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Agronomic, physical and chemical characterization of banana fruits

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ABSTRACT - *The purpose of this study was to characterize 26 banana accessions of the active genebank of Embrapa Cassava and Tropical Fruits (Brazil) for agronomic, physical and physicochemical characteristics. The plant height of the diploid 028003-01 and triploid Walha was short. Regarding the number of fruits and bunch weight, the triploids Caipira, Thap Maeo and the tetraploids Ambrósia and Calipso performed particularly well. Total carotenoid contents were highest in the diploids Jaran and Malbut. The total contents of flavonoid and polyphenol, two natural antioxidants, were highest in tetraploid Teparod. Wide genetic variability was detected for most agronomic, physical and chemical characteristics of the fruits of the banana accessions, enabling the planning of breeding for the development of hybrids with short stature, high yield, pest resistance and high carotenoid, flavonoid and/or polyphenol contents.*

Key words: *Musa* spp. variability, functional compounds, bunch weight, yield.

INTRODUCTION

Banana is the second most consumed fruit in Brazil, second only to orange. In relation to its social role, the crop is exploited by rural small-scale enterprises, ensuring the labor retention and recruitment in the country, representing a source of continuous income. Brazil is the fourth largest producer of banana, with a production of 7.0 million tons in 2007, in an area of approximately 500´000 ha. In the same period, India produced 11.7 million tons on 400´000 ha (FAO 2010). The low productivity in Brazil is a result of the lack of commercial varieties that combine short stature, drought and cold tolerance, good post-harvest characteristics and pest resistance (Silva et al. 2002a).

Typically, banana production is based on triploid cultivars, although diploids are important as allele sources for resistance/tolerance to biotic and abiotic factors (Jenny et al. 1999). Banana breeding programs with these genotypes, which are crossed with commercial triploid cultivars, have generated promising tetraploid hybrids with good performance for the agronomic traits of interest and high physical and chemical fruit quality (Silva et al. 2002a). The information of the agronomic, physical and chemical characterization of banana fruit is useful both for the choice of parents for crosses, and in the selection of diploid elites for the development of improved hybrids. The objective of this study was to characterize the agronomic, physical and chemical characteristics of 26 diploid, triploid and tetraploid banana accessions.

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MATERIAL AND METHODS

Plant material

From the Active Genebank of *Musa* (banana BAG) Embrapa Cassava and Tropical Fruits, Cruz das Almas (BA), 26 banana accessions were used, including wild diploid and improved, triploid and tetraploid genotypes (Table 1).

Agronomic characterization

The experiment was conducted from April 2007 to June 2008. An orchard was planted in 3 m x 2 m spacing, irrigated and treated with cultural practices according to technical recommendations. At least three plants (replications) per accession were evaluated in a completely randomized design. The following traits described by Silva et al. (2002a) were evaluated: plant height in m (PLH), stem diameter in cm (SteD), number of tillers at flowering (NTF), number of leaves at harvest (NLH), stalk length in cm (StaL), stalk diameter in mm (StaD), stalk weight in g (StaW), number of hands per bunch (NHB), number of fruits (NFR), bunch weight in kg (BUW).

Yellow Sigatoka was evaluated under natural infestation in the field at flowering (YSF) and at harvest (YSH), following the methodology proposed by Stover (1972), modified by Gauhl et al. (1993). The following descriptive scale was used: 0 for no symptoms; 1 for symptoms on 1-10% of the leaf; 2 for symptoms on 11-30% of the leaf; 3 for symptoms on 31-50% of the leaf; 4 for symptoms on 51-70% of the leaf; 5 for symptoms on over 70% of the leaf.

Physical and chemical fruit characterization

The following physical characteristics were analyzed: fruit length in cm (FRL), fruit diameter in cm (FRD), fruit weight (FRW) and flesh weight (FLW) in g, flesh diameter in cm (FLD), peel thickness in mm (PTH); flesh firmness in Lb (FLF), soluble solids content, in °Brix (SS), pH and titrable acidity (TAC), according to AOAC (1997).

