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Sweet Cassava Growing, Yield and Harvest Indexes in Different Population Densities

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Abstract: The adequate choice in different population densities of crops for improving the yield of available natural resources resulting in increase productivity and quality in the harvested product. The objective of this study has been to evaluate the influence on the plant population in the productivity of sweet cassava, growing IAC 14-18 and harvesting in different periods. Four population densities were studied, varying from 9,000 to 33,000 plants ha^{-1}, in six harvest times, beginning in the fourth and concluding 24 months after planting. The maximum productivity of 84.5 t ha^{-1} was observed in the mass from the plants after 21 months. The best harvest time for growing roots occurred at 19 months with a yield of 42 t ha^{-1}. The 33,000 plants was the highest population density ha^{-1} that brought about the lowest harvest yield index (H).

Key words: Assimilated partition · Fresh root mass · Harvest time · *Manihot esculenta* Crantz and Total dry plant mass

INTRODUCTION

Cassava can be consumed *in natura* (naturally) as well as through its sub-products, as meal, chips, bread, cookies and beverages. There are varieties for industrial usage and they can be consumed by human beings just after cooking processes. What determines if cassava root can be consumed or not, directly or through industrial process is its concentration of cyanogenic compounds [1].

Sweet cassava crops can be consumed naturally, as it contains less than 100 ppm of cyanuric acid (HCN) in the raw pulp from the roots [2]. The main characteristic, added to others, may more or less important in determining the quality of product in regards to consumer demands, such as culinary quality, cooking time, color of the suberosal skin, color of root pulp, size, shape and among others [3, 4].

Cassava roots are rich in carbohydrates. According to FAO [5], cassava is the third most important source of calories in the tropics, followed by rice and corn. Sweet cassava is frequently found growing in Brazilian backyard gardens and it is also grown in larger areas for commercial purposes aimed at horticultural markets. Recently cassava intended for natural consumption has become more noteworthy due to its characteristics as related to foodstuffs for human consumption.

However, there is a lot of technical information still missing on growing sweet cassava, such as planting time, the number of plants for a given area, plant nutrition, pest control, diseases and harvest times; different from cassava intended for industry, as it is possible to verify in diverse studies in literature [6-9] regarding the density of planting.

Knowledge and adequate handling of plant density for a given area can promote great changes in plant development, also the ideal adjustment for sweet cassava has not been studied in great detail and the growers are unaware of its benefits as well. Plants when grown more densely provide greater productivity, although they present reduced root size, which can negatively impact the quality when the crop is sold. On the other hand, when planting is done less densely, the roots become individually more quickly developed and therefore, provide more commercial quality.

Thus, the objective of this study was to evaluate the influence from the number of plants per given area on the productivity of sweet cassava plants when growing IAC 14-18 harvested at different times.

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MATERIALS AND METHODS

The experiment was conducted in the period from January 2005 to September 2007, which included two cassava vegetation cycles in the city of Assis, SP (22° 40'S; 50°26'W and 563 m altitude). The soil in that location is classified as dystrophic Dark Red Latosol with a medium texture, sandy phase [10].

The preparation of the soil was performed by plowing at a depth of 20 cm. Harrowing and level grading were not necessary, as the soil was sandy. The area was tilled to a depth of 35 cm and the plant rows were alternated. The spacing between rows was 70 cm or 105 cm, as that was the necessary distance between plants for meeting the needs of the desired populations. After the preparation, the furrows were opened mechanically and the planting was performed manually. Good physiological and sanitary planting material was sought and used for growing IAC 14-18. Five viable knots, 0.15 m in length were spread horizontally along the furrows.

The experiment was laid out in randomized complete block design in split plots, with two replications. The plots were constituted by the following plant densities: 9,000, 17,000, 25,000 and 33,000 plant per ha^{-1} and the sub-plots per plant harvest times (evaluations), performed 4, 8, 12, 16, 20 and 24 months after planting (MAP). Each plot contained four rows 10 m in length. Each sub-plot included six plants, harvested in the useful area of each plot.

For each quarterly harvest, the plants were dried in a forced-circulated-air drying oven, at 65°C for 96 hours and the dry mass was determined by the gravimetric method. The first analyzed variables were: total productivity of fresh plants (MF), total productivity of dried plants (MS) and the productivity of fresh roots (MFR). Based on these data, the secondary variable harvest index was analyzed (H), determined by the following equation:

$$H = \frac{MFR(t\ ha^{-1})}{MF\ (t\ ha^{-1})}$$

The data were submitted to the Liliefors test in statistical analysis to verify the normality of the residues and homogeneity among the variances by the Cochran test [11]. The data were submitted to variance analysis to be verified and adhere to these assumptions in order to verify the presence of significant effects and in these cases the Tukey test was applied to determine the differences among the averages of 5% level of significance for plant densities. The effects from the harvest times were evaluated by regression analysis.

