Performance of banana genotypes with resistance to black leaf streak disease in Northeastern Brazil

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Abstract – The objective of this work was to evaluate the growth and the production of banana plants with resistance to black leaf streak disease (BLSD), in comparison with the performance of traditional cultivars susceptible to the disease. Twenty cultivars were planted at the Jaguaribe-Apodi plateau, in Northeastern Brazil: 15 with resistance to BLSD, namely Pacovan Ken, PV42-68, BRS Vitória, BRS Japira, BRS Preciosa, BRS Garantida, Thap Maeo, BRS Tropical, BRS Platina, BRS Maravilha, FHIA 02, FHIA 18, Galil 18, Caipira, and Buccaneer; and five susceptible to the disease, namely Williams, Grande Naine, Pacovan, Prata Anã, and Maçã. Banana growth and production of bunches were evaluated during three successive cycles. 'BRS Tropical' and 'Caipira' can replace 'Maçã', which is very susceptible to *Fusarium* wilt. The BRS Maravilha, BRS Platina, FHIA 02, FHIA 18, and Galil 18 cultivars show adequate height and high yield potential, being alternatives to the traditional Prata subgroup. The Buccaneer cultivar is an alternative to the susceptible cultivars of the Cavendish subgroup and can be explored in an irrigated agrosystem.

Index terms: *Musa*, *Mycosphaerella fijiensis*, banana cultivars, black leaf streak disease.

Desempenho de genótipos de bananeira com resistência à sigatoka-negra no Nordeste brasileiro

Resumo – O objetivo deste trabalho foi avaliar o crescimento e a produção de bananeiras com resistência à sigatoka-negra, em comparação ao desempenho de cultivares tradicionais suscetíveis à doença. Vinte cultivares foram plantadas no planalto Jaguaribe-Apodi, no Nordeste do Brasil: 15 com resistência à sigatoka-negra, a saber, Pacovan Ken, PV42-68, BRS Vitória, BRS Japira, BRS Preciosa, BRS Garantida, Thap Maeo, BRS Tropical, BRS Platina, BRS Maravilha, FHIA 02, FHIA 18, Galil 18, Caipira e Buccaneer; e cinco suscetíveis à doença, a saber, Williams, Grande Naine, Pacovan, Prata Anã e Maçã. O crescimento e a produção de cachos das bananeiras foram avaliados durante três ciclos sucessivos. 'BRS Tropical' e 'Caipira' podem substituir 'Maçã', que é bastante suscetível à murcha de *Fusarium*. As cultivares BRS Maravilha, BRS Platina, FHIA 02, FHIA 18 e Galil 18 apresentam porte adequado e alto potencial de rendimento, sendo alternativas ao tradicional subgrupo Prata. Já a cultivar Buccaneer é alternativa às cultivares suscetíveis do subgrupo Cavendish e pode ser explorada em agrossistema irrigado.

Termos para indexação: *Musa*, *Mycosphaerella fijiensis*, cultivares de bananeira, sigatoka-negra.

Introduction

Banana (*Musa* spp.) plants are widely cultivated in tropical regions, and developing countries account for over a third of global banana production (FAO, 2016), generating opportunities and income for producers and other agents in the fresh fruit value chain. In Brazil, the banana crop is spread throughout all regions, with an annual harvest of 7 million tons. The Northeast of the country represents nearly 40% of the planted area and 35% of the national production (IBGE, 2015). However, despite the high production levels in this particular region, fruit yield is still low (<13 Mg ha^{-1}), which is associated with the productivity potential of traditional cultivars, such as Prata (Donato et al., 2009), compared with other types of banana.

The banana cultivars traditionally planted in Brazil are susceptible to Panama disease and Sigatoka leaf spot disease (Silva et al., 2015). In addition, inadequate cultivation practices are often adopted, in particular planting under rainfed conditions in semiarid regions. In irrigated areas, for example, the Prata cultivar can produce fruit yields of up to 40 Mg ha^{-1} (Donato et al., 2009), which can easily be exceeded by the cultivars of the Cavendish subgroup, mainly destined for the export market, such as Grande Naine. This cultivar produced 70 to 75 Mg ha^{-1} per year under irrigation and a dense spacing of 2,000 to 4,000 plants per hectare (Flori et al., 2004). It should be noted, however, that consumers in Northeastern Brazil show a preference for 'Prata', 'Maçã' (Matsuura et al., 2004), and 'Pacovan' (Garruti et al., 2012) bananas.

Several different diseases infect banana plants, but, of all fungal infections, black leaf streak disease (BLSD), also known as black Sigatoka, is considered to be the worst, due to its widespread occurrence in many countries, its severe negative impact on banana production (Robert et al., 2012), and its effects on cultivars belonging to different genomic groups (Churchill, 2011). In Brazil, BLSD causes significant losses in the humid areas of the Amazon (Gasparotto et al., 2006), affecting bananas of the 'Prata' and 'Cavendish' subgroups (Silva et al., 2014). The disease spreads through the spores of the fungus *Mycosphaerella fijiensis* (Silva et al., 2014), which could happen during the transport of banana plant material that could contain the pathogen propagules, causing concern in the banana agribusiness. As a result, strategies for the genetic improvement and the development of cultivars resistant to BLSD are being sought in Brazil (Silva et al., 2013).

