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EVALUATION OF DIFFERENT PLANTING SPACINGS IN CASSAVA CROP AND ITS RELATIONSHIPS WITH WEED INCIDENCE AND PRODUCTIVITY

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ABSTRACT: One of the main factors for low productivity, as well as for the increase in production cost in cassava crops, is related to inadequate weed control. This study analyzed different planting spacings using two cassava cultivars: “Arapiraca” and “Saracura”, in the municipality of Itapicuru, State of Bahia, in order to perform the cultural control of weeds, as well as to evaluate the productivity of both cultivars. The experimental area was set up as follows: C 01 (“Arapiraca”) and C 02 (“Saracura”), and four planting spacings E 01 (1.0 m X 1.0 m); E 02 (1.0 m X 0.8 m); E 03 (1.0 m X 0.6 m) and E 04 (1.0 m X 0.5 m), in a 2 x 4 factorial scheme, totaling 8 treatments, adopting a randomized block design, with 3 replicates. Treatments were as follows: T1: C01E01; T2: C01E02; T3: C01E03; T4: C01E04; T5: C02E01; T6: C02E02; T7: C02E03; T8: C02E04. Periodic observations of weed incidence in all treatments and the crop behavior as a function of these planting spacings were performed. The average root production and the average commercial root production per plant occurred in treatments T1 and T2; however, the highest total root yields occurred in planting spacings T3 and T4, due to the greater number of plants per area. Therefore, it could be concluded that, for the production of table cassava, even requiring a third weeding, less dense planting spacings are the most suitable, due to their better quality, as well as the greater amount of roots produced; however, for root production destined for industry, denser planting spacings are recommended, as greater productivity is achieved, in addition to better control of the negative effects of weed infestations, reducing production costs.

KEYWORDS: *Manihot esculenta* Crantz. Productivity. Commercial roots. Production cost.

AVALIAÇÃO DE DIFERENTES ESPAÇAMENTOS NA CULURA DA MANDIOCA E SUAS RELAÇÕES COM A INCIDÊNCIA DE PLANTAS DANINHAS E PRODUTIVIDADE

RESUMO: Um dos principais fatores da baixa produtividade, assim como o aumento do custo de produção na cultura da mandioca está relacionado ao controle inadequado de plantas daninhas. O presente estudo buscou analisar diferentes espaçamentos utilizando duas cultivares de mandioca de mesa, Arapiraca e Saracura, no município de Itapicuru, no Estado da Bahia, com o objetivo de realizar o controle cultural de plantas daninhas, bem como avaliar a produtividade em ambas as cultivares. A área experimental foi montada da seguinte maneira: C 01 (Arapiraca) e C 02 (Saracura), e quatro espaçamentos E 01 (1,0 m X 1,0 m); E 02 (1,0 m X 0,8 m); E 03 (1,0 m X 0,6 m) e E 04 (1,0 m X 0,5 m), constituindo um fatorial 2 x 4, totalizando 8 tratamentos adotando um delineamento em blocos casualizados, com 3 repetições. Os tratamentos foram: T1: C01E01; T2: C01E02; T3: C01E03; T4: C01E04; T5: C02E01; T6: C02E02; T7: C02E03; T8: C02E04. Realizaram-se observações periódicas da incidência de plantas daninhas em todos os tratamentos e o comportamento da lavoura em função desses espaçamentos. Os tratamentos T3 e T4 apresentaram excelentes resultados no controle de plantas daninhas em ambas as variedades aos 75 dias após o plantio, dispensando uma terceira capina. A produção de média de raízes e a produção média de raízes comerciais por planta se deram nos tratamentos T1 e T2, no entanto, as maiores produtividades de raízes totais ocorreram nos espaçamentos T3 e T4, devido ao maior número de plantas por área. Portanto, conclui-se que, para a produção de mandioca de mesa, mesmo necessitando de uma terceira capina, os espaçamentos menos adensados são os mais indicados, devido à melhor qualidade das mesmas, bem como à maior quantidade de raízes produzidas, no entanto, para a produção de raízes para a indústria, os espaçamentos mais adensados são recomendados, pois há uma maior produtividade, além de melhor controlar os efeitos negativos das infestações de plantas daninhas, diminuindo os custos de produção.

