ORIGINAL ARTICLE

Evaluation of the Application of Biocarbon in the Cultivation of Bananas

Evaluación de la aplicación de biocarón en el cultivo del plátano

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ABSTRACT: The banana is a crop of great importance for providing a food with a high rate of fresh consumption within the Cuban diet. For several regions of the world, it is considered a species whose agronomic value lies in its great seasonal production, for which its obtaining methods need to be developed to achieve high rates of this. The object of the study was to evaluate the effect of two bioproducts on banana cultivation during the vegetative phase. The experiment was carried out at the "Seed Biofabrication" Institute located on the Jamaica highway and national highway, San José de las Lajas, Mayabeque province, between the months of July and August 2022. The experiment had four treatments: T1 Witness, T2 soil + organic matter, T3 soil + organic matter + Ecomic and T4 soil + organic matter + biochar + Ecomic. The variables evaluated were: pseudostem height (cm), number of leaves/plants, pseudostem diameter (cm), leaf area (cm) and chlorophyll concentration. The data obtained from the test were evaluated under the analysis of variance and the comparison of means was verified by Tukey's test at 5% probability. The results obtained showed positive effects for treatments three and four comprised of soil + organic matter + Ecomic and soil + organic matter + Ecomic + biochar where they showed a tendency to increase the parameters evaluated.

Keywords: Bioproduct, Ecomic, Soil, Food, Vegetative Phase.

RESUMEN: El plátano es un cultivo de gran importancia por brindar un alimento de elevado índice de consumo fresco dentro de la dieta del cubano. Para varias regiones del mundo, es considerado una especie cuyo valor agronómico reside en su gran producción estacional, por lo cual necesita desarrollarse sus métodos de obtención para alcanzar altos índices de esta. El objeto del estudio fue evaluar el efecto de dos bioproductos en el cultivo del plátano durante la fase vegetativa. El experimento se desarrolló en el Instituto "Biofabrica de Semillas" ubicado en la carretera de Jamaica y Autopista Nacional, San José de las Lajas, provincia Mayabeque, entre los meses de julio y agosto 2022. El experimento contó con cuatro tratamientos: T1 Testigo, T2 suelo + materia orgánica, T3 suelo + materia orgánica + Ecomic y T4 suelo + materia orgánica + biocarbón + Ecomic. Las variables evaluadas fueron: Altura del pseudotallo (cm), Diámetro del pseudotallo (cm), Número de hojas/ plantas, Área foliar (cm). Los datos obtenidos del ensayo se evaluaron bajo el análisis de varianza y la comparación de promedios se verificó mediante el Test de Tukey al 5% de probabilidad. Los resultados obtenidos presentaron efectos positivos para los tratamientos tres y cuatro comprendidos por suelo + materia orgánica + Ecomic y suelo + materia orgánica + Ecomic + biocarbón respectivamente donde mostraron una tendencia al aumento de los parámetros evaluados.

Palabras clave: bioproducto, ecomic, suelo, alimento, fase vegetativa.

INTRODUCTION

Restoring severely damaged agroecosystems is one of the purposes of the scientific community. To achieve this, one of the indicators in need of attention is related to the balanced recovery of the biotic components of the soil, for which biofertilizers have been created that enrich the soil biota with beneficial organisms such as mycorrhizal fungi; nutrient fixation facilitators with the purpose of improving crop

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productivity. The plantain or banana (*Musa* sp.) is a fruit with a pleasant flavor that is characterized by its thick, yellow skin which is very easy to peel, and which is of great importance due to its ability to produce every month of the year and its high production volume. This represents more than 40% of the production of root vegetables and fruits in our country, which is why it is of vital importance for the nation's food security (Sepúlveda *et al.*, 2017).

However, the soils are provided with bioproducts that improve the physical, physicochemical and biological properties, which increase the growth indicators of the crop (Pérez-Hernández *et al.*, 2006).

The bioproduct that is easiest for producers to obtain is biochar, as the most used in the acclimatization and nursery stage, which offers greater crop production and contributes to improving soil quality, hence the interest in this practice. agroecological, since it increases the capacity to retain moisture and nutrients (Alburquerque-Méndez *et al.*, 2013).

It is some material rich in carbon, which is obtained from the thermo-chemical decomposition of organic residues at temperatures that generally range between 300 and 700 °C and in the absence of oxygen (pyrolysis) and which is intended for agricultural use, which makes it different from carbon used as fuel and activated carbon (Amin *et al.*, 2016).

