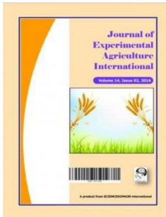

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Agronomic Performance of Banana Genotypes under Agroecological Management in the Semi-arid Region of Paraiba, Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Northeastern Brazil is a banana producing zone where the selection of banana tree genotypes has significantly increased crop productivity.
Aims: The study aimed to evaluate the agronomic performance of different banana-tree genotypes under agroecological management in northeastern Brazil.

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Methodology: The experiment was conducted in the orchard of the Federal Institute of Education, Science and Technology of Paraíba following a randomized complete block design with nine treatments (banana tree genotypes) in four replications. Banana tree seedlings used as planting material were provided by Empresa Campo Biotecnologia. They were produced by micropropagation of plantlets. Cropping was handled following agroecological practices. Growth measurements and yield data regarding the the first crop cycle were recorded.

Results and Conclusions: Significant differences in yields and yield traits within banana-tree genotypes were observed. Prata Graúda and Grande Naine genotypes came out on top in terms of agronomic performance under agroecological practices.

Keywords: Musa sp; auto-sustainability; fitotecnia; fruticulture; interior.

1. INTRODUCTION

The banana tree (*Musa* sp) is a tropical fruit of great economic importance with fruit flavour, consumption power, energy source, vitamins and minerals, besides the low cost for the consumer [1]. In Brazil, it is planted in all states, being one of the largest fruit producer and the seventh most exported fruit in the country [2].

The amount of banana produced nationwide in 2016 was equivalent to 6,764.324 tons of bunches with a medium income of 14.401 Kg ha-1, the Northeast area of the country being the largest producer with 2.285.796 tons, with prominence in Bahia, Pernambuco and Ceará [3]. Banana cultivation for large scale production usually being with conventional management.

In Brazil, organic production in Brazil is extremely incipient, even for fruit trees of great national expression, such as citrus, banana, papaya, mango, grape, there are no consolidated organic production systems [4]. However, the demand for sustainable products is growing due to the need to consume these products.

Agroecological management is one of the more maintainable agricultural systems under all of the aspects and intends to rescue the farmers' human dignity that tamed plants and animals throughout history and maintained great part of the genetic diversity used by the human species [5]. Characterised by cultural practices as rotation, consortium, organic manuring, reuse of vegetable remains, planting of repellent plants, production of bio-pesticides, exemption of pesticides and other inorganic inputs [6]. It was known that there could be many genetic and environmental effects on the yield [7].

Studies aiming to evaluate the agronomic performance of banana genotypes are primordial to select those that best behave in certain edaphoclimatic conditions and cropping systems [8,9,10]. The most relevant characteristics for the evaluation and selection of superior genotypes in this fruit are crop cycle, plant height, perimeter of the pseudocaule, fresh bunch mass, number of leaves and fruits per bunch, as well as the length and diameter of the fruits [11].

In the upper interior of Paraiba, few varieties of banana are produced, especially the varieties Nanica, Prata Comum and Pacovan. Thus, studies are required regarding the productive potential of new banana genotypes that can be incorporated and adapted to the edaphoclimatic conditions of the region. In addition, agroecological management in banana farming is scarce [2], therefore the present work aimed to evaluate the agronomic performance of different banana genotypes under agroecological management in the upper interior region of Paraiba.

2. MATERIALS AND METHODS

2.1 Location of the Experiment

The experiment was conducted in the orchard of the Federal Institute of Education, Science and Technology of Paraíba (IFPB), in the horticulture section of the Sousa campus, located in the irrigated perimeter in São Gonçalo, 6°45' latitude S, 38°13' longitude W and altitude of 223 m,in a Flossic Neosol soil. According to Köppen's climatic classification adapted to Brazil [12], the climate of the region is of BSh type, representing hot and dry semiarid climate, with average precipitation of 700 to 900 mm year^{-1}, average temperature of 26.1°C and average annual evaporation of 1000 to 1100 mm [13].

