Cultivos Tropicales, 2016, vol. 37, no. 2, pp. 165-174 April-June

ISSN impreso: 0258-5936
ISSN digital: 1819-4087

Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas
http://ediciones.inca.edu.cu

DOI: 10.13140/RG.2.1.2893.9763
http://dx.doi.org/10.13140/RG.2.1.2893.9763

PLANTAIN CROP RESPONSE TO DIFFERENT SOIL AND BOCASHI PROPORTIONS COMPLEMENTED WITH MINERAL FERTILIZER AT PLANT NURSERY STAGE

Respuesta del cultivo del plátano a diferentes proporciones de suelo y Bocashi, complementadas con fertilizante mineral en etapa de vivero

David Ramos Agüero[1], Elein Terry Alfonso[2], Francisco Soto Carreño[2], Adriano Cabrera Rodríguez[2], Gloria M. Martín Alonso[2] and Lucía Fernández Chuaerey[3]

ABSTRACT. An alternative to reduce fertilizer rates applied to crops is by using organic manures (compost, biosolids, among others), which can provide the required nutriments to plants. Bocashi is an example, since it increases the amount of microorganisms in the soil, improves its physical characteristics and supplies nutriments to plants. Therefore, this investigation was conducted with the objective of evaluating "Cuerno Rosado" plantain clone response to a joint application of Bocashi organic manure and mineral fertilizer at crop nursery stage. Experiments were carried out in Bocas del Toro province, Panama, within the period from October to December, 2011, studying six treatments arranged in randomized blocks and performing different evaluations on plant growth at this physiological phase. Results showed that it is possible to obtain plantain seedlings in the nursery seven days before the production control (soil + 3 g di-ammonium phosphate (DAP) per plant). An adequate plant growth is achieved in some variables as height, pseudostem diameter and leaf number at 50:50 (v/v) soil substrate: Bocashi ratio, besides adding 1,5 g DAP per bag. Moreover, plants have a similar nutrient concentration to those grown with the production treatment.

Key words: organic manure, growth , *Musa* spp., nutrients, seedlings

RESUMEN. Una alternativa a la disminución de las dosis de fertilizantes a aplicar a los cultivos, la constituye la aplicación de abonos orgánicos (compost, biosólidos, entre otros), los cuales pueden proveer los nutrimentos requeridos por las plantas; un ejemplo de ello lo constituye el Bocashi, cuyo uso aumenta la cantidad de microorganismos en el suelo así como mejora sus características físicas y suministra nutrimentos a las plantas. Por estas razones, la presente investigación se realizó con el objetivo de evaluar la respuesta del plátano clon Cuerno Rosado a la aplicación conjunta del abono orgánico tipo Bocashi y fertilizante mineral, en la etapa de vivero del cultivo. Los experimentos se ejecutaron en Bocas del Toro, Panamá, durante el período octubre–diciembre de 2011. Se estudiaron un total de seis tratamientos ubicados en bloques al azar y fueron realizadas diferentes evaluaciones relacionadas con el crecimiento de las plantas en esta fase fisiológica. Los resultados demostraron que es posible la producción de plántulas de plátano en vivero, con un adelanto de siete días con respecto al control de producción (suelo + 3 g de fosfato diamónico (DAP) por planta). A partir de la proporción 50:50 (v/v) del sustrato suelo: Bocashi, con la adición de 1,5 g de DAP por bolsa se logra un adecuado crecimiento de las plantas en variables como altura, diámetro del pseudotallo y número de hojas. Además, las plantas cuentan con una concentración de nutrientes similar a las que crecieron con el tratamiento de producción.

Palabras clave: abono orgánico, crecimiento, *Musa* spp., nutrientes, plántulas

INTRODUCTION

Plantains and bananas (*Musa* spp.) are among the main plants grown in tropical and subtropical areas from Latin America, Asia and Africa, where high temperatures and relative humidity are prevailing (1).

[1] Instituto de Investigaciones Agropecuarias de Panamá (IDIAP), Panamá

[2] Instituto Nacional de Ciencias Agrícolas (INCA), gaveta Postal 1, San José de las Lajas, Mayabeque, Cuba, CP 32700.

[3] Universidad Agraria de la Habana

✉ davramos31@yahoo.es

Most worldly banana production is destined to supply the own consumption of producing countries and only a small portion is sold in international markets (2). Almost 38 million tons of bananas were harvested in 2011 all over the world, 25 % of it in Latin America, where the leading producers are: Colombia, Peru, Cuba, Ecuador, Dominican Republic, Bolivia, Venezuela and Honduras[A]. Despite Panama is not considered among them, banana represents an important food for its people's diet (3). In this same year, a total of 97 432 t/9103 ha were produced, reaching an average yield of 10,70 t ha^{-1}.

Mineral fertilization (MF) is required to supply crop nutritional needs; however, current market formulations demand the use of large quantities, due to high rates of losses, causing environmental problems to agro-ecosystems. In addition, the increasingly higher prices make those products unaffordable for many crop producers (4).

Organic manures are a complement to mineral fertilizer, since they have high contents of organic matter and nutritional elements for plants. Depending on the level applied to the soil, they may increase ion exchange and moisture retention capacities as well as pH (5). With regard to soil physical properties, they improve water infiltration, structure and conductivity, whereas reduce bulk density and evaporation rate (6).

