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RESEARCH ARTICLE

CHARACTERIZATION, DISSIMILARITY AND GENETIC PARAMETERS ON CASSAVA VARIETIES

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ABSTRACT

Although cassava plants present high productive potential, national productivity is low, especially in the north of Minas Gerais. Therefore, the evaluation and characterization of genotypes adapted to the north of Minas Gerais are important because it enables the selection of genotypes with agronomic potential for cultivation and the integration in breeding programs. Therefore, the aim was to evaluate the most cultivated cassava varieties in the north of Minas Gerais, in order to obtain information of genetic parameters, correlations, dissimilarity and agronomic performance. For that, 54 morpho-agronomic traits were evaluated in 6 varieties in a randomized block design with four replications. For the dissimilarity study was performed the Tocher test and hierarchical dendrogram by the UPGMA method. There was genetic variability among the varieties and prevalence of genetic effects over the environmental ones for most evaluated features. The Vassourinha variety stood out with higher roots productivity being the most recommended for cultivation. The features, net photosynthesis and transpiration rate correlated with the root productivity, making them important for breeding programs. Three groups were formed by multivariate analysis, verifying that the crossing of variety Vassourinha with Amarelinhavarietie, Ass. E.N. or Sabará can enable obtaining high genetic variability progenies.

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INTRODUCTION

The importance of the cassava crop (*Manihot esculenta* Crantz) grows increasingly on a global scale due to the increase of its offer, the carbohydrate content, low technological level requirement and rusticity to poor soil and subjected to water deficit regions (Johanns & Contiero 2006). Therefore, this crop is of great importance as for food security, particularly for family agriculture, and may be destined for human or animal feed, or as raw material for the flour industry (Azevedo *et al*., 2006, Johanns & Contiero 2006, Silva *et al*. 2007). Brazil is the second largest producer of cassava, with approximately 10.5% of production. Consumption per capita is 12.4 kg per year in Brazil, with 1.7 million hectares of cultivation and production of 24 million tons (FAO 2010).

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Despite of having high yield potential, reaching in some regions yields above 80 t ha^{-1} (Albuquerque *et al*. 2008), the national cassava productivity is low (14.73 t ha^{-1}) and has not evolved (MinasGerais 2010). According to data from the Superintendence of Policy and Agricultural Economy of Minas Gerais, the production of cassava in Minas Gerais, in 2014 was approximately 858,000 tons, with an average yield of 14.31 t ha^{-1}. The northern region of Minas Gerais accounts for approximately 19.24% of the state production, about 165,000 tons and productivity of only 12.24 t ha-^{1} (Minas Gerais, 2010). Therefore, the evaluation and characterization of genotypes adapted to the north of Minas Gerais are important because it enables the selection of genotypes with agronomic potential for cultivation and for the integration on breeding programs. For genetic breeding, some studies are important, standing out the parameters estimative as the residual variation coefficient, genetic variation, heritability, and the variation and correlations index (Azevedo *et al*., 2012). In addition to genetic parameters, the study of genetic dissimilarity is important, since the selection of dissimilar parents with a high value per se, increases the possibility of obtaining segregating populations with a high variability and high genetic values for characteristics of interest.

Thus, to get information for future breeding programs, it was aimed to evaluate the cassava varieties most cultivated in the north of Minas Gerais, in order to obtain information of genetic parameters, correlations, dissimilarity and agronomic performance.

