Growth parameters and organoleptic characteristics of plantain (*Musa* AAB Simmonds cv. Farta Velhaco) at different planting densities

Parámetros de crecimiento y características organolépticas del plátano (*Musa* AAB Simmonds cv. Farta Velhaco) en diferentes densidades de siembra

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ABSTRACT

In view of the role of density and spacing in the growth parameters and organoleptic characteristics of plantains, this study sought to identify the best planting density for the cultivar Farta Velhaco (Terra group) cultivated in Mato Grosso (Brazil), evaluating three spacings. For this, we carried out an experiment in a randomized block design according to the following spaces (between plants x between rows): 2.0 m x 3.0 m (density of 1,600 plants ha⁻¹); 2.5 m x 3.0 m (density of 1,320 plants ha⁻¹) and 3.0 m x 3.0 m (density of 1,110 plants ha⁻¹), with 25 replicates per treatment. The following attributes were evaluated: plant height (cm); diameter of the pseudostem (cm); number of leaves; number of hands per bunch; number of fruits per hand; fresh fruit weight (g); fruit height (cm); external and internal fruit lengths (cm); fruit diameter (cm); bunch weight (kg), and productivity (t ha⁻¹), in addition to the percentage of total soluble solids, titratable acidity, pH and flavor of the fruits. The density of 2.0 m x 3.0 m in the cultivation of the plantain group Terra cv. Farta Velhaco improves fruit classification attributes as well as the fruit organoleptic characteristics such as the percentage of total soluble solids and flavor.

Key words: adaptation of cultivars, tropical agriculture, family farms.

RESUMEN

En función del papel que cumplen la densidad y el espaciamiento en los parámetros de crecimiento y las características organolépticas de los plátanos, este estudio buscó identificar la mejor densidad de siembra para el cultivar Farta Velhaco (grupo Terra) cultivado en Mato Grosso (Brasil), evaluando tres espaciamientos. Para ello, realizamos un experimento en un diseño de bloques al azar según los siguientes espacios (entre plantas x entre hileras): 2.0 m x 3.0 m (densidad de 1600 plantas ha⁻¹); 2.5 m x 3.0 m (densidad de 1320 plantas ha⁻¹) y 3.0 m x 3.0 m (densidad de 1110 plantas ha⁻¹), con 25 repeticiones por tratamiento. Se evaluaron las siguientes características: altura de la planta (cm); diámetro del pseudotallo (cm); número de hojas; número de manos por racimo; número de frutos por mano; peso fresco de la fruta (g); altura del fruto (cm); longitudes externas e internas del fruto (cm); diámetro del fruto (cm); peso del racimo (kg) y productividad (t ha⁻¹), además del porcentaje de sólidos solubles totales, la acidez titulable, el pH y el sabor de frutos. La densidad de siembra 2.0 x 3.0 m en el cultivo del plátano grupo Terra cv. Farta Velhaco mejora los atributos de clasificación de la fruta, así como sus características organolépticas como el porcentaje de sólidos solubles totales y el sabor.

Palabras clave: adaptación de cultivares, agricultura tropical, granjas familiares.

Introduction

The banana (*Musa* spp.) is one of the most important tropical fruits, and its productivity depends on many production factors. Planting density and the type of seed used are important factors that influence productivity. Additionally, the number of hands per bunch, number of fruits per bunch, and weight and length of fruits contribute to the production of quality fruits (Camolesi *et al*., 2012).

The different banana cultivars are classified according to the genomic group and its subgroups, mainly differing

in the size of the plant. This last factor directly interferes with the spacing adopted for the breeding stock and the productivity obtained at the end of the cycle, and it also influences the resistance to pathogens (Perrier *et al*., 2011). On the other hand, the low genetic variability of this crop represents an imminent risk due to the lack of new cultivars or their decimation by pests, as occurred with the export of Latin American bananas based exclusively on the cultivar Gros Michel that is susceptible to the disease of Panama (Silva *et al*., 2016). The evaluation of cultivars in experiments conducted in the field can select expressive

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phenotypic characters from environmental influence and, consequently, responses to production and productivity. The measurement of productivity in banana plants is complex and results from the association of different factors influenced by the environment. Thus, for selection to be carried out efficiently, it is important to know the associations between agronomic characters of great importance for its cultivation (Amorim *et al.*, 2008). As a result, several banana breeding programs have emerged (Lédo *et al.*, 2018) and different cultivars have been made available to farmers (Castricini *et al.*, 2017; Irish *et al.*, 2019).

