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Estimation of Genetic Parameters and Prediction of Breeding Values for Fruit-Quality Traits in Hybrid Mangoes

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ABSTRACT

Genetic parameters to fruit quality of mango hybrids were estimated using a mixed model REM/BLUP. Twenty-seven hybrids (Tommy Atkins cross with Haden, Palmer, Van Dyke, Kent and Coquinho) were evaluated, in two crop seasons. Physical and chemical traits analyzed were weight, longitudinal length, transverse diameter, fiber presence, pulp firmness, skin and pulp color, fibers presence titratable acidity, and soluble solids (SS). Repeatability varying from 0.53 (SS) to 0.89 (diameter). Selective Accuracy (A_{cm}) based on average harvests varying from 0.73 (SS) to 0.94 (weight, length, and diameter). According to selection gain and the new averages the most promising hybrids were selected.

KEYWORDS

Mango breeding; mixed model; selective accuracy; repeatability; mango hybrids

Introduction

Brazil is one of the largest fruit producers in the world, and mango is one of the most important fruit crops cultivated in this country (Pommer and Barbosa, 2009). The potential export market of mango fruit had demanded studies of its varieties around the world (Vázquez-Celestino et al., 2016). At São Francisco Valley, the use of irrigation and edaphoclimatic conditions, such as low rainfall and high temperatures, have been enabled the fruits growing, as well as increased mango production (Cardoso et al., 2015). From 2017 to 2018, this region had increased the area for mango production from approximately 27,000 hectares to over 30,000 hectares, it has been considered the largest mango producing region in Brazil (HORTIFRUTI Brasil CEPEA, 2018).

Tommy Atkins, Rosa, Palmer, Espada, Haden, Kent and Keitt are the main varieties grown at São Francisco Valley, and Tommy Atkin is the dominant mango variety in Brazilian market (Machado et al., 2017). However, Tommy Atkins has been losing ground to Palmer, Kent and Keitt varieties in this region.

Development of new varieties for semiarid conditions it is necessary. Estimating heritability becomes essential for obtaining new varieties, which contributes to define the best strategy for mango breeding programs. Little is known about traits that have quantitative inheritance for this crop (Brown et al., 2009).

The use of breeding techniques and experimental designs is difficult in perennial species, making it complex to estimate genetic parameters such as heritability, but it does not prevent the repeatability estimation (Silva et al., 2015). The variance components can be estimated by the mixed REML/BLUP model, which REML is the restricted maximum likelihood method and the BLUP method could predict genotypic values by the best non-biased linear prediction. This methodology is essential for an earlier selection to perennial or semi-perennial plants (Maia et al., 2017).

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Thus, this research aimed to estimate genetic parameters associated to fruit quality of mango hybrids (F_1) using a mixed model REM/BLUP, to select superior genotypes from the genetic breeding program of EMBRAPA for cultivation in Brazilian semiarid region and development of new varieties.

Material and Methods

The study was carried out at the Experimental Field of Mandacaru, in Embrapa Semiárido at Juazeiro, Bahia State, Brazil (9°24′S, 40°26′O, and 375 m altitude), with a hot and dry tropical climate and soil classified as vertisol (Silva et al., 2005).

Each hybrid (F_1) is represented by a single plant, without repetitions. All hybrids were obtained through open pollination, with 'Tommy Atkins' (T) being the pollen donor in all crosses. The Haden (H), Palmer (P), Coquinho (C), Kent (K), and Van Dyke (V) varieties were the pollen recipients, and they generate the hybrids that were called as HT, PT, CT, KT, and VT, respectively.

The meteorological data during the evaluation period of the years 2017 and 2018 are present in Figure 1 (A.B).

At the first crop season, from October to December 2017, it was possible to evaluate 50 hybrids: 25 CT hybrids, 7 HT hybrids, 7 PT hybrids, 5 KT hybrids, and 6 VT hybrids. In the second crop, from November to December 2018, it was possible to repeat the evaluations in 27 hybrids (Table 1).

Although almost all hybrids evaluated in the 2017 crop flourished in the 2018 crop, it was not possible to reevaluate the same number of hybrids in the second crop due to these factors: i) some hybrids presented advanced maturity stage at the time of evaluation, exceeding the appropriate time to evaluate; ii) advanced symptoms of fungal disease (unidentified) in the hybrids after harvest, even when they were stored in cold room; and iii) labor reduction in the activities performed, resulting in the reduction of fruits evaluated per day.

