doi:10.14720/aas.2025.121.3.21587 Original research article / izvirni znanstveni članek

Efficacy and economic assessment of commercial *Beauvaria bassiana* (Bals.-Criv.) Vuill. in managing cucumber (*Cucumis sativus* L.) insect pests in a derived savanna agroecosystem

Caroline Oyindamola FILANI [1, 2], Busola Ajoke OGUNIYI [1], Olufemi Richard PITAN [1]

Received January 09, 2025; accepted September 01, 2025.
Delo je prispelo 9. januar 2025, sprejeto 1. september 2025

Efficacy and economic assessment of commercial *Beauvaria bassiana* (Bals.-Criv.) Vuill. in managing cucumber (*Cucumis sativus* L.) insect pests in a derived savanna agroecosystem

Abstract: A study was conducted in 2021 and 2022 planting seasons to determine the most efficient and profitable rate and frequency of applying *Beauvaria bassiana* to control insect pests on cucumber crop. *Beauvaria* application produced significantly lower insect pest numbers compared to untreated plots. Although leaf and fruit damage were statistically similar in the treated plots, the values were lower than the untreated plots. Significantly higher fruit yield (14.43 tons ha^{-1} and 13.44 tons ha^{-1}) was obtained when *Beauvaria* was applied at 8 kg ha^{-1} once a week relative to the control 2.26 tons ha^{-1} and 2.34 tons ha^{-1}, 2021 and 2022, respectively, resulting in a corresponding increase of 84 % and 83 % over the control. The relationship between insect pest infestation and yield was negative and significant (r = -0.90 and r = -0.80). In addition, the highest profitability index of 1.00 was obtained when *Beauve*ria was applied at 8 kg ha^{-1} once a week in both years.

Key words: *Beauveria bassiana*, fruit damage, insect pest infestation, cucumber, application rate, application frequency, economic assessment, derived savanna

Učinkovitost in ekonomsko ovrednotenje komercialnih sevov glive *Beauvaria bassiana* (Bals.-Criv.) Vuill. pri uravnavanju žuželčjih škodljivce na kumarah (*Cucumis sativus* L.) v ekosistemu prehodne savane

Izvleček: Raziskava je bila narejena v rastnih sezonah 2021 in 2022 za določitev najbolj učinkovite in donosne uporabe glive *Beauvaria bassiana* za nadzor žuželčjih škodljivcev na kumarah. Uporaba omenjene glive je povzročila znantno manjši napad žuželčjih škodljivcev v primerjavi z netretiranimi ploskvami. Čeprav so bile poškodbe listov in plodov statistično podobne na obravnavanih ploskvah, so bile vrednosti manjše kot na neobravnavanih. Značilno večji pridelek plodov (14,43 t ha^{-1} in 13,44 t ha^{-1}) je bil dosežen, ko je bila gliva *Beauvaria* uporabljena 8 kg ha^{-1} , enkrat na teden v primerjavi s kontrolo (2,26 t ha^{-1} in 2,34 t ha^{-1}, v letih 2021 in 2022). V primerjavi s kontrolo je bilo povečanje pridelka za 84 % in 83 %. Razmerje med napadom žuželk in pridelkom je bilo značilno negativno (r = -0,90 in r = -0,80). Največja vrednost indeksa dobičkonosnosti (1,00) je bila dosežena, kadar je bila gliva *Beauve*ria uporabljena z 8 kg ha^{-1} enkrat na teden v obeh letih.

Ključne besede: *Beauveria bassiana*, poškodba plodov, napad žuželčjih škodljivcev, kumara, velikost odmerka, pogostost uporabe, ekonomska ocena, prehodna savana

1 Federal University of Agriculture, Abeokuta, College of Plant Science and Crop Production, Department of Crop Protection, Ogun State, Nigeria.
2 Corresponding author's e-mail: filanico@funaab.edu.ng

1 INTRODUCTION

A significant vegetable crop of the family Cucurbitaceae, cucumber (*Cucumis sativus* L. (Elum, 2016) are grown throughout West Africa, including Nigeria (Okpani et al., 2023). Cucumber plays a very important role in improving human nutrition and health as it contains substances that stimulate digestion. It acts as laxatives or diuretics with its pectin and phenolic compounds regulating the pH of intestines (Victor and Amujoyegbe, 2019). It is well known for its diuretic effects and thus can serve as an active drug for secreting and promoting flow of urine (Okpani et al., 2023). Potassium, dietary fibers, manganese, phosphorus, pantothenic acid, copper, magnesium, as well as vitamins A, C, K, and B6 are all abundant in cucumbers (Ajibola and Amujoyegbe, 2019).

