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BRIEF RESEARCH ARTICLE

The New Rhizospheric Bacteria *Brevibacillus* Benefits Eggplant and Peeper Growth and Productivity Under Organoponic System

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Abstract Eggplant and pepper are horticulture crops with a worldwide distribution, dietary, and culinary importance. In developing countries, they are mainly cultivated under organic amendments as the organoponic system applied in Cuba. In the present research, the plant growth promoting strain B65 of *Brevibacillus* sp. was applied as inoculant on eggplant and pepper crops cultivated in two organoponics that belong to the urban agriculture program of Santiago de Cuba. Influence of B65 inoculum on plants' growth and crops' yield was evaluated. Inoculation of the strain B65 significantly increased plants' height, number of flowers, and number of fruits per plant as fruits size, weight, and yield. It also increased the root fresh matter. The beneficial effects of B65 under organic amendments could be related with its previously reported plant growth-promoting traits. The present research shows for the first time biostimulating and biofertilizing effects of *Brevibacillus* sp. inoculation in horticulture crops and reveals that *Brevibacillus* sp. strain B65 could be applied as part of sustainable agriculture strategies.

Keywords Eggplant · Pepper · *Brevibacillus* · PGPR · Organoponic · Biostimulation · Biofertilization

Introduction

Eggplant (*Solanum melongena* Linn.) and pepper (*Capsicum annuum* Linn.) are members of the Solanaceae family which are becoming important vegetable crops worldwide with a dietary and culinary importance due to their concentration of vitamins and other antioxidants substances [2, 9]. Eggplant has antifungal properties and reduces serum cholesterol levels [5]. Its worldwide production is of more than 40 million tons per year [9].

Eggplant and pepper crops in Cuba are mainly cultivated through organoponic system, where they are organically fertilized with manure, earthworm composts, and sugarcane residues [16]. These amendments contribute to soil health and are rich sources of mineral nutrients for plant growth [8]. Other essential substances may be supplied through the physiological activity of plant growth promoting rhizobacteria (PGPR) [4], which have the potential to enhance plant growth and productivity through a variety of mechanisms [7]. A number of Gram-negative genera as *Pseudomonas*, *Azotobacter, Azospirillum,* and *Beijerinckia* have received considerable attention as potential inoculants [15]. In addition, *Bacillus* and related aerobic endospore forming bacteria (AEFB) are receiving attention, mainly due to their ability to survive under stressful conditions by endospore formation [10].

Brevibacillus sp. B65 is an AEFB isolated from sugarcane rhizosphere, which showed plant growth-promoting

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potential in in vitro experiments [12]. Recently, the strain B65 showed significant stimulating properties on seedlings' germination of eggplant and pepper grown under organic amendments and in greenhouse conditions [11]. In the present investigation, the effects of *Brevibacillus* sp. B65 on eggplant and pepper growth and productivity were evaluated, when they were cultivated under organic amendments and in uncontrolled climatic conditions.

Materials and Methods

The strain B65 of *Brevibacillus* sp. was previously isolated from sugarcane rhizosphere and its PGP traits were reported [12]. There were used seeds of eggplant (*S. melongena* Linn.), cultivar FHB-1, and pepper (*C. annuum* Linn.), variety Chay, Line 3, both from the National Research Institute for Tropical Agriculture (INIFAT), Havana.

The experiments were conducted in parallel from March to July 2012 under field and in open sky conditions in two horticulture gardens, using the Cuban organoponic system [13]. The horticulture garden La Ketty (organoponic La Ketty), a peri-urban area placed at 5.7 km from Santiago de Cuba city and in the experimental garden of the National Centre of Applied Electromagnetism (CNEA's experimental garden), an urban area located in Santiago de Cuba city.

The inoculum of *Brevibacillus* sp. B65 was prepared following the methodology proposed by Erturk et al. [6]. The strain B65 was grown in nutritive broth (NB) at pH 7 and 30 °C for 18 h under agitation (150 rpm). The culture grown was centrifuged at 5000 rpm and the concentrated cells biomasses were suspended in distilled and sterilized water up to a cell concentration of 10^7 CFU mL^{-1} (adjusted by turbidimetry).

Three hundred seeds of eggplant and pepper were bacterized with a previously prepared suspension of *Brevibacillus* sp. B65 and grown under greenhouse conditions for 25 days. Twenty-five days old plantlets were transplanted to field and open sky conditions and cultivated under organic substrates. The organic substrate used in the organoponic La Ketty was a mixture of soil supplemented with caw manure (1:1) and the organic substrate used in CNEA's experimental garden was a mixture of soil and sugarcane-composted residue (1:1). The chemical characteristics of each organic substrate mixture were previously determined in the Laboratory of Soil Analysis (Agriculture Ministry of Santiago de Cuba). The climatologic data collected from January to December 2012 recorded an average temperature of 27.5 °C, a relative humidity of 68.9 %, and rainfalls of 79.6 mm.