No occurrences of BLSD have been reported in Northeastern Brazil to date. However, this can be a matter of time, since, during certain times of the year, the climatic conditions of some banana-producing areas are favorable to the development of the disease, with air temperatures of approximately 27ºC and high relative humidity of around 80% (Ghini et al., 2007; Jesus Júnior et al., 2008). Because of this, some researches on genotypes resistant to BLSD (Silva et al., 2015) and on cultivars tested in semiarid conditions (Lédo et al., 2008; Azevedo et al., 2010) are already being carried out. However, the plant size and the productive capacity of cultivars resistant to BLSD may not be suitable for growing in open coastal areas.

The objective of this work was to evaluate the growth and the production of banana plants with resistance to BLSD, in comparison with the performance of traditional cultivars susceptible to the disease.

Materials and Methods

A total of 20 banana cultivars were evaluated: 15 considered resistant to BLSD, namely, Pacovan Ken, PV42-68, BRS Vitória, BRS Japira, BRS Preciosa, BRS Garantida, Thap Maeo, BRS Tropical, BRS Platina, BRS Maravilha, FHIA 02, FHIA 18, Galil 18, Caipira, and Buccaneer; and five susceptible to the disease, namely, Williams, Grande Naine, Pacovan, Prata Anã, and Maçã. The experiment was set up at the Frutacor farm, located in the irrigation district of Jaguaribe-Apodi, in the Jaguaribe-Apodi plateau, in the municipality of Limoeiro do Norte, in the state of Ceará, Brazil (05°20'S, 38°05'W, at 80 m above sea level). The climate of the area is hot and semiarid, BSw'h' according to Köppen-Geiger (DNOCS, 2016). During the experimental period, the average temperature at the farm was 26.4±1.2°C, the relative humidity was 73.4±8.8%, and the average wind speed was 5.8±0.6 m s^{-1}. The soil of the experimental area was classified as an Inceptisol, and the 0–20 cm-depth, according to the analytical methods of Silva (2009), showed: pH (H_2O) 7.1 (ratio of 1:2.5); 18.8 mg kg^{-1} P, 20.4 mmol$_c$ kg^{-1} K, 1.3 mmol$_c$ kg^{-1} Na, 4.9 mg kg^{-1} Cu, 10.6 mg kg^{-1} Fe, 55.8 mg kg^{-1} Mn, and 2.0 mg kg^{-1} Zn extracted with Mehlich-1; and 79.7 mmol$_c$ kg^{-1} Ca and 1.3 mmol$_c$ kg^{-1} Mg extracted with 1 mol L^{-1} KCl.

The preparation of the area consisted of soil plowing, harrowing, and furrowing (0.4-m depth and 2 or 4 m apart). Bovine manure (12 L per plant) was placed in the furrows, along with 300 g per plant of monoammonium phosphate, 200 kg ha^{-1} P_2O_5, and 100 kg ha^{-1} N. These fertilizer dosages are commonly used for planting banana seedlings in the irrigation district of Jaguaribe-Apodi. After the furrows were closed and the soil incubated for a month, hose pipes and Gyronet micro-sprinklers (Netafim Brasil, Ribeirão Preto, SP, Brazil) were installed, with a flow rate of 40 L per hour and a wetting diameter of 4 m. On sunny days, up to 53 L of water per plant per day were used throughout the experimental period.

Micropropagated seedlings were planted (Table 1), which were initially acclimatized in 1-L capacity plastic bags, containing a mixture of vermicompost, soil, and washed sand (in a 1:6:3 ratio by volume), under a black shade cloth to reduce luminosity from sunlight in 25%. The substrate, according to the analytical methods of Silva (2009), showed: pH (H_2O) 7.3 (ratio of 1:2.5); 43.8 mg kg^{-1} P, 7.5 mmol$_c$ kg^{-1} K, 2.1 $mmol_c$ kg^{-1} Na, 0.4 $mmol_c$ kg^{-1} Cu, 29.7 mg kg^{-1} Fe, 43.1 mg kg^{-1} Mn, and 2.1 mg kg^{-1} Zn extracted with Mehlich-1; and 49.6 $mmol_c$ kg^{-1} Ca and 18.9 $mmol_c$ kg^{-1} Mg extracted with 1 mol L^{-1} KCl. In April 2008, when planting was performed in the field, the seedlings with root clods had more than 30 cm of shoot height. For the distribution of the seedlings of the 20 evaluated cultivars, a randomized complete block design was used, with three replicates with 20 plants. The spacing between planting rows was 2 and 4 m, and between plants in the row was 2.5 m. Seedlings of the Prata Catarina cultivar were planted in the external borders.

Thirty days after planting, ferti-irrigation of the banana plants began. Every three days, on average, low doses of urea (45% N), potassium sulphate (18% S and 50% K_2O), and potassium chloride (60% K_2O) were provided, totaling almost 270 kg ha^{-1} N, 21 kg ha^{-1} S, and 233 kg ha^{-1} K_2O in the first year. The management of the fertilizers and of the cultivation practices was carried out in alignment with the recommendations of Borges et al. (2009).