Cucumbers are extremely beneficial to human health, but insect pests limit their production in Nigeria. Insect pests such as *Podagrica uniforma* Jacoby, 1903 (Coleoptera: Chrysomelidae), *Aphis gossypii,* Glover, 1877 (Hemiptera: Aphididae) *Myzus persicae,* Sulzer, 1776 (Hemiptera: Aphididae) *Bemisia tabaci,* Gennadius, 1889 (Hemiptera: Aleyrodidae) *Aulacophora foveicollis,* Lucas, 1849 (Coleoptera: Chrysomelidae), *Epilachna chrysomelina* (Fabricius, 1775) (Coleoptera: Coccinellidae) and the fruit flies, *Bactrocera invadens* Drew,_*Tsuruta & White, 2005* (Diptera: Tephritidae) and *Dacus ciliatus* Loew, 1862 (Diptera: Tephritidae) are a major threat to the crop's productivity (Adeoti and Pitan, 2023). They cause substantial reduction in cucumber fruit yield through their damaging activities (Akinkunmi et al., 2021). In response to the insect pest infestations most farmers heavily apply conventional insecticides without which production could be unprofitable. These insecticides, if effective at all, provide short-term dividends. This practice is unsustainable and affects human health and causing severe effects on entire planet (Pitan et al., 2013). Hence, there is an urgent need for non-chemical alternatives. Biological control, which involve using natural enemies like bacteria, viruses, and fungi, are one type of non-chemical alternative.

Entomopathogenic fungi are a potential alternative to chemical insecticides against many insect pests infesting vegetables and legumes (Flinn and Scholler, 2012; Rumbos and Athanassiou, 2017; Batta and Kavallieratos, 2018; Wakil et al., 2021). Host-specific and contact-based, entomopathogenic fungi are considered an environmentally safe and acceptable management strategy. (Shahid et al., 2012). They have been reported to be effective against aphids, thrips, whiteflies, weevils, locusts, scarabs and caterpillars (Bahadur, 2023). *Beauveria bassiana* [(Bals.-Criv.) Vuill., 1912] belongs to the soil-borne Entomopathogens class. The fungus has been proven to be effective in controlling many dipterans and coleopterans (Galecki et al., 2019; Wakil et al., 2021). *B. bassiana* creates enzymes and attaches itself to cuticular substrates to assault insect hosts in order to facilitate insect cuticle disintegration and penetration (Pedrini et al., 2013). According to Rai et al. (2014), *B. bassiana* causes white muscardine disease by acting as a pathogen on a variety of insect species. A range of toxins such as beauvericin, bassianin, bassianolide, beauverolides, tenellin, oosporein, and oxalic acid are produced by *B. bassiana* after it invades insect hosts. These poisons aid in the parasitization and eventual death of the hosts by *B. bassiana* (Wang et al., 2021). According to Atwa et al. (2009), *B. bassiana* (F2) and *B. bassiana* (F1) reduced insect populations of cauliflower under field conditions, while Nouh et al. (2022) found that *B. bassiana* efficiently suppressed the main insect pests of cabbage.

Thus, the study assessed the bioactivity of *B. bassiana* against insect pests of cucumber for improved fruit yield.

2 MATERIALS AND METHODS

2.1 DESCRIPTION OF THE STUDY AREA

The study was carried out at the Federal University of Agriculture Abeokuta's Teaching and Research Farm in Abeokuta, Ogun State (7º 15´N, 3º 25´E; 159 m above sea level). The location is in southwest Nigeria's derived savannah zone. The field trials were conducted in the late season of 2021 and early season of 2022.

2.2 EXPERIMENTAL SETUP

The trials were conducted using the 'Saira F1' cucumber, a variety notable for its susceptibility to insect pests and *Beauveria bassiana*, CGA IPFBS-012, a fungal strain marketed under the trade name FIXIT-GA (1.15% WP). The study was set up using a 4 x 3 factorial arrangement with three replicates in a randomized complete block design (RCBD). Treatments included three application frequencies of *B. bassiana* (once a week, once every two weeks, and once every three weeks), a control, and four application rates of *B. bassiana* (8, 6, 4, and 3 kg ha-1). The field measured 53 m by 10 m in total, and each plot measured 3 m by 2 m, with a 2 m boundary separating each plot.

Two cucumber seeds were sown per hole at a distance of 1 m × 1 m apart and at two weeks after planting (WAP), the number of cucumber plants per stand was reduced to one plant. Manual weeding was done once every two weeks while neither fertilizer nor herbicide was applied throughout the duration of the experiment. Five hundred litres (500 litres) of water were used to suspend a 1.25-kilogram powder formulation of the fungus strain. This mixture was prepared to achieve a final concentration of 2 x 10^8 colony-forming units (CFU) per gram, which was manufacturer's recommended concentration (dosage) for optimal efficacy against target insect pests. Foliar application of the bio-insecticide was carried out between 7.00 and 8.00 a.m. (local time) when insect pests were less active with a 4-litre capacity handheld sprayer. Application commenced two weeks after planting cucumber until fruit maturity. Control plots were sprayed only with water according to treatment plans (once a week, once every two weeks, and once every three weeks) using a handheld sprayer. There was also no herbicide or fertilizer application to the control plots throughout the experiment.

