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Genetic diversity of cassava varieties (*Manihot esculenta* Crantz) in theagro-morphologicalconditions of Malanje, Angola

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Abstract: *The joint analysis of qualitative and quantitative variables has been pointed as a useful tool in the estimate of the genetic diversity among the varieties of a germoplasm collection. The aim of the present study was to evaluate the genetic diversity of cassava varieties in the conditions agroecologics of Malanje, based on morpho-agronomics characters, for identification of divergent groups and to direct of hybridization works and subsequent selection. Traits such as number of branches, plant height, stem diameter, distance between internodes, height of the first branch, number of roots, root diameter, root length, shoot yield and root yield in experiments conducted in the Experimental Farm of Malanje Food Company were evaluated. Data collected were subjected to an analysis of variance, for the selection of the quantitative descriptors it was effectuate for the grouping analysis with the job of the distance of standardized medium Mahalanobis and the level of entropy, for the selection of the qualitative descriptors. The morpho-agronomic traits used to assess the 40 cassava genotypes pointed out the existence of promising materials that can be used to diversify cassava cultivation in Malanje. For the Method UPGMA, they were formed three groups basing on the analysis. Genetic variability exists starting from the characteristics morph agronomics in the appraised cassava varieties. The analysis quantitative and qualitative datasets provides larger efficiency in the knowledge of the existent divergence among the cassava varieties, and it allows to guide the future studies of hybridizations. The genotypes 29 (Malanje),2 (Maria dia Pedro), 19 (Banana), 36 (Muringa), 39 (Gueti) they were shown quite divergent of the others, being like this, selected as varieties of better answer.*

Key Words: *Manihot, Genetic divergence, Genetic variability.*

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I. Introduction

Cassava (*Manihot esculenta* Crantz), it is a Heliophyte plant, perennial, shrubed that belongs to the family of Euforbiáceas, has as origin South America [4]. The species is used in human and animal diets [17], besides being used as raw material in countless industrial goods. The world production in 2016 was 277.1 million tons [15], and Angola ranks the 10th position in the rank of the biggest cassava producers with it's approximately 10 million tons.

Northern and Western Angola are the regions hosting the highest cassava production rates and their populations use to consume the roots and leaves of this vegetable. Moreover, cassava can replace bread and cereals in some regions, since it is a subsistence culture and given its relatively simple production technology and great ability to adapt to different soil and weather conditions [2], [3].

Mattos et al. (2006), mentioned by Lema [23], the cassava is a culture that has great accommodation the agro ecological conditions of Malanje, that it serves as source of human feeding and animal, however big part of his/her stem is left in the cultivation field and the other, it is taken advantage for the following agricultural time.

The cultivation of the cassava, is an activity that has great social and economic importance at world level, mainly in tropical areas, where it is one of the important sources of energy (carbon hydrates) for thousands of people mainly in families of low income [18]. However, the social and economic importance of the cassava, relapses in the alimentary subject. The cassava is one of the cultures more explored in the family agriculture in everybody, his/her use as root cropped is just overcome by the English potato [31].

In the social extent, the importance of the cultivation of that root cropped crosses limits. As El-Sharkawy [13], the cassava beside the corn, sugarcane and rice, they constitute the important sources of energy in the feeding of the populations of most of the tropical countries. The gender *Manihot* to present characteristics specific agronomics that they allow its cultivation not only in conditions of high technology as well as lack of inputs, and also for being versatile as for the use possibilities it is considered as resource of great alimentary value.

The cassava is characterized by its great genetic diversity, being a generating culture of an infinity of individuals capable to adapt to different areas cultivation eco-geographic, to the fact of the cassava to be a plant allogeneic, highly heterozygotic and with great segregation in the first filial generation [16].

Considering the importance of cassava to the farmers in the Malanje, the aim of the present study was to evaluate the genetic diversity of cassava varieties in the conditions agroecologics of Malanje, based on morpho-agronomics characters, for identification of divergent groups and to direct of hybridization works and subsequent selection

II. Materials And Methods

Experimental guidance

The study was conducted in the Malanje Food Company's experimental field for one cropping campaign (2017/18). The forty (40) cassava genotypes assessed were provided by the Agronomic Investigation Institute (IIA)'s germplasm maintained in Malanje Agricultural Experimental Station, and in IDA of Cuanza Norte and Uíge. These provinces are located at latitude 8º 49' South and longitude 13º 13' East, at 368 m above sea level [19] and covered a total area of 8,960 Km^2. Details on the forty (40) genotypes are presented in Table 1.