When bunches first appeared, the height and diameter of the pseudostem were measured at about 30 cm from the base, and the number of green leaves on 12 central plants per plot were counted. Data collection was programmed according to the appearance of bunches. For this, bunches were cut, the hands and fingers were separated, and their fresh weight was determined in order to calculate the production of bunches without stalks. In addition, in order to calculate the production cycles, the period of time between the planting of seedlings in the field and the harvest of bunches was noted.

Banana growth and production data were analyzed in a randomized complete block design, in a split-plot arrangement. The plots were considered the banana

Table 1. Traits of the banana (*Musa* spp.) cultivars planted at the Frutacor farm, in the municipality of Limoeiro do Norte, in the state of Ceará, Brazil.

Cultivar	Group	Subgroup	Genealogy (origin)[1]	Sensibility to plant diseases
Pacovan Ken	AAAB	Prata	Pacovan hybrid (AAB) x M 53 (AA) from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt[2]
PV42-68	AAAB	Prata	Pacovan hybrid (AAB) x M 53 (AA) from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt[2]
BRS Vitória	AAAB	Prata	Pacovan hybrid (AAB) x M 53 (AA) from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt[2]
BRS Japira	AAAB	Prata	Pacovan hybrid (AAB) x M 53 (AA) from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt[2]
BRS Preciosa	AAAB	Prata	Pacovan hybrid (AAB) x M 53 (AA) from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt[2]
BRS Garantida	AAAB	Prata	Prata São Tomé hybrid from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt[2]
Thap Maeo	AAB	Mysore	Mysore-type cultivar from Thailand and Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt[2]
BRS Tropical	AAAB	Prata	Yangambi hybrid 02 x M 53 from Embrapa, Brazil	Moderately resistant to BLSD, YS, and *Fusarium* wilt
BRS Platina	AAAB	Prata	Prata Anã hybrid (AAB) x M53 (AA) from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt
BRS Maravilha	AAAB	Prata	Prata Anã hybrid (AAB) x SH31-42 (AA) from Embrapa, Brazil	Resistant to BLSD and *Fusarium* wilt, and moderately resistant to YS[3]
FHIA 02[4]	AAAB	Prata	FHIA hybrid from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt
FHIA 18	AAAB	Prata	FHIA hybrid from Embrapa, Brazil	Resistant to BLSD, moderately resistant do YS, and susceptible to *Fusarium* wilt[2]
Galil 18	AAAB	Prata	FHIA hybrid from Multiplanta, Brazil	Resistant to BLSD[5]
Buccaneer	AAAA	Gros Michel	High Gate hybrid from Jamaica and Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt
Caipira	AAA	Ibota	Cultivar from Embrapa, Brazil	Resistant to BLSD, YS, and *Fusarium* wilt
Pacovan	AAB	Prata	Cultivar from Embrapa, Brazil	Susceptible to BLSD and YS, and moderately susceptible to *Fusarium* wilt[2] (Foc, race 1).
Prata Anã	AAB	Prata	Cultivar from Embrapa, Brazil	Susceptible to BLSD and YS, and moderately susceptible to *Fusarium* wilt[2] (Foc, race 1)
Maçã	AAB	Prata	Cultivar from Embrapa, Brazil	Susceptible to BLSD and *Fusarium* wilt[3], and moderately resistant to YS[5]
Williams	AAA	Cavendish	Cultivar from Embrapa, Brazil	Susceptible to BLSD and YS, and resistant to *Fusarium* wilt[3] (Foc, race 1)
Grande Naine	AAA	Cavendish	Cultivar from Embrapa, Brazil	Susceptible to BLSD and YS, and resistant to *Fusarium* wilt[3] (Foc, race 1)

[1]Embrapa, Empresa Brasileira de Pesquisa Agropecuária (Brazil); and Multiplanta, Multiplanta Tecnologia Vegetal Ltda. [2]According to Borges et al. (2009). [3]According to Cunha et al. (2015). [4]FHIA 02 belongs to the Prata subgroup (Jesus et al., 2013). [5]According to Costa et al. (2012). BLSD, black leaf streak disease; YS, yellow Sigatoka; and Foc, *Fusarium oxysporum* f. sp. *cubense* fungus.

cultivars, and the subplots, the production cycle. Data were subjected to the analysis of variance (Anova) using the Sisvar software, version 5.6 (Universidade Federal de Lavras, Lavras, MG, Brazil), and the means of treatments were grouped by the Scott-Knott test, at 5% probability. The means of the variables for all three cycles were subjected to ascending hierarchical classification (AHC), using the Euclidean distance matrix as a measure of dissimilarity and the unweighted pair-group method with arithmetic mean (UPGMA) for the formation of clusters (Sneath & Sokal, 1973). The variable "cycle" was considered as the number of days between planting and harvest of the first bunch, assuming that the later cycles would be affected by the thinning of banana plants. Moreover, to help define and select genotypes with the desired agronomic traits, the same data matrix was subjected to Pearson's multivariate principal component analysis (PCA) and to a correlation biplot with the automatic coefficients. AHC and PCA were performed by computing the data matrix (Abdi & Williams, 2010) with the XLSTAT software, version 2015.3.01 (Addinsoft, Inc., Brooklyn, NY, USA).

