

Effect of harvesting times on agronomic characteristics of industrial cassava genotypes

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ABSTRACT: The use of cassava genotypes low-yield coupled with inappropriate harvest times lead to the country's low average yield. This study aimed to evaluate the agronomic characteristics of cassava genotypes at different harvest times in the Recôncavo region of Bahia. The experiment was conducted during two crop cycles in Cruz das Almas, Bahia, with eight cassava genotypes (BRS Poti Branca, BRS Caipira, BRS Kiriris, BRS Verdinha, BRS Tapioqueira, 9624-09, 98150-06 and 9783-13) were evaluated at different harvest times. The characteristics yield of shoot, root, flour and starch, root dry matter and harvest index were evaluated, as well as their correlation with the harvest time. Data were submitted to analysis of variance and fitted to linear regression models. The means of all the characteristics increased with the permanence of the plants in the field. The correlations between the harvest time and yield characteristics were high and positive. All genotypes evaluated had yield means higher than the means of the Recôncavo and the state of Bahia, indicating the yield potential of the genotypes.

Key words: *Manihot esculenta* Crantz.; Recôncavo of Bahia; selection; yield

Características agronômicas de genótipos de mandioca tipo industrial em diferentes épocas de colheita

RESUMO: A utilização de genótipos de mandioca de baixo potencial produtivo, aliado à colheita em épocas inadequadas, ocasionam em baixa produtividade média. Este trabalho objetivou avaliar características agronômicas de genótipos de mandioca em diferentes épocas de colheita no Recôncavo da Bahia. O experimento foi conduzido em dois ciclos de cultivo em Cruz das Almas, Bahia, no qual oito genótipos de mandioca (BRS Poti Branca, BRS Caipira, BRS Kiriris, BRS Verdinha, BRS Tapioqueira, 9624-09, 98150-06 e 9783-13) foram avaliados em diferentes épocas de colheita. Avaliaram-se as características produtividade da parte aérea, de raiz, farinha e amido, o teor de matéria seca das raízes e índice de colheita, além da correlação destas com a época de colheita. Os dados foram submetidos à análise de variância e ao ajuste de modelos de regressão linear. Observou-se aumento das médias de todas as características com a permanência das plantas em campo. A relação entre época de colheita e os caracteres produtivos apresentaram magnitudes elevadas e positivas. Todos os genótipos avaliados apresentaram médias para produtividade superiores à média da região do Recôncavo e do estado da Bahia, indicando o potencial de uso dos genótipos.

Palavras-chave: *Manihot esculenta* Crantz.; Recôncavo da Bahia; seleção; produtividade

Introduction

Brazil is the fourth largest producer of cassava in the world, with production estimated at 21.08 million tons, behind Nigeria (57.13 million tons), which ranks first, and Thailand (31.16 million tons) (FAO, 2018). In Brazil, the greatest cassava producers are the states of Pará (4.2 million tons), Paraná (3.04 million tons), and Bahia (2.07 million tons) (IBGE, 2018).

The crop is of great social importance as one of the main sources of energy for millions of low-income people around the world (Guimarães et al., 2017), notably in underdeveloped countries, mainly in tropical Africa, Asia and South America (Vieira et al. 2013). Small farmers cultivate it almost entirely and widely disseminated and exploited throughout the Brazilian territory (Tironi et al., 2015).

More than two-thirds of the total cassava production is for human consumption, with recent importance for animal feed and as a source of starch for the processed food industry, mainly in South East Asia and South America (Oliveira et al., 2010).

The State of Bahia is among the three largest domestic producers and has the second largest area planted with cassava, approximately 230.14 thousand ha (IBGE, 2018). Among the regions of the state, the Recôncavo is an important producer and consumer of the crop. The average yield of this region is 14.2 t ha⁻¹, which is above the average of the state (11.01 t ha⁻¹).

Although the average yield of the Recôncavo is higher than that of the state, genotypes with higher productive potential than the cultivars currently in use, they could increase the region's average yield, increasing the income and improving farmers' quality of life.

Soares et al. (2017), argued that the use of improved varieties adapted to the local edaphoclimatic conditions is one of the means to improve the production system of cassava and yield increase. Souza et al. (2017) claimed that the degree of variability among Brazilian cassava germplasm confirms the importance of regional research work for evaluation and selection of new and/or improved genotypes.

