Vol. 14(34), pp. 1892-1896, November, 2019
DOI: 10.5897/AJAR2019.14344
Article Number: 4025D1962336
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Yield of different varieties of cassava (*Manihot esculenta* Crantz) in different harvest intervals

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Received 24 July, 2019; Accepted 3 October, 2019

This experiment was installed in the experimental plot of the Faculty of Agrarian Sciences, National University of Asunción Department of Amambay, Paraguay, with the objective of evaluating the yield of four varieties of cassava in three harvest intervals. The experimental design was randomized blocks, with four treatments (Seda, Pomberi, Sa'yju and Tacuara) and five repetitions. The spacing was 0.8 x 0.7 m, with a population density of 17,870 plants per hectare. Root quantity per plant, root weight per plant, amount of commercial and non-commercial root, weight of commercial and non-commercial root, yield per hectare were evaluated at eight, ten and twelve months after planting. The root number per plant was infuenced (p <0.05) by the varieties, and was higher for the variety Seda; number and weight of commercial root which did not vary (p> 0.05) depending on the varieties and harvest intervals. The root weight per plant does not present significant differences (p> 0.05) between varieties and harvest intervals. Commercial root weight and root yield were significantly (p <0.05) higher in harvest intervals performed 12 months after sowing, where the Tacuara variety showed the highest yield. Variety of table or sweet manioc Tacuara presents superior performance at 12 months after sowing. Cassava varieties tested have acceptable production parameters, and the knowledge of them as well as cutting interval may allow better use mainly by small farmers. It is recommended to evaluate the influence of planting density on the varieties and cutting interval.

Keywords: *Manihot esculenta*, agronomic behavior, cultivars, harvest index.

INTRODUCTION

Cassava is a woody, perennial shrub plant that produces tubers rich in starch, suitable for human and animal consumption (Okogbenin et al., 2013). It is the third most important source of calories in the tropics, after rice and corn, and may be responsible for a more sustainable diet of the human population, mainly for people with low income. Production of this plant is characterized by small peasant farmers worldwide, mainly in South America,

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Table 1. Initial physical and chemical characteristics of the soil for the experiment.

Depth (cm) (cm)	pH (Water)	M.O (dag.kg^{-1})	Al^{3+} (Cmolc.dm^{-3})	Ca+Mg (Cmolc.dm^{-3})	P (mg.kg^{-1})	K (mg.kg^{-1})	Text. Touch
0-20	6.30	3.0	0.0	8.00	6.00	220.7	A

Extractors: pH=Water; PyK=Mehlich^{-1}; Ca+Mg yAl_3^+=KCl 1 mol.L^{-1}; A=Clay.
Source: Soil Laboratory of the Faculty of Agricultural Sciences, Pedro Juan Caballero, Paraguay.

Africa and South-East Asia (Delaquis et al., 2018), where they are widely marketed and consumed.

Due to its phenotypic and genotypic plasticity, cassava can be cultivated in different ecological environments and in low-input systems, due to its drought tolerant attributes that make cassava attractive to low-income farmers. In cassava roots with good sensory characteristics, the firing is fast and uniform, with few fibers and reduced concentration of cyanide acids, mainly in improved varieties for human consumption. These characteristics are associated with genotype, plant age, harvest time and population density (Aguiar et al., 2010).

Preferably, cassava is harvested with a vegetative cycle that varies between eight to fourteen months. Before eight months, they are not normally harvested because they do not have the appropriate commercial diameters or standards, or after fourteen months, there is reduction of their principal sensory and culinary characteristics. However, the success of cassava cultivation can be influenced by different factors, including the incidence of diseases (Chikoti et al., 2016), planting density (Adeniyan et al., 2014), genetic variability (Adjebeng-Danquah et al., 2016) and mainly harvest time and varieties of greater adaptation to the specific región, factors that can compromise the success of the crop.

In Paraguay, cassava is one of the main areas of family farming (Carballo et al., 2010) and is one of the areas with the lowest fluctuation in terms of production area between the last two decades (Lesmo et al., 2018); thus, knowledge of the agronomic behavior of the main varieties used in the northern region of Paraguay is essential to collaborate with a more sustainable production.

The objective of the present investigation was to verify the agronomic characteristics of four varieties of cassava in three harvest intervals in the district of Pedro Juan Caballero, Paraguay.

MATERIALS AND METHODS

Study site description

The experiment was conducted in the Experimental Field of the Faculty of Agricultural Sciences, located in the Raúl Ocampos Rojas Colony (Chirigüelo) on Route V, 20 km from the city of Pedro Juan Caballero, Department of Amambay (22º39'36"S and 55º53'36"W, 485 m above sea level). The climate of the región is of the Cwa type according to the Köppen classification, temperate climate with dry winter and rainy summer. 1,050 mm of precipitation was recorded during the experiment. The type of soil where the experiment was executed is predominantly sandy loam texture, whose physical and chemical characteristics were determined through soil analysis (Table 1).