Of the numerous triploid subgroups, some stand out for being widely cultivated far from their region of origin (Asia), as in the case of the AAB group "African Plantain" (Ploetz *et al.*, 2007), to which the cultivar Farta Velhaco or Pacova belongs. This cultivar stands out for its starch content and its possibility of use in the cuisine of Mato Grosso, a state in the interior of Brazil. Banana is the main tropical fruit produced in Mato Grosso, the main crop of family farming in the state, and is typically used for local or regional commercialization (IBGE, 2020).

In this sense, identifying the best density of plants that improves agronomic characters is important since denser crops tend to increase the cost of planting and the need for more specific nutrition and irrigation management. Additionally, denser crops influence the obtaining of maximum crop production according to its cycle.

In view of the importance of choosing the appropriate spacing for increasing productivity and quality of plantain fruits, this study was carried out to identify the best planting density for the cultivar Farta Velhaco (Terra group) cultivated in the region of Baixada Cuiabana, Mato Grosso, Brazil.

Materials and methods

Experimental area

The experiment was conducted in the Fruit Sector of the Experimental Farm of the Federal University of Mato Grosso - UFMT, located in Santo Antônio do Leverger - MT, Brazil. The experimental farm was 30 km from Cuiabá, at 15°47'11" S, 56°04'17" W and 140 m a.s.l. The regional climate is classified as Aw according to Köppen and Geiger (1928) with distinct periods of droughts and rains. The mean annual temperature is around 26°C, with a mean precipitation of 1360 mm, and relative air humidity of 66%.
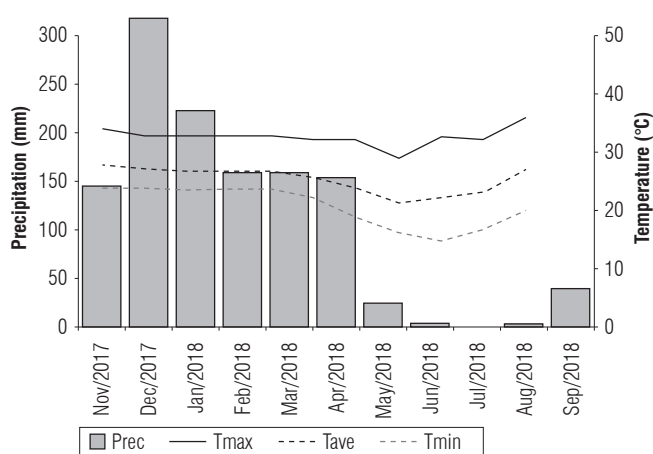

FIGURE 1. Precipitation (Prec, mm), maximum (Tmax), average (Tave) and minimum (Tmin) temperatures (°C) in the experimental area (November 2017 to September 2018).

The results of the soil chemical analysis (Teixeira *et al.*, 2017) at 20 cm depth were as follows: pH ($CaCl_2$) = 5.8; P = 37.5 mg dm^{-3}; K = 99.0 mg dm^{-3}; Ca = 2.5 $cmol_c$ dm^{-3}; Mg = 0.4 $cmol_c$ dm^{-3}; Al = 0.5 $cmol_c$ dm^{-3}; H + Al = 0.8 $cmol_c$ dm^{-3}; base saturation of 55%, and soil organic matter of 1.75 g dm^{-3}. The soil was classified as an Alfisols (74% sand, 8% silt, 19% clay) (Soil Survey Staff, 2014).

The soil was corrected according to the results of the soil chemical analysis with an application of 2.0 t ha^{-1} of dolomitic limestone, relative power of total neutralization 88%, aimed to raise the base saturation to 70%; 100 kg ha^{-1} of N in the form of urea, 120 kg ha^{-1} of P_2O_5 (simple superphosphate), and 300 kg ha^{-1} of K_2O (potassium chloride) were applied at 30, 60, 90, 120, and 150 d after transplanting the seedlings to the field following the recommendations of Borges and Souza (2009) and Oliveira *et al.* (2014).

