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Influence of harvest time and agricultural year in yield components of table cassava cultivars

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ABSTRACT

Agricultural year and harvesting season may interfere with yield and post-harvest performance of table cassava cultivars, with consequences for their commercialization and net profit. The objective of this work was to quantify the effects of harvesting season and agricultural year on yield performance of table cassava cultivars and their correlations. Planting was carried out in September in two consecutive years near Londrina city, PR, in a Clay-textured Oxisols red eutrophric. The experiment followed a randomized complete block design (RCBD) with four replications, consisting of seven harvesting times (8, 10, 12, 14, 16, 18 and 20 months after planting) for each agricultural year. The table cassava cultivars used were: Catarina Amarela, Catarina Branca, Mato Grosso, Pretona, IAPAR 19-Pioneira and IAC 576-70. The following agronomic characteristics were evaluated: number of roots per plant, length, diameter and yield of tuberous roots, as well as the following post-harvest characteristics: net yield and peeling time per kg of each cassava cultivar. The cultivars, harvesting time and agricultural year affected the yield and post-harvest characteristics. 'IAPAR 19-Pioneira' presented a larger number of roots per plant (9.9) and peeling time (224.8 seconds.kg^{-1}), but lower yield % (66.2%) and diameter of tuberous roots (4.0 cm), regardless of harvest time and year of planting. 'Catarina Amarela', 'Catarina Branca', 'IAC 576-70' and 'Pretona' provided higher yields, diameters and reduced peeling times. The root mean diameter is one of the characteristics that can be used as a selection criterion in a table cassava genetic breeding program: the larger the root mean diameter the larger are tuber root yield and percentage of weight of the tradable part of the roots, and the lower is the time of peeling.

Key words: *Manihot esculenta* Crantz, post-harvest, tuber root yield, minimum processing.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is the main source of carbohydrates for over 800 million people worldwide, especially in developing countries (FAO 2013). Its origin was probably Brazil, being disseminated to other continents by Portuguese and Spanish in the colonial period. It stands out for its rusticity and great adaptability to unfavorable climate and soil conditions, and is considered an alternative crop, once it presents adaptation strategies to climate changes (FAO 2015).

According to the United Nations Food and Agriculture Organization (FAO), cassava production continues to grow at a rapid pace. Brazil led the world production of the root until 1991, when it was overtaken by Nigeria. It remained in the second place until 2011 (25.3 million t). In 2016, world production was 277.1 million t. Nigeria totaled 57.13 million t, followed by Thailand, Indonesia and Brazil, the 4th, with 21.08 million t. Thailand's output growth over the last 20 years has been 4% a year and productivity 2.1% a year, as a result of massive investments in public and private research (Prakash 2018).

In addition to the use of cassava roots, its leaves can be used as calcium and vitamins source, as well as a protein-rich food, responsible for the elimination of cyanogenic compounds (cooking and drying) (Lancaster and Brooks 1983). The branches, usually used for propagation (10 to 20%), present an mean of 30% of starch. They can be extracted with water after being ground, and the waste can be used as fuel (Zhu et al., 2015).

In Brazil, there is a great disparity among the producing states, especially when comparing the North-Northeast with those of the Center-South. Therefore, research in Brazil has to target not only the genetic material but also the management of planting, harvesting and post harvest. The mean yield of 15.2 $t.ha^{-1}$ is considered low and has remained with small oscillations in the last 40 years (Conab 2016). This value is much lower than the biological productive potential of the crop, which is 90 $t.ha^{-1}$. Cassava is an important product in the Brazilian agribusiness. Besides being the basis of food for both a significant part of the population and for animals, the root is raw material for the agroindustry of different types of flour, which are income sources for many families. Starch and other modified starches have their use, apart from food, in the chemical, steel and oil industries, among others (Felipe 2018).

Planting time is the main factor related to the production of tuberous roots, regardless of the cultivar or any other cultural practice that may be adopted, and it depends on the region it is produced. In the Northwest of Paraná, planting begins after winter and early summer. The best planting times for cassava are also related to the availability of mature branches and climatic conditions favoring sprouting and root formation (Takahashi and Gonçalo 2005).

Cassava is cultivated in all Brazilian states and several cultivars are used, a fact that demands specific information about the most popular ones, regarding the agronomic characteristics, such as: plant spacing and density, adequacy to mechanized planting, pruning management, cultural practices and yield. The wide genetic variability is fundamental to the development of productive and resistant or tolerant to biological and environmental stress cultivars (Albuquerque et al., 2009).

Table cassava, in addition to these characteristics, must meet the sensorial and technological demands of the final consumer, demonstrating good shelf life, flavor and characteristic colors, soft texture and fast cooking. The roots have a short shelf life, due to a process known as post-harvest physiological deterioration (Salcedo and Siritunga 2011). The bark on the outermost part of the root has a thin suberose layer (felema), with a texture varying from smooth to rough, and with colors ranging from white, brown or gray. Then, a layer called cortex is found, containing cells rich in starch. In addition, there is the phloem, which may contain linamarin, a substance that releases hydrocyanic acid HCN by hydrolysis, the poisonous principle that will classify the cultivars between meek (table), intermediate or *bravas* (industrial). The edible part is the central cylinder, where the starch is accumulated in parenchymal cells. In the center, there is the vascular cambium and the xylem, which form a cord of cellulosic nature (Bernardes et al., 2009).

Low levels of cyanogenic and fiber compounds and high contents of starch and dry matter are desirable for *in natura* consumption and are strongly influenced by the age of the plant (Borges et al., 2002; Valle et al., 2004; Franck et al., 2011), usually up to 13 months (Lorenzi 2003).