MATERIALS AND METHODS

The experiment was carried out from October 2011 to August 2012 in Montes Claros-MG (16º40'35.96" S, 43º50'52.51" and height of 1100 m). Before soil preparation, a sampling of the layer of 0-20 cm of the soil of the experimental area was made. The following results were found: pH in water: 7,9; available phosphorus :260 mg dm^{-3} ($Mehlic^{-1}$extractor); available potassium: 546mg dm^{-3} (extractor KCL 1mol/L); calcium: 9,60 $cmol_c dm^{-3}$(extractor KCL 1 mol/L); magnesium: 3,60 $cmol_c$ dm^{-3}(extractor KCL 1 mol/L);Al: 0,01 $cmol_c dm^{-3}$ (Extractor $Mehlic^{-1}$); H+Al: 0,77 $cmol_c dm^{-3}$(Extracted with calcium acetate 1 N, pH 7,0); BS: 14,60 $cmol_c dm^{-3}$(Extracted with calcium acetate 1 N, pH 7,0); t: 14,60 $cmol_c dm^{-3}$(Extracted with calcium acetate 1 N, pH 7,0); m (%): 0,01; T: 15,37 $cmol_c dm^{-3}$(Extracted with calcium acetate 1 N, pH 7,0); V: 95%; organic matter 7,13 dag kg^{-1}; coarse sand : 5,90 dag kg^{-1}; fine sand: 36,10 dag kg^{-1}; silt: 34,00 dag kg^{-1}(Pipette method after dispersion with NaHO 1mol/L); Clay: 24,00 dag kg^{-1} (Pipette method after dispersion with NaHO 1mol/L). Soil preparation was done by plowing, disking and then the opening of the furrows was taken with a plow, pulled by tractor. The row spacing was one meter. Planting and cover fertilization were made considering the soil analysis and the crop recommendations. The steam cuttings were collected from the middle third of the plants and cut with a length of 20 cm, with five to seven stems, being planted horizontally in furrows 10 cm deep. For fertilizing, were applied 2 kg per linear meter of cured cow manure, equivalent to 20 tons per hectare. The varieties were grown with spacing of 1.00 x 0.50 meters. The experimental design was a randomized block with four replications. The experimental plot consisted of four rows with six plants each. Eight central plants composed each representative plot. Treatments consisted of six varieties of cassava collected in three municipalities on the north of Minas Gerais: Amarelinha (Riacho – Claro dos Poções Farm); Amarela (São Francisco – São Francisco II settlement); Cacau (Riacho Farm – Claro dos Poções); Sabará (Riacho Farm – Claro dos Poções), Vassourinha (ICA – Montes Claros) and Estrela do Norte settlement (Estrela do Norte settlement– Montes Claros). During the period in which the trial was conducted, manual weeding did the weed control. Two weeding operations were conducted, one made at 30 days after planting and the other at 60 days. Irrigations were carried out during periods of prolonged drought. The use of irrigation also occurred on a supplementary way to the rainfall during the months of March 2012 to mid-May 2012.In August 2012, at harvest, the following agronomic traits were assessed: Root yield in $t.ha^{-1}$, obtained by weighing the tuberous roots of four central plants of the experimental plot; shoot productivity $t.ha^{-1}$, obtained by weighing the aerial parts of four central plants of the experimental plot; Harvest index from the relation between root mass and total plant mass; plant height with the aid of a graduated tape in cm; the first branching height with the aid of a graduated tape in cm; number of cuttings per plant, number of roots per plant and average weight of root obtained by weighing in semi-analytical balance. The rate of net photosynthesis, transpiration rate and stomatal conductance was determined in the leaves of the upper canopy of plants when these completed nine months after planting, by using IRGA Li- 6400, with a measuring chamber for broadleaf, coupled to the equipment. The device was calibrated to a reference carbon concentration of 380 µmol (CO_2) $mol^{-1}$and a light intensity of 1.200 µmol m^{-2} s^{-1}. The evaluations were always made between 8:30 am and 11:30 am. Thirteen minimum descriptors, twelve main, nine secondary and eight primary agronomic were evaluated, which are detailed by Fukuda & Guevara (1998). Minimum descriptors: apical leaf color; pubescence of the apical bud, the central lobe shape, petiole color, stem cortex color, external color the stem, length of phyllotaxy, presence of stem roots, external color of the root, root cortex color, root pulp color, root epidermis texture and flowering, the lobe, lobe width, length / width ratio of the central lobe, petiole length, stem epidermis color, stem growth habit, color terminal branches of the adult plant, plant height, first branch height and constrictions root. Main descriptors: color developed sheet, number of lobes, lobules length, lobe width, length / width ratio of the central lobe, petiole length, stem epidermis color, stem growth habit, terminal branches color of adult plants, plant height, first branch and root constrictions height. Secondary descriptors: leaf veins color, petiole position, prominence of leaf scars, length of the stipules, margin of stipules, branching habit, sinuosity of the leaf lobe, root form and type of plant. Preliminary agronomic descriptors: weight of the aerial part of the plant, number of commercial cuttings per plant, average root length, detachment of the root film, root cortex detachment, root position, number of roots per plant and average weight of roots per plant. The statistical model considered for univariate analysis with quantitative data was: $Y_{ij} = m + t_i + b_j + e_{ij}$.In which: Y_{ij} = observation regarding the j-th block of the i-th genotype; m = general average; t_i = effect of the i-th genotype (i = 1, 2, ..., I) assumed as fixed; b_j = effect of the j-th block (j = 1, 2, ..., J) assumed to be random; e_{ij} = effect of error of the i-th genotype error in the j-th block assumed to be random. The data were submitted to variance analysis and comparison of Tukey's range test at 5% probability. The variance components, genetic parameters and correlations were obtained by the expressions cited by Cruz *et al*. (2012). In the multivariate statistical analysis, for the implementation of Tocher grouping method the Gower algorithm was used to obtain the dissimilarity matrix in order to study the quantitative and qualitative data simultaneously. For the best viewing of existing dissimilarity among accessions, a hierarchical dendrogram by UPGMA method was made. The univariate and multivariate analyzes were performed using the genetic-statistical application GENES (Cruz 2013).