Results and Discussion

A vigorous aerial growth and a satisfactory production of bunches were observed for 19 of the evaluated cultivars (Tables 2 and 3). The exception was 'Maçã', for which only a few small bunches were obtained due to the incidence of *Fusarium* wilt caused by the fungus *Fusarium oxysporum* f. sp. *cubense* (Foc). This result was expected in the areas that had been occupied five years before by banana plants of the Maçã cultivar. Although the BRS Platina, BRS Tropical, BRS Garantida, and Grande Naine cultivars were planted in neighbor plots to Maçã, no symptoms of the disease were detected, confirming the resistance of those plants to Foc, possibly race one. The cultivars Grande Naine and Williams from the Cavendish subgroup are susceptible to Foc, race TR4 (Ploetz, 2015), for which there are no known reports in the area, still considered under risk. Among the genotypes tested, 'BRS Tropical', 'Thap Maeo', and 'Caipira', also resistant to *Fusarium* wilt, produce small fruits and can be considered as a type of 'Maçã' banana (Carvalho et al., 2011).

In relation to yellow Sigatoka (YS), no control measures were adopted in the experimental area. Although the disease has been controlled in the surrounding banana plantations, this did not prevent the emergence of mild symptoms of YS on older leaves of the Pacovan, Prata Anã, William, and Grande Naine cultivars. The tested materials did not exhibit symptoms of BSLD, however. It should be pointed out that the local climatic conditions are favorable to the emergence of BLSD, according to Guini et al. (2007) and Jesus Júnior et al. (2008), with milder temperatures from 25 to 27°C during April and May (rainy season) and a high relative humidity of >75%. Besides, the Jaguaribe-Apodi plateau, where the experiment was carried out, is not very far (just over 1,000 km) from the productive areas of the Amazon region, where BLSD appears to be endemic.

Data on the growth and production of all studied cultivars, except Maçã, were subjected to Anova, and an interaction between cultivars and cycles was observed ($p<0.05$) (Tables 2 and 3). Cultivars with different genealogy (Table 1) are expected to show a different performance even when uniform-sized plantlets are planted in the field. The Pacovan Ken, PV42-68, BRS Victoria, BRS Japira, BRS Preciosa, and BRS Garantida cultivars grew to be tall, measuring 5.8 m from the base to the insertion of the bunch, especially in the third cycle, together with the traditional cultivar Pacovan (Table 2); therefore, they are not recommended for crops grown in plateaus without windbreak protection. The Thap Maeo cultivar was also considered unsuitable, showing average height ranging from 3.5 m, in first cycle, to 5.1 m, in the third cycle, besides a thin pseudostem in the early cycles of bunch production. This banana plant cultivar is also subject to pseudostem drop at the bunch insertion point. It should be highlighted that, during the experiment, winds reached 9.17 m s^{-1} in February 2009 and 9.26 m s^{-1} in January 2010. Winds rated as force 4 (5.5 to 7.9 m s^{-1}) according to Beaufort's scale can already cause minor damage to leaves, but, in the Jaguaribe-Apodi plateau, winds reaching force 6 (10.8 to 13.8 m s^{-1}) occasionally occur.

Regarding the size of the banana plant, the following cultivars were selected: BRS Tropical, derived from Yangambi 02; BRS Platina and BRS Maravilha, both derived from Prata Anã; the FHIA cultivars, i.e., FHIA 02, FHIA 18, Galil 18, or false FHIA 18; and

Buccaneer and Caipira, whose pseudostems did not exceed 4.3 m in height (Table 2). A lower plant height was accompanied by a greater pseudostem diameter, except for the Caipira cultivar, during the second and third production cycles. The green leaves varied between banana cultivars and cycles, but overall they were satisfactory when bunches first appeared. In general, shorter cultivars have a wider pseudostem that better supports the bunches, which is desirable for banana plantations on irrigated plateau areas, together with a large number of leaves that enable a greater banana production (Nomura et al., 2013).

The production of banana hands and fruits was affected by the interaction of cultivars and cycles (Table 2). 'BRS Garantida', 'BRS Tropical', and 'Caipira' produced fewer hands during the first cycle, similarly to 'Prata Anã'. In turn, the Thap Maeo cultivar showed the greatest potential to produce hands and fruits in the bunch during the second and third cycles, 13 and 19 months after the seedlings were planted, respectively. The last period covers the three production cycles, for which the BRS Tropical, BRS Maravilha, FHIA 02, FHIA 18, Galil 18, Caipira, and Prata Anã cultivars showed similar results. Unlike the second and third cycles, which were in part affected by thinning and scheduled harvest, the first cycle has been used as an indicator of precocity for banana production. The harvest time of the first banana bunches was quite short (>9 months) for the BRS Maravilha, FHIA 02, FHIA 18, and Buccaneer cultivars (Table 3). However, this precocity was also a notable feature in 'BRS Preciosa' and 'BRS Garantida', both tall, and in 'Thap Maeo'. Longer production cycles have been reported for banana cultivars under irrigation in other

Table 2. Plant height from the ground up to the point of emission of the bunch (BPH), diameter of the base of the pseudostem (PD), number of green leaves at the flowering stage (GLN), and number of hands (HN) and of fruits in the bunch (FN) of banana (*Musa* spp.) cultivars planted at the Frutacor farm, in the municipality of Limoeiro do Norte, in the state of Ceará, Brazil[(1)].