The adoption of cultural practices (Cardoso et al., 2014), control of pests and diseases, and harvesting at appropriate times (Soares et al., 2017) are prerequisites for reaching the productive potential of a genotype. According to Vitor et al. (2015), lack of information on the cycle of a cultivar and consequently harvest at inappropriate time may cause financial loss to farmers.

Mtunga et al. (2016) reported that the ideal harvest time for cassava is not defined once the crop has a varying maturity period. However, Aguiar et al. (2011) argued that the best harvest time is when the plants loose totally or partially the leaves, because in this period, there is a greater accumulation of photoassimilates, due to the vegetative cycle, and consequently the roots have a higher content of dry matter and starch, leading to higher yields.

Therefore, studies on the selection of genotypes with proven higher yield potential than the cultivars currently in

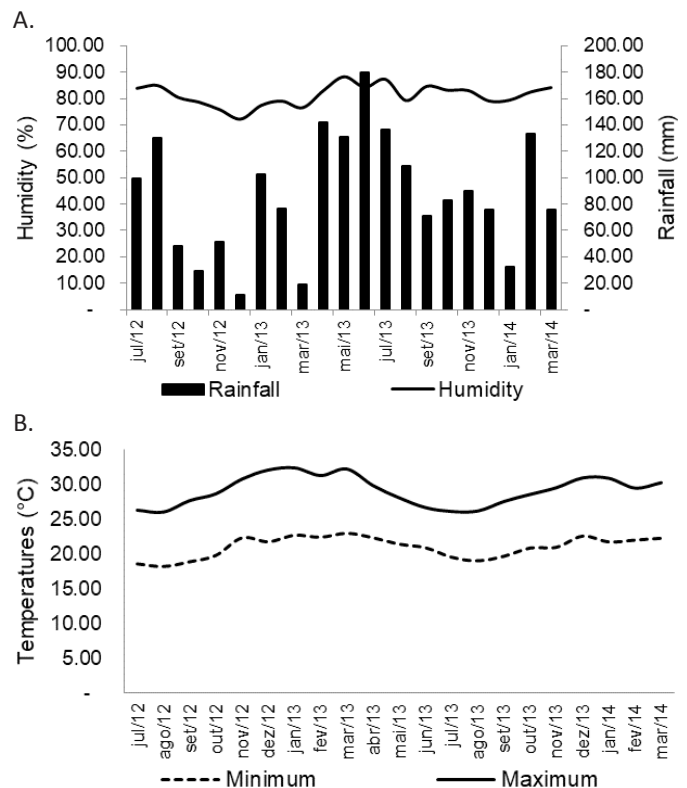
use. Determination of the appropriate harvesting time and its relation with the most important agronomic characteristics, are fundamental for recommendation and incorporation of genotypes into production systems. Thus, the objective of this work was to evaluate the agronomic characteristics of cassava genotypes at different harvest times in the Recôncavo region of Bahia.

Material and Methods

The experiment was conducted between 2012 and 2014 at the experimental field of the Federal University of Recôncavo of Bahia, Cruz das Almas - Bahia, at 12° 48' 38" S and 39° 06' 26" W, 220 m altitude. The climate was classified as hot and humid, Aw to Am, according to the Köppen's classification (Agritempo, 2018). Figure 1 shows the averages of rainfall, humidity and temperatures (maximum and minimum).

The experimental area has a flat to slightly wavy relief, with deep Typic Dystrocohesive Yellow Latosol, medium texture and well drained (Rodrigues et al. 2009). The chemical attributes of the 0-20 cm layer were: 1.25% organic matter; pH 5.47; 6 mg dm⁻³ P; 37 mg dm⁻³ K; 1.5 cmolc dm⁻³ Ca + Mg; 1 cmolc dm⁻³ Ca; 0.5 cmolc dm⁻³ Mg; 0.2 cmolc dm⁻³ Al; 2.78 cmolc dm⁻³ H + Al; 0.16 cmolc dm⁻³ Na; 1.75 cmolc dm⁻³ S; CEC = 4.53 cmolc dm⁻³ and V% = 38.63.

