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Evaluation of varieties and hybrid selections of mango in the brazilian semi-arid region

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Abstract: The aim of this study was to estimate genetic parameters and select superior mango genotypes using the mixed-models approach. The 16 genotypes, varieties and hybrid selections, were evaluated regarding physical and physical-chemical traits of the fruit using the REML/BLUP methodology. Mango fruit weight and pulp weight can be selected indirectly based on fruit length and diameter, which are more easily evaluated. The hybrids CPAC 26394, Lita, and Rosa 46 stand out in regard to fruit size. The genotypes R12P09, CPAC 2293, Roxa, Omega, Alfa, and Lita have better quality fruit than the Tommy Atkins variety that is widely used in commercial orchards. The Roxa variety has pulp with little or no fiber, a trait that is of great importance to consumers and for industrial processing. The genotypes Alfa, CPAC 5895, Ômega, R10P08, R12P09, R13P10, Rosa 2, Rosa 36, and Rosa 46 have pulp free of internal breakdown. The varieties and hybrid selections of mango show variability regarding fruit traits, and the REML/BLUP methodology is efficient for selection of genotypes with desirable fruit traits in mango.

Keywords: Genetic correlation, genetic gain, heritability, *Mangifera indica* L.

Avaliação de variedades e seleções híbridas de mangueira no semiárido brasileiro

Resumo: Objetivou-se estimar parâmetros genéticos e selecionar genótipos superiores de mangueira, utilizando a abordagem de modelos mistos. Os 16 genótipos, variedades e seleções híbridas, foram avaliados quanto aos caracteres físicos e físico-químicos do fruto, utilizando a metodologia REML/BLUP. A massa do fruto e a massa da polpa de mangueira podem ser selecionadas indiretamente com base no comprimento e no diâmetro do fruto, que são mais facilmente avaliados. Os hí-

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bridos CPAC 26394, Lita e Rosa 46 destacam-se quanto ao tamanho do fruto. Os genótipos R12P09, CPAC 2293, Roxa, Omega, Alfa e Lita apresentam frutos de melhor qualidade do que a variedade Tommy Atkins, bastante utilizada em pomares comerciais. A variedade Roxa apresenta polpa com pouca ou nenhuma fibra, característica muito requisitada por consumidores e para processamento industrial. Já os genótipos Alfa, CPAC 5895, Ômega, R10P08, R12P09, R13P10, Rosa 2, Rosa 36 e Rosa 46 apresentam polpa livre de colapso interno.

termos de indexação: *Mangifera indica* L, herdabilidade, correlação genética, ganho genético.

Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical fruit-bearing trees, and wide genetic variability is available. However, fruit production in commercial orchards is concentrated in few cultivars. As the number of competitors in Brazilian exports has increased, there is the need to diversify the cultivars grown through generating and selecting new varieties. Investment in mango breeding programs plays a fundamental role in this process (LIMA NETO 2009, MAIA et al., 2017).

Mango breeding is a strategy to obtain greater efficiency in production and product quality. The use of specific methodologies that accurately represent the heritability of the traits for selection is necessary, and this results in high-yielding successor plants with a standard of fruit quality that may determine product acceptance and directly affect the price obtained on the market (HADNER et al., 2012, SILVA et al., 2012).

In dealing with a perennial fruit tree like mango, more efficient methods of analysis and ranking of genotypes may be necessary because of the complexity of some traits of the crop. More refined statistical procedures, such as standard analysis of estimation of variance components and prediction of mean components through REML/BLUP, has been a recent trend in plant breeding, providing additional important parameters in identification of superior genetic materials (BROWN et al., 2009, MAIA et al., 2011, MAIA et al., 2017, MATOS FILHO et al., 2019).

Maia et al. (2014) used the REML/BLUP methodology in a study in estimating variance components and in predicting genotypic values in a mango population based on agroindustrial traits of the fruit. It allowed technical information to be obtained to make early selection in the population.

Evaluation of promising mango hybrids is one of the pre-requisites for success in growing the fruit tree. Therefore, a decisive aspect is studying the performance of different mango hybrid selections for the purpose of making materials available that can compete with those already on the market (SINGH et al., 2015).