Table 1. Charcteristics of the 40 cassava cultivars studied.

Origin	Maingrowingprovinces	Cultivars	Number
Malanje	Nordern	Waticamana	1
Malanje	Nordern	Maria dia Pedro	2
Malanje	Nordern	Hoto	3
Malanje	Nordernand Western	Mata Capim	4
Malanje	Nordernand Western	Kambaxi	5
Malanje	Nordernand Western	Paco Vermelho	6
Cuanza Norte	Nordern	Tio Jojo	7
Malanje	Nordern	Verdinha	8
Malanje	Nordern	MukotouaNguadi (Pé de perdiz)	9
Cuanza Norte	Nordern	Paco branco	10
Cuanza Norte	Nordern	Munenga	11
Cuanza Norte	Nordern	Kimbanda	12
Cuanza Norte	Nordern	Suzi	13
Cuanza Norte	Nordern	Jaca Branca	14
Cuanza Norte	Nordern	Jaca Vermelha	15
Cuanza Norte	Nordern	Kalazula	16
Uíge	Countrywide	Ngana Rico 1 (Uíge)	17
Uíge	Countrywide	TMS3	18
Uíge	Countrywid	Mandioca Banana	19
Uíge	Countrywid	Rio Dange	20
Uíge	Countrywide	Cassandi	21
	Countrywide	Vermute	22
Malanje	Nordern	Guita	23
Malanje	Nordern	Chico dia kombe	24
Malanje	Nordern	TMS 4025 (precoce de Angola)	25
Malanje	Nordern	Kalami	26
Malanje	Countrywide	Baco	27
Malanje	Nordern	Katenda	28
Malanje	Nordern	Malanje	29
Malanje	Countrywide	Ngana Rico 2 (Malanje)	30
Malanje	Nordernand Western	Kalawenda	31
Malanje	Nordernand Western	Gonçalo	32
Malanje	Nordern	Mundele Paco	33
Malanje	Nordern	Suingui	34
Malanje	Nordern	NganaYuculu	35
Malanje	Nordern	Muringa	36
Malanje	Nordern	Kinzela	37
Uíge	Nordernand Western	Mpelo	38

Malanje	Nordern	Gueti	39
Malanje	Nordern	Kapumba	40

The local soil was classified as fersialitic [12]. According to INAMET [19], the climate of the region was humid subtropical, the annual mean temperature was 26°C with a thermal amplitude of 14°C, a relative humidity between 80 and 85%, and a mean annual rainfall between 1000 and 1200 mm well distributed throughout the year.

The trial was arranged in a completely randomized block design with four repetitions. Each plot encompassed five rows of 10 plants, thus totalizing 50 plants per plot. Each row was 10 m long, spaced 0.90 m from each other. The distance between plants was 0.90 m.

The soil was plowed and harrowed before planting. It was applied 350 kg ha^{-1} of compound fertilizer (N-P-K: 12-24-12). The cover fertilizer was applied 250 kg ha^{-1} of N-P-K (16-8-12) six months after planting. Planting was mechanically performed with an 80 HP tractor (ISO- 9001, Mainland, China). The tractor was coupled to a two-row cassava planter (Bazuca 1) for 13.5 cm long stakes and horizontally placed in 0.10 m-deep grooves.

Stakes were treated before use by immersing for five minutes in a solution containing 80% Maconzebe (1 kg), 80% Fipronil (1 kg), Boron (1 L), Manganese (1 L) at 1500 L/water. Weeds were controlled manually with hoes at different development phases and stages. The herbicides Capizade and Flumioxazine were used at planting in order to avoid weeds during the initial growth of cassava plants.