The mango trees spacing was in a 4.0 × 4.0 m, and the irrigation system used was the micro-sprinkler type, the cultural treatments followed the recommendation for the semiarid region (EMBRAPA, 2010). However, cultural treatments did not aim to increase the productivity, as they are still in the evaluation process at an early stage. The plants are approximately 6 years-old and these were the first evaluations performed on these hybrids.

Ten fruits of each hybrid were randomly harvested and were analyzed for physicochemical characteristics at Postharvest Physiology Laboratory from Embrapa Semiárido, in Petrolina, Pernambuco State, Brazil. The harvested fruits were packed in properly identified sanitized containers and stored in a cold room, at 12°C.

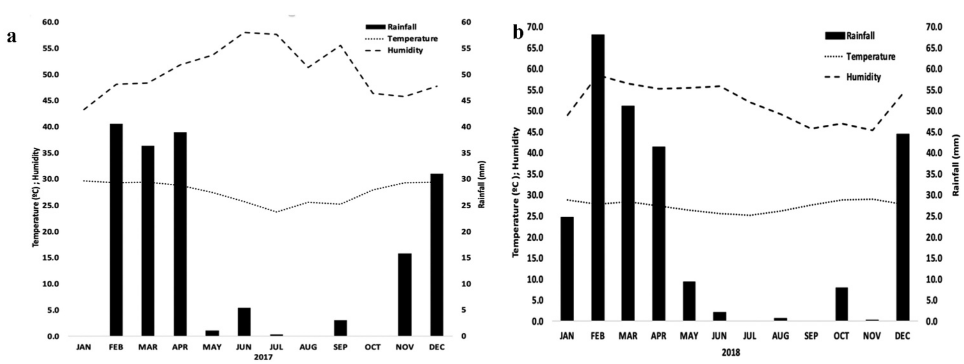

Figure 1. Meteorological data provided by the Univasf weather laboratory (LABMET) – Campus Juazeiro, BA (latitude 09°26′56″S, longitude 40°31′27″W, altitude of 356 m for Juazeiro (BA) city, containing the average temperatures (°C), air relative humidity and rainfall during the years 2017 (A) and 2018 (B).

Table 1. Number of genotypes (hybrids) evaluated in the two crop seasons (2017 and 2018) for each cross.

Cross	Number of genotypes
Tommy Atkins x Coquinho	13
Tommy Atkins x Van Dyke	5
Tommy Atkins x Palmer	4
Tommy Atkins x Keitt	3
Tommy Atkins x Haden	2

Each fruit was analyzed individually, and their evaluated characteristics were weight (g), fruit length (mm), fruit diameter (mm), skin and pulp color, fibers presence (visual), pulp firmness, soluble solids content (SS – °Brix) and titratable acidity (TA), following the methodology of Zenebon et al. (2008).

The skin and pulp colors were determined using a colorimeter (Konica Minolta, CR-400, Tokyo, Japan), with the values expressed in L (brightness), C (chromaticity), and °H (Hue angle) (Azeredo et al., 2016).

The fruit weight was measured on a semianalytical precision scale (Acculab, VI 2400, Florida, USA) to obtain the fresh weight (FW). The length and diameter were determined using the digital caliper (Mitutoyo, 500–196-20B, Auroras, Illinois, USA).

Before the fruits being processing, it was removed a small portion of the skin next to the pulp, on opposite sides, so that the pulp firmness could be measured using the digital texturometer (Stable Micro Systems, TA.XT.plus, Surrey, UK), attached to a computer.

During fruits processing, the pulp of each fruit was individually cut. In this phase, each fruit was visually analyzed to verify the fiber presence, using a scale which value varies from 1 (low fiber), 2 (average), and 3 (a lot of fiber).

After this stage, each fruit had the juice extracted manually, with the aid of a common sieve and a tablespoon. When all samples were analyzed, soluble solids (SS) content was performed with a refractometer (Milwaukee, MA 871, North Carolina, USA). The samples were stored in the freezer at −18°C for later evaluation of the titratable acidity).