We used the cultivar Farta Velhaco (Terra Group), with an average height of 3.5 to 4.5 m, pseudostem diameter of around 25 cm at the base of the plant, 3 to 7 bunches per plant, a vegetative cycle of 390 to 420 d, and production of around 690 to 720 d.

Seedling preparation and planting

Micropropagated seedlings of the cultivar Farta Velhaco were used, which, when removed from the laboratory, were transplanted into tubes of 280 cm^3 (63 mm in diameter and 190 mm in height) using Carolina Soil® (Pardinho, São Paulo, Brazil) substrate and acclimatized in a greenhouse at a temperature between 27°C and 32°C, containing greenhouse screen shading at 50% and constant nebulization for 60 d. At 61 d, the seedlings were transferred to plastic

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containers of 25 cm x 35 cm x 0.015 cm (with a volume of 3.6 L) and placed under a 35% shading screen for a period of 60 d. In both phases, a modified nutrient solution (Hoagland & Arnon, 1950) was applied at a volume of 250 ml per plant twice a week. At 120 d after transplanting, the seedlings were taken to an open area for hardening for 7 d and then planted according to the different treatments (spacing).

Experimental design

The experiment was conducted in a completely randomized design with three treatments and one cultivar (Farta Velhaco). The treatments consisted of spacings of 2.0 m x 3.0 m (between plants x between lines) with a density of 1,600 plants ha^{-1}; 2.5 m x 3.0 m, with a density of 1,320 plants ha^{-1}, and 3.0 m x 3.0 m, with a density of 1,110 plants ha^{-1}, with 25 replicates per treatment, and each experimental unit was composed of three plants.

Phenological and organoleptic analyses

The phenological variables of plant height (m), diameter of the pseudostem at 30 cm from the ground (cm), and number of leaves were measured at 26, 27, 57, 87, 126, 157 and 186 d after rhizome emission. The fruit bunch was harvested at the agronomic harvest point (bunch formation). The fruit height (cm), external and internal fruit lengths (cm), fruit diameter (mm), number of fruits per hand, number of hands per bunch, fresh fruit weight (g), bunch weight (kg), and productivity (t ha^{-1}) were evaluated. For fruit evaluations, the first bunch produced was harvested due to the greater homogeneity of the fruits in this period of the experiment.

Measurements were taken using a measuring tape, a scale, and a digital caliper. To obtain the weight of the bunch, the number of fruits per hands was multiplied by the number of hands per bunch. For the calculation of productivity, the values of the weight of the bunch were multiplied by the estimated density of plants for each treatment.

The organoleptic variables measured in the fruits were total soluble solids content (°Brix), using a field refractometer (model RT-10 ATC, Salvi Casagrande, Mettler Toledo, Brazil); total titratable acidity (% citric acid) by acid/base titration was performed in the laboratory. Fruit pH was determined using a pH benchtop meter (Orion Dual Star, Thermo Fisher, Brazil). The flavor was obtained by the ratio between the percentage of total soluble solids and total titratable acidity.

The phenological and organoleptic variables were checked for homogeneity of variances according to O'Neill and Matthews (2000) and for normality of errors according to

Shapiro and Wilk (1965). A one-way analysis of variance was then applied. When significant, the Tukey's post hoc test was used with a *P*-value set to 0.05 using the ExpDes. pt package (Ferreira *et al*., 2014) in R version 3.6.3 (R Core Team, 2019). For variables whose data did not meet the normality of errors and/or homogeneity of variances, the Kruskal and Wallis (1952) non-parametric test was used through the R version 3.6.3 (R Core Team, 2019).

Results and discussion

Growth characters

Planting densities had significant effects on the phenology of the plantain Farta Velhaco cultivated under the edaphoclimatic conditions of Baixada Cuiabana. Wind, light, and temperature are the main edaphoclimatic characteristics that affect this cultivar. Plants grown at a density of 1,110 plants ha^{-1} (spacing 3.0 m x 3.0 m) were taller and had higher pseudostem diameter when compared to the other treatments (Fig. 2).