PALAVRAS CHAVE: *Manihot esculenta Crantz. Produtividade. Raízes comerciais. Custo de produção.*

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INTRODUCTION

Cassava, *Manihot esculenta* Crantz, is native to Brazil and its cultivation extends to all states of the country, being more widespread through family farming. Its use goes far beyond human consumption, serving as animal feed, production of capsules for medicines, toothpaste; its starch is used to cool drills for drilling oil wells, among others. The United Nations Food and Agriculture Organization (FAO) presents cassava as the agricultural crop of the 21st century, due to its importance in human nutrition, being cultivated in more than 80 countries and serving as the basis for feeding more than 800 million people in developing countries (FAO, 2013).

According to FAO (2013), Brazil ranks second in cassava production, corresponding to 10% of world production, reaching 23 million tons of fresh roots, only behind Nigeria. When evaluating Brazilian agricultural production in 2010, FAO found that cassava occupied the fifth position among the country's main agricultural activities. Among Brazilian states, Pará, Paraná and Bahia stand out as the largest producers of fresh cassava roots, corresponding to 46.4% of national production (Silva et al., 2014).

Despite its position in relation to world production, Brazilian productivity is still low, especially in the Northeastern region, where average productivity does not exceed 9 tons/ha. According to Felipe et al., (2010), Brazilian productivity grew only 0.8% between 1990 and 2008, below the Thai average, which increased by 3% in the same period. The low productivity in the Northeastern region of Brazil is due to unfavorable climate conditions, use of cultivars not very resistant to water stress, and cultivation practices that limit the potential of cultivars (Diniz et al., 2013).

According to Hoffmann (2014), cassava plays a very important role in the income of family farmers throughout Brazil. For the author, who cites data from the 2006 Agricultural Census (IBGE), 83% of cassava produced in the country came from family farming. Much of the cassava production is consumed by farmers themselves in the fresh form (macaxeira), or processed in industries (Hoffmann, 2014) to produce flour, starch (tapioca), "beiju", biscuits, among others.

In addition to the consumption of fresh roots (macaxeira) and the family production of flour and starch, cassava is highlighted as a by-product of numerous products sold throughout the world. More than 170 patents for products that use cassava in their composition have been catalogued, the most common and representative include pasta, meats, cakes, flours, and breads (Santos et al., 2018), which makes this culture versatile and a profitable alternative, especially for family farming.

Among cassava culture production costs, the most expensive is the weed control, commonly carried out mechanically, with manual weeding, which may need to be repeated more than three times, depending on the procedures adopted (spacing, planting time). In an attempt to reduce this cost, it is common for producers in regions of the municipality of Itapicuru, Bahia, to carry out chemical control in an indiscriminate manner, using herbicides not registered for the crop, due to their low cost. These practices have a potential environmental impact due to the deposition of pesticides in the soil, in addition to the risk of contamination of reserve roots, caused by application at an advanced stage of crop development.

Assessing the planting density in cassava cultivation not only seeks results regarding productivity related to the number of plants per area, but is also related to greater soil coverage by the crop, thus physiologically interfering with the population of weeds occurring in the cultivation area, since the decrease in solar radiation on the soil reduces the incidence of spontaneous plant germination.

This research project proposes the establishment of denser planting spacing for cassava cultivation for plants to cover the soil more quickly, reducing the incidence of spontaneous plants. This procedure will enable a significant reduction in production costs, due to the lower number of weedings, increasing productivity, and thus increasing the crop profitability, resulting from the reduction in allelopoly between crop and weed.

MATERIAL AND METHODS

This study was carried out between September 1, 2020 and September 30, 2021, in the municipality of Itapicuru, located in the northeastern region of the state of Bahia, which belongs, among 49 municipalities, to the Itapicuru River Hydrographic Basin and to the "Litoral Norte e Agreste Baiano" Identity Territory. Its territorial extension is 1,556,747 km^2, which gives it the largest territorial area in the northeastern mesoregion of Bahia and the "Ribeira do Pombal" microregion. The estimated municipal population in 2018 is approximately 35,256 inhabitants, with demographic density of 20.35 inhabitants.km^{-2}. Itapicuru borders the municipalities of Olindina, Cipó, Nova Soure, Crisópolis, Rio Real and Ribeira do Amparo, in the state of Bahia, and municipalities of Tobias Barreto, Poço Verde and Tomar do Geru, in the state of Sergipe.

