Enhancement of Cucumber Growth, Production and Protection Against Insect Pests by the Endophytic Entomopathogenic Fungus *Beauveria bassiana*

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Abstract

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Two strains of the entomopathogenic fungus *Beauveria bassiana* (Bals.) Vuil. were used in the present study to inoculate cucumber plants using cucumber seed treatment for different durations (2h, 6h, and 10h) in the laboratory, in addition to root dipping in the greenhouse. Their effects on plant colonization, seed germination, growth and production parameters were examined, and their impact in preventing insect pest attack under greenhouse conditions was investigated. The results of the laboratory experiment showed a significant increase in the length and number of roots, and the seedling vigor, 10 days after seed soaking in the fungal suspension for different treatment durations, with no significant effect on germination. Increasing the seed soaking duration also increased the hypocotyl length. Significant increase was observed in leaf number, fruit number, wet fruit weight, wet and dry shoot weight, plant height, and root length, 43 days after fungal application under greenhouse conditions. Both *B. bassiana* strains reduced infestation and severity of agromyzid leaf miners, aphids, and whiteflies on cucumber plants grown in the greenhouse.

Keywords: Colonization, fungal endophytes, entomopathogenic fungi, infestation, severity, plant growth promotion.

Introduction

Plant-fungal endophytes interaction was known and studied for more than 100 years (Rodriguez *et al*., 2009) and has attracted a lot of attention in the last decade (Chen *et al*., 2020; Kumar & Dara, 2021; Kumari *et al.,* 2023; Vázquez de Aldana *et al*., 2013). Fungal endophytes (FEs) are fungi that inhabit and colonize plant tissues without any disease symptoms (Wilson, 1995). The interaction between a host plant and a wide group of FEs is considered a type of mutualism in which the two organisms in the relationship benefit, and the benefit is larger than the cost (Rodriguez *et al*., 2009). Most research has focused on the benefits of this interaction for the host plant. FEs have been reported to protect plants from pathogens, insect pests, and different abiotic stresses (Akter *et al.*, 2023; Bamisile *et al*., 2018; Begum & Tamilselvi, 2016; Card *et al*., 2016; Rodriguez *et al*., 2009; Lugtenberg *et al*., 2016). FEs have also been shown to function as plant growth promoters (PGPs) due to the fungal compounds (i.e. the secondary metabolites and growth hormones) produced inside the plant tissues in addition to enhancing nutrient uptake by the root system (Bamisile *et al*., 2018; Begum & Tamilselvi, 2016).

The entomopathogenic fungus *Beauveria bassiana* (Bals.) Vuil. (Hypocreales: Cordycipitaceae) has been reported as an endophyte colonizing many different plant species around the world showing the ability to enhance plant growth parameters and protect them from biotic and abiotic threats (Jaber & Ownley, 2018; Lopez & Sword, 2015; Vega, 2008; 2018; Vidal & Jaber, 2015). The present study investigated the ability of two Syrian indigenous strains of *B. bassiana* (isolated from soil and plant material) to colonize and promote the growth of cucumber plant (*Cucumis sativus* L.: Cucurbitaceae), which is considered one of the most important vegetable crops in Syria and many other countries around the world, in the laboratory and in the greenhouse following seed and root treatments.

In addition, this study provides initial data about the role of endophytic entomopathogenic fungi-plant interaction in reducing the damage of different insect pests on cucumber plants.

Materials and Methods

Plant and fungal materials used

Cucumber seeds (Raade F1 hybrid, Russia) were surface sterilized by immersing in sodium hypochlorite (1.5%) for 3 min, then in ethanol (70%) for 1 min, followed by rinsing in sterile distilled water (SDW) three times, 2 min in each time. Finally, to evaluate the success of the surface sterilization procedure, 100 µl of the last rinsing water was incubated on potato dextrose agar plates (PDA; TM MEDIA®, India) at 25±1°C in the dark for 2 weeks. Seeds were used when no fungal growth was observed in the plates inoculated with the last rinsing water.

Two strains, BNE20 and BS195, of *Beuaveria bassiana* were used in this study (Table 1). The fungal strains were maintained in 10% w/w glycerol at -2 °C in the Laboratory. When required, frozen conidia were used to inoculate PDA plates and incubated in the dark at 25±1°C for 14 days. These cultures were used to inoculate additional PDA plates, incubated for 14 days, and then stored at 4°C until use.