Sensory characteristics follow regional patterns. In São Paulo, the commercial standard is that of the cultivar IAC 576-70, which covers almost 100% of the *in natura* and frozen markets. They are cylindrical, yellow and have fast- cooking roots (Lorenzi and Valle 2002).

Studies carried out by Fialho et al. (2007), with eight cassava cultivars harvested at 8, 10, 12, 14 and 16 months after planting, showed that the shortest cooking times were observed for the roots harvested at 8 and 10 months.

Knowledge about the most favorable period for harvesting is necessary in order to obtain the highest yield with the highest quality. When harvest is anticipated, there is a reduction in yield, and late harvest results in quality loss, development of fibrous roots and reduction of starch (Benesi et al., 2008). The objective of this research was to investigate the effects of the harvesting season and year of planting on the productive performance of table cassava cultivars and their correlations.

MATERIAL AND METHODS

The research was carried out in two subsequent agricultural years, on a farm near Londrina, Paraná, Brazil, (Latitude 23º19 'S and Longitude 51º12' W), with altitude of 835 m. The soil is classified as Oxisols red eutrophric (Embrapa 2013), with a very clayey texture. Rainfall and mean air temperature data were provided by Paraná Agronomic Institute IAPAR).

The cassava cultivars evaluated in this study were Catarina Amarela, Catarina Branca, Mato Grosso, Pretona, IAPAR 19-Pioneira and IAC 576-70. The IAPAR 19-Pioneira cassava cultivar (Iapar 1992) was registered by IAPAR. The cultivar IAC 576-70 was registered by Campinas Agronomic Institute (IAC) (Lorenzi et al., 1996). The others are the most commonly planted cultivars in the region. The description of the physical and morphological characteristics of the table cassava cultivars were performed by the mean of four plants harvested at eight months after planting (Table 1).

Table 1. Description of physical and morphological characteristics of cassava cultivars evaluated in the research. Londrina, PR.

Cultivar	Code Brazil	Color							PH[1] (m)	FBH[2] (m)
		Pulp	Skin	Cortex	Stem	Sprout	Leaf	Petiole		
Catarina Amarela	-	Yellow	Brown	Cream	Yellow	Purple	Green	Green	2.45	0.44
Catarina Branca	-	White	LB[3]	White	Yellow	PG[6]	Green	Green	2.55	0.58
Mato Grosso	-	White	LB	White	LB-G[4]	Green	Green	Green	2.41	0.68
Pretona	-	White	Brown	White	DB[5]	PG	Green	PG	2.65	0.79
IAPAR 19-Pioneira	BRA-078280	Yellow	LB	Cream	LB	PG	Green	Purple	2.62	0.91
IAC 576-70	BRA-078271	Yellow	Brown	Cream	LB-G	Green	Green	PG	2.38	0.69

[1]PH: Plant height. [2]FBH: first branch height. [3]LB: light brown. [4]LB-G: light brown – Green. [5]DB: dark brown. [6]PG: Purple green.

The experiment was designed using randomized complete blocks, followed by the split plot in time model with four replications, consisting of seven harvesting times (8, 10, 12, 14, 16, 18 and 20 months after planting), for each agricultural year. Each cultivar represented a plot, and each harvest season represented a subplot. Each experimental unit was formed by six lines with 8 m in length, spacing 1 m between rows and 1 m between plants, totalizing 48 plants per experimental unit. Ten manioc lines were planted as a border around the experimental area.

The stems were cut into five to seven axillary buds. Planting was carried out in September of each agricultural year, covered using hand hoes at an mean depth of 0.08 m. Seven harvest times were performed every year. The first harvesting season was carried out eight months after planting, that is, in May, and the next every 60 days, corresponding to the months of July (10 months), September (12 months), November (14 months), January (16 months), March (18 months) and May (20 months) of each agricultural year. At each harvest, three competitive plants of each repetition were collected. Therefore, 12 plants per cultivar were evaluated at each harvesting season. The experiments were conducted similarly to that carried out by the rural producers of the region. Fertilizers were not applied and, when necessary, manual weeding was used. The roots of commercial size (length greater than 0.20 m and weight larger than 150 g) were evaluated.

The following productive and post-harvest characteristics were determined:

Tuberous Root Length (TRL): distance between the base and the apex of the root, using a graduated ruler (cm);
Tuberous Root Diameter (TRD): measure the diameter of the middle part of the already stripped root, using a pachymeter (cm);
Mean number of roots per plant (NRP);
Tuber root yield (TRY): mean weight of roots with bark (kg.plant^{-1});
Yield (PTP): percentage relation between the tradable portion of the roots and their respective productivities (%);
Time used for debarking: one kg of the tradable part of the root (TKD): total time spent by three people to peel the roots of three plants, divided by the weight of the marketable part of these roots (seconds kg^{-1}).

Before performing the analysis of variance (ANOVA), data were transformed as follows: number of roots per plant per square root; mean diameter of tuberous roots, peeling time and tuberosic root yield, by natural logarithm and yield, by arcsen (PPC.100-1) 1/2 (Steel and Torrie 1980). The values of each experimental unit were obtained based on the mean of three competitive plants of each plot. The coefficients of experimental variation were calculated based on the mean square error calculated in the ANOVA.

For the F test ($p < 0.05$ and $p < 0.01$), in the ANOVA for each year, the Cultivar x Repetition interaction was used as an error estimate, and in the joint ANOVA, the Cultivar x Repetition interaction was used throughout the year. The individual ANOVA was performed with the GENES® 0,1,0 program (Cruz 1998) for each year, and the SAS® 6,12 program (SAS 1996) was used for the joint ANOVA. The Tukey's test ($p < 0.05$) was used to compare the means. Pearson's correlation coefficients were calculated using the STATISTICA® 5.0 program (Statistica 1998).