The experiment was carried out over two crop cycles. Agronomic characteristics were recorded at 240, 360, 480 and 600 days after planting (DAP). Determinations were as follows:



Source: Agrometeorology Laboratory of Embrapa Cassava and Fruticulture (2014).

Figure 1. Averages of rainfall, humidity and temperatures (maximum and minimum) between July/2012 and Mars/2014 in Cruz das Almas – Bahia.

Shoot yield (SY- t ha⁻¹); Root yield (RY- t ha⁻¹); Flour yield (FY- t ha⁻¹), estimated by processing 5.0 kg samples of cassava. Root dry matter content (RDM - %), estimated according to the methodology of Kawano et al. (1987); Starch yield (STY - t ha⁻¹), estimated by multiplying RY by RDM (= 4.61); Harvest index (HI - %). The cassava varieties were: BRS Poti Branca, BRS Kiriris, BRS Verdinha, BRS Tapioqueira, BRS Caipira, and the hybrids: 9783-13, 9624-09, and 98150-06 (Table 1).

The experiment was arranged in a split-plot randomized complete block design, with three replications, having the eight genotypes of cassava in the main plots and the four harvest times in the subplots. The subplots consisted of 20 plants in the spacing of 0.60 m x 1.0 m and 10 central plants as the harvest area.

Data were submitted to analysis of variance according to the model of split-plot randomized blocks, using the statistical program SISVAR (Ferreira, 2014). Means of the genotypes were grouped by the Scott-Knott's test at 5% probability and the means of the different harvest times were fitted to regression models. The required unfolding procedures were carried out when the interaction genotypes x harvest time was significant. Coefficients of phenotypic correlation between the harvest time and the other characters were also estimated using the statistical program SAS version 9.2 (SAS Institute Inc. 2002-2008).

Results and Discussion

The coefficients of variation in this work were considered as adequate according to the classification of Pimentel-Gomes

(1985) and were in accordance with those found by other studies (Oliveira et al. 2010; Maieves et al., 2011; Adjebeng-Danquah et al., 2016). It was also found significant interaction for root and starch yields, dry matter content and harvest index (Table 2).

Shoot yield is an important characteristic for the crop and is related to both the production of plant material for propagation and animal feed due to its high nutritional value, mainly protein content and excellent acceptability by the animals, besides the forage potential of leaves (Silva et al., 2011; Cardoso et al., 2014; Adjebeng-Danquah et al., 2016). There was no significant interaction for this characteristic, indicating that the genotypes studied had the same development pattern over the cycles, reaching the point of maximum yield estimated at 554 DAP with 42.48 t ha⁻¹ (Table 3).

In this study, root yield, the characteristic of highest economic and market importance (Cardoso et al. 2014), was favored by the increased reserve accumulation by the genotypes with the longer crop cycle, peaking at 600 DAP (Table 3), that is, 20 months after planting (end of the second cycle). Similar results were reported by a number of authors (Oliveira et al., 2010; Souza et al., 2010; Cardoso et al., 2014; Chikoti et al., 2016).

The variety BRS Tapioqueira (85.41 t ha⁻¹) showed the highest root yield, followed by BRS Poti Branca (63.93 t ha⁻¹) and BRS Caipira (62.91 t ha⁻¹). Among the hybrids evaluated, 9783-13 (56.41 t ha⁻¹) showed the highest yield potential (Table 3). Overall, the root yield found in this study was higher than the averages recorded for Brazil (14.82 t ha⁻¹), State of

Table 1. Genealogy and purpose of utilization of cassava genotypes evaluated in the Recôncavo of Bahia, between 2012 and 2014.

Genotypes	Genealogy ¹	Utilization
BRS Poti Branca	CIAT – Hibrid 8735/01 – Female Parent SM807, open pollination.	Flour
BRS Caipira	BGM CNPMF – Hibrid 9655/02 – Female Parent BGM662 (Paroara), open pollination.	Flour
BRS Kiriris	BGM CNPMF – Hibrid 9505/261 – Female Parent BGM 921, open pollination.	Table / Flour
BRS Verdinha	BGM CNPMF – Hibrid 96/02/02 – Female Parent BGM116 (Cigana Preta), open pollination.	Flour
BRS Tapioqueira	BGM CNPMF – Hibrid 96/07/07 – Female Parent BGM555 (Izabel deSouza), open pollination.	Flour
9624-09	BGM CNPMF – Female Parent BGM146, open pollination.	Flour
98150-06	BGM CNPMF – Male Parent BGM116 (Cigana Preta), Parental Feminino clone 86/128/08 (Bibiana).	Flour
9783-13	BGM CNPMF – Female Parent BGM184, open pollination.	Flour