2.2 Origins of the Seedlings

The banana tree seedlings used in the planting were acquired in the Empresa Campo

Biotecnologia, in Cruz das Almas - BA, produced by the micro-propagation process, being transferred initially into plastic sacks filled out with the appropriate substrate. After a period of acclimatisation in a covered nursery (50% shade) for 90 days, they were transplanted for holes of 50 cm x 50 cm x 50 cm, previously fertilised with 4 kg of manure by plant, with a spacing of 3.0 m x 2.0 m.

2.3 Treatments and Experimental Design

To evaluate the vegetative growth, the experimental design was a randomized block experimental design, with nine treatments (genotypes), four repetitions, constituting of thirty six portions, with the experimental unit constituted by three plants, totalling one hundred and eight plants. The treatments consisted of T1: Pacovan Ken; T2: Prata Anã; T3: PHIA-18, T4: Prata Graúda; T5: Grandet Naine; T6: Maçã comum; T7: Princesa; T8: Tropical and T9: Terra.

For evaluation of the reproductive phase, the experimental design was a randomised block design, with seven treatments (genotypes), four repetitions, constituting of twenty-eight portions, experimental unit constituted by three plants, totaling eighty four plants. Due to the differences of the production cycle (days for flowering and fructification) the genotypes T8 (tropical) and T9 (terra) were not appraised.

2.4 Irrigation System

The irrigation system used in the area was of the micro sprinkler type, with the emitter having a flow rate of 103 L. H-1, with wetting of all experimental area. Upon perceiving the water deficit, the dancer was removed from the microsprinkler, maintaining the flow of the micro and increasing the irrigation blade.

2.5 Cultural Treatments

Cultural practices were carried out according to agroecological methods. Manual weeding was performed; fertilisation with bovine manure, sheep goat and poultry in the foundation and every 30 days according to the needs of the crop by soil analysis. The chemical and fertility analysis was performed at the Soil and Mineral Nutrition Laboratory (IFPB), using the methodologies employed by [14], and the data are presented in the Table 1.

Dead cover was made with the cultural remains of the banana plant and the spontaneous plants in order to reduce the loss of water by evaporation; defoliation was performed biweekly, being cut well at the base of the petiole near the pseudocaule; the thinning was carried out monthly after the evaluation by means of "Lurdinha", where the mother plant, daughter and granddaughter were separated from each other in order to reduce the density of plants per hole, thus preventing competition for nutrients and shoring was carried out with wooden stakes. During all the periods of conduction of the experiment measurements of temperature, humidity and precipitation were taken as shown in Fig. 1.

2.6 Analysed Variables

The evaluations of the agronomic characteristics were carried out monthly after the final planting, determining the following parameters:

Height of the plant: Using measuring tape graduated in centimeters, measuring from the base of the plant to the apical meristem, and the data expressed in centimeters per plant;

Perimeter of the pseudocaule: Determined using a measuring tape graduated in centimeters, performed 10 cm above the soil base;

Number of tillers born for plant: Counting of the total number of tillers born per plant;

Days from planting to flowering: The period between transplanting the genotypes in the field and the emission of the heart;

Days of flowering to harvest: Period between the emission of the heart and the harvest of the bunch;

Weigh of the bunch: Were weighed using a scale and the results expressed in kilograms;

Number of leaves per bunch and number of fruits per bunches: Counting the total number of variables per bunch;

Weigh of the fruit: Determined in the central fruit of the outer row of fruits of the second seed, the results being expressed in grams per fruitt;

Length of the fruit: Performed with a tape measure, on the outer curvature of the central fruit of the second bunch, in centimeters;

Table 1. Chemical and soil fertility analysis before and during the cultivation of the different banana tree genotypes, IFPB, Sousa, 2015

Chemical and soil fertility analysis										
Before the cultivation										
pH	**P**	**K**	**Na**	**Ca^{2+}**	**Mg^{2+}**	**Al^{2+}**	**$H^{+} + Al^{2+}$**	**SB**	**CTC**	**V**
(H_2O)	**(mg dm^{-3})**	--------------------	----------	----------	**($cmol_c$ dm_{-3})**	----------	----------	----------	--------------------	**(%)**
7.4	730	0.40	0.37	7.0	4.1	0.0	0.0	11.87	11.87	100
During the cultivation										
6.6	762	0.33	0.12	5.6	2.5	0.0	0.7	8.6	9.3	92