"Bocashi" is among the organic manures currently employed in agro-ecosystems, which is a Japanese word meaning "fermented organic matter". Farmers have applied Bocashi as soil amelioration, since it increases microbial diversity, improves soil physical and chemical conditions, as well as supplies nutrients to crop development (7, 8).

The introduction of conservationist strategies, such as Bocashi produced by producers, is not only important for small farmers, but also for large agricultural areas, both in Panama and elsewhere in the world. Organic manure production is an alternative of handling large amounts of agricultural wastes to make a product capable of becoming a nutritional source for the soil and crops.

An adequate plantain management demands to solve the negative effects caused by non-uniform plants in the field, which is attained by planting nursery seedlings, so saving from six to eight weeks of field management and reaching a better pest and weed control, without checking them in a larger area for two months.

The use of substrate at the nursery stage is essential for the early crop development, with structural and chemical characteristics that enable root growth. If it is a suitable substrate, seedlings will get a good root development and they will be ready for planting after being in the nursery for about eight weeks (1). Substrates must provide adequate amounts of nutriments, depending on seedling demands; however, not all substrates *per se* are always capable of supplying the necessary nutrients to plants. Thus, it is important to study different organic and mineral combinations to attain an appropriate nutritional balance in plants.

According to this background information, the present work was aimed at evaluating different soil: Bocashi ratios and complementary mineral fertilizer rates, as an alternative to obtain plantain in nurseries under the humid tropical conditions of Panama.

MATERIALS AND METHODS

A nursery experiment was conducted for 90 days (October-December, 2011) in Antonio Pandiella's farm, located in "El Silencio", Empalme municipality, District of Changuinola, Bocas del Toro province, Panama, at 9º39'36,7" North Latitude and 82º52'97,32" West Longitude, 15 m above sea level, in order to evaluate the effect of different soil: Bocashi ratios complemented with mineral fertilizer.

Nurseries were placed under a bamboo structure covered by shading net, using cormlets from "Cuerno Rosado" clone of about 300 g weight, equivalent to E size, according to Plantain Technical Instruction (3), which are suitable for pre-germinating or nursing conditions.

Cormlets were previously disinfected by a sodium hypochlorite (NaOCl) solution at 1 % and planted in black polypropylene bags of 15 cm diameter, 20 cm high and 2 kg capacity. One cormlet was put per bag and the whole mineral fertilizer was placed around each at planting time. For experimental development, nursery bags were arranged in a randomized block design with four replications. In every block, 10 bags were put

[A] FAOSTAT. *Statistical Databases* [en línea]. 2014, [Consultado: 3 de enero de 2014], Disponible en: <http://faostat.fao.org/site/339/default.aspx>.

per replicate to make a total of 40 seedlings per each of six treatments, as shown in Table I. For production control, 3 g di-ammonium phosphate (DAP) was added as mineral fertilizer (3) at a formula of 18-46-0.

Table I. Treatments studied with soil-Bocashi-mineral fertilizer combinations

Treatments studied
1.Absolute control 100 % soil
2. Production control (soil + 100 % FM)
3. 25 % soil + 75 % Bocashi (v/v)
4. 50 % soil + 50 % Bocashi (v/v)
5. 25 % soil + 75 % Bocashi (v/v) + 25 % FM
6. 50 % soil + 50 % Bocahi (v/v) + 50 % FM

Bocashi was prepared according to the methodology for obtaining one ton (8) and its nutritional content can be seen in Table II.

Nutritional conditions of the soil employed for filling bags are shown in Table III.

Results show that soil is fairly acid with low organic matter content and suitable macronutrient concentration.

Cultural farming was practiced to plantlets in the nursery by following Panama's plantain crop instruction manual (3), without irrigation, since the area under study has a tropical rain forest climate.

Ten days after planting cormlets, the following growth variables were evaluated in 20 seedlings per treatment every ten days for 70 days:

- Height (cm) from pseudostem base up to the last V-forked leaves using a tape measure
- Pseudostem diameter (cm) evaluated 1.0 cm over the base with a Vernier caliper
- Leaf number per plant by visual counting

Table III. Soil nutritional composition

pH H_2O	OM (%)	Ca	Mg^{2+}	Na^+ (cmol kg^{-1})	K	ECC
5,6	1,60	11,9	2,6	0,2	0,90	15,6

Five plantlets per replicate and treatment were sampled at the end of the nursing cycle (70 days), in order to evaluate leaf and pseudostem dry mass (g), and then samples were put in an oven at 65 °C until reaching constant mass values.

Leaf nutrient concentration was determined at the Soil and Foliar Laboratory from the University of Costa Rica. For nitrogen (N) content, a dry combustion was performed in auto-analyzer, according to CIA-SC09-01-01-P06, whereas phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K), sulfur (S), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and boron (B) were determined by wet digestion with HNO_3 and evaluated by atomic absorption spectrophotometry with plasma, according to CIA-SC09-01-01-P10.

Nutriment content was calculated from dry mass data of plants and the corresponding concentration of each element (% in dry base) through the following formula (9):

Nutriment content= [Dry mass (g) x element concentration in each organ (%)]/100

Data normality and variance homogeneity were proved. In the cases they did not meet variance analysis assumptions, variables were transformed by the methods of: log (x) for continuous variables and √x for discrete ones. Afterwards, a two-way classification ANOVA was performed.