For chemical fruit analysis, the flesh was sampled in the middle and at both ends of each fruit. The pieces were ground in a household blender with water, at a ratio of 1:2 (flesh: water) (Dadzie and Orchard 2003).

Vitamin C (VIT) was analyzed following the methodology proposed by Terada et al. (1979) in mg $100g^{-1}$ and the total carotenoids (CTN) were evaluated according to Rodriguez-Amaya (1999) in $\mu g\ g^{-1}$. For flavonoid analysis in mg $100g^{-1}$ (FLA), the method of Rijke et al. (2006) was used. Polyphenol in mg $100g^{-1}$ (PLF) was extracted from the samples in 50% methanol and 70% acetone solutions, as described by Larrauri et al. (1997) and quantified in a spectrophotometer using the reagent Folin-Ciocauteau, according to the methodology of Obanda and Owuor (1997).

Analysis of agronomic, physical and chemical fruit characteristics

Data normality and homoscedasticity were tested for the analysis of variance and grouping of accessions according to the Scott and Knott (1974)'s test modified by Bhering et al. (2008), using the software Genes (Cruz et al. 2006). The variables YSF and YSH were transformed into $\sqrt{x+0.5}$. The mean Euclidean distance among the 26 banana genotypes was estimated, considering the 26 agronomic and physicochemical fruit characteristics. The means were grouped by the UPMGA method using software Genes.

RESULTS AND DISCUSSION

The F test analysis of variance revealed significant differences between the means of banana accessions for most agronomic traits, except for the number of tillers at flowering (NTF) (Table 1). The coefficient of variation ranged from 9.12% (SteD) to 57.08% (NTF). These values are within the range observed by Amorim et al. (2009a) and Amorim et al. (2009b) for the same characteristics.

The plant height (PLH) ranged from 1.44 m for the triploid Walha (AAB genome) to 3.54 m for tetraploid hybrid Ambrosia (AAAA genome), with a mean of 2.79 m (Table 1). The grouping test of Scott and Knott (1974) formed four groups; the improved diploid 028003-01 (Tuugia x Calcutta) and triploid Walha were classified in the last group, with the lowest values for this character. Results indicated wide genetic variability for plant height among the accessions tested, a positive factor for improving this fruit plant, since it is possible to identify diploid parents for hybridization targeting the development of short-stature hybrids.

The mean stem diameter (CPD) was 17.76 cm, with highest values for the triploid Champa Madras and tetraploids Ambrosia and Calipso of the first group (Table 1). This trait is related to the vigor and crack resistance of the pseudostem, reflecting the support capacity of the

Table 1. Means of six agronomic traits in 26 banana accessions of the active genebank of Embrapa

