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Selection of natural hybrids of 'Ubá' mango from Zona da Mata, Minas Gerais state, Brazil

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Abstract – The 'Ubá' mango tree is found in all the cities of the Zona da Mata and its fruits are destined for both *in natura* consumption and for processing. However, there is a great heterogeneity among plants in the orchards, which contributes to low productivity. This study aimed to evaluate and select superior accessions of 'Ubá' mango trees collected in Ubá, Visconde do Rio Branco, and Viçosa, based on agronomic characteristics, aiming to produce high-quality fruits. The experiment was installed in Visconde do Rio Branco, MG. We evaluated 195 'Ubá' mango tree accessions, in a completely randomized design, with four replications, of one tree each. The productions of the first five crops (mass and number of fruits, and alternate bearing index - per plant), and the fruit quality characteristics from the 2017-2018 crop (fruit, peel, seed and pulp masses; length, ventral and transversal diameters, peel and pulp color index, soluble solids content, titratable acidity, vitamin C and total carotenoids content of the pulp) were evaluated. Seventy-eight accessions of 'Ubá' mango trees were selected, 24 were based on accumulated production, over 200 kg of fruits per plant, and 59 accessions were based on fruit quality characteristics.

Index terms - *Mangifera indica* L., plant breeding, fruit quality.

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Seleção de híbridos naturais de mangueira 'Ubá' obtidos na Zona da Mata, Minas Gerais, Brasil

Resumo – A mangueira 'Ubá' é encontrada em todos os municípios da Zona da Mata, e seus frutos são destinados tanto para consumo *in natura* como para o processamento. No entanto, há grande heterogeneidade entre plantas nos pomares, o que contribui para a baixa produtividade da cultura. O objetivo deste trabalho foi avaliar e selecionar acessos superiores de mangueiras 'Ubá' coletados em Ubá, Visconde do Rio Branco e Viçosa, com base em características agronômicas, visando à produção de frutos de qualidade. O experimento foi instalado em Visconde do Rio Branco-MG. Foram avaliados 195 acessos de mangueira 'Ubá', em delineamento inteiramente casualizado, com quatro repetições, de uma árvore cada. Foram avaliadas as produções das cinco primeiras safras (massa, número de frutos e índice de alternância de produção por planta) e as características de qualidade dos frutos, da safra 2017-2018 (massa do fruto, da casca, da semente e da polpa, comprimento, diâmetro ventral e transversal, índice de cor de casca e polpa, teor de sólidos solúveis, acidez titulável, vitamina C e teor de carotenoides totais da polpa). Foram pré-selecionados 78 acessos de mangueiras 'Ubá', sendo 24 com base em produção acumulada superior a 200 kg de frutos por planta e 59 acessos com base em características de qualidade dos frutos.

Termos para Indexação- *Mangifera indica* L., melhoramento vegetal, qualidade de fruto.

Introduction

World production of tropical fruits is expanding. Mango (*Mangifera indica* L.) is a tropical fruit with a prominent position in the world market and consumption. Brazil occupies the seventh place in the world scenario producing 2.1 million tons of mango, with one of the highest average productivity (22.7 t/ha). India is the main producer, with 24.7 million tons in 2020 (FAO, 2022).

Commercial mango orchards in Brazil are based on a few cultivars such as 'Tommy-Atkins', 'Haden', 'Palmer', 'Keitt', 'Kent', 'Espada' and 'Rosa', which are mainly consumed as fresh fruit (OLIVEIRA ARAÚJO et al., 2017). On the other hand, intending to produce pulp, juice, and nectar, the 'Ubá' mango is the most used cultivar in the Minas Gerais state. However, other cultivars can also be used, such as 'Mamão' and 'Coité', which are relevant to agroindustry in the Northeastern Brazil (PINTO et al., 2011).

'Ubá' mango tree grows spontaneously in almost all cities of the Zona da Mata region in Minas Gerais State (SILVA et al., 2012). Fruits of this cultivar can be consumed as fresh fruit; however, it is more used by juice industries, due to its excellent flavor qualities, aroma, texture, and pulp color (ROCHA et al., 2012). 'Ubá' mango tree is a vigorous, high size plant, and can reach more than 10 meters high, with rounded, dense and well-foliated canopy. Fruits are oblong and small, weighing from 100 to 150 g, composed of 13% of peel, 17% of seed, and 70% of pulp. Pulp is firm and juicy has an orange color when ripe, and presents short and soft fibers (RAMOS et al., 2005). Soluble solids content is around 17.5°Brix and titratable acidity content is close to 0.46% (SILVA et al., 2009).