For this reason, recovering the ecological balance of the soil brings as a consequence a decrease in damage to the crop, increasing diversity, in addition to strengthening the process of restoration of soils without economic damage, for which new and diverse methods are studied and used of agroecological management (Escalante-Rebolledo *et al.*, 2016).

Based on this analysis, the objective of this work was to evaluate the efficiency of the application of biochar in the growth of the plantain crop.

MATERIALS AND METHODS

The study was carried out in two locations, the first at CENSA (National Center for Agricultural Health), located on National Highway, 23 km 1/2, San José de las Lajas highway, and the second at the Seed Biofactory located at XRQX+458 , Jamaica highway and, National Highway, San José de las Lajas. This took place from July 22 to August 19, 2022.

Obtaining biochar

The biochar was obtained from artisanal pyrolysis carried out according to the protocol detailed in PNO-FI-039. This procedure consists of obtaining biochar from different parts of the plants, by the decoction method. This procedure is carried out with the objective of establishing a laboratory-scale methodology for the preparation of aqueous extracts from different plants of interest. The proportion of plant material-water, used for the extraction in this method, was 1/10, which remained constant for all crops. The biochar, after obtaining it, was sterilized using an autoclave for half an hour at 300 degrees Celsius in the CENSA Laboratory.

Characteristics of the soil used in the investigation

The experiments were carried out on a district agrogenic leached red ferralitic soil, according to Hernández *et al.* (2015) in the classification of the soils of Cuba, Xu *et al.* (2015) which correlates with the Soil Taxonomy.

The physiographic position of the place and the topography of the surrounding land are flat and the slope is less than 2%, with regular surface and internal drainage. Some of the main chemical characteristics of the soil are shown in Table 1.

TABLE 1. Some of the main chemical characteristics of soil

Characteristics	Unit	Value
Depth	cm	0-20
pH	H2O	6,4
O. M.	%	2,11
P	Mg^{-1}	234
K+	$cmolc \cdot kg^{-1}$	0.52
Ca_2+	$cmolc \cdot kg^{-1}$	9,93
Mg_2+:	$cmolc \cdot kg^{-1}$	1,80

*Source: Personal elaboration.

Climatic Variables

During the development of the experiments, the maximum, minimum and average air temperature, percentage of relative humidity (%) and rainfall (mm) were recorded at the Meteorological Station adjacent to the experimental area, processing the data throughout the experiment. In addition, the thermal amplitude (difference between maximum and minimum temperature) and the accumulated temperature were calculated, which is nothing more than the sum of the thermal amplitude from the moment of planting to the final evaluation (Table 2).

Methodology to carry out the experiments

The banana variety studied was Pisang Lilin (banana fruit), where a total of 56 seedlings were used. The seedlings were created by means of the in vitro culture technique in the laboratories of the seed biofactory, with 15 days of sprouting, later a selection is made by trained personnel to eliminate possible sources of infection and work with seedlings of better quality. quality. Treatments 2, 3 and 4 were inoculated with Trichoderma spp strain 13, as a means of protecting the rootlets of vitroplants against nematodes, whose solution was prepared at a rate of 20g/liter of water.

TABLE 2. Main climatic variables during the development period of the experiments

Months	Relative humidity, average, %	Temperature, ^{0}C			Precipitation, mm
		minimum	medium	maximum	
June	84	20.2	24,0	28,5	195,6
August	84	19,2	23,3	28,4	72,8

*Source: Personal elaboration

Preparation of the root ball and nursery for the transplant of vitroplants

Soil and sieved organic matter from the areas of the teaching and production unit "EL Guayabal" was used, which belongs to the Agrarian University of Havana "Fructuoso Rodríguez Pérez" (UNAH) of the San José de Las Lajas municipality located in the province Mayabeque, whose classification is typical Red Ferralitic according to Hernández *et al.* (2015). The Ecomic was donated by the Department of Biofertilizers and Nutrition of the National Institute of Agricultural Sciences (INCA), as well as the biochar, which was produced through pyrolysis at the Center for Agricultural Health (CENSA).

A tray of 247 alveoli was taken, disinfected with 1% chlorine, later the different treatments were prepared, which were:

T1 (Control): 100% Red Ferralitic Soil.

T2: 50% Red Ferralitic Soil + 50% Organic Matter.

T3: 50% Red Ferralitic Soil + 25% Organic Matter + 25% Ecomic.

T4: 25% Red Ferralitic Soil + 25% Organic Matter + 25% Ecomic + 25% biochar.

