Impact of Commercial Beauveria bassiana Application on Okra (Abelmoschus esculentus) Insect Pests, Pollinator Densities and Some Growth and Fruit Parameters

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Research Article

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Abstract

Insect pest infestation severely constrains okra (*Abelmoschus esculentus* L. Moench) production globally, prompting reliance on chemical insecticides with associated environmental and human health risks. This study evaluated the bio-efficacy of commercial *Beauveria bassiana* (Fixit-GA™) on pest density, pollinator abundance, agronomic characteristics, and fruit quality. Field trials were conducted across late (2021) and early (2022) growing seasons using a 4×3 factorial Randomized Complete Block Design. Treatments comprised four fungal concentrations (2.00–8.00 kg/ha) and three spray frequencies (weekly to tri-weekly). Weekly application at 8.00 kg/ha exhibited optimal efficacy, significantly ($p<0.05$) reducing major pest densities (*Podagrica* spp., *Dysdercus cingulatus*, *Nezara viridula*) by 78–98% compared to untreated controls. Consequently, fruit damage decreased from 96.7% in controls to 15.47% in treated plots, substantially mitigating relative yield loss. Ecologically, *B. bassiana* treatment correlated with higher densities of the pollinator *Apis mellifera* (5.33 vs. 1.00 in control), contrasting with the reduction observed in the predatory coccinellid *Cheilomenes lunata*. Proximate analysis revealed no significant differences ($p>0.05$) in nutritional composition (moisture, protein, fiber, ash) between treated and untreated fruits. These findings demonstrate that commercial *B. bassiana* provides effective pest control while safeguarding pollinator services and food quality, positioning it as a sustainable, ecologically safe alternative to synthetic insecticides in okra production systems.

Keywords: *Beauveria bassiana*; *Abelmoschus esculentus*; Biological control; Pollinator safety; Fruit quality; Sustainable agriculture.

INTRODUCTION

Abelmoschus esculentus (L.) Moench, known as okra, is an important vegetable from the Malvaceae family. It is widely grown in tropical and subtropical regions around the world. The crop has tender green pods that are rich in vitamins A, C, and K, as well as minerals, dietary fiber, and antioxidants. Therefore, it plays a key role in food and nutrition security in developing countries (Gemede et al. 2016; FAO 2020). Okra is also a significant source of income for smallholder farmers in developing nations, particularly in Africa. Globally, Nigeria ranks second in okra production after India, contributing more than 1.8 million tonnes of okra each year (FAO 2020). Although okra can adapt to various agroecological zones, its production faces serious threats from insect pests, leading to yield losses between 30% and 70% (Alegbejo et al. 2008; Kumari et al. 2024).

The okra agro-ecosystem is home to a variety of insect pests from different orders, especially Coleoptera, Hemiptera, and Orthoptera. Among these, flea beetles from the genus *Podagrica*, particularly *Podagrica sjostedti* Jacoby and *Podagrica uniforma* Jacoby (Coleoptera: Chrysomelidae), are significant early-season pests for okra (*Abelmoschus esculentus* L. Moench) in Africa. These beetles damage leaf tissues, creating distinct round holes known as “shot-hole” or “buckshot” damage. This reduces the plant's photosynthetic area and weakens its growth and yield (Pitan and Ekoja 2011; Obeng-Ofori and Sackey 2003; Egwuatu 1982). Adult feeding can lead to severe leaf loss and yield drops of up to 50% during heavy infestations. Meanwhile, the larvae feed on roots, which can hinder nutrient absorption and lead to seedling death in severe cases (Pitan and Ekoja 2011; Vanlommel et al. 1996). Besides the direct damage from feeding, *Podagrica* spp. act as effective carriers of okra mosaic virus (OkMV), a tymovirus in the family Tymoviridae. Infected plants show symptoms like yellowing, mosaic patterns, stunted growth, and deformed fruit, which significantly reduce growth and yield (Alegbejo et al. 2008; Fajinmi and Fajinmi 2010; Atiri 1984). Other significant insect pests that affect okra include both sap-sucking and chewing insects from various orders. Hemipteran pests, such as the red cotton stainer (*Dysdercus* spp.) and the southern green stink bug (*Nezara viridula* L.), feed on plant sap, causing damage to tissues, discoloration, and lowering fruit quality. Additionally, orthopteran pests like the variegated grasshopper (*Zonocerus variegatus* L.) cause extensive leaf damage by feeding on leaves, flowers, and developing pods throughout the crop's growth period, thus impacting yield and marketability (Obeng-Ofori and Sackey 2003; Egwuatu 1982; Hill 2008). Together, these pests put significant economic strain on okra production in tropical agro-ecosystems.