Accessions	Ploidy	Agronomic traits#					
		PLH	SteD	NTF	NLH	StaL	StaD
Jaran	AA	2.83b	15.73d	1.67	8.67a	52.00b	37.33b
028003-01	AA	1.76d	9.75e	1.50	7.25a	22.25c	31.25c
Malbut	AA	2.55b	15.00d	2.67	8.33a	25.33c	34.67c
IDU-110	AA	2.33c	9.67e	2.67	5.00b	40.33b	32.00c
Tuugia	AA	2.53b	12.67d	2.67	6.67a	14.67c	28.67c
M-48	AA	2.75b	14.67d	3.33	6.33a	43.00b	42.00b
Pipit	AA	2.21c	12.00d	3.50	5.00b	34.00c	31.50b
Caru Roxo	AAA	3.33a	21.00b	1.67	8.00a	48.33b	50.33a
Wasolay	AAA	2.64b	13.33d	2.00	7.67a	37.33c	34.67c
Markatooa	AAA	2.45b	17.50c	1.50	7.50a	33.50c	39.00b
Bakar	AAA	3.33a	18.00b	2.00	9.00a	47.00b	50.00a
AAA Desc.	AAA	2.90b	16.50d	2.00	6.50a	30.50c	40.50b
Nam	AAA	2.23c	16.50d	1.00	3.00b	41.50b	44.00b
Towoolle	AAA	2.20c	14.50d	1.50	2.00b	41.50b	40.50b
Caipira	AAA	2.46b	17.17b	1.33	3.00b	37.33c	51.00a
Thap Maeo	AAB	3.43a	20.60b	4.25	8.00a	44.25b	55.75a
Walha	AAB	1.44d	14.67d	0.67	2.67b	24.00c	33.67c
Pacha Nadan	AAB	3.47a	18.00b	2.50	3.50b	46.00b	51.00a
C. Madras	ABB	3.49a	21.50a	2.00	5.00a	70.00a	45.50b
Ambrosia	AAAA	3.54a	24.42a	1.80	7.40a	38.00c	60.60a
Calipso	AAAA	3.15b	24.56a	1.60	7.00a	36.80c	58.00a
Tropical	AAAB	2.76b	20.40b	1.80	9.20a	45.60b	48.20b
Maravilha	AAAB	2.66b	20.60b	3.00	9.20a	44.00b	48.80b
Porp	AAAB	2.85b	20.25b	3.00	7.75a	34.50c	46.25b
Ouro da Mata	AAAB	3.22a	20.67b	2.67	8.67a	47.67b	51.33 a
Teparod	ABBB	2.93b	18.00b	2.00	5.00b	34.00c	36.67c
F test		12.30*	22.05*	1.38	2.37*	3.87*	7.97*
CV (%)		9.77	9.12	57.08	35.28	23.91	13.44
Mean		2.79	17.76	2.19	6.77	38.59	44.34

PLH: plant height (cm), SteD: stem diameter (cm), NTF: tillers at flowering, NLH: number of leaves at harvest, StaL: stalk length (cm), StaD: stalk diameter (mm); * significant at 5%.
Means followed by the same letter, in the columns, belong to the same group by the clustering test of Scott and Knott (1974), at 5% probability.

bunch. Genotypes with greater stem diameter are less susceptible to lodging (Silva et al. 2002a, Donato et al. 2003). Since the diploids are thin plants, the mean SteD was low, with lowest values observed for 028003-01and IDU-110, classified in the last group.

Regarding the number of leaves at harvest (NLH), the mean was 6.77, and two groups were formed (Table 1). The highest mean value was 9.20 leaves for the cultivars Tropical and Maravilha and the lowest 2.00 leaves for genotype Towoolle. It is known that fruit filling (size) is directly correlated with the number of green leaves at harvest. According to Soto Ballestero (1992), cultivars of the subgroup Cavendish generally need at least eight active leaves per plant for good fruit development.

For stalk length (StaL), the shortest stalk (14.67 cm) was observed for accession 'Tuugia', while Champa Madras had the longest (70.00 cm). A direct relationship between stalk diameter (StaD) and stalk weight (StaW) was observed, with higher values of the hybrids Ambrosia and Calipso (Tables 1 and 2) and shortest stalk diameter and weight of the diploid Tuugia.

Table 2. Means of six agronomic traits in 13 accessions of the active banana genebank of Embrapa