Once the treatments were formed, the alveoli were filled, for which an irrigation or mine was previously carried out and later the vitroplants were planted (14 plants were planted per treatment, including the control). The samplings were carried out weekly using a manual caliper (vernier caliper), for a total period of one month for the acclimatization phase (tray). After this period, the plants were carefully removed from the trays to be planted in 12.5 x 20 cm black nylon bags, to continue with the weekly evaluation of the parameters evaluated for a second period of one month. The total follow-up time of the experiment was two months.

Indicators evaluated throughout the experiment

Vitality: It was evaluated visually. For the vitality index, the number of seedlings per treatment was taken into account, the number of surviving plants was noted until the last evaluation and the percentage value was subsequently calculated.

Seedling length (cm): The height of the plants was measured in cm using a manual caliper (Vernier caliper) in the first two weeks and from the third week a graduated ruler began to be used due to the height of the pseudostem. The measurement was taken into account from the neck of the pseudostem to the exit of the leaf.

Pseudostem diameter (cm): The measurement was made with a manual caliper (Vernier caliper)

Number of leaves per plant: All visible leaves per plant were counted in each of the treatments.

Leaf surface: It was estimated from the linear measurements of all the leaves (length and width in cm) and the use of a formula previously obtained by linear regression for the variety under study Ramírez-Rivero (2018).

Chlorophyll concentration

It was obtained through the Spad team

Fresh mass and dry mass: Fresh mass (g): The plants of each treatment were taken, separating them by plot and weighed on a technical balance (Santorius 2kg ± 1 g)

Dry mass (g): To determine this indicator, the plant organs were separated and placed in paper bags and placed in a ± 5 0 recirculating air oven, where they were kept for 7 days at a temperature of 80 0C until constant weight and subsequently the dry mass was determined on an analytical balance (Sartorius of 160 ± 0.001 g).

*The data was recorded and stored in a database using the Excel tool of the Microsoft Office program.

Statistical analysis

For the experiments, four treatments with repetitions were used. Each trial consisted of fourteen seedlings, seven of which were evaluated taking into account the indicators described. In addition, in the first trial (tray phase), an ANOVA was used to evaluate the effects of the bioproducts, while the data obtained in the second trial (nursery) were analyzed and compared by a one-way ANOVA. In both trials, the comparison of means was performed using Duncan's multiple range test ($p<0.05$). All analyzes and statistical comparisons were performed using the IBM SPSS Statistics v.19.0 software.

Economic Evaluation

The economic evaluation of the results was evaluated using the indicators according to the methodology proposed by Arias *et al.* (2002).

RESULTS

Effect of bioproducts on plant height in banana cultivation

Figure 1, shows the effect of the different treatments on the development in height of the pseudostem of the plantain crop, it can be seen that there are significant differences over time in the different samplings carried out, showing the best results achieved by the combination of Ecomic and biochar, the latter being according to the data the component that significantly affected this variable the most. It can be seen that from the first treatment to the last one, already after 35 days, there were significant differences between the treatment that used biochar and those that did not.

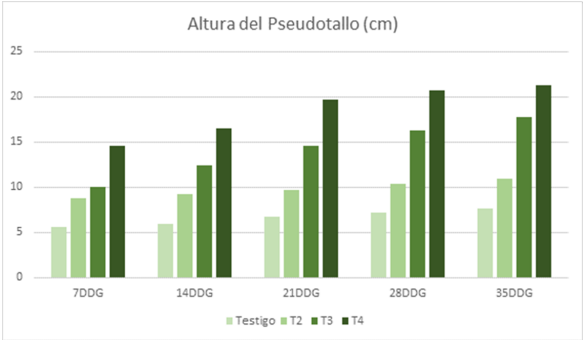

FIGURE 1. Effect of bioproducts on plant height in banana cultivation.

Effect of bioproducts on pseudostem diameter in banana cultivation

As Figure 2, shows us, there was a significant variability on this indicator in the different treatments, with treatments two and three being the ones that obtained the best results with a great difference and within these the one that used biochar was the one that most positively affected. It is worth mentioning that the seedlings presented a greater consistency in the treatments with bioproducts with respect to the control, this being of great importance since the plant depends on this vigor to face the other processes, that is, to go from the vegetative to the reproductive phase with good nutrition.