RESULTS AND DISCUSSION

By comparing the two growing years, temperatures showed to be similar, but there were differences in rainfall distribution (Figure 1). There was significant effect of the agricultural year on the root length, root diameter, number of roots per plant and yield (Table 2). The agronomic characters, therefore, were influenced by the climatic conditions of each agricultural year, likely due to the difference in the rainfall distribution. The characteristics related to the processing, such as peeling time and net yield, were not influenced by the agricultural year.

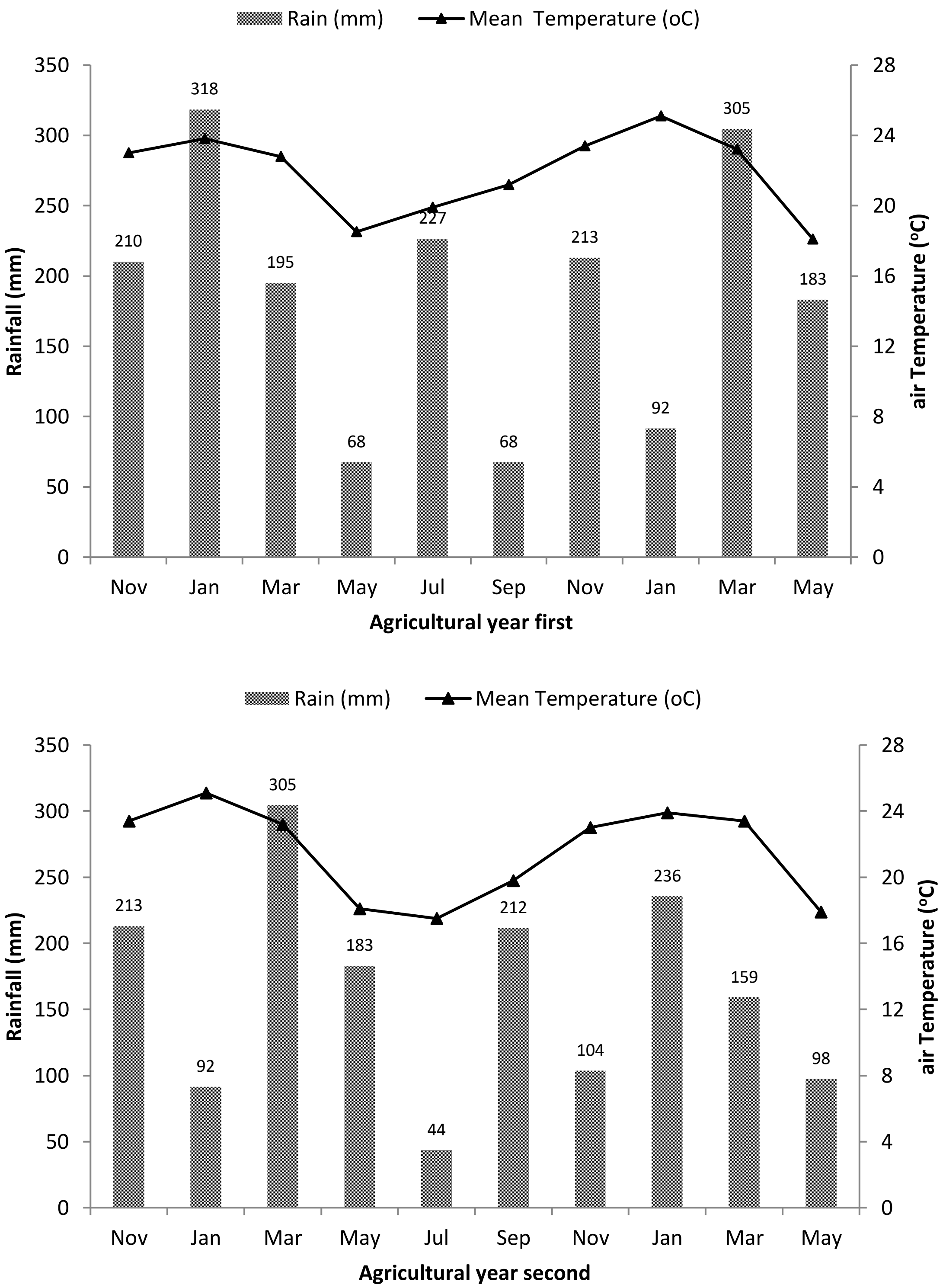

Figure 1. Mean values of rainfall (mm) and mean air temperature (ºC) during the period from planting to the last harvest in two agricultural years. Londrina, PR.

Table 2. Sources of variation effects and levels of significance of the F tests and their respective degrees of freedom (GL), evaluated by the joint analysis of variance of two agricultural years, for six characteristics. Londrina, PR.

SOURCE OF VARIATION	G.L.	MRL[1] cm	RMD cm	NRP	TRY Kg.plant^{-1}	Yield (%)	TDK Seconds.kg^{-1}
Agricultural year (Y)	1	**[2]	**	**	**	ns	ns
Cultivar (C)	5	**	**	**	**	**	**
Y x C	5	ns	ns	ns	ns	ns	**
Repetition	6	ns	ns	ns	ns	ns	ns
Harvest time (H)	6	**	**	ns	**	**	**
C x H	30	**	**	ns	**	ns	**
C x H x Y	36	ns	*	ns	ns	ns	ns
Mean		30.6	4.6	8.6	4.5	72.7	163.0
Coefficient of variation %		9.8	10.5	8.9	13.3	4.5	22.9

[1]MRL: mean root length (cm), RMD: Root mean diameter (cm), NRP: mean number of roots per plant, TRY: tuber root yield (kg / plant), Yield (%), and TDK: time for debarking one kilogram of the marketable part of the root (sec / kg). [2]ns: not significant, *significant (p <0.05, and ** significant (p <0.01).