Note: pH: hydrogen potential; P: phosphorus; K: potassium; Na: sodium; Ca^{2+}: calcium; Mg^{2+}: magnesium; Al^{2+}: Aluminum; SB: sum of bases; CTC: total cation exchange capacity; V: saturation for base

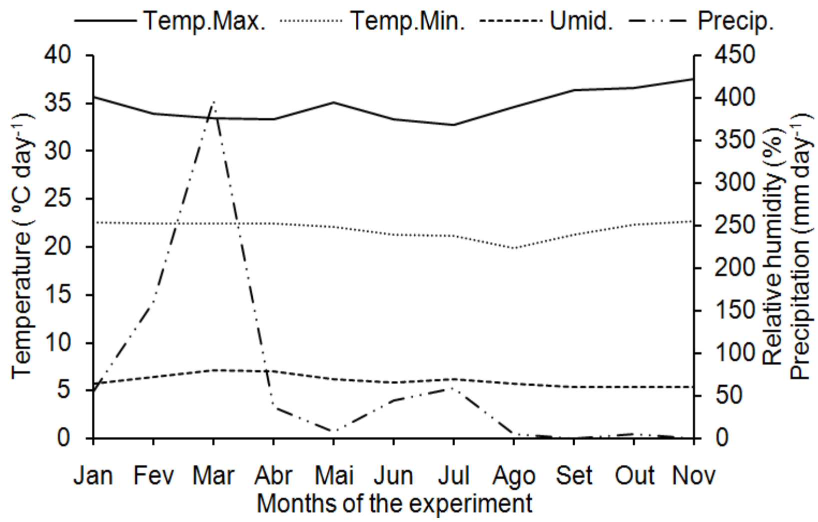

Fig. 1. Values for the data of temperatures (°C), relative humidity of the air (%) and rainfall precipitation during the experiment (January to November) in function of the cultivation of different banana tree genotypes under agroecological management, appraised during the first production cycle, IFPB, Sousa, 2015

Diameter or lateral calibration of the fruit: Performed with a digital caliper, measured in the middle part, towards the length of the central fruit of the second bunch, and the results in millimeters per fruit.

2.7 Statistical Analysis

The results were submitted to a variance analysis (F test, 1 and 5%) and the means of the data compared by the Tukey test at 5% of probability, using the SISVAR statistical program (version 5.6) [15].

3. RESULTS AND DISCUSSION

3.1 Vegetative Phase

Table 2 shows the variance analysis for the height, perimeter of the pseudocaule, number of tillers per plant, days from planting to flowering variables, as a function of the cultivation of different banana tree genotypes. A significant effect was observed for all variables analysed, demonstrating that the factor evaluated directly influences these parameters.

In relation to plant height (Table 3), it was verified that the banana genotypes with the highest values were Terra and Tropical, while PHIA-18, Prata anã and Grande Naine genotypes were smaller in height. Possibly due to the characteristics of these genotypes [16], the cultivars Pacovan Ken and Terra belong to a group of tall banana trees, when adults exceed 4m in height, while the genotypes Prata Anã and Grande Naine belong to the group of banana trees of low size, when adults, the height does not exceed 2 m high. The genotypes Maçã, Princesa and Tropical belong to the group of medium-sized banana trees, when adults ranging from 2 to 4m.

Similar results were found by [8] evaluating the agronomic performance of banana genotypes in the Recôncavo of Bahia, verified values of 2.78 and 2.52 m for the genotype Prata Anã and PHIA-18, in the first crop cycle. According to Farias et al. [17] height is an important parameter to determine the vigor of the plant, crop management, as this determines the ease or difficulty in harvesting banana tree bunches. Therefore, genotypes with short stature are the favorites of farmers, since practices such as the lack of shortage and the increase in planting density lead to a higher economic return [18].