The aim of the present study was to estimate genetic parameters and select superior mango genotypes using the mixed-models approach.

Materials and Methods

The experiment was conducted at the Mandacaru Experimental Station in the municipal region of Juazeiro, BA, Brazil, belonging to Embrapa Semiárido, at the geographical coordinates 9°24′ S and 40° 26′ W. The climate is semi-arid, with a *Vertissolo* soil type. According to meteorological data of the Experimental Station, in 2017, rainfall was 99.13 mm and mean relative humidity was 68.24%. Mean annual temperature is 26.76 ºC, with a mean maximum temperature of 33.52 °C and mean minimum temperature of 21.05 °C (Figure 1).

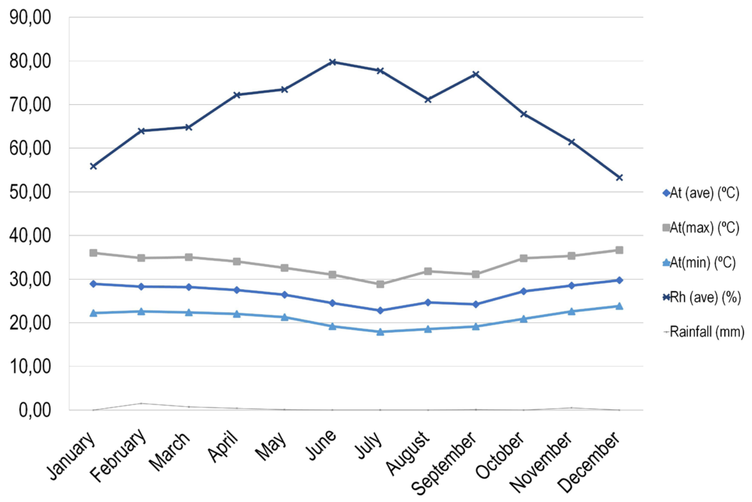

Figure 1. Average maximum and minimum monthly air temperature, rainfall, and relative humidity in the municipality of Juazeiro, BA, Brazil, in 2017. Source: Embrapa Semiárido (2017).

In a national trial of the Mango Breeding Program implemented in Embrapa Semiárido, the following varieties and hybrid selections were evaluated in the 2017/2018 crop season: Rosa 2, CPAC 26394, Rosa 36, Rosa 46, CPAC 5895, Lita, Alfa, Ômega, Beta, Roxa, CPAC 2293, R12P09, R6P06, R10P08, R13P010, and Tommy Atkins (control variety). A randomized block design was used with six replications, with one plant per plot, aiming at recommendation of genetic material that combines traits of high yield, adaptability, stability, and important technologies to meet the requirements of growers, consumers, agro-industry, and distributors.

The recommended crop practices were implemented, with micro-sprinkler irrigation and cleaning pruning after harvest operations for removal of dry, diseased, and late branches and harvest residues, for the purpose of plant health and obtaining high-yielding branches. Regular weeding was also performed through mowing and herbicide application. Nutritional requirements were estimated based on leaf and soil analyses performed after harvest operations.

For analyses, fruit was collected at the harvest stage (physiological maturity) from the plants themselves. Ten of these mangos were used, which were taken to the Post-Harvest Physiology Laboratory of Embrapa Semiárido where they were placed in cold storage at 12 ºC until they were ripe, at the point of consumption, to perform the analyses.

The following traits were evaluated: fruit weight (g), fruit length (mm), fruit diameter (mm), peel weight (g), seed weight (g), pulp weight (g), pulp yield (%), pulp firmness (N), total soluble solids content (ºBrix), total titratable acidity (% citric acid / g of pulp), total soluble solids content / total titratable acidity ratio (TSS/TTA), peel color and pulp color, pulp fibrousness, and the presence of internal breakdown of the pulp (AOAC, 2010).

Fruit weight, peel weight, and endocarp (stone/seed) weight were determined on a precision balance. The length and diameter of the fruit was measured with the aid of a digital caliper rule. Pulp weight was calculated by the difference between the total fruit weight and the combination of the peel weight and seed weight. Pulp yield, in %, was obtained by the ratio between the weights of the pulp and the fruit, multiplied by 100.