Traditionally, managing insect pests in okra production has mainly relied on synthetic insecticides because they act quickly, reduce pest populations immediately, and are easy to apply (Egwuatu1982; Damalas and Eleftherohorinos 2011). However, overusing these chemicals has led to several negative effects. These include the development of resistance in pest populations, the return of secondary pests, environmental pollution, and the buildup of pesticide residues in food, which can harm human health and other non-target organisms (Aktar et al. 2009; Sparks and Nauen 2015; Nicolopoulou-Stamati et al. 2016). These therefore show the need for sustainable and biological pest management methods.

Entomopathogenic fungi (EPF) have emerged as effective biological control agents due to their host specificity, environmental safety, minimal impact on non-target organisms, and compatibility with integrated pest management (IPM) programs (Islam et al. 2023). These fungi infect insects through contact and enzymatic degradation of the cuticle, making them effective alternatives to chemical insecticides while supporting sustainable agriculture. Among these, *Beauveria bassiana* (Balsamo) Vuillemin is one of the most extensively studied and commercially utilized fungal biocontrol agents. It has demonstrated efficacy against a wide range of insect pests across multiple orders, including Coleoptera, Hemiptera, Lepidoptera, and Diptera (Pedrini, 2022).

B. bassiana infects insects by first attaching its spores to the insect cuticle. The spores then germinate, forming germ tubes and appressoria. The fungus penetrates the insect cuticle through mechanical pressure and enzymatic breakdown using enzymes that degrade the cuticle, such as proteases, chitinases, and lipases. Once inside the hemocoel, the fungus grows, producing blastospores and secondary metabolites like beauvericin and bassianolide. These disrupt normal physiological processes and lead to insect death through tissue damage, poisoning, and nutrient loss (Pedrini, 2022). These traits make *B. bassiana* a key part of sustainable and eco-friendly pest management programs. This study therefore aimed to evaluate the bio-efficacy of commercial *Beauveria bassiana* (Fixit-GA™) on insect pest density, pollinator abundance, agronomic characteristics, and fruit quality in okra production.

Material and Methods

The study was carried out at the experimental farm of the Department of Crop Protection, Federal University of Agriculture, Abeokuta (7o14'54″N and 7o19'30″N; 3o20'28″E and 3o27'54″E) during the late season (Sept- Nov) 2021and early growing season of 2022 (May- July).

Source of Experimental Materials

Okra variety 'Clemson spineless' and the biological insecticides *Beauveria bassiana* (Fixit-GA™CGA IPFBS-012-1.15%WP) were obtained from a reputable agrochemical store in Abeokuta, Ogun State.

Experimental Design

The experimental design was 4×3 factorial fitted into Randomized Complete Block Design (RCBD) with three replicates. It comprised of two factors viz *B. b a s s i a n a* (FIXIT-GA™) concentration and *B. bassiana* spray frequency. Four (4) levels of *B. bassiana* concentrations (8.00, 6.00, 4.00 and 2.00 kg/ha) and three (3) spray frequencies of *B. bassiana* (spray once a-week, once in two weeks and once in three-weeks) and untreated plot (no spray) were used.