Banana cultivar	BPH (m)			PD (cm)			GLN			HN			FN		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
Pacovan Ken	3.8bA	4.7dB	5.6dC	27.8aA	34.2bB	37.8cC	14.3bA	13.0bA	10.3aA	7.3aA	8.3bA	9.5aB	113.6aA	126.6aA	156.8aB
PV42-68	3.8bA	5.3dB	6.0dC	29.1aA	35.1bB	38.5cC	12.8bB	12.9bB	9.1aA	7.2aA	8.1bA	9.0aB	104.4aA	124.9aA	139.3aA
BRS Vitória	4.0bA	4.5cA	5.7dB	28.5aA	31.6aB	35.3cC	12.9bB	12.0bB	9.0aA	7.1aA	8.6bB	8.8aB	107.3aA	128.9aA	137.1aA
BRS Japira	4.0bA	4.9dB	6.0dC	27.9aA	32.4bB	38.6cC	14.4bA	14.0bA	8.9aA	7.5aA	8.4bA	8.8aA	110.9aA	126.8aA	130.0aA
BRS Preciosa	3.7bA	4.3cB	5.8dC	26.7aA	33.0bB	38.3cC	11.8aA	11.0aA	9.9aA	6.8aA	8.7bB	8.9aB	98.3aA	137.8aB	140.9aB
BRS Garantida	3.6bA	4.4cB	5.8dC	24.9aA	31.6aB	38.1cB	12.3bB	10.3aA	9.8aA	6.6aA	7.0aA	8.3aB	88.9aA	111.4aB	124.9aB
Thap Maeo	3.5bA	3.7bA	5.1cB	27.2aA	30.2aA	37.1cB	11.7aA	11.9bA	12.1aA	11.3cA	12.9dB	15.8dC	204.0cA	237.3cB	278.7dC
BRS Tropical	3.7bA	3.9bA	4.3bB	33.6bA	33.8bA	33.8cA	13.2bB	11.9bB	9.0aA	7.3aB	7.2aB	7.6aB	134.3bA	132.2aA	137.8aA
BRS Platina	2.9aA	3.7bB	4.1bB	26.9aA	33.3bB	37.0cC	11.8aA	11.2aA	10.2aA	8.2bA	9.1bA	10.8bB	120.3aA	140.3aA	178.5bB
BRS Maravilha	2.8aA	3.4bB	4.3bC	26.0aA	32.5bB	37.5cC	10.3aA	8.9aA	9.3aA	10.2cA	10.8cA	12.1cB	153.3bA	182.8bB	213.2cC
FHIA 02	2.6aA	3.6bB	4.2bC	25.9aA	33.2bB	36.0cB	10.2aA	10.3aA	8.8aA	10.3cA	11.2cB	12.1cB	155.6bA	179.3bA	217.8cB
FHIA 18	2.8bA	3.5bB	4.2bC	26.1aA	32.3bB	36.4cC	10.6aA	10.0aA	9.9aA	10.0cA	10.5cA	13.2cB	152.3bA	175.2bA	226.6cB
Galil 18	3.2aA	4.1cB	4.1bB	32.6bA	36.7bB	36.7cB	10.8aA	10.9aA	10.9aA	10.1cA	10.8cA	12.0cB	167.8bA	164.8bA	180.0bA
Buccaneer	2.8aA	3.7bB	4.2bC	28.1aA	35.3bB	36.2cC	10.3aA	11.9bA	9.8aA	8.0bA	11.0cB	12.4cC	138.1bA	210.3cB	210.8cB
Caipira	2.7aA	3.3aB	3.9bC	25.2aA	29.8aB	29.3bB	10.5aA	12.3bB	9.8aA	8.4bA	10.0cB	10.5bB	178.8cA	225.6cB	238.9cB
Pacovan	3.6bA	4.1cA	5.7dB	24.3aA	30.3aB	35.3cC	11.2aA	13.4bB	10.5aA	7.9bA	8.0bA	9.3aA	110.3aA	114.9aA	139.3aA
Prata Anã	2.6aA	3.6bB	3.2aB	26.8aA	32.3bB	29.9bB	11.7aB	14.0bC	7.8aA	9.3cA	10.1cA	9.6aA	148.8bA	170.3bA	149.4aA
Williams	2.5aA	3.0aA	3.1aA	25.8aA	29.4aB	26.6aA	9.8aA	10.0aA	11.1aA	8.0bA	11.0cB	10.4bB	148.8bA	205.6cB	183.6bB
Grande Naine	2.5aA	2.9aB	3.1aB	26.6aA	28.4aA	31.2bB	11.3aA	11.0aA	11.1aA	8.3bA	9.3bA	12.1cB	156.6bA	168.9bA	237.1cB

[(1)]Values followed by equal letters, lowercase in the columns and uppercase in the lines for each parameter, do not differ significantly by the Scott-Knott test, at 5% probability.

productive areas, such as in the municipality of Urandi, in the state of Bahia (Donato et al., 2009), and in the municipality of Goiânia, in the state of Goiás, both in Brazil (Mendonça et al., 2013). At the region of Vale do Ribeira, in the state of São Paulo, Nomura et al. (2013) reported production periods ranging from 9.1 months, for the cultivar BRS Japira, to 13.8 months, for Caipira.