Evaluating both the height and the diameter of the pseudostem is an important factor because it determines the growth vigor of the plant in addition to its carrying capacity, both in terms of resistance to wind and to the weight of the bunch in the reproductive stage (Arantes *et al*., 2010).

According to Aguiar *et al*. (2016), this group of bananas is characterized by height between 3.0 to 5.0 m. These data agree with those obtained for Farta Velhaco when conducted under local edaphoclimatic conditions. However, very tall plants tend to have thinner pseudostems, which facilitates tipping by winds (Mahmoud *et al*., 2018). In this sense, a positive correlation can be observed between the height and the diameter of the banana plants at a density of 1,110 plants ha^{-1} (3.0 m x 3.0 m spacing) (Fig. 1), which may confer greater resistance to wind, a major factor for maintaining the banana plantation. It should also be noted that there was no incidence of strong winds (75 km/h) during the experiment.

The number of leaves was higher in plants at a density of 1,600 plants ha^{-1} (spacing 2.0 m x 3.0 m) (Fig. 1). The evaluation of the number of photosynthetically active leaves is a fundamental condition for estimating the time for bunch emission and serves as a parameter to assess the balance between photosynthesis and banana production (Arantes *et al*., 2010). The number of functional leaves is an important phenological descriptor as it directly influences planting density and crop management, with consequences for production.
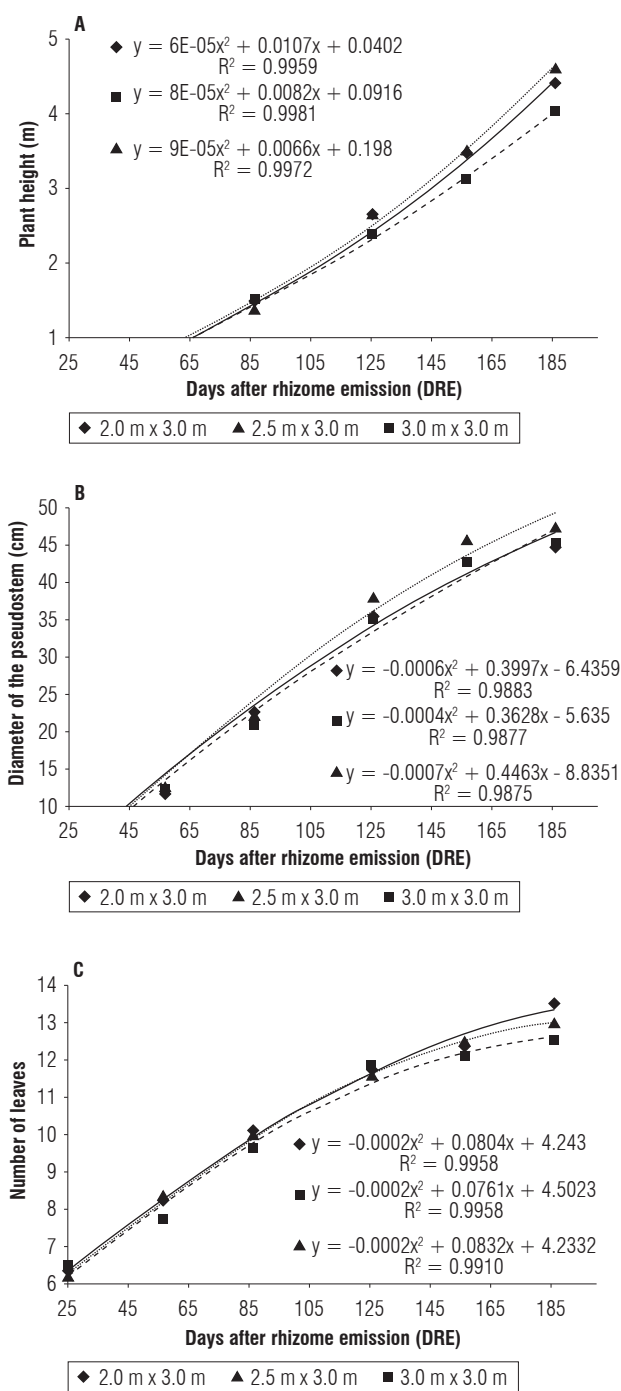
FIGURE 2. A) Plant height, B) diameter of the pseudostem, and C) number of leaves of Farta Velhaco plantains planted at different spacings, in Mato Grosso (Brazil) during 185 d after transplanting.