A total experimental area of 53m × 10m (530 m²) was marked out with plot sizes of 3 m x 2 m and 2 m border spacing. The experiment consist of four rates of application of *Beauveria bassiana*: (8.00, 6.00, 4.00 and 2.00 kg/ha), three spray frequencies of *B. bassiana* (once a week, once in two weeks and once in three weeks) and untreated plot (no spray). Three okra seeds were planted per hill at 1 m × 0.5 m and were thinned to one seedling at 14 DAP. Weeding of the plot was carried out manually with the use of hoe once in two weeks. There was no application of fertilizer or herbicide throughout the experiment.

The fungus strain (1.25 kg) was prepared in 500 litres of water to form a concentration of 2 x 108 CFU/gm min (manufacturer recommendation) and applied two weeks after planting cucumber. The prepared fungus strain was applied between 6.30 -7.30 a.m. (local time) at weekly intervals till fruit maturity with the aid of four (4) litres volume capacity hand-held sprayer.

Data Collection

Insect species found on okra plants were assessed and counted at weekly intervals between 7.30 – 9.30 a.m. Five selected plants within the central rows of each plot were sampled through visual counting. Collected insects from the okra experimental plots were preserved in70 % ethanol and were air-dried before mounting in insect box at the laboratory. The insect samples were taken to the Insect Museum of the Department of Crop Protection and Environmental Biology (CPEB), University of Ibadan, Ibadan for proper identification by taxonomist. Harvesting of fresh okra fruit commenced at full maturity of 8 WAP by detaching the fruits with the aid of knife. The fruits harvested from 10 selected tagged plants in each plot were sorted into damaged and undamaged fruits. Data on characteristics of insect induced damage viz leaf damage, leaf damage intensity, flower abortion, fruit damage and relative yield loss. Undamaged cucumber fruits were counted and weighed for marketable yield evaluation while the damaged were used for damage assessment.

Proximate Analyses

Proximate analysis of okra fruit samples from each treatment was done in the laboratory using Association of Official Analytical Chemists (AOAC) method (2021). The protein, fat, crude fiber, moisture, ash, dry matter, fat and carbohydrate contents of the okra fruits were determined.

Data Analysis

Insect population density and percentage values were normalized by use of square root and arcsine transformations respectively. Data on insect population density, yield, damage and growth characteristic were subjected to Analysis of Variance (ANOVA) while Student Newman Keul's (SNK) Test was used for mean separation. Okra fruits from each treatment were stored at room temperature (20- 22ºC) and days to deterioration were noted.

RESULTS

The study revealed the presence of eight insect species associated with okra (*Abelmoschus esculentus* L. Moench) across late season 2021 and the early season 2022 (Table 1). The insect species included six pest complex: Coleoptera (three species), Hemiptera (two species), and Orthoptera (one species). The coleopteran pests included two species of flea beetles of the chrysomelid family, namely, *Podagrica sjostedti* Jacoby and *Podagrica uniforma* Jacoby and the meloid blister beetle *Mylabris pustulatus*. The hemipteran pests included the pyrrhocorid *Dysdercus cingulatus* (Fabricius) (red cotton stainer), and the pentatomid *Nezara viridula* (L.), (southern green stink bug). The orthopteran *Zonocerus variegatus* (L.) (variegated grasshopper) completed the pest complex. Also included is a beneficial predator, *Cheilomenes lunata* Fabricius (Coleoptera: Coccinellidae), and one pollinator, *Apis mellifera* L. (Hymenoptera: Apidae).