Pulp firmness was determined through removal of the entire peel, leaving the fruit pulp exposed for introduction of an analogical dual-scale penetrometer device (TR brand). Results were expressed in N.

Total soluble solids content, in ºBrix, was obtained with readings on a digital refractometer (ATAGO PAL-1) through drops of juice from each fruit sample. Total titratable acidity was determined through the weight of 1 g of juice dissolved in 50 ml of distilled water, subsequently measured in a titrator, Titrino Plus 848 (Metrohm), and expressed in % of citric acid. The TSS/TTA ratio corresponded to the ratio between the total soluble solids content and the total titratable acidity.

The presence of fiber was analyzed on a subjective scale (visual and tactile), attributing scores, considering 1 = absent, 2 = moderately fibrous, and 3 = fibrous. The peel color and pulp color were determined with the aid of a colorimeter (Konica Minolta) using the attributes of lightness (L), chroma (C), and hue (H). The L (lightness) coefficient ranges from 0 to 100, with L* of 0 = dark or opaque colors and L* of 100 = white or maximum brightness colors. The C (chroma – saturation or intensity of color) coefficient indicates greater purity or intensity of the color. The H (hue – true color) coefficient ranges from 0° to 360º, with 0º = red, 90º = yellow, 180º = green, and 270º = blue (MCGUIRE, 1992).

The fruit samples were also analyzed regarding the presence or absence of symptoms of internal breakdown of the pulp. The samples with pulp degradation, formation of a cavity below the peduncle, splitting of the seed, and necrotic spots on the pulp and on the peduncular cavity were characterized as fruit with symptoms of physiological disorder.

Statistical analyses were performed according to the mixed linear model described as follows:

$$y = Xb + Zg + e\,,$$

where Y is the vector of phenotypic observations; X is the incidence matrix of the fixed effects; b is the vector of fixed effects (blocks); Z is the incidence matrix of the random effects; g is the vector of random effects of the plants or of the genotypes; and g ~ NMV (G, 0).

The variance components were estimated by the restricted maximum likelihood (REML) method. The mixed linear model was fitted and the BLUE (best linear unbiased estimate) solutions of the fixed effects and the BLUP (best linear unbiased prediction) of the genotypic values were able to be obtained through Proc Mixed of SAS (LITTELL et al., 2006). The accuracies (ac) of the BLUP predictions and the heritability (h^2) for selection on the plant level were also estimated (RESENDE, 2002).

The associations between the traits were assessed by the estimate of genetic correlation, the significance of which was tested using the non-parametric bootstrap method, applied with the aid of the Genes software (CRUZ, 2016). Genetic gain was estimated from the mean value of the BLUP of the genotypic values of the hybrids evaluated (SAS, 2008).

Results and Discussion

The estimates of individual narrow-sense heritability (h^2) for the traits analyzed exhibited values of medium to high magnitude (0.45 to 0.99) (Table 1). The traits of fruit weight, fruit length, and fruit diameter had high heritability values ($h^2 > 0.70$), showing high genetic control in the selection process. The traits examined are important for fruit commercialization and direct consumption.

For total soluble solids and the TSS/TTA ratio, the heritability values showed higher magnitude, 0.99 and 0.89, respectively, which confirms the possibility of genetic gain from selection. The two traits are related to both direct consumption and to processing.

Hadner et al. (2012) performed a study using the REML/BLUP methodology and successfully predicted genetic gains for mean fruit weight in mango from unbalanced data collected over various crop seasons and various trials. Heritability estimates ranged from 0.46 to 0.94, indicating medium to high genetic control.

Table 1 - Estimates of heritability and accuracy for fruit traits evaluated in 16 mango varieties and hybrid selections at the experimental station of Embrapa Semiárido in Juazeiro, BA, Brazil, in the 2017/2018 crop season.