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Table 1. *Beauveria bassiana* strains used in this study.

Strain	Origin	Geographic Coordinates	Source	Isolation year	GenBank accession No. for the ITS region	GenBank accession No. for the EF1-α gene	References
BS195	Al-Shabatliyah (Latakia, Syria)	35°41'10"N 35°49'36"E	Olive orchard soil	2018	OM302229	OP573422	Rajab *et al*., 2024
BNE20	Al-Kharab (Tartus, Syria)	35°05'27.6"N, 35°54'09.8"E	Cucumber stems	2019	OM302228	OP573421	Rajab *et al*., 2023

Preparation of the fungal inoculum

Spore suspensions were prepared as described by Inglis *et al*. (2012). Ten ml of SDW with 0.05% Tween 80 and 2% of carboxymethylcellulose (CMC) were added to 14–day–old colonies grown on PDA, and the surface of the colonies was gently scraped off to harvest maximum number of conidia. The suspension obtained was filtered to remove any mycelial and medium fragments and homogenized with a magnetic stirrer for 10 min. Suspension concentration was calculated using a Malassez counting chamber, then adjusted to 1×10^7 spores/ml. Conidia viability for each fungal strain was determined before inoculation based on germ tube formation and used if the viability was more than 90%.

Effect of seed treatment duration on cucumber seedling performance *in vitro*

Surface–sterilized seeds were soaked in the conidial suspension of each fungal strain for 2, 6, and 10 h and kept in the dark at room temperature for the designated duration with gentle stirring every 30 min. For the control treatment of each period, seeds were soaked only in SDW containing 0.05% Tween 80 and 2% CMC. Seeds were then individually placed onto sterile, moist filter paper inside Petri dishes (12 cm) and incubated in the dark at 25±1°C for 10 days for monitoring. Sterile water was added periodically as needed to keep the filter paper moist (Jaber & Enkerli, 2016). The occurrence of cotyledons was monitored, and the total seed germination rate was calculated (Germination % = [the number of seeds germinated/the total number of seeds used] × 100). The length of the hypocotyl and the length and number of roots of the resulting seedlings of each treatment were recorded ten days post–inoculation. Seedling vigor was calculated based on seedling growth and germination using the following formula (Sharma *et al*., 2023):

$$\text{Seedling vigor} = \text{germination (\%)} \times (\text{mean hypocotyl length} + \text{mean root length})$$

The correlation coefficient (r) of the effect of the fungal strains and seed treatment duration on seedling vigor was calculated.

Fifteen replicate dishes were prepared for each treatment combination (fungal strain inoculation or the control + seed treatment duration). The experiment was replicated twice under the same conditions. At the end of the experiment, five seedlings were selected randomly for fungal colonization assessment.

Effect of fungal inoculation on cucumber colonization, growth, yield and protection under greenhouse conditions

This assay was performed by applying the fungal suspension of each *B. bassiana* strain endophytically, following the root soaking method. Roots of the first true leaf seedling were soaked in the fungal suspension for 2 h in the dark at room temperature and then transplanted in the greenhouse soil. Control plants were prepared in the same way without the fungus. Plants were watered as needed and allowed to grow for 43 days after transplanting. There was no fertilization throughout the experiment. Fifteen plants were planted for each treatment, 10 of them were used for studying the morphological parameters and the other five were used for fungal colonization assessment. Cucumber plants were left without mesh covering to allow the natural infestation with insect pests. At the sampling date, plants were uprooted, and insect pests present on each plant were recorded.

The numbers of three major insect pests were recorded: (1) agromyzid leaf miners belonging to the genus *Liriomyza* (Diptera: Agromyzidae) which appeared through their tunnels in the cucumber leaves, (2) aphids (Hemiptera: Aphididae) which appeared as adults and nymphs on the whole shoot parts of the plant, and (3) whiteflies (Hemiptera: Aleyrodidae) which were counted as eggs and nymphs (Adults of whiteflies were ignored in the counting process). Other pests like thrips and tetranychid mites (*Tetranychus urticae*) also were observed attacking the plants in this experiment but were not included in the analysis because their density was still very low.