In the same way, the perimeter of the pseudocaule (PPC) was statistically higher in the Tropical and Earth variety, while the Grande Naine genotype obtained the lowest PPC equivalent to a 27.96% reduction when compared to Terra (Table 3).

Bolfarini et al. [19] evaluating the growth, the phenological cycle and the production of five banana cultivars in subtropical conditions, found circumference of the pseudocaule from 62.6 cm to 71.8 cm, respectively presented by the cultivars Prata Anã and PHIA 18, values lower than those found in this work. This characteristic assumes importance in the genetic improvement of the banana, since it is related to the vigor of the plant, besides reflecting in the capacity of support of the bunch and the susceptibility to the tipping [20].

Grande Naine genotype presented higher tillering and the Common Apple genotype was inferior in relation to the other genotypes (Table 3). According to Bolfarini et al. [19], the number of tillers is a very important parameter when evaluating the agronomic performance of cultivars or genotypes, since it allows the continuity of the family, as well as the yields of the following cycles. For small producers, the knowledge about the tillering potential of the cultivars allows the production of their own seedlings, reducing the costs of their acquisition. These same authors, when evaluating the genotype Grande Naine and PHIA-18 produced in Botucatu São Paulo, obtained observed averages of 5.5 and 2.6 tiller per plant, respectively.

Table 3 shows the data referring to the days required for the flowering of the different genotypes. It was verified that the later genotypes were Tropical and Princesa, however the most precocious genotype was Prata Anã under the conditions in which the experiment was carried out. The earlier the faster the genotype will be the financial return of the farmer, the genotype Prata Anã presents potential to be produced under the conditions of the semi-arid Paraíba.

Bolfarini et al. [19] evaluating the growth, the phenological cycle and the production of five cultivate of banana tree in subtropical conditions, they observed inferior values to the obtained in this work in what refers to the period between the planting and flowering of the Prata Anã (302 days). Ramos et al. [21], studying different genotypes in the climatic conditions of Botucatu, São Paulo, they verified that the genotype Prata Anã needed 327 days to begin the flowering. As Silva et al. [22] in the edaphoclimatic conditions of Juazeiro, Bahia, the genotype Prata Anã presented first production cycle (of the planting to the first harvest) of 347.2 days, while for the second production cycle (between the plant-mother's crop and the one of the plant-daughter) 224.6 days were necessary.

In the data referring to the period between flowering and harvesting of the bunch, it was observed that the earliest genotypes were Pacovan Ken, followed by the Grande Naine. On the other hand, the genotypes Maça Comum and Prata Anã (Table 3) were the most recent genotypes, ie, that require a longer period of time for the formation and complete maturation of the fruits. Early genotypes are relevant to the banana producer, especially from the economic point of view, as it results in successive cycles of production in a shorter period of time, increasing production and productivity [23].

Bolfarini et al. [19], studying the growth, the phenological cycle and the production of different banana tree varieties in subtropical conditions, they found superior values to this work for Grande Naine (117 days). Souza et al. [24] evaluating the growth and the production of genotypes of banana trees in subtropical climate, they verified that Grande Naine presented 154 days between the flowering and harvesting of the bunch. Silva et al. [25] they observed 131 days between the flowering and harvest for the Pacovan Ken banana tree in the Valley Siriji River, Pernambuco, being later than this study, maybe the agroecological management has influenced precocity.

Table 2. Summary of the F Test of the height (HEIG), perimeter of the pseudocaule (PPC), number of tillers for plant (NTP), days of the planting to flowering (DPF) variables, in function of the cultivation of different banana tree genotypes under agroecological management, appraised during the first production cycle, IFPB, Sousa, 2015

Variation source	GL	F test			
		HEIG (cm)	PPC (cm)	NTP	DPF (days)
Block	3	4.43*	3.91*	0.32^{ns}	0.79^{ns}
Genotype	8	22.76**	35.52**	5.01**	24.48**
Residue	24	-	-	-	-
CV (%)		6.08	4.07	21.68	3.41
Average		402.72	67.21	3.50	393.21