Accessions	Ploidy	Agronomic traits#					
		StaW	NHB	NFR	BUW	YSF	YSH
Jaran	AA	0.33c	8.00b	148.00a	3.20d	2.35a	2.11a
2803-01	AA	0.24c	5.00c	67.00b	3.30d	0.71d	0.71c
Malbut	AA	0.20c	6.00c	64.00b	2.93d	2.12a	1.94b
IDU-110	AA	0.40c	7.00b	87.00b	3.30d	0.71d	0.71c
Tuugia	AA	0.23c	6.00c	59.00b	2.09d	0.71d	1.25b
M-48	AA	0.50c	6.00c	84.00b	4.57d	0.71d	0.71c
Pipit	AA	0.28c	5.00c	92.00b	3.80d	1.14b	1.29b
Caru Roxo	AAA	0.80b	5.00c	64.00b	7.00c	1.58b	1.58b
Wasolay	AAA	0.30c	5.00c	51.00b	3.03d	0.88d	2.35a
Markatooa	AAA	0.49c	5.00c	63.00b	4.75d	1.73b	1.58b
Bakar	AAA	0.90b	6.00c	79.00b	9.80c	1.22c	1.40b
AAA Desc.	AAA	0.41c	6.00c	57.00b	6.20c	1.55b	1.40b
Nam	AAA	0.90b	6.00c	87.00b	4.33d	1.87b	1.73b
Towoolle	AAA	0.32c	4.00c	42.00b	2.85d	1.40b	1.40b
Caipira	AAA	0.80b	7.00b	132.00a	9.67c	0.71d	0.71c
Thap Maeo	AAB	0.93b	10.00a	158.00a	15.03b	0.71d	0.71c
Walha	AAB	0.19b	4.00c	30.00c	1.71d	1.90b	1.72b
Pacha Nadan	AAB	0.89b	7.00b	88.00b	8.47c	1.58b	1.58b
C. Madras	ABB	0.65c	7.00b	94.00b	12.90b	0.71d	0.71c
Ambrosia	AAAA	1.82a	9.00a	154.00a	21.26a	0.71d	0.71c
Calipso	AAAA	1.60a	8.00b	138.00a	18.62a	0.71d	0.71c
Tropical	AAAB	0.80b	6.00c	92.00b	9.96c	0.71d	0.71c
Maravilha	AAAB	0.61c	5.00c	53.00b	6.74c	1.58b	1.75b
Porp	AAAB	0.53c	5.00c	51.00b	5.95c	1.22c	1.58b
O. da Mata	AAAB	0.70b	5.00c	78.00b	6.75c	1.29c	1.39b
Teparod	ABBB	0.33c	6.00c	37.00b	3.87d	0.71d	1.00c
F test		8.95*	4.59*	5.97*	14.93*	22.80*	7.89*
CV (%)		40.22	21.53	32.76	33.77	17.07	26.61
General mean		0.67	6.00	83.00	7.78	1.08	1.35

StaW: stalk weight (kg), NHB: number of bunches, NFR: number of fruits, BUW: bunch weight (kg), YSF: Yellow Sigatoka at flowering, YSH: Yellow Sigatoka at harvest; * significant at 5%.
Means followed by the same letter, in the columns, belong to the same group by the clustering test of Scott and Knott (1974), at 5% probability.

The number of hands (NHB) and fruits (NFR) per bunch were in the mean 6 and 83, respectively (Table 2). The number of fruits was highest for the triploids Caipira (138) and Thap Maeo (158), tetraploids Ambrosia (154) and Calipso (138) and the diploid Jaran (148), classified in the first group. The characters number of hands and fruits are of great interest for the producer and fundamental for the genetic improvement of banana, since the bunch (fruits) is the commercial unit. Besides, an increase in the number of hands can result in a higher bunch weight, a character that expresses the productivity of a genotype (Silva 2002b, Silva et al. 2003). Similar results were observed for bunch weight (BUW), since this character is related to the number of fruits per bunch and the mean weight of each fruit.

In the evaluation of yellow Sigatoka four groups were formed at flowering and three groups at harvest. Disease resistance was observed in most genotypes, with the exception of diploids Jaran and Malbut. Results show that it is possible to plan new combinations involving diploid and tetraploid genotypes to breed new cultivars with good agronomic characteristics and resistance to yellow Sigatoka (Table 2).

Except for titrable acidity, significant differences and group formation were stated for all physical and chemical characteristics (Tables 3 and 4). The coefficients of variation ranged from 0.86% for flavonoids to 31.24% for fruit weight.