For each pest, the severity of infestation (IS) and incidence (PI) were calculated.

$$\text{Incidence (PI \%)} = \frac{\text{number of infested plants}}{\text{total number of plants}} \times 100$$

For agromyzid leafminers, an additional parameter, the infestation percentage (IF) was calculated for each plant

$$\text{Infestation (IF \%)} = \frac{\text{number of infested plants}}{\text{total number of plants}} \times 100$$

The severity of infestation (IS) (%) was calculated according to the number of tunnels/leaves as described by Manjy (2019) using a standard 0-3 scale as follows: 0= there are no tunnels per leaf, 1= 5 tunnels/ leaf, 2 = 6–10 tunnels/ leaf, and 3= there are 11 or more tunnels per leaf.

Aphid infestation was evaluated by assigning scores ranging from 1 to 5: 1= there are 10 or less aphids per plant, 2 = 11–25 aphids per plant, 3= 26–50 aphids per plant, 4= 51–100 aphids per plant, and 5= there are more than 100 aphids per plant (Jun *et al*., 2012). In addition, aphid population size between the treated and untreated plants was compared.

The assessment of the severity of infestation by the whiteflies was done depending on the numbers of eggs and nymphs as described by Anjorin *et al*. (2013) using a standard 1-4 scale: 1= scattered appearance of few whitefly

on the plant, 2= severe infestation of whiteflies on any one part of the plant, 3= severe infestation of whiteflies on more than one part or half portion of the plant, and 4= severe infestation of whiteflies on the whole plant.

After counting the insect pests per plant, the number of cucumber fruits and leaves, plant height, root length, and wet weight of roots, fruits, and shoots (leaves and stems) were recorded. The dry weight of the root and shoot were measured after drying in the oven at 65°C until the weight was constant. The dry matter content (DMC) was calculated as a percentage: DMC % = (dry shoot/wet shoot) × 100.

Fungal colonization assessment

Five random plants were selected from each experiment for the fungal colonization assessment, following the protocol of Rajab *et al.* (2023). Briefly, plant parts were harvested, washed with running water, and dried at room temperature. After that, they were surface sterilized using sodium hypochlorite (2%) for 3 min and ethanol (70%) for 1 min. Plant parts were then rinsed three times using SDW and cut into 4 mm long pieces for each of the stems and roots, and 1 cm diameter discs for the leaves. Six random sections of each of the stems, leaves, and roots for each replicate were incubated on PDA plates after surface sterilization. The fungal colonization rate (C %) was calculated according to Petrini & Fisher (1986):

$$C\ (\%) = \frac{\text{number of plant discs showing fungal growth}}{\text{total number of plant discs}} \times 100$$

Statistical analysis

Prior to statistical analyses, data were tested for normality using Shapiro–Wilkes test and homogeneity of the variance using Levene's test. When the resulting probability of $P \leq 0.05$, data were transformed with a natural logarithm function [ln (y) = Log (y + 1)] to correct for heterogeneity of the variance and produce approximately normally distributed data sets. Data from the laboratory experiment were subjected to two-way completely randomized ANOVA (2WCR.ANOVA). Means of colonization rates and germination were separated using Tukey's HSD test when a significant F test was obtained at $P \leq 0.05$. Means of hypocotyl length, root length and number were separated using Tukey–Kramer test because the number of replicates was not equal (not all of the seeds had germinated). Data from the greenhouse experiment were subjected to one-way ANOVA and means were separated using LSD test. Data were statistically analyzed using R version 4.3.1 software (R Core team, 2022).

Results

Effect of seed treatment duration on cucumber seedling performance *in vitro*

Both fungal strains, BS195 and BNE20, were able to colonize all cucumber plant parts (stems, leaves, and roots) 10 days after seed soaking in both experiments with no fungal colonization observed in the control plants. In general, there were no significant differences between the two strains in plant colonization in all time durations (Table 2).

Seed inoculation with *B. bassiana* showed no significant effect on germination regardless of duration, fungal strain, or the interaction between them in both experiments (Table 2). Results obtained also showed that seed soaking (with or without fungal spores) for 10 hr. significantly increased the growth parameters studied (hypocotyl length, root length, and the number of roots), followed by seed soaking for 6 hr. then 2 hr.