*** significant (P <0.01); * significant (P <0.05); ns: not significant*

Table 3. Growth variables in function of the cultivation of different banana tree genotypes under agroecological management, appraised during the first production cycle, IFPB, Sousa, 2015

Genotypes	Variables				
	HEIG	PPC	NTP	DPF (days)	DFH (days)
T1	453.00 AB	65.08 BC	2.92 CD	388 BC	72 E
T2	354.75 D	60.91 CD	3.91 BCD	349 D	135 B
T3	331.75 D	59.66 CD	4.08 AB	363 BC	106 C
T4	370.16 CD	64.16 BC	3.66 BCD	367 BC	126 B
T5	352.50 D	57.50 D	5.08 A	393 BC	86 D
T6	337.25 CD	70.33 B	2.25 D	417 AB	151 A
T7	417.91 BC	67.67 B	3.58 BCD	428 A	101 C
T8	448.35 B	79.83 A	2.58 CD	442 A	-
T9	508.83 A	79.75 A	3.50 BCD	-	-

** Genotypes (T1: Pacovan Ken; T2: Prata Anã; T3: PHIA-18, T4: Prata Graúda; T5: Grande Naine; T6: Maçã Comum; T7: Princesa: T8: Tropical and T9: Terra). HEIG: Height; PPC: perimeter of the pseudocaule; NTP: number of tillers for plant; DFP: days of planting to flowering; DHF: days of flowering to harvest*

3.2 Reproductive Phase

For the weight of the bunch, numbers of leaves per bunch, number of fruits per bunch, weight of the fruit, length of the fruit and diameter of the fruit variables, in function of the different appraised genotypes in the first production cycle, it was verified that all the production variables presented significant effect (Table 4).

The data of the weight of the bunch of the different appraised genotypes demonstrated better performance in the Prata Graúda genotypes, followed by PHIA-18, however, the genotypes Pacovan Ken and Princesa presented the smallest values of weight of the bunch if compared to the other appraised genotypes (Table 5). Santos and Carneiro [26] they also verified superiority in the PHIA-18 genotype for mass of the bunches in banana tree in Goiás state, the authors still affirm that the number of bunches and fruits directly influence the size and weight of the bunch, that are variables related to the expression of a genotype.

In the number of fruits per bunch, it was verified that the largest values were observed in the Grande Naine and Prata Anã genotypes, in compensation the smallest values were verified in the genotypes Pacovan Ken and Maçã Comum.

Fehlauer et al. [27] evaluating the production of banana genotypes introduced in the area of Bonito, Mato Grosso do Sul, they obtained values of 119.30 and 69.31 fruits for bunch in the PHIA-18 and Prata-Anã genotypes, respectively. In agreement with [28] the fruits of the genotype PHIA-18 presented larger fresh mass and length, to the they evaluate quality of bananas cultivated in organic system, those authors still denote that this genotype presented excellent agronomic characteristics, being an alternative to cultivate Prata-Anã.

The genotypes that obtained larger acting as for the number of leaves per bunch (Table 5) were Grande Naine (7.50), Prata Graúda, Princesa and PHIA-18 (7.25). Corroborating with [24] where the genotype Grande Naine was the one that obtained a larger number of leaves per bunch. Oliveira et al. [29] they detach the importance of that variable, as being of interest for the producer and fundamental for the genetic improvement of the banana tree, once the bunch is constituted in the commercial unit.

The weight of the fruit was superior in the Prata Graúda genotype with 199 g, while the smallest weights were observed in the genotypes Princesa 69.75 g, followed by Pacovan Ken with 88.50 g (Table 5). Camili et al. [30] they also verified mass of the equivalent fruit to 200 g for the Prata Graúda banana tree in conventional cultivation in Campo Grande - MS, in other words, the agroecological cultivation can be an alternative production in the upper interior of Paraiba.