Table 3. Means of seven physical and chemical characteristics of the fruits of 26 banana accessions of the active genebank of Embrapa

Accessions	Ploidy	Physical and chemical character istics#						
		FRL	FRD	FRW	FLW	FLD	PTH	FLF
Jaran	AA	6.78d	2.45d	23.56c	16.59c	1.98d	0.19c	0.88b
028003-01	AA	14.22b	2.25d	49.30c	31.49c	1.86d	0.21c	0.86b
Malbut	AA	9.67d	3.08c	49.39c	36.57c	2.72b	0.16c	0.98b
IDU-110	AA	10.22c	2.49d	37.11c	28.15c	2.22c	0.13c	0.94b
Tuugia	AA	12.22c	2.16d	36.48c	24.36c	1.82d	0.14c	0.70c
M-48	AA	15.11b	2.19d	49.21c	34.30c	1.85d	0.15c	0.67c
Pipit	AA	8.67d	2.56d	31.56c	16.89c	2.15c	0.30b	0.78c
Caru Roxo	AAA	14.67b	3.73b	113.98b	84.41b	3.30b	0.28b	0.82c
Wasolay	AAA	13.78b	2.68d	63.33c	47.13c	2.30c	0.17c	0.81c
Markatooa	AAA	13.83b	3.04c	82.60b	60.37b	2.64b	0.19c	0.87b
Bakar	AAA	15.25b	3.60b	116.08b	67.48b	2.75b	0.47a	1.13a
AAA Desc.	AAA	17.67a	3.93a	144.32a	112.03a	3.57a	0.20c	1.20a
Nam	AAA	11.58c	3.07c	67.61c	46.31c	2.44c	0.20c	0.90b
Towoolle	AAA	11.83c	3.15c	72.73c	56.14b	2.92b	0.19c	0.70c
Caipira	AAA	11.67c	3.37b	68.58c	53.37b	3.01a	0.17c	0.89b
Thap Maeo	AAB	11.67c	4.00a	95.98b	74.49b	3.55a	0.24b	0.98b
Walha	AAB	10.61c	2.96b	57.48c	37.14c	2.52b	0.24b	1.03a
P. Nadan	AAB	13.67b	3.62a	110.88b	73.96b	3.17a	0.28b	0.97a
C. Madras	ABB	12.75b	4.07a	134.63a	94.34a	3.62a	0.41a	1.21a
Ambrosia	AAAA	18.11a	3.85b	162.42a	107.70a	3.16a	0.38a	0.93c
Calipso	AAAA	18.72a	3.76c	150.28a	104.52a	3.16a	0.26b	0.84b
Tropical	AAAB	15.28b	4.21a	152.37a	113.98a	3.77a	0.30b	1.02a
Maravilha	AAAB	16.89a	3.78b	131.40a	82.14b	3.02a	0.34b	0.90b
Porp	AAAB	13.67b	4.30a	137.21a	103.10a	3.78a	0.29b	0.98b
O. da Mata	AAAB	13.61b	3.31c	94.19b	64.66b	2.92b	0.20c	0.83c
Teparod	ABBB	13.72b	3.65b	119.78b	73.93b	3.03a	0.30b	1.22a
F test		20.53*	32.03*	19.32*	20.89*	35.60*	10.25*	10.54*
CV (%)		13.64	10.33	31.24	30.47	10.49	30.79	13.72
Mean		13.31	3.26	89.95	62.98	2.80	0.24	0.91

FRL: fruit length (cm), FRD: fruit diameter (cm), FRW: fruit weight (g), FLW: flesh weight (g); FLD: flesh diameter (cm), PTH: peel thickness (cm), FLF: flesh firmness(Lb); * significant at 5%.

Means followed by the same letter, in the columns, belong to the same group by the clustering test of Scott and Knott (1974), at 5% probability.

The mean fruit length (FRL) was 13.31 cm, ranging from 6.78 cm for diploid Jaran to 18.72 cm for tetraploid Calipso, with the formation of four groups. In general, tetraploids had a higher mean FRL (15.71 cm) than triploids (13.24 cm) and diploids (10.98 cm). A similar performance was observed for the mean fruit diameter and weight and flesh weight and diameter, which formed four, three, three and four groups, respectively. Similar results were reported by Lima et al. (2005), who assessed banana triploid and tetraploid genotypes and found a variation in fruit length of 13 - 18 cm and a mean fruit diameter of 3.0 cm.