Trait	Heritability	Accuracy
Fruit weight (g)	0.73	0.85
Fruit length (mm)	0.84	0.91
Fruit diameter (mm)	0.71	0.84
Peel weight (g)	0.59	0.76
Seed weight (g)	0.82	0.91
Pulp weight (g)	0.72	0.75
Pulp yield (%)	0.57	0.76
Pulp firmness (N)	0.62	0.79
Total soluble solids content - TSS (°Brix)	0.99	0.99
Total titratable acidity – TTA (%)	0.45	0.67
TSS/TTA ratio	0.89	0.94
Lightness of peel color	0.87	0.93
Chroma of peel color	0.83	0.91
True fruit peel color	0.77	0.88
Lightness of pulp color	0.67	0.82
Chroma of pulp color	0.77	0.87
True pulp color	0.68	0.82

Heritability estimates ranging from 0.67 to 0.87 were obtained regarding the traits related to fruit color and pulp color. The true color/hue of the peel of the fruit (HPF) and true color/hue of the pulp (HP) traits had medium to high heritability values, 0.77 and 0.68, respectively (Table 1). Fruit color is an important quality trait; it not only contributes to good appearance, but also determines consumer preference. In addition, it can be an important factor in determination of the stage of ripeness (MOTTA et al., 2015).

Heritability estimates add information valuable to mango breeders for efficient establishment of crossing schemes and in the selection process (BROWN et al., 2009). It should be emphasized that heritability is not immutable, but is affected by the trait analyzed, by the population, by the environmental conditions to which the populations are subjected, by the experimental unit, by sample size, and by accuracy in data collection (FALCONER, 1987).

In the genotypic evaluation set, the most important statistical parameter is accuracy (ac), which refers to the correlation between the true genotypic value of the genetic material and that estimated or predicted from information from field experiments (MAIA et al., 2014). In the present study, the variation from 0.67 to 0.99 was obtained (Table 1); that is, high accuracies (ac > 0.70) were observed for all the traits considered, except for total titratable acidity (0.67).

In the studies of Maia et al. (2017), accuracy values ranging from 0.23 (% of pulp) to 0.97 (pH of the pulp) were obtained, and estimates greater than or equal to 0.71 were found for 11 of the 12 traits analyzed. The authors thus highlighted that a significant degree of certainty in the inferences, in the accuracy, and in calculation of gain from selection could be observed, except for pulp percentage (%).

A selection process becomes more effective when it acts on high heritability traits that have some association with a trait of economic importance, which is considered most important in the program developed (ASISS et al., 2010). In this respect, the genetic correlation coefficients among the traits analyzed were estimated.

The fruit weight and pulp weight traits showed positive and significant correlations with fruit length and fruit diameter (Table 2), which leads to the conclusion that the latter can be used for selection of the former, the former being more difficult to measure. Positive and significant genetic associations were also obtained between pulp yield and the fruit weight and fruit diameter traits. Pulp yield is a characteristic of great importance for fruit processing industries. According to Maia et al. (2014), estimates of genetic associations between traits are indispensable since they allow the breeder to evaluate the selection response and obtain indirect gains in other variables.

Table 2 - Estimates of genetic correlation coefficients between fruit traits[1], evaluated in 16 mango varieties and hybrid selections at the experimental station of Embrapa Semiárido in Juazeiro, BA, Brazil, in the 2017/2018 crop season.

Trait	FW	FFL	FFD	PPLW	SSW	PPF	PPW	PPY	TTSS	TTTA	TSS/TTA	LLPLC	CCPLC	HHPF	LLPC	CCPC	HP
FW	1	0.70*	0.84*	0.92*	0.93*	0.02	0.99*	0.81*	-0.56	-0.12	-0.35	-0.19	-0.02	-0.73*	-0.33	-0.21	-0.07
FL			0.31	0.64*	0.75*	0.01	0.68*	0.44	-0.31	-0.02	-0.19	-0.04	0.03	-0.46	-0.01	-0.48	-0.13
FD				0.68*	0.79*	0.08	0.84*	0.79*	-0.47	-0.18	-0.39	-0.04	0.10	-0.70*	-0.28	0.07	-0.15
PLW					0.82*	-0.07	0.90*	0.61	-0.53	-0.18	-0.25	-0.17	0.01	-0.69*	-0.36	-0.27	-0.03
SW						0.02	0.91*	0.61	-0.55	-0.07	-0.35	-0.03	0.11	-0.70*	-0.24	-0.24	-0.12
PF							0.02	0.10	-0.47	0.45	-0.61	0.45	0.42	-0.17	0.40	0.71*	-0.26
PW								0.83*	-0.55	-0.12	-0.35	-0.21	-0.03	-0.73*	-0.33	-0.19	-0.07
PY									-0.31	-0.06	-0.33	-0.28	-0.16	-0.62*	-0.29	-0.03	-0.14
TSS										-0.14	0.60	-0.01	-0.12	0.27	0.14	-0.28	0.10
TTA											-0.76*	0.19	0.17	0.01	0.32	0.12	0.05
TSS/TTA												-0.31	-0.38	0.29	-0.16	-0.20	0.02
LPLC													0.57	0.10	0.64*	0.19	0.10
CPLC														-0.20	0.57	0.10	0.19
HPF															-0.03	0.04	0.03
LPC																0.05	0.41
CPC																	-0.41