Table II. Macronutrient, micronutrient and organic matter contents of Bocashi fertilizer after 30 days of being prepared

Stadigraphs	N	P	K (%)	Mg	Ca	S
χ	1,01	0,39	1,57	1,16	1,67	0,12
E.S.	0,03	0,01	0,05	0,01	0,01	0,01
C.V.	6,25	5,51	7,24	1,08	1,24	6,70
Stadigraphs	Fe	Cu (mg kg^{-1})	B	Mn	Zn	OM (%)
χ	39033,80	72,25	105,75	781,00	159,75	16,76
E.S.	435,36	0,75	4,17	5,49	3,94	1,03
C.V.	2,23	2,08	5,89	1,41	4,94	2,24

Where there were significant differences between treatments, means were compared by Duncan's Multiple Range test (p≤ 0,05). In addition, correlations were made between height, pseudostem diameter, leaf number, dry mass and N as well as K contents.

On the other hand, the Logistic regression model was used to estimate growth curves in the six treatments according to the following expression:

$$Y(t) = \frac{A}{(1 + be^{-kt})}$$

where:
Y(t) -average plant height (cm) on the control day
t -day; A, b -parameters to be estimated; e≈ 2.7183 natural logarithm base

Determination coefficient (R^2) was included when validating and the first derivative allowed describing the average growth rate of these plants within the first 70 days.

First derivative of the logistic model

$$Y'(t) = \frac{Abke^{-kt}}{(1+be^{-kt})^2}$$

RESULTS AND DISCUSSION

Evaluations on height, pseudostem diameter, leaf number and dry mass of plantlets in the nursery are shown in Table IV, which denotes differences between treatments at every measuring time. The absolute control (T1) was always inferior to treatments with mineral fertilization, Bocashi or its combination, showing that the soil by itself cannot supply plant nutritional requirements.

At the fifth week, all treatments with mineral fertilizer and Bocashi were higher than the absolute control. From the sixth week on, T6 had a differentiated behavior, since plants reached 25 cm high a week before the other treatments, whereas at the seventh week, T4 and T6 surpassed the rest.

On the other hand, a more detailed analysis of height in each treatment shows that, from T2 to T6, a speed-up plant growth keeps on even at 50 days, unlike T1, which already has stability at 40 days (Figure A).

This behavior is confirmed by growth rate (Figure B), which denotes that plants growing in 50 % soil + 50 % Bocashi (v/v) + 50 % MF have higher speed than the remaining treatments.

Table IV. Mineral fertilizer-Bocashi combination on some morphological variables of plantain in the nursery

	Treatments	Weeks: 5	6	7	5	6	7
		Height (cm)			Leaf number^T		
T1	Absolute control 100 % soil	12,18 b	12,42 c	14,22 d	4,13 c	4,60 d	4,67 c
T2	Production control (soil + 100 MF[1])	16,55 a	20,48 b	23,55 c	5,40 ab	6,13 c	7,07 b
T3	25 % soil + 7 5 % Bocashi (v/v)	15,86 a	21,72 b	27,18 b	5,73 a	6,67 ab	7,40 b
T4	50 % soil + 50 % Bocashi (v/v)	16,03 a	21,79 b	29,09 ab	5,67 a	6,53 abc	7,47 ab
T5	25 % soil + 75 % Bocashi (v/v) + 25 MF[2]	15,80 a	22,30 b	24,01 c	5,20 b	6,4 bc	7,33 b
T6	50 % soil + 50 % Bocashi (v/v) + 50 MF[3]	18,52 a	25,17 a	30,46 a	5,33 ab	6,93 a	7,87 a
SEx		0,07 *	0,04 *	0,03 *	0,03 *	0,027 *	0,03 *
		Pseudotem diameter^T (cm)			Dry mass (g per plant) Pseudotem^T		Dry mass (g per plant) Leaves^T
T1	Absolute control 100 % soil	2,03 c	2,28 c	2,36 c	2,23 c		2,82 c
T2	Production control (soil + 100 % MF[1])	2,55 ab	2,76 b	2,93 b	2,92 b		4,12 b
T3	25 % soil + 75 % Bocashi (v/v)	2,44 b	2,75 b	2,83 b	3,44 a		4,94 ab
T4	50 % soil + 50 % Bocashi (v/v)	2,50 b	2,81 b	2,83 b	3,54 a		4,74 ab
T5	25 % soil + 75 % Bocashi (v/v) + 25 MF[2]	2,77 a	3,02 a	3,14 a	3,48 a		4,74 ab
T6	50 % soil + 50 % Bocashi (v/v) + 50 % MF[3]	2,57 ab	2,83 b	3,15 a	3,62 a		5,50 a
SEx		0,03 *	0,07 *	0,02 *			0,16 *

T: transformed variable *Means with different letters in the same column differ between themselves, according to Duncan's test (p<0,05)
Dry mass: evaluation at the seventh week

As shown in this figure, T6 reaches its maximum value from 30 to 40 days and begins to decrease at 50 days tending to stabilize; however, T1 grows very fast at the beginning but decreases dramatically at 20 days. This result reaffirms that the optimal seedling quality values are achieved with T6 in a shorter time than the remaining substrate combinations.