In the Zona da Mata region, farmers usually install 'Ubá' commercial orchards with 'ungrafted trees. In this sense, those orchards are very unequal due to the great diversity in plant characteristics, with some plants showing excellent agronomic quality while others showing poor ones. Even in orchards formed by grafted seedlings, heterogeneity is observed among plants, as propagative material used in the formation of seedlings is randomly collected in orchards. Plant diversity associated with a low technological production system and typical alternate bearing of the ‘Ubá’ cultivar, results in low fruit yields, ranging from 5 to 7 t/ha (SALOMÃO et al., 2018).

Thus, this research intended to evaluate and select superior hybrids of the ‘Ubá’ mango from a group of 200 accessions during five consecutive seasons, regarding higher yields and high-quality fruit for agroindustry and fresh market.

Material and Methods

A group of 200 ‘Ubá’ mango matrices selected and collected in the municipalities of Viçosa, Ubá and Visconde do Rio Branco, Zona da Mata, Minas Gerais state was used in this research. These plants were grafted over ‘Ubá’ mango rootstock and planted in Visconde do Rio Branco, Minas Gerais (latitude of 21º00’37” S, longitude of 42º50’26” O, and altitude of 352 m), in 2017/2018.

The climate is classified as Aw, characterized by dry winter and rainy summer, with an average annual temperature of 22.6°C and 1.248 mm annual average rainfall. Seedlings spacing was 5.0 m x 4.0 m, with four plants per accession, and one plant per experimental unit, totaling four replicates per accession. Each plant was initially conducted with three to five branches and, then, was let to grow freely. The first harvest was obtained in 2013, in the fourth year after planting, and the yield was evaluated in the first five crops, besides the fruits’ physical parameters was obtained in 2017-2018 season or year. During the research, some plants from accessions 64, 71, 91, 103 and 181 died. Thus, those were removed and 195 accessions were evaluated. In the orchard, no pests and disease control were done except for cutter ants, when it was necessary. Plants were rainy fed (no irrigation) and fertilizations were done according to the recommendations of the CFSEMG (1999) for mango crops.

For yield evaluation, all the fruits harvested from each plant were weighted. The average fruit weight was obtained from a sample composed of ten fruits per plant. The number of fruits per plant was estimated by dividing the total yield by the average fruit weight.

Due to the irregularity in production over the years, the alternate bearing index (ABI) was calculated for each plant for the last three seasons or years based on the model proposed by Monselise and Goldshmidt (1982). The first two crops were not included in this calculation because plants were still young at the beginning of the transition to reproductive life.

$$\text{ABI} = \frac{1}{n-1}\left\{\left|\frac{(a_2 - a_1)}{(a_2 + a_1)}\right| + \left|\frac{(a_3 - a_2)}{(a_3 + a_2)}\right| + \cdots + \left|\frac{(a_{(n-1)} - a_n)}{(a_{(n-1)} + a_n)}\right|\right\}$$

ABI = alternate bearing index, n = number of years in study, a_1, a_2, ... $a_{(n-1)}$, a_n = corresponds to the yield per plant during the years in evaluation. The ABI value was calculated for each plant individually and subsequently for each accession. The ABI values can vary from 0 to 1, and values closer to zero reflect lower fluctuation in production over the years (STENZEL et al., 2005).

The evaluations of the fruit’s physical components were performed from December 2017 to February 2018. Twenty physiologically mature fruits were collected from each plant totaling 80 fruits per accession. The fruits were immersed in water plus 2 mL L^{-1} of neutral detergent for five minutes, intending to clean the surface and remove the latex. After that, they were immersed for two minutes in a solution containing 20 mL of Magnate 500 EC fungicide (a.i. imazalil) per 100 L of water and dried at room temperature. Finally, fruits were immersed for five minutes in a solution containing 1 mL a.i. L^{-1} of 2-chloroethyl phosphonic acid solution (Ethrel®, 240 g a.i. L^{-1}, Rhône-Poulenc), dried at room temperature, and stored at 20 ± 1°C and 85% of relative air humidity, until complete the ripening.