The experiments were performed in a complete randomized block design with two treatments: T1 (control) and T2 (plants inoculated with B65). Four replications (R1–R4) per treatment of twenty plants each one were prepared. There were selected twenty plants per treatment (five for each replication) for the analysis, discarding those plants bearing border effect. In eggplant crop, plant height (PH) was determined in plants of 45 days after planting (DAP), in growing phase and number of flowers per plant (NFl/P) was determined in plants of 75 DAP, in flowering phase. The number of fruits per plants (NFr/P), fruits size (FrS), fruit yield (FrY), and fresh matter of roots (RW) were determined in plants of 100 DAP, in harvest phase. In pepper crop, PH and NFl/P were determined in plants of 45 DAP (growing and flowering phase). The number of fruits per plant (NFr/P), the FrY, and RW were determined in plants of 75 DAP (harvest phase). The FrY was expressed as the weight of fruits per cultivated area.

Statistical analysis was performed using a one-way analysis of variance (ANOVA) and the significant differences among the means were determined by Tukey's honest significant difference test at $p \leq 0.05$ using the software *Statgraphics Plus* 5.1 for Windows (http://www.statgraphics.com/statgraphics_plus.htm).

Results and Discussion

In Fig. 1, it can be seen that eggplant and pepper crops, grown from previously bacterized seeds with *Brevibacillus* sp. B65 and cultivated in the organoponic La Ketty and in CNEA's experimental garden, showed a significant increase in PH (Fig. 1).

Flowering of eggplant and pepper crops was also promoted through the inoculation with the strain B65. The NFl/P in eggplant and pepper plants treated with bacterial inoculum and cultivated in both experimental locations, was significantly increased compared with their controls (Fig. 2). In CNEA's experimental garden, NFl/P in bacterized and non-bacterized eggplant plants of 45 DAP was statistically similar and showed not differences with NFl/P determined in non-bacterized plants of 75 DAP. In contrast to, NFl/P significantly increased in bacterized eggplant plants of 75 DAP (Fig. 2a).

The NFr/P collected from eggplant plants of 100 DAP as the NFr/P collected from pepper plants of 75 DAP, was significantly increased in plants previously bacterized with the strain B65 compared with their controls. Eggplant and pepper fruits were also heavier and bigger in bacterized plants compared with the ones collected from non-bacterized plants (Table 1).

The inoculum of B65 also stimulated eggplant and pepper roots development. As shown in Table 3, eggplant

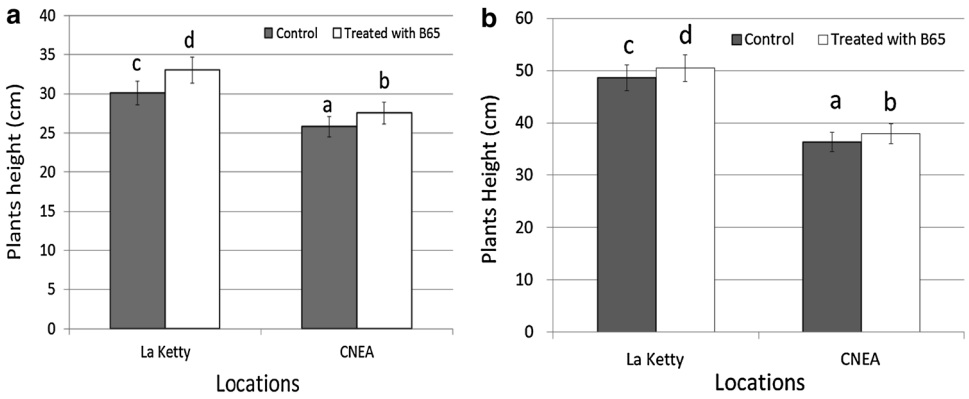

Fig. 1 Effects of *Brevibacillus* sp. strain B65 on eggplants (**a**) and pepper (**b**) plants height at 45 days after planting (DAP).Trials were conducted in the organoponic La Ketty and in CNEA's experimental garden between March and July 2012. *Bars* on columns represent standard deviation (σ) at 5 % error. Different letters mean significantly statistical differences between the treatments at $p \leq 0.05$