In both experiments, cucumber seed inoculation with *B. bassiana* and longer treatment durations significantly increased root length and number, 10 days post treatment (Table 3, Figures 1 and 2).

For hypocotyl length, there was no significant difference between fungus-inoculated seeds and control seeds, neither in the first experiment nor in the second. However, hypocotyl length was significantly increased with increased soaking duration. The interaction between the fungal strain and the duration resulted in significantly longer hypocotyl in the first experiment but not in the second (Table 3, Figures 1 and 2).

Fungal structures of *B. bassiana* were observed to grow on of three ungerminated seeds after soaking in the suspension of the strain BS195 for 10 hours (Figure 2).

Increased seedling vigor was observed after soaking the seeds in the fungal suspension for two hours (in both experiments: r = 0.948 and 0.978 in the first and second experiments, respectively) and six hours (in the second experiment: r = 0.8841, but not in the first: r = 0.066), but the duration of the seed treatment had no high correlation with the seedling vigor (r values were 0.3663, 0.4449, and 0.811 for BS195, BNE20, and control, respectively, in the first experiment; and 0.423, 0.8059, and 0.6539 in the second, respectively). In both experiments, soaking seeds for 10 hours had no high correlation with the vigor of the seedlings (r = 0.306 and 0.42, respectively) (Figure 3).

Effect of fungal inoculation on cucumber colonization, growth, yield, and protection under greenhouse conditions

Both *B. bassiana* strains, BNE20 and BS195, had significant effects on cucumber plant growth parameters under greenhouse conditions 43 days after the plants were inoculated with the fungal suspension by root soaking (Table 4). Both strains were successfully re–isolated from each of the stems (LSD test after One way ANOVA, $df = 2$; $F = 365.93$; $P \leq 0.0001$), leaves ($F = 959.45$; $P \leq 0.0001$), and roots ($F = 2728.98$; $P \leq 0.0001$) (Table 5). The plant colonization by the fungus significantly enhanced the leaf number ($F = 8.27$; $P = 0.0016$), fruit number ($F = 9.74$; $P = 0.0007$), fresh fruit weight ($F = 15.8$; $P \leq 0.0001$), fresh shoot weight ($F = 8.24$; $P = 0.0016$), and dry shoot weight ($F = 10.44$; $P = 0.0004$) compared with the control plants. There was a significant improvement in plant height when the plants were inoculated with the strain BS195 ($F = 3.22$; $P = 0.06$). The root length in plants treated with the strain BNE20 was significantly higher than the control plants, and such enhancement was not observed on plants treated with BS195. The fresh root weight ($F = 2.063$; $P = 0.15$), the dry root weight ($F = 0.55$; $P = 0.58$), and the DMC ($F = 2.21$; $P = 0.13$) were not affected by fungal colonization (Table 4).

Table 2. The effects of cucumber inoculation with *Beauveria bassiana* (strains BS195 and BNE20) and different seed treatment durations (2, 6, and 10 h) on seed germination and plant colonization (mean ± SE), ten days post-treatment.

		Means ± SE							
		Experiment 1				Experiment 2			
		Colonization rate (%)			Germination	Colonization rate (%)			Germination
Treatment	Duration time (hr)	Stems	Leaves	Roots	(%)	Stems	Leaves	Roots	(%)
BS195	2.0	69.99 ab*	46.67 a	73.33 a	100.0 a	26.67 bc	19.99 ab	39.99 ab	100.0 a
	6.0	86.67 a	49.99 a	69.99 a	93.33a	56.67 ab	46.67 a	66.67 ab	100.0 a
	10.0	89.99 a	49.99 a	66.67 a	80.0 a	76.67 a	56.67 a	63.33 ab	86.67a
BNE20	2.0	36.67 bc	39.99 a	53.33 a	100.0 a	39.99 abc	33.33 ab	36.67 b	100.0 a
	6.0	59.99 ab	46.67 a	43.33 a	100.0 a	46.67 ab	59.99 a	73.33 a	100.0 a
	10.0	76.67 a	46.67 a	53.33 a	86.67 a	76.67 a	36.67 ab	73.33 a	93.33a
Control	2.0	00.0 c	00.0 b	00.0 b	100.0 a	00.0 c	00.0 b	00.0 c	93.33a
	6.0	00.0 c	00.0 b	00.0 b	100.0 a	00.0 c	00.0 b	00.0 c	93.33a
	10.0	00.0 c	00.0 b	00.0 b	93.33 a	00.0 c	00.0 b	00.0 c	86.67a
Strain		*F*=78.76 *P*≤0.0001	*F*=32.59 *P*≤0.0001	*F*=49.75 *P*≤0.0001	*F*=1.09 *P*=0.34	*F*=37.06 *P*≤0.0001	*F*=23.72 *P*≤0.001	*F*=67.98 *P*≤0.0001	*F*=1.04 *P*=0.36
Time duration		*F*=4.58 *P*=0.02	*F*=0.17 *P*=0.85	*F*=0.19 *P*=0.83	*F*=4.82 *P*=0.009	*F*=8.05 *P*=0.001	*F*=3.41 *P*=0.04	*F*=8.27 *P*=0.001	*F*=2.38 *P*=0.09
Strain*time duration		*F*=1.53 *P*=0.22	*F*=0.06 *P*=0.99	*F*=0.19 *P*=0.94	*F*=0.39 *P*=0.82	*F*=2.45 *P*=0.06	*F*=2.08 *P*=0.1	*F*=2.3 *P*=0.08	*F*=0.15 *P*=0.96

