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Agronomic performance of melon cultivars in the Amazon Savannah environment of Brazil

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Abstract: An experiment was conducted with the objective of evaluating the agronomic performance of eight melon cultivars under the soil and climatic conditions of the Amazon savannah. The experimental design was a randomized complete block with four replications and five plants per plot. The treatments consisted of eight cultivars: Eldorado 300, Favo, and Goldex (Yellow type), Hales Best Jumbo, Imperial, and Rock (Cantaloupe type), Gaúcho (Caipira type), and Juazeiro (Piel de Sapo type). Productive characteristics, seed characteristics, and fruit quality were evaluated. The highest commercial yields were obtained with the cultivars Juazeiro (27,551.75 kg ha^{-1}), Rock (24,170.0 kg ha^{-1}), and Imperial (24,116.75 kg ha^{-1}), respectively. Seed characteristics varied depending on the cultivar, with the highest seed quantity in the 'Favo' cultivar and the highest seed mass in 'Eldorado 300'. Regarding fruit quality, the cultivars Juazeiro and Goldex exhibited greater pulp firmness and higher soluble solids content, which meet the qualitative demand of both domestic and international markets. The cultivars Juazeiro, Rock, and Imperial demonstrated high potential for cultivation under the soil and climatic conditions of the Amazon savannah. It was concluded that the soil and climatic conditions of the Amazon Savannah favored productive characteristics and fruit quality for different analyzed cultivars.

Keywords: Adaptation, *Cucumis melo* L., productivity, post-harvest, cultivars.

Introduction

The melon (*Cucumis melo* L.) belongs to the Cucurbitaceae family. It is a vegetable crop which is appreciated for its great popularity in the national and international markets (Romo-Tovar et al., 2024). This vegetable crop is not only cherished for its taste but also holds a significant position in the Brazilian agribusiness sector, and is currently one of the most exported fresh fruits (Nascimento Neto et al., 2012; Hu et al., 2024). In terms of its economic importance, melons are among the most exported fresh fruits in Brazil. However, recent data showed that China is the largest producer of melons, contributing over half of the global production. The global melon yield was over 28.62 million tons in 2021, with China producing over 14.02 million tons (Hu et al., 2024).

In Brazil, the cultivation of melon began in the decade of 1960, particularly in the states of São Paulo and Rio Grande do Sul. However, due to its great adaptation to different soil and climatic conditions, it has spread to all regions of the Brazilian territory. In the Northeastern States (Rio Grande do Norte, Ceará, Bahia), Southeast (São Paulo), South (Santa Catarina and Rio Grande do Sul) and the Midwest (Mato Grosso) (Paula et al., 2017). In addition to promoting the diversification of agricultural activities, culture has an important socioeconomic role in the producing regions, contributing to employment and income generation (Campelo et al., 2014; Silva et al., 2014).

In the Northern Brazilian region, especially in Roraima, the cultivation of melon is very prominent in the Savannah areas, due to favorable soil and climatic conditions that allows for cultivation for most of the year. In this state, the melon is produced mainly in a conventional monocrop system with irrigation, predominantly by drip system. The main melons cultivars cultivated by the local producers are of the yellow type. However, low yields and lower fruit quality, coupled with market demands, necessitates the selection of new potential varieties (Silva et al., 2017).

Traditionally, there is a great availability of melon cultivars in the market, and the selection has primary importance in obtaining more productive materials, tolerant to transport, standard size and other sensory characteristics, especially of flavor and appearance that satisfy the consumer market. However, melon cultivars do not vary only in relation to these traits, but also for its responsiveness to the different soil and climatic conditions (Pereira et al., 2010; Nunes et al., 2011; Weng et al., 2021).
Competition trials conducted under different soil and climatic conditions have resulted in a considerable diversity of behavior among melon cultivars (Adamczewska-Sowinska, 2024). Most of these studies suggest a significant interaction between genotype and environment, which is a preponderant factor in the physiological and morphological changes of the plant and consequently in fruit production and quality (Dalastra et al., 2015). The research on adaptability and stability of cultivars in different regions is of paramount importance, since it makes possible the identification of cultivars with predictable behavior that respond positively to the environmental variations.
Considering that the cultivation conditions influenced the productive and qualitative characteristics of the fruits of each cultivar, the objective of this study was to evaluate the agronomic performance of eight melon cultivars under the soil and climatic conditions of the Amazon Savannah.