The fresh weights of fruits, hands, and bunches were also affected by the interaction between cultivars and cycles (Table 3). For bananas, a smaller size and lower weight are desirable, which were observed for the Thap Maeo, BRS Tropical, and Caipira cultivars, especially in the first two cycles. The shape of the fruits of the resistant cultivars is similar to that of the Maçã and Prata Anã bananas, which are preferred in the domestic consumer market (Matsuura et al., 2004). During the first cycle, large and heavy bunches were obtained with the BRS Platina, BRS Maravilha, FHIA 02, FHIA 18, Galil 18, and Buccaneer cultivars, which also showed good yield potential in the other cycles, and with banana plants derived from Pacovan, which were not recommended because of their height.

The choice of the most adequate cultivar by farmers naturally depends on their production goals and targets. However, considering the planting density used of 1,333 plants per hectare, a high production of bananas may be expected, ranging from 39.3 Mg ha^{-1}, for the BRS Maravilha cultivar (first crop cycle), to 50.2 Mg ha^{-1}, for FHIA 02 (second cycle). Regarding high productive potential, the Buccaneer cultivar should also be considered, since it produced up to 41 Mg ha^{-1} in the first cycle and 47.5 Mg ha^{-1} in the third one, being an alternative to the Williams and Grande Naine cultivars, which are sensitive to BLSD and produce bananas with a similar shape (Lédo et al., 2008). Despite this, in the regional consumer market, there is still uncertainty on the intention of buying 'Buccanero' banana (Garruti et al., 2013), showing that it could be tested in new products and markets.

The cluster analysis according to the AHC enabled the formation of four major clusters with the assessed bananas (Figure 1). The first cluster consisted of only one cultivar, Thap Maeo, from the Mysore subgroup. The second cluster was formed by the Caipira and BRS Tropical cultivars from the Ibota and Prata subgroups, respectively, and by Prata Anã. The third cluster was the largest, with the following cultivars: Williams and Grande Naine, both from the Cavendish

Table 3. Period from planting to harvest, as well as fresh weight of hands (HW), of fruits (FW), and of bunches without stalks (BW) of the banana (*Musa* spp.) cultivars planted at the Frutacor farm, in the municipality of Limoeiro do Norte, in the state of Ceará, Brazil[(1)].

Banana cultivar	Period until harvest			HW (kg)			FW (g)			BW (kg)		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
Pacovan Ken	282.9bA	432.2bB	599.3bC	3.0cA	3.0cA	2.7bA	190.9bA	194.4bA	167.1cA	21.7cA	24.6cA	26.0cA
PV42-68	299.0bA	447.2bB	600.3bC	3.2cB	2.7cA	2.7bA	222.3cB	175.7bA	181.2cA	23.3cA	21.9bA	24.4bA
BRS Vitória	271.0aA	431.8bB	604.6bC	3.0cA	2.9cA	2.6bA	194.0bA	195.1bA	167.5cA	20.8cA	25.1cA	23.1bA
BRS Japira	299.0bA	431.3bB	619.6bC	3.5dB	3.0cA	2.9bA	239.1cB	195.2bA	194.7cA	26.5dA	24.8cA	25.3bA
BRS Preciosa	262.0aA	422.9bB	605.0bC	2.7bA	2.5bA	2.6bA	187.3bA	157.3bA	162.3cA	18.4bA	21.2bA	22.9bA
BRS Garantida	262.0aA	401.8aB	612.1bC	2.7bB	3.0cB	2.1aA	200.2bB	191.7bB	136.7bA	17.8bA	20.8bA	17.2aA
Thap Maeo	268.7aA	399.3aB	589.1aC	2.1aA	2.1aA	1.9aA	118.4aA	113.4aA	105.7aA	24.2cA	26.9cA	28.8cA
BRS Tropical	298.3bA	430.7bB	587.5aC	1.8aA	2.2aA	2.2aA	98.3aA	119.3aA	124.0aA	13.2aA	15.8aA	16.9aA
BRS Platina	294.9bA	411.3aB	604.3bC	3.6dB	2.8cA	2.8bA	247.5cB	181.7bA	170.2cA	30.0dA	25.5cA	30.4dA
BRS Maravilha	262.0aA	396.9aB	577.3aC	2.9cA	3.0cA	3.1bA	192.4bA	178.1bA	176.3cA	29.5dA	32.5dA	37.6eB
FHIA 02	262.0aA	390.8aB	589.5aC	3.0cA	3.4cA	2.8bA	199.2bB	212.2bB	157.5cA	31.0dA	37.7eA	34.3dA
FHIA 18	262.0aA	393.3aB	589.3aC	3.0cA	3.3cA	3.2bA	198.4bA	194.6bA	183.2cA	30.2dA	34.0eA	41.5eB
Galil 18	279.3bA	390.8aB	572.3aC	3.1cB	2.7cA	2.4aA	189.4bA	180.4bA	158.6cA	31.8dA	29.7dA	28.6cA
Buccaneer	262.0aA	433.6bB	623.3bC	3.8dB	2.9cA	3.0bA	223.0cB	154.3bA	184.7cA	30.8dA	32.5dA	37.1eB
Caipira	298.5bA	416.3bB	587.9aC	2.1aA	2.0aA	2.7bB	98.5aA	89.4aA	118.8aA	17.6bA	20.2bA	27.8cB
Pacovan	287.8bA	419.8bB	610.3bC	2.7bA	2.6bA	2.2aA	191.5bB	179.7bB	143.9bA	21.1cA	20.6bA	20.1aA
Prata Anã	271.2aA	421.8bB	589.0aC	2.1aA	2.2aA	1.8aA	130.5aA	128.7aA	114.6aA	19.4bA	21.9bA	17.2aA
Williams	262.0aA	427.4bB	600.1bC	4.0dC	3.1cB	2.6bA	216.2cB	166.1bA	146.7bA	32.2dB	34.2eB	27.0cA
Grande Naine	262.0aA	419.3bB	600.1bC	3.7dB	3.2cA	2.9bA	199.2bB	174.7bB	147.6bA	31.2dA	29.5dA	35.0dA