All traits evaluated had a genotypic effect, that is, the cultivar. The only effect was that of the interaction (year x cultivar) on peeling time. There was no effect of the repetitions within the year for any of the characters, indicating that the experimental area was homogeneous. The variation coefficients were low in general, indicating an excellent experimental precision of data collection.

Harvest time had significant effects at 1% level on the traits studied, except for the number of roots per plant. At 8 months (first harvest), plants showed a certain number of tuberous roots that was not altered during their development. There was no effect of the interaction cultivar x harvest season for number of roots per plant and yield (PTP). Triple interaction occurred (cultivar x harvesting season x year), with significant effect (p <0.05) for root diameter (Table 2).

The mean length and number of roots per plant remained practically unchanged from the first to the seventh harvest in the two years (Tables 3 and 4). The diameter of the roots showed a gradual increase, with the permanence of the plants in the field due to the accumulation of reserves (carbohydrates, especially starch) until at least 16 and 18 months after planting.

Due to the great variation in the length of table cassava commercial roots, the most important factor for their classification is their diameter. In this way, larger diameter of roots obtains a better classification, according to the standards adopted by CEAGESP. In a study conducted by Williams (1974), linear relationships between the mean mass and the root diameter were demonstrated, so that the larger the root diameter, the higher the mean yields of roots per plant.

Root lengths means for 'Mato Grosso' (27.0 cm), followed by 'IAPAR 19-Pioneira' (30.9 cm), at most harvest times and in the first agricultural year presented lower values than those of other cultivars (Table 3). Considering the two agricultural years (Table 5), 'Mato Grosso' presented the lowest root length (27.1 cm). 'IAPAR 19-Pioneira' presented lower mean root diameter values of 3.7 and 4.2 cm for the first and second agricultural years, and higher numbers of roots per plant (11.2) in the first year, in almost all harvest seasons (Tables 3 and 4). In the mean of the two agricultural years, 'IAPAR 19-Pioneira (Table 5) showed the lowest root diameters (4.0 cm) and yields (66.2%), and the highest number of roots per plant (9.9) and stripping time (224.8 seconds.kg^{-1}). These results are consistent, since it is more time-consuming to peel finer and smaller roots. These cultivars were differentiated from the others regarding these characteristics, which will have an impact on the processing performance. An important observation was that 'IAPAR 19-Pioneira' has reduced cooking time in all harvest seasons (data to be published).

There was an increase in root diameter with the permanence of the plants in the field (Tables 3 and 4), which results in a smaller discrepancy in peeling time values among the cultivars. Thus, 'IAPAR 19-Pioneira', can be harvested from 14 months of planting, when the cultivars do not present marked differences among them both in yield and in peeling time. In practice, for table cassava processing, these differences are important until the eighteenth month after planting. Thus, the roots acquire a high diameter, which makes them not well accepted by the consumer market.

Table 3. Mean values, coefficients of variation (CV%) and test of means (Tukey) of the agronomic characteristics evaluated in the first agricultural year for the six cultivars of table cassava, in seven harvest seasons. Londrina, PR.