Results

According to the results obtained by analysis of variance, a significant difference was observed between the cultivars for all the characteristics analyzed (Table 1), indicating different capacities of response to the culture conditions. The low to average coefficients of variation obtained in this work indicate good experimental precision and low genetic variations among the cultivars, which varied between 5.06% and 17.07%.
The total number of fruits per plant varied from 4.75 to 1.20, and a higher amount was observed in the Rock cultivar (Table 2). The less expressive values were recorded in 'Favo' and 'Goldex'. As for the number of commercial fruits per plant, the Rock cultivar was superior to the others, with an average of 3.75 fruits. In general, most of the fruits produced by the cultivars analyzed had potential to be commercialized in the external market (Figure 1).
Regarding the total average mass and commercial average fruit mass, the highest values were found in the cultivars Gaúcho, Juazeiro, Eldorado 300 and Goldex, respectively (Table 2). Although the other cultivars (Favo, Imperial, Hales Best Jumbo and Rock) presented lower values for the mass of commercial fruits, they still supply the demand of the domestic and foreign markets.
Relating the total average mass to the average commercial fruit mass, it was observed that for most of the cultivars, there was an increase in the commercial average mass, a fact not evident in the Gaúcho cultivar, due to the greater number of fruits with a size that exceeds the limit (>3.65 kg).
Regarding total productivity, 'Juazeiro' was the most productive (31,440.0 kg ha^{-1}) (Table 2). The lowest values were observed in 'Goldex' and 'Favo' and may indicate little adaptation of these cultivars to the soil and climatic conditions of the Amazon Savannah.
As for commercial productivity, Juazeiro again recorded higher yields (27,551.75 kg ha^{-1}), followed by cultivars Rock and Imperial, with 24,170.0 and 24,116.75 kg ha^{-1}, respectively. It was observed that commercial productivity was driven by the highest number of commercial fruits per plant.
The evaluation of the number of seeds revealed a wide variation among the studied cultivars, with values ranged from 214.25 (Hales Best Jumbo) to 1,070.25 ('Favo'). The cultivars Rock, Eldorado 300 and Hales Best Jumbo were characterized by the low number of seeds (Table 3).
The largest masses of seeds and 1000 seeds were found in the Eldorado 300 cultivar with 35.45 and 11.24 g respectively. In relation to the mass with the number of seeds, Eldorado 300 was found to have seeds of greater mass, though in a relatively low quantity. However, the cultivar Favo had higher number of seeds but with reduced mass.
As for pulp thickness, Juazeiro showed higher average with 5.36 cm. In contrast, the other cultivars had a thinner shell, ranging from 4.55 cm ('Eldorado 300') to 3.89 cm ('Favo').
For the firmness of the pulp, there was a wide variation among the analyzed cultivars. The values ranged from 19.97 ('Hales Best Jumbo') to 36.10 N ('Juazeiro') (Table 3).
The values of soluble solids (SS) were relatively high (>9° Brix) in all evaluated cultivars, especially Juazeiro and Goldex, with 13.70 and 13.27° Brix, respectively (Table 3).

Discussion

The low to average coefficients of variation (CV) obtained in this work indicate good experimental precision and low genetic variations among the cultivars, which varied between 5.06% and 17.07%. Our result was consistent with the findings of Ferreira et al. (2016) on Comparison of methods for classification of the coefficient of variation in papaya. They concluded that CV < 10% is low, CV between 10 and 20% is average, CV between 20 and 30 is high, while CV > 30% is very high.
Because melon 'Rock' is a relatively new cultivar, launched in 2011, there is a shortage of studies inherent to the behavior of this cultivar under different soil and climatic conditions. The number of commercial fruits observed for this cultivar in the edaphoclimatic conditions of the Amazon Savannah was relatively above the values obtained by Medeiros et al. (2011) and Nascimento et al. (2012). They evaluated Cantaloupe melons in the soil-climatic conditions of Mossoró, (RN), whose climate is of the BSh type, very hot, and the soils were classified as Yellow Argisol and Eutrophic Red-Yellow Argisol, respectively. In these studies, the authors found averages of 1.54 and 2.46 commercial fruits, respectively.
Most fruits produced had the potential to be marketed in the foreign market. This situation is favorable to the producer, due to the greater market horizons and prices. Although the cultivars Gaúcho, Juazeiro, Eldorado 300 and Goldex presented higher mean total mass and commercial average fruit mass, the other cultivars (Favo, Imperial, Hales Best Jumbo and Rock) presented lower values for commercial fruit mass, supply the domestic and foreign markets. The external market specifically requires fruits with a mean mass between 3.65 kg (type 4) and 1.05 kg (type 7) (Terceiro Neto et al., 2013). This feature may be of great importance to local producers, since fruits that do not meet the requirements of the internal and external market are discarded as waste or used in industry.
The mean total and commercial fruit mass values were higher than those obtained by Camara et al. (2007) with 'Goldex' working in the edaphoclimatic conditions of the Northwestern part of Rio Grande do Norte (1.5 kg); and Santos et al. (2011) with 'Eldorado 300' in the Paraíba hinterland (1.55 kg). However, the results for these same variables, in the Juazeiro cultivar, were lower than those verified by