* Means followed by the same letter in the same column are not significantly different (Tukey's HSD test after 2WCR.AOV; *df*=2 for strains, *df*=2 for duration time, *df*=4 for interaction between them).

Table 3. ANOVA parameters for main effects and associated interactions for colonization of *Beauveria bassiana* strains with three seed treatment durations in cucumber plants (Tukey–Kramer test after 2WCR.ANOVA).

	Strain*		Time durations**		Strain×time duration	
Source	*F*	*P*	*F*	*P*	*F*	*P*
Experiment 1						
Hypocotyl length	0.61	0.55	80.58	≤ 0.0001	6.130	0.0002
Root length	28.87	≤ 0.0001	58.59	≤ 0.0001	3.069	0.0200
Number of roots	6.06	0.003	30.63	≤ 0.0001	0.620	0.6500
Experiment 2						
Hypocotyl length	0.07	0.93	205.05	≤ 0.0001	1.330	0.2600
Root length	28.38	≤ 0.0001	32.72	≤ 0.0001	0.990	0.4100
Number of roots	9.91	0.0001	55.33	≤ 0.0001	2.140	0.0800

* Strain represents BS195, BNE20, and control treatment; Time durations represent 2, 6, and 10 h; *df*=2 for strains, *df*=2 for duration time, *df*=4 for interaction between them.

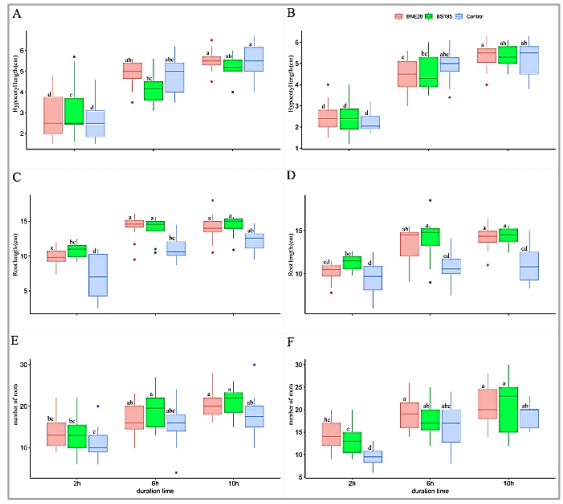

Figure 1. The effects of seed cucumber inoculation with *Beauveria bassiana* (strains BS195 and BNE20) and different seed treatment durations (2, 6, and 10 hr) on hypocotyl length, root length, and the number of roots (mean ± SE), ten days post-treatment. A, C, and E represent the first experiment, and B, D, and F represent the second. Box plots with different letters differ significantly among all seed treatment durations at P = 0.05 (Tukey–Kramer test after 2WCR.ANOVA).