Application of *Beauveria bassiana* at different times and concentrations throughout the late season of 2021, showed significantly lower pest population compared with untreated control (Table 2). Okra subjected to once a-week spray of *Beauveria bassiana* at 8.00 kg/ha exhibited significantly ($p<0.05$) lower pest densities where *Podagrica sjostedti* (3.00 ± 0.00), *P. uniforma* (1.33 ± 0.33), *Dysdercus cingulatus* (1.33 ± 0.33), *Mylabris pustulatus* (0.33 ± 0.33), *Nezara viridula* (0.33 ± 0.33), and *Zonocerus variegatus* (0.33 ± 0.33) were reduced by 78–98% compared to unsprayed controls. However, the pest population increased significantly ($p<0.05$) with reduction in concentration and frequency of application. The unsprayed control plots recorded the highest densities for all pest species: *P. sjostedti* (14.00), *P. uniforma* (6.00), *D. cingulatus* (9.00), *M. pustulatus* (9.33), *N. viridula* (4.00) and *Z. variegatus* (5.00). Plots sprayed once every three weeks at concentration 2:00 Kg/ha exhibited pest densities almost comparable with unsprayed control plots for several species, particularly *M. pustulatus* (7.00) and *P. sjostedti* (11.33). Notably, the coccinellid predator *Cheilomenes lunata* exhibited an inverse response pattern, with highest densities in control plots (13.00 ± 0.00) and lowest in weekly-sprayed plots at 8:00 Kg/ha (1.33 ± 0.33), which accounts for about 89 % population reduction. However, higher population of *A. mellifera* was found in plots sprayed once a week at 8:00 Kg/ha (5.33 ± 0.33), while plots sprayed once in three weeks and control plots had lower population (1.00 ± 0.00)

The field trials conducted during the late season of 2021 showed a significant dose- and frequency-dependent response of insect species to the application of the entomopathogenc fungus *B. bassiana* (Table 2). Okra subjected to once a-week spray of *B. bassiana* at 8.00 kg/ha exhibited significantly ($p<0.05$) lower pest densities where *Podagrica sjostedti* (3.00 ± 0.00), *P. uniforma* (1.33 ± 0.33), *Dysdercus cingulatus* (1.33 ± 0.33), *Mylabris pustulatus* (0.33 ± 0.33), *Nezara viridula* (0.33 ± 0.33), and *Zonocerus variegatus* (0.33 ± 0.33) were significantly reduced by 78-98% compared to the unsprayed control plots. However, the pest population significantly increased with the decrease in concentration and frequency of application. The pest population in the unsprayed control plots was the highest for all the species of pests: *P. sjostedti* (14.00), *P. uniforma* (6.00), *D. cingulatus* (9.00), *M. pustulatus* (9.33), *N. viridula* (4.00), and *Z. variegatus* (5.00).

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The same trend of dose- and frequency- dependent response of insect species to the application of *B. bassiana* was recorded in the early cropping season, 2022 (Table 3). The okra subjected to once a-week spray of *B. bassiana* at 8.00 kg/ha also, exhibited significantly ($p<0.05$) lower pest densities where *P. sjostedti* (5.00 ± 0.00), *P. uniforma* (3.33 ± 0.33), *D. cingulatus* (3.33 ± 0.33), *M. pustulatus* (1.33 ± 0.33), *N. viridula* (1.33 ± 0.33), and *Z. variegatus* (2.33 ± 0.33) with reduction of 45-73% from once every three weeks to weekly spray. Population of Apis mellifera was significantly higher at plots sprayed once a week when compared with the control. C. lunata recorded higher population density in the plots sprayed once in two and three weeks while there was reduction in the weekly application. The effect of application of *B. bassiana* on insect induced damaged on okra revealed a clear dose- and frequency- dependent relationship across the two planting seasons (Table 4). In the late season 2021, okra plots sprayed once a-week at 8.00 Kg/h had the least damage metrics, where leaf damage recorded was 20.89 % compared with unsprayed plot (87.58% during the late season, 2021. Also, the fruit damage and relative yield loss was reduced to 15.47% and 16.42% respectively contrary to control plot with 96.7%and 74.34% respectively. Similar trends were observed in the early season 2022, where okra plot sprayed once a-week at 8.00 Kg/ha recorded low fruit damage (12.22%) and relative yield loss (16.42%) contrary to control plots (80.72% and 73.15%, respectively).