Table 4. Means of seven physical and chemical fruit characteristics of 26 banana accessions of the active genebank of Embrapa

Accessions	Ploidy	Physical and chemical characteristics #						
		SS	TAC	PH	CTN	FLA	PLF	VIT
Jaran	AA	17.74c	0.11	5.13a	8.23a	2.47e	28.76l	17.61k
028003-01	AA	18.93c	0.12	4.86a	3.53d	2.88d	38.51g	31.52f
Malbut	AA	17.70c	0.14	4.52b	6.88b	2.09f	26.90m	20.42j
IDU-110	AA	20.67b	0.13	4.96a	2.86d	2.88d	40.96g	20.10j
Tuugia	AA	20.73b	0.13	4.69b	1.41e	1.64g	31.05k	51.10c
M-48	AA	15.27c	0.13	4.64b	3.52d	4.08c	41.18g	9.03n
Pipit	AA	17.65c	0.10	5.06a	2.95d	4.68b	61.48e	15.72l
Caru Roxo	AAA	20.87b	0.12	4.92a	5.91b	2.16f	33.32i	24.63i
Wasolay	AAA	18.00c	0.18	4.20b	3.15d	1.16h	17.51o	14.72l
Markatooa	AAA	17.90c	0.14	4.61b	2.29d	1.09h	16.23p	14.41l
Bakar	AAA	18.50c	0.10	4.79a	3.99c	1.61g	79.14c	29.43g
AAA Desc.	AAA	19.70b	0.21	4.44b	2.45d	2.45e	35.48h	54.20b
Nam	AAA	20.40b	0.11	5.26a	2.77d	2.75d	31.86j	44.67d
Towoolle	AAA	14.60c	0.16	4.62b	2.33d	2.04f	12.84r	10.87m
Caipira	AAA	21.40b	0.09	5.03a	1.05e	1.72g	146.31b	11.48m
Thap Maeo	AAB	17.07c	0.18	3.84b	3.78c	1.50g	15.71p	37.21e
Walha	AAB	18.27c	0.14	5.16a	2.52d	4.02c	43.41f	17.85k
P. Nadan	AAB	22.70a	0.16	4.41b	5.83b	1.86g	64.90d	26.85h
C. Madras	ABB	17.80c	0.16	4.38b	3.34d	1.76g	27.41m	12.45m
Ambrosia	AAAA	18.47c	0.11	4.73a	1.39e	1.38h	27.52m	11.60m
Calipso	AAAA	20.13b	0.12	4.85a	1.40e	1.35h	27.12m	9.49n
Tropical	AAAB	20.00b	0.15	4.34b	0.98e	1.20h	14.83q	14.68l
Maravilha	AAAB	20.73b	0.19	4.46b	1.89e	0.85h	16.03p	9.66n
Porp	AAAB	19.80b	0.19	4.29b	2.34d	1.08h	14.77q	13.65l
O. da Mata	AAAB	23.73a	0.15	4.43b	4.70c	1.42g	24.56n	19.45j
Teparod	ABBB	25.70a	0.07	5.27a	1.44e	6.64a	257.80a	76.83a
F test		11.64*	13.92	7.83*	40.79*	105.19*	34.877.64*	1161.36*
CV (%)		10.38	18.59	7.84	12.72	8.11	0.86	2.90
Mean		19.48	0.13	4.68	3.19	2.25	45.31	23.82

SS: soluble solids (ºBrix), TAC: titrable acidity, pH, CTN; carotenoids ($\mu g.g^{-1}$), FLA: flavonoids (mg $100g^{-1}$), PLF: polyphenols (mg $100g^{-1}$), VIT: vitamin C (mg $100g^{-1}$), * significant at 5%.

Means followed by the same letter, in the columns, belong to the same group by the clustering test of Scott and Knott (1974), at 5% probability.

The mean peel thickness (PTH) was 0.24 cm, ranging from 0.13 cm (diploid IDU-110) to 0.47cm (triploid Bakar). Three groups were formed (Table 3). Likewise, flesh firmness (FLF) ranged in the mean from 0.67 Lb (M-48) to 1.22 Lb (Teparod).