Terceiro Neto et al. (2013), Carmo et al. (2017) and Dalastra et al. (2015), for melons type frog skin in the edaphoclimatic conditions of Mossoró (RN), Boa Vista (RR) and Marechal Cândido Rondon (PR), respectively.

The average mass found in 'Juazeiro' satisfies the requirements of the Spanish market which is the main importer of Brazilian peel toad melon, due to its preference for medium to large sized fruits.

The total yields obtained in this study were considerably higher than the average yield of melon in the North region (16,134.0 kg ha^{-1}). In an experiment carried out in the state of Roraima with melon cultivars, Carmo et al. (2017) obtained yield of 15,790.0 kg ha^{-1} for 'Juazeiro', which was well below the value recorded in this study. Lower yields, for the same cultivar, were also observed in trials in the different regions of the Brazilian territory. However, the high yields obtained by Terceiro Neto et al. (2013) in frog skin melons with 44,585.0 kg ha^{-1}, indicate the productive potential of this cultivar, which may be related to the soil and climatic condition of the producing region.

With respect to commercial productivity, Medeiros et al. (2011) and Terceiro Neto et al. (2013), in trials with peel-to-toe melons in the edaphoclimatic conditions of Mossoró (RN) reported higher yields than those reported in this study, with 48,620.0 and 34,825.0 kg ha^{-1}, respectively. However, Queiroga et al. (2013) and Santos et al. (2015), also in the edaphoclimatic conditions of Rio Grande do Norte, obtained similar productivities, in Cantaloupe melons of 25,313.0; 27,020.0 kg ha^{-1}, respectively, indicating that the response capacity of these cultivars is not only related to the edaphoclimatic conditions of the study but also to the management used in the cultivation.

The cultivars Rock, Eldorado 300 and Hales Best Jumbo presented a low number of seeds, however, the number of seeds obtained in the cultivars is still quite high. This fact may compromise commercialization, since a larger number of seeds increases the internal cavity of the fruit, considerably reducing its post-harvest life, in addition to having a preference in the consumer market for fruits with less seeds.

The pulp thickness was higher than that obtained by Dalastra et al. (2015) in studies with melon frog skin with 3.63 cm. The greater thickness is desirable, since it indicates greater edible part due to the greater yield of pulp. This is also a feature related to fruit tolerance to handling and post-harvest life.

For the firmness of the pulp the values verified in this study in the cultivars Juazeiro and Goldex corroborate with those obtained by Camara et al. (2007). However, it differs from those reported by Gurgel et al. (2010), which showed a lower mean pulp firmness. This characteristic is of relevant importance since it makes the fruits more resistant to the injuries caused by the transportation and commercialization.

From the internal aspects of the fruit, the firmness of the pulp is one of the essential, as it determines the shelf-life of a cultivar. Studies have shown that fennel-type melon fruits when firmly harvested in the 26 to 28 N range reach the European shelves with good post-harvest conservation (Terceiro Neto et al., 2013). As for yellow melon, the recommended value of firmness of pulp, when the fruit is destined to the external market, is from 33 to 35 N (Camara et al., 2007). In general, the firmness values obtained in this study in the cultivars Juazeiro and Goldex are within the acceptable marketing standards for both domestic and foreign markets.