* significant at 1% by the *t*-test.

[1] Traits: fruit weight – FW (g), fruit length – FL (mm), fruit diameter – FD (mm), peel weight – PLW (g), seed weight – SW (g), pulp weight – PW (g), pulp yield – PY (%), pulp firmness – PF (N), total soluble solids content – TSS (°Brix), total titratable acidity – TTA (%), total soluble solids content and total titratable acidity ratio – TSS/TTA, lightness of peel color – LPLC, chroma of peel color – CPLC, true peel color – HPF, lightness of pulp color – LPC, chroma of pulp color – CPC, and true pulp color – HP.

The selection of genotypes with desirable fruit traits becomes easier with positive and significant genetic correlations between them. That way, traits of a complex genetic nature, considerably affected by the environment, can be selected indirectly from the traits that are easier to measure and less subject to errors in measurement (CRUZ et al., 2004, MAIA et al., 2014).

With the descriptor related to true color / hue of the peel of the fruit (HPF), significant negative correlations were obtained with the fruit weight, fruit diameter, pulp weight, and pulp yield traits (Table 2). Thus, larger fruit had lower values in relation to HPF, lower values indicating colors tending to be from yellow to red. Smaller sized fruit tended to be from yellow to green. Larger size fruit with reddish color is favored in the selection process.

Fruit appearance is a very important quality determinant. Thus, mango color is an important factor in the choice of the consumer. Fruit covered with red color is especially of greater value in international markets (BROWN et al., 2009); however, this demand regarding color is not so great in the Brazilian domestic market.

The prediction of genotypic values, of genetic gains, and of new mean values for the traits analyzed shows that for fruit weight and pulp weight (Table 3), there was a high degree of coincidence in ranking of the genotypes, with the best gains for the treatments CPAC26394, Tommy Atkins, Lita, Rosa 46, and R6P16. Similar results were obtained by Maia et al. (2014), with a high degree of agreement in ordering among the genotypes for the traits in question, due to the high magnitude correlations found among them.

The Tommy Atkins variety was outperformed regarding fruit weight and pulp weight by the hybrid selection CPAC26394 (Table 3). Maia et al. (2017) observed that the Tommy Atkins variety was better than the other genotypes regarding fruit weight. However, from the results found in this study, considering the fruit weight and pulp weight traits, the genotype CPAC 26394 can be a candidate for selection.

For the other traits, there were changes in the ranking of the genotypes, results that corroborate those obtained by Maia et al. (2014). The authors associate the change in ordering of the genotypes to a response with low and medium magnitude correlations found, with some exceptions.

Regarding fruit firmness, the genotypes that had the greatest gains were CPAC5895, Rosa 46, R13P10, CPAC26394, Rosa 36, Rosa 2, Ômega, and R6P16 (Table 3). One of the most significant aspects of mango quality for consumers is firmness because it represents ripeness and may define shelf life and resistance to transport (JHA et al., 2010, PINTO et al., 2011, MAIA et al., 2014).

For pulp yield, the Tommy Atkins variety had the greatest gains; however, the genotypes CPAC 26394, Roxa, Lita, Ômega, R6P16, Rosa 46, and Rosa 2 also had gains, and may thus be selected regarding this descriptor. For industrial processing, mango varieties with pulp yield values greater than 60% are most in demand, an aspect observed in this study, in which all the genotypes evaluated had pulp yield greater than 70% (Table 3). Maia et al. (2017) obtained a different ordering of the genotypes and gains lower than those found in this study.