For titratable acidity (TA) analysis, when the samples reached ambient temperature (25°C), 50 mL of distilled water was added to 1 g of each sample, making it ideal for measuring on the digital titrator (Metrohm, 848 Tritino Plus, Herisau, Switzerland). The titratable acidity was estimated to measure the SS/TA ratio.

The evaluation of genotypes (F_1 hybrid) Table 1 was performed by a nonrepetitive individual test, based on the multivariate selection at the individual level, via Selegen software model 63, which is a repeatability model without a design in analyses by site (Resende, 2016). This model can be employed when repeated measures are evaluated in individual plants in the absence of an experimental design. It can also be applied to studies using evaluated genotype averages.

Results

The variance components (individual REML) estimated for each variable analyzed can be observed in Table 2. To have a greater chance of success in selecting superior individuals, it is necessary that the permanent phenotypic variance (V_{pp}) values represent a larger portion of phenotypic variance (V_p), and it was observed for fruit weight (*FW*), fruit length (*FL*) and fruit diameter (*FD*).

To analyze the permanent phenotypic variance (V_{pp}) values, it should consider the comparison with the values of temporary environmental variance (V_{te}). If the V_{pp}values are higher than V_{te} values for the same variable analyzed, then V_{pp}could be considered as high values.

Thus, the phenotypic permanent variance (V_{pp}) was considered high for those variables: fruit weight (9478.15); fruit length (252.96) and fruit diameter (94.95). It was considered intermediate for pulp firmness (14.40) and for SS/TA ratio (71.57). In addition, it was considered low for soluble solids

Table 2. Variance components (Individual REML) for Mango fruits quality characters.

Variables*	Overall Average	V_{pp}	V_{te}	V_p	$r = h^2$	R	A_{cm}
FW	236.07	9478.15	2372.85	11851.01	0.799 ± 0.344	0.88	0.94
FL	93.14	252.96	63.09	316.05	0.800 ± 0.344	0.88	0.94
FD	66.85	94.95	22.58	117.53	0.807 ± 0.345	0.89	0.94
FP	2.18	0.37	0.37	0.74	0.496 ± 0.271	0.66	0.81
FIRM	10.24	14.40	22.93	37.33	0.385 ± 0.239	0.55	0.74
SS	14.46	1.70	2.97	4.67	0.364 ± 0.232	0.53	0.73
Ratio	23.20	71.57	91.35	162.92	0.439 ± 0.255	0.61	0.78

FW (Fruit weight, in grams); *FL* (Fruit length, in millimeters); *FD* (Fruit diameter, in millimeters); *FP* (Fibers Presence, visual analysis with notes: 1, 2, and 3); *FIRM* (Firmness, in Newtons); *SS* (Soluble solids, in Brix); *Ratio* (SS/TA, dimensionless); V_{pp}: permanent phenotypic variance; V_{te}: temporary environmental variance; V_p: phenotypic variance; $r = h^2$: individual repeatability; R: repeatability coefficient of two harvests; A_{cm}: selective accuracy based on average of two harvests.

Table 3. Ranking and estimates of the 27 genotypes and their average components (individual BLUP) for the characters fruit weight (FW), fruit length (FL), and fruit diameter (FD) of Mango hybrids.

