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EFFICACY OF ENTOMOPATHOGENIC FUNGI *Beauveria bassiana* AS BIOLOGICAL CONTROL AGENTS OF INSECT PESTS OF OKRA (*Abelmoschus esculentus* (L.) Moench)

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ABSTRACT

Okra production is greatly hampered by numerous insect pest infestations during the various stages of its growth, resulting in poor yield. The study, therefore, aimed to investigate the effectiveness of *Beauveria bassiana* in controlling insect pests and improving yield of two okra varieties under field conditions at the Federal University of Agriculture, Abeokuta, during 2021 and 2022. The experiment was laid out in 2 × 3 factorial fitted into randomized complete block design (RCBD) with three replicates. The factors were okra varieties (Jokoso and V35) and spraying regime (*B. bassiana* (1.25 kg in 500 liters of water to form a concentration of 2 x 10^8 CFU/gm min), lambda-cyhalothrin (25 g a.i/ha) and No spray - control). Application of *B. bassiana* significantly reduced the population densities of insect pests on okra, regardless of the variety or planting seasons. Okra plants treated with *B. bassiana* exhibited significantly lower leaf and fruit damage compared to untreated plants. Levels of leaf and fruit damage in *B. bassiana* and lambda-cyhalothrin-treated plots were similar across both okra varieties and planting seasons. Application of *B. bassiana* led to a five-times increase in fruit yield compared to untreated plants in 2021 and a three-times increase in 2022 but similar to lambda-cyhalothrin-treated plots in both years. Insect pest populations displayed a significant positive correlation with leaf and fruit damage, while no negative effects on agronomic traits or proximate composition were observed. Application of *B. bassiana* effectively reduced infestation of insect pests, minimized damage, and enhanced fruit yield in okra without adversely affecting its agronomic traits. Based on these findings, *B. bassiana* can be used as a substitute for synthetic chemicals and can therefore form an integral component of integrated pest management strategies for okra cultivation.

Keyword: Okra; *Beauveria bassiana*; Lambda-cyhalothrin; insect pests; fruit yield

INTRODUCTION

Okra *(Abelmochus esculentus* (L.) Moench is an important annual fruit vegetable crop of the Family Malvaceae. It is a warm season, tropical and temperate annual to perennial vegetable crop (Patil *et al*., 2016). Global okra production is estimated to be around 9.96 million tons, India leading with 6.18 million tons followed by Nigeria with 1.82 million tons (FAOSTAT, 2020). Nigeria recorded the highest okra fruit yield in 2010 with an average yield of 27,275 kg/ha, and since then it has been on the decline with the sharpest drop recorded in 2011 with an average yield of 8,735 kg/ha (Ibitoye and Kolawole, 2022)). Okra is a multipurpose and economic crop in Nigeria because all its parts, fresh leaves, buds, flowers, pods, stems and seeds can be put into various uses and are valued in food, medicinal, artisanal and even industrial sectors. Okra is cultivated in Nigeria for its edible immature pods but in most African countries, young fresh leaves, fresh and dried fruits and mature seeds are consumed as vegetable and made into diverse soup products (Oyelade *et al.,* 2003). Industrially, okra mucilage is usually used for glace paper production and also has a confectionery use (Soranpong, 2013).

One of the major constraints in okra cultivation is its susceptibility to numerous insect pests and diseases. The level of okra production has been greatly hampered by numerous insect pest infestations during the various stages of its growth, resulting in poor yield and low market value (Asare-Bediako *et al*., 2014; Pitan and Ekoja, 2011). Pests cause reduction in the quality and quantity of okra produced with total losses of about 35 - 40 % (Mohankumar *et al*., 2016) or to 69 % yield loss in okra (Rawat and Sahu, 1973). Okra is generally attacked by myriads of insect pests at different growth stages. Most commonly reported insect pests are: Cotton stainer (*Dysdercus cingulatus*), aphids (*Aphis gossypii*), flea beetle (*Podagrica* spp.) white fly (*Bemisia tabaci*) and green stink bug (*Nezera viridula*) (Pitan and Ekoja, 2012).