After ripening, ten fruits of each plant were selected, which totalized 40 fruits per accession, and those presenting some injury were discarded. Fruit characterization was performed using the following evaluations: fruit, pulp, peel and seed masses, peel, seed and pulp percentages, length, longitudinal and transversal diameters, peel and pulp colors (hue angle and Chroma, Konica-Minolta CR-10 colorimeter), pulp soluble solids content (Atago model PAL-1 refractometer), titratable acidity and vitamin C. Titratable acidity and vitamin C (Tillman´s method) were determined according to the methodologies proposed by Zenebon et al. (2008), and total carotenoids analysis was performed according to the Higby (1962) methodology.

Length, longitudinal and transversal diameters as well as, peel and pulp color index were individually evaluated for each fruit. For all the other analysis we used a pool of ten fruits selected from each plant.

For the yield and fruit quality data evaluations, the averages were grouped by the Scott-Knott criterion, at 5% of probability, and by the Tocher grouping method through Euclidean distance and based on the characteristics of soluble solids, carotenoid content, fruit mass, pulp percentage, fruit length and pulp color based on the hue angle parameter. In addition, for the study of the physical characteristics of the fruits, main components analysis and Pearson’s correlation were performed. Statistical and Genetic Analyses System program (SAEG of the Federal University of Viçosa, version 9.1) was the software used for the analysis.

Results and Discussion

Considering that low productivity is the biggest obstacle to the large-scale cultivation of the ‘Ubá’ mango, it was decided to select the accessions based on productivity and also, fruit quality. Regarding productivity, accessions that presented accumulated yield above 200 kg per plant were selected. Thus, twenty-four accessions were identified (Table 1).

For fruit quality, accessions grouped with the best average characteristics evaluated were selected. Over half of these 24 more productive accessions were framed in the classes of lower fruit mass, length, transversal diameter, ventral diameter, and pulp solid solubles content (Table 1). Additionally, a negative correlation was observed between accumulated yield production and fruit mass, dimensions, and pulp soluble solids content (Table 2), that is, the greater the production, the smaller the size of the fruits. Therefore, average values for these characteristics vary due to the greater or lower fruit yield by plant, suggesting that individually they are not good criteria for the ‘Ubá’ mango selection.

Regarding pulp yield (pulp %), 17 of the accessions exhibited in Table 1 presented pulp % higher than the general average of the accessionses, that was 67,4%, which makes these accessions more promising. Folegatti et al. (2002) recommend a minimum of 60% pulp yield for industrialization, and an average of 68.2% was observed for the 24 accessions. Besides higher pulp % yield, accessions obtained high vitamin C content, with nine of the 24 accessions presenting averages higher to 50 mg of ascorbic acid per 100 g of pulp. According to Siqueira and Salomão (2017), this value is similar to that found in orange juice, showing ‘Ubá’ mango richness in vitamin C, wich is a desirable fact for human health. Regarding carotenoids content, 10 accessions presented in Table 1 have carotenoids content higher than the general average. Carotenoids play an important role for plants, being responsible, together with other pigments, for the pulp color, which is of paramount importance for the juice industry (Taiz et al.,2017).

Finally, 23 of the 24 most productive accessions are located in the class of lower alternate bearing index, suggesting that the most productive plants tend to be less alternate (Table 1). Souza et al. (2004) evaluated the alternate bearing during 18 cycles of 19 cultivars of mango, and they also found alternation of production, being the magnitude of the alternate bearing index variable accord-

Table 1 - Cumulative production in five crops (Y) and physical and chemical characteristics of the fruits of 'Ubá' mango accessions with accumulated yield above 200 kg per plant