¹CIAT: International Center for Tropical Agriculture; BGM: Cassava Germplasm Bank; CNPMF: National Center for Research on Cassava and Fruticulture - Embrapa

Table 2. Summary of variance analysis for shoot yield (SY), root yield (RY), flour yield (FY), root dry matter content (DMC), starch yield (STY) and harvest index (HI) of cassava genotypes harvested at different times in the Recôncavo of Bahia.

SV	DF	Mean square					
		SY (t ha ⁻¹)	RY (t ha ⁻¹)	FY (t ha ⁻¹)	DMC (%)	STY (t ha ⁻¹)	HI (%)
Block	2	179.06 ^{ns}	9.65 ^{ns}	3.50 ^{ns}	8.29 ^{ns}	3.48 ^{ns}	201.47 ^{**}
Genotype	7	268.04 [*]	676.16 ^{**}	60.57 ^{**}	39.29 ^{**}	63.37 ^{**}	436.81 ^{**}
Error (a)	14	63.19	97.83	13.70	2.23	9.27	26.47
Time	3	1913.72 ^{**}	8087.50 ^{**}	1039.16 ^{**}	390.01 ^{**}	732.95 ^{**}	1374.98 ^{**}
Genotype x Time	21	44.10 ^{ns}	154.88 [*]	16.86 ^{ns}	10.55 ^{**}	17.99 ^{**}	46.70 ^{**}
Error (b)	48	33.62	86.15	10.58	3.21	7.51	20.35
CV ₁ (%)		23.76	26.28	29.46	5.01	25.87	10.18
CV ₂ (%)		17.33	24.66	25.89	4.99	23.29	8.93
Mean		33.45	37.64	12.56	35.92	11.77	50.54

* And **: Significant at 5 and 1% probability levels, respectively. ^{ns}: non-significant by the f test.

Table 3. Regression equations, coefficients of determination (R^2), maximum point (x) and maximum value observed for the characteristic (\hat{y}) of cassava genotypes harvested at different times in the Recôncavo of Bahia.