The total area of the experiment was 1.040 m^2, the useful plots corresponded to the two central rows of each block, each with 200 m^2 (40 x 5 m), a separation between blocks of 2 m and the treatments consisted of four varieties of cassava. The evaluations were carried out in three intervals, at eight, ten and twelve months after planting. The preparation of the land, previously covered by green manure, was done mechanically, by using a harrow to break the lumps and thus generate good aeration in the soil.

The sowing was carried out in September 2015 with a density of 17,870 plants per hectare as well as a separation of 80 cm between rows and 70 cm between plants. In each block, six rows 40 m long were sown, seed stakes were used from three to five yolks to ensure the outbreak, the depth was conditioned with soil moisture where in each hole a seed stake was placed at a depth that did not exceed 10 cm. Cultural care was done manually.

Statistical analysis

The experimental design used was randomized complete blocks in a 4 × 3 factorial scheme with five repetitions per treatment. With the data, the analysis of variance and the comparison of means with the 5% Tukey test was performed using the AgroEstat® software (Barbosa and Maldonado, 2015).

RESULTS AND DISCUSSION

Significant effect ($p < 0.05$) of the different varieties was verified for the variable number of roots per plant. However, there was no effect ($p > 0.05$) of the commercial root number, non-commercial root weight for varieties and harvest intervals, or significant interactions ($p > 0.05$) between varieties and harvest seasons (Table 2).

According to Shindoi et al. (2018), the number of commercial roots per plant, defines the ability of the genetic material to be sold fresh. Although, statistically there was no significant differences between the harvest intervals for the variable number of roots per plant, a greater tendency is observed (Table 2) when they are harvested at eight months after planting. In general, the total number of roots per plant and number of commercial roots observed in the present investigation was lower than those reported by Shindoi et al. (2018) in an investigation of agronomic performance of ten cultivars of cassava in the Argentine Chaco.

Table 2. Root number per plant, commercial root number per plant and non-commercial root weight per plant of four cassava varieties in three harvest intervals.

Parameter	No. of root/ plant	No. of comercial root	Non-commercial root weight (kg)
Variety (V)			
Seda	7.86[a]	4.13[a]	0.43[a]
Pomberí	5.66[c]	3.60[a]	0.25[a]
Sa'yju	6.00[bc]	3.13[a]	0.42[a]
Tacuara	7.60[ab]	4.00[a]	0.43[a]
CV (%)	16.14	12.13	23.38
p - value	0.004**	0.196[ns]	0.113[ns]
Harvest intervals (HI)			
8 months	7.25[a]	3.55[a]	0.44[a]
10 months	6.80[a]	3.00[a]	0.33[a]
12 months	6.30[a]	3.70[a]	0.37[a]
CV (%)	7.01	4.72	14.55
p - value	0.301[ns]	0.721[ns]	0.344[ns]
Variety x Harvest intervals (VxHI)	0.728[ns]	0.127[ns]	0.148[ns]

[abc]Lowercase letters in the columns differ with 5% probability; ns = not significant. CV = coefficient of variation.

Among the factors that influence commercial root production is the population density used (silver/hectare), which according to Aguiar et al. (2010), is positively correlated with low planting density, making it possible to obtain good root production per plant from six to 10 months after planting with a density of 5,000 plants/ha. However, in the present investigation, the plantation was 0.8 x 0.7 m, with a density of 17,870 plants/ha; even so, there is a tendency of greater number of roots per plant eight months after planting.

Root weight per plant does not show significant differences ($p>0.05$) depending on the variety and time of harvest; also, the root weight per plant was not influenced ($p> 0.05$) by harvest interval. The Tacuara variety presents 36,144 kg/ha and superior yield ($p <0.05$) to the other varieties. Higher ($p<0.05$) commercial root weight and yield per hectare is verified in the harvest made at 12 months after planting. There were significant interactions ($p <0.05$) between varieties and harvest time for the variables of commercial root weight and yield per hectare (Table 3).

Oliveira et al. (2015) evaluated three varieties of cassava and observed that the best time to harvest the evaluated cultivars is between 12 and 24 months after planting, where there is greater accumulation of dry matter in the roots, resulting to a larger size of starch granules in that growth cycle (Fernandes et al., 2019). Motta et al. (2012) reported that the Tacuara variety has 3.6 roots per plant and a yield of 22,319 kg/ha, lower than those observed in the present investigation, which was 7.6 root per plants and 36,144 kg/ha yield. The yield include traits of high heritability, high positive correlation with the number of leaves, crop index, root yield per plant, height of the first branch and plant height (Adjebeng-Danquah et al., 2016; Chipeta et al., 2016).