RESULTS AND DISCUSSION

The effect of varieties was not significant at 5% probability only for the characteristic productivity of the aerial part (Table

1 and Table 2). When considering the effect of varieties as fixed, the significance for the purposes of varieties indicate that the average of at least one genotype differs significantly from the others.

The highest residual variation coefficients were found for the characteristics of net photosynthesis, transpiration rate and stomatal conductance (Table 2), which can be explained by the variation as a function of leaf position on the plant and evaluation time.

Table 1. Comparison of average and genetic parameters for root productivity features (PRA - t.ha^{-1}), aerial part productivity (PPA - t.ha^{-1}), harvest index (IC), plant height (AP - cm), first branch height (A1R - cm), number of ma stem cuttings per plant (NEPP), number of roots per plant (NRPP) and average weight of the root (PMR - kg)

Varieties	PRA*	PPA^{ns}	IC**	AP**	A1R**	NEPP**	NRPP**	PMR**
Vassourinha	79,24 a	59,56	56,45 a	240,00 cd	135,00 a	6,00 c	7,00 b	3,96 a
Amarelinha	43,07 b	44,28	50,23 a	251,00 cd	93,00 b	11,00 bc	11,00 ab	2,15 b
Amarela	48,49 ab	58,54	44,91 ab	320,00 a	65,00 c	13,00 b	7,00 b	2,43 b
Cacau	38,18 b	60,74	38,60 b	290,00 ab	82,00 bc	16,00 ab	8,00 b	1,91 b
Ass. E.N.	59,05 ab	67,39	46,39 ab	227,00 d	60,00 c	19,00 a	16,00 a	2,95 ab
Sabará	55,75 ab	47,83	53,45 a	266,00 bc	116,00 a	15,00 ab	9,00 b	2,79 ab
				Genetic parameters				
CVe (%)	27,64	18,77	10,58	5,72	10,86	19,2	25,29	23,1
CVg(%)	23,26	12,14	12,48	12,62	31,39	32,37	33,32	24,45
CVg/CVe	0,84	0,65	1,18	2,21	2,89	1,69	1,32	1,06
H^2 (%)	73,91	62,62	84,77	95,12	97,1	91,91	87,41	81,76
				Phenotypic correlations				
PRA	1,00	0,27	0,76	-0,54	0,59	-0,51	-0,04	0.98
PPA		1,00	-0,40	-0,07	-0,42	0,33	0,25	0,27
IC			1,00	-0,53	0,76	-0,63	-0,08	0,76
AP				1,00	-0,31	0,07	-0,64	-0,54
A1R					1,00	-0,72	-0,48	0,59
NEPP						1,00	0,61	-0,51
NRPP							1,00	-0,04
PMR								1