In the fruit length, it was observed that the genotypes Prata Graúda and Grande Naine presented the highest averages observed, while the lowest values were observed in the genotypes Pacovan Ken, Princesa and Maçã Comum (Table 5). Similar results were observed by Nomura et al. [31] when studying the development and production of Grande Naine banana, verified an average of 17.8 cm. Castracini et al. [32] studying the post-harvest characterisation of banana genotypes, produced in Nova Porteirinha, Minas Gerais, observed values of 21 and 22.33 cm for the genotype Prata Anã and PHIA-18, respectively. Borges et al. [33] evaluated the physico-chemical characterisation of different banana genotypes produced in the climatic conditions of Nossa Senhora das Dores, Sergipe, and verified that PHIA-18, Prata Anã and Maçã presented a length of 17.36, 13.87 and 15, 74 cm, respectively.

In relation to the diameter of the fruits in function of the different banana tree genotypes cultivated in the Upper interior of Paraíba, it was verified

Table 4. Summary of the F Test of the weight of the bunch (WB), numbers of leaves per bunch (NBB), number of fruits per bunch (NFB), weight of the fruit (WF), length of the fruit (LF) and diameter of the fruit (DF) variables in function of the cultivation of different banana tree genotypes under agroecological management, appraised during the first production cycle, IFPB, Sousa, 2015

Variation source	GL	F test					
		WB (kg)	NBB	NFB	WF (g)	LF (cm)	DF (mm)
Block	3	0.40^{ns}	0.85^{ns}	0.93^{ns}	0.36^{ns}	0.40^{ns}	0.60^{ns}
Genotype	6	15.51**	4.23**	3.21*	7.86**	6.91**	5.57**
Residue	18	-	-	-	-	-	-
CV (%)	-	15.39	11.14	17.11	24.30	9.94	9.09
Average	-	10.25	6.71	82.43	120.68	17.64	40.17

*** significant (P <0.01); * significant (P <0.05); ns: not significant*

Table 5. Production variables in function of the cultivation of different banana tree genotypes under agroecological management, appraised during the first production cycle, IFPB, Sousa, 2015

Genotypes	Analysed variables					
	WB (kg)	NBB	NFB	WF (g)	LF (cm)	DF (mm)
T1	6.75 D	5.75 B	63.75 A	88.50 B	15.00 B	40.50 AB
T2	12.25 AB	7.25 AB	87.75 A	122.75 B	18.00 AB	42.50 A
T3	9.75 BCD	6.25 AB	92.50 A	126.75 B	18.50 AB	43.50 A
T4	15.50 A	7.25 AB	81.75 A	199.00 A	20.75 A	45.75 A
T5	11.75 BC	7.50 A	95.25 A	131.75 AB	20.00 A	37.75 AB
T6	7.50 D	5.75 B	66.25 A	106.25 B	15.75 B	38.50 AB
T7	8.25 CD	7.25 AB	89.75 A	69.75 B	15.50 B	32.75 B

** Genotypes (T1: Pacovan Ken; T2: Prata Anã; T3: PHIA-18, T4: Prata Graúda; T5: Grande Naine; T6: Maçã Comum and T7: Princesa). WB : Weigh of the bunch; NBB: numbers of leaves perr bunch, NFB: number of fruits per bunch; WF: weigh of the fruit; LF: length of the fruit; DF: diameter of the fruit* that the fruits of the Prata Anã genotype presented the largest averages, already the smallest values were observed in the Princesa genotype (Table 5). Results lower than this work were observed by Castracini et al. [32] characterising the post-harvest and sensorial quality of banana genotypes, produced in a conventional cultivation system, which verified a diameter of 38.59 mm and 38.20 mm for the genotypes Prata Anã and PHIA-18, respectively. Nomura et al. [31] evaluating the development and production of the Grande Naine banana in different management systems in the Ribeira Valley, São Paulo, observed a diameter of 27.8 mm. Borges et al. [33] evaluating different banana genotypes in the northern state of Paraná, obtained fruit diameters of 27 and 34 mm in the genotypes Princesa and Prata Anã. These results demonstrate that the system of agroecological management promotes the obtaining of fruits of larger diameters and consequently greater production, being, therefore, a viable alternative for the conditions of the upper interior of Paraiba.

4. CONCLUSION

Prata Graúda and Grande Naine genotypes came out on top in terms of agronomic performance under agroecological practices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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