Flea beetles have been reported to cause serious economic damages on okra (Adesina and Afolabi, 2014; Kedar *et al*., 2014). Abang *et al.* (2014) reported aphids as one of the major pests of okra. The adults *Podagrica* spp. feed on the leaf laminae by making numerous holes on the leaves which subsequently result in the reduction of assimilative tissues leading to a significant loss in crop yield. The larvae are also reported to feed on rootlets in the soil leading to plant death at the seedling stage (Pitan and Ekoja, 2012).

Insect pests are of serious economic concern in okra production and the need for their control becomes imperative (Ekoja *et al*., 2022). Damage severity and high levels of infestation have led to widespread use of chemical insecticides due to their quick action and lasting effect (Alao *et al*., 2011). However, the problems of insecticide resistance, environmental damage and high level of pesticide residues in food have compelled the need for an alternative control method that is cheap, effective, easily biodegradable, environmentally and ecologically safe (Naqqash *et al*., 2016; Aetiba and Osekre, 2016) e.g., use of biopesticides. Bioinsecticides are types of pesticides derived from natural materials such as animals, plants, bacteria and certain minerals. Therefore, biopesticides such as those produced from entomopathogenic fungi holds such promises and are rapidly emerging as prime substitutes for synthetic insecticides.

Many fungus-based bio-pesticides have been developed for the biological control of insect pests, and as such entomopathogenic fungi (EPF) have received a lot of attention (Hussain *et al*., 2016). EPF is host-specific, acts through contact, and its use is regarded as an environmentally friendly control method (Shahid *et al*., 2012). *Beauveria bassiana* is an entomopathogenic fungus used as a biological control agent of insect pests. It grows naturally in soils and acts as a pathogen on various insect species, causing white muscardine disease (Rai *et al*., 2014). After invading insect hosts, *B. bassiana* produces a variety of toxins, which are secondary metabolites such as beauvericin, bassianin, bassianolide, beauverolides, tenellin, oosporein, and oxalic acid. These toxins help *B. bassiana* to parasitize and kill the hosts (Wang *et al*., 2021).

A feature of *Beauveria* sp. is the high host specificity of many isolates and the ability to infect over 100 species of insects from a wide range of orders. Apart from *Bacillus thuringiensis, B. bassiana* is the most studied biopesticide and isolates of this fungus vary in host range and also exhibit a high host specificity (McCoy *et al*., 1988). In addition to being more environmentally sound control method, *B. bassiana* is harmless to human health (Umaru and Simarani., 2020). Nouh *et al.* (2022) reported that *B. bassiana* effectively controlled the major insect pests of cabbage while Atwa *et al.* (2009) reported reduction in insect populations of cauliflower under field conditions by *B. bassiana* (F2) *and B. bassiana* (F1). The study therefore, aimed to determine the effectiveness of *B. bassiana* in the control of major insect pests of okra.

MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta Ogun State (7º 15´N, 3º 25´E; 159 m above sea level). The site is located in the derived Savannah zone of South western Nigeria. The experiment was carried out in 2021 (April-May) and repeated in 2022 (September-October). The fungus strain, *Beauveria bassiana* CGA IPFBS - 012 under a trade name FIXIT-GA (1.15% WP/ Greenfields Company) and a synthetic insecticide, Lambda-cyhalothrin (Laraforce E.C. 2.5/ Jubaili agrotec Agrotec) were sourced from a reputable agrochemical company in Abeokuta, Ogun State while okra varieties 'Jokoso' (local variety) and V-35 (hybrid) were obtained from Institute of Agricultural Research and Training (IAR &T), Ibadan.

A 2 × 3 factorial arrangements fitted into randomized complete block design (RCBD) in three replications. The treatments include two (2) okra varieties: Jokoso, V-35, and three (3) levels of spraying regime: *B. bassiana*, Lambda-cyhalothrin (positive check) and control (water only). The fungus strain (1.25 kg) was mixed with 500 liters of water to form a concentration of 2 x 10^8 CFU/gm min (manufacturer recommendation) and lambda-cyhalothrin was applied according to manufacturer recommendation at 25g a.i/ha. The treatments were applied between 6.30 and 7.30 a.m. (local time) on a weekly basis till fruit maturity, using a separate hand-held sprayer.