[(1)]Values followed by equal letters, lowercase in the columns and uppercase in the lines for each parameter, do not differ significantly by the Scott-Knott test, at 5% probability.

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subgroup; Buccaneer, from the Gros Michel subgroup; FHIA 02, FHIA 18, and Galil 18; and BRS Maravilha and BRS Platina. The fourth cluster consisted of the Pacovan cultivar and of its hybrids BRS Preciosa, BRS Vitória, PV42-68, BRS Japira, Pacovan Ken, as well as of BRS Garantida, a hybrid derived from Prata São Tomé. The formation of clusters was not an exact match to the genomic groups of banana plants. The major groups were identified mainly with tetraploid materials, whereas the small groups were formed by triploid materials (Table 1). The latter genomic group possibly shows a greater divergence regarding plant growth and production of bunches that could be further explored in future works on breeding for new resistant hybrids with desirable traits for the banana crop.

PCA was also performed using the same matrix of multivariate data (Figure 2), which consisted of the means of the three production cycles of each variable. The first two components explained 70.9% of the total variance observed among the data. In the graphical analysis, the variables are represented by vectors that show the increase in the variable's intensity, while the samples are placed in the region of the graph next to the variables that characterize them. The length of vector decomposition in each component emphasizes its importance in the component, which helps to explain the differences between the samples that were observed in the present study. In the first component (F1) the cultivars were distinguished from each other according to growth, whereas, in the second one (F2), they were differentiated in terms of the size of the banana plants.

The most important variables in F1, with a significant coefficient of correlation, were number of hands, number of fingers in the hand, fresh weight of the bunch, height or length of the pseudostem, number of green leaves, and cycle or period from planting in the field until harvest of the first bunch. In F2, the most important variables with high positive correlation were fresh fruit and hand weight (Table 4). In this way, it was possible to visualize four distinct groups, very similar to those obtained by the cluster analysis. The Pacovan, Pacovan Ken, PV42-68, BRS Vitória, BRS Japira, and BRS Preciosa cultivars were grouped on the negative side of F1, predominantly in the upper quadrant (Figure 2), and were characterized as being tall, having a larger pseudostem diameter, and presenting a low production potential compared with the other cultivars. The BRS Garantida cultivar showed

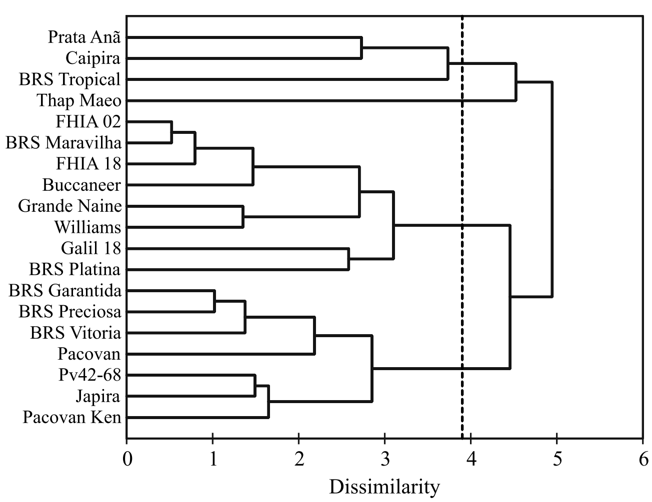

Figure 1. Dendrogram constructed by the cluster analysis (UPGMA) of banana (*Musa* spp.) cultivars planted at the Frutacor farm, in the municipality of Limoeiro do Norte, in the state of Ceará, Brazil. Dissimilarity generated with the average values of the agronomic variables evaluated during the three production cycles.