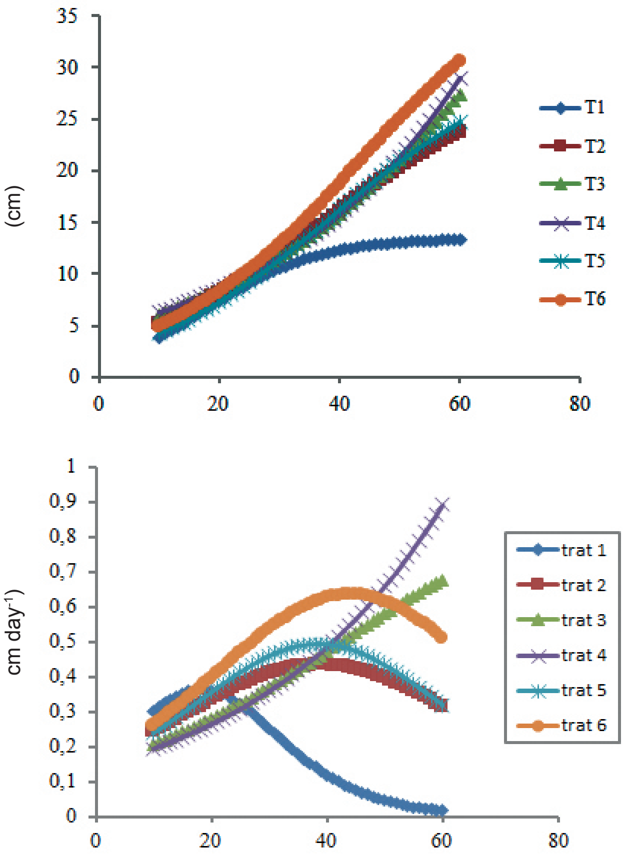

Figure. Growth description (A) and its speed (B) at the first derivative of each regression model

Concerning pseudostem diameter (Table IV), the highest values of this variable were recorded at the production control and treatments with soil: Bocashi combination complemented with mineral fertilizer rates in the fifth week (T5 and T6); nevertheless, only T5 in the sixth week whereas T5 and T6 in the seventh week reached the highest values.

Regarding leaf number, the highest values were achieved by T2, T3, T4 and T6 in the fifth week; it was significantly higher in T3, T4 and T6 within the sixth week, whereas the highest values were recorded only by T4 and T6 at the end of the evaluation.

As for leaf dry mass, at the seventh week, the best behavior was observed in all treatments with Bocashi in the substrate, which did not differ from the production control, except 50:50 (soil: Bocashi) combination plus 50 % mineral fertilizer rate, which surpassed the production control.

So far as pseudostem dry mass, all treatments with Bocashi exceeded the absolute control and production control.

The logistic model (Table V) corroborated the results for each treatment, obtaining high coefficients of determination, excelling treatment 6 with the largest adjustment. R^2 is lower in absolute control treatment where plants had a slower growth rate in relation to the rest of the positions that grew under the different substrates studied

When analyzing the results related to nursery plant morphology as a whole, it was found that at the end of the sixth week, T6 was the only one that reached optimal height levels (25-30 cm) for transplanting, which should be achieved at the seventh week (1).

Table V. Logistic model results

Treatment	Model result	
T1	$y = \frac{13,5059}{(1+7,12e^{-0,1\,t})}$	$R^2 = 94,69$
T2	$y = \frac{31,14}{(1+8,69e^{-0,05\,t})}$	$R^2 = 98,75$
T3	$y = \frac{84,20}{(1+18,56e^{-0,03\,t})}$	$R^2 = 99,14$
T4	$y = \frac{4841,97}{(1+1042,06e^{-0,03\,t})}$	$R^2 = 98,90$
T5	$y = \frac{30,93}{(1+11,55e^{-0,06\,t})}$	$R^2 = 98,17$
T6	$y = \frac{42,40}{(1+13,90e^{-0,05\,t})}$	$R^2 = 99,67$

Similar results have been obtained in previous studies made on substrates for banana nurseries (10), where plants developed with Bocashi manure were higher than those grown in control substrates.

In this sense, it is pointed out that the content of organic manure in substrates is a determining factor for plant height in nurseries, as a result of nutriment supply, mainly available nitrogen (11, 12).

The behavior of pseudostem diameter makes evident that the best effect is obtained by combining organic manure with mineral fertilizer at 75 % Bocashi + 25 % MF ratio. Regarding this combination, some authors state that nutriment supply of substrates to plants is very important for pseudostem diameter development at the nursery stage (11).

It is very important to observe significant differences for pseudostem diameter between treatments, since it ensures proper plant acclimation in the field; thus, it can be considered among the fundamental variables studied in this research. However, counting leaf number was not definitive, because the other variables (height and pseudostem diameter), in the fifth week, could not yet accomplish the parameters established to take out plants from the nursery, which could only be achieved by T6 at the sixth week.

It is noteworthy that all treatments, except the absolute control, had reached the appropriate leaf number for transplanting from the fifth week, which should be of more than five leaves[B]. In this sense, Bocashi has some advantages, since it provides organic substances such as amino acids, vitamins, organic acids, enzymes and antioxidants that are crop growth promoters (13).