AC	Y	FM	PEM	SM	PM	PE	SE	PUL	LEN	TD	VD	VIT	TA	CAR	SS	h°PC	CPC	h°PC	CPC	ABI
		---------------g--------------				----------%---------			--------mm--------			mg/100g	g/100g	mg/100g	°Brix	°	unit	°	---unit---	
2	201.8 A	129.0 B	21.3 A	15.1 A	92.6 A	16.7 A	11.8 A	71.5 A	76.3 B	52.4 B	49.5 B	38.8 B	0.48 B	1.98 A	19.0 B	94.4 A	30.3 A	80.2 A	61.2 A	0.47 A
24	204.1 A	120.8 B	24.5 A	16.1 A	80.2 B	20.3 A	13.4 A	66.4 A	75.2 B	53.3 B	51.6 A	39.6 B	0.50 B	1.72 A	19.1 B	95.2 A	27.6 B	78.5 A	60.6 A	0.34 B
7	204.4 A	122.8 B	22.0 A	14.9 A	85.9 B	18.0 A	12.2 A	69.8 A	75.3 B	53.5 B	50.5 B	85.4 A	0.40 C	2.70 A	19.9 B	94.8 A	27.7 B	76.3 A	61.1 A	0.30 B
10	207.1 A	113.8 B	24.6 A	14.3 A	74.9 B	21.7 A	12.7 A	65.7 A	73.4 B	52.4 B	49.8 B	65.0 A	0.48 B	2.06 A	21.2 A	97.0 A	24.7 B	79.1 A	59.2 A	0.32 B
108	207.5 A	124.0 B	24.1 A	15.8 A	84.1 B	19.7 A	12.8 A	67.5 A	75.2 B	53.8 B	50.3 B	46.5 B	0.26 C	2.66 A	22.7 A	91.4 A	29.4 B	74.8 B	60.7 A	0.17 B
11	208.6 A	124.1 B	23.5 A	15.6 A	85.0 B	19.0 A	12.7 A	68.4 A	76.5 B	55.3 A	52.0 A	23.1 B	0.42 B	2.33 A	18.1 B	91.6 A	24.5 B	79.5 A	63.8 A	0.18 B
8	208.9 A	125.1 B	23.6 A	15.1 A	86.4 B	18.8 A	12.1 A	69.1 A	76.6 B	53.5 B	50.7 B	55.2 B	0.50 B	2.44 A	18.7 B	96.3 A	28.0 B	76.3 A	60.3 A	0.35 B
29	215.2 A	134.8 B	27.3 A	15.3 A	92.3 A	20.3 A	11.3 A	68.4 A	80.0 A	55.0 A	51.9 A	77.0 A	0.49 B	2.01 A	19.6 B	97.6 A	25.1 B	75.7 B	59.0 A	0.23 B
39	217.2 A	143.3 A	28.9 A	16.1 A	98.3 A	20.1 A	11.3 A	68.5 A	78.9 A	56.7 A	53.0 A	33.2 B	0.54 B	2.09 A	19.2 B	98.9 A	25.7 B	76.0 B	62.6 A	0.21 B
107	219.7 A	143.9 A	30.8 A	16.5 A	96.6 A	21.6 A	11.6 A	66.9 A	78.0 A	56.8 A	54.0 A	31.5 B	0.29 C	3.09 A	22.0 A	88.8 B	30.4 A	70.1 B	58.8 A	0.15 B
12	223.1 A	115.6 B	22.5 A	14.5 A	78.6 B	19.8 A	12.7 A	67.5 A	75.1 B	52.8 B	49.6 B	19.3 B	0.52 B	2.11 A	17.6 B	95.1 A	26.9 B	77.8 A	60.2 A	0.24 B
31	226.8 A	138.8 A	28.3 A	15.3 A	95.3 A	20.2 A	11.0 A	68.8 A	77.7 A	56.7 A	53.5 A	24.1 B	0.51 B	1.96 A	18.1 B	95.8 A	25.5 B	73.4 B	55.3 A	0.18 B
109	231.2 A	147.5 A	28.0 A	19.1 A	100.4 A	19.2 A	13.0 A	67.7 A	81.3 A	57.1 A	53.3 A	24.1 B	0.26 C	2.64 A	21.2 A	91.5 A	29.4 B	72.5 B	55.7 A	0.28 B