The municipality has semiarid climate, with average annual rainfall of 680 mm, according to data from the Municipal Department of Agriculture and City Council. The predominant soils in the municipality are Argisols, according to pedological data from INEMA. The area where the project was developed has flat topography, with sandy loam soil.

The experimental area was set up using two cassava cultivars **C 01** ("Arapiraca") and **C 02** ("Saracura"), and four planting spacings **E 01** (1.0 m X 1.0 m); **E 02** (1.0 m X 0.8 m); **E 03** (1.0 m X 0.6 m) and **E 04** (1.0 m X 0.5 m), with 2 x 4 factorial scheme (2 cultivars x 4 planting spacings), totaling 8 treatments, adopting a randomized block design, with 3 replicates. Treatments were: **T1:** C01E01; **T2:** C01E02; **T3:** C01E03; **T4:** C01E04; **T5:** C02E01; **T6:** C02E02; **T7:** C02E03; **T8:** C02E04. Periodic observations of the incidence of weeds in all treatments and the crop behavior as a function of planting spacing were performed.

To evaluate the number of weeds, collections were carried out through phytosociological characterization and evaluation of the weed community using the inventory square method (Braun-Blanquet, 1950), which is based on the use of a 1.0 m x 1.0 m square randomly placed in the useful area inside treatments. Weeds were identified by their taxonomic specifications and counted. Subsequently, frequency (Fr), relative frequency (Frr), density (De), relative density (Der), abundance (Ab), relative abundance (Abr) and relative importance index (IVI) were calculated according to methodology used by Brandão et al. (1998), Brighenti et al. (2003) and Castro et al. (2011), who used the following formulas:

Fr = Number of plots containing the species / Total number of plots under study (1)
De = Total number of individuals per species / Total sampled area (2)
Ab = Total number of individuals per species / Total number of plots containing the species
Frr = Fr of each species x 100 / total Fr of all species (4)
Der = De of the species x 100 / Total De of all species (5)
Abr = Ab of the species x 100 / Total Ab of all species (6)
IVI = Frr + Der + Apr (7).

After the count, manual weeding was carried out using a hoe, and this procedure was repeated three times in each block from 25 to 75 days after planting (DAP), since weeds that appear after this period do not interfere in the productivity of cassava roots and shoots (Albuquerque et al., 2008),

During the crop cycle, drip irrigation was used in each crop row, carried out when necessary. The irrigation material used was drip tape with 16 mm in diameter and spacing between drips of 20 cm, allowing the entire planting row to be wet, simulating "wet" conditions during rainy periods, favoring the spontaneous emergence of weeds and regular crop growth.

All treatments received the same phosphorus-based fertilizer (super simple) at 25 DAP at dosage of 50 g/plant, and were fertilized with N-P-K fertilizer in the 04-14-08 formulation at 54 DAP and 90 DAP, respectively, both at dosage of 50 g/plant, totaling three fertilizations.

To evaluate productivity, harvest was carried out at 12 months of age. Ten plants were collected within each treatment (Aguiar et al., 2011), corresponding to the useful area of the treatment, and the total root production of each plant was weighed and then the arithmetic mean was taken. Subsequently, commercial roots were weighed, taking into account the size of roots sold in local stores, and the arithmetic average was also taken. The productivity of each treatment was estimated, both for total roots destined for industry and the productivity of commercial roots destined for fresh consumption.

Data were grouped into tables and graphs and treated with the Tukey test at 5% for analysis of variance, where interactions between variables were observed.

RESULTS AND DISCUSSION

Incidence of Weeds

According to data collected, the highest number of weeds was found at 25 days after planting (DAP) in all treatments, since the initial cassava growth is slow, leaving the soil exposed to light and, consequently, there is greater germination of weed seeds (Albuquerue et al., 2008; Azevedo et al., 2000). Also according to Albuquerque et al. (2008), up to 25 DAP, the cassava plant does not suffer negative interference from the presence of weeds in the cultivation area; however, between 25 and 75 DAP is the critical period of interference, requiring adequate weed control (Silva et al., 2012). (Figure 1 and 2).

Figure 1: Average number of weeds in "Arapiraca" cultivar treatments.