	Harvest time (months after planting)							
Cultivar	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**Mean**
	Mean root length (cm) (MRL)							
Catarina Amarela	34.7 a A[1]	32.7 a A	32.8 a A	35.5 a A	30.9 a A	36.5 a A	35.2 a A	34.0 ab
Catarina Branca	34.8 a AB	31.7 a AB	29.3 ab B	33.6 a AB	33.7 a AB	30.7 ab AB	36.2 a B	32.9 ab
Mato Grosso	28.2 b A	28.6 a A	26.3 b A	24.4 b A	27.3 a A	24.6 b A	29.7 a A	27.0 c
Iapar-19 Pioneira	32.8 ab A	30.8 a A	29.5 ab A	31.6 ab A	30.5 a A	29.1 ab A	32.1 a A	30.9 b
Pretona	35.8 a A	32.3 a A	32.9 a A	29.2 ab A	31.9 a A	32.8 ab A	32.6 a A	32.5 ab
IAC 576-70	35.2 a A	32.0 a AB	31.0 ab B	34.8 a AB	33.0 a AB	32.6 ab AB	35.3 a A	33.4 ab
Mean	33.6 A	31.5 AB	30.3 B	31.5 AB	31.2 AB	31.0 AB	33.5 A	31.8
Coefficient of variation(%)	7.6	8.5	7.0	10.7	10.1	12.7	9.8	9.4
	Mean root diameter (cm) (MRD)							
Catarina Amarela	3.5 ab E	3.7 ab DE	3.6 a DE	4.4 ab CD	5.0 a BC	6.0 a AB	6.8 a A	4.7 a
Catarina Branca	3.4 abc D	3.5 b D	3.6 a D	4.6 ab C	5.3 a B	6.0 a AB	6.2 ab A	4.7 a
Mato Grosso	3.6 a C	3.9 a C	3.8 a C	4.1 bc BC	4.8 ab AB	5.5 a A	5.6 ab A	4.5 a
Iapar-19 Pioneira	3.0 c C	3.1 c BC	3.2 b C	3.6 c BC	3.8 b B	4.9 a A	4.6 b A	3.7 b
Pretona	3.7 a C	4.0 a C	3.9 a C	4.8 a B	5.5 a AB	6.1 a A	5.7 ab AB	4.8 a
IAC 576-70	3.1 bc D	3.4 b CD	3.4 ab D	4.1 bc C	5.2 a B	6.3 a A	5.7 ab AB	4.5 a
Mean	3.4 D	3.6 D	3.6 D	4.3 C	5.0 B	5.8 A	5.8 A	4.5
Coefficient of variation(%)	4.6	2.9	4.6	4.8	7.1	7.0	8.1	9.4
	Mean number of roots per plant (NRP)							
Catarina Amarela	7.5 a A	9.0 ab A	8.8 b A	9.7 a A	9.0 a A	8.3 a A	8.6 a A	8.9 b
Catarina Branca	8.8 a A	9.1 ab A	10.8 ab A	9.3 a A	9.5 a A	11.0 a A	8.9 a A	9.5 b
Mato Grosso	7.8 a A	7.9 b A	9.9 ab A	9.4 a A	9.0 a A	8.8 a A	8.9 a A	9.2 b
Iapar-19 Pioneira	11.8 a A	11.8 a A	13.3 a A	10.2 a A	10.8 a A	11.8 a A	11.7 a A	11.2 a
Pretona	9.0 a AB	9.3 ab AB	9.4 b AB	11.6 a A	9.0 a AB	6.5 a B	8.3 a AB	9.1 b
IAC 576-70	8.3 a A	10.1 ab A	9.4 b A	9.3 a A	9.3 a A	10.3 a A	8.8 a A	9.2 b
Mean	8.8 A	9.5 A	10.3 A	9.9 A	9.4 A	9.4 A	9.3 A	9.5
Coefficient of variation(%)	9.6	6.7	7.6	8.3	5.3	11.8	9.1	8.5
	Tuberous roots Yield (kg.plant^{-1}) (TRY)							
Catarina Amarela	3.0 a C	3.2 a C	3.1 a C	5.4 ab B	5.5 ab B	8.0 a AB	8.7 a A	5.3 a
Catarina Branca	3.0 a C	3.0 a C	3.6 a C	5.4 ab B	6.8 a AB	8.1 a A	8.7 a A	5.5 a
Mato Grosso	2.6 a B	2.6 a B	3.6 a AB	3.5 c AB	3.8 c AB	4.7 a A	5.4 a A	3.7 b
Iapar-19 Pioneira	2.8 a C	3.1 a C	3.4 a BC	4.0 bc ABC	4.4 bc ABC	5.4 bc ABC	6.5 a A	4.2 b
Pretona	3.3 a B	3.8 a B	4.1 a B	6.4 a A	6.3 ab A	6.1 a A	6.3 a A	5.2 ab
IAC 576-70	2.6 a D	3.1 a CD	3.2 a CD	4.9 abc BC	6.4 a AB	7.8 a AB	7.5 a A	5.1 a
Mean	2.9 D	3.1 C	3.5 C	4.9 C	5.5 B	6.7 A	7.2 A	4.8
Coefficient of variation(%)	2.2	2.4	3.0	1.7	1.5	2.7	2.5	2.3
	Yield (%)							
Catarina Amarela	72.8 a A	74.3 a A	76.2 a A	76.8 a A	74.4 ab A	75.9 ab A	78.5 a A	75.6 a
Catarina Branca	70.3 a B	70.3 a B	76.3 a A	78.2 a A	76.6 a A	79.4 a A	76.1 a A	75.3 a
Mato Grosso	71.9 a A	69.8 a A	74.5 a A	71.4 a A	73.7 a A	72.4 ab A	74.5 a A	72.6 bd
Iapar-19 Pioneira	62.5 b AB	58.7 b B	66.6 b AB	66.7 a AB	60.1 b AB	67.8 b A	66.5 b AB	64.1 d
Pretona	72.1 a A	73.2 a A	76.7 a A	76.5 a A	73.9 a A	72.1 ab A	75.9 a A	74.4 ab
IAC 576-70	69.2 a A	71.8 a A	74.6 a A	76.4 a A	70.2 ab A	67.6 b A	74.8 a A	72.1 c
Mean	69.8 B	69.9 B	74.0 A	74.3 A	71.5 AB	72.5 AB	74.4 A	72.3
Coefficient of variation(%)	2.5	2.8	1.9	5.0	3.9	4.4	2.9	3.6
	Time for debarking one kilogram of the marketable part of the root (seconds.Kg^{-1}) (TDK)							
Catarina Amarela	149.9 b B	220.7 b A	145.6 b B	75.3 b C	96.2 b C	89.6 ab C	91.4 a C	124.0 c
Catarina Branca	186.4 b B	286.6 b A	174.5 ab B	82.7 ab C	99.3 ab C	77.3 b C	108.1 a C	145.8 bc
Mato Grosso	237.4 ab A	266.0 b A	131.5 b B	119.7ab B	141.4 ab B	133.9 ab B	139.2 a B	170.0 b
Iapar-19Pioneira	384.3 a AB	433.8 a A	246.4 a BC	136.4 a D	177.6 a CD	211.8 a CD	155.0 a CD	241.7 a
Pretona	184.4 b AB	228.4 b A	136.7 b BC	79.2 b D	108.4 ab CD	110.7 ab BC	138.4 a BC	143.8 bc
IAC 576-70	201.6 b AB	279.1 b A	146.0 b BC	82.8 b D	96.3 ab CD	102.7 ab CD	106.2 a CD	144.8 bc
Mean	224.4 B	286.6 A	163.4 C	96.0 E	119.5 DE	121.0 D	123.1 D	161.9
Coefficient of variation(%)	3.5	2.3	2.9	3.8	4.6	4.3	4.0	3.1

[1]Values followed by different lowercase letters, in the same column, indicate significant differences between cultivars by Tukey´s test (p> 0.05). Values followed by different capital letters, in the same row show differences between harvesting times. Yield (%): Percentage of the weight of the marketable part of the roots (%).