These results suggest that plantain seedlings, grown in a substrate with Bocashi in the nursery, were able to develop a proper metabolism, thereby present higher values of morphological variables, which give them greater advantages at the nursery stage.

This behavior results from adding organic manure to the substrate, which not only supplies nutriments, but also improves its physical and biological properties, providing a better structure, drainage and possibly promoting root emission, as well as controlling pests and diseases. In this regard, Bocashi activates beneficial micro- and macro-organisms during fermentation process (8), so strengthening the effects from using this organic manure.

Its effect on dry mass increase could be related to a greater recovery of water, nutriments and better photosynthesis, indicating that fermented organic manures enhance plant growth and its development (11), an aspect proved in this investigation, where Bocashi provided plant growth.

Similar results have been obtained when Bocashi was prepared with banana residues, which proved to be a good substrate for tomato seedlings produced in seedbeds that attained the best growth, early transplanting and low production costs (14).

In general, results from plant height, pseudostem diameter, leaf number and dry mass make evident that organic-mineral nutrition of banana crop based on 50:50 soil: Bocashi ratio, complemented with 50 % mineral fertilizer rate recommended (T6), allow obtaining seedlings with appropriate quality for transplantation.

Moreover, Table VI presents the correlation analysis performed between height, pseudostem diameter, leaf number, dry mass and nitrogen as well as potassium contents of banana plants at the seventh week of stay in the nursery.

A significant and positive correlation was found between leaf number, its dry mass, N and K contents; furthermore, height and pseudostem diameter correlated with them, but not among them.

The fact that there was a strong correlation between height, dry mass and nutriment content enables to establish that higher plants with greater leaf number in the nursery show the best nutritional characteristics that give them excellent conditions for their subsequent transplantation to the farm.

In order to achieve good seedling development in the nursery, it is necessary to use a substrate that provides the required quantities of nutritional elements that allow promoting cell division processes, thereby, seedling growth and development.

[B] Coto, J. *Guía para la multiplicación rápida de cormos de plátano y banano*. 2.ª ed., edit. Fundación Hondureña de Investigación Agrícola, La Lima, Honduras, 2009, 9 p.

It is of practical importance to take a vigorous material to the field, which is defined, among other features, by plant erection and pseudostem diameter, since the chances of success will be much better for crop establishment (1).

Macronutrient concentrations of leaves and pseudostem can be seen in Table VII at the seventh week of crop establishment. In general, nitrogen and phosphorus contents of leaves were higher in all treatments with Bocashi. For potassium, all treatments were similar, except the absolute control. In the case of pseudostem, for nitrogen and phosphorus, all treatments with Bocashi and the production control exceeded the absolute control; however, potassium content was higher in treatments with Bocashi.

When analyzing secondary macronutrient content, the organs evaluated did not respond to calcium absorption. The highest magnesium content in leaves was presented in T3 and T4, whereas sulfur was higher in T4 and T6. Magnesium absorption in pseudostems showed no differences between treatments, whereas sulfur absorption was higher in T3 and T4, although without differences with T6.

In general, leaves are the organ that better shows crop nutritional status and most macronutrients are located in them, making up about 50 % plant material (3).

Table VI. Correlation matrix between some growth and development variables of banana plants at the seventh week of stay in the nursery during 2010

	Height	Diameter	Leaves	Dry mass	Nitrogen	Potassium
Height		0,7618	0,9549*	0,9564*	0,9602*	0,9415*
Diameter			0,8925*	0,8620*	0,8986*	0,7582
Leaves				0,9591*	0,9989*	0,9339*
Dry mass					0,9655*	0,9624*
Nitrogen						0,9329*

* Correlations between variables with statistical significance for a confidence level of 95 %. Diameter (pseudostem); Leaves (number); Dry mass (total); Nitrogen and Potassium (contents)

Table VII. Macronutrient concentration (g per plant) in banana leaves and pseudostem at the seventh week of stay in the nursery

	Treatments	N	P	K	Ca	Mg	S
					Leaves		
T1	Absolute control 100 % soil	0,10 c	0,010 c	0,24 b	0,031	0,011 c	0,006 c
T2	Production control (soil + 100 MF[1])	0,16 b	0,014 b	0,39 a	0,031	0,016 b	0,011 b
T3	25 % soil + 75 % Bocashi (v/v)	0,18 ab	0,020 a	0,47 a	0,034	0,021 a	0,012 b
T4	50 % soil + 50 % Bocashi (v/v)	0,19 ab	0,019 ab	0,40 a	0,033	0,020 a	0,013 ab
T5	25 % soil + 75 % Bocashi (v/v) + 25 MF[2]	0,18 ab	0,017 ab	0,40 a	0,035	0,016 b	0,012 b
T6	50 % soil + 50 % Bocashi (v/v) + 50 MF[3]	0,22 a	0,021 a	0,47 a	0,041	0,015 b	0,015 a
SEχ		0,02*	0,0015*	0,05*	0,0044 N.S.	0,001*	0,001*
					Pseudotems		
T1	Absolute control 100 % soil	0,035 b	0,0073 c	0,16 c	0,0188	0,0054	0,0022 d
T2	Production control (soil + 100 MF[1])	0,077 a	0,0146 ab	0,26 b	0,0124	0,0043	0,0028 c
T3	25 % soil + 75 % Bocashi (v/v)	0,096 a	0,0183 a	0,37 a	0,0138	0,0066	0,0045 a
T4	50 % soil + 50 % Bocashi (v/v)	0,089 a	0,0134 b	0,35 a	0,0121	0,0059	0,0040 ab
T5	25 % soil + 75 % Bocashi (v/v) + 25 MF[2]	0,080 a	0,0131 b	0,33 ab	0,0141	0,0051	0,0032 c
T6	50 % soil + 50 % Bocashi (v/v) + 50 MF[3]	0,092 a	0,0157 ab	0,36 a	0,0179	0,0053	0,0037 b
SEχ		0,092*	0,0014*	0,03*	0,12 N.S.	0,13 N.S.	0,0001*