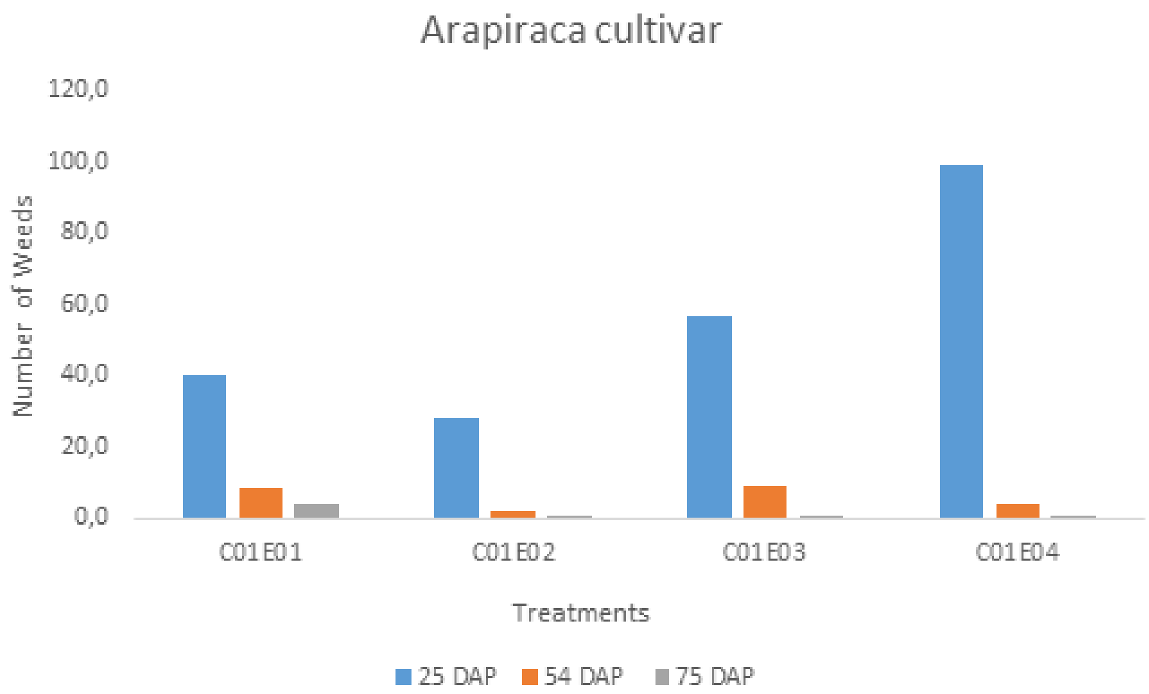
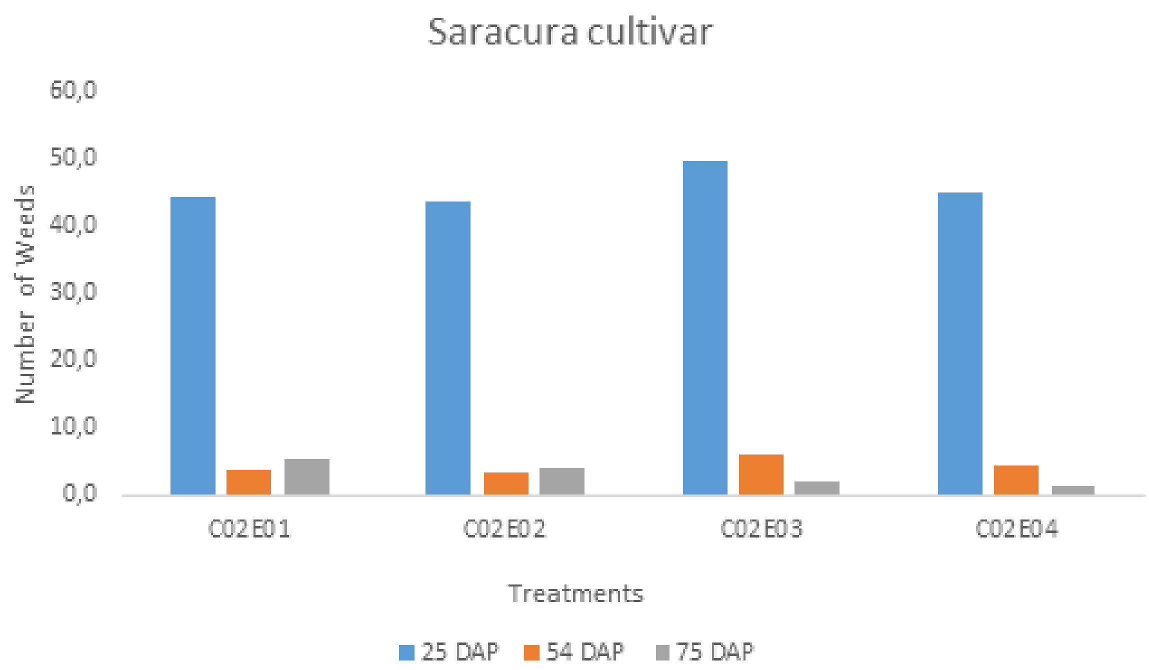


Figure 2: Average number of weeds in "Saracura" cultivar treatments.