Appraised parameters

Cuts were performed in February/2017 to February/2018 at maturity. All plants of the five rows of each plot were harvested. The 10 parameters measured were (i) number of branches (NB), (ii) plant height (PH), (iii) stem diameter (SD), (iv) length of internodes (ID), (v) height of the first branch (HFB), (vi) number of tubers (NR), (vii) root diameter (RD), (viii) root length (RL), (ix) shoot yield (SY), and (x) root yield (RY). NB resulted from the ratio of the sum of the number of sprouts in the stem cutting over the number of plants subjected to evaluation. PH was measured from ground level up to the most distal tip. SD was measured with a caliper at 10 cm from the ground. ID was the mean distance between knots of the plant stems. HFB was measured from ground to the first branch. NR was the ratio of the number of roots in the stem cuttings over the number of plants subjected to evaluation. RD was the mean diameter of ten roots randomly sampled in each experimental plot. RL was the mean length of ten randomly sampled roots in each experimental plot. SY was recorded by weighing the shoot of all useful plants in the experimental plots. RY of a cultivar was the weight of roots of all useful plants of the corresponding experimental plots.

Harvests were mechanized and preceded by cutting of the areal part at maturity. The harvest was performed with a tuber crops harvester (P9000) coupled to the tractor.

Analyses

Data collected were subjected to the variance analysis, for the selection of the quantitative descriptors it was effectuate for the grouping analysis with the job of the distance of standardized medium Mahalanobis, once the varieties are established without obeying the experimental no straight line [11]. This analysis involved all of the characters and it was executed with base in the average of the taken measures of each descriptor, being used the procedure PRINCOMP of the SAS, version 9.1.3 [30] and the computer program GENES.

For the construction of the program inside based on the distance Euclidian and Clustering method UPGMA the program Statistica 7.1 was used [32].

In relation to genetic diversity, the minimum values were made calculations, maximum, average, standard deviation, variation coefficient us quantitative descriptors, being used the software SAS statistical version 9.1.3 [30].

The selection of the qualitative descriptors was accomplished through the level of entropy of the characters (H), proposed by [29], in agreement with the following model:

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Where the Entropy is a measure of the frequency of the distribution of (n) accesses P = (p1, p2... ps), being: p1 = fi/n and (p1 + p2 +... + ps = 1) since (n = f1 + f2 +... + fs), where f1, f2... fn, are the accountings of each one of the classes (s) in the considered descriptor. This estimate of the entropy was accomplished with the aid of the SAS program - Statistical Analysis System [30]. They were considered as discarded variables all those that presented level of inferior entropy to 0,60.

III. Results And Discussion

Factors obtained linking the entropy level from the qualitative descriptors (Table 1), presented their phenotypic classes, percentile frequency of the accesses in each one of the classes and the level of entropy of Renyi. It was considered as discarded variables all those that presented level of inferior entropy to 0,60.

The entropy level can be used to quantify the present variability in qualitative variables through the observation of the relative frequencies of the classes for each variable evaluated [22]. Works related to level of entropy of Renyi have been developed in several cultures, as cassava [33]; [27]; [1], tobacco [10], Banana [7]; [19], Papaya tree [26].

The variables that presented low entropy were to constrictions of the root (0,00), color of the pulp of the root (0,31), color of the adult leaf (stalk 0,33), in the root presence (0,56). Low values for entropy are associated to a smaller amount of phenotypic classes for the applied variable and to a larger instability in the proportion among the frequency of the varieties in the different phenotypic classes [27].

Table 1. Qualitative Descriptors, phenotypic categories, percentile frequency and entropy level in 40 cassava genotypes, in the Province of Malanje, 2018.

Qualitative Descriptors	Category	Absolute frequency	Percent frequency	Entropy Level
Color ofthepetiole	Green	3	7,50	
	Reddish green	7	17,50	
	Redgreenish	1	2,50	
	Purple	29	72,50	0,82
Pubescenceofyoungleaves	Smooth	1	2,50	
	Fewhair	30	75,00	0,64
	Manyhair	9	22,50	
Apical leaf color	Light green	1	2,50	
	Dark green	3	7,50	0,99
	Purplish green	15	37,50	
	Purple	21	52,50	
Adult leaf color	Geen	36	90,00	0,33
	Purplish green	4	10,00	
Cor externa do Caule	Orange	2	5,00	
	Yellowish green	3	7,50	
	Light brown	19	47,50	1,26
	Silver	13	32,50	
	Dark brown	3	7,50	
Habitofbranching	Erect	4	10,00	
	Dichotomic	25	62,50	0,88
	Tricotomic	11	27,50	
Root epidermis texture	Smooth	20	50,00	0,69
	Rugous	20	50,00	
Root cortex color	Whiteorcream	1	2,50	
	Yellow	2	5,00	0,95
	Pinkish	19	47,50	
	Purple	18	45,00	
External root color	Whiteorcream	26	65,00	0,65
	Yellow	14	35,00	