Lessa *et al.* (2012), when conducting a banana plantation for three productive cycles, observed a positive correlation between the diameter of the pseudostem and the number of leaves until flowering. Pereira *et al.* (2000) found that to produce the first bunch of banana cv. Dwarf Silver it is necessary to emit approximately nine functional leaves.

In this study, there was an average of thirteen functional leaves prior to the inflorescence emission to produce Farta Velhaco. For Chaudhuri and Baruah (2010), the greater number of functional leaves of plants grown in areas with lower planting density indicates less competition for nutrients, soil moisture and light intensity in the vegetative and reproductive stages, when compared to plants grown at higher densities.

Thus, the possible adaptation of Farta Velhaco to photosynthetic and physiological activities is an important feature, as it promotes more balanced vegetative growth and, consequently, better reproductive development when grown at different spacings.

Income and income-attributing characters

The planting density influenced yield and income-attributing characters in the plantain crop. As a result, and when evaluating the productive attributes of number of hands per bunch, number of fruits per hand, and fresh fruit weight (Fig. 3), it was possible to observe reductions both in the number of hands per bunch and in the fresh weight of the fruit in plants with a planting density of 1,320 plants ha^{-1} (spacing 2.5 m x 3.0 m) with mean values of 8.55 kg per bunch, whereas the plants grown at a density of 1,600 plants ha^{-1} (2.0 m x 3.0 m) produced 10.77 kg per bunch and a density of 1,110 plants ha^{-1} (3.0 m x 3.0 m) resulted in the production of 10.13 kg per bunch.

For productivity (obtained by multiplying the mass of the bunch by the number of plants ha^{-1} for each treatment), values of 17.95 t ha^{-1} could be observed for the plants at the highest planting density (2.0 x 3.0 m) in comparison to those obtained at other densities: 11.28 t ha^{-1} in spacing of 2.5 m x 3.0 m and 11.24 t ha^{-1} in spacing of 3.0 m x 3.0 m.

According to the State Secretariat for Family Agriculture of Mato Grosso, productivity results for Farta Velhaco are, on average, 15.0 t ha^{-1} when conducted at a density of 1,111 plants ha^{-1} for the state of Mato Grosso (Salmazo *et al.*, 2021). Thus, the data obtained by this research expressed that when using the density of 1,600 plants ha^{-1}, productivity can be increased by 2.95 t ha^{-1} for this cultivar, which is an important agronomic indicator for gains in production and productivity. On the other hand, they point out that the average yield of the banana group is 20.0 t ha^{-1}.

The evaluation of banana genotypes, mainly from the Cavendish group, is typically done for at least two cycles. However, studies carried out aiming at the evaluation of banana cultivars type Terra are rare, mainly due to the

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scarcity of varieties of this group. As a result, it might be acceptable to evaluate the productive attributes of the land group in a single cycle since many genotypes are currently cultivated as an annual crop (Arantes *et al.*, 2010).

Silva *et al.* (2003) highlight some productive parameters for the Terra group, such as bunch weight of 25 kg, number of fruits per bunch of 160 fruits, and number of hands per bunch of 10. Thus, cv. Farta Velhaco, under the experimental conditions of this study, obtained productive values

below those recommended by those authors when planted at higher densities, where six hands per bunch and 48 fruits per bunch were observed with a total of 13 kg per bunch. However, in order to obtain gains in productivity for Farta Velhaco, planting density becomes an important factor for the economic viability of the crop.

When evaluating the qualitative phenological attributes of fruits used for the commercial classification of the Terra group banana (Silva *et al.*, 2003), there was a significant influence on the height, the external and internal lengths, and the fruit diameter, with significant reduction of these attributes for the fruits obtained from plants conducted at the 2.5 m x 3.0 m spacing (Fig. 4).

In general, the cultivar Farta Velhaco, when grown under a high planting density, maintained an adequate balance in the source-sink ratio at all its physiological stages. Ganapathi and Dharmatti (2018), when evaluating different spacing for two cultivars marketed in India, found that shading was the main factor affecting plantations with high populations and that the plants compensated for this factor, investing in leaf development with a consequent imbalance in the source-sink ratio at the reproductive stage.