*Means with different letters in the same column differ between themselves, according to Duncan's test (p<0,05)

Among all essential nutriments, potassium is required in larger quantities by the crop. In this sense, plantain is an extremely demanding plant, which requires from three to four times more potassium than nitrogen (15). With this regard, it is the second highly demanded element, although all elements are generally very important, due to their physiological-biochemical role (16).

Results from nutriment contents of this work are similar to those described by another author for Harton plantain (AAB) under nursery conditions, who states they are vital for the optimal plant growth (17).

Table VIII shows microelement contents towards the end of plant cycle in this stage. Adequate ranges of copper, zinc and boron contents were recorded in all treatments, when compared with the concentrations found for banana (18).

However, there was an excessive amount of iron and manganese contents in leaves and pseudostems, according to leaf concentration ranges of microelements considered suitable for banana crop (18).

It is possible that these high contents of iron and manganese are due to their large concentrations found in the Bocashi prepared on the farm, which were present in pig manure and probably nursery plants absorbed a greater amount; however, no visual symptoms of toxicity were detected, since there were not any small brown spots or chlorosis on leaf edges (1), which shows evident disorders of plant metabolism and suggests that the contents of these elements on the substrate did not affect the crop.

It is stated that the amounts of nutritional elements often surpass the ranges established as optimal for plantain and banana crops; nevertheless, plants do not show symptoms of deficiency or failed production, inferring that the ranges considered as appropriate in a particular location may be different from others adopted, which indicates the need to establish regional patterns per type of soil and climate (19).

In the case of microelements, it is important to determine its content in the plant, since they take part in most physiological processes; thus, it should be determined in order to know the physiological status of perennial plants, because fertilization programs based on chemical analysis of plants can be used in this type of crop during the same harvest or cycle as deficiencies can be detected (20).

Table VIII. Micronutrient content in banana leaves and pseudostems at the seventh week of stay in the nursery

	Treatments	Fe	Cu	Zn	Mn	B
				Leaves (mg por planta)		
T1	Absolute control 100 % soil	1,40 b	0,027 c	0,069 b	0,69 c	0,036 d
T2	Production control (soil+100 MF[1])	2,72 a	0,049 b	0,111 a	3,62 a	0,047 c
T3	25 % soil + 75 % Bocashi (v/v)	2,28 a	0,064 ab	0,142 a	2,58 b	0,069 a
T4	50 % soil + 50 % Bocashi (v/v)	2,37 a	0,072 a	0,132 a	2,79 b	0,056 bc
T5	25 % soil + 75 % Bocashi (v/v) + 25 MF[2]	2,40 a	0,059 ab	0,117 a	2,86 b	0,052 bc
T6	50 % soil + 50 % Bocashi (v/v) + 50 MF[3]	2,39 a	0,075 a	0,124 a	4,00 a	0,060 ab
	SEχ	0,15*	0,007*	0,01*	0,20*	0,003*
				Pseudotem (mg por planta)		
T1	Absolute control 100 % soil	0,52 c	0,016 c	0,002 c	0,16 e	0,033 b
T2	Production control (soil+100 MF[1])	1,97 b	0,026 b	0,124 b	0,60 b	0,053 a
T3	25 % soil + 75 % Bocashi (v/v)	1,88 b	0,037 a	0,350 a	0,44 c	0,064 a
T4	50 % soil + 50 % Bocashi (v/v)	2,90 ab	0,031 ab	0,239 ab	0,34 cd	0,054 a
T5	25 % soil + 75 % Bocashi (v/v) + 25 MF[2]	2,70 b	0,031 ab	0,163 b	0,30 d	0,049 a
T6	50 % soil + 50 % Bocashi (v/v) + 50 MF[3]	4,09 a	0,031 ab	0,287 a	0,72 a	0,051 a
	SEχ	0,42*	0,003*	0,038*	0,04*	0,005*

Means with different letters in the same column, to each year, differ among them according to Duncan test (p<0,05)

Despite the results of this investigation do not correspond to concentrations mentioned by other authors (18), which were made in indicative leaves from adult banana (subgroup AAA) plants, they can estimate the nutritional status of banana (plantain subgroup, AAB, "Cuerno Rosado" clone) seedlings in the nursery.

