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Original Research Article

The effects of a biofertilizer containing growth-promoting bacteria on the eggplant (Solanum melongena L.)

ABSTRACT

The use of organic fertilizers in the cultivation of vegetables is important in the pursuit of increased production to improve the physical, chemical and biological characteristics of soil, to promote plant growth, and to achieve economically viable productivity for farmers of small- and medium-sized farms. This study aimed to evaluate the development and productivity of eggplant after its fertilization with a biofertilizer that was composed of sugar and alcohol waste and a bacteria growth promoter for plants. The Ciça genotype of eggplant plants were distributed in 20 pots with a capacity of 10 L for each pot. The experiment was conducted using a completely randomized design with four treatments and five repetitions. The following treatments were analyzed: control (without any fertilizer), chemical fertilizer (NPK), manure and biofertilizer. The analyzed parameters included height, stem diameter, weight and number of fruit. The treatments that received some type of fertilizer (chemical or organic) showed higher plant height, and the 'bio-fertilizer' treatment showed better results than the remaining treatments for all parameters. The results for growth in height, stem diameter and number of fruit demonstrated that eggplant adequately responded to fertilization with biofertilizer in the experimental conditions and in relation to the assessed conventional fertilizers.

Keywords: ***Pseudomonas fluorescens, filtercake, vinasse, microorganisms***

1. INTRODUCTION (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

For the production of different species of vegetables, which are typically grownin intensive cultivation conditions, an adequate supply of nutrients is required from the seedling stage to the harvest stage, considering that nutritional imbalance, which indicatesa lack or excess of nutrients, is a stressor to plants [1].

An alternative for the preparation of biofertilizers is the combination of fertilizer with *Pseudomonas* rhizobacteria, which promotes growth in plants[2, 3]. These microorganisms are active in nutrient transformations in soil, which influence their solubility and availability to plants.

The most beneficial species of the genus *Pseudomonas. fluorescens* [4]. These bacteria fix atmospheric nitrogen, degrade aromatic compounds, and promote the regulation of the synthesis of plant growth and other antagonistic metabolites, as well as siderophores, lytic enzymes (glucanases and chitinases) and antibiotics [5]. These species have been extensively investigated due to their positive interaction with the growth, development and resistance of crops, such as tomatoes, lettuce and citrus[6,7].

The eggplant (*Solanum melongena* L.), which is a plant of Asian origin, has been introduced and employed for consumption since the Middle Ages. It belongs to the *Solanaceae* family, height that exceeds 1.0 m and well-developed side branches, hermaphrodite flowers and fruit of an elongated and dark form [8]. Eggplant is grown in Brazil in an area of approximately 1,500 ha; its increased consumption is attributed to its properties, which are beneficial to human health, and its ability to provide an alternative to vegetable producers [9].

The objective of this study is to evaluate the development and yield of eggplant from its fertilization with biofertilizer that is composed of sugar and alcohol waste and promoter bacteria from growing plants.

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2. MATERIAL AND METHODS

The experiment was conducted in a greenhouse on the IFPE – Vitoria de Santo Antão, Pernambuco Forest in the Greater Region, with the coordinates 8 ° 5'53 "S 35 ° 17'28" W and an altitude of 167 m. The climate is a type As climate, which is characterized as warm tropical and humid with autumn and winter rains according to the Köppen classification. The micro-region of Vitória de Santo Antão has high temperatures and a long dry season; the average annual rainfall is between 1,008 and 1,395 mm [10].

Eggplant seeds of the Ciça genotype were purchased from domestic businesses; theysatisfy all quality specifications (ISLA – Rio Grande do Sul – Brazil). The test microorganism that was employed in this study—*Pseudomonas fluorescens*—was purchased from the Microorganisms Reference Collection of the National Health Institute (FIOCRUZ – Rio de Janeiro – Brazil). The culture was maintained on nutrient agar (NA) at 28 °C. Aliquots of bacterial cultures were diluted in saline (0.85 g/100 mL) until a concentration of approximately 10^8 UFC/mL, which corresponds to the range of 0.5 McFarland, was attained. The soil employed in the experiment was obtained in the IFPE- Vitória area and is classified as Chromic Acrisols [11]. The soil chemical properties, which were determined according to [12]are listed in (Table 1). Soil correction was performed with hydrated plaster at a dose of 685 $Kg.ha^{-1}$ [13].