Qualitative parameters of the fruit quality

When assessing planting density for the effect on fruit quality, a significant influence can be observed on the percentage of total soluble solids and flavor. Flavor is a measure obtained by the ratio between the concentration of total soluble solids (°Brix) and titratable acidity (% of citric acid), and the higher the value, the greater the perception of improvement in the flavor of the fruit.

In this research, an improvement in the organoleptic characteristics of the fruits was observed when growing Farta Velhaco plantains in more dense systems. Despite the higher concentration of total soluble solids in the fruits of the plants arranged at a lower density (spacing 3.0 m x 3.0 m), increased flavor can be obtained in fruits from plants conducted at a higher density (Fig. 5).

As this is a cultivar recently introduced to the market, comparative data is not yet available in the literature. However, the analysis of physical-chemical and biochemical parameters (fruit quality), such as soluble solids, pH, titratable acidity and bioactive compounds, will be useful for the characterization and selection of genotypes with superior characteristics for genetic improvement as well as for the introduction of new varieties in the existing agricultural systems (Borges & Souza, 2009).
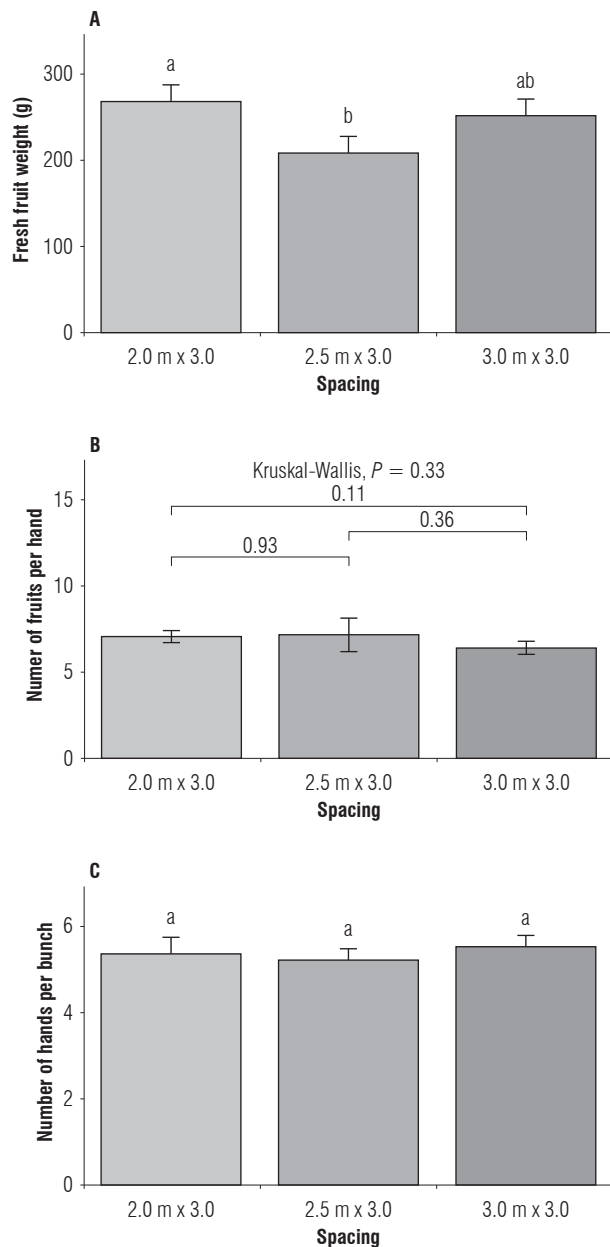