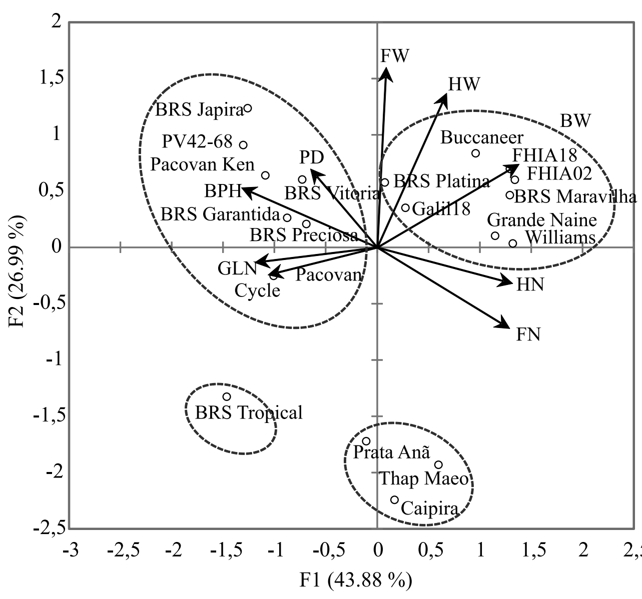

Figure 2. Principal component analysis with average values from the three production cycles for: banana (*Musa* spp.) plant height from the ground up to the point of emission of the bunch (BPH); diameter of the base of the pseudostem (PD); fresh weight of fruits (FW), of hands (HW), and of bunches without stalks (BW); number of hands (HN) and of fruits in the bunch (FN); number of days from planting to harvest of the first bunch (Cycle); and number of green leaves in the flowering phase (GLN). F1, first component; and F2, second component.

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growth and production that were very close to those observed for BRS Preciosa and Pacovan. However, both the BRS Garantida and BRS Preciosa cultivars had a shorter first cycle, in comparison with Pacovan.

The BRS Platina and BRS Maravilha cultivars, both derived from Prata Anã, resembled the FHIA genotypes and the cultivars of the Cavendish subgroup, all with low height and high productivity. The Buccaneer cultivar showed a profile that was quite similar to that of small-sized clusters. 'BRS Tropical', 'Prata Anã', 'Thap Maeo', and 'Caipira' were allocated at the bottom part of the graph (Figure 2) on the opposite side of the vectors of fresh hand and finger weight, since the produced bananas were small and similar to those of the Maçã cultivar.

The combined use of AHC, Pearson's correlation, and PCA provided an adequate explanation for the nature of the growth and the production of the banana genotypes and should be used as a basis for the selection of more appropriate cultivars to be cultivated in semiarid regions, according to the desirable agro-morphological traits. Based on the obtained results, it became clear that cultivars derived from Pacovan keep the agronomic traits of this female genitor. However, banana cultivars from crossbreeding with Prata Anã may differ in growth and in production of bunches, when compared with their progenitor plant. The latter genotypes maintain phenotypic traits that are similar to those of the FHIA hybrids from the Cavendish subgroup and of the Buccaneer cultivar.

Table 4. Correlation matrix among the studied variables of banana (*Musa* spp.) cultivars planted at the Frutacor farm, in the municipality of Limoeiro do Norte, in the state of Ceará, Brazil(1).

Variables	PD	BPH	GLN	HN	FN	BW	FW	HW	Cycle
PD	-	0.58	0.22	-0.12	-0.35	-0.06	0.30	0.03	0.22
BPH		-	0.62	-0.54	-0.69	-0.51	0.27	-0.15	0.38
GLN			-	-0.39	-0.37	-0.54	-0.09	-0.28	0.58
HN				-	0.89	0.71	-0.15	0.08	-0.43
FN					-	0.57	-0.41	-0.02	-0.30
BW						-	0.49	0.75	-0.48
FW							-	0.86	-0.16
HW								-	-0.27
Cycle									-

(1)Values underlined represent significant correlations by the least significant difference t-test, at 5% probability. PD, pseudostem diameter; BPH, banana plant height; GLN, number of green leaves at the flowering stage; HN, number of hands in the bunch; FN, number of fruits in the bunch; BW, fresh weight of bunches; FW, fresh weight of fruits; HW, fresh weight of hands; and Cycle, number of days from planting to harvest.

Conclusions

1. The 'Maçã' banana (*Musa* spp.) cultivar is unsuitable for planting in irrigated soil due to its susceptibility to *Fusarium* wilt and it can be replaced by Caipira and BRS Tropical, which are resistant to *Fusarium oxysporum* f. sp. *cubense* and black leaf streak disease (BLSD) and also present high potential productivity.
2. The Pacovan Ken, PV42-68, BRS Vitoria, BRS Japira, BRS Preciosa, BRS Garantida, and Thap Maeo cultivars are too tall to be planted on plateaus unprotected from winds.
3. The BRS Maravilha, BRS Platina, FHIA 02, FHIA 18, and Galil 18 cultivars are alternatives to Pacovan, Prata Anã, and Maçã, which are susceptible to BLSD.
4. The Buccaneer cultivar is short and has good productive potential, which means it could be an alternative to the susceptible cultivars belonging to the Cavendish subgroup.

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