Root pulp color	Cream	2	5,00	0,31
	White	37	92,50	
	Yellow	1	2,50	
Root constrictions	Fewornone	40	100,00	0,00
Presence of peduncle in the root	Pedunculated	30	75,00	0,56
	Mixed	10	25,00	

Afonso [1], they found in accesses of *Manihot* low entropy for the descriptors: color of the adult leaf, the bloom, prominence of the foliar scars, pubescence of the young leaves, skin surface of the root, presence of belts in the root, easiness delivering of the root, prominence of the film of the root and covering of root.

The variables that presented larger entropies were external color of the stem (1,26), color of the terminal leaf (0,99), color of the cortex of the root, (0,95), ramification habit (0,88), color of the cover (0,82), cover of the epidermis of the root (0,69), external color of the root (0,65), puberty of the young leaf (0,64), once they presented high number of classes, ally to a larger balance among the frequency of the varieties in the different phenotypic classes, what reveals genetic variability among the studied varieties. In study accomplished in germ flat of *Manihot* for Oliveira [27], the largest entropies were found for the descriptors color of the cover, forms of the central lobe, extern color of the stem and number of lobes.

The results obtained in the experimental conditions (Table 2), they indicate that the width of the variation coefficients (CV), they varied of 16, 82% to 80,87% for the related variables the plant height (PH) and shoot yield (SY) respectively, indicating that the plant height (PH) presents smaller dispersion degree and shoot yield (SY) the largest degree, among the variables analyzed. [1], studying the selection of morphologic descriptors in accesses of cassava through techniques multivarieties, observed value of the width of CV, that they varied of 5, 57% to 42,37% for the variables tenor of starch of the root and number of roots for plant. Just [23],verified that the width of CV was from 13,42% to 47,41% to the variables related to the diameter of roots and root yield, in the evaluation study morph agronomics and analysis of grouping cassava in varieties (*Manihot esculenta* Crantz) in the agriculture-ecological conditions of Malanje, what doesn't corroborate with result this study.

To observe that the largest variations happened in the variables plant height (113,82 to 325,65 cm), presenting an average of 193,82 cm; shoot yield (4 a146,00 kg/part), with average of 32,26; root yield (5,50 to 128,0kg/part), with an average of 46,02 kg and height of the first branch (12,54 to 113,03 cm), with an average of 46,68 cm. The variables shoot yield (SY), number of branches and the weight of the roots for plant are linked to the architecture of the plant and, although reports don't exist of which would serialize the ideal, it is known that these descriptors are important, because they facilitate the accomplishment of the cultural deal (1).

In compensation, the smallest variations were detected for the stem diameter (4,45 to 19,58 cm), with an average of 8,98; length of internodes (5,41 to 12,25cm), presenting an average of 8,33; number of tubers (0,54 to7,65), with average of 2,63; and number of branches(1,29 to 6,86), with an average of 2,35.

In relation to the standard deviation, it was verified values of 26,09 for the shoot yield, 40,89 for plant height, indicating that they were the variables that more presented dispersion in relation to the average, while the number of branches and the stem diameter with respective values of 0,71 and 2,71, they were the variables that presented smaller variations in relation to the average (Table 2).

Table 2. Statistics descriptive for the quantitative descriptors used in the characterization of 40 cassava genotypes, in the Province of Malanje, 2018.