Plot size was 3 m x 3 m with 1 m border, while the total plot size was 23 m by 11 m (253 m^2). Two seeds of okra were planted per hole at the spacing of 1m × 0.5 m and later thinned to one seedling per stand at 2 weeks after planting (WAP). Plants were thinned to one seedling per hill at 10 days after planting. Manual weeding was carried out once every 3 weeks. There was no fertilizer application throughout the experiment.

Assessments of insect pest populations and agronomic parameters

Assessment of population densities of insect pests of okra was done once a week from 2 WAP till fruit maturity by visual counting on the 10 randomly selected okra plants from the middle row of each plot between 7.00 and 9.00 a.m. when the insects were relatively inactive. Data on plant height, number of leaves, number of branches, number of flowers, number of damaged leaves and leaf area were collected from 10 randomly selected okra plants at 30-35 days after planting (DAT) okra. Harvesting of okra fruits commenced 40 DAT okra by cutting green fresh fruits with a sharp knife at 3 days interval. At harvest, okra fruits were collected from the ten randomly selected okra plants per plot and sorted into damaged and undamaged. Evaluation of damage was based on damaged okra leaves and fruits from 10 randomly selected okra plants from each plot while, fruit yield evaluation was based on the weight and number of undamaged okra fruits

Data analyses

Data were analyzed using the General Statistical Software package (GEN STAT 12th edition, VSNI, Hemel Hempstead, UK). Data on insect counts were transformed using $\sqrt{(x + 0.5)}$.

Data on insect counts, yield, damage, and agronomic parameters evaluated were subjected to analysis of variance after appropriate transformations. Fisher's Least Significant Difference was used to compare the means. Correlation analysis was done on insect pest, leaf damage, fruit damage, yield loss and yield.

RESULTS

A total of four species of insect pests from four insect Families were encountered in the study area. The insect pests include the leaf pest: *Podagrica* spp. (Coleoptera: Chrysomelidae); *Aphis gossypii* Glover (Hemiptera: Aphididae); *Dysdercus* spp. (Hemiptera: Pyrrhocoridae) and *Bemisia tabaci* (Hemiptera: Aleyrodidae). *Dysdercus* spp. was the only fruit pest recorded in the study area (Table 1). The population density of *B. tabaci* on V-35 was significantly lower in the *B. bassiana*-treated plots compared to the control and was not significantly different from the lambda-cyhalothrin-treated plots in 2021 cropping season. However, Jokoso recorded significantly higher number of *B. tabaci* in 2021 while there was no difference in its infestation among the treatments in 2022 cropping season (Table 1). Significantly higher numbers of *Podagrica* and *Dysdercus* spp. were observed from the control plots compared to the *B. bassiana* plot for both V-35 and Jokoso varieties in 2021 and 2022 cropping seasons.

The populations of *Podagrica* and *Dysdercus* spp. were reduced in 2022 cropping season relative to 2021 which recorded higher numbers of these insect pests. V-35 had fewer populations of *Podagrica* and *Dysdercus* spp. relative to Jokoso in 2021 cropping season (Table 1). The population densities of *Aphis gossypii* were significantly reduced in *B. bassiana* and lambda-cyhalothrin-treated plots compared to the control plots in both 2021 and 2022 cropping seasons. However, higher number of *Aphis gossypii* was obtained in 2022 compared to 2021 cropping season (Table 1).

In 2021, both *B. bassiana* and lambda-cyhalothrin-treated plants showed a significant reduction in leaf damage, and there was no significant difference between the two treatments. However, in 2022, lower leaf damage was observed in the lambda-cyhalothrin-treated plants compared to the *B. bassiana*-treated plants. Despite this, the *B. bassiana*-treated plants still exhibited a better reduction of leaf damage compared to the untreated control plants. Irrespective of the okra variety used, leaf damage was higher ($p < 0.05$) in the 2021 cropping season than in

2022, with the control plots having the highest leaf damage (Table 2).

Fruit damage and yield losses in okra plots treated with *B. bassiana* was significantly reduced 2021 and 2022 cropping seasons (Table 2). Higher fruit damage and yield loss were obtained in V-35 compared to Jokoso in 2021 but the fruit damage and yield loss of the two varieties were comparable in 2022. Fruit damage and yield loss in okra plants treated with *B. bassiana* and lambda-cyhalothrin were not different from each other (Table 2).