The aim of the study developed by Pinto et al. (2009) in seven hybrid selections obtained at Embrapa Cerrados was to identify agronomic traits and quality features of the fruit that were superior to those of Tommy Atkins. They obtained genotypes with excellent pulp yield, from 10% to 18% greater than the pulp yield of Tommy Atkins.

The genotypes R12P09, Alfa, Lita, Ômega, CPAC 2293, and Roxa had the greatest gains for total soluble solids (Table 4); their new estimated mean values were greater than 20° Brix, and were greater than the overall mean and the mean of the Tommy Atkins variety. Therefore, the genotypes highlighted are candidates for selection. The results obtained corroborate those found by Maia et al. (2017).

Table 3 - Ordering of the 16 mango varieties and hybrid selections, based on the new mean of BLUP, evaluated for the following traits: fruit weight – FW (g), fruit length – FL (mm), fruit diameter – FD (mm), peel weight – PLW (g), seed weight – SW (g), pulp weight – PW (g), pulp yield – PY (%), and pulp firmness – PF (N), at the experimental station of Embrapa Semiárido, in Juazeiro, BA, Brazil, in the 2017/2018 crop season.

FW (g)	FL (mm)	FD (mm)	PLW (g)	SW (g)	PW (g)	PY (%)	PF (N)
CPAC26394 561.62	CPAC26394 152.58	Tommy 93.89	Tommy 57.95	CPAC26394 67.92	CPAC26394 432.29	Tommy 77.25	CPAC5895 10.97
Tommy 559.68	R6P16 146.00	CPAC26394 92.52	CPAC26394 57.68	Tommy 66.48	TOMMY 432.09	CPAC26394 76.97	Rosa46 10.92
Lita 532.97	Lita 139.28	Rosa46 90.86	R13P10 56.52	Rosa46 63.92	LITA 411.19	Roxa 76.63	R13P10 10.78
Rosa46 500.70	Alfa 135.25	Rosa2 89.78	R6P16 55.07	Rosa36 61.74	ROSA46 384.47	Lita 76.34	CPAC26394 10.61
R6P16 480.42	Rosa46 132.35	Rosa36 89.10	CPAC2293 54.01	Alfa 60.09	R6P16 367.56	Omega 76.06	Rosa36 10.48
Rosa36 466.03	CPAC2293 130.29	Roxa 88.57	R10P08 53.16	Rosa2 58.57	R10P08 355.58	R6P16 75.82	Rosa2 10.38
R10P08 455.39	Tommy 128.41	R10P08 87.94	Lita 52.42	R10P08 57.30	ROSA36 346.45	Rosa46 75.63	Omega 10.31
Alfa 447.04	Rosa36 126.45	R13P10 87.30	Alfa 51.84	Lita 56.32	ALFA 339.17	Rosa2 75.47	R6P16 10.24
R13P10 439.86	Omega 124.44	Lita 86.73	Rosa36 51.29	CPAC2293 55.49	ROXA 333.06	Alfa 75.32	Tommy 10.18
Rosa2 433.63	Beta 122.57	Alfa 86.21	Rosa46 50.75	R6P16 54.73	R13P10 327.96	R10P08 75.17	R12P09 10.11
Roxa 428.05	R10P08 120.77	R6P16 85.68	Rosa2 50.29	Beta 53.97	ROSA2 323.76	Rosa36 75.05	Lita 10.03
CPAC2293 422.92	Rosa2 119.06	Omega 85.14	Omega 49.83	R13P10 53.23	CPAC2293 319.61	R13P10 74.94	CPAC2293 9.93
Omega 417.48	R12P09 117.58	Beta 84.61	Beta 49.38	Roxa 52.49	OMEGA 315.08	CPAC5895 74.80	Roxa 9.83
Beta 411.30	R13P10 116.25	CPAC2293 84.07	Roxa 48.98	Omega 51.76	BETA 310.05	R12P09 74.66	R10P08 9.72
R12P09 403.91	Roxa 115.01	R12P09 83.56	R12P09 48.43	R12P09 51.00	R12P09 304.01	CPAC2293 74.54	Beta 9.60
CPAC5895 395.69	CPAC5895 113.79	CPAC5895 83.03	CPAC5895 47.75	CPAC5895 50.19	CPAC5895 297.51	Beta 74.41	Alfa 9.49