Table 1. Soil chemical properties employed in the experiment.

pH (H_2O)	Ca^{2+}	Mg^{2+}	K^+	Na^+	SB	Al^{3+}	CTCe	(H+Al)	T	v	m	P
	----------Cmolc/dm3----------									%		$mg.dm^{-3}$
5,48	1,67	3,73	0,20	0,19	5,79	1,37	7,16	4,83	11,99	48,29	19,13	10,37

The chemical fertilizer (NPK) consisted of urea, superphosphate and potassium chloride. The cattle manure was obtained in the cattle sector of IFPE –Vitória. The biofertilizer was composed of a mixture of derivatives of sugarcane products (filter cake and vinasse) and the bacterium *Pseudomonas fluorescens* inoculum in the concentration of 10^8 UFC/mL. The filter cake was collected in the Santa Tereza sugarcane industry, which is located in the Goiana District and the vinasse was collected in the JB sugarcane industry, which islocated in the Vitoria de Santo Antão District of Pernambuco state, Brazil.

Initially, eggplant seeds of the Ciça genotype were manually sown in a Styrofoam tray that contained 200 cells. The substrate consisted of a mixture of soil and cattle manure in a 2:1 proportion. Micro irrigation was performed throughout the crop cycle. Thinning was conducted fifteen days after sowing to obtain one plant per cell. Transplanting was performed when the average height of the seedlings was ten centimeters, which occurred after 45 days. The treatments were distributed in 20 pots with a capacity of 10 L for each pot. Due to the absence of pests and diseases, pesticides were not utilized.

The experiment was conducted using a completely randomized design with four treatments and five repetitions. The following treatments were analyzed: control, chemical fertilizer, manure and biofertilizer.

The control treatment contained soil without any fertilizer. The chemical fertilizer treatment (NPK), which consisted of urea (0.5g per pot in planting + 0.75g per pot in cover) superphosphate (2.8g per potted planting) and potassium chloride (0.5g per pot in planting + 0.33g per pot in cover), was placed according to the soil analysis and the recommendations for culture in the state of Pernambuco [14].The manure treatment contained only cattle manure. The biofertilizer treatment was composed of a mixture of derivatives of sugarcane products (filter cake and vinasse) and the bacterium *Pseudomonas fluorescens* inoculum in the concentration of 10^8 UFC/mL. The addition of manure and bio-fertilizer was performed according to the organic fertilizer recommendation for culture in the state of Pernambuco [14].

Each batch of biofertilizer was obtained by mixing 5.5 kg of filter cake that was dry in the air, 300 ml of the bacterial inoculum, 400 ml of distilled water and 2.5 L of vinasse to obtain a homogeneous material with a moisture level that was similar to the moisture level of the field capacity.

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The analyzed parameters included the height, stem diameter, weight and number of fruit. Plant height (cm) was determined by measuring the plant cervix to the upper edge using a ruler that was graduated in centimeters (cm). The stem diameter was estimated to be 150 mm by performing measurements close to the ground with the aid of a digital caliper model. Measurements were obtained for all plants for each repetition of four treatments. To determine the weight and number of fruit, one sample was extracted per week for four weeks.

Variables were submitted to analysis of variance (ANOVA), where the F test was significant for diameter, plant height, root and aboveground biomass, fruits number and wet fruit weight. The regression analysis and the Tukey test was performed to compare each treatments.

3. RESULTS AND DISCUSSION

For dry root mass and dry shoot mass treatment with biofertilizer stood out among the others, showing the best results (Table 2). [15] found higher values of root growth in lettuce plants inoculated with isolates of *Pseudomonas fluorescens*.

Table 2. Root and aboveground biomass, fruits number and fresh fruit mass from eggplants after 80 days of transplanting.

Treatments	MSR	MSPA	Number of fruits	weight fruit
	g plant^{-1}			g plant^{-1}
Control	3,50 c	6,00 d	0,00 b	0,00 c
Chemical fertilizer	19,00 b	27,60 c	1,40 a	149,67 b
Cattle manure	16,00 b	40,40 b	0,40 ab	9,00 c
Biofertilizer	49,33 a	73,67 a	2,60 a	266,33 a
CV (%)	8,86	5,56	15,21	17,08

[*] *The averages followed by the same letter in the column do not statistically differ based on the Mann-Whitney test (p < 0,01).*

[16] found a positive correlation between shoot dry mass onion and inoculation of bacteria growth promoter isolates, being that isolated from *Pseudomonas fluorescens* was the one who most influenced these results. [17] found out that isolates of *Pseudomonas fluorescens* promoted increment in the development and biomass of lettuce plants.

Several studies report that endophytic microorganisms are able to promote plant growth in different plants. PGPR like Pseudomonas are of particular interest because of the intrinsic ability of certain strains to colonize the rhizosphere at a high density, to compete successfully with other microbes, and to produce secondary metabolites involved in plant growth stimulation and induced systemic resistance to biotic stress posed by pests and pathogens [18].