	[2]FW			[3]FL			[4]FD		
[1]RK	[5]GEN	Gain	[6]NA	[5]GEN	Gain	[6]NA	[5]GEN	Gain	[6]NA
1	HT1	182.57	418.64	PT4	31.87	125.02	PT1	15.77	82.62
2	PT4	167.46	403.53	HT1	31.65	124.80	PT4	15.10	81.95
3	VT1	157.53	393.61	VT2	29.65	122.80	HT1	14.43	81.28
4	PT1	152.46	388.53	PT1	28.31	121.46	VT1	14.09	80.94
5	VT4	149.33	385.40	VT4	26.18	119.33	PT3	13.80	80.65
6	VT2	146.57	382.65	VT1	24.39	117.54	VT4	13.61	80.46
7	PT3	140.16	376.23	PT3	22.22	115.37	VT5	13.41	80.26
8	VT5	130.74	366.82	PT2	19.98	113.13	VT2	12.97	79.83
9	VT3	116.06	352.13	VT5	17.89	111.04	VT3	11.75	78.60
10	PT2	103.69	339.76	KT3	15.91	109.06	CT9	10.67	77.52
11	CT9	92.60	328.68	CT2	14.13	107.28	CT8	9.67	76.53
12	CT8	83.21	319.29	CT9	12.64	105.79	PT2	8.84	75.69
13	HT2	74.96	311.03	CT5	11.32	104.47	HT2	8.07	74.92
14	KT3	67.19	303.26	CT13	10.12	103.27	KT1	7.15	74.00
15	KT1	59.39	295.46	HT2	9.02	102.17	CT1	6.29	73.15
16	CT5	52.14	288.22	VT3	8.06	101.21	KT2	5.55	72.40
17	CT13	45.52	281.59	CT4	7.19	100.33	CT12	4.86	71.71
18	KT2	39.50	275.58	CT8	6.41	99.56	KT3	4.25	71.10
19	CT3	34.03	270.10	CT1	5.64	98.79	CT11	3.68	70.53
20	CT11	29.08	265.15	KT1	4.93	98.08	CT5	3.14	70.00
21	CT4	24.56	260.63	CT3	4.25	97.39	CT2	2.64	69.49
22	CT1	20.39	256.46	CT11	3.60	96.75	CT3	2.18	69.03
23	CT2	16.41	252.48	CT7	2.92	96.07	CT13	1.72	68.57
24	CT6	12.08	248.1	KT2	2.27	95.42	CT4	1.28	68.13
25	CT12	7.84	243.91	CT6	1.66	94.81	CT7	0.84	67.69
26	CT7	3.77	239.85	CT10	0.91	94.05	CT10	0.42	67.27
27	CT10	0.00	236.07	CT12	0.00	93.14	CT6	0.00	66.85

[1]RK: Ranking; [2]FW: weight in grams; [3]FL: Length in millimeters; [4]FD:Diameter in millimeters; [5]GEN: Genotype; [6]NA: New Average.

content (1.7) and fiber presence (0.37). The selection becomes more difficult for variables with low V_{pp} values, as observed for soluble solids content, presence of fibers, pulp firmness, and SS/TA ratio, in this study.

The estimates of repeatability coefficient (r) were considered median to high ranged from 0.53 (SS) to 0.89 (FD) (Table 2). When the results presented high or median values for repeatability coefficient we consider that it had a high genetic control and great average stability in terms of values similarity for the variables in the evaluations successive cycles. Low values for r could demonstrate that there was a greater environmental influence on the variables.

The values found for selective accuracy (A_{cm}) ranged from 0.73 (SS) to 0.94 (FW, FL, and FD), all these values are considered high, which indicates that precision and selection gain are highly reliable for all traits (Table 2). Higher is the selective accuracy value, greater is the confidence in the evaluation and genetic value of the individual.

The genetic prediction values, such as genetic gain and new average (individual BLUP) for the 27 genotypes, for all variables, except for fibers presence, are presented in Tables 3 and 4. The genotypes were ranked for each attribute in descending order. The variable fibers presence was increasingly ranked, since the lower the fibers presence, more attractive it will be to consumers (Table 5).

Table 4. Ranking and estimates of the 27 superior genotypes and their average components (individual BLUP) for the firmness, soluble solids, and ratio of Mango hybrids fruits.