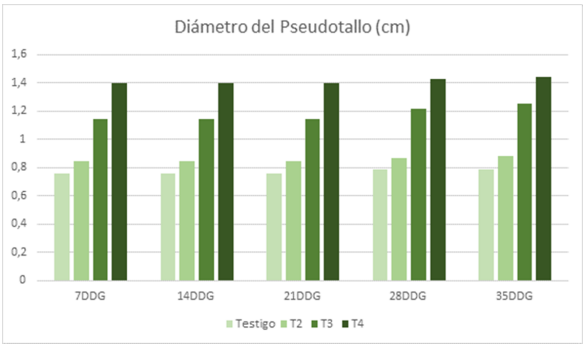

FIGURE 2. Effect of bioproducts on pseudostem diameter in banana cultivation.

Average number of leaves per treatment in different samplings

Figure 3, shows the average number of leaves per treatment in plantain plants from 7, 14, 21, 28 and 35 days, highlighting that in the treatment where biochar + Ecomic was applied there was a greater increase in this indicator, achieving a benefit for the plant since the magnitude of the leaf surface depends to a large extent on this, and the greater the number of leaves, the greater the leaf area of the plant. Despite there being differences between the number of leaves of the different treatments, this is not very significant, and it is not possible to verify the positive effect of biochar on this indicator, and this result can be explained by the work carried out by Sanchez-Pilcorema *et al.*, (2021) where he shows that a high amount of biochar in the soil can decrease the absorption of nutrients from the soil to the plant due to its high alkalinity.

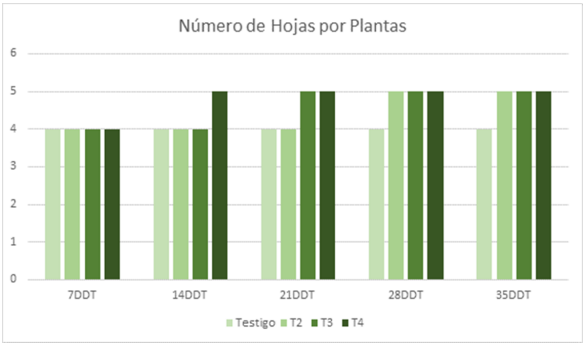

FIGURE 3. Number of leaves per plant in the different samplings.

Effect of bioproducts on the leaf area of the plants in banana cultivation

As shown in Figure 4, there was significant variability on this indicator in the treatment where

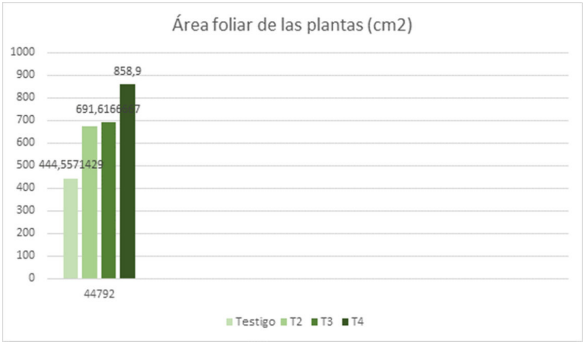

FIGURE 4. Effect of bioproducts on the leaf area of the plants in plantain cultivation.

biochar was used in more than 100 cm^2 with respect to the other treatments, the difference being 400 cm^2 with respect to the control, demonstrating the benefits of biochar. about this indicator. One of the main components that affected this factor was the quality of the soil and, as can be seen in the bibliography, biochar is a soil improver biofertilizer, this being one of its main and most important characteristics, so this would be the explanation for the great difference in yields that exists between the treatment that used biochar and those that used other biostimulants.

Chlorophyll concentration

Treatment four presented the highest concentration of chlorophyll, with 1.91 SPAD units, while the one with the lowest response in this parameter is treatment one with 1.5 SPAD units, these results being partially consistent with those reported by González-Marquetti *et al.* (2020), where the application of cytokinins generated an increase in chlorophyll in the plant.

Fresh dough and dry dough

Table 3, shows the result of the fresh mass of the aerial part of the plants. Statistically significant differences were found between the evaluated treatments, not being in the same way the control, which differs from the rest of the treatments with the lowest values.

The same occurs with the dry mass indicator, showing a similar behavior according to the treatment. For all cases, the highest values were obtained in the treatment where biochar was applied. This behavior coincides with the results of other authors who found an increase in the total dry mass of the aerial part of the plants, compared to the control treatment before the application of bioregulators in the cultivation of banana (Gorst, 2008).