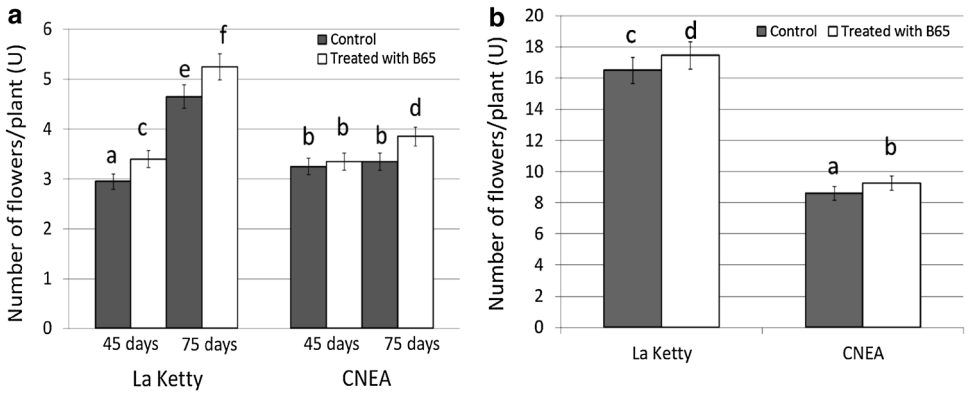

Fig. 2 Effects of *Brevibacillus* sp. strain B65 on flowering of eggplant plants of 45 DAP (**a**) and pepper plants of 75 DAP (**b**). Foot notes as in Fig. 1

Table 1 Effects of *Brevibacillus* sp. strain B65 on fructification of eggplant and pepper

Experimental locations	Eggplant fruits (100 DAP)						Pepper fruits (75 DAP)			
	Number of fruits (U)		Fruits size (mm)		Fruits weight (Kg)		Number of fruits (U)		Fruits weight (Kg)	
	Control	Treated with B65	Control	Treated with B65	Control	Treated with B65	Control	Treated with B65	Control	Treated with B65
La Ketty	3.4b	4.05c	88.9c	1011d	0.33c	0.356d	9.0c	10.35d	0.109c	0.117d
CNEA	2.85a	3.0a	65.3a	71.7b	0.27a	0.302b	8.7a	10.15b	0.098a	0.105b

Different letters mean significantly statistical differences between the treatments at $p \leq 0.05$

Table 2 Effects of *Brevibacillus* sp. strain B65 on eggplant and pepper fruits yield

Experimental locations	Fruits weight per cultivated area (Kg/m^2)			
	Eggplant (100 DAP)		Pepper (75 DAP)	
	Control	Treated with B65	Control	Treated with B65
La Ketty	4.511g	5.126h	1.072c	1.478d
CNEA	3.373e	4.233f	0.939a	1.109b

Different letters mean significantly statistical differences between the treatments at $p \leq 0.05$

and pepper roots fresh matter determined in treated plants, sampled from the organoponic La Ketty and CNEA's experimental garden, were statistically weightier than their controls for 95 % of confidence.

Inoculation with *Brevibacillus* sp. strain B65 positively influenced FrY. Eggplant FrY (5.12 kg m^{-2}) determined in the organoponic La Ketty was higher than the historically recorded for eggplant crop in Cuba (3.5–4.5 kg m^{-2}) [1].

Table 3 Effects of *Brevibacillus* sp. B65 on eggplant and pepper root fresh matter

Roots fresh matter (Kg)				
Experimental locations	Eggplant		Pepper	
	Control	Treated with B65	Control	Treated with B65
La Ketty	0.102c	0.111d	0.047c	0.055d
CNEA	0.085a	0.093b	0.034a	0.039b

Different letters mean significantly statistical differences between the treatments at $p \leq 0.05$

Pepper FrY, which was seriously affected in untreated plants cultivated in both experimental locations, reached-up in treated plants from the organoponic La Ketty a yield of 1.478 kg m^{-2}, nearby to the historically reported for pepper crop in Cuba (1.5–2.0 kg m^{-2}) [1] (Tables 2, 3).

The results presented in the study revealed for the first time—the stimulating effects of an isolate of *Brevibacillus* genus (strain B65) on growth and productivity of eggplant and pepper crops, grown under organic amendments in summer-like climatic conditions. Literature reports about plants' height stimulation, roots development, and grains yield increase by AEFB inoculants have been restricted to strains of *Bacillus* and *Paenibacillus* [7, 10]. Although *Brevibacillus* strains have been frequently isolated from bulk soil and rhizosphere samples, showing antifungal and P-solubilization activities [3, 14], nothing have been published about its effects as plant inoculant until this moment.

Conclusions

Brevibacillus sp. strain B65 showed plant biostimulating and biofertilizing effects which could be related with in vitro plant growth-promoting traits previously reported [12]. Nevertheless, results presented here are preliminary. The presence of the strain B65 on eggplant and pepper rhizosphere must be determined, as the increase of available P content in inoculated soils. However, stimulation of eggplant and pepper growth and productivity in urban agriculture systems as evaluated in the present research, suggests that B65 could be used as part of sustainable agriculture strategies, favoring an efficient use of organic amendments for horticulture crops fertilization.

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