Fruit yield varied significantly among the treatments in both 2021 and 2022 cropping seasons. Application of *B. bassiana* resulted in a significant increase in okra fruit yield, irrespective of the okra variety planted (Figure 1). The increase in fruit yield by the *B. bassiana* -treated plants was statistically similar to the yield observed in lambda-cyhalothrin-treated plants. On the other hand, the untreated control plants recorded the lowest yield. There were no significant ($p < 0.05$) differences in the moisture, dry matter, fat, ash, crude fibre, crude protein and carbohydrate contents of okra treated with *B. bassiana* compared to okra from the control plots

Table1: The population densities of insect pests on two okra varieties treated with *Beauvaria bassiana* in 2021 and 2022 cropping seasons

		2021				2022			
Variety	Treatment	*Bemisia tabaci*	*Podagrica* spp.	*Dysdercus* spp	*Aphis gosypii*	*Bemisia tabaci*	*Podagrica* spp	*Dysdercus* spp	*Aphis gosypii*
Jokoso	Beauveria	0.00b	3.33cd	0.87c	0.33b	0.67a	1.10b	1.00bc	2.67b
	Control	2.33a	16.67a	10.12a	0.67b	1.67a	4.33a	4.33a	8.33a
	Lambda	0.00b	3.33cd	0.57c	0.00b	1.67a	1.03b	0.03c	3.00b
V35	Beauveria	0.00b	4.74c	0.77c	0.33b	1.67a	0.87b	1.33bc	3.33b
	Control	1.00b	10.67b	8.08b	2.33a	1.00a	5.33a	3.67a	8.33a
	Lambda	0.00b	2.33d	0.83c	0.00b	2.00a	0.00b	0.67c	3.67b
	SE(±)	0.34	0.57	0.14	0.30	1.07	0.40	0.83	1.29
	CV(%)	78.20	10.10	4.90	59.90	90.90	23.20	55.20	32.30

Means followed by the same alphabet along the same column are not significantly different from one another using Student Newman Keul's Test (SNK)) at $P < 0.05$. Beauveria = *Beauveria bassiana*, C= control, L= Lambda-cyhalothrin, SE = Standard error and CV= Coefficient of variation

Table 2: Leaf and fruit damage of two okra varieties treated with *Beauvaria bassiana* in 2021 and 2022 cropping seasons

		2021			2022		
Variety	Treatment	Damaged leaves (%)	Damaged fruits (%)	Yield loss (tons/ha)	Damaged leaves (%)	Damaged fruits (%)	Yield loss (tons/ha)
Jokoso	Beauveria	25.11b	0.00c	0.00c	15.90c	6.16b	0.73b
	Control	88.70a	13.89b	2.15b	32.40b	38.76a	2.91a
	Lambda	26.94b	0.00c	0.00c	13.81d	1.90b	0.53b
V35	Beauveria	26.31b	2.733c	0.73c	16.20c	0.95b	0.76b
	Control	88.58a	26.11a	2.93a	35.40a	46.51a	3.20a
	Lambda	27.92b	0.00c	0.00c	12.62d	3.33b	0.52b
SE (±)		1.66	2.26	0.22	0.41	4.73	0.17
CV(%)		4.30	38.90	27.50	2.40	35.60	14.20

Means followed by the same alphabet along the same column are not significantly different from one another using Student Newman Keul's Test (SNK)) at P < 0.05. Beauveria = *Beauveria bassiana*, C= control, L= Lambda-cyhalothrin, SE = Standard error and CV= Coefficient of variation