Based on the fact that suitable micronutrient levels were found when characterizing the Bocashi prepared on the farm (Table II), which was later used in the substrate and enabled the plants to present adequate contents of them, it can be inferred that by preparing a fermented organic fertilizer from farm crop residues, the recycling of microelements and its convenient supply to plants is achieved.

Different authors report that the recycling of boron, zinc and copper, derived from an adequate management of banana organs incorporated to the soil, should be taken into account in the fertilization program, due to their minimum amount exported by harvests (21). In other studies, it is even suggested to compost banana harvest residues to increase the efficiency and effectiveness of micronutrients supplied by organic manure (19).

These experimental results confirm that organic-mineral combination in a substrate makes mineral fertilizer complete nutriment availability as well as organic manure improve the chemical, physical and biological characteristics of substrates, enhancing plant growth and development.

Consequently, the investigation found that by combining 50 % soil: Bocashi plus adding 50 % mineral fertilizer rate recommended (T6), not only the highest plant growth was obtained in the nursery, but also plants reached the highest contents of macro- and micro-nutrients in leaves and pseudostems in the nursery one week before, compared to the other treatments studied.

This result shows that height, pseudostem diameter and leaf number can define a plant of optimal quality to be taken to the farm for transplanting, also to be used as indicators to evaluate plant response when using various nutritional alternatives under nursery conditions.

The application of organic manures combined with mineral fertilizers is a sustainable alternative to obtain banana in the nursery, since the rapid effect of fertilizer provides the nutrients that organic manure cannot release and the slow release of organic manures allows the plant to take nutrients as they need them, avoiding losses by leaching and volatilization mostly observed in the humid tropics (22).

CONCLUSIONS

Results proved the efficiency of Bocashi, an organic manure made up of banana (*Musa* spp) production by-products, as a nutritional alternative to obtain seedlings under nursery conditions, where 50:50 soil: Bocashi (v/v) ratio plus 1,5 g di-ammonium phosphate (DAP) mineral fertilizer should be used, in order to achieve seedlings of adequate quality with one week stay reduction in the nursery.

BIBLIOGRAPHY

1. Instituto de Investigaciones de Viandas Tropicales. *Instructivo técnico del cultivo del plátano*. edit. Ministerio de la Agricultura, Artemisa, Cuba, 2010, 13 p., ISBN 978-959-7210-15-3.
2. Gañán, L.; Bolaños, B. M. M. y Asakawa, N. "Efecto de la micorrización sobre el crecimiento de plántulas de plátano en sustrato con y sin la presencia de nematodos fitoparásitos". *Acta Agronómica*, vol. 60, no. 4, 2011, pp. 297–305, ISSN 0120-2812.
3. Marcelino, L. A.; González, V. y Ríos, D. *Manual de Recomendaciones Técnicas para el Cultivo Tecnificado de Plátano (Musa paradisiaca L.)*. edit. Pacífico S.A., 2009, 30 p., ISBN 9962-653-00-2.
4. Zhang, N.; He, X.; Zhang, J.; Raza, W.; Yang, X.-M.; Ruan, Y.-Z.; Shen, Q.-R. y Huang, Q.-W. "Suppression of Fusarium Wilt of Banana with Application of Bio-Organic Fertilizers". *Pedosphere*, vol. 24, no. 5, octubre de 2014, pp. 613-624, ISSN 1002-0160, DOI 10.1016/S1002-0160(14)60047-3.
5. Kalemelawa, F.; Nishihara, E.; Endo, T.; Ahmad, Z.; Yeasmin, R.; Tenywa, M. M. y Yamamoto, S. "An evaluation of aerobic and anaerobic composting of banana peels treated with different inoculums for soil nutrient replenishment". *Bioresource Technology*, vol. 126, diciembre de 2012, (ser. Advances in Biological Waste Treatment and Bioconversion Technologies), pp. 375-382, ISSN 0960-8524, DOI 10.1016/j.biortech.2012.04.030.
6. Zhai, L.; Liu, H.; Zhang, J.; Huang, J. y Wang, B. "Long-Term Application of Organic Manure and Mineral Fertilizer on N_2O and CO_2 Emissions in a Red Soil from Cultivated Maize-Wheat Rotation in China". *Agricultural Sciences in China*, vol. 10, no. 11, noviembre de 2011, pp. 1748-1757, ISSN 1671-2927, DOI 10.1016/S1671-2927(11)60174-0.
7. Pérez, C. R.; Pérez, C. A. y Vertel, M. "Caracterización nutricional, físicoquímica y microbiológica de tres abonos orgánicos para uso en agroecosistemas de pasturas en la subregión Sabanas del departamento de Sucre, Colombia". *Tumbaga*, vol. 1, no. 5, 2010, pp. 27-37, ISSN 1909-4841.
8. Restrepo, J. *A, B, C de la agricultura orgánica y panes de piedra: Abonos orgánicos fermentados*. 1.ª ed., edit. Feriva S.A., Colombia, 2010, 86 p., ISBN 978-958-44-126-1.