21	234.0 A	133.3 B	25.3 A	15.6 A	92.4 A	19.0 A	11.8 A	69.3 A	77.5 A	55.6 A	52.2 A	32.0 B	0.76 A	1.83 A	18.2 B	90.9 A	28.4 B	79.7 A	61.5 A	0.23 B
56	234.4 A	123.8 B	24.7 A	15.8 A	83.3 B	19.9 A	12.8 A	67.3 A	77.5 A	52.8 B	49.7 B	47.3 B	0.29 C	2.82 A	22.8 A	93.2 A	27.3 B	69.1 B	58.2 A	0.27 B
110	241.0 A	132.3 B	28.3 A	16.5 A	87.5 B	21.2 A	12.4 A	66.4 A	77.6 A	54.2 B	50.9 B	43.7 B	0.24 C	3.17 A	23.0 A	89.2 B	28.4 B	70.9 B	59.6 A	0.16 B
153	241.5 A	135.8 A	29.0 A	15.7 A	91.2 A	21.4 A	11.6 A	67.1 A	76.7 B	54.8 B	51.8 A	39.6 B	0.25 C	2.53 A	23.3 A	83.5 B	29.1 B	74.5 B	60.2 A	0.44 B
30	247.2 A	110.1 B	20.8 A	14.0 A	75.4 B	18.9 A	12.7 A	68.4 A	74.1 B	50.1 B	47.6 B	72.3 A	0.60 A	2.09 A	18.0 B	96.7 A	27.5 B	77.1 A	60.9 A	0.13 B
125	256.9 A	120.6 B	25.0 A	17.0 A	78.6 B	20.7 A	14.1 A	65.2 A	74.5 B	52.6 B	50.0 B	54.6 B	0.31 C	2.80 A	21.4 A	97.2 A	25.6 B	76.2 A	58.1 A	0.26 B
37	263.5 A	129.8 B	24.3 A	13.9 A	91.6 A	18.7 A	10.7 A	70.6 A	77.5 A	55.4 A	52.4 A	29.6 B	0.45 B	2.48 A	18.7 B	93.8 A	27.1 B	75.8 B	59.7 A	0.10 B
106	270.2 A	144.3 A	29.8 A	15.5 A	99.0 A	20.6 A	10.8 A	68.6 A	79.2 A	55.9 A	52.9 A	39.2 B	0.23 C	2.98 A	23.2 A	89.9 A	29.0 B	72.0 B	62.4 A	0.25 B
25	276.1 A	124.0 B	20.2 A	16.2 A	87.7 B	16.2 A	13.0 A	70.8 A	76.9 A	53.8 B	50.4 B	60.2 B	0.48 B	1.72 A	20.4 B	94.8 A	27.5 B	76.0 B	62.0 A	0.13 B
4	292.4 A	114.0 B	21.9 A	13.9 A	78.3 B	19.3 A	12.2 A	68.5 A	73.3 B	52.3 B	48.8 B	64.5 A	0.35 C	2.79 A	22.8 A	95.9 A	25.3 B	76.6 A	62.7 A	0.21 B
112	353.5 A	137.9 A	24.6 A	17.2 A	96.2 A	18.0 A	12.5 A	69.5 A	77.7 A	54.5 B	52.1 A	53.2 B	0.32 C	2.30 A	22.1 A	85.6 B	34.5 A	75.6 B	58.9 A	0.24 B
MD	**236.9**	**128.7**	**25.1**	**15.6**	**88.0**	**19.5**	**12.2**	**68.2**	**76.7**	**54.2**	**51.2**	**45.8**	**0.4**	**2.4**	**20.4**	**93.3**	**27.7**	**75.6**	**60.1**	**0.2**
GAV	**139.7**	**131.8**	**26.8**	**16.0**	**89.0**	**20.4**	**12.2**	**67.4**	**77.0**	**55.0**	**52.0**	**55.5**	**0.40**	**2.50**	**21.6**	**91.0**	**29.5**	**75.7**	**60.3**	**0.43**