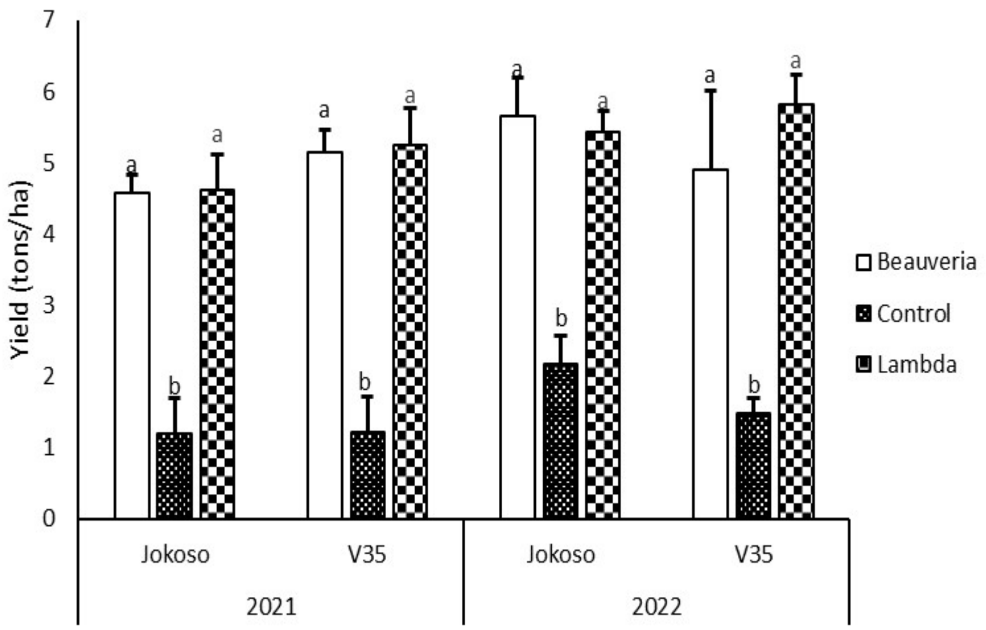

Figure 1: Yield of two okra varieties treated with *Beauveria bassiana* in 2021 and 2022 cropping seasons

Table 3: Proximate composition of okra fruits treated with *Beauveria bassiana*

Nutritional Composition	*Beauveria bassiana*	Lambda-cyhalothrin	Control
Moisture content	85.98a	81.95b	84.80a
Dry matter content	15.02b	18.05a	15.20b
Fat content	0.52a	0.69a	0.57a
Ash content	1.10a	1.52a	1.24a
Crude fibre content	6.37a	8.22a	6.86a
Crude protein content	2.90b	3.59a	3.01b
Carbohydrate content	3.49b	4.03a	3.52b

Means followed by the same alphabet along the same column are not significantly different from one another using Student Newman Keul's Test (SNK)) at P < 0.05.

There were no significant differences observed in the plant height and leaf area between the okra plants treated with Beauveria, Lambda-cyhalothrin and the control plots. However, application of Beauveria and Lambda-cyhalothrin significantly increased the number of leaves compared to the untreated control, which had the lowest number of leaves in 2021 and 2022 cropping seasons (Table 4). In both cropping seasons, *Aphis gosypii, Dysdercus* spp*, Podagrica* spp *and Bemisia tabaci* population densities were significantly associated with damaged leaves, damaged fruit, yield loss and fruit yield. A positive and significant association was observed between the insect population densities and damaged leaves, damaged fruit and yield loss in 2021 and 2022 with the exception of *B. tabaci* in 2022 (Table 5). However, in 2021 and 2022 cropping seasons, fruit yield was negatively correlated to the population densities of *Aphis gosypii* (r = -0.7547 and 0.8453)*, Dysdercus* spp (r = -0.9498 and -0.8316)*, Podagrica* spp (r = -0.8919 and 0.9659) *and Bemisia tabaci* (r = 0.759) (Table 5).

Table 4: Effect of *Beauveria bassiana* on the growth characteristics of two okra varieties in 2021 and 2022 cropping seasons

Variety	Treatment	2021 Plant height	2021 Number of leaves	2021 Leaf Area (cm^2)	2022 Plant height	2022 Number of leaves	2022 Leaf Area (cm^2)
Jokoso	Beauveria	44.48ab	21.67a	736.30ab	30.45a	17.47b	305.50a
	Control	35.97b	16.67c	546.10b	31.77a	15.00d	319.00a
	Lambda	45.43ab	21.44a	760.20ab	31.50a	15.73c	244.40a
V35	Beauveria	49.27a	18.78b	763.30ab	35.23a	19.00a	310.10a
	Control	42.39ab	14.50d	610.20b	33.93a	14.27d	309.90a
	Lambda	48.78a	22.56a	906.60a	35.17a	17.37b	344.20a
SE (±)		2.78	0.48	63.2	2.02	0.39	53.5
CV(%)		7.70	30	10.70	7.50	2.90	21.40