Table 4 - Ordering of the 16 mango varieties and hybrid selections, based on the new mean of BLUP, evaluated for the following traits: total soluble solids content – TSS (°Brix), total titratable acidity – TTA (%), total soluble solids content and total titratable acidity ratio – TSS/TTA, lightness of peel color – LPLC, chroma of peel color – CPLC, true fruit peel color– HPF, lightness of pulp color – LPC, chroma of pulp color – CPC, and true pulp color – HP, at the experimental station of Embrapa Semiárido, in Juazeiro, BA, Brazil, in the 2017/2018 crop season.

TSS (°Brix)	TTA (%)	TSS/TTA	LPLC	CPLC	HPF	LPC	CPC	HP
R12P09 20.62	CPAC5895 0.75	R12P09 42.47	Rosa46 71.51	Rosa46 66.92	CPAC5895 99.27	R12P09 77.50	Rosa2 69.79	R12P09 90.04
Alfa 20.56	Lita 0.73	CPAC2293 41.81	R6P16 70.55	R6P16 66.39	Beta 98.68	Lita 77.41	CPAC5895 69.37	Lita 90.02
Lita 20.43	Rosa2 0.70	Beta 41.13	Rosa2 69.37	R13P10 65.61	R10P08 97.95	CPAC5895 77.21	Omega 68.91	R10P08 89.89
Omega 20.29	Rosa46 0.68	Roxa 40.69	Rosa36 68.39	Rosa36 64.91	R12P09 97.09	Rosa46 77.00	Rosa46 68.63	Tommy 89.71
CPAC2293 20.11	Rosa36 0.66	Omega 40.23	R13P10 67.57	Alfa 64.36	Roxa 96.23	Rosa36 76.86	Rosa36 68.34	R13P10 89.55
Roxa 19.92	CPAC26394 0.64	R10P08 39.79	R12P09 66.88	Rosa2 63.9	Omega 95.44	R6P16 76.74	R12P09 68.05	CPAC5895 89.42
Rosa2 19.74	CPAC2293 0.64	Alfa 39.44	Alfa 66.24	R12P09 63.14	R13P10 94.45	R13P10 76.60	R13P10 67.84	Beta 89.31
R10P08 19.58	Tommy 0.63	R6P16 39.09	CPAC5895 65.54	CPAC5895 62.12	Alfa 93.40	CPAC2293 76.41	Roxa 67.62	Alfa 89.22
Beta 19.42	Alfa 0.62	Rosa36 38.67	R10P08 64.58	R10P08 61.02	Rosa2 92.41	Alfa 76.18	Tommy 67.38	R6P16 89.12
Rosa36 19.28	R13P10 0.62	R13P10 38.25	Lita 63.57	Tommy 59.91	R6P16 91.42	Rosa2 75.99	CPAC2293 67.10	Rosa36 88.97
R6P16 19.13	Omega 0.61	Lita 37.85	CPAC2293 62.46	Lita 58.93	CPAC26394 90.47	Roxa 75.80	R6P16 66.79	CPAC26394 88.76
CPAC5895 19.01	R10P08 0.61	Rosa46 37.52	Omega 61.28	CPAC26394 57.92	CPAC2293 89.54	CPAC26394 75.61	R10P08 66.52	Roxa 88.53
Rosa46 18.89	R6P16 0.60	Tommy 37.23	Tommy 60.27	CPAC2293 56.79	Rosa46 88.64	Beta 75.44	CPAC26394 66.23	CPAC2293 88.29
Tommy 18.78	Beta 0.60	Rosa2 36.95	CPAC26394 59.38	Omega 55.68	Lita 87.79	Tommy 75.28	Beta 65.90	Rosa46 88.05
R13P10 18.66	Roxa 0.59	CPAC26394 36.69	Beta 58.52	Beta 54.65	Rosa36 86.85	R10P08 75.14	Lita 65.48	Rosa2 87.84
CPAC26394 18.52	R12P09 0.59	CPAC5895 36.35	Roxa 57.53	Roxa 53.48	Tommy 85.30	Omega 74.98	Alfa 64.89	Omega 87.62

Soluble solids consist of substances that are dissolved in the fruit pulp, with sugars as the main elements; they are a decisive factor in market acceptance of the fruit (BATISTA et al., 2015). For Pinto et al. (2011), total soluble solids content (TSS) is among the fruit traits of an ideal variety, and the TSS should be greater than 18° Brix and slightly acidic.