Means followed by the same letter in the column do not differ statistically by the Tukey test (p<0,05). **, * and^{ns}refer to significance of 1%, 5% and not significant at 5% by the F-test for treatment effect.

Table 2. Comparison of average and genetic parameters for the characteristics of net photosynthesis (A), transpiration rate (E), stomatal conductance (EC), root productivity (PRA), aerial part productivity (PPA), harvest index (IC), plant height (AP), the first branch height (A1R), number of stem cuttings per plant (NEPP), number of roots per plant (NRPP) and average weight of the root (PMR)

Varieties	A (μmol CO_2 m^{-2}s^{-1})**	E (μmol H_2O m^{-2}s^{-1})**	CE (mol m^{-2}s^{-1})**
Vassourinha	20,16 a	1,62 d	0,10 b
Amarelinha	6,69 d	3,40 b	0,25 a
Amarela	11,50 c	3,53 b	0,21 a
Cacau	15,10 b	3,70 b	0,16 b
AsstE.N	12,04 c	2,54 c	0,17 b
Sabará	11,65 c	4,30 a	0,30 a
		Genetic parameters	
CVe (%)	38,62	27,72	45,25
CVg(%)	32,63	29,11	32,78
CVg/CVe	0,84	1,05	0,72
H2 (%)	87,71	91,63	83,99
		Phenotypics correlations	
A	1,00	-0,53	-0,77
E	-0,53	1,00	0,79
CE	-0,77	0,79	1,00
PRA	0,67	-0,72	-0,46
PPA	0,55	-0,44	-0,75
IC	0,17	-0,39	0,12
AP	-0,11	0,59	0,20
A1R	0,49	-0,24	-0,05
NEPP	-0,39	0,52	0,29
NRPP	-0,42	-0,15	0,08
PMR	0,67	-0,72	-0,46

Means followed by the same letter in the column do not differ statistically by the Tukey test (p<0,05). **, * e ^{ns}refer to significance of 1%, 5% and not significant at 5% by F-test for treatment effect.

Besides these features, root productivity showed a higher value for the residual coefficient variation compared to the other parameters (Table 1). Among the possible reasons for higher residual coefficients of variation for the root productivity can mention the difficult local control of the soil, not getting homogeneous blocks and the fact that the roots are not immediately visible, which can cause incomplete cropping. Devide *et al*. (2009) and Fagundes *et al*. (2010) also observed higher residual coefficients of variation of root productivity of cassava in relation to other characteristics. For the genetic coefficient variation, greater estimates were observed for the characteristics of the first branch height, number of stem cuttings per plant, number of roots per plant, net photosynthesis and stomatal conductance (Table 1 and Table 2). Higher estimates for the genetic coefficient variation indicates a higher genetic variability. For the relative variation index (CVg / CVe) only the features root productivity, shoot productivity, net photosynthesis and stomatal conductance showed lower estimates to an unit. Values of the variation index close to or above a unity are desirable for genetic breeding because, they are indicative of the predominance of genotypic variation in relation to the environmental and consequently increases the possibility of breeders to obtain genetic selection gains with the selection (Azevedo *et al*. 2012).