Likewise, the root length has a high positive correlation with the weight of the fresh root (Adu et al., 2018), however, the leaf área and root diameter are the main features that they contribute to genotypic variation between varieties.

Aguiar et al. (2010) show a higher production of commercial roots per plant when population density decreases (plant/ha), being higher at a density of 5,000 plants/ha for six harvest intervals (6, 8, 10, 12, 14 and 16 months). This finding by the authors is attributed to plants competition being at a lower density, less competition for nutrients, absence of restriction of luminosity, and therefore, greater development of the roots. Likewise, according to Zanetti et al. (2014), the best spacing adjustment for the productivity of cassava roots was 0.9 x 0.7 m, this being a viable option for the producer, since it can provide low cost of cuttings per planted area.

Higher population density according to Aguiar et al. (2010) results in greater total root productivity, regardless of the harvest interval, however, with lower commercial root yields, since lower planting density increases commercial root production in relation to total production. In the present investigation, it is observed that the weight of the commercial root was not influenced ($p> 0.05$) by the varieties, but significantly ($p <0.05$) by the times of harvest, being greater weight of the commercial root when harvested at 12 months. This difference is probably

Table 3. Root weight per plant (kg), commercial root weight (kg/plant) and root yield (kg/ha) of four cassava varieties in three harvest intervals.

Parameter	Root weight /plant (kg)	Commercial root weight (kg)	Yield (kg/ha)
Variety (V)			
Seda	1.76[a]	1,30[a]	22,446[d]
Pomberí	1.63[a]	1,38[a]	28,467[c]
Sa'yju	1.91[a]	1,48[a]	33,460[b]
Tacuara	2.06[a]	1,62[a]	36,144[a]
CV (%)	10.13	9,66	20.01
p - value	0.216[ns]	0,379[ns]	0.000**
Harvest intervals (HI)			
8 months	1.64[a]	1.17[b]	25,671[c]
10 months	1.87[a]	1.53[ab]	30,519[b]
12 months	2.01[a]	1.63[a]	34,197[a]
CV (%)	10.06	16.97	14.19
p - value	0.143[ns]	0.018*	0.000**
Variety x Harvest intervals (VxHI)	0.272ns	0.028*	0.000**

[abcd]Lowercase letters in the columns differ with 5% probability. ns = not significant. CV = coefficient of variation.

related to a greater assimilation of carbohydrates in the tubers when the plants are 12 months old, at the time of greatest development of the plant.

The number of tuberous roots is defined mainly in the first 120 days after planting (Lorenzi, 2003); after that period, the continuous growth of these roots is verified by the accumulation of carbohydrates. The phase in which the greatest development of the roots occurs goes from the sixth to the tenth month after planting, when the highest rate of carbohydrate translocation for the roots is observed. According to Alves (2002), during the development cycle, the cassava plant concomitantly has two main drainage of photoassimilates: the tuberous roots that are the main storage organs, and the aerial part, which consumes a large part of the sugars produced in the photosynthesis for the development of leaves and stems.

The average yield obtained (Table 3) were higher than those verified by Caballero et al. (2010). In this investigation, the Tacuara variety was the variety with the highest yield, while Romero and Caballero (2013) study on agronomic behavior of five cassava varieties revealed that the one with the highest commercial root yield is the Sa'yju variety, which at the same time, has a higher content of dry matter and starch. Likewise, the observed yield (Table 3) in the four varieties evaluated are within the parameters for table cassava varieties, similar to those observed by Tironi et al. (2015).

However, according to Chipeta et al. (2016), some cassava genotypes may present at a higher age carbohydrate accumulation, a situation not observed in the varieties evaluated (Table 3). The soil preparation has an influence on the yield, causes an increase in the resistance to the penetration of the roots in the soil, results in a greater accumulation of dry matter in the stem than in the roots, able to decrease the growth of the cassava roots (Figueiredo et al., 2017), and also influences the diameter of the roots, in the fresh and dry matter, at the beginning of the physiological and retaken rest phases of the new vegetative period, while not influencing the chronological definition of the components of production, nor the morphology of mandioca roots (Gonzales et al., 2014). These parameters may have been determinants in the differences observed for yield, in addition to the varieties evaluated.

Conclusion

The commercial root number and weight of the non-commercial root is not related to the variety and harvest intervals. Tacuara variety presents superior yield, and harvest intervals at 12 months after planting is the ideal time to obtain better yields.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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