9. Barrera, J. L.; Combatt, E. M. y Ramírez, Y. L. "Efecto de abonos orgánicos sobre el crecimiento y producción del plátano Hartón (*Musa* AAB)". *Revista Colombiana de Ciencias Hortícolas*, vol. 5, no. 2, diciembre de 2011, pp. 186-194, ISSN 2011-2173.
10. Arcila, P.; Valencia, J. A. y Morales, H. ''Efecto de diferentes sustratos sobre el crecimiento de plántulas de Dominico-Hartón en el Quindío''. En: *XV reunión*, edit. Asociación de Bananeros de Colombia AUGURA, Cartagena de Indias, Colombia, 2002, pp. 431-435, ISBN 958-33-3905-9.
11. González, C. C. y Guzmán, P. Ó. A. "Efecto de la limpieza sanitaria de cormos y la fertilización orgánica sobre el crecimiento de plántulas de Dominico Hartón (*Musa* AAB Simmonds) y su relación con nemátodos fitoparásitos''. *Agronomía Costarricense*, vol. 19, no. 1, 2011, pp. 42-56, ISSN 0568-3076.
12. Arencibia, A. C.; Echemendía, J. A.; Negrín, A. B.; Caraballoso, A. J.; López, J. L. R.; Vega, D. B. y Peña, P. L. ''Producción de humus de lombriz a partir de subproductos de cosecha del plátano (*Musa* spp.) y cachaza''. *Centro Agrícola*, vol. 39, no. 1, 2012, pp. 41-47, ISSN 0253-5785, 2072-2001.
13. Joseph, S. y Taylor, P. "The production an application of biochar in solis''. En: ed. Waldron K., *Advances in Biorefineries. Biomass and Waste Supply Chain Exploitation*, edit. Woodhead Publishing, 2014, pp. 525-555, ISBN 978-0-85709-521-3.
14. Zhang, N.; Wu, K.; He, X.; Li, S.; Zhang, Z.; Shen, B.; Yang, X.; Zhang, R.; Huang, Q. y Shen, Q. ''A new bioorganic fertilizer can effectively control banana wilt by strong colonization with *Bacillus subtilis* N11''. *Plant and Soil*, vol. 344, no. 1-2, 20 de febrero de 2011, pp. 87-97, ISSN 0032-079X, 1573-5036, DOI 10.1007/s11104-011-0729-7.
15. Ganeshamurthy, A. N.; Satisha, G. C. y Patil, P. "Potassium nutrition on yield and quality of fruit crops with special emphasis on banana and grapes". *Karnataka Journal of Agricultural Sciences*, vol. 24, no. 1, 11 de noviembre de 2011, pp. 29-38, ISSN 0972-1061.
16. Atim, M.; Beed, F.; Tusiime, G.; Tripathi, L. y van Asten, P. "High Potassium, Calcium, and Nitrogen Application Reduce Susceptibility to Banana Xanthomonas Wilt Caused by *Xanthomonas campestris* pv. *musacearum*''. *Plant Disease*, vol. 97, no. 1, 30 de agosto de 2012, pp. 123-130, ISSN 0191-2917, DOI 10.1094/PDIS-07-12-0646-RE.
17. Herencia, J. F.; García, G. P. A.; Ruiz, D. J. A. y Maqueda, C. ''Comparison of nutritional quality of the crops grown in an organic and conventional fertilized soil''. *Scientia Horticulturae*, vol. 129, no. 4, 27 de julio de 2011, pp. 882-888, ISSN 0304-4238, DOI 10.1016/j.scienta.2011.04.008.
18. Taulya, G. "East African highland bananas (<i>Musa<i> spp. AAA-EA) 'worry' more about potassium deficiency than drought stress''. *Field Crops Research*, vol. 151, septiembre de 2013, pp. 45-55, ISSN 0378-4290, DOI 10.1016/j.fcr.2013.07.010.
19. Hernández, Y.; Villa, N.; Fourtul, G. y Cruz, J. D. L. "Niveles de giberelinas endógenas y elementos minerales durante la transición floral en plátano (*Musa* AAB) cv Hartón''. *Revista de la Facultad de Agronomía*, vol. 29, no. 1, 2012, ISSN 0378-7818, [Consultado: 7 de enero de 2016], Disponible en: <http://www.produccioncientifica.luz.edu.ve/index.php/agronomia/article/view/12541>.
20. Muñiz, O. *Los microelementos en la agricultura*. edit. Instituto de suelos, La Habana, Cuba, 2008, 132 p., ISBN 978-959-246-201-4.
21. Damatto, J. E. R.; Villas, B. R. L.; Nomura, E. S.; Fuzitani, E. J. y Garcia, V. A. "Alterações nos teores nutricionais foliares de bananeira «prata-anã» adubada com composto orgânico em cinco ciclos de produção''. *Revista Brasileira de Fruticultura*, vol. 33, no. spe1, octubre de 2011, pp. 692-698, ISSN 0100-2945, DOI 10.1590/S0100-29452011000500097.
22. Thompson, A. K. "Banana (*Musa* spp.)". En: ed. Yahia E. M., *Postharvest biology and technology of tropical and subtropical fruits*, (ser. Woodhead Publishing Series in Food Science, Technology and Nutrition, no. ser. 207), edit. Woodhead Publishing, 2011, pp. 216-243, ISBN 978-1-84569-734-1, CABDirect2.

Received: October 24th, 2015
Accepted: August 7th, 2016

Revista Cultivos Tropicales
Instituto Nacional de Ciencias Agrícolas