TABLE 3. Analysis of the dry and fresh mass (g) at 30 days after transplanting the crop

Treatments	Fresh mass (g)	Dry mass (g)
S+MO	25,8 c	0,33 c
S+MO+B	29,7 a	0,37 a
S+MO+B+T	27,9 b	0,35 b
CV %	10,07 %	13,07 %
ESx	0,81	0,42

Means with common letters do not differ significantly according to Duncan's test ($p \leq 0.05$)

Economic Evaluation

Taking the results obtained as data, an economic evaluation was carried out where the prices of synthetic fertilizers are compared with organic fertilizers, taking into account their required doses in banana cultivation (Table 4):

TABLE 4. Economic Evaluation

Input	Unit	Price (CUP)	Dose in kg/ha
NPK	kg	183.60	600
Organic Matter	kg	1,2	8500
Ecomic	kg	30.00	6000
Biochar	kg	1.9	10000

*Source: Personal elaboration

DISCUSSION

Refers Pérez-Hernández *et al.* (2006) that the height of the plants responds to different effects or treatments that promote a growth stimulus, as well as that this indicator is a quantitative approximation to understand the growth of a plant or a population of plants under natural or controlled environmental conditions. With regard to banana Musa spp. It is an alternative that allows sustainable development for different agricultural regions that its followers achieve, in addition to ecological coherence, necessary for the sustained optimization of food and crop diversification, essential for the agroecological management of truly sustainable systems (Soorianathasundaram, 2016). It is also known according to studies carried out such as that of Silva *et al.* (2016), that the addition of biochar to the soil improves the interaction between physical, chemical and biological properties, increasing soil fertility, which can favor crop growth and yield, positively increasing the plant height indicator, since It is a physiological characteristic of great importance as it is in correspondence with the nutrient reserve of the plant from the process of photosynthesis.

According to Israeli y Lahav (2017) states that one of the main components that affect the pseudostem diameter indicator are climatic conditions. Proof of this can be seen, that in the period where the experiment was carried out, the climatological variables behaved as established in the literature, remaining constant for all treatments, apart from the fact that the only significant changes between treatments were the substrates used, thus demonstrating that the addition of bioproducts considerably improves the diameter of the pseudostem in plantain plants and mainly the addition of biochar greatly improves this indicator, demonstrating its positive effect. Other investigations such as that of Huang y Gu (2019) have demonstrated the positive effect of biochar on the diameter of the pseudostem of the plantain crop in its different phenotypic phases, reaching much higher values than those of this investigation.

The number of leaves is an important parameter in the growth of plants, because the leaves absorb sunlight to make food through photosynthesis, mainly depending on this the development, filling of the fruits and development of the plant. According to DellaPenna (2007) the addition of bioferments or biols

to biochar such as Si_2O can help a better assimilation of plant nutrients, which are stored in the corm, in its offspring stage, and are taken in the foliar emission in its juvenile stage.

According to León *et al.* (2016), they concluded that the application of natural bioproducts play an important role in growth and with it an increase in the leaf surface in addition to the productivity of any plant species, because it stimulates the production of various metabolites that cause a reduction in transpiration and therefore the ability to obtain more available water for better growth and production becomes possible. According to what was indicated by Solis (2007), a close relationship has been established between the number of fully expanded leaves (on which the magnitude that the leaf surface reaches depends) and the size that they reach. the fruits, but this must be done in a specific state of the growth cycle of the crop, which corresponds to the maximum moment in which said variable is reached.

According to Totoy-Nilve (2019) the chlorophyll content is widely used in the evaluation of the nitrogen content in a plant due to the fact that there is a direct correlation between the intensity of the green and the concentration of nitrogen in the leaf, since nitrogen participates in the constitution of the chlorophyll molecule. In addition, nitrogen is essential in the formation of vegetable protein.

Regarding the last indicator (fresh and dry mass of the plants), Roux *et al.* (2008) confirm that the total dry mass of the aerial part contains the photoassimilates that constitute the reserve of grain filling, which could be considered as an element to be taken into account by breeders for the selection of cultivars with possibilities of high yield potential.

CONCLUSIONS

According to the test carried out, it was concluded:

- The use of biochar, in the sense of Red Ferralitic Soil - Organic Matter - Ecomic - biochar in plantain cultivation, provided great benefits such as the increase in the evaluated indicators (pseudostem height, pseudostem diameter, number of leaves, area leaf, chlorophyll concentration and dry and fresh mass).
- The good agronomic response of the plantain crop allowed a pleasant acceptance by the staff of the Biofabrica de Semillas in the use of biochar as a biostimulant.
- From the economic point of view, biochar had greater effects and economic benefits on plantain cultivation since, despite its high dose per hectare, its cost is very low and, compared to other synthetic biofertilizers, its use is more profitable.

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