Regarding the number of fruit (Table 2), no significant difference between the biofertilizer treatment and chemical fertilizer treatment was observed, which differed from the cattle manure treatment and the control, which yielded the lowest average. This result is probably attributed to the potential slow release of the nutrients in the biofertilizer. The deficiency or excess of some nutrients can directly affect the fruit yield and quality. Nitrogen and potassium, for example, are nutrients that significantly affect the quality of fruit; they are applied in optimal ratios and amounts to the culture and may enhance the physical and chemical characteristics of fruit [19].

The results of this study corroborate the results obtained by [20], who determined that eggplant adequately responds to fertilization and organic management, including productivity similar to other cropping systems.

A larger number of fruit in treatment with biofertilizers are also observed by [21], who claim that vegetables adequately react to the use of solid organic fertilizers and that biofertilizer is noteworthy because its composition nutrients are readily available compared with other organic fertilizers.

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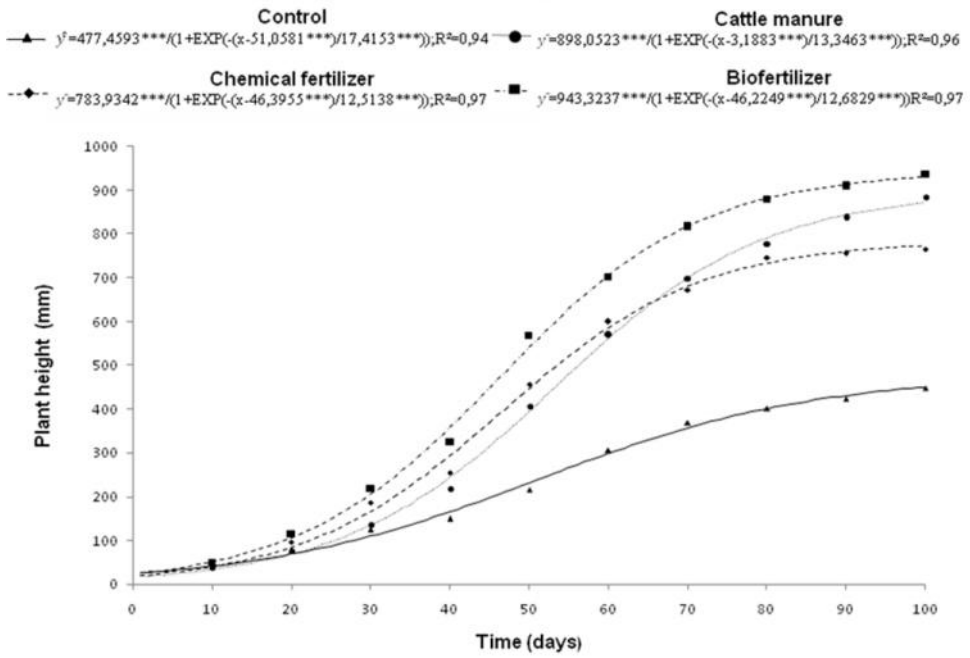
Treatment with biofertilizers also showed higher fruit weight (Table 2). Thus, the best performance in the number and weight of fruit for treatment with biofertilizers is because this material contains vinasse. Still age is a byproduct of sugarcane, which contains a significant amount of potassium. According to [22], potassium important is in production and fruit formation as participates in carbohydrate metabolism, which directly influences the productivity and maintenance of the turgor leaf, which is essential in the internal transport of sugars and the electrochemical balance of the plant.

With regard to plant height (Figure 1), the results show that the bio-fertilizer yielded higher values than the remaining treatments. This occurrence was possibly attributed to the presence of the bacteria of the genus *Pseudomonas* sp., which was added to the organic material employed in this treatment.

Figura 1. Plant height of eggplants submitted to different treatments of fertilization as a function of time.



The bacteria that belong to the genus *Pseudomonas* sp. have the ability to produce different substances that accelerate plant growth, especially in the early stages, and induce growth and root formation [23]. The major stimulator substances include hormones, such as auxins, cytokinins and gibberellins, as well as other types of substances, such as amino acids and specific growth promoters [24].

Another factor that may have enhanced the positive action of bio-fertilizer in the plant height is the inclusion of vinasse in its constitution, which is abundant in potassium. [23] suggested that the potassium presence in a greater or less eramount was sufficient for establishing the differences in plant height.

Within 40 days after transplanting, different treatments were provided to plants, such as growth behavior, although treatment with biofertilizer has achieved greater plant height values from 20 days after transplanting.

Between 40 and 50 days, a significant increase in the growth rate was observed for the treatments, with the exception of the control. After 60 days, the tendency of stabilization of this growth, which coincided with the beginning of the production phase of the plants, was observed.