Means followed by the same alphabet along the same column are not significantly different from one another using Student Newman Keul's Test (SNK)) at P < 0.05. Beauveria = *Beauveria bassiana*, C= control, L= Lambda-cyhalothrin, SE = Standard error and CV= Coefficient of variation

Table 5: Correlation matrix of insect pest densities, damaged fruits, damaged leaves, yield loss and yield in 2021 and 2022

	Insect	Damaged fruits (%)	Damaged leaves (%)	Yield loss (tons/ha)	Yield (tons/ ha)
	Aphis gosypiis	0.8204**	0.6915**	0.8251**	-0.7547**
	Dysdercus spp	0.8377**	0.9861**	0.8992**	-0.9498**
2021	*Podagrica* spp	0.7329**	0.923**	0.8992**	-0.8919**
	Bemisia tabaci	0.6183**	0.8083**	0.7485**	-0.7597**
	Aphis gosypiis	0.7949**	0.8518**	0.8434**	-0.8453**
2022	*Dysdercus* spp	0.8486**	0.8468**	0.8512**	-0.8316**
	Podagrica spp	0.9417**	0.9701**	0.966**	-0.9659**
	Bemisia tabaci	0.3325	0.3664	0.4283	-0.39

** significant P<0.01

DISCUSSION

This study revealed *Aphis gosypii, Dysdercus* spp*, Podagrica* spp. *and Bemisia tabaci* as the major insect pests associated and attacking okra in the study area. *Podagrica* species were the most prevalent and damaging leaf insect pest encountered in the study in both cropping seasons, thus considered as major constraint to cultivation of okra. This is consistent with the reports of Damilola and Temitope (2020), Kudemepo *et al.* (2018) and Pitan and Olatunde (2006) that *Podagrica* spp. defoliate and damage okra plant leaves and flowers thereby causing reduction in the photosynthetic capability of the okra plant.

Dysdercus spp. were recorded both on young and matured okra fruits, eating up the fruit and drilling hole on the fruit for other pathogenic diseases. This agrees with the findings of Fajinmi and Fajimi (2010). *Bemisia tabaci* damaged okra plants directly through excessive sap removal, or indirectly by promoting the growth of sooty mold, inducing systemic disorders through feeding, or by vectoring plant viruses (Athar *et al.*, 2011). Abang *et al.* (2014) implicated *Aphis gosypii* as one of the major pests of okra. This was evident in this study as *A. gossypii* feeding on okra resulted in curling and deformation of young okra leaves and contaminated the fruits and leaves of okra with honeydew. It was also observed that the level of insect pest infestations in the two okra varieties, Jokoso and V-35, used for this study were similar in the 2021 and 2022 cropping seasons. Also, more insect pest infestation observed in 2022 might likely be due to weather conditions in 2021 that promoted more infestation during the planting season.

The consistent lower insect pest population densities recorded in *B. bassiana*- treated plot contrary to the unsprayed (control) plot irrespective of the variety in the study indicated the effectiveness of *B. bassiana* in reducing the populations of *Aphis gosypii, Dysdercus spp. Podagrica* spp. *and Bemisia tabaci* on okra. The study demonstrated that *B. bassiana* could be used to effectively control the major insect pests of okra. Wu *et al.* (2013) and Bayu and Prayogo (2017) reported that application of

B. bassiana significantly reduced the insect pest's infestation in both mung bean and onion. Similar results were also reported by Kudemepo *et al.* (2018); Kaiser *et al.* (2015); Olatinwo *et al.* (2018). Lewis *et al.* (1996) and Poprawski *et al.* (1997) reported that foliar applications of *B. bassiana* have proven to be useful in suppressing the populations of several economically-important insects, including *Bemisia tabaci.*

There was no significant difference in the population of insect pests observed in *B. bassiana* and lambda-cyhalothrin sprayed plots in both cropping seasons, showing that *B. bassiana* was effective as pyrethroids in controlling insect pests on okra irrespective of the variety used. Similar results were obtained by Bayu and Prayogo (2017) and Kudemepo *et al.* (2018) who obtained similar responses of insect pest populations to applications of *B. bassiana* and lambda-cyhalothrin.