Beauveria bassiana were applied at 8, 6, 4, and 3 kg ha^{-1} rates once a week, once every two weeks, and once every three weeks depending on the treatment plans for each plot. Applications were done in evenings between 5.00 and 7.00 p.m. (local time), at weekly intervals for once a week, every two weeks for once every two weeks and every three weeks for once every three weeks application frequencies. There was re-application of *B. bassiana* in every *B. bassiana*-treated plots after heavy rainfall throughout the study to reduce wash-off effects of rain on the fungi's efficacy.

2.3 INSECT PEST INFESTATION ASSESSMENT

Weekly visual counts of insect pests were conducted in the plots starting two weeks after planting (WAP) cucumber and continued until fruit maturity on five tagged plants from the central rows between 7:00 and 9:00 a.m. Additionally, data on fruit damage, blossom abortion, leaf damage

(%), and leaf damage intensity were collected. Cucumber fruit harvesting began 8 WAP until 10 WAP with harvesting occurring at three-days intervals. The percentage of fruit damaged was determined after the fruits were sorted into categories of undamaged and damaged. A cost-benefit analysis was conducted on the marketable yield, which consisted of the undamaged fruits (Dormon et al. 2007).

2.4 DATA ANALYSES

Analysis of variance (ANOVA) tests were performed on the data collected using the General Statistical Software package (GEN STAT 12th edition, VSNI, Hemel Hempstead, UK) at $p < 0.05$. Prior to analysis, the square root method ($\sqrt{X + 0.5}$) was used to transform the number of insects. When significant differences were found, they were separated using the Student Newman Keul's Test (SNK). Analysis of the correlation between fruit damage and insect pest density was also arried out.

3 RESULTS AND DISCUSSION

3.1 RESULTS

In the late season of 2021, plots sprayed with *B. bassiana* at 8, 6, 4, and 2 kg ha^{-1} showed significantly ($p < 0.05$) lower population densities of *Aulacophora nigripennis* Motschulsky, 1857 (Coleoptera: Chrysomelidae), *Aulacophora hilaris* (Boisduval, 1835) (Coleoptera: Chrysomelidae), *Coridus viduatus* Fabricius, 1794, (Het-

Table 1: Physicochemical properties of soil used for the study during 2021 and 2022 cropping seasons

Parameters	Values
pH	5.75
Particle size	
Sand (%)	88.60
Silt (%)	6.20
Clay (%)	5.20
Exchangeable bases (cmol kg^{-1})	
Ca	3.70
Mg	0.80
K	
Acidity	0.08
EC	4.12
Base (Sat)	
Total available (mg kg^{-1})	
N (%)	0.08
P	3.27
Organic carbon	0.65
Fe	1.65
Zn	0.85
Cu	0.45
Mn	3.60

Ca: Calcium, Mg: Magnessium, K: Potassium, EC: Electrical conductivity, N (%): Nitrogen (percentage), P: Phosphorus, Fe: Iron, Zn: Zinc, Cu: Copper and Mn: Manganese.

eroptera: Dinidoridae) and *Epilachna chrysomelina* (Fabricius, 1775) (Coleoptera: Coccinellidae), *Aulacophora foveicollis* Lucas, 1849 (Coleoptera: Chrysomelidae) than untreated plots. The control plots, however, had considerably greater densities of *A. foveicollis, A. hilaris, and E. chrysomelina* (11.00, 11.33, and 14.00), whereas the plots sprayed with *B. bassiana* at 8, 6, 4, and 2 kg ha^{-1} weekly in the early season of 2022, had the lowest densities (Table 2).

The frequency of *B. bassiana* application had a significant impact on floral abortion, fruit damage, leaf damage, leaf damage intensity, and relative yield loss in

Table 2: Insect pest densities on cucumber treated with *Beauveria bassiana* at different application rates and frequencies in the late season, 2021 and early season, 2022