Yield was estimated using the TRY (kg.plant^{-1}) character, presented in Tables 3 and 4. There was a significant effect at the 5% level of significance among cultivars at the first agricultural year, with 14 and 16 months of planting, and in the general means of the first and second agricultural years. As in the results discussed above, 'Mato Grosso' and 'IAPAR 19-Pioneira' showed, on these occasions, yields of medium tuberous roots smaller than those of other cultivars, with estimated values of 3.7 and 4.2 kg.plant^{-1}, respectively (Table 4). There was an increase in yield, with the permanence of the plants in the field until the 16th month in the first year, and until the 18th month in the second agricultural year. Considering that a plant was planted per linear meter, and that the spacing was one meter between rows, the yield estimate in $t.ha^{-1}$ could be obtained by multiplying the PRT value by 10, for purposes of comparison with other results in terms of $t.ha^{-1}$.

Determination of harvesting time is an essential factor for tuberous roots yield studies. The lack of knowledge on the cycle can cause losses to the producers. If cassava is harvested early, loss of yield occurs because it has not yet reached the maximum amount of dry matter accumulation. If it is harvested late, root rot index caused by the fungus *Phytophthora drechsleri* Tuker increases, in addition to keeping the area occupied for longer than necessary (Moura 1998). Carvalho et al. (1993) evaluated six cultivars at 20 months after planting and observed high root yield, higher starch content and lower moisture content. However, Moura (1998), evaluating cultivars and times of cassava harvest in Acre, verified that the best harvest season is conditioned on the cultivar.

The yield % was estimated by the percentage of weight of the marketable part of the roots. In the first agricultural year (Table 3), 'IAPAR 19-Pioneira' presented lower results (64.1% in the mean of the seven harvesting seasons) at practically all harvesting times, followed by 'IAC 576-70' (72.1% in the mean of the seven harvest seasons). In the second agricultural year (Table 4), the difference between the cultivars was not as evident, since it only showed a significant difference ($p < 0.05$) up to 14 months, but 'IAPAR 19-Pioneira' had the lowest mean in the two agricultural years (68.3%) (Tables 3 and 4).

Time spent for debarking one kilogram of the marketable part of the root (TKD) was determined because it is one of the most important steps for the minimum processing of cassava tuber roots. In both agricultural years, it was verified that 'IAPAR 19-Pioneira' presented greater peeling times than the others (242.7 and 206.9 $seconds.kg^{-1}$), but this difference was only significant ($p < 0.05$) until reaching the 14th month after planting in the first year of planting; and in the 12 th and 18 th months after planting in the second crop year, and in the means of the seven crop seasons for the two years (Tables 3 and 4). The highest values were observed at 8 and 10 months after planting, referring to the months of May and July. This period is marked by low temperatures and the cold makes the bark more adhered to the root, making it difficult to peel.

Taking into account the characteristics of diameter, number of roots, yield, yield and peeling time, 'Catarina Amarela', 'Catarina Branca', 'Pretona' and 'IAC 576-70' cultivars would be indicated for cultivation, aiming at the production of minimally processed table manioc. However, 'Pretona' may not be the most suitable for this purpose, for it presented rapid darkening after peeling, which could hinder the commercialization of the product.

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The mean number of roots per plant ranged from 6.0 to 13.3, the root diameter of 3.0 to 7.2 cm and tuber roots yield were estimated from 17 to 87 $t.ha^{-1}$, which demonstrate the high yield achieved in the research (Tables 3 and 4).

Yield % results ranged from 58.9 to 80.8%. Possibly our yield-related results, with low coefficients of variation, are associated with the fact that the people who processed the roots were well trained and do this work on a daily basis. For the 'IAPAR 19-Pioneira' cultivar, yields at 12 months were 65.6 and 68.2% for the first and second year of planting and 66.5, and 74.4% for 20 months after planting (Tables 3 and 4).

Pearson correlation analysis was performed for each character studied, among the means of the results obtained, in the first and second year of planting. It aimed at evaluating repeatability (Table 6). With the exception of the number of roots per plant, there were correlations above 0.53 for the characters studied in the two years of planting (Table 6), especially for diameter, root peeling time and yield (0.93, 0.85 and 0.86, respectively).

Table 4. Mean values, coefficients of variation (CV%) and test of means (1) (Tukey) of the agronomic characteristics evaluated, in the second agricultural year of cultivation for the six cultivars of table cassava, in seven harvest seasons, Londrina, PR.