Average groups with the same letter in the columns are similar to 5% probability level by the Scott-Knott criterion. Averages five crops (Y), for fresh fruit mass (FM), peel (PEM), seed (SM) and pulp masses (PM); peel (PE), seed (SE) and pulp percentages (PUL); fruit length (LEN), transversal diameter (TD) and ventral diameter (VD), pulp vitamin C content (VIT), titratable acidity (TA), total carotenoids (CAR) and soluble solids (SS ºBrix); hue angle (h°PC) and peel chrome (CPC); hue angle (hºCP) and pulp chrome (CPC); alternance bearing index (ABI), 24 acessions (MD) and 195 accessions (AC).

Table 2 – Estimation of Pearson’s correlation coefficients for 19 variables (Var) obtained from 184 ‘Ubá’ mango accessions

VAR	TA	VIT	CAR	SS	FM	PEM	SM	PM	PE	SE	PUL	TD	VD	LEN	CPC	h°CP	CPC	h°CP
TA																		
VIT	0.3573**																	
CAR	-0.5809**	-0.3298**																
SS	-0.7675**	-0.1600**	0.4527**															
FM	-0.1252*	-0.1535*	0.0605	0.0917														
PEM	-0.235**	-0.0627	0.1436*	0.2008**	0.6449**													
SM	-0.0145	0.0339	-0.0227	-0.0655	0.4171**	0.3728**												
PM	-0.0687	-0.1709**	0.0261	0.0494	0.9507**	0.3918**	0.2578**											
PE	-0.1908**	0.0813	0.1274*	0.1996**	-0.0685	0.7124**	0.1048	-0.3516**										
SE	0.1082	0.1846**	-0.0767	-0.1487*	-0.6212**	-0.3198**	0.4424**	-0.7059**	0.1497*									
PUL	0.1079	-0.1512*	-0.07	-0.0967	0.3397**	-0.4415**	-0.2882**	0.6117**	-0.8926**	-0.5794**								
TD	-0.1249*	-0.1521*	0.0801	0.0972	0.8813**	0.6532**	0.3931**	0.8045**	0.0544	-0.5392**	0.201**							
VD	-0.2061**	-0.2094**	0.1468*	0.1496*	0.8494**	0.6861**	0.3300**	0.7612**	0.1204*	-0.5634**	0.1577*	0.9492**						
LEN	0.0338	-0.1224*	-0.0363	-0.0297	0.8481**	0.4977**	0.4146**	0.8163**	-0.1236*	-0.482**	0.3217**	0.7073**	0.6556**					
CPC	-0.053	0.4111**	-0.1319*	-0.0531	0.1594**	0.1227*	0.0501	0.1465*	0.0354	-0.1021	0.0174	0.0944	0.0861	0.0547				
h°CP	0.6047**	0.285**	-0.304**	-0.5803**	-0.4026**	-0.3302**	0.012	-0.3797**	-0.0684	0.4074**	-0.1294*	-0.3845**	-0.4273**	-0.2228**	-0.3266**			
CPC	0.0842	0.2909**	-0.1266*	-0.1585*	-0.0943	-0.0047	0.0064	-0.1153	0.0799	0.1225*	-0.1217*	-0.1511*	-0.1633**	-0.0768	0.2896**	0.2425**		
h°CP	0.5483**	0.4929**	-0.4593**	-0.54**	-0.0972	-0.1615**	-0.0183	-0.0598	-0.1182*	0.1024	0.0507	-0.1118	-0.147*	-0.0697	0.3579**	0.3202**	0.3448**	
Y	0.112	-0.239**	0.0078	-0.185**	-0.1979**	-0.273**	-0.0473	-0.1407*	-0.1841**	0.1397*	0.0881	-0.2417**	-0.2172**	-0.1156	-0.2354**	0.1862**	-0.0509	-0.1145

** e * Significant at 1 and 5% probability by the t-test; titratable acidity (TA), vitamin C (VIT), total carotenoids (CAR), soluble solids (SS), fresh fruit mass (FM), peel mass (PEM), seed mass (SM), pulp mass (PM), peel percentage (PE), seed percentage (SE), pulp percentage (PUL), transversal diameter (TD) and ventral diameter (VD), fruit length (LEN), peel chrome (CPC), peel hue angle (h°PC), pulp chrome (CPC), pulp hue angle (hºCP) and accumulated production of the 5 crops (Y).

ing to the cultivar. The alternate bearing can be explained by physiological, biochemical, genetic and environmental factors (Sharma et al., 2019).

Pearson's correlation analyses aim to measure the linear association degree between two variables, allowing selection based on more easily measurable characteristics. According to Ferreira et al. (2012), when there is a significative correlation between two characters, it is possible to obtain gain in one of them by an indirect selection of the other. Solids solubles content was positively correlated with the carotenoids content and, negatively with titratable acidity, vitamin C, accumulated production, and the hue angle of peel and pulp. This sugest that sweeter fruits are also less acidic, have less vitamin C, and have pulp and peel with more orange or yellow coloring (Table 2). Rufini et al. (2011) state that the higher the soluble solids content the lower the fruit acidity will be, but these relationships can also indicate that the fruit is more or less advanced in its maturation stage. In addition, by increasing the production (number of fruit per plant) there is a decrease in the solid solubles content, which occurs due to a redistribution of solid solubles for all fruit load in the plant, causing a lower availability of these components for each fruit (LÉCHAUDEL and JOAS, 2007).

Fruit mass presented a positive correlation with pulp mass and pulp percentage, and a negative with seed percentage and accumulated production (Table 2). Likewise, fruit length, transversal diameter and ventral diameter correlated positively with pulp yield. Therefore, heavier fruits result in higher pulp yield, which is desirable both for fresh consumption and for the pulp and juice industry. A similar result was found by Maia et al. (2014), while evaluating the physicochemical characteristics of 'Rosa' mango, obtaining positive correlations among the variables fruit mass and, pulp, length, transversal diameter and ventral diameter. However, as discussed previously, selection based solely on the fruit mass or dimensions is not indicated, because these characteristics are influenced by the number of fruits produced by the plant. Thus, a higher quantity of fruits per plant results in reduced fruit size, which can be observed in Table 2.