For total titratable acidity (TTA), gains were observed for the genotypes CPAC 5895, Lita, Rosa 2, and Rosa 46 (Table 4). For Maia et al. (2017), less acid fruit is preferred for direct consumption. The genotypes that had the lowest mean values for total titratable acidity were R12P09 and Roxa, and may thus be selected regarding this trait. However, according to the Brazilian Ministry of Agriculture, MAPA (2000), in establishment of quality standards for mango pulp, with the new mean values associated with gains from selection, the use of genotypes classified as having greater acidity is allowed for agroindustrial processing.

Regarding the ratio between total soluble solids content and total titratable acidity (TSS/TTA) (Table 4), the greatest gains were observed for the genotypes R12P09, CPAC2293, Beta, Roxa, Ômega, R10P08, and Alfa. The ratio under study is an indicator of fruit flavor, that is, high values are attributed to better quality fruit (MAIA et al., 2014). According to Chitarra & Chitarra (2005), this is one of the most used manners of flavor evaluation, and it is more representative than isolated measurement of sugars or acidity.

The pulp fibrousness and internal breakdown of the pulp traits were analyzed qualitatively by the level of fiber in the pulp and by the presence or absence of breakdown in the pulp. The Roxa variety had pulp with little or no fiber. The genotypes Alfa, CPAC 2293, CPAC 26394, Lita, Ômega, R10P08, R12P09, R13P10, R6P16, and Tommy Atkins had moderate fiber content, whereas the others had pulp classified as fibrous. Consumers prefer mango with lower fiber content in the pulp. According to Pinto et al. (2011), the fibrousness of the fruit pulp is among the traits considered in an "ideal" variety, and it should have little or no fiber.

Regarding the presence or absence of internal breakdown of the pulp, the genotypes Alfa, CPAC 5895, Ômega, R10P08, R12P09, R13P10, Rosa 2, Rosa 36, and Rosa 46 did not show symptoms. The results of the present study corroborate those found by Pinto et al. (2009) for breakdown in the genotypes Tommy Atkins and CPAC 26394, and differ regarding the absence of breakdown in CPAC 2293, though the intensity found in this study was low.

The occurrence of this physiological disturbance is normally related to nutritional imbalance. Calcium is the nutrient most studied in this respect and the element recommended aiming at post-harvest quality and reduction in symptoms in the fruit. Internal breakdown of pulp may also be conditioned on other factors, such as the genetic patrimony, since some cultivars are more susceptible, even under the same edaphic and climatic conditions and with the same crop management practices (PRADO, 2004).

With internal breakdown of the pulp, the affected fruit loses quality and commercial value because there is degradation of the pulp around the endocarp, forming a gelatinous mass with a characteristic smell (NJUGUNA et al., 2016), along with formation of a cavity with necrotic spots below the peduncle. The symptoms of breakdown are not always visible on the outer part of the fruit, which makes it even more difficult to be detected. Generally, it can be detected even in unripe fruit, with softening of the pulp and change in peel color in the affected area.

Conclusions

The varieties and hybrid selections of mango show variability regarding fruit traits.

The REML/BLUP methodology is efficient for selection of genotypes with desirable fruit traits in mango.

The mango fruit weight and pulp weight traits can be selected indirectly based on fruit length and diameter, which are more easily evaluated.

The hybrids CPAC 26394, Lita, and Rosa 46 stand out in regard to fruit size.

The genotypes R12P09, CPAC 2293, Roxa, Omega, Alfa, and Lita have fruit of better quality than the Tommy Atkins variety that is widely used in commercial orchards.

The Roxa variety has pulp with little or no fiber, a trait required by consumers and for industrial processing. The genotypes Alfa, CPAC 5895, Ômega, R10P08, R12P09, R13P10, Rosa 2, Rosa 36, and Rosa 46 have pulp free of internal breakdown.

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