FIGURE 3. A) Fresh fruit weight, B) number of fruits per hand, and C) number of hands per bunch of Farta Velhaco plantain conducted at different spacings in Mato Grosso (Brazil).
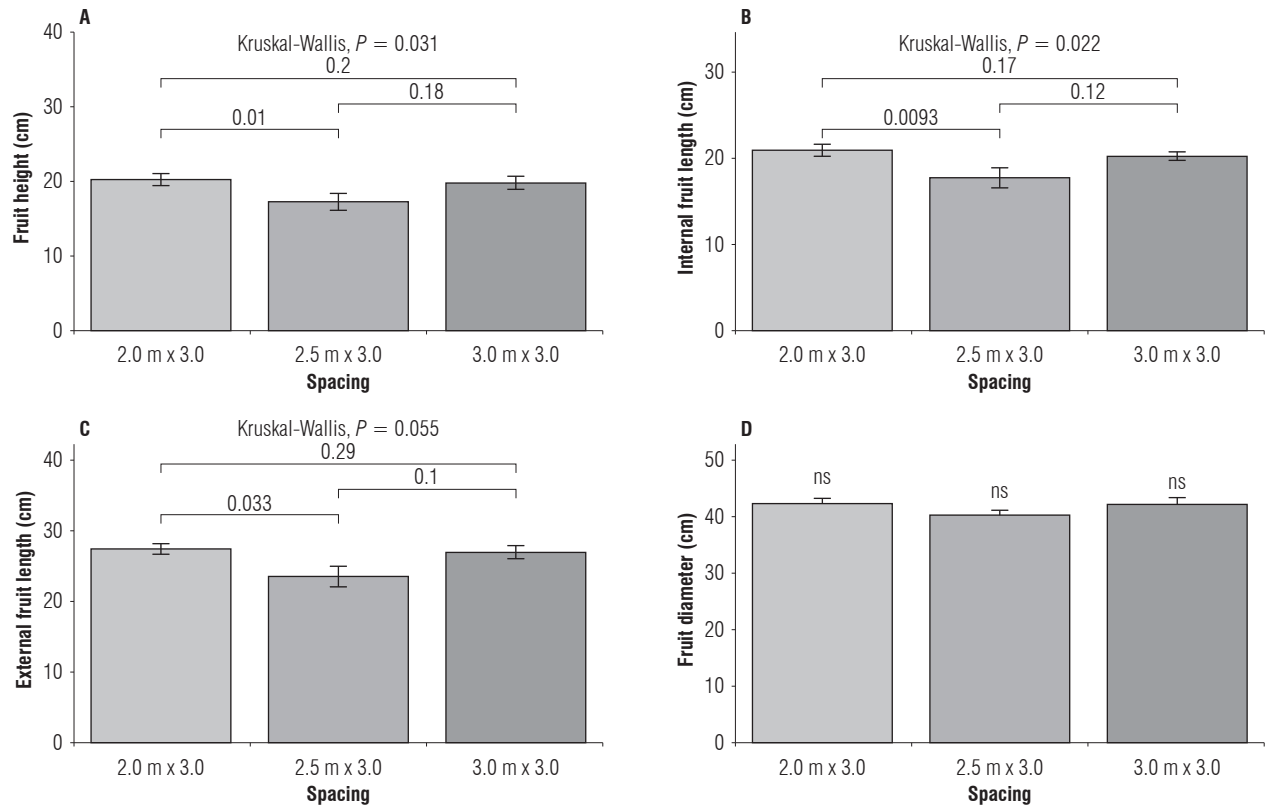
FIGURE 4. A) Fruit height, B) internal and C) external fruit lengths, and D) fruit diameter of the Farta Velhaco plantain conducted at different spacings in Mato Grosso (Brazil). ns - not significant.
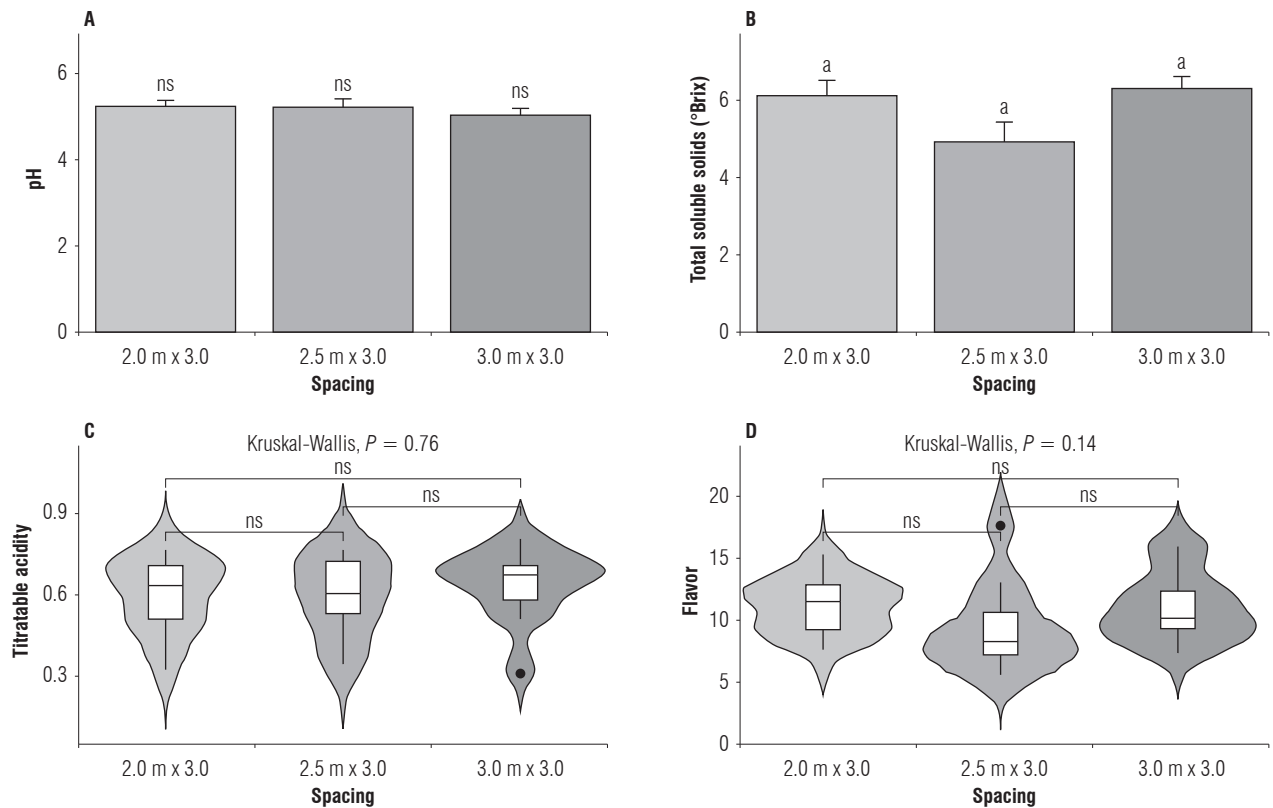