Grouping by Tocher optimization method was based on six chosen characteristics aiming to select accessions that could attend both fresh consumption and processing industries. These characteristics were: soluble solids content, carotenoid content, fruit mass, pulp yield, fruit length, and pulp color based on the hue angle parameter (Table 3). For understanding which group should be selected, a table was assembled with the averages of the groups formed by the Tocher grouping for the variables soluble solids content, fruit mass, pulp yield, fruit length, carotenoids content, and pulp color based on the hue angle parameter (Table 4).

Tocher grouping method resulted in eight accession groups, with group 1 composed of 115 accessions (58% of 195 accessions), the highest number of all accessions (Table 3). Characteristic averages of group 1 accessions were similar to the general averages obtained by the 195 accessions (Table 4). However, 14 accessions of the 114, presented accumulated production averages above 200 kg per plant (Tables 1 and 3).

Group 2 was formed by 51 accessions with physical and chemical characteristics with average values higher than those of group 1 accessions, and also higher than the general average of the 195 evaluated accessions (Table 4). Group 2 was characterized by high soluble solids content, fruit mass of 136.5 g, and pulp yield of 68% (Table 4). Besides good fruits' physical and chemical characteristics, five of the 49 accessions presented accumulated production above 200 kg per plant (Table 1).

Group 3 was formed by 18 accessions (Table 3), with physical and chemical characteristics lower than when most of the other groups and also lower than the general averages of 195 accessions (Table 4). However, five from the 18 accessions presented accumulated production averages above 200 kg per plant (Tables 1 and 3).

Group 4 showed promising for presenting chemical and physical characteristics higher than most of the other groups and also higher than the general averages of 195 accessionss (Table 4).

Fruits physical and chemical characteristics of accessions from group 5 were lower than the other groups' averages (Table 4). Among the groups, this presented the second worst average for soluble solids content, total carotenoid content, and pulp color, measured by the hue angle parameter, and the results of pulp yield (64%) were the lowest (Table 4).

Group 6 stood out by presenting high averages for the physical and chemical characteristics of fruit when compared to the other groups. Soluble solids content, fresh mass,

Table 3 – Accession groups formed by the Tocher grouping method for 195 accessions of 'Ubá' mango based on the average Euclidean distance and considering the characteristics soluble solids content, total carotenoids content, fruit mass, pulp yield, fruit length and pulp color based on the hue angle parameter.

Group	Accessions														
1	**2**	3	5	7	**8**	9	**11**	13	14	16	17	19	20	**21**	22
	24	**25**	**29**	32	34	35	36	**37**	38	41	42	43	45	47	48
	49	50	51	52	53	54	55	**56**	57	58	59	60	61	65	66
	67	74	75	77	78	80	83	84	85	86	87	89	90	92	93
	94	96	97	99	100	101	104	**106**	**107**	**112**	113	114	116	118	119
	120	121	122	**125**	126	127	128	129	130	135	136	137	138	142	146
	147	149	151	158	159	161	167	168	169	170	171	176	178	179	182
	183	184	186	187	188	191	192	193	194	197					
2	15	18	23	26	27	28	**31**	33	**39**	40	63	73	79	88	95
	102	105	**108**	**109**	111	115	123	132	133	139	140	141	143	145	148
	150	152	**153**	156	157	160	162	163	164	165	166	172	173	175	177
	180	189	190	195	199	200									
3	1	**4**	6	**10**	**12**	**30**	44	46	62	68	76	81	82	98	**110**
	117	124	198												
4	131	144	155	185	196										
5	69	72													
6	154	174													
7	70														
8	134														

Bold values refers to accessions with accumulated yield over 200 kg of fruits per plant.

Table 4 – Average soluble solids content (SS, Brix°), fruit mass (FM, g), pulp percentage (PUL, %), fruit length (LEN, mm), total carotenoids content (CAR, mg/100 g of pulp) and pulp color based on the hue angle parameter (h°CP) for each 'Ubá' mango accessions group formed by the Tocher grouping method.