The nutritional composition of okra treated with *B. bassiana* at various application rates was statistically similar ($p > 0.05$) to those of unsprayed controls (Table 5). Okra fruits from plots where treatment was applied once a week at 8.00 kg/ha and 4.00 kg/ha had comparable moisture content (97.59-97.87%), dry matter (2.13-2.41%), crude protein (0.21-0.25%), crude fiber (0.57-0.61%), ash (0.14-0.15%),fat (0.07-0.08%), and carbohydrate content (1.13-1.29%) relative to unsprayed controls.

DISCUSSION

The recorded insect fauna comprises a typical pest complex of West African okra pests that mirrors the crop's susceptibility to polyphagous herbivores and the agroecosystem of smallholder farming systems (Ounis et al. 2024). The preponderance of *Podagrica* flea beetles is also in line with their recognized role as key early-season defoliators of okra in Nigeria and neighboring countries, where crop losses of more than 50% have been recorded under severe infestations (Ekoja and Pitan 2022). More importantly, these flea beetles play two key pest roles: they are key folivores of okra and also vectors of okra mosaic virus (OMV), a tymovirus that contributes to crop loss due to yield depression caused by stunting and fruit deformities (Fajinmi and Fajinmi, 2010).

The enhanced pest management efficacy of weekly *B. bassiana* treatments correlates with the infection process of the pathogen and the environmental conditions that limit its efficacy in the field. In particular, entomopathogenic fungi need a critical density of fungal conidia on plant surfaces to ensure contact with mobile pest species, such as flea beetles and stink bugs (OECD 2025). Nevertheless, UV light and dry conditions accelerate conidial inactivation, causing a 50- to

90% reduction in conidial survival on plant surfaces after 3 to 7 days in tropical agro-ecosystems (Kaiser et al. 2019). Therefore, weekly treatments ensured that lethal concentrations of *B. bassiana* were consistently provided to ensure pest management, whereas less frequent treatments (every 2 and 3 weeks) allowed pest populations to recover between treatments, a trend that has been observed in West African cotton cropping systems, where treatment intervals of more than 7 days have been shown to impair the efficacy of *B. bassiana* against lepidopteran pests (Dannon et al. 2020). Furthermore, recent studies have confirmed that both conidial density and persistence are critical determinants of field performance, with higher conidial concentrations and sustained conidial presence significantly improving mortality rates and overall pest suppression (Islam et al. 2023; Gunjan and Srivastava 2024).

The significant reduction of the coleopteran flea beetles (*Podagrica* spp.) and hemipteran pests (*D. cingulatus, N. viridula*) with the weekly applications of *B. bassiana* confirms the established pathogenicity of the entomopathogenic fungus against chewing and piercing-sucking insects. The coleopteran flea beetles, which cause characteristic shot-hole damage to okra foliage during the early stages of vegetative development, were particularly susceptible to weekly applications of the entomopathogenic fungus. This agrees with recent findings demonstrating high susceptibility of flea beetles to *Beauveria bassiana*, with mortality rates exceeding 90% depending on conidial concentration and exposure duration (Pu et al 2025).

The positive correlation between the application intensity of *B. bassiana* and *A. mellifera* abundance is a key ecological advantage over synthetic insecticides. Contrary to the assumption that *B. bassiana* applications may have adverse effects on pollinators like *A. mellifera*, this study reveals that application of the appropriate formulation of *B. bassiana* can be safely used, alongside pollination services through indirect effects like reduced floral damage from pest infestation, reduced competition from damaged plants for floral resources, and the absence of neurotoxic chemicals that disrupt pollination behavior (Leng 2024). This is in line with the findings that have established the minimal risk potential of *B. bassiana* on honeybees under conventional application methods (OECD 2025).