The values of soluble solids (SS) obtained in this work were comparatively satisfactory to those found in different melon producing regions in Brazil (Santos et al., 2011; Dalastra et al., 2015). Soluble solids content has been identified as the most important characteristic of melon fruit quality. According to Dantas et al. (2011) soluble solids content is used as the classification index, being less than 9º Brix considered as non-marketable, from 9 to 12º Brix as marketable and above 12º Brix as extra melon.

The soluble solids content recommended for export of melon toad skin is 11° Brix. However, in practice, the minimum value of 9.0° Brix has been adopted. For yellow melon, the levels required for export must be at least 9° Brix. It is possible to affirm that, in relation to soluble solids content, all cultivars evaluated meet the standards of the most demanding consumer markets.

According to Scott et al. (1975), the high temperatures inherent in the study region influence fruit quality due to the greater synthesis of secondary compounds and the accumulation of higher concentrations of soluble sugars. This helps explain the high soluble solids contents obtained in the different melon cultivars studied.

In general, the evaluated cultivars showed satisfactory yield and quality values, proving that the soil and climatic conditions of the Roraima savanna are suitable for the cultivation of melon, particularly of the cultivars Juazeiro, Rock and Imperial.

Material and Methods

Experimental site description

The experiment was conducted in two crop cycles: a) December 2014 to February 2015 and b) December 2015 to February 2016, at the Embrapa Roraima Water Boa Experimental Field, Boa Vista (RR), located in the east central region of the State, at 02° 39' 00''N and 60° 49' 40''W, with a height of 90 m above sea level. The local climate, according to Köppen classification, is Aw, tropical rainy type, characterized by annual averages of precipitation, relative humidity and ambient temperature around 1,667 mm, 70% and 27.4° C, respectively.

The soil is classified as Yellow Latosol Dystrophic (LAdx) of medium texture (Embrapa, 2013) which presented the following physical and chemical properties in the 0 to 15 cm layer: pH = 5.9; P = 52.0 mg dm^{-3}; K^{+} = 0.05 cmolc dm^{-3}; Ca^{2+} = 1.66 cmolc dm^{-3}; Mg^{2+} = 0.470 cmolc dm^{-3}; Al^{3+} = 0.03 cmolc dm^{-3}; H^{+} + Al^{3+} = 1.93 cmolc dm^{-3}; MW = 12.98 g kg^{-1}; CECt = 1.86 cmolc dm^{-3}; V (%) = 49.0; m (%) = 2.0.

Plant material, growth conditions and experimental design

The experiment was arranged in a randomized complete blocks design with four replicates and five plants per plot. The treatments consisted of eight melon cultivars: Eldorado 300, Favo and Goldex (Yellow type), Hales Best Jumbo, Imperial and Rock (Cantaloupe type), Gaúcho (Caipira type) and Juazeiro (Frog Skin type). The plot was constituted by a row of plants with 7.0 m in length, spaced with 2.0 m between rows and 1.0 m between plants, totaling 14.0 m^2; of these 10.0 m^2 were used as harvested area and remaining as border.

Soil preparation was performed 30 days before sowing and consisted of a plowing at depth of 20 cm, two gradients, furrows and lifting of the ridges. In addition, liming was applied by applying 500 kg ha^{-1} of dolomitic limestone (PRNT 90%), in order to supply 70% of base saturation (V%) recommended for melon cultivation.

The foundation fertilization was carried out seven days before sowing and consisted of 120 kg ha^{-1} of P_2O_5, 160 kg ha^{-1} of K_2O and 25 kg ha^{-1} of micronutrients in the form of single superphosphate, potassium chloride and FTE BR 12, respectively. Nitrogen fertilization consisted of 110 kg ha^{-1} of N in the form of urea, divided into two equal applications, at 15 and 30 days after emergence (DAE), in addition to 10 m^3 ha^{-1} of sheep manure.

The seeds of the cultivars were sown directly in the field, placing three per hole. At 15 days after the crop emergency, the thinning was done leaving only one plant.

Irrigation was done by dripping with a nominal flow rate of 3.0 L h^{-1}. The irrigation monitoring was done by the tensiometer method.

Table 1. Summary of variance analysis for total number of fruits per plant (TNFPL), number of commercial fruits per plant (NCFPL), total average mass (TAM), commercial average mass (CAM), total productivity (TP), commercial productivity (CP), number of seed (NS), seed mass (SM), mass of 1000 seeds (M1000), pulp firmness (PF), pulp thickness (PT) and soluble solids (SS) content cultivars of melon (*Cucumis melo* L.), Boa Vista, Roraima, Brazil.