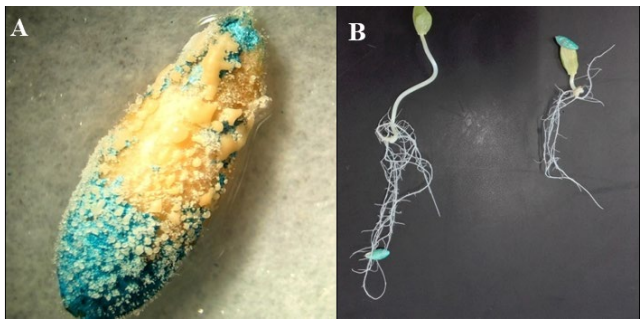

Figure 2. The effects of seed cucumber inoculation with *Beauveria bassiana* on plant growth parameters in vitro, A: an ungerminated seed covered with fungal conidia; B: a seedling inoculated with *B. bassiana* (left) and control (right).

Effect of cucumber plant inoculation with fungal suspension on plant protection from insect pests under greenhouse conditions

Results obtained showed that no significant differences in the incidence (%) of agromyzid leaf miners (*df* = 2; *F* = 1.08; *P* = 0.35), aphids (*F* = 1.08; *P* = 0.35), or whiteflies on cucumber plants.

The strain BNE20 has significantly reduced the infestation rate (%) (*F* = 2.24; *P* = 0.13) and the infestation severity (%) (IS) (*F* = 2.58; *P* = 0.09) with agromyzid leaf miner on inoculated cucumber plants, while BS195 had no significant effects (Table 6).

Fungal colonization showed a highly significant effect on the size of aphid populations (*F* = 8.96; *P* = 0.001). Both fungal strains, BS195 and BNE20, were able to reduce aphids population density on cucumber to 17.5 (±5.03) and 23 (±5.05) aphids/plant, respectively, in comparison with 253.8 (±77.75) aphids/plant on the control plants, achieving reduction rates of 93.1 and 90.94%, respectively. In addition, both strains reduced infestation severity to 38 and 44 %, respectively, compared with 74% for the control (Table 6). Whereas the infestation severity with whiteflies in control plants was 77.5%, cucumber plants endophytically colonized with BS195 and BNE20, showed a significant reduction in the infestation severity (52.5 and 50%, respectively) (Table 6).

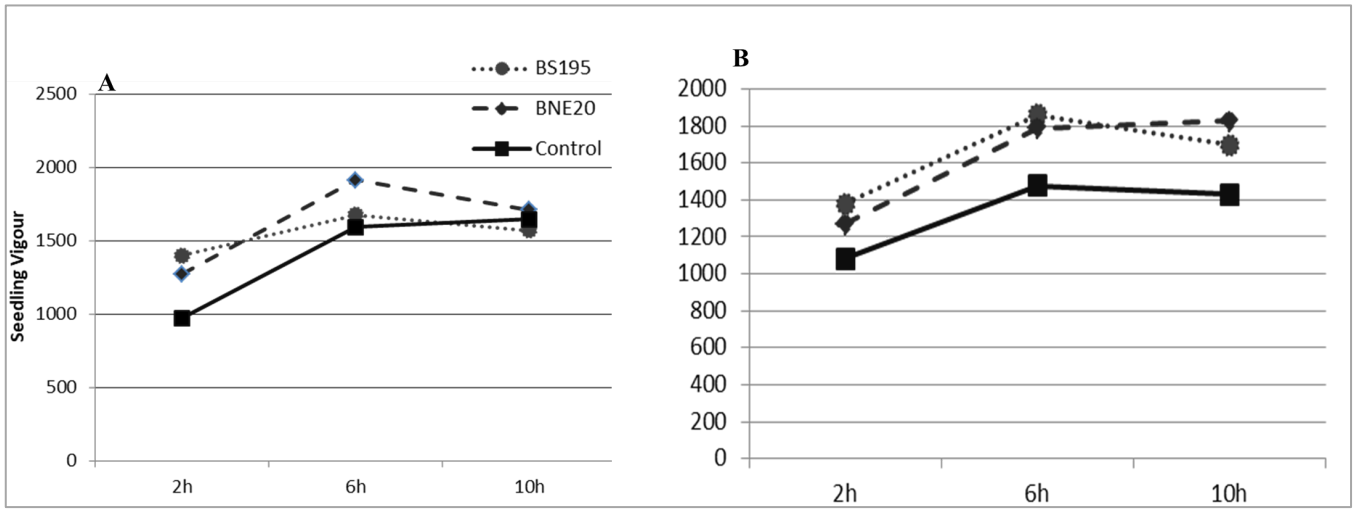

Figure 3. The effects of seed cucumber inoculation with *Beauveria bassiana* (strains BS195 and BNE20) and different seed treatment durations (2, 6, and 10 hr) on seedling vigor, ten days post-treatment. Letters A and B represent the first and the second experiments, respectively.