Quantitative descriptors	**Minimum**	**Maximum**	**Average**	**Standard deviation**	**Variation coefficient(%)**
Number of branches	1,29	6,86	2,35	0,71	30,46
Plant height (cm)	113,82	325,65	193,87	40,89	21,11
Stem diameter (cm)	4,45	19,58	8,98	2,71	30,19
Length of internodes (cm)	5,41	12,25	8,33	1,35	16,82
Height of the first branch (cm)	12,54	113,03	46,68	16,13	34,55
Number of tubers	0,54	7,65	2,63	1,29	49,24
Root diameter (cm)	9,70	35,20	21,94	3,69	16,82
Root length (cm)	15,20	62,60	30,44	7,00	23,01
Shoot yield (kg)	4,00	146,00	32,26	26,09	80,87
Root yield (kg)	5,50	128,00	46,02	24,51	53,25

In the figure 1 the program of obtained similarity less is represented using the quantitative descriptors for the cassava accesses in study. The coefficient of confenetic correlation (CCC) it was of 0,73 **, the cut point was suggested by the criterion of the pseudo-t2. The formation of three groups was verified.

The group I was constituted by the genotype 29 (Malanje). The group II was constituted by the genotype 19 (Banana). The most divergent genotypes were the 29 (Malanje) and the 19 (Banana), that they formed unitary groups. The genotype Malanje is characterized by plants that possess number of roots that vary from four to seven. Already the group III was constituted of 38 genotypes, being the largest group.

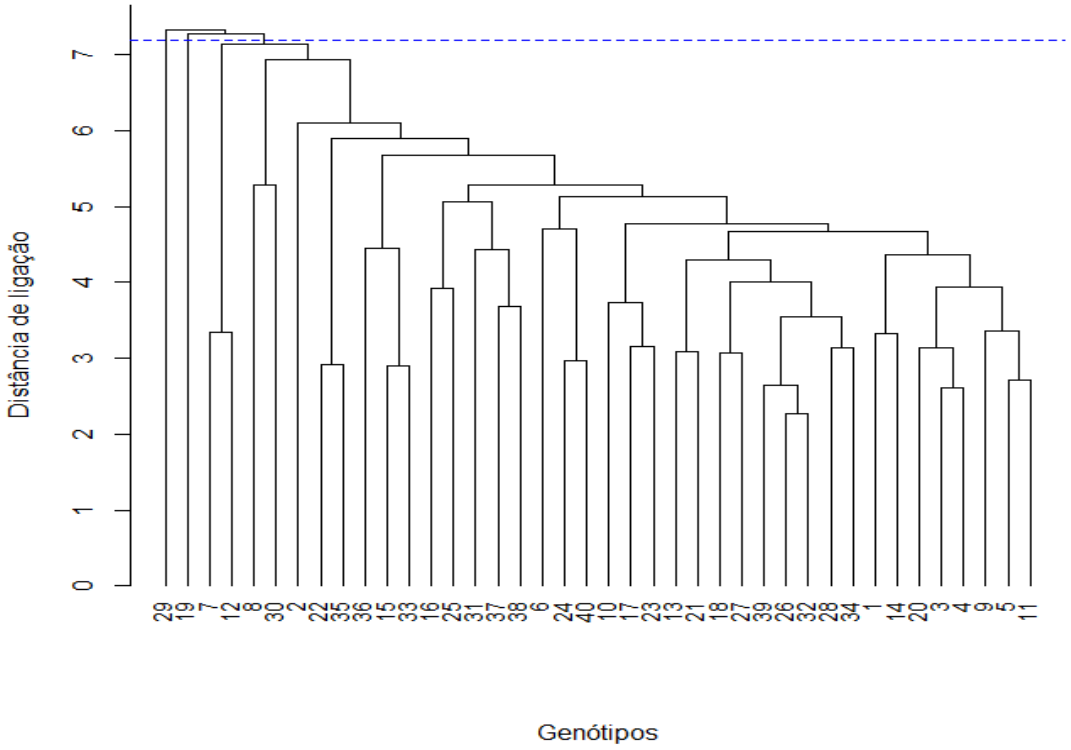

Figure 1. Dendrogram based on the distance Mahalanobis and UPGMA clustering method for quantitative descriptors, used in the evaluation of 40 cassava genotypes in Malanje, 2018.

With base us 12 qualitative descriptors, it was obtained the into program with formation of three groups and coefficient of correlation confenetic of 0,80 ** (Figure 2). it can be verified that the group I was formed by 12 genotypes, being the most common characters the presence of few hair in the puberty of the young leaf, color of the leaf green purpled, stalk presence in the root pedunculated, habit of ramification diversification, and the color of the pulp of the root cremates.