Application of *B. bassiana* significantly controlled insect pest infestation and consequently reduced leaf and fruit damage to okra in both 2021 and 2022 growing seasons. The level of damage by both leaf and fruit pests in the unsprayed plot was fourfold lesser than in the *B. bassiana*-treated okra in 2021 and two-fold in 2022 lesser growing season for both varieties of okra. The significant yield loss reduction with application of *B. bassiana* in Jokoso and V-35 varieties during 2021 and 2022 growing seasons coupled with lower percentage defoliation and fruit damage further confirms the effectiveness of *B. bassiana* in controlling both leaf and fruit insect pests on okra. The report of Damilola and Temitope (2020) that application of biopesticides gave a lower percentage defoliation of okra compared to the control supports these findings.

Higher insect pest infestation in 2021 compared to 2022 growing season might be due to the environmental/weather conditions in 2021 growing season that reduced the efficacy of *B. bassiana.* The efficacy of *B. bassiana* as reported by Dannon (2020) depends mainly on environmental abiotic factors, including moisture, temperature, precipitation, and ultraviolet (UV) radiation for inoculum build -up and storage. Thus, climatic conditions could influence the physiology of the fungus, its ability to infect the host, the infection progression within the living or dead host, cadaver sporulation, the dissemination ability and survival of infectious conidia, also the host's susceptibility or resistance to infection (Sabbahi, 2008). This study also showed that the efficacy of *B. bassiana* in the two growing seasons was not variety-dependent because the two varieties, Jokoso and V-35 tested were similar in damage, insect infestation and yield levels in both years. This implies that *B. bassiana* could effectively control insect pests on okra regardless of the variety used whether local or hybrid variety.

It was shown from this study that the proximate composition and growth parameters of okra sprayed with *B. bassiana* were not significantly different from that of unsprayed plot in 2021 and 2022 growing seasons. This shows that application of *B. bassiana* has no adverse effects both on the nutritional composition and on the growth characteristics of okra. Similar reports were given by Kudemepo (2018) that application of *B. bassiana* had no negative effect on the proximate composition of okra treated with *B. bassiana.*

This study has also shown that foliar application of *B. bassiana* effectively increased fruit yield of okra going by the multiple increase in yield in *B. bassiana*-treated plots compared to the control plots. Yields obtained from *B. bassiana* plots were comparable to the yields from lambda-cyhalothrin plots. Bayu and Prayogo (2018) reported that mungbean yield from *B. bassiana* plot was six-times better than yield from control. This suggested the efficacy of *B. bassiana* in enhancing okra yield and that the use of *B. bassiana* can be an alternative control strategy to replace the use of insecticides for the management of insect pests on okra. This is in line with the findings of Adesina and Idoko (2013) and Adesina and Afolabi (2014) that okra sprayed with biopesticides had a higher yield compared to untreated plots. Luangsa-Ard *et al.* (2005) concluded that *B. bassiana* could be used as mycoinsecticides that will provide biological alternatives to chemical insecticides.

The significant positive relationship between insect pests' population and damaged fruit and leaves of okra and yield loss indicated that the higher the insect pest population on okra field, the more the fruit and leaf damage and consequently yield loss. The high damage and yield loss observed in this study were mainly due to high insect pests' population. Hence, the need to put control measures in place to avoid significant yield loss in okra field as recorded in the unsprayed plots on both varieties in the two growing seasons. This study also confirmed that okra yield reduces as insect population increases. Damilola and Temitope (2020) implicated insect pest infestation as the major cause of low yield in okra production in Nigeria.

CONCLUSION

Foliar application of *B. bassiana* controlled insect pest infestation, reduced fruit damage and significantly improved growth and yield of okra plant without any adverse effects on the nutritional composition of okra fruits. Hence, foliar application of *B. bassiana* can be used as an alternative control strategy to replace the use of chemical insecticides for the management of insect pests on okra

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