Table 4. Effect of root cucumber inoculation with *Beauveria bassiana* (strains BS195 and BNE20) on plant growth and production parameters, 43 days post-treatment under greenhouse conditions.

	Plant growth parameters (Means ± SE)									
Treatment	Plant Height (cm)	Root length (cm)	Leaves No.	Fruits No.	Wet fruit weight (g)	Wet shoot weight (g)	Wet root weight (g)	Dry shoot weight (g)	Dry root weight (g)	DMC %
BS195	151.79 a*	20.41 ab	29.3 a	20.9 a	269.65 a	113.17 a	5.084 a	16.17 a	0.83 a	14.49 a
BNE20	144.08 ab	21.8 a	25.8 a	18.1 a	206.798 a	90.38 a	5.47 a	11.36 b	0.94 a	12.81 a
Control	112.20 b	15.3 b	19.4 b	12.7 b	118.11 b	61.86 b	4.024 a	8.601 b	0.79 a	14.009 a

* Means followed by the same letter in the same column are not significantly different at *P* = 0.05 (LSD test after One way ANOVA).

Table 5. Effect of root cucumber inoculation with *Beauveria bassiana* (strains BS195 and BNE20) on plant colonization, 43 days post-treatment under the greenhouse conditions.

	Means ± SE		
Treatment	**Stems**	**Leaves**	**Roots**
BS195	69.99 a*	56.67 a	86.67 a
BNE20	49.99 a	49.99 a	93.33 a
Control	00.00 b	00.00 b	00.00 b

* Mean followed by the same letter in the same column are not significantly different at $P = 0.05$ (LSD test after One way ANOVA).

Table 6. Effect of root cucumber inoculation with *B. bassiana* (strains BS195 and BNE20) on plant infestation with agromyzid leafminers, aphids, and whiteflies, 43 days post-treatment under greenhouse conditions.

	Mean ± SE*						Whiteflies infestation	
	Agromyzid leaf miners infestation			Aphids infestation				
Treatment	**PI %**	**IF %**	**IS %**	**PI %**	**Population size (aphid/plant)**	**IS %**	**PI %**	**IS %**
BS195	90.0 a	17.93 ab	7.28 ab	80.0 a	17.5 b	38	100 a	52.5
BNE20	80.0 a	12.95 b	5.06 b	100 a	23.0 b	44	100 a	50.0
Control	100.0 a	25.14 a	10.89 a	90.0 a	253.8 a	74	100 a	77.5

* The severity of infestation of agromyzid leaf miners was calculated for each infested plant separately, so its results were shown as a mean ± SE, while the severity of infestation of each of aphids and whiteflies was calculated for the infested plants in general, so their results were shown as one value.

Discussion

In this study, two strains of the EPF *B. bassiana*, one isolated from soil substrate and the other from cucumber tissues, were able to enhance cucumber plant growth in vitro and under greenhouse conditions and protect it against insect pest attacks. The findings showed that soaking cucumber seeds with *B. bassiana* spore suspension and extending the duration of the treatment substantially increased the length of the hypocotyl and the length and number of the roots 10 days after seed inoculation. However, the presence of *B. bassiana* growth on some ungerminated seeds (three seeds) deserves further study to get a better understanding of this phenomenon and its impact on the use of *B. bassiana*. This failure in germination may be due to the vigor of the seeds themselves, and the fungal outgrowth appeared later due to the very high humidity in the plate, because the filter paper was kept moist. The positive effects of increasing the seed treatment duration of endophytic EPFs on enhancing plant growth were first reported by Jaber & Enkerli (2016) in faba bean plants (*Vicia faba* L.) and was demonstrated later in chili plants (*Capsicum annuum* L.) (Trizelia, 2020), and in cabbage (*B. oleracea* var. *capitata* L.) (Yunisman *et al*., 2023).