Season	Frequency	Rate (kg ha^{-1})	*Aulacophora foveicollis*	*Aulacophora nigripennis*	*Aulacophora hilaris*	*Bactrocera cucurbitae*	*Coridius viduatus*	*Epilachna chrysomelina*
Late season, 2021	Once a week	8	1.33f	1.00g	0.33e	0.32bc	1.67d	2.10f
		6	2.00f	1.67g	1.00e	0.67bc	3.33d	3.02f
		4	1.33f	1.33g	0.67e	1.00bc	1.67d	2.33f
		2	1.67f	1.67g	1.00e	0.67bc	2.33d	3.40f
	Once every two weeks	8	3.67e	3.67f	3.00d	2.00bc	7.33c	7.30de
		6	6.33b-d	4.67ef	4.33cd	2.67a-c	8.00bc	6.00e
		4	5.33cd	5.67c-e	4.33cd	2.67a-c	10.33b	6.02e
		2	7.33b	5.33de	6.33b	3.00a-c	10.33b	8.67c
	Once every three weeks	8	5.33d	4.33ef	3.33d	2.67a-c	8.00bc	8.03cd
		6	7.33b	6.33b-d	4.67cd	1.33bc	9.33bc	7.40de
		4	6.67bc	7.00bc	5.67bc	3.00a-c	9.33bc	8.33cd
		2	7.33b	7.33b	7.00b	3.67ab	9.00bc	10.33b
	Control	0	10.00a	9.67a	10.33a	5.00a	12.00a	13.10a
		SED	0.52	0.55	0.66	0.90	0.80	0.54
		F-value	57.50	46.67	38.62	4.58	41.28	75.88
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Early Season, 2022	Once a week	8	2.33f	2.00e	1.33e	1.33c	2.67h	3.00f
		6	3.00f	2.67e	2.00e	1.67bc	4.33g	4.00f
		4	2.33f	2.33e	1.67e	2.00bc	2.67h	3.33f
		2	2.67f	2.67e	2.00e	1.67bc	2.67h	4.00f
	Once every two weeks	8	4.67e	4.67de	4.00d	3.00bc	8.33cd	8.00de
		6	7.33b-d	5.67d	5.33cd	3.67a-c	9.00bc	7.00e
		4	6.33cd	9.67b	5.33cd	3.67a-c	6.33df	7.00e
		2	8.33b	6.33cd	7.33b	4.00a-c	8.33cd	9.67c
	Once every three weeks	8	6.33cd	5.33d	4.33d	3.67a-c	9.00bc	9.00cd
		6	8.33b	7.33c	5.67cd	2.33bc	10.33ab	8.00d-e
		4	7.67bc	7.33c	6.67bc	4.00a-c	7.67c-f	9.33c
		2	8.33b	8.33b	8.00b	4.67ab	8.33b-e	11.33b
	Control	0	11.00a	10.67a	11.33a	6.00a	11.00a	14.0a
		SED	0.78	0.79	0.91	0.81	0.82	0.91
		F-value	46.21	37.34	30.90	4.12	30.96	49.32
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Mean values along the same column within a season followed by similar alphabets are not significantly different from one another using SNK at $p < 0.05$. SED, Standard error of the differences of the mean.

Table 3: Characteristics of insect-induced damage on cucumber treated with *Beauveria bassiana* at different application rates and frequencies in the late season, 2021

Frequency	Rate (kg ha^{-1})	Leaf damage (%)	Leaf damage intensity (%)	Flower abortion (%)	Fruit damage (%)	Relative yield loss (%)
Once a week	8	6.75j	23.67f	12.28d	13.57f	14.16d
	6	9.57i	27.44e	13.75d	14.17f	12.94d
	4	10.44ef	25.32f	14.93cd	15.90f	12.63d
	2	13.23e	24.94f	15.95cd	14.93f	15.58cd
Once every two weeks	8	16.55d	32.43cd	20.66b-d	30.27de	32.86bc
	6	16.95d	31.79cd	29.62b-d	26.00e	32.95ab
	4	16.95d	32.31cd	24.43b-d	28.70de	31.51bc
	2	18.51bc	34.60c	40.09ab	40.00c	46.37ab
Once every three weeks	8	22.05b	35.76c	32.86b-d	44.17c	41.94ab
	6	24.49b	34.03c	39.12ab	37.03cd	38.03ab
	4	25.09b	39.79b	36.14b-d	31.93de	43.55ab
	2	23.81b	38.17b	40.35a-c	54.30b	48.33ab
Control	0	60.46a	60.17a	60.17a	62.70a	72.72a
	SED	7.91	4.03	0.55	3.04	0.24
	F-value	5.80	5.12	7.39	52.81	57.53
	p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Mean values along the same column within a season followed by similar alphabets are not significantly different from one another using SNK at $p <$ 0.05.SED, Standard error of the differences of the mean.

Table 4: Characteristics of insect-induced damage on cucumber treated with *Beauveria bassiana* at different application rates and frequencies in the early season, 2022

Frequency	Rate (kg ha^{-1})	Leaf damage (%)	Leaf damage intensity (%)	Flower abortion (%)	Fruit damage (%)	Relative yield loss (%)
Once a week	8	17.44f	11.88e	13.94d	9.87h	12.25e
	6	21.77de	16.97de	16.37d	14.00g	15.79e
	4	19.91e	17.88de	16.91cd	16.50g	15.12e
	2	19.09e	22.57de	18.33cd	25.47ef	25.68de
Once every two weeks	8	24.10de	29.73cd	23.37b-d	34.70e	39.34cd
	6	26.52d	20.33de	32.40b-d	34.33e	37.98cd
	4	26.80d	29.44cd	25.86b-d	35.70e	35.01cd
	2	30.40c	28.70cd	39.50ab	43.90cd	55.10bc
Once every three weeks	8	31.05c	37.13bc	34.60b-d	40.00cd	51.85c
	6	29.46c	42.10b	39.73a-d	47.73c	45.16d
	4	36.01b	48.31b	37.61b-d	42.40cd	52.83c
	2	33.94c	44.02b	43.18a-c	54.53b	59.62b
Control	0	47.64a	80.64a	61.36a	61.97a	72.51a
	SED	4.28	4.62	0.55	8.98	0.45
		36.18	3.99	7.39	6.06	20.23
		< 0.001	0.002	< 0.001	< 0.001	< 0.001