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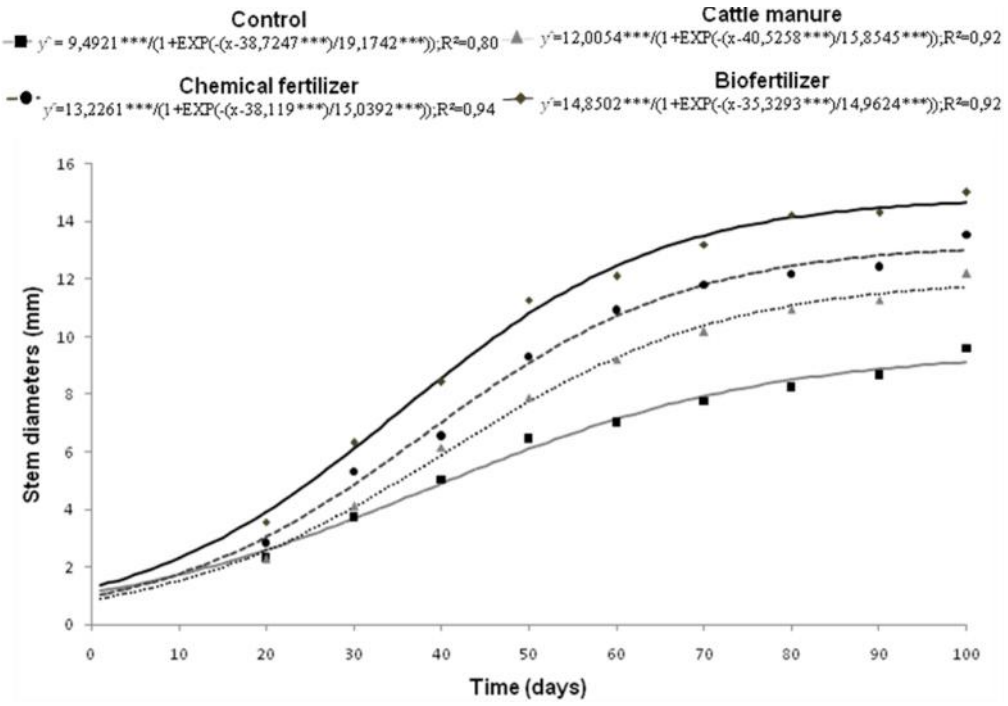
The decrease in vegetative growth 60 days after transplanting may be related to the beginning of the plant production period. [25] also found that lower relative growth rates in plant height and stem diameter coincide with the reproductive phases of the plant.

After 70 days, the treatment with bovine manure exceeded the average height of a chemical fertilizer. This finding is probably attributed to the notion that the mineral topdressing occurred after 20, 40 and 60 days after transplanting. After this period, the availability of nutrients in the chemical fertilizer, which is more soluble, may have decreased. Thus, the manure may have enabled a gradual release of nutrients, which enabled this material to continue to supply nutrients to plants for a longer period, especially nitrogen, which directly affects plant growth.

These results corroborate the results obtained by [26], who also observed a positive correlation between the application of manure and the growth of eggplant. According to [27], the release of nutrients in cattle manure is gradual compared with other organic materials, such as chicken litter.

For the stem diameter (Figure 2), the treatment with biofertilizer continued to present higher averages than the other treatments. This finding is attributed to the presence of growth-promoting bacteria in the material, which contributes to an increase in the growth rate of plants, germination, root growth, and the growth of stalks or stems.

Figure 2 – Stem diameters of eggplants submitted to different treatments of fertilization as a function of time.



[28] observed that leachate added with *P. fluorescens* and G. fasciculatum affected stem diameter, and the soluble solids and pH of the tomato fruits.

[29] noted that rhizosphere bacteria, such as *Pseudomonas fluorescens*, can stimulate plant growth and reduce the incidence of nematodes by antagonism. [30] found higher average plant height in the presence of *P. fluorescens.* The same was observed in [31], which had significant differences in height of corn plants in the presence of *Pseudomonas*.

As noted for plant height, stem diameter also yielded values of a stabilizing trend for the plant flowering period (60 days after transplanting).

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Increased force production is frequently due to a reduction in vegetative growth. Recent studies, for example, have indicated that spraying apple trees with gibberellin biosynthesis inhibitor can reduce vegetative growth and improve fruit quality [32]. Its application before the harvest regulator prohexadione-calcium growth (ProCa) reduces vegetative growth and the competition between branches and fruits by available photoassimilates can generate a greater quantity and quality of fruit [33].

4. CONCLUSION

The results revealed that eggplant plants of the Ciça genotype shows a better response to organic fertilizer with bio-fertilizer than the response of conventional fertilizers. The biofertilizer prepared with *Pseudomonas fluorescens* is a promising alternative to conventional fertilization in the eggplant culture.

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APPENDIX