Estimates greater than 90% for genotypic determination coefficient (H^2) were found for plant height, height of the first branch, number of stem cuttings per plant and transpiration rate. The genotypic determination coefficient is the reliability with which the phenotypic value represents the genotypic value thus features with high H^2 reflect the least influence of the environment, which increases the discriminating power of these (Ivoglo *et al*., 2008). The highest average for the root yield was found for the Vassourinha variety with 79,24 $t.ha^{-1}$, being superior to the Amarelinha and Cacau varieties. This productivity is much higher than the national average of 14.73 $t.ha^{-1}$ (Minas Gerais, 2014). Productivity found for the Vassorinha variety outweigh the productivity encountered by Johanns & Contiero (2006), Fagundes *et al*. (2010), Devide *et al*. (2009) and Albuquerque *et al*. (2008), which evaluated different varieties and cultural practices for cassava. The high yields obtained in this study can be justified by the adoption of appropriate cultural practices for the crop and the choice of varieties of good adaptation in the North of Minas Gerais. There was no significant difference between varieties for the aerial parts productivity, with average ranging from 44.28 to 67.39 t ha^{-1}. These values are higher than those found by Albuquerque *et al*. (2008) Fagundes *et al*. (2010). According to Azevedo *et al*. (2006) the aerial part of cassava has adequate fermentation characteristics with bromatologial and nutritional values suitable for use in ruminant feed. For the harvest index the Cacau variety showed lower average differing significantly from Vassourinha, Amarelinha and Sabará varieties. This index shows the percentage of root weight in relation to the total weight of the plant (root + shoot). The values found for this index are lower than the averages found by Alves *et al*. (2008) for the cropping taken at seven (67.10%) and 13 months after planting (58.24%). The Amarela variety had the highest plant height, being similar only to Cacau variety. On the other hand, the Vassourinha and Sabara varieties obtained the highest averages of the first branch height, averaging 135 and 116 cm respectively. The averages for this trait ranged from 60 to 135 cm. These results are close to those found by Mezette (2007), who found the height to first branch ranging from 75 to 127 cm. Although cassava produce viable seeds, the crop is planted commercially by a vegetative propagation. It is estimated that the use of healthy stem cuttings has influence in up to 30% in the production of roots (Rodrigues *et al*., 2008). In this study, the varieties Ass. E. N and Amarelinha had the highest number of stem cuttings per plant, in this regard, the Vassourinha variety reached the lowest average number, and the averages ranged from to 16 cuttings per plant. As for the average weight of the root, the varieties that stood out were Vassourinha with 3.96 kg, Ass E.N. with 2.95 kg and 2.79 kg with Sabará. The other had a mean intermediate weight. The means for this feature varied from 3.96 to 1.91 kg of roots. Mezette (2007) found values below the presented with an average value of 0.52 kg.

The Vassourinha variety had the highest average for net photosynthesis rate and lower average for the transpiration rate and stomatal conductance (Table 2). This variety was the one who presented photosynthetic activity within the range of 20 to 30µmol CO_2 m^{-2} s^{-1}, proposed by El-Sharkawy *et al*. (1989), for the cultivation of cassava, while all others were below this range, is worth underlining that this range was set in optimum environmental conditions. According to these authors, climatic conditions and physiological factors of the plant should be ideal for this potential to be achieved at the field. However, the range indicated by Cury (2008), of 13 - 18 µmol CO_2 m^{-2} s^{-1}, is best suited to the rates found in field conditions. The varieties Amarelinha, Amarela and Sabaráhad higher average stomatal conductance. The opening of the stomata influences directly, the stomatal conductance (gs), which is associated with carbon dioxide diffusion (CO_2). In all varieties, the net photosynthetic rate increases, as the stomatal conductance decreases, leading to a negative correlation (-0.777).

