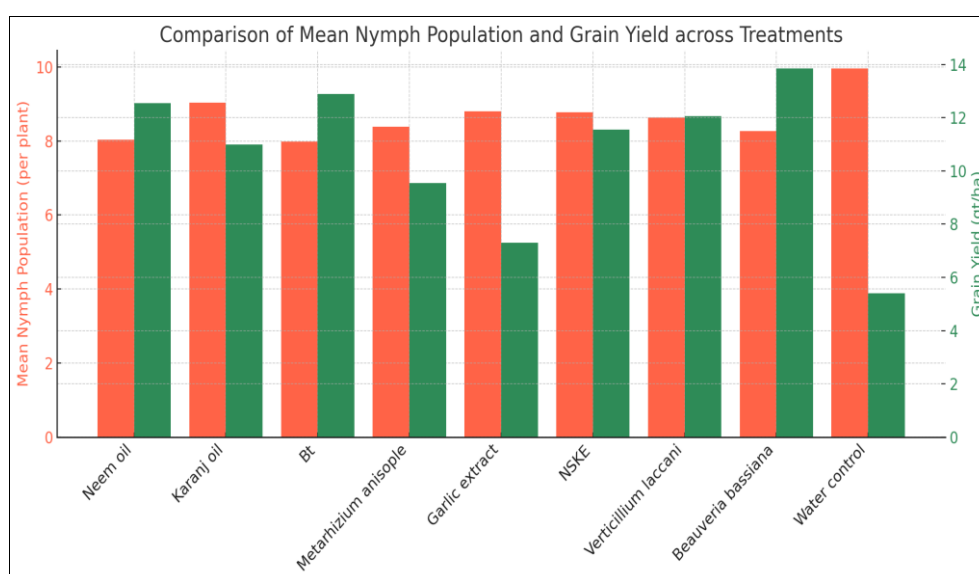


Fig 2: Effect of Bio-pesticides and Botanicals on Mean Nymph Population and Grain Yield of Black Gram

4. Discussion

The present investigation clearly demonstrated that bio-pesticides and botanical extracts significantly reduced the population of whitefly (*Bemisia tabaci* Genn.) in black gram

compared with the untreated control. The consistent reduction in nymphal density across observation intervals after both sprays indicates that these eco-friendly treatments can provide effective suppression of *B. tabaci* under field conditions.

5. Comparative efficacy of treatments

The results of this study demonstrate significant differences in the efficacy of various bio-pesticides against *Bemisia tabaci* nymphs on black gram. Among the evaluated treatments, *Bacillus thuringiensis* var. *kurstaki* (Bt), *Beauveria bassiana*, and neem oil consistently recorded the lowest nymph populations following both application cycles, establishing them as the most viable options for integrated management of this pest.

The superior performance of the Bt formulation, which maintained the lowest mean nymph population (3.00 nymphs per plant) at 14 days after the second spray, is particularly noteworthy. While Bt is traditionally renowned for its larvicidal activity against Lepidoptera, its efficacy against a hemipteran pest like *B. tabaci* can be attributed to the discovery of novel pesticidal proteins. Recent research has identified specific Bt strains that produce insecticidal crystals and vegetative proteins from the Cry and Vip families, which exhibit toxicity against sap-sucking insects by disrupting gut integrity. Chakraborty *et al.*, 2016^[4] extensively reviewed these proteins, noting their specific action on hemipteran midgut receptors, which aligns with the pathological effects observed in the present study.

Neem oil, containing the active compound azadirachtin, also proved highly effective, closely following Bt and *B. bassiana*. Its rapid suppressive action, observable as early as three days after application, aligns with its well-documented multiple modes of action. Azadirachtin-based products act as potent antifeedants, growth regulators by interfering with ecdysone function, and oviposition deterrents, disrupting the normal development and fecundity of whiteflies (Campos *et al.*, 2016)^[3]. This broad physiological impact leads to a swift decline in nymphal density, a phenomenon corroborated by studies on cotton and other leguminous crops where neem applications significantly suppressed whitefly populations (Ghongade *et al.*, 2021)^[7].

The entomopathogenic fungus *Beauveria bassiana* emerged as the most effective fungal agent, with its impact becoming more pronounced 7–14 days after spraying. This time-dependent efficacy is characteristic of EPF, which infect hosts through cuticular penetration and require time to proliferate and induce mortality (Quesada-Moraga *et al.*, 2024; Lacey *et al.*, 2015)^[18]^[10]. The superior performance of *B. bassiana* in this trial can be attributed to two key factors: the high relative humidity prevalent during the *khari* season, which is conducive to fungal spore germination and infection, and the advanced oil-based formulation used, which is known to enhance UV protection and spore viability (Kaiser *et al.*, 2019; Faria and Wraight, 2023)^[9]^[5]. Other EPF like *Metarhizium anisopliae* and *Lecanicillium lecanii* also reduced nymph counts but were less effective, possibly due to differences in host specificity or environmental suitability, as noted by Ownley *et al.*, 2020)^[15].

Other botanical extracts, namely karanj oil and garlic extract, demonstrated moderate levels of efficacy. Karanj oil, derived from *Pongamia pinnata*, contains bioactive principles like karanjin and pongamol, which are known for their insecticidal, anti-juvenile hormone, and repellent properties against a range of pests (Purkait *et al.*, 2021)^[16]. Similarly, the bioactivity of garlic extract is primarily due to sulfur-containing volatile compounds, such as allicin and diallyl disulfide, which exhibit fumigant, repellent, and oviposition-deterrent effects (Miretti *et al.*, 2021)^[12]. The relatively lower performance of these botanicals compared to the leading treatments is likely a consequence of the rapid photodegradation and volatility of their active compounds under field conditions, reducing their residual

activity (Isman, 2020)^[8].

Crucially, the effective suppression of whitefly nymph populations directly translated into agronomic benefits. Treatments that maintained lower nymph densities, particularly Bt, *B. bassiana*, and neem oil, subsequently produced significantly higher pod yields. This finding strongly supports the well-established negative correlation between *B. tabaci* infestation and legume yield, which is exacerbated by the pest's role as a vector for begomoviruses like the Mungbean Yellow Mosaic Virus (Sani, 2020)^[20]. By reducing direct phloem feeding damage and, more importantly, minimizing the transmission of virulent pathogens, these bio-pesticides effectively safeguarded the crop's yield potential, underscoring their value in sustainable agriculture (Gerling *et al.*, 2021)^[6].

6. Conclusion

The results suggest that combining botanicals with entomopathogenic fungi could provide complementary benefits—botanicals offering rapid knockdown and repellency, while fungi ensure sustained mortality. Such combinations may also delay resistance development and conserve beneficial arthropods, aligning with the principles of Integrated Pest Management (IPM). Successful use of EPF in humid environments has been and recommend evening or early-morning applications to enhance spore survival.

Disclaimer (Artificial intelligence)

Option 1: 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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