FIGURE 5. A) pH, B) total soluble solids (°Brix), C) titratable acidity (% citric acid), and D) flavor of Farta Velhaco plantain conducted in different spacing in Mato Grosso (Brazil). ns - not significant.

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According to previous studies, fruits with high levels of total soluble solids are the most likely to be accepted by consumers (Gibert *et al*., 2009). Values range from 7.18 to 25.37 °Brix for plantain genotypes used for cooking. Cooked plantains are consumed at many ripening stages after being cooked; they are generally not appreciated in their fresh form due to the absence of sweetness and unpleasant firmness (De Jesus *et al*., 2013). The values below 6.26 °Brix found in this study indicate that the cultivar Farta Velhaco can be used for different forms of processing.

The genotypes with firmer fruit pulp are suitable for industrial use, mainly for the preparation of fried products, such as plantain chips. In addition, more firm fruits are more resistant to transport and durable after harvest (Youryon & Supapvanich, 2017). During the ripening process, the percentage of dry weight of the pulp decreases. This characteristic is important for the selection of genotypes for industry or even for domestic consumption, for the preparation of cooked and/or fried dishes, preferable in many countries.

Conclusions

The high planting density (2.0 x 3.0 m spacing) in the cultivation of the plantain group Terra, cv. Farta Velhaco improved the fruit classification attributes, productivity and organoleptic characteristics such as the percentage of total soluble solids and flavor, characteristics appreciated for choices related to fruit consumption.

Conflict of interest statement
The authors declare that there is no conflict of interest regarding the publication of this article.

Author's contributions
GCG and ECN designed the experiment. DHC and TOM performed the field experiment and laboratory analysis. JWFS contributed to the data analysis. GCG and ECN wrote the article. All authors have reviewed the manuscript.

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