The feature that most correlated with the root yield was average weight of roots and harvest index (0.76). High correlation coefficients between these characteristics are expected, since all directly or indirectly reflect the weight of the roots (Table 1). The characteristic transpiration rate (E) also showed a correlation with the root productivity greater than 0.70 (-0.72) showing the importance of this feature for breeding programs with the crop. In studies conducted by El-Sharkawy *et al*. (1989) and El-Sharkawy *et al*. (1990) there was a significant correlation between the roots yield of cassava and net photosynthesis rate, since biomass production may depend, directly on the photosynthetic capacity. Cassava has a large capacity for dry matter accumulation in relation to the production of leaves and, moreover, the leaves remain more photosyntheticallyactive, avoiding new energy costs for the leaf recomposition (Cury 2008). The formation of three groups was observed by the Torcher method. The first formed by the varieties Amarelinha, Amarela, Ass. E.N. and Sabará, the second group by the Cacau variety and the third by the variety Vassorinha. This information is consistent with the verified by the hierarchical dendrogram using the UPGMA method (Figure 2) and by the projection of the dissimilarity matrix (Figure 3).

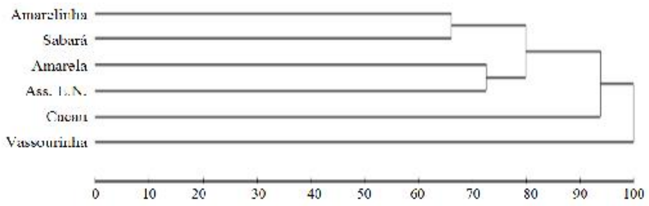

Figure 2. Illustrative dendrogram of the dissimilarity pattern obtained by the UPGMA method based on the dissimilarity matrix obtained by the Gower algorithm for 6 varieties of cassava grown in then orthof Minas Gerais. Montes Claros, UFMG, 2012

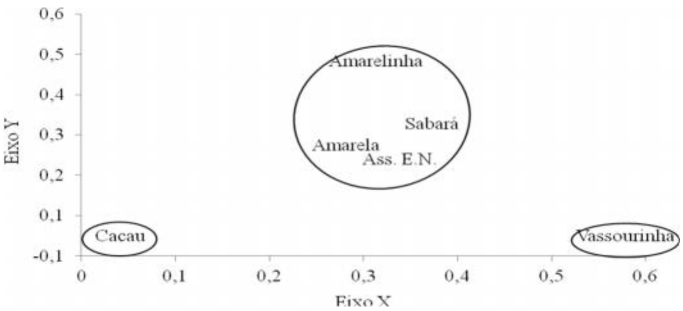

Figure 3. Dissimilarity matrix projection obtained by the Gower algorithm for 6 cassava varieties grown in the north of Minas Gerais. Montes Claros, UFMG, 2012

The Vassourinha variety stands out from the others varieties due to its greater potential for the roots production (Table 1), greater net photosynthesis (Table 2), form of the linear central pyramidal lobe, cortex color of the yellow stem, external color from yellowish green stem , the sinuosity of the leaf l sinuous lobe, cylindrical type of plant, longer length of the lobe, greater length / width central lobe relation, ratio central lobe, the greater length of the petiole and the lower lobe width (Table 3). On the other hand, the Cacaovariety Already Cocoa variety distinguished in relation to the others for presenting lower root productivity (Table 1), lower harvest index, greater height, lower average root weight, external golden color stem (Table 3), light green color of the developed leaf, color green, leaf rib yellow with red and petiole length inclined downward. CFA (Apical leaf color); PBA (pubescence of the apical bud); FLC (central lobe shape); CP (petiole color); CCC (stem cortex color); CEC (stem External Color); CF (phyllotaxis length); PPR (peduncle presence in the roots); CER (external color of the root);CCR (root cortex color);CPR (root pulp color); B (the root epidermis texture); FLOWER (Flowering); CFD (developed leaf color); CEC (stem skin color); HCC (Stem growth Habit); CRT (Terminal branches color); CR (Roots Constrictions); CN (leaf rib color); PC (petiole position); PC (Prominence of leaf scars); CE (Length of stipules); ME (Margins of stipules); HR (branching habits); SLF (Sinuosity of leaf lobes); FR (root shape); TP (plant type);

Table 3. Qualitative and quantitative morpho-agronomic descriptors on 6 cassava varieties grown in northern Minas Gerais. Montes Claros, UFMG, 2012