The mean solids content was 19.48 °Brix, with a range of 14.60 °Brix (triploid Towoolle) to 25.70 º Brix (tetraploid Teparod). Three groups were formed by the Scott and Knott test. These results were similar to those described by Soto Ballestero (1992) for banana. There was no variation in acidity among the 26 accessions (Table 3).

The mean content of total carotenoids among the 26 accessions was 3.19 mg g^{-1}, ranging from 0.98 mg g^{-1} (Tropical, tetraploid AAAB) to 8.23 mg g^{-1} (Jaran, diploid AA) (Table 4). Englberger et al. (2003a) quantified carotenoid levels in 21 banana accessions and found a mean of 11.13 mg g^{-1}, with amplitude of variation from 0.62 to 53.70 mg g^{-1}. Similar results were obtained by Englberger et al. (2003b) with 17 banana accessions (mean of 9.21 mg g^{-1}) and Amorim et al. (2009b), who obtained a mean of 4.73 mg g^{-1} in the analysis of 42 diploid, triploid and tetraploid banana accessions.

The total flavonoid contents of the 26 banana accessions was in the mean 2.25 mg 100g^{-1} and the variation between 0.85 mg 100g^{-1} (Maravilha AAAB) and 6.64 mg 100g^{-1} (Teparod ABBB), indicating the existence of variation for this substance in these accessions (Table 4). Among the diploids, the mean was 2.96 mg 100g^{-1}, with a high value of Pipit (4.68 mg 100g^{-1}). For the triploids, the variation was from 1.09 to 4.02 mg 100g^{-1}, while the mean of the tetraploids was 1.95 mg 100g^{-1}, with best performance of Teparod (6.64 mg 100g^{-1}).

Lako et al. (2007) found a variation of 2.00-10.00 mg 100g^{-1} of flavonoids in different genotypes of *Musa* sp. The mean level of total polyphenols among the 26 banana accessions was 45.31 mg 100g^{-1}, ranging from 12.84 mg 100g^{-1} for triploid Towolle to 257.80 mg 100g^{-1} for the tetraploid Teparod (Table 4).

Teparod and an unknown AAA contained most vitamin C, with respective values of 76.83 mg 100^{-1} and 54.20 mg 100^{-1}. Amorim et al. (2007) observed a variation of vitamin C from 21 to 54 mg 100^{-1} in diploid banana, in agreement with our results.

The dendrogram of genetic distances based on agronomic data and physicochemical fruit characteristics, obtained by the UPGMA method, is shown in Figure 1. The cophenetic value was high ($r = 0.86$, $P < 0.0001$, 10,000 permutations) and appropriate, since $r^{3}0.56$ is considered ideal, indicating good agreement with the values of genetic distance (Vaz Patto et al. 2004). The cluster analysis allows the conclusion of the existence of wide genetic variability among the 26 banana genotypes, a positive factor for the choice of parents for hybridization. Three major groups and several subgroups were formed. Bunch weight was highest for the tetraploids Ambrosia and Calipso and hybrids type Gross Michel, which were grouped together.

Results with bananas indicate that the carotenoid content is a quantitative trait determined by the activity of multiple gene products (Davey et al. 2009). The results of this study support this statement, since the diploids 'Jaran' and 'Malbut' with highest total carotenoid contents, although classified in the same group, formed different subgroups. This allows the conclusion that the genetic control for this trait is influenced by multiple genes. In other crops, similar results were obtained (Santos and Simon 2002, 2006).