Evaluated characteristics	QM	CV%	Overall Means
TNFPL	6.71**	5.06	2.55
NCFPL	4.35**	12.58	2.16
TAM	0.34**	16.02	1.58
CAM	0.21**	14.16	1.66
TP	274,197,352.08**	12.17	1,9245.53
CP	210,669,347.43**	17.07	1,7422.19
NS	381,287.3**	9.51	611.28
SM	220.0**	7.05	26.56
M1000	38.9**	14.15	54.6
PF	7,044.27**	13.13	26.49
PT	0.901**	6.40	4.33
SS	10.12**	7.09	11.42

**Significant at the 1% level by the F test.

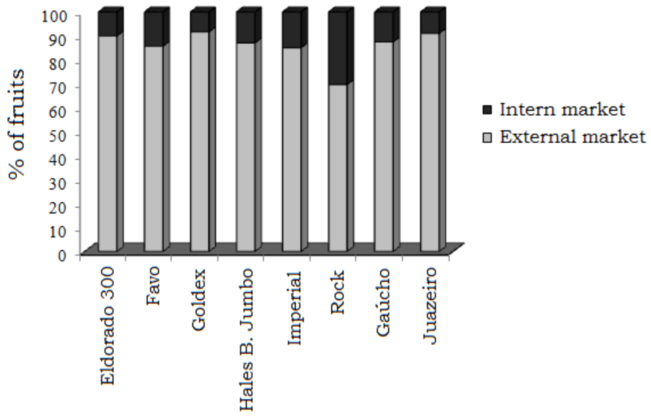

Figure 1. Percentage of fruits produced for the internal and external markets of the different cultivars of melon (*Cucumis melo* L.), Boa Vista, Roraima, Brazil.

Table 2. Mean values of total number of fruits per plant (TNFPL), number of commercial fruits per plant (NCFPL), total average mass (TAM), commercial average mass (CAM), total productivity (TP), commercial productivity (CP) of cultivars of melon (*Cucumis melo* L.), Boa Vista, Roraima, Brazil.

Cultivars	TNFPL	NCFPL	TAM (kg)	CAM (kg)	TP (kg ha^{-1})	CP (kg ha^{-1})
Eldorado 300	2.10 e	2.00 c	1.77 a	1.80 a	18,557.27 c	18,135.52 b
Favo	1.20 g	1.05 d	1.48 b	1.60 b	8.692.25 d	8,194.75 c
Goldex	1.20 g	1.10 d	1.67 a	1.70 a	10,112.75 d	9,730.25 c
Hales B. Jumbo	2.60 d	1.95 c	1.30 b	1.54 b	17,039.50 c	15,111.25 b
Imperial	3.70 b	3.30 b	1.38 b	1.46 b	25,598.75 b	24,116.75 a
Rock	4.75 a	3.75 a	1.16 b	1.28 b	27,685.50 b	24,170.00 a
Gaúcho	1.50 f	2.25 d	1.99 a	1.97 a	14,838.25 c	12,367.25 c
Juazeiro	3.35 c	2.90 b	1.87 a	1.90 a	31,440.00 a	27,551.75 a

Means followed by the same letters in the column do not differ from each other by the Scott-Knott test at 5% probability.

Table 3. Average values of seed number (NS), seed mass (SM), mass of 1000 seeds (M1000), pulp thickness (PT), pulp firmness (PF) and soluble solids (SS) content cultivars of melon (*Cucumis melo* L.), Boa Vista, Roraima, Brazil.

Cultivars	NS	SM (g)	M1000 (g)	PT (cm)	PF (N)	SS (ºBrix)
Eldorado 300	307.75 e	35.45 a	112.4 a	4.55 b	23.38 c	11.57 b
Favo	1,070.25 a	28.91 b	27.0 d	3.89 c	29.86 b	9.29 c
Goldex	517.50 d	28.13 b	57.3 c	4.40 b	34.97 a	13.27 a
Hales B. Jumbo	214.25 f	19.67 c	92.1 b	3.91 c	19.97 d	11.60 b
Imperial	637.50 c	19.90 c	31.7 d	4.09 c	21.07 d	10.96 b
Rock	382.25 e	15.68 d	41.2 d	4.13 c	21.95 d	11.63 b
Gaúcho	896.50 b	30.41 b	41.3 d	4.36 b	24.66 c	9.37 c
Juazeiro	864.25 b	29.34 b	34.0 d	5.36 a	36.10 a	13.70 a

Means followed by the same letters in the column do not differ from each other by the Scott-Knott test at 5% probability.