	HARVEST TIME (months after planting)							
Cultivar	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**Média**
	----- **Mean root length (cm) (MRL)** -----							
Catarina Amarela	35.5 a A	29.3 a A	30.6 a A	32.8 a A	30.5 a A	32.2 a A	29.2 a A	31.5 a
Catarina Branca	31.9 ab AB	27.8 a B	30.6 a AB	35.6 a A	30.9 aAB	33.2 a AB	29.7 a AB	31.4 a
Mato Grosso	26.6 b AB	30.4 a AB	24.3 b B	24.8 c B	25.6 a B	25.3 b B	33.3 a A	27.2 b
Iapar-19 Pioneira	30.1 ab A	28.8 a A	28.2 ab A	25.9 bc A	25.9 a A	26.9 ab A	28.7 a A	27.8 b
Pretona	29.5 ab A	28.5 a A	29.5 a A	32.5 a A	30.9 a A	30.3 ab A	28.1 a A	29.9 ab
IAC 576-70	28.7 ab A	37.6 a A	29.3 a A	31.7 ab A	28.4 a A	32.1 a A	27.9 a A	29.4 ab
Mean	30.4 A	28.7 A	28.8 A	28.8 A	30.6 A	28.7 A	30.0 A	29.5
Coefficient of variation(%)	12.1	12.4	6.2	6.2	9.1	10.1	9.2	8.9
	----- **Mean root diameter (cm) (MRD)** -----							
Catarina Amarela	4.1 a C	3.6 a C	3.7 ab C	5.3 a B	6.3 a AB	6.8 ab A	6.1 a AB	5.1 a
Catarina Branca	3.7 a C	3.5 a C	3.8 ab C	5.1 a B	5.6 abAB	6.1 abc AB	6.4 a A	4.9 ab
Mato Grosso	3.8 a C	3.9 a BC	4.3 a BC	5.0 a AB	5.9 ab A	6.3 abc A	6.4 a A	5.1 a
Iapar-19 Pioneira	3.1 b C	3.4 a C	3.2 b C	3.7 b C	4.8 b B	5.1 c AB	5.9 a A	4.2 c
Pretona	3.7 a D	4.2 a CD	4.1 a CD	5.3 a BC	6.4 a AB	7.2 a A	5.8 a AB	5.3 a
IAC 576-70	3.6 a C	3.5 a C	3.7 ab C	4.3 ab BC	5.2 abAB	5.5 bc A	6.2 a A	4.6 b
Mean	3.6 C	3.7 C	3.8 C	4.8 B	5.7 A	6.2 A	6.1 A	4.8
Coefficient of variation(%)	3.7	10.1	4.7	6.0	5.2	5.0	8.9	11.3
	----- **Mean number of roots per plant (NRP)** -----							
Catarina Amarela	6.3 ab A	6.3 a A	6.8 bc A	6.5 a A	6.5 a A	7.8 a A	6.5 a A	7.4 a
Catarina Branca	6.3 ab A	8.0 a A	7.0 bc A	6.5 a A	7.5 a A	7.3 a A	9.5 a A	7.7 a
Mato Grosso	7.7 ab A	6.5 a A	6.5 c A	6.5 a A	6.8 a A	8.0 a A	8.5 a A	7.4 a
Iapar-19 Pioneira	8.3 a A	9.0 a A	9.3 a A	8.0 a A	8.5 a A	9.0 a A	10.0 a A	8.6 a
Pretona	6.5 b B	6.5 a AB	6.8 bc AB	6.0 a B	6.8 a AB	6.0 a B	9.0 a A	6.9 a
IAC 576-70	7.5 ab A	8.0 a A	8.5 ab A	7.8 a A	10.3 a A	8.8 a A	9.8 a A	8.2 a
Mean	7.8 AB	7.4 B	7.5 B	6.9 B	7.7 AB	7.8 AB	8.9 A	7.7
Coefficient of variation(%)	10.0	11.4	5.6	10.9	11.8	9.4	10.3	9.3
	----- **Tuberous roots yield (kg.plant^{-1}) (TRY)** -----							
Catarina Amarela	2.8 a D	2.5 a BC	2.2 a CD	3.9 a CD	5.8 a B	7.1 a A	7.8 a A	4.6 a
Catarina Branca	2.5 a D	2.5 a C	2.8 a C	4.2 a C	5.6 a B	6.6 a AB	7.6 a A	4.5 a
Mato Grosso	1.9 a D	2.7 a CD	2.1 a BC	2.9 a ABC	4.2 a BC	5.1 a AB	7.4 a A	4.0 c
Iapar-19 Pioneira	2.2 a B	2.3 a B	2.4 a B	2.7 a B	4.4 a B	4.9 a A	6.4 a A	3.6 bc
Pretona	2.2 a C	2.4 a C	2.5 a C	3.7 a C	5.7 a B	6.0 a A	7.3 a A	4.2 ab
IAC 576-70	2.5 a C	1.7 a C	3.1 a C	3.8 a C	5.8 a B	6.5 a A	6.6 a A	4.3 ab
Mean	2.3 D	2.4 CD	2.5 C	3.5 B	5.3 B	6.0 A	7.4 A	4.2
Coefficient of variation(%)	1.9	2.7	2.6	1.9	1.8	1.8	2.9	2.2
	----- **Yield (%)** -----							
Catarina Amarela	67.3 aA	68.3 a A	80.8 a A	77.6 ab A	76.5 a A	78.7 a A	72.8 a A	74.6 a
Catarina Branca	71.5 a AB	65.9 a AB	76.1 ab A	78.4 a B	74.2 a B	79.2 a AB	73.6 a B	74.1 a
Mato Grosso	69.4 a A	69.1 a AB	78.8 ab AB	77.0 ab C	75.2 aBC	76.2 a ABC	75.7 a BC	74.5 a
Iapar-19 Pioneira	58.9 a A	66.4 a AB	68.2 b BC	69.2 b C	69.8 a C	71.1 a C	74.4 a C	68.3 b
Pretona	67.7 a AB	68.7 a A	76.3 ab A	78.6 a BC	77.6 a C	78.6 a C	76.0 a C	74.0 a
IAC 576-70	67.6 a A	63.9 a A	73.4 ab A	76.9 ab A	71.3 a A	76.3 a A	76.1 a A	72.2 ab
Mean	67.1 B	66.2 B	75.6 A	76.3 A	74.1 A	76.7 A	74.8 A	73.1
Coefficient of variation(%)	9.7	5.2	4.3	3.2	5.2	3.6	5.2	5.2
	----- **Time for debarking one kilogram of the marketable part of the root (seconds.Kg^{-1}) (TDK)** -----							
Catarina Amarela	223.8 a B	374.6 a A	126.5 ab C	67.3 a D	46.4 a D	52.9 b D	119.9 a C	144.5 b
Catarina Branca	300.3 a A	360.3 a A	127 ab B	72.0 a C	78.0 a C	67.8 ab C	115.5 a B	160.2 b
Mato Grosso	360.9 a A	300.2 a A	124.1 b B	89.1 a B	71.7 a B	72.3 ab B	96.0 a B	159.5 b
Iapar-19 Pioneira	461.8 a A	383.5 a A	195.2 a B	106.0 a C	87.9 a C	96.3 a C	117.7 a C	206.9 a
Pretona	278.1 a AB	314.6 a A	161.1 ab BC	81.4 a D	66.7 a D	67.8 ab D	104.8 a CD	153.4 b
IAC 576-70	282.4 a AB	318.4 a A	151.1 ab BC	96.6 a C	90.3 a C	86.3 ab C	96.7 a C	160.2 ab
Mean	317.9 A	341.9 A	147.7 B	85.4 D	73.3 D	73.9 D	108.8 C	164.1
Coefficient of variation(%)	5.0	3.3	3.2	4.8	6.1	4.1	6.9	4.8

[1]Values followed by different lowercase letters, in the same column, indicate significant differences between cultivars by Tukey´s test (p> 0.05). Values followed by different capital letters, in the same row show differences between harvesting times. Yield (%): Percentage of the weight of the marketable part of the roots (%).