Mean values along the same column within a season followed by similar alphabets are not significantly different from one another using SNK at $p <$ 0.05.SED, Standard error of the differences of the mean

Table 5: Yield of cucumber sprayed at different rates and frequencies of *Beauveria bassiana* application in late season, 2021 and early season, 2022

		Late season, 2021			Early season, 2022		
Frequency	Rate (kg ha $^{-1}$)	Yield plant $^{-1}$ (kg)	Yield (ton ha $^{-1}$)	YI (%)	Yield plant $^{-1}$ (kg)	Yield (ton ha $^{-1}$)	YI (%)
Once a week	8	0.97a	14.43a	84.34	0.86a	13.44a	82.59
	6	0.74c	13.57ab	83.35	0.64c	12.06b	80.60
	4	0.83b	13.50ab	83.26	0.73b	11.22bc	79.14
	2	0.65d	12.23b	81.52	0.55d	10.48c	77.67
Once every two weeks	8	0.47ef	7.12de	68.26	0.37ef	6.24e	62.50
	6	0.59d	8.88c	74.55	0.49d	8.20d	71.46
	4	0.50e	7.51cd	69.91	0.39e	6.686e	65.02
	2	0.37gh	5.60ef	59.64	0.27gh	4.44fg	47.30
Once every three weeks	8	0.36f-h	5.45ef	58.53	0.26f-h	4.38fg	46.58
	6	0.44e-g	6.57d-f	65.6	0.34e-g	5.64ef	58.51
	4	0.35f-h	5.31ef	57.44	0.25gh	4.23fg	44.68
	2	0.31h	4.63f	51.19	0.21hi	3.47gh	32.56
Control	0	0.15i	2.26g	-	0.14i	2.34h	-
	SED	0.06	0.67		3.79	40.51	
		3.41	69.31		53.59	58.01	
		< 0.001	< 0.001		< 0.001	< 0.001	

Mean values along the same column within a season followed by similar alphabets are not significantly different from one another using SNK at $p <$ 0.05. SED, Standard error of the differences of the mean, YI = Yield increase over control (%)

Table 6: Correlation coefficients of the relationship between insect pest densities, fruit damage and cucumber yield in the late season, 2021 and early season, 2022

	Late season 2021			Early season, 2022		
Insect	Leaf damage (%)	Yield ha $^{-1}$	Fruit damage (%)	Leaf damage (%)	Yield ha $^{-1}$	Fruit damage (%)
Aulacophora foveicollis	0.62**	-0.89**	0.86**	0.76**	-0.87**	0.82**
Aulacophora hilaris	0.71**	-0.87**	0.86**	0.79**	-0.88**	0.79**
Aulacophora nigripennis	0.67**	-0.90**	0.85**	0.44	-0.45**	0.41
Epilachna chrysomelina	0.71**	-0.9**	0.94**	0.81**	-0.95**	0.82**
Coridius viduatus	0.57**	-0.92**	0.79**	0.66**	-0.87**	0.73**
Bactrocera cucurbitae	NA	NA	0.72**	NA	NA	0.48*

** = significant at $p < 0.01$, NA = not applicable

both seasons. The control plots had the greatest levels of leaf damage and leaf damage intensity, however, there was no significant difference among the treated plots. Notably, fruit damage was lower in plots treated with 8, 6, 4 and 2 kg ha $^{-1}$ of *B. bassiana* weekly relative to the control plots (Table 3 and 4).

Cucumber fruit yield was the highest in plots treated with 8 kg ha $^{-1}$ compared to other treatments, while the control plots had the lowest yield. Yield increase of more than 80 % over the control were observed in both 2021 and 2022 seasons in plots treated with *B. bassiana* at 8 kg ha $^{-1}$ relative to other treated plots (Table 5). Additionally, leaf and fruit damage were significantly correlated with insect pest densities except *A. nigripennis* (Table 5). Most insect pests showed positive and significant correlations with leaf damage ($r = 0.66$ and $r = 0.69$) and fruit damage ($r = 0.84$, and $r = 0.68$), indicating that higher insect densities led to more significant damage in both 2021 and

Table 7: Profitability of cucumber grown at different rates and frequencies of *Beauveria bassiana* application in late season, 2021 and early season, 2022