	[2] FIRM			[3] SS			[4]RATIO		
[1]RK	[5]GEN	Gain	[6]NA	[5]GEN	Gain	[6]NA	[5]GEN	Gain	[6]NA
1	HT2	10.16	20.40	CT11	1.35	15.81	CT12	16.35	39.56
2	CT5	7.65	17.90	KT3	1.35	15.81	PT4	15.59	38.79
3	CT4	5.98	16.23	VT3	1.35	15.81	HT2	13.50	36.71
4	CT3	5.08	15.32	HT2	1.28	15.75	VT3	12.31	35.51
5	PT1	4.43	14.67	KT1	1.24	15.71	KT1	11.53	34.73
6	VT5	3.90	14.14	PT4	1.17	15.63	VT2	10.45	33.66
7	CT1	3.48	13.72	VT1	1.12	15.58	PT3	9.55	32.75
8	CT7	3.17	13.41	CT8	1.05	15.51	CT1	8.61	31.81
9	CT8	2.89	13.13	CT13	0.99	15.46	KT2	7.74	30.94
10	CT2	2.59	12.83	CT1	0.92	15.39	VT5	7.01	30.22
11	PT3	2.34	12.58	CT9	0.86	15.33	CT11	6.36	29.57
12	KT3	2.13	12.37	CT12	0.82	15.28	KT3	5.75	28.95
13	CT6	1.94	12.18	PT3	0.77	15.24	CT13	5.18	28.38
14	CT10	1.77	12.01	VT5	0.74	15.20	CT7	4.65	27.85
15	CT11	1.61	11.85	CT4	0.69	15.15	PT2	4.14	27.35
16	CT12	1.46	11.70	CT7	0.63	15.10	VT4	3.70	26.91
17	KT1	1.33	11.58	PT2	0.58	15.04	CT6	3.26	26.47
18	CT13	1.19	11.43	VT4	0.53	15.00	CT5	2.86	26.06
19	PT2	1.06	11.30	CT3	0.48	14.94	CT9	2.49	25.69
20	VT3	0.92	11.16	CT5	0.43	14.89	HT1	2.16	25.36
21	VT1	0.78	11.02	CT6	0.38	14.85	CT8	1.83	25.04
22	KT2	0.63	10.87	HT1	0.32	14.78	CT4	1.51	24.71
23	VT2	0.50	10.74	KT2	0.26	14.72	VT1	1.21	24.41
24	CT9	0.37	10.61	VT2	0.20	14.67	CT3	0.91	24.12
25	HT1	0.25	10.49	CT2	0.14	14.61	CT10	0.60	23.81
26	VT4	0.14	10.38	PT1	0.09	14.55	PT1	0.31	23.51
27	PT4	0.00	10.24	CT10	0.00	14.46	CT2	0.00	23.20

[1]RK: Ranking; [2] FIRM: Firmness; [3] SS: Soluble solids; [4]RATIO: SS/AT – dimensionless; [5]GEN: Genotype; [6]NA: New average.

Table 5. Ranking for the trait fibers presence in fruits of Mango hybrids and estimates of the 27 superior genotypes and their average components (individual BLUP).

[1]RK	[2]GEN	Gain	[3]NA	[1]RK	[2]GEN	Gain	[3]NA	[1]RK	[2]GEN	Gain	[3]NA
1	VT2	0.00	2.18	10	VT4	0.26	2.44	19	CT4	0.57	2.76
2	VT1	0.03	2.21	11	KT2	0.28	2.47	20	CT3	0.62	2.80
3	PT3	0.06	2.24	12	KT1	0.31	2.49	21	KT3	0.68	2.86
4	PT2	0.08	2.26	13	HT2	0.34	2.52	22	CT13	0.70	2.89
5	PT1	0.10	2.29	14	HT1	0.37	2.55	23	CT9	0.73	2.92
6	CT11	0.13	2.31	15	PT4	0.41	2.59	24	CT2	0.78	2.97
7	CT10	0.16	2.34	16	CT12	0.45	2.64	25	CT7	0.87	3.05
8	CT8	0.19	2.37	17	VT3	0.51	2.69	26	CT6	0.87	3.05
9	VT5	0.22	2.41	18	CT5	0.54	2.72	27	CT1	0.87	3.05

*[1]RK: Ranking; [2]GEN: Genotype; [3]NA: New Average

According to morphological descriptors for mango fruit, length can be classified as short (6 to 8.9 cm), medium (9 to 10.9 cm), long (11 to 13.9 cm) and very long (greater than 14 cm). The width or diameter is classified as narrow (5 to 6.4 cm), medium (6.5 to 8.4 cm), large (8.5 to 9.9 cm), and very large (greater than 10 cm). The pulp firmness is classified as weak (less than 1.9 N), medium (2 to 3.9 N), and firm (greater than 4 N). The soluble solids content is considered low (10 to 13.9°), medium (14 to 15.9°), high (16 to18.9°), and very high (greater than 19°). The titratable acidity is classified as low (0.1 to 0.29%), medium (0.3 to 0.39%), high (0.4 to 0.49%), and very high (greater than 0.5%). The ratio between soluble solids and titratable acidity can be very low (less than 40), low (40 to 64), medium (65 to 89), high (90 to 114), and very high (greater than 115) (MAPA, 2011).