The Group II was composed by a genotype, has some of the characters in common, not differentiating of some groups, color of the cortex of the root white or cream-colored, habit of ramification erect and texture of the epidermis of the flat root. The Group III was formed by 27 genotypes, has in common and different from the others the external color of the silver stem, external color of the yellowish root and stalk presence in the mixed roots and pedunculated. The genotype 36 (Muringa), it was shown quite divergent of the others, because it formed an exclusive group in the analysis (Figure 2).

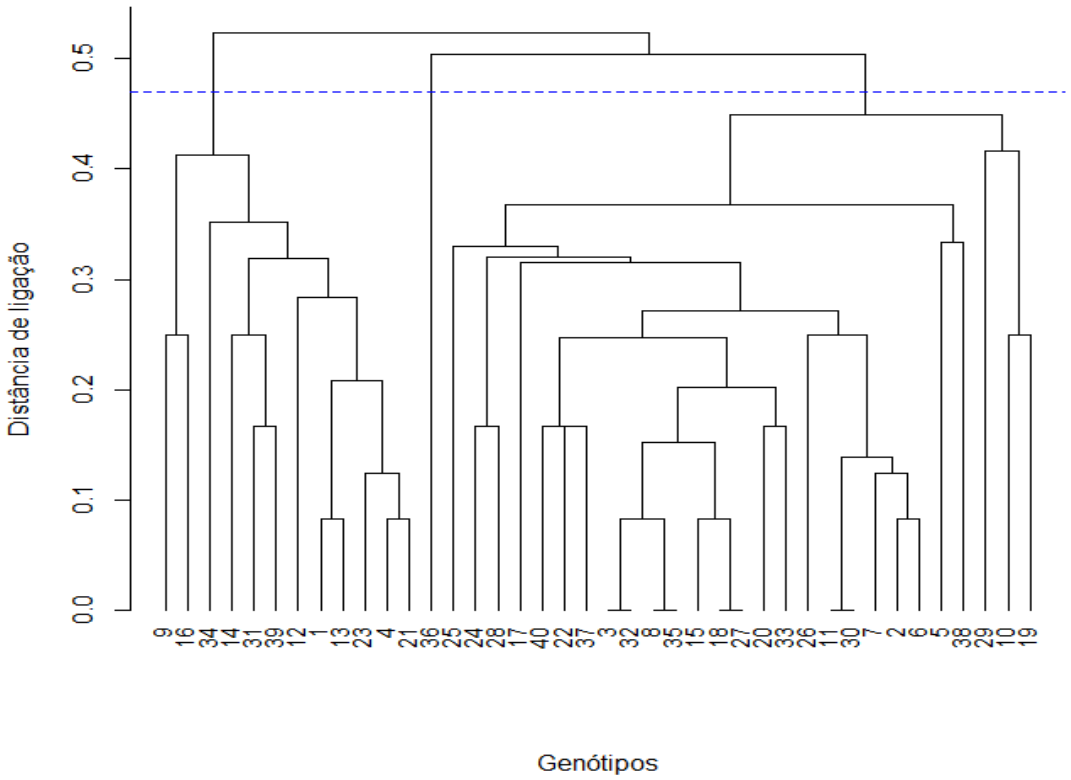

Figure 2. Dendrogram based on the complement of the similarity coefficient and UPGMA clustering method for categorical qualitative descriptors used in the evaluation of the 40 cassava genotypes in Malanje, 2018.

The simultaneous analysis for the algorithm of Gower was used to represent the variability of the cassava accesses graphically for his/her largest efficiency in quantifying the differences among them (Figure 3). For the criterion of the pseudo-t2, it can be observed that the maximum point was reached in the step of the formation of 3 groups (correlation confenetic 0,71**), indicating that this point is related with to smallest probability of mean wise of the test and, consequently, it indicates the interruption of the grouping process. It is observed that the group I was composed by a variety and the group II formed by a variety and group III was the largest formed by 38 varieties. Aligned to the obtained results, a characterization of Nobre [26] with accesses of papaya tree of BAG of Embrapa it verified the formation of 3 groups in the analysis multivariety (Gower), that it indicates the existence of narrow genetic base of that species. Other researches with coconut tree, banana tree, umbu-cajazeira and passion fruit, they indicated the same pattern in the formation of small groups [7]; [5]; [22]; [24].