			Late season, 2022			Early season, 2022		
Frequency	Rate (kg ha^{-1})	Number of spray	Additional revenue ($)	Additional cost ($)	Marginal return	Additional revenue ($)	Additional cost ($)	Marginal return
Once every week	8	6	6,582.19	3,430.10	1	7,204.18	3,430.10	1
	6	6	6,117.06	3,389.00	0.8	6,308.52	3,389.00	0.86
	4	6	6,079.20	3,245.67	0.87	5,763.34	3,245.67	0.78
	2	6	5,392.31	3,090.98	0.74	5,283.06	3,090.98	0.71
Once every two weeks	8	3	2,628.55	1,768.59	0.49	2,531.20	1,768.59	0.43
	6	3	3,580.45	1,748.31	1.05	3,808.28	1,748.31	1.18
	4	3	2,839.48	1,728.03	0.64	2,816.77	1,728.03	0.63
	2	3	1,806.45	1,707.75	0.05	1,362.95	1,707.75	-0.2
Once every three weeks	8	2	1,725.32	1,541.43	0.12	1,324.01	1,541.43	-0.14
	6	2	2,331.08	1,511.69	0.54	2,141.78	1,511.69	0.42
	4	2	1,649.61	1,476.53	0.12	1,226.67	1,476.53	-0.17
	2	2	1,281.82	1,324.55	-0.03	733.4	1,324.55	-0.45
Control	0	-	-	-		-	-	-

Based on N250.00 and 300.00 per kg of cucumber in late season, 2021 and early season, 2022, respectively. Costs of labour/ha = N10,000, Cost of water usage /ha = N3000, and treatment cost/spray/ha = N22,500. Also, conversion rate to dollar ($) is N 462.232

2022 planting seasons. A strong negative and significant correlation (r = -0.90 and r = -0.80) was observed between fruit yield and pest density, suggesting that higher insect densities reduced cucumber fruit yield (Table 6).

The highest profit margins, exceeding 100 %, were obtained using *B. bassiana* at 8 kg ha^{-1} weekly, and 6 kg ha^{-1} once every two weeks in both 2021 and 2022 planting seasons, respectively (Table 7).

3.2 DISCUSSION

Insect pest infestations were considerably reduced, and insect-induced damage to cucumber leaves and fruits was mitigated using *Beauveria bassiana* according to findings of the study. These findings align with the report of Dannon et al. (2020) that the fungus *B. bassiana* strain RSB was effective against western flower thrips *Frankliniella occidentalis* Pergande, 1895 (Thysanoptera: Thripidae) on broccoli causing a mortality of 69-96 % in laboratory and green house trials. Mehinto et al. (2014) also reported similar efficacy of *B. bassiana* in controlling *Maruca vitrata* (Fabricius, 1787) (Lepidoptera: Crambidae). Also, *B. bassiana* has demonstrated efficacy in managing pests that have evolved a high level of resistance to chemical insecticides, including whiteflies, aphids, thrips and spider mites (Kliot et al., 2016). Similar reports on the effectiveness of *B. bassiana* for pest control have been documented in cotton (Dannon et al., 2020), potato (Bohata et al., 2024), beans (Mutue et al., 2016), and grapevine (Jaber, 2015).

In this study, *B. bassiana* also proved effective against fruit flies, particularly with applications at 8 kg ha^{-1} once every week and 6 kg ha^{-1} once every two weeks, which emerged as the most cost-efficient treatment regimens. These results are corroborated by other studies that show fruit flies are extremely vulnerable to entomopathogenic fungus, with *B. bassiana* exhibiting remarkable pathogenicity against both pupal and adult stages (Hamzah et al., 2021). Mortality rates of 82–100 % have been reported for fruit flies treated with *B. bassiana* (Shahzad et al., 2019). Moreover, contact application methods have been shown to yield higher virulence compared to alternative approaches, such as oral treatments (Gul et al., 2015).

A notable positive correlation was observed among the presence of leaf and fruit pests and the percentage fruit damage in both 2021 and 2022, planting seasons. This implies that higher number of leaf pests, *E. chrysomelina, A. hilaris, A. nigripennis,* and *A. foveicollis* observed in both 2021 and 2022 planting seasons led to higher leaf damage observed on cucumber in both seasons. It also, revealed that as the density of fruit pest, *B. cucurbitae* (Coquillett, 1899) observed on cucumber increased, the damage to cucumber fruits also increased. This aligns with the findings of Akinkunmi and Pitan (2021), that a strong association exists between *E. chrysomelina* density and cucumber fruit damage. The most prevalent insect species found in the study included *E. chrysomelina, A. hilaris, A. nigripennis, A. foveicollis, Coridus viduatus,* and *B. cucurbitae*. These pests played important roles in influencing outcomes in cucumber production. Similar pest profiles have been highlighted by Tamoghna et al. (2018) as key contributors to cucumber production challenges.