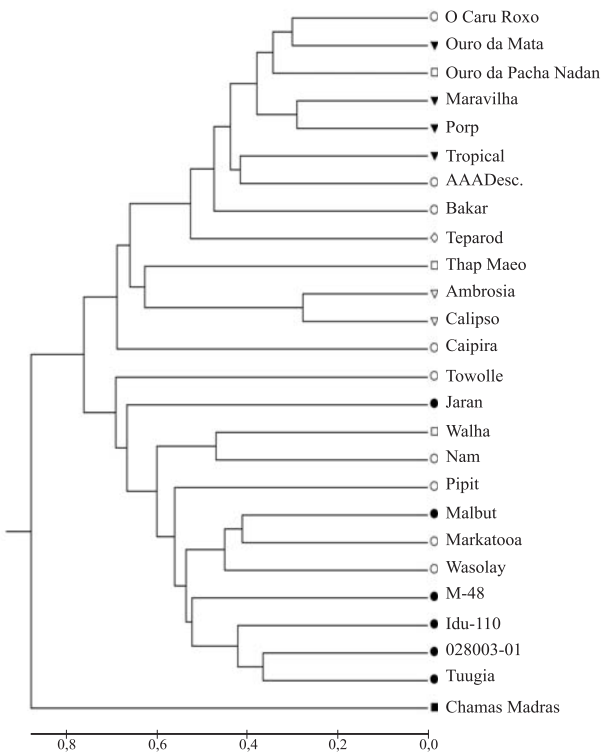

Figure 1. Genetic distance between 26 banana genotypes diploids, triploids and tetraploids based on 26 agronomic and physicochemical fruit characteristics. Black circle (diploids AA), empty circle (Triploids AAA), empty square (triploids AAB), black square (triploid ABB), empty triangle (tetraploids AAAA), black triangle (tetraploids AAAB) and diamond (tetraploid ABBB).

The improved diploid 028003-01 grouped together with 'Tuugia' as expected, since this genotype is one of its parents. The tetraploids with genome AAAB (Tropical, Maravilha, Porp and Ouro da Mata) were also grouped together. The tetraploid Champa Madras, the only representative of genome ABB, formed a separate group.

It was concluded that it is possible to obtain cultivars with high levels of polyphenols, flavonoids, vitamin C and carotenoids, by crossing different genotypes and selection in the progeny. Cultivars with this profile can potentially neutralize free radicals, preventing certain diseases, including some types of cancer (Vijayakumar et al. 2008).

In general, wide genetic variability was detected for most agronomic, physical and chemical characteristics of the 26 banana accessions, enabling the planning of crosses for the development of cultivars with short stature, high yield (bunch weight) high carotenoid, flavonoid and/or polyphenol contents. Among the accessions, the triploids Caipira and Thap Maeo and the tetraploids Ambrósia and Calipso performed particularly well for number of fruits and bunch weight. Highest carotenoid contents were observed in the diploid genotypes Jaran and Malbut. The highest values of total flavonoid and polyphenol contents, two natural antioxidants, were found in the tetraploid Teparod.

CONCLUSIONS

In seven of the eight wheat lines used as parents, the genotypes containing loci responsible for the grain color inheritance were fully or partially characterized. Among the genotypes evaluated, Frontana and Ônix have three genes for the determination of pre-harvest sprouting resistance, and this expression only occurs when all alleles are recessive homozygous.

The red seed color is not considered solely as a full guarantee of greater pre-harvest sprouting resistance.

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Caracterização agronômica, física e química de frutos de bananeira

RESUMO - *O objetivo do trabalho foi caracterizar 26 accessions de bananeira pertencentes ao banco ativo de germoplasma da Embrapa Mandioca e Fruticultura Tropical (Brasil), em relação a agronomic traits, físicas e físico-químicas dos frutos. Para altura de planta, o diplóide 028003-01 e o triplóide Walha apresentaram porte baixo. Em relação ao número de frutos e peso do cacho, destaque para os triplóides Caipira e Thap Maeo e para os tetraplóides Ambrósia e Calipso. Os diplóides Jaran e Malbut apresentaram os maiores valores para carotenóides totais. O tetraplóide Teparod foi o que apresentou maiores valores para teor de flavonóides e polifenóis totais, dois antioxidantes naturais. Detectou-se ampla variabilidade genética para a grande maioria das agronomic traits, físicas e químicas dos frutos entre os accessions de bananeira, possibilitando planejar cruzamentos que visem o desenvolvimento de híbridos com porte baixo, alta produtividade, resistentes a pragas e com altos teores de carotenóides, flavonóides e ou polifenóis.*

Palavras-chave: *Musa* spp. variabilidade, componentes funcionais, peso do cacho, rendimento.

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