In both the first and second agricultural years (Table 6), the diameter presented negative correlation with peeling time (-0.71 and -0.84, respectively), positive correlations with yield % (0.48 and 0.67, respectively) and with yield (0.91 and 0.82, respectively). The correlation between peeling time and yield % in the first agricultural year was -0.82, and in the second agricultural year was -0.66. Between peeling time and yield was -0.62 in the first agricultural year, and - 0.76 in the second agricultural year. Therefore, the mean diameter of the roots is one of the characteristics that can be used as a selection criterion in a table cassava genetic breeding program, since it is correlated positively with yield and yield % and negatively with time of peeling.

Table 5. Means of two agricultural years for the agronomic characteristics and culinary quality of the six table cassava cultivars. Londrina, PR.

Cultivar	MRL[1]	MRD	NRP	TRY	Yield (%)	TDK
	cm	cm		Kg.plant^{-1}		Seconds. kg^{-1}
Catarina Amarela	32.7 a[2]	4.9 a	8.2 b	5.0 a	75.1 a	134.2 c
Catarina Branca	32.1 b	4.8 ab	8.6 b	5.0 a	74.7 a	153.0 bc
Mato Grosso	27.1 c	4.8 ab	8.3 b	3.8 b	73.6 ab	164.8 b
IAPAR 19-Pioneira	29.3 b	4.0 c	9.9 a	3.9 b	66.2 c	224.8 a
Pretona	31.2 ab	5.0 a	8.0 b	4.7 a	74.2 ab	148.6 b
IAC 576-70	31.4 ab	4.6 b	8.7 ab	4.7 a	72.2 b	152.5 b

[1]MRL: mean root length (cm), (cm), MRD: mean root diameter (cm), NRP: mean number of roots per plant, TRY: tuber root yield (kg per plant), Yield (%): percentage of weight of the marketable part of the roots (%), and TDK: time for debarking one kilo of the marketable part of the root (seconds per kg). [2]Values followed by different letters in the same column indicate significant differences among cultivars by the Tukey´s test (p <0.05).

Table 6. Estimates of Pearson correlation coefficients between six characteristics related to table cassava at the first agricultural year (above the main diagonal), second agricultural year (below the main diagonal), and the correlation between the two agricultural years (diagonal main, bold). Londrina, PR.

	PRODUCTIVE AND POST-HARVEST CHARACTERISTICS[(1)]					
	MRL[1]	MRD	NRP	TRY	Yield (%)	TDK
MRL	**0.53****	0.12^{ns}	-0.32*	0.28^{ns}	0.19^{ns}	0.21^{ns}
MRD	0.16^{ns}	**0.93****	-0.15^{ns}	0.91**	0.48**	-0.71**
NRP	-0.16^{ns}	-0.04^{ns}	**0.15^{ns}**	0.07^{ns}	-0.31*	0.15^{ns}
TRY	0.01^{ns}	0.82**	0.31*	**0.86****	0.48**	-0.62**
Yield(%)	0.23^{ns}	0.67**	-0.32*	0.40**	**0.62****	-0.82**
TDK	-0.14^{ns}	-0.84**	0.14^{ns}	-0.76**	-0.66**	**0.85****

[1]MRL: mean root length (cm), (cm), MRD: mean root diameter (cm), NRP: mean number of roots per plant, TRY: tuber root yield (kg per plant), Yield (%): percentage of weight of the tradable part of the roots (%), and TDK: time for debarking one kilo of the marketable part of the root (seconds per kg). ns: not significant, * significant (p < 0,05), ** significant (p < 0,01).

CONCLUSIONS

The cultivar affected the yield and post-harvest components, as well as the agricultural year influenced the yield characteristics. The harvesting time interfered with the yield and post-harvest components, except for the number of roots per plant.

The cultivar IAPAR 19-Pioneira showed a higher mean number of roots per plant (9.9) and time for peeling (224.8 seconds kg^{-1}), but lower percentage of weight of the tradable part of the roots (66.2%) and lower root diameter (4.0 cm), regardless of harvest season and agricultural year.

The cultivars Catarina Amarela, Catarina Branca, IAC 576-70 and Pretona provided higher percentage of weight of the tradable part of the roots (75.1, 74.7, 72.2 e 74.2%), diameters (4.9, 4.8, 4.6 and 5.0 cm) and reduced debarking times (134.2, 153.0, 152.5 and 148.6 seconds.kg^{-1}), respectively. The cultivar Mato Grosso presented lower root length (27.1 cm) and tuber root yield (3.85 kg.plant^{-1}).

The root mean diameter is one of the characteristics that can be used as a selection criterion in a table cassava genetic breeding program, for it is correlated positively with tuber root yield and percentage of weight of the tradable part of the roots, and it is correlated negatively with time of peeling. In other words, the larger the root mean diameter the larger are tuber root yield and percentage of weight of the tradable part of the roots, and the lower is the time of peeling.

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