For the fruit weight variable (FW), the selection gain estimate ranged from 0 to 182.57 g. Five hybrids obtained the highest gain and, consequently, presented the highest new average were HT1 (418.64 g), PT4 (403.53 g), VT1 (393.61 g), PT1 (388.53 g), and VT4 (385.40 g). For the fruit length variable (FL), there was a variation in the selection gain estimation of 0 to 31.87 mm, and the five genotypes that presented the highest new averages were the hybrids PT4 (125.02 mm), HT1 (124.8 mm), VT2 (122.80 mm), PT1 (121.46 mm), and VT4 (119.33 mm). All early hybrids had genotypes with long lengths. Therefore, for these variables, the most promising genotypes were the hybrids Tommy Atkins with Haden, Palmer, and Van Dyke.

It is noteworthy that these evaluations correspond to these genotypes first harvests, and that the plants received the basic crop treatments recommended for the region, but they were not sufficient to increase the productivity and improve the physicochemical fruits characteristics.

The soluble solids content presented a very similar new average for all the 27 genotypes evaluated, where the variation was 14.4° Brix (CT10) to 15.8° Brix (CT11). These values are still below the ideal value (>18° Brix) that are expected for mango fruits, but they are within a median range, according to morphological descriptors. The low selection gain for this variable may be associated with the low heritability for this variable.

It was observed a selection gain ranging from 0 to 16.35 can be found for SS/TA ratio, and thus the new averages ranged from 23.20 to 39.56, which are considered very low averages.

There are several physicochemical characteristics that are able to show fruit quality, such as pulp firmness, which is widely used as a quality indicator. The new pulp firmness averages ranged from 10.24 N to 20.40 N, which can be considered high averages, according to the morphological descriptors. However, the selection gain for pulp firmness was low for the most of hybrids. As maturity advances, this value is reduced.

The fibers high presence in mango fruits is indicative as a very positive nutritional characteristic. However, the consumer market does not see the same way, considering fiber as undesirable. We can understand that a middle ground would be ideal, aiming to reach good nutritional qualities and reach the consumer market.

The selection gain estimated for fiber presence (FP) ranged from 0 to 0.87, and the new averages for the 27 genotypes were similar, ranging from 2.18 to 3.05 (Table 5). Note 2 indicates t the presence of the fiber was medium, neither excessive nor very low.

Genotypes CT1, CT6 and CT7 presented new averages that were higher than 3, which indicate a lot of fiber presence in these hybrids, which could cause fruits rejection by most of consumer market. The genotypes VT2 (2.18), VT1 (2.21), and PT3 (2.24) can be considered excellent because they have medium fiber content, but several other genotypes present similar values to the first three.

Regarding color analysis, the skin and pulp colors of all the fruits collected were estimated using the parameter L, C, and H. It can be observed the mean repeatability coefficient value (r) was considered low for the skin (0.23) and pulp (0.41) brightness, medium for skin chromaticity (0.50) and for pulp Hue angle (0.69) and high for the skin Hue angle (0.86) and the pulp chromaticity (0.74) (Table 6). Then, for skin and pulp luminosity there was a low genetic control and low average stability and in opposite to observed for the other color parameters.

Table 6. Variance components (REML Individual) for the skin and pulp color, following the parameter L, C, and H, in Mango fruits.

	SKIN COLOR			PULP COLOR		
	L	C	H	L	C	H
Overall Average	51.61	37.55	86.25	71.75	64.40	87.07
V_{pp}	12.23	16.13	512.31	3.56	12.57	4.78
V_{te}	81.19	31.81	164.98	9.84	8.74	4.26
V_p	93.43	47.94	677.29	13.41	21.31	9.04
$r = h^2$	0.13 ± 0.13	0.33 ± 0.22	0.75 ± 0.33	0.26 ± 0.19	0.58 ± 0.29	0.52 ± 0.27
R	0.23	0.50	0.86	0.41	0.74	0.69
A_{cm}	0.48	0.70	0.92	0.64	0.86	0.83

L (brightness); C(chromaticity); H (Hue angle); V_{pp}: permanent phenotypic variance; V_{te}: temporary environmental variance; V_p: phenotypic variance; $r = h^2$: individual repeatability; R: repeatability coefficient of two harvests; A_{cm}: selective accuracy based on average of two harvests.