RESULTS AND DISCUSSION

The variance analyses did not detect significant difference among the interactions, plant densities and harvest times in any of the studied parameters. However, in the evaluation of isolated factors, the parameters were different for all harvest times ($p \leq 0.05$). Since the variation among plant densities was only stated as being significant in the harvest index ($p \leq 0.01$), (Table 1).

The average productivity results, regarding the plants as well as the roots per area, were well adjusted to the cubic polynomial regression models ($y=a+bx+cx^2+dx^3$). All the equations were significant for 5% probability and the determined coefficients in the equations used for the adjustments were greater than 95%, explaining accurately the interaction among the productivity variations as related to harvest time (Fig. 1).

Table 1: Summary of ANOVA of total fresh plant productivity (MF) and dried, yield of fresh roots (MRF) and harvest index (H) of sweet cassava IAC 14-18 planted in different population densities and harvest seasons

		Quadrado médio			
SOV	df	MF	MS	MFR	H
Block	1	125.70	78.75	222.58	0.051
Harvest time (E)	5	3336.60^{*}	1335.97^{*}	1852.94^{*}	0.1266^{*}
Residue 1	5	539.60	100.63	94.53	0.0082
Plant density (D)	3	145.80^{ns}	38.89^{ns}	273.03^{ns}	0.0768^{**}
E*D	15	236.30^{ns}	51.58^{ns}	74.10^{ns}	0.0039^{ns}
Resídue 2	18	230.70	48.89	133.40	0.0063
CV1(%)		14.09	15.12	18.29	15.99
CV2(%)		12.00	13.03	15.23	12.93

SV-source variation; DF-degree of freedom; -CV Coefficient of variation.

n.s. = Not significant; * = Significant at 5%; ** = Significant at 1%.

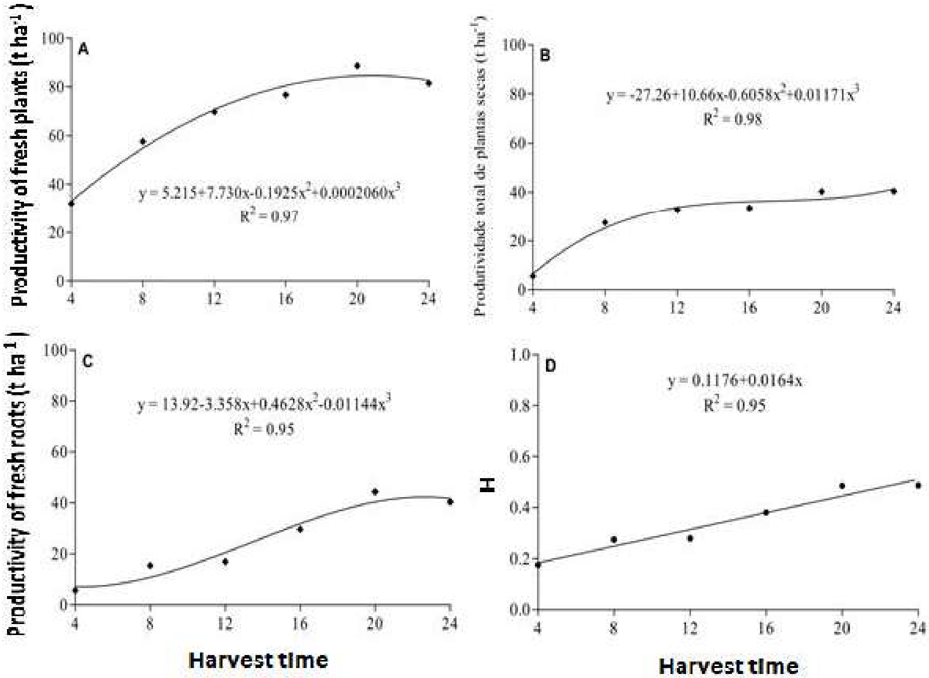

Fig. 1: Estimate of the total productivity of fresh plants (A), dried (B), fresh roots (C) and harvest index (D) of sweet cassava IAC 14-18 in the different harvest times.

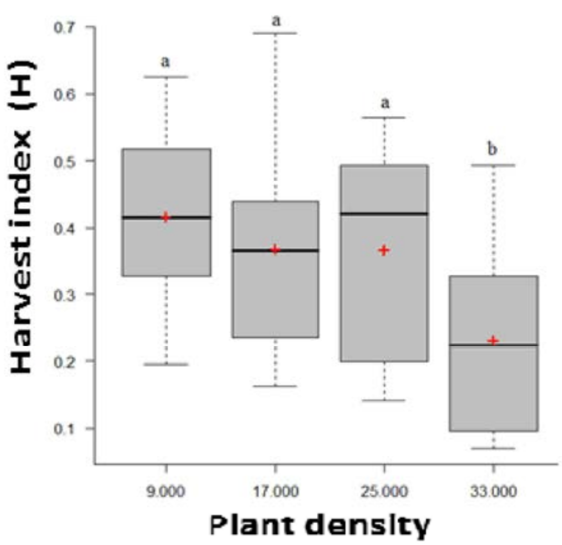

Fig. 2: Box plot to harvest index (H) according to the four population densities of sweet cassava IAC 14-18. Means followed by the same letter, between the box plot does not differ statistically by the Tukey test ($p \leq 0.05$).