Results also showed that dipping the cucumber roots in the fungal suspension prior to planting enhanced several growth and production parameters under greenhouse conditions such as root length, plant height, fruit number, leaf number, fresh fruit and shoot weight, and dry shoot weight. This role of the fungus *B. bassiana* as a PGP has been reported earlier in many different plants such as wheat (Sánchez-Rodríguez *et al*., 2018), corn (Kuzhuppillymyal-Prabhakarankutty *et al*., 2020), tomato (Barra-Bucarei *et al*., 2020), rice (Akter *et al*., 2023), and cacao (Hanada *et al.*, 2010), and showed a high increase in morphological growth and production parameters of the colonized host plants. In cucumber plants, few studies have investigated the role of the fungus *B. bassiana* as a PGP under controlled conditions. Homayoonzadeh *et al*. (2022) studied its effects on plant height, stem diameter, number of nodes/plant, and total yield (kg fresh weight of fruit per plant) of cucumber plants after foliar application. Shaalan *et al*. (2021) examined the number of leaves, flowers, and fruits, and the plant height after fungal seed treatment. Both reported an enhancement in most studied parameters. To the best of our knowledge, the present study is the first report examined the impact of *B. bassiana* in enhancing cucumber plant growth and production after the root soaking method under uncontrolled conditions in the greenhouse.

Beauveria bassiana is widely known as an effective plant protector from different insect pests through direct spray on the target pest or following colonization of plant parts (Bamisile *et al*., 2018; Begum & Tamilselvi, 2016). However, studies investigated its efficacy against cucumber insect pests are still very limited and were conducted mainly using foliar application of this entomopathogen. They showed its potential in controlling the cotton aphid, *Aphis gossypii* Glover (Homayoonzadeh *et al*., 2022; Mseddi *et al.*, 2022; Shaalan *et al*., 2021), the whitefly, *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae) (Ghongade & Sangha, 2021), and the western flower thrips *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) on cucumber plants (Jacobson *et al*., 2001). Results of this study demonstrated its ability to reduce the infestation rate and infestation severity of several insect pests, including the leaf mining insect (*Liriomyza* sp.), aphids, and whiteflies on cucumber plants grown in greenhouse after inoculating the seedlings roots with a spore suspension.

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الملخص

رجب، لبنى، إبتسام غزال ومحمد أحمد. 2026. تعزيز نمو وإنتاجية محصول الخيار وحمايته من الآفات الحشرية بإستخدام الفطر الممرض للحشرات داخلي النمو *Beauveria bassiana*. مجلة وقاية النبات العربية، 44(2):281–289. https://doi.org/10.22268/AJPP-001394

استخدِم في هذا البحث سلالتان من الفطر الممرض للحشرات *Beauveria bassiana* (Bals.) Vuil. لإلقاح نباتات الخيار بطريقة نقع البذور لفترات زمنية مختلفة (2، 6 و 10 ساعات) في التجربة المختبرية، وغمر الجذور في تجربة البيت المحمي، وذلك بهدف دراسة تأثير إلقاح النبات بالفطر الممرض للحشرات في إنبات البذور، ونمو وإنتاج النبات، ومنع إصابته بالآفات الحشرية ضمن ظروف البيت المحمي. أظهرت نتائج الدراسة المختبرية زيادة معنوية في كلٍّ من طول البادرات وعدد جذورها وفي حيويتها بعد 10 أيام من نقع بذور الخيار بالمعلّق البوغي للفطر لفترات زمنية مختلفة، مع عدم وجود تأثير معنوي على إنبات البذور. أدّت زيادة مدّة نقع البذور إلى زيادة في طول الساق. كما لوحظت زيادة معنوية في بعض مؤشرات نمو وكتلة النبات بعد 43 يوماً من استعمال الفطر في ظروف البيت المحمي، مثل عدد الأوراق وعدد الثمار والوزن الرطب للثمار والوزن الرطب والجاف للمجموع الخضري وارتفاع النبات وطول الجذور. تمكّنت عزلتا الفطر من خفض نسبة وشدّة الإصابة بكل من حافرات أنفاق الأوراق والمنّ والذباب الأبيض على نباتات الخيار في البيت المحمي.

كلمات مفتاحية: استيطان، فطور داخلية، فطور ممرضة للحشرات، نسبة الإصابة، شدّة الإصابة، تعزيز نمو النبات.

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