Genotypes	Equation	R^2	x	\hat{y}
Shoot yield (t ha ⁻¹)				
Mean	$\hat{y} = -21.9790 + 0.2327x - 0.0002x^2$	91.32 **	554	42.48
Root yield (t ha ⁻¹)				
BRS Poti Branca	$\hat{y} = -27.3300 + 0.1521x$	91.77 **	600	63.93
BRS Kiriris	$\hat{y} = -10.1480 + 0.1179x$	95.31 **	600	60.59
BRS Verdinha	$\hat{y} = 6.9740 + 0.0639x$	81.61 **	600	45.31
BRS Tapioqueira	$\hat{y} = -22.2276 + 0.1794x$	94.47 **	600	85.41
BRS Caipira	$\hat{y} = -10.5346 + 0.1224x$	96.41 **	600	62.91
9783-13	$\hat{y} = -10.5476 + 0.1116x$	88.75 **	600	56.41
9624-09	$\hat{y} = -10.5963 + 0.1055x$	95.22 **	600	52.70
98150-06	$\hat{y} = -7.9123 + 0.0837x$	97.69 **	600	42.31
Flour yield (t ha ⁻¹)				
Mean	$\hat{y} = -23.4190 + 0.1412x - 0.0001x^2$	99.92 **	588	18.12
Root dry matter content (%)				
BRS Poti Branca	$\hat{y} = -1.4615 + 0.1904x - 0.0002x^2$	67.07 **	425	39.00
BRS Kiriris	$\hat{y} = -8.7953 + 0.2420x - 0.0003x^2$	90.39 **	396.72	39.21
BRS Verdinha	$\hat{y} = 5.3286 + 0.1625x - 0.0001x^2$	99.08 **	439.19	41.01
BRS Tapioqueira	$\hat{y} = -1.2690 + 0.2009x - 0.0002x^2$	95.07 **	416.80	40.60
BRS Caipira	$\hat{y} = -4.7411 + 0.2057x - 0.0002x^2$	98.21 **	441.42	40.66
9783-13	$\hat{y} = -8.0385 + 0.2392x - 0.0002x^2$	90.36 **	400	39.80
9624-09	$\hat{y} = 8.3005 + 0.1367x - 0.0001x^2$	65.30 **	429.87	37.68
98150-06	$\hat{y} = 3.8918 + 0.1796x - 0.0002x^2$	99.31 **	433.82	42.85
Starch yield (t ha ⁻¹)				
BRS Poti Branca	$\hat{y} = -6.9346 + 0.0428x$	98.47 **	600	18.75
BRS Kiriris	$\hat{y} = -27.2295 + 0.1737x - 0.0001x^2$	99.98 **	487.92	15.15
BRS Verdinha	$\hat{y} = 2.1980 + 0.0216x$	70.59 **	600	15.16
BRS Tapioqueira	$\hat{y} = -45.9795 + 0.2718x - 0.0002x^2$	93.77 **	514.77	23.98
BRS Caipira	$\hat{y} = -3.2030 + 0.0391x$	91.07 **	600	20.26
9783-13	$\hat{y} = -38.1800 + 0.2278x - 0.0002x^2$	95.07 **	474.58	15.88
9624-09	$\hat{y} = -2.8036 + 0.0310x$	99.40 **	600	15.80
98150-06	$\hat{y} = -2.3076 + 0.0282x$	92.33 **	600	14.61
Harvest index (%)				
BRS Poti Branca	$\hat{y} = 13.9673 + 0.0785x$	95.92 **	600	61.07
BRS Kiriris	$\hat{y} = 43.2253 + 0.0400x$	68.55 **	600	67.23
BRS Tapioqueira	$\hat{y} = 33.9527 + 0.0504x$	96.64 **	600	64.19
BRS Caipira	$\hat{y} = 30.8783 + 0.0495x$	99.62 **	600	60.58
9783-13	$\hat{y} = 18.4713 + 0.0690x$	95.14 **	600	59.87
9624-09	$\hat{y} = 33.1500 + 0.0371x$	85.22 **	600	55.41
98150-06	$\hat{y} = 18.0133 + 0.0530x$	98.57 **	600	49.81

** Significant at 1% probability by test f

Bahia (11.00 t ha⁻¹) and for the Recôncavo region (14.2 t ha⁻¹) (IBGE, 2018), showing that the use of these genotypes could increase farmer's production and income, with consequent improvement in quality of life.

Flour yield, the main product of the crop, is of great importance, since most cassava production is for flour manufacture and the remainder is divided between consumption of fresh produce, animal feed and industrial processing (Fernandes et al., 2016). For this characteristic, even with no significant interaction, it is suggested that the genotypes have similar performance over the crop cycles, with production increased by plants remaining longer time in the field. For some authors (Souza et al., 2010; Aguiar et al., 2011; Siviero et al., 2012), this performance was already expected, since the harvest time influences the most the agroindustrial yield of the crop. The maximum flour yield was estimated at

18.12 t ha⁻¹, at 588 DAP (Table 3), approximately 300% above the average of the Recôncavo region (4.9 t ha⁻¹; IBGE 2018).

Dry matter content of roots is the characteristic that determines the agroindustrial yield of the (Cardoso et al., 2014). It is desirable that genotypes with high root yields also have high contents of dry matter and starch or flour, as the starch content is directly related to dry matter (Souza et al., 2010; Siviero et al., 2012). Thus, the quadratic model fitted to this character data shows that there is variation of the characteristic over the crop cycles (Table 3). The climate of the region (Figure 1), notably the rainfall period, was determinant for the physiological behavior of the genotypes regarding this characteristic, as also reported by Souza et al. (2010).

The highest root dry matter content was recorded for the hybrid 98150-06 (42.85%) at 433 DAP, following the varieties BRS Verdinha (41.01%) and BRS Caipira (40.66%),

Table 4. Phenotypic correlations between harvest time (HT) and shoot yield (SY), root yield (RY), flour yield (FY), harvest index (HI), dry matter content (DMC) and starch yield (STY) over two cycles of industrial cassava in the Recôncavo of Bahia.