The lack of notable changes in proximate composition parameters after application of *B. bassiana* is identified as a key food safety advantage of this entomopathogenic fungus as a biopesticide alternative to conventional insecticides in vegetable production systems. Unlike conventional insecticides, which might leave residues after application and interact with food matrices, potentially degrading nutrient bioavailability (Leng 2024), *B. bassiana* employs a completely different mode of action to control arthropods through contact infection and subsequent degradation of fungal propagules after application to plant surfaces (Aynalem et al. 2021).

Similarly, Oguniyi et al. (2024) found no adverse effect on the growth parameters and fruit quality characteristics of cucumber (*Cucumis sativus* L.), after the application of the same commercial *B. bassiana* formulation at similar concentrations, while at the same time reducing the populations of major insect pests such as *Podagrica* spp. and *D. cingulatus* by 68 to 82%. It was also found that the weekly application of *B. bassiana* to the cucumber crop not only controlled the pest-induced damage but also ensured the maintenance of the fruit's quality characteristics without detectable residues to the sensory and nutritional qualities of the fruit (Oguniyi et al. 2024). The parallel findings of the studies on these two major vegetable crops (okra and cucumber) in Nigeria reinforce the argument for the nutritionally safe pest management potential of *B. bassiana.*

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Table 1: Insect species associated with okra in the study area

Scientific name	Systematic position	Part found	Status
Podagrica uniforma	Order: Coleoptera Family: Chrysomelidae	Leaves	Pest
Podagrica sjostedti	Order: Coleoptera Family: Chrysomelidae	Leaves	Pest
Dysdercus cingulatus	Order: Hemiptera Family: Pyrrhocoridae	Leaves and Fruit	Pest
Myla brispustulatus	Order: Coleoptera Family: Meloidae	Fruit	Pest
Nezara viridula	Order: Hemiptera Family: Pentatomidae	Shoots and Fruit	Pest
Cheilomenes lunata	Order: Coleoptera Family:Coccinellidae	Leaves	Predator
Zonocerus variegatus	Order: Orthoptera Family:Pyrgomorphidae	Leaves	Pest
Apis mellifera	Order: Hymenoptera. Family: Apidae	Flowers	Pollinator

Table 2: Population densities of insects associated with okra at different spraying frequencies and *Beauveria bassiana* application rate in late season 2021

Frequency	Rate	*Apis melifera*	*Cheilomenes lunata*	*Dysdercus Cingulatus*	*Mylabris Pustulatus*	*Nezara viridula*	*Podagrica Sjostedti*	*Podagrica uniforma*	*Zonocerus Variegatus*
	8:00	5.333^{a}	1.333^{f}	1.333^{f}	0.333^{e}	0.333^{bd}	3.000^{g}	1.333^{b}	0.333^{d}
Once a-week	6:00	4.000^{ab}	2.333^{f}	2.000^{f}	1.000^{e}	0.667^{bcd}	4.000^{g}	1.333^{b}	0.667^{cd}
	4:00	4.333^{ab}	1.667^{f}	1.333^{f}	0.667^{e}	1.000^{bcd}	3.333^{g}	2.000^{ab}	1.000^{cd}
	2:00	4.000^{ab}	2.333^{f}	2.000^{ef}	1.000^{e}	0.667^{bcd}	4.000^{g}	3.000^{ab}	0.667^{cd}
	8:00	2.333^{ab}	6.333^{e}	3.000^{e}	3.000^{d}	1.000^{bcd}	8.000^{de}	4.000^{ab}	2.000^{bcd}
Once-in two-weeks	6:00	3.333^{ab}	7.000^{ce}	5.333^{bc}	4.333^{cd}	2.667^{ab}	6.000^{f}	3.333^{ab}	3.667^{ab}
	4:00	2.333^{ab}	9.333^{bcd}	5.333^{bcd}	4.333^{cd}	1.667^{bcd}	7.000^{ef}	3.667^{ab}	2.667^{bcd}
	2:00	3.333^{ab}	9.333^{bc}	6.333^{b}	6.333^{b}	1.667^{bcd}	9.667^{c}	3.000^{ab}	2.667^{abcd}
	8:00	1.333^{b}	7.000^{e}	4.333^{c}	3.333^{d}	1.667^{bcd}	9.000^{cd}	4.667^{ab}	2.667^{bcd}
Once-in three-weeks	6:00	2.000^{ab}	8.333^{cde}	6.333^{b}	4.667^{cd}	1.000^{bcd}	8.000^{de}	1.667^{b}	1.333^{bcd}
	4:00	2.000^{ab}	8.000^{cde}	5.667^{bc}	5.667^{bc}	2.000^{bcd}	8.333^{cde}	4.000^{ab}	3.000^{abc}
	2:00	2.000^{ab}	10.667^{b}	6.333^{b}	7.000^{b}	2.667^{abc}	11.333^{b}	4.667^{ab}	3.667^{ab}
Control	0	1.000^{b}	13.000^{a}	9.000^{a}	9.333^{a}	4.000^{a}	14.000^{a}	6.000^{a}	5.000^{a}