As they suggest Bussab [9], in the grouping analyses they are acceptable values of coefficient of correlation confenetic starting from 0,80. However, it is important to stand out that there is in the literature coefficients of correlation confenetic, with values starting from 0,60 [8]; [6]. Coefficients with values understood between 0,60 and 0,80 can be consequence of the small number of used variables, the type and the amount of variables, as well as the quality of the obtained data, they can influence the results [27].

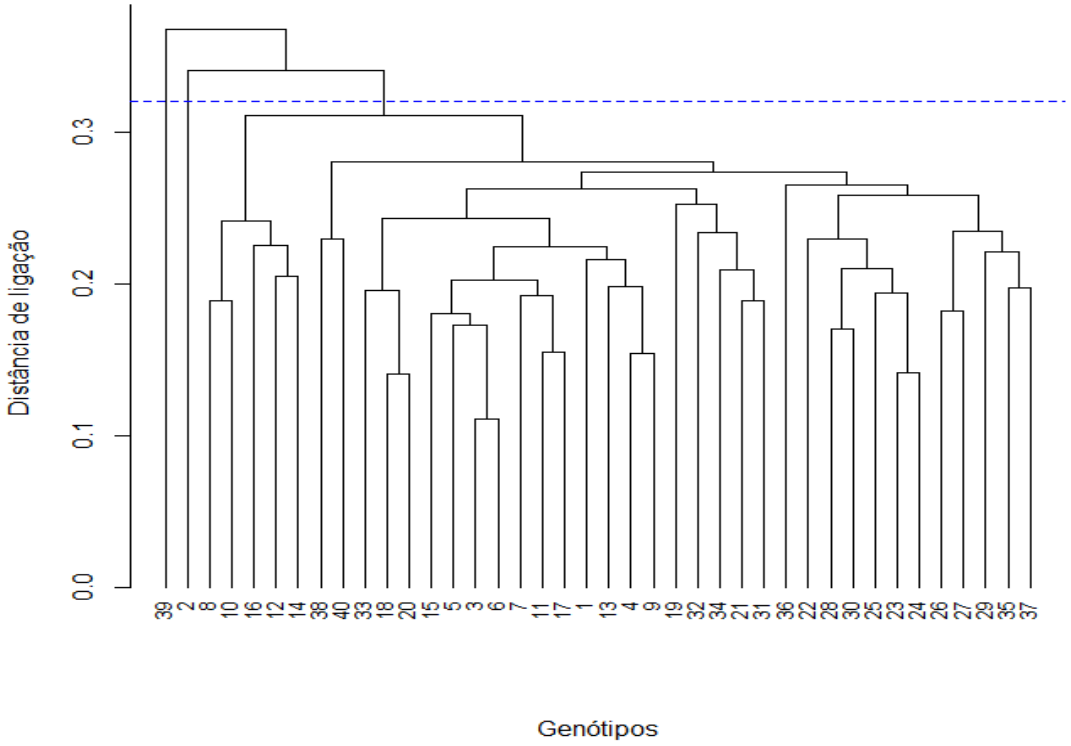

Figure 3. Dendrogram based on Gower distance and UPGMA clustering method for quantitative and qualitative descriptors, used in the evaluation of the 40 cassava genotypes in Malanje, 2018.

IV. Conclusions

Genetic variability exists starting from the characteristics morph agronomics in the appraised cassava varieties.

The qualitative descriptors that more contributes to the genetic divergence among the cassava varieties are external color of the stem, color of the terminal leaf, color of the cortex of the root, ramification habit and covered color.

The analysis quantitative and qualitative datasets provides larger efficiency in the knowledge of the existent divergence among the cassava varieties, and it allows guide future studies of hybridizations.

The genotypes 29 (Malanje), 2 (Maria dia Pedro), 19 (Banana), 36 (Muringa), 39 (Gueti) they were shown quite divergent of the others, being like this, selected as varieties of better answer.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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