Descriptors	Varieties					
	Vassourinha	Amarelinha	Amarela	Cacau	AsstE.N	Sabará
CFA	Dark green	Purplish green	Light green	Light green	Dark green	Purplish green
PBA	Present	Present	Present	Present	Present	Present
FLC	Linear piramidal	Elliptic Lanceolate	Lanceolate	Lanceolate	Elliptic lanceolate	Elliptic lanceolate
CP	Reddish green	red	Yellowish green	Red	Reddish green	Reddish green
CCC	Yellow	Light green	Light green	Light green	Dark green	Dark green
CEC	Yellowish green	Silver	Grey	Golden	Silver	Grey
CF	Short	Short	Medium	Medium	Medium	Long
PPR	Sessile	Mixt	Sessile	Mixt	Sessile	Mixt
CER	Light brown	Light brown	Dark brown	Dark brown	Dark brown	Dark brown
CCR	White or cream	Yellow	White or cream	Pink	White or cream	Pink
CPR	White	Yellow	Cream	White	White	White
TER	Wrinklelly	Wrinklelly	Wrinklelly	Wrinklelly	Wrinklelly	Wrinklelly
FLOR	Absent	Present	Absent	Absent	Absent	Absent
CFD	Dark green	Dark green	Dark green	Light green	Dark green	Dark green
CEC	Cream	Cream	Light brown	Light brown	Light brown	Light brown
HCC	Straight	Straight	Straight	Straight	Straight	Straight
CRT	Green	Purplish green	Green	Purplish green	Green	Purplish green
CR	Few or none	Few or none	Few or none	Few or none	Few or none	Few or none
CN	Green	Green	Green	Green with red	Green	Green
PC	Horizontal	Inclined upward	Horizontal	Inclined downward	Horizontal	Inclined upward
PC	Prominent	Prominent	Prominent	Prominent	Prominent	Prominent
CE	Long	Long	Long	Short	Short	Long
ME	Complete	Complete	Laciniated	Complete	Laciniated	Laciniate
HR	Trichotomous	Trichotomous	Erect	Trichotomous	Trichotomous	Dichotomous
SLF	Sinuous	Flat	Flat	Flat	Flat	Flat
FR	Cylindrical	Conic-cylindrical	Conic-cylindrical	Conic-cylindrical	Conic-cylindrical	Cylindrical
TP	Cylindrical	Umbrella	Umbrella	Compact	Compact	Umbrella
CMR	Intermediate	Long	Intermediate	Intermediate	Intermediate	Long
DMR	Thick	Thick	Thick	Thick	Thick	Thick
PR	Horizontal tendency	Irregular	Irregular	Horizontal tendency	Horizontal tendency	Horizontal tendency
	20,00	17,30	14,60	16,00	17,00	17,33
LL	3,30	5,70	4,45	3,60	4,30	7,23
RCL	6,06	3,03	3,28	4,44	4,00	2,40
CP	42,30	27,30	24,60	35,30	26,00	33,60

CMR (average root length); DMR (root mean diameter); PR (Position of roots); CL (lobe length - cm); LL (lobe width - cm); RCL (relation length / width of the central lobe - cm); CP (petiole length - cm).

The genitor's choice with high performance *per se* and high genetic dissimilarity is desirable for breeding, allowing obtaining progenies with high average for the features of interest and great genetic variability (Cruz *et al*., 2012). Thus, the crossing of the Vassourinha variety with Amarelinha, Amarela, Ass. E.N. and Sabará varieties can enable obtaining progenies with high productive potential.

Conclusion

There was a predominance of genetic effects over the environmental. The Vassourinha variety stood out with higher roots productivity being the most recommended for cultivation. The features, net photosynthesis and transpiration rate correlated with the root productivity, making it important for breeding programs. Three groups were formed by multivariate analysis, verifying that the crossing of the variety Vassourinha with Amarelinha, Amarela, Ass. E.N. or Sabará can make possible obtaining progenies with high genetic variability.

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