Data collections carried out at 54 and 75 DAP showed significant decrease in the number of weeds in all treatments; however, in treatments with the lowest densities, the highest incidences occurred, requiring a third weeding, thus increasing production costs. According to Albuquerque et al. (2008), the highest production cost in cassava cultivation is linked to control or poor control of weeds (Figure 1 and 2).

In smaller planting spacings (1.0 m x 0.8 m, 1.0 m x 0.6 m and 1.0 m x 0.5 m), there was no need for a third weeding, since at 75 DAP, the number of weeds per m² did not justify the need for control. This result corroborates Albuquerque et al. (2008), who detected that after 75 DAP, the incidence of weeds does not cause damage to the cassava crop if control has been carried out appropriately.

In general, with smaller planting spacings in both cultivars, reduction in the incidence of weeds was observed; however, at 75 DAP, the "Saracura" cultivar presented higher averages than the "Arapiraca" cultivar, due to its phenology, which presents narrower leaves, allowing greater aeration and luminosity inside plots, favoring the germination and growth of weeds (Figure 3 and Table 1).

Figure 3: Average number of weeds in all treatments.

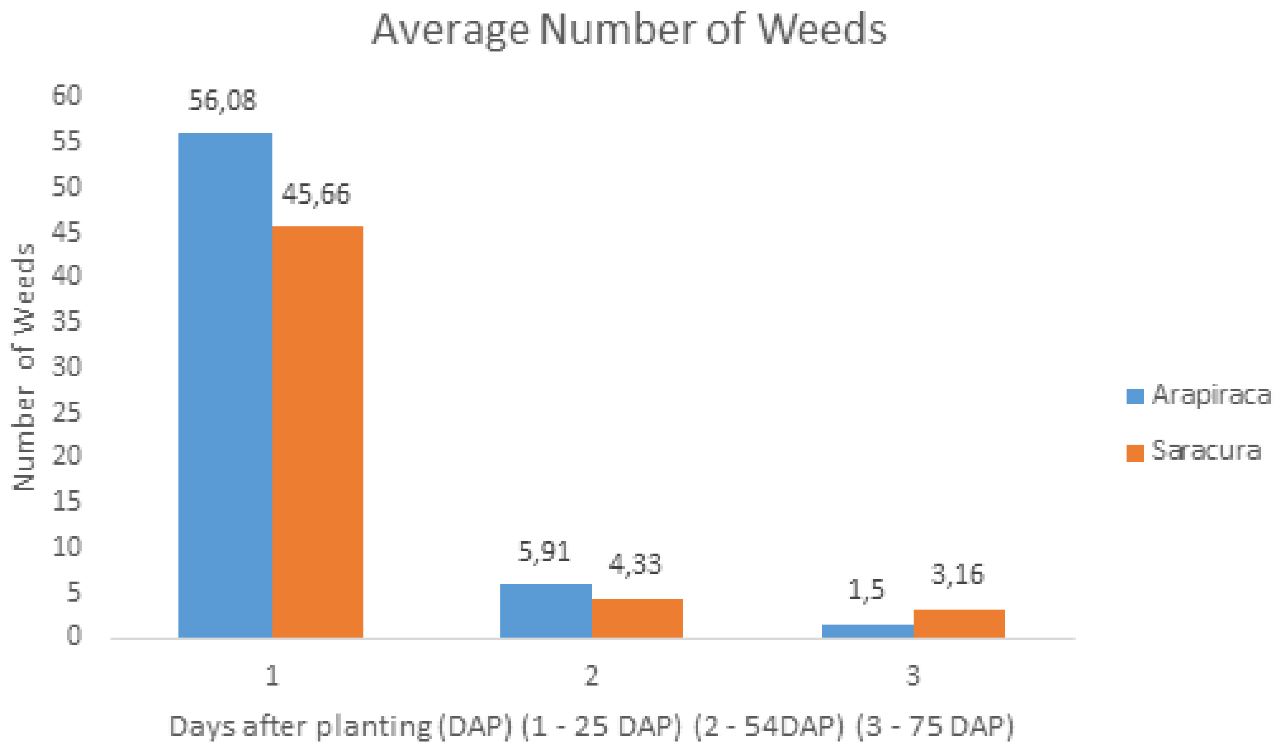


Table 1: Average number of weeds

Average number of weeds		
Days After Planting (DAP)	"Arapiraca" cultivar	"Saracura" cultivar
25	56.083333 a2	45.666667 a2
54	5.916667 a1	4.333333 a1
75	1.500000 a1	3.166667 a1
CV (%)	93.91	

CV: Coefficient of variation. Means followed by the same letter and number in columns do not differ from each other by the 5% Tukey test for the analysis of variance.

For Streck et al. (2014), although plants submitted to denser planting spacing reduce the number of leaves and lateral shoots, the leaf mass index is compensated due to apical dominance, as plants grow in search of light. In addition, there is greater number of cassava plants per area, which favors soil shading and, consequently, lower incidence of weeds. However, this factor is directly linked to the cultivar phenology (Albuquerque et al., 2008).

Productivity

Analysis of variance shows interactions between variables under study, showing that in both cultivars, the root production behavior was similar, presenting the highest total root production and commercial root production in the largest planting spacing and decreasing in denser planting spacings. According to Aguiar et al. (2011), plants exposed to less competition among themselves have greater root production, as well as improvement of their commercial quality. Streck et al. (2014) reported that the lower the planting density, the higher the productivity per plant (Tables 2 and 3)

Table 2: Average total root weight per plant.

Total root production in kg/plant		