Up to 16 days after the emergency (AED), irrigation was performed when the tensiometers reached a reading of 30 to 45 kPa (shift of three to four days); of the 17 days until the formation of the fruits, was irrigated when tensiometers recorded tension of 20 to 30 kPa (shift of two to three days), and during the maturation phase of the fruits, irrigated when the tensiometers recorded reading of 30 to 45 kPa (shift of three to four days).

The cultural treatments during the crop cycle consisted of manual weeding between rows with the use of hoe. Pest control was carried out according to the standards used by the local producers.

For the evaluation of the fruits, two harvests were performed according to maturation. The point of harvest was determined by the change in coloration of the epicarp and/or by the formation of the abscission layer near the peduncle of the fruit (Dalastra et al., 2015). The total fruits of each harvested area were counted and weighed to obtain the total number of fruits per plant, number of commercial fruits per plant, total average mass, commercial average mass, total productivity and commercial fruit yield.

Commercial productivity was determined by the sum of productivity for the external and domestic markets. For the external market, the fruits were considered intact, healthy, clean, with uniform external appearance and without deformations, cracks or signs of rot, insect attacks, diseases and mechanical damages. In addition, with mass and classification of 3.65-2.70 kg (type 4); 2.70-2.15 kg (type 5); 2.15-1.85 kg (type 6); and 1.85-1.05 kg (type 7). For the domestic market, fruits of type 8 were considered, with small formation defects or spots caused by the sun, with mass varying between 1.05 and 0.85 kg. The total yield was: fruits that presented formation defects, mechanical injury, damage caused by pests or diseases, with size higher or lower than that demanded by the external and internal markets (Terceiro Neto et al., 2013).

Physico-chemical characterization of fruits and seeds

For the physico-chemical characterization, four fruits of each cultivar, destined to the external market, were randomly selected, which were sent to the Embrapa-RR Post-Harvest Laboratory.

Among the biometric characters, the firmness of the pulp and the thickness of the shell were analyzed. The firmness of the pulp was determined by a manual penetrometer, type CAT 729-20, with an 8 mm diameter ferrule. Each fruit was divided longitudinally into two parts, with three readings equidistantly and in the equatorial region of the pulp, the values being expressed in Newtons (N). The thickness of the bark was defined through three readings in the median region of the fruit with the aid of a manual pachymeter, with values expressed in centimeters (cm).

Regarding the physicochemical characteristics of the fruits, the soluble solids content, which was obtained from the pulp, was evaluated by refractometry with temperature correction, and the results were expressed in ºBrix.

For the analysis of the seeds, the fruits of each cultivar were removed and the seed mass and the mass of 1000 seeds were counted and determined using a precision digital scale of 0.002 kg.

Statistical analysis

Finally, data on the mean of the two crop cycles were subjected to analysis of variance supplemented by the F test ($p \leq 0.05$). For the comparison between the means of the cultivars, the Scott-Knott test at 5% probability was used with the aid of the statistical program SISVAR version 5.1 (Ferreira, 2014).

Conclusion

The soil and climatic conditions of the Amazon Savannah of Roraima favor the productive and quality characteristics of fruits for the different cultivars analyzed. All cultivars evaluated in this study meet the standards of the most demanding consumer markets. The cultivars Juazeiro, Rock and Imperial present high potential for cultivation under the soil and climatic condition of the Amazon Savannah of Roraima, Brazil.

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Statement of Author Contributions

Edgley Soares Silva: Experiment design, data collection, scientific writing, and statistical analysis; Roberto Dantas de Medeiros: Supervision; José de Anchieta Alves de Albuquerque: Co-supervision, review, and final adjustments; Musibau Oyeleke Azeez: Final adjustments, translation, standardization, and submission; João Luiz Lopes Monteiro Neto: Statistical analysis; Wellington Farias de Araújo and Ozimar de Lima Coutinho: Scientific writing review; Laura Soliane Cruz Braz, Hananias dos Santos Cruz, and Felipe Fernandes Dias: Final adjustments.

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