The potential mechanisms underlying the negative and significant relationship between insect pest density and cucumber fruit yield is (r = -0.90 and r = -0.80) suggests a strong influence of insect species densities on cucumber fruit yield. Pest pressure drastically reduces crop yield such that simultaneous attack by multiple insect pests interactively affected biomass and fruit yield of cucumber through reduction in plant growth. However, the magnitude of such attack and damage is dependent on the densities and frequency of attack. All most all of the pests, *E. chrysomelina, A. hilaris, A. nigripennis,* and *A. foveicollis* and *B. cucurbitae* cause serious damage in cucumber production which lead to yield loss. Attack on crop plants by many pests affect plants survival, growth and reproduction and as a consequence influence crop yield (Oerke, 2006). According to Stephen et al. (2013), the effects of insect attack on plants growth and yield is negative.

4 CONCLUSIONS

Epilachna chrysomelina is a highly destructive pest that poses a significant threat to cucumber cultivation. The application of *Beauveria bassiana* has demonstrated remarkable effectiveness in controlling cucumber-associated pests when used at various rates and frequencies. The optimal application rate was determined to be 8 kg ha^{-1}, administered weekly. Furthermore, the study identified that *B. bassiana* is most cost-effective when applied either at 8 kg ha^{-1} weekly or at 6 kg ha^{-1} once every week. These strategies not only reduced pest infestation and crop damage but also significantly enhanced fruit yield while lowering pest control costs.

5 REFERENCES

Adeoti, A. O. & Pitan, O. R. (2023). Influence of time of introduction and proportion on the efficacy of grain amaranth trap crop against *Aulacophora foveicollis,* Lucas, 1849 (Coleoptera: Chrysomelidae), *Epilachna chrysomelina* Fabricius (Coleoptera: Coccinellidae) on cucumber (*Cucumis sativus* L.). *Archives of Phytopathology and Plant Protection, 56*(14), 1062-1075.

Akinkunmi, O. Y. & Pitan, O. R. (2021). Aspect of the biology and morphometrics of the life stages in *Epilachna Chrysomelina* Fabricius (Coleoptera: Coccinellidae). *Nigeria Journal of Entomology, 37*, 1-10.

Akinkunmi, O. Y., Pitan, O. R. & Adeoye, O. T. (2021). Assessment of fruit yield loss in cucumber due to leaf feeding by *Epilachna chrysomelina* Fabricius (Coleoptera: Coccinellidae). *Ethiopian Journal of Environmental Study Management, 14*(3), 380–389.

Atwa, A. A., El-Sabah, B.A. and Gihad, M. M. 2009. The effect of different biopesticides on the cabbage white butterfly, *Pieris rapae* L. in cauliflower fields. *Alexandria Journal of Agricultural Research, 54*(1), 147-153.

Bahadur, A. (2023). The potential of the entomopathogenic fungus *Beauveria bassiana* [(Bals.-Criv.) Vuill., 1912] to manage insect pests and diseases. *Natural Resources Conservation and Research, 6*(2), 2543.

Batta, Y. A. & Kavallieratos, N. G. (2018). The use of entomopathogenic fungi for the control of stored-grain insects. *International Journal of Pest Management, 64*(1), 77-87.

Bohata, A., Folorunso, E. A., Lencova, J., Osborne, L. S. & Mraz, J. (2024). Control of sweet potato whitefly *Bemisia tabaci* Gennadius, 1889 (Hemiptera: Aleyrodidae) using entomopathogenic fungi under optimal and suboptimal relative humidity conditions. *Journal of Pest Management Science, 80*(3), 1065-1075.

Dannon, H. F., Dannon, A. E. & Douro-kpindou, O. K. (2020). Toward the efficient use o *Beauveria bassiana* [(Bals.-Criv.) Vuill.,1912] in integrated cotton insect pest management. *Journal of Cotton Research,* (3), 24.

Elum, Z. A., Etowa, E. B., & Ogonda, A. U. (2016). Economics of cucumber production in Rivers State, Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension, 15*(2), 48–53.

Flinn, P. W. & Schöller, M. (2012). Biological control: Insect pathogens, parasitoids, and predators. *Stored Product Protection,* pp.203-212.

Gałęcki, R., Bakuła, T., Wojtacki, M. & Żuk-Gołaszewska, K. (2019). Susceptibility of ancient wheat species to storage pests *Sitophilus granarius* (Linnaeus) (Coleoptera: Curculionidae) and *Tribolium confusum* Duval, 1868 (Coleoptera: Tenebrionidae). *Journal of Stored Products Research*, *83,* 117-122.

Gul, H. T., Freed, S., Akmal, M. & Malik, M. N. (2015). Vulnerability of different life stages of *Bactrocera zonata* (Tephritidae: Diptera) against entomogenous fungi. *Journal of Zoology, 47*(2), 307–317.