Treatments	"Arapiraca" cultivar	"Saracura" cultivar
E01	4.203333 a2	4.963333 a3
E02	3.316667 a1	4.083333 a2
E03	2.766667 a1	3.313333 a1
E04	2.786667 a1	3.096667 a1
CV (%)	6.67	

CV: Coefficient of variation. Means followed by the same letter and number in columns do not differ from each other using the 5% Tukey test for the analysis of variance.

Table 3: Average weight of commercial roots per plant

Production of commercial roots in kg/plant		
Treatments	"Arapiraca" cultivar	"Saracura" cultivar
E01	3.583333 a3	4.626667 a4
E02	2.570000 a2	3.420000 a3
E03	1.470000 a1	2.416667 a2
E04	1.400000 a1	1.743333 a1
CV (%)	9.16	

CV: Coefficient of variation. Means followed by the same letter and number in columns do not differ from each other using the 5% Tukey test for the analysis of variance.

Among cultivars, "Saracura" obtained the highest production averages, both for total roots and commercial roots, which is probably due to the fact that the morphology of the leaves of this cultivar presents narrower leaflets and erect stems (Souza; Lima, 2017), and with few branches, favoring plant development without competing with each other for space and light (Aguiar et al., 2011).

Considering the individual performance of each cultivar, analyzing variable total root production, the "Arapiraca" cultivar showed no statistical difference in treatments T2, T3 and T4, while treatment T1, it showed the highest individual productivity averages. The "Saracura" cultivar showed significant interaction between treatments T5 and T6 for the same variable, presenting the highest average productivity per plant, while in treatments T7 and T8, there was no statistical difference, according to the Tukey test for analysis of variance (Figure 4 and 5).

For the production of commercial roots, the "Arapiraca" cultivar showed statistical difference between treatments T1 and T2 with the highest average production per plant, indicating that lower densities provide greater yield of commercial roots (Aguiar et al., 2011). Treatments T3 and T4 did not show statistical variation for this variable. For the "Saracura" cultivar, there was variation between all treatments, with the highest average production of commercial roots per plant in treatments with the lowest densities (Figures 4 and 5).

With regard to productivity per area of commercial roots, treatments with larger planting spacings presented the highest averages in both cultivars. This is due to less competition between cassava plants themselves (Aguiar et al., 2011), resulting in lower losses of roots that are not accepted in the cassava market. Among cultivars, "Saracura" was the one that performed best for this variable in all treatments compared to the "Arapiraca" cultivar (Figures 6 and 7).

Figure 4: Average production of total and commercial roots per plant for the “Arapiraca” cultivar.