Mean values along the column followed by the same alphabets are not significantly different using SNK at $P<0.05$.

Table 3: Population densities of insects associated with okra at different spraying frequencies and *Beauveria bassiana* application rate in early season 2022

Frequency	Rate	*Apis melifera*	*Cheilomenes lunata*	*Dysdercus Cingulatus*	*Mylabris pustulatus*	*Nezara viridula*	*Podagrica Sjostedti*	*Podagrica uniforma*	*Zonocerus Variegatus*
	8:00	4.333^{a}	3.333^{f}	3.333^{e}	1.333^{e}	1.333^{bd}	5.000^{g}	3.333^{b}	2.333^{d}
Once a-week	6:00	3.000^{ab}	4.333^{f}	4.000^{de}	2.000^{e}	1.667^{bcd}	6.000^{g}	3.333^{b}	2.667^{cd}
	4:00	3.333^{ab}	3.667^{f}	3.667^{de}	1.667^{e}	2.000^{bcd}	5.333^{g}	4.000^{ab}	3.000^{cd}
	2:00	3.000^{ab}	4.333^{f}	4.000^{ef}	2.000^{e}	1.667^{bcd}	6.000^{g}	5.000^{ab}	2.667^{cd}
	8:00	1.333^{ab}	8.333^{e}	5.000^{d}	4.000^{d}	2.000^{bcd}	10.000^{de}	6.000^{ab}	4.000^{bcd}
Once-in two-weeks	6:00	2.333^{ab}	9.000^{ce}	5.333^{bc}	5.333^{d}	3.667^{ab}	8.000^{f}	5.333^{ab}	5.667^{ab}
	4:00	1.333^{ab}	11.333^{bc}	7.333^{bc}	5.333^{cd}	2.667^{bcd}	9.000^{ef}	6.000^{ab}	4.667^{bcd}
	2:00	2.333^{ab}	11.333^{bcd}	8.333^{b}	7.333^{b}	2.667^{bcd}	11.667^{c}	5.000^{ab}	4.667^{abcd}
	8:00	0.333^{b}	9.000^{e}	6.333^{c}	4.333^{d}	2.667^{bcd}	11.000^{cd}	6.667^{ab}	4.667^{bcd}
Once-in three-weeks	6:00	1.000^{ab}	10.333^{cde}	8.333^{b}	5.667^{d}	2.000^{bcd}	10.000^{de}	3.667^{b}	3.333^{bcd}
	4:00	1.000^{ab}	10.000^{cde}	7.667^{bc}	7.000^{bc}	3.000^{bcd}	10.333^{cde}	6.000^{ab}	5.000^{abc}
	2:00	1.000^{ab}	12.667^{b}	8.333^{b}	8.000^{b}	3.667^{abc}	13.333^{b}	6.667^{ab}	5.667^{ab}
Control	0	0.000^{b}	15.000^{a}	11.000^{a}	10.333^{a}	5.000^{a}	16.000^{a}	8.000^{a}	7.000^{a}

Mean values along the column followed by the same alphabets are not significantly different using SNK at $P<0.05$.