Hamzah, A. M., Mohsin, A. U., Naeem, M. & Khan, M. A., (2021). Efficacy of *Beauveria bassiana* (Hypocreales: Cordicipitaceae) and *Metarhizium anisopliae* (Hypocreales: Clavicipitaceae) against *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) under controlled and open-field conditions on bitter gourd. *Egyptian Journal of Biological Pest Control, 31*, 1-8.

Jaber, L. R. (2015). Grapevine leaf tissue colonization by the fungal entomopathogen *Beauveria bassiana* and its effect against downy mildew. *Biological Control, 60*, 103–112.

Kliot, A., Kontsedalov, S., Lebedev, G. & Ghanim, M. (2016).

Advances in whiteflies and thrips management. *Advances in Insect Control and Resistance Management,* pp.205-218.

Mehinto, J. T., Atachi, P., Kobi, O., Kpindou, D. & Tamo, M. (2014). Pathogenicity of entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* (Hypocreales: Cordicipitaceae) on larvae of the legume pod borer *Maruca vitrata* (Lepidoptera: Crambidae). *International Journal of Advanced Research, 9*(2), 55-64.

Mutune, B., Ekesi, S., Niassy, S., Matiru, V., Bii, C and Maniania, N. K. (2016). Fungal endophytes as promising tools for the management of bean stem maggot *Ophiomyia phaseoli* on beans *Phaseolus vulgaris* (L.). *Journal of Pest Science, 89*, 993–1001.

Nouh, G. M., Aziza, E., Kamel, H. M. and Adly, D. (2022). Efficacy of the entomopathogenic fungus, *Beauveria bassiana* and certain insecticides on some cabbage insects in field. *Egyptian Journal of Agricultural Research, 100*(4), 499-510.

Oerke, J. E. C. (2006). Crop loss to pests. *Journal of Agricultural Science, 144*, 31-43.

Okpani, F. M., Orji, K. O. and Umekwe, P. N. (2023). A review on the benefits, techniques, constraints and solutions to cucumber production. *Nigerian Journal of Scientific Research*, *22*, 0794-0378.

Pedrini, N., Ortiz-Urquiza, A., Zhang, S. & Keyhani, N. O. 2013. Targeting of insect epicuticular lipids by the entomopathogenic fungus *Beauveria bassiana* (Hypocreales: Cordicipitaceae) hydrocarbon oxidation within the context of a host-pathogen interaction. *Frontiers in Microbiology*, *4*, 42518.

Pitan, O. R., Jinadu, G. M., Shodunke, O. K., Filani, C. O. & Adewole, M. M. (2013). Influence of varietal differences and pyrethroid insecticides on the population densities of cucumber insect pests, *Dacus* spp. and *Bactrocera invadense* (Diptera: Tephritidae) and fruit damage. *Nigerian Journal of Horticultural Science, 18*(1), 69–77.

Rai, D., Updhyay, V., Mehra, P., Rana1, M., and Pandey, A. K., 2014. Potential of entomopathogenic fungi as biopesticides. *Indian Journal of Science Research and Technology, 2*(5), 7-13.

Rumbos, C. I. & Athanassiou, C. G. (2017). Use of entomopathogenic fungi for the control of stored-product insects: can fungi protect durable commodities. *Journal of Pest Science 90,* 839-854.

Shahid, A. A., Rao, A. Q., Bakhsh, A. and Husnain, T. (2012). Entomopathogenic fungi as biological controllers: new insights into their virulence and pathogenicity. *Archives of Biological Sciences, 64*, 21–42.

Shahzad, M. U., Qayyum, M. A., Ishtiaq, M., Ikram, R. M. and Saleem, M. A. (2019). Entomopathogenicity of *Beauveria bassiana* (Hypocreales: Cordicipitaceae) against two bactrocera species (Tephritidae: Diptera) under laboratory condition. *Journal of Agricultural Sciences, 1*(1), 19–24.

Stephen, A. E., Srivastava, D. S. and Myers, J.H. (2013). Strength in numbers? Effects of multiple natural enemy species on plant performance. *Proceeding of the Royal Society, London Biological Science 290,* 20122756.

Tamoghna, S., Nithya, C., Sunil, K. & Kiran, K. (2018). Effect of weather parameters on incidence of insect pests of cucumber (*Cucumis sativus* L.) in Eastern Bihar. *Journal of Agrometeorology, 20*(1), 57-61.

Wakil, W., Kavallieratos, N. G., Ghazanfar, M. U., Usman, M., Habib, A. & El-Shafie, H. A., (2021). Efficacy of different entomopathogenic fungal isolates against four key store-grain beetle species. *Journal of Stored Products Research, 93,* 10184.

Wang, H., Peng, H., Li, W., Cheng, P. and Gong, M. 2021. The toxins of *Beauveria bassiana* and the strategies to improve their virulence to insects. *Frontier Microbiology, 12*, 705343. doi: 10.3389/fmicb.2021.705343.