Group	Variables					
	SS	FM	PUL	LEN	CAR	h°CP
1	21.37	131.33	67.56	76.73	2.47	75.81
2	22.14	136.15	67.63	77.27	2.56	75.13
3	20.93	122.55	66.74	75.30	2.41	76.70
4	22.93	131.78	67.74	76.15	2.83	74.91
5	19.60	105.90	64.00	70.85	2.45	82.5
6	23.47	141.29	66.33	78.04	3.27	74.25
7	19.33	130.00	67.91	76.62	2.27	84.67
8	21.76	130.88	66.98	76.84	2.86	74.62
AV	**21.60**	**131.80**	**67.40**	**76.95**	**2.50**	**75.70**

AV = General average of 195 accessions

pulp yield, and fruit length were the highest values observed in this group (Table 4). These results explain the higher distance of group 6 compared to the other groups and the lower distance within the group (Table 5). Therefore, accessions 154 and 174 are promising in the ‘Ubá’ mango selection program, as they present good fruit quality.

Group 7 was formed by only accession 70 (Table 3) and is characterized by presenting the lowest averages for fresh mass, length, carotenoid content, and hue pulp angle characteristics, besides low soluble solids content and pulp yield (Table 4). These group averages are close to those observed for group 5, which explains the lowest intergroup distance (Table 5).

Group 8 is a promising one due its chemical and physical characteristics were higher than the majority of the other groups and very close to those observed in group 4 (Table 4). Greatest intergroup distances were observed among group 6 accessions and the accessions of all of the other groups (Table 5), which is explained by the fruits of group 6 accessions presented the highest averages for soluble solids content, fruit mass, total carotenoids content, fruit length and pulp color (Table 4).

The lowest intergroup distances were between groups 5 (accessions 69 and 72) and 7 (accession 70), indicating that accessions of these two groups are closer among themselves (Table 5). In general, these two groups were characterized by presenting lower physical and chemical characteristics averages than the other groups formed by the Tocher grouping method.

Most of the variation among vitamin C, total carotenoids, fruit mass, solids soluble, pulp yield and pulp color variables was retained in the two first main components (MC), which explained 61,41% of the variation (Table 6).

Table 5 - Intra and intergroups distance of the Tocher grouping method for 195 ‘Ubá’ mango accessions based on the average Euclidean distance

Group	1	2	3	4	5	6	7	8
1	4.7							
2	31.0	4.7						
3	16.5	22.4	4.1					
4	30.8	34.4	22.5	2.7				
5	16.5	22.2	2.2	22.1	4.2			
6	41.4	41.8	37.4	41.9	37.0	3.7		
7	16.0	21.8	1.8	21.7	1.4	36.7	0.0	
8	16.6	22.1	2.7	21.7	1.7	36.4	1.8	0.0

Table 6 - Eigenvalues (λj) and eigenvectors associated with the main components, obtained from the correlation matrix among six variables: vitamin C (VIT), total carotenoids (CAR), fruit mass (FM), soluble solids (SS), pulp percentage (PUL) and pulp color measured by the hue angle (h°CP) of ‘Ubá’ mango accessions.

Variable	Eigenvectors associated with the main components (MC)					
	MC_1	MC_2	MC_3	MC_4	MC_5	MC_6
VIT	-0.2940	-0.1252	0.8185	-0.0761	0.1977	-0.7830
CAR	0.3229	-0.1465	0.0332	0.5084	0.9794	-0.2874
FM	0.1326	0.5329	0.3755	0.7660	-0.4217	-0.0691
SS	0.3124	-0.1583	0.6618	-0.3989	-0.1191	0.8976
PUL	0.0311	0.6022	0.0099	-0.7272	0.5533	-0.0867
h°CP	-0.3628	0.0813	0.0743	0.3884	0.5023	11.189
λj	22,806	13,978	0.7964	0.5918	0.5719	0.3616
λj (%)	38.01	23.30	13.27	9.86	9.53	6.03

* Bold values highlight the highest weight variable in eigenvectors.

MC_1 explained 38% of the existing variation and had the pulp hue angle as the major variable, and MC_2 which explained 23% of the variation, had the pulp yield as the most important variable.

It was observed that MC_1 explained characteristics regarding the fruit quality, such as the pulp hue angle, carotenoid content, and soluble solids content, while MC_2 explained physical fruit characteristics, such as fruit mass and pulp yield.

According to Cruz et al. (2014), the highest weights variables in the first eigenvector are considered the most important for the genetic diversity study. Thus, the most important variables in this were pulp hue angle and pulp yield.

Conclusions

Based on cumulative fruit yield greater than 200 kg per plant in five consecutive crops, it was possible to select 24 accessions. Based on the fruit quality, measured by vitamin C content, total carotenoids content, fruit mass, soluble solids content, pulp yield and pulp color, 59 superior 'Ubá' mango accessions were pre-selected. In total, 78 'Ubá' mango trees were pre-selected.

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