Characteristics	SY	RY	FY	HI	DMC	STY
HT	0.6140**	0.7920**	0.7839**	0.6388**	0.0084 ^{ns}	0.7294**
SY	1	0.7010**	0.7104**	0.1704 ^{ns}	0.1907 ^{ns}	0.7121**
RY		1	0.9606**	0.7525**	-0.0183 ^{ns}	0.9370**
FY			1	0.7313**	0.2106*	0.9776**
HI				1	-0.0019 ^{ns}	0.7128**
DMC					1	0.3092**

** and *: significant at 1% and 5% probability level, respectively; ^{ns}: Non-significant

at 439 DAP and 441 DAP, respectively (Table 3). The variety BRS Kiriris (39.21%) stood out for peaking root dry matter accumulation at 396 DAP, showing the genotype's earliness for this characteristic. Similarly, the hybrid 9783-13 (39.80%) showed maximum dry matter production at 400 DAP, standing out for the earliness of this characteristic compared with the other hybrids (Table 3).

The starch yield of a cassava variety is a very important characteristic for the processing industries. According to Souza et al. (2010), although little investigated, starch yield is very useful in decision making, especially when aiming at starch production.

BRS Tapioqueira showed the highest starch yield, 23.98 t ha⁻¹ at 514 DAP, followed by the varieties BRS Caipira and BRS Poti Branca, with 20.26 t ha⁻¹ and 18.75 t ha⁻¹, respectively, at 600 DAP (Table 3). Among the hybrids, 9783-13 (15.88 t ha⁻¹) stands out, reaching its maximum production at 474 DAP. These results show that the permanence of the plants in the field over a period of more than one cycle increases the production of roots, flour and starch, agreeing with other reports (Oliveira et al. 2010; Aguiar et al, 2011). It should be emphasized that the results of this study are superior to those observed by Oliveira et al. (2010), Souza et al. (2010) and Cardoso et al. (2014), indicating the potential of utilization of the genotypes evaluated in the Recôncavo region.

Harvest index measures the biomass distribution to economically useful parts of the plant (Guimarães et. al., 2017); we found that most of genotypes, excluding BRS Verdinha, showed a linear model fitting, indicating that the permanence of the plants in the field increased the harvest index (Table 3).

The highest means for this characteristic were recorded for BRS Kiriris (67.23%), BRS Tapioqueira (64.19%), and BRS Poti Branca (61.07%) at 600 DAP (Table 3). According to Guimarães et al. (2017), the harvest index is considered satisfactory if greater than 50%. In the present study, the harvest index reference was exceeded by most of the genotypes, with the exception of hybrid 98150-06 (49.81%).

Most of the genotypes in the study showed means that favored their selection and incorporation into the local production system, considering the superiority of the means found for the main agronomic characteristics compared with the regional means.

The correlations show that most associations were significant at 1% probability level (Table 4). The harvest time had significant and high association with shoot yield (SY), root

yield (RY), flour yield (FY), harvest index (HI) and starch yield (STY). (Table 4), as already reported by other authors (Lopes et al., 2010; Oliveira et al., 2010; Cardoso et al., 2014).

When relating root and shoot yield with harvest index, it was found that the root weight increased linearly with the permanence of the plants in the field, peaking at 600 DAP (Table 3), corroborating with results of Conceição (1981) and confirming that high HIs are due to the increase in root yield or reduction in shoot production.

The dry matter content had no linear relationship with the harvest time and shoot yield, root yield and harvest index. The lack of significant association was also observed between shoot yield (SY) and harvest index (HI), indicating that shoot production had little influence on harvest index.

On the other hand, the high correlation between harvest index (HI) and root yield (RY) shows that the increase in harvest index is directly related to the increase in root yield, and this, with the harvest time (Table 4).

Conclusions

The genotypes evaluated can be harvested at 12 months after planting.

The varieties BRS Tapioqueira, BRS Caipira and BRS Poti Branca can be incorporated into the production system of the Recôncavo region of Bahia.

The hybrid 9783-13 had root yield higher than the others, showing potential for cultivation in the region.

The harvest time positively influences the increase in root and flour yields.

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