The basis of these equations explains the existing relationship between harvest times and productivity of 'IAC 14-18'; it was possible to find the monthly values presenting the maximum response from variables derived in this study. Thus, the derived partial values were calculated related to the desired parameter. The productions were calculated as to present the maximum response based on partial derived values for each variable studied.

The productively, at 21 months was equivalent to 84.5 t ha^{-1} (Fig. 1A) achieved the greatest monthly harvest from fresh cassava plants. The productivity parameter, at 24 months was equivalent to 39.7 t ha^{-1} presented the greatest productivity from dry plant mass. This difference between dry cassava meal and fresh at the end of the crop is about 45%, which means, almost half the fresh weight is accumulated from carbohydrates that shows the high potential of assimilated partition from cassava plants (Fig. 1B). These results are corroborated by some researchers who have studied the influence from the harvest time on the productivity of cassava for industry and for sweet cassava [9, 12, 13].

In Fig. 1C the adjusted averages are presented on the productivity of fresh cassava roots. Cubic adjustment has also been observed based on the function of time for the variable response. The highest yield was obtained after 19 months at 42 t ha^{-1}, as that was a semi-perennial plant constantly storing starch in its tuberous roots.

It has become evident that the production of cassava roots gradually increased the average yield related to the time, based on which, there is an increased rate in the accumulation of carbohydrates at the end of the first cycle, whereas, the leaves drop in the drier and colder periods. Beginning in the second cycle (12 months), when good precipitations and higher temperatures have been conciliated, the plants grow new leaves and restart more accentuated root development.

These results corroborate with those verified by Benesi [14] and Fukuda [15]. As, the greatest amount of starch extracted was verified after 20 months. Defining the ideal moment for harvesting cassava is an important factor, as it can influence the concentration of starch and the dry material in the roots, cooking time, production of the aerial part, productivity of the tuber roots and among other agronomical characteristics [16].

Sagrilo [12], after evaluating the effect from the harvest time on growth and productivity of varieties, also confirmed in the second physiological resting phase, the plants displayed more conducive for harvesting, due to the increased productivity of tuberous roots, dry material of roots and starch concentration.

Another important variable making it possible to obtain a proportional ratio between the roots produced as compared to the total biomass of the plants (roots, cuttings, stems and leaves), is the harvest index. This parameter can supply a good balance between the total production of carbohydrates by the plants and their distribution to the roots. Currently in plant improvement programs, a harvest index is included as contributing to selection processes, due to the enormous existent variation among varieties [17].

The H also presented variation based on harvest times (Fig. 1D). It increased significantly linearly until the harvest occurred after 24 months, due to the high development rate of plants. Generally, there are great variations in Hs among diverse cultivated genotypes, so that the elevated Hs rates are desirable, as they demonstrate the root capacity for attracting and accumulating as starch, the carbohydrates produced by the aerial part.

The high Hs values have been shown to be extremely important in selecting the variety for growing and selecting the genotype of sweet cassava and besides being closely related to higher commercial yields, they make it possible to achieve high quality from root production, as well as supplying growers increased economic yields due to the quantity produced and quality of the obtained product.

Regarding H as a function of the plant density per area, the variations among planting densities was confirmed in the harvest result index, as the greater the planting density, 33,000 plants per ha^{-1}, there was higher aerial part development, caused by the accumulation in these parts and competing with the development of tuberous roots.

In lower planting densities, it allowed higher root production per plant, but the total yield per unit tended to increase based on increased density. However, when we analyze commercial production, whereas greater disposal rates occur in higher densities, the highest yields are obtained from lower densities and higher Hs, demonstrated in the case of commercial sweet cassava roots, producing a good ratio between productivity per area unit.

For 'IAC 14-18' the accumulation of dry and fresh materials, harvest index and root productivity reached their maximum points from 20 to 24 months after planting. Beginning in the fourth month up to two years, the harvest index increased at an average rate of 0.0164 monthly. In the populations of 9,000, 17,000 and 25,000 plants per hectare around 40% of the total plant mass accumulated in the roots, in the case of 33,000 plants per hectare a little over 20% of the total plant mass is represented by the roots. Thus, the assimilated partition was significantly influenced and negatively in higher populations.

CONCLUSION

The productions of fresh mass as well as dry mass adjust to the third degree polynomial model in all evaluated harvest times. Therefore, the best time for harvesting fresh IAC 14-18 cassava plants is 21 months after planting, however, after 19 months, the planting confirmed the highest productivity of the roots. The plant densities of 33,000 ha^{-1} showed the lowest harvest rates.

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