Table 4: Characteristics of insect-induced damage on okra treated with *Beauveria bassiana* at different application rates and frequencies in the late season, 2021

Frequency	Rate (kg/ha)	Leaf Damage (%)	Leaf Damage intensity (%)	Flower Abortion (%)	Fruit Damage (%)	Relative yield loss (%)
Late season, 2021						
Once	8.00	20.89f	21.60d	18.37cd	15.47g	17.80e
a-week	6.00	26.57ef	22.17d	18.85d	21.34fg	17.73e
	4.00	31.93d	21.27d	20.35cd	31.39de	23.21e
	2.00	37.85cd	20.41d	24.61cd	32.78de	33.37d
Once-in	8.00	49.49cd	24.27b-d	32.08b-d	33.68d-f	54.33c
Two-weeks	6.00	51.94cd	25.02b-d	41.44b-d	30.71ef	57.71b
	4.00	57.39cd	23.98b-d	35.27b-d	33.81d-f	60.49b
	2.00	59.91c	23.76b-d	39.63b-d	43.52cd	61.55b
Once-in	8.00	65.13b	25.76b-d	38.63b-d	44.76c	60.03b
Three-weeks	6.00	80.16b	24.58b-d	44.09bc	50.99bc	64.48b
	4.00	78.43b	26.52bc	43.09b	55.91bc	64.50b
	2.00	57.20b	26.89b	43.19b-d	65.66b	64.21b
Control	0.00	87.58a	29.87a	58.96a	96.17a	74.34a
Early season, 2022						
Once a-week	8.00	28.87e	23.50^{d}	20.46e	12.22f	16.42e
	6.00	29.95e	24.17^{cd}	21.39e	18.62ef	17.06e
	4.00	29.54e	23.77^{d}	22.39e	27.25de	22.82e
	2.00	49.54b	23.71^{d}	28.97de	28.61de	40.34d
Once in two weeks	8.00	67.70c	25.27^{bcd}	37.20d	31.77de	53.91c
	6.00	72.06cd	25.02^{bcd}	44.58cd	28.34d-f	59.59b
	4.00	80.00d	24.98^{bcd}	40.83cd	28.94de	62.24b
	2.00	71.12cd	25.58^{bcd}	44.71c	39.93cd	64.26b
Once in three weeks	8.00	77.99cd	25.86^{bcd}	43.13c	44.21bc	62.44b
	6.00	78.97cd	25.58^{bcd}	49.50b	48.35bc	64.33b
	4.00	79.89cd	26.52^{bc}	47.70bc	53.61bc	60.59b
	2.00	77.33cd	26.89^{b}	49.00b	64.50ab	68.82b
Control	8.00	84.75a	28.87^{a}	58.89a	80.72a	73.15a

Mean values along the column followed by the same alphabets are not significantly different from one another using SNK at $p<0.05$

Table 5: Proximate Analysis of okra at different application rate and frequencies of *Beauveria bassiana*

Nutritional composition (%)	100% (Spray once a week)	50% (Spray once a week)	No spray	LSD (0.05)	Remarks
Moisture content	97.87	97.59	97.65	1.12	Not significant
Dry matter content	2.13	2.41	2.35	1.01	Not significant
Fat content	0.08	0.08	0.07	0.11	Not significant
Ash content	0.14	0.14	0.15	0.22	Not significant
Crude fibre content	0.57	0.57	0.61	0.31	Not significant
Crude protein content	0.21	0.21	0.25	0.12	Not significant
Carbohydrate content	1.13	1.13	1.29	0.26	Not significant