The high value for permanent phenotypic variance (V_{pp}) indicates that it is easy to select such a character, and for color evaluation, the Hue angle (512.31) was the only one with high value. The others were median or low, as in the case of pulp luminosity (3.56) and pulp Hue angle (4.78).

In exception of skin luminosity (0.48), all other average accuracy values (A_{cm}) were considered high, from 0.64 to 0.92, which indicates that the parameters had high accuracy and reliability in the data presented.

Discussion

Knowledge of the genetic diversity between mango genotypes is very important for breeding programs and it can be verified through physicochemical fruits traits. However, the inadequate application of some statistical methods that do not fit on the study may be able to erroneously influence the final results (Alves et al., 2012). Khan et al. (2015) also cited the importance to identify genetic diversity and its inheritance, which would contribute, for example, to identify possible redundancies in mango germplasm banks.

The breeding study in perennial plants is difficult due to their long cycle and the estimation of repeatability and heritability ($r = h^2$) are important genetic parameters that could contribute to study this fruit crop due to the scarcity of repeatability/heritability information (Sanchéz et al., 2017) and mango crop is an example. Sales et al. (2019) conducted a study like this research, where 81 vine hybrids were evaluated for important agronomic traits during three harvests. It was observed that the estimates for repeatability coefficient (R) ranged from 0.28 to 0.85, being low for soluble solids (0.28) and Ratio (0.30), indicating low stability and low genetic control for these traits. In the present research, all values for R were considered medium to high, including for soluble solids (0.53) and Ratio (0.61) and indicating high stability and genetic control. The repeatability parameter helps perennial breeding programs because it is able to measure how is reliable the data and is expressed by a portion of the total variance (Oliveira and Moura, 2010).

On the individual repeatability estimates ($r = h^2$) of this present study, the weight (0.88), length (0.88), and pulp firmness (0.56) of the fruits were very close to the values found for the same traits by Maia et al. (2017), where r of the fruits weight was 0.83, length was 0.89, and pulp firmness was 0.51. Rosa mango genotypes were evaluated during two harvests via REML/BLUP. Costa (2003), who evaluated 21 mango cultivars of Embrapa Semiárido germplasm during 4 harvests, also found a similar value for fruit weight (0.81), estimating repeatability using the principal component analysis (PCA). However, for the soluble solids content (0.53), considered a median value, it is lower than that found by Maia et al. (2017) that was 0.91, which evaluated genotypes during three harvests. Median to high values indicate good stability and genetic control in successive evaluation cycles and that there is little environmental interference in the analyzed variables.

The variations in repeatability values, when dealing with the same species, may be associated with the difference between mango genotypes.

The interaction between genotype and environment is a factor that should be evaluated in genetic improvement studies and the presence of this interaction is able to influence genetic values prediction and consequently the selection gain (Hardner et al., 2012).

Sanchéz et al. (2017), in a study with soursop (*Annona muricata)* evaluated over 16 years and through the REML/BLUP method, found r = 0.90 for yield, indicating a high genetic control for this characteristic and the selection gain (%) for the same characteristic ranged from 84.06 to 129.87%.

Hardner et al. (2012) evaluated mango genotypes for the fruit weight during six harvests (1999 to 2004) using the mixed linear model and found heritability values (h^2) ranging from 0.79 to 0.93, a value that grew over the years of evaluation. In this study, the repeatability value ($r = h^2$) found for fruit weight in the 27 genotypes evaluated was 0.79 similar to Hardner study but with only two harvests.

Selection gains for soluble solid variables and fiber presence had a little variation, from 0 to 1.35 ° Brix and 0 to 0.87, respectively. Sales et al. (2019) also observed a low variation in the selection gain in the soluble solid variable (0.39 to 0.99 °Brix) in grapes compared to the other traits evaluated.

The overall average found for soluble solids content (14.46 °Brix) was similar value (approximately 14 °Brix) found in other study (Ribeiro et al., 2013), but it was much smaller when compared to other studies as 18.60 °Brix (Maia et al., 2017) or 16.09 °Brix (Maia et al., 2014). Ribeiro et al. (2015) found a variation of 8.2 to 12.2 °Brix in the evaluation of 22 foreign accessions of the Embrapa Semiárido germplasm bank at the physiological maturity during two crops. However, Ribeiro et al. (2015) observed 24.7 °Brix in ripe fruits of a genotype.

Ribeiro et al. (2013) characterized 103 mango accessions from the Embrapa Semiárido Germplasm Bank and found average values for the length ranging from 60 to 139 mm and for the fruit's diameter ranging from 65 to 85 mm. The overall average for these two variables, observed in this study, was 93.14 and 66.85 mm, respectively, considered median values for both.

Some hybrids of the Rosa variety were evaluated by Maia et al. (2017) in Teresina (PI), and the overall average found for fruit weight (299.94 g), length (101.27 mm), diameter (69.06 mm), and soluble solids content (18.60 °Brix) were higher than the overall averages found in the present study for the same variables. However, it is noteworthy that they are hybrids involving other parents. Regarding fruit weight, Ribeiro et al. (2013) found smaller weight than 250 g for most characterized mango accessions, but also found accesses that had fruits with average weight between 250 and 400 g, close to ideal for mango export markets in Brazil.

The average for the fruit weight in the present study was 236.07 g, which can be considered below export standards. However, it should be considered that the majority of the evaluated hybrids were from the cross between Coquinho (C) x Tommy Atkins (T) which presented the smallest fruits, consequently the lightest fruits. Disregarding the average obtained by the fruits of the CT crossing, the average fruit weight for the other hybrids was 306.11 g, which represents an increase of almost 30% in the fruit weight. The first six weight-ranked genotypes (HT1, PT4, VT1, PT1, VT4, and VT2) were close to export standards, ranging from 382.64 (VT2) to 418.64 g (HT1).

Pulp firmness is widely used as a quality indicative feature in mango fruits. It is known to remain practically constant throughout its growth process and during fruit ripening the firmness is strongly reduced, in addition to changes in fruit size and color. Fruit firmness is also understood to be related to skin thickness and soluble solids content (Jha et al., 2010).

Maia et al. (2017) also evaluated the pulp firmness and obtained 8.15 N average value, considered a lower average than found for the genotypes in this present research (14.46 N) considered a high average. Maia et al. (2014) found average value of 6.39 N in pulp firmness for mango fruit, also lower than that presented in the present study.

The selective accuracy (A_{cm}) in this study presented a variation from 0.73 (soluble solids) to 0.94 (weight), a variation much lower than that found by Maia et al. (2017), which was 0.23 (% pulp) to 0.97 (pH).

It is known that consumers are looking for fruits with less fiber. Ribeiro et al. (2013) found most of accessions presented low fiber presence, but also found absence of fibers in some accessions and much fiber in others. In the present study, most genotypes evaluated presented medium to high fiber presence, CT1, CT6, and CT7 genotypes can be classified with a lot of fiber, standing out in relation to the other hybrids.

Regarding the selection gain, Maia et al. (2014) found a maximum of 7.94 N for pulp firmness, 4.56 °Brix for soluble solids and 306.84 g for fruit weight. The pulp firmness gain in this study was higher, with 10.16 N, but for the other two traits, the values found were lower, 1.35 °Brix to SS and 182.57 g for fruit weight.

Carotenoids and chlorophyll are pigments responsible for mango characteristic pulp and skin color. The color begins with a dark green tone and when the fruit starts the maturation it turns to light green, then yellowish and finally reddish and tanned. According to Trindade et al. (2015), the average Hue angle (H) values may determine the skin and pulp color as follows: 0° red, 90° yellow, 180° green, and 270° blue. The Hue angle values for both pulp (87.07) and skin (86.25) were close to the yellow color in this study.

Therefore, according to our results for some traits as fruit weight, fruit length, and fruit diameter, only two harvest were sufficient to have good values of individual repeatability $(r = \mathrm{h})^2$; repeatability coefficient (R) and selective accuracy (A_{cm}). According to selection gain and the new averages, the most promising hybrids were HT, VT, PT, and KT. Therefore, these genotypes will be chosen for advanced selection to prove their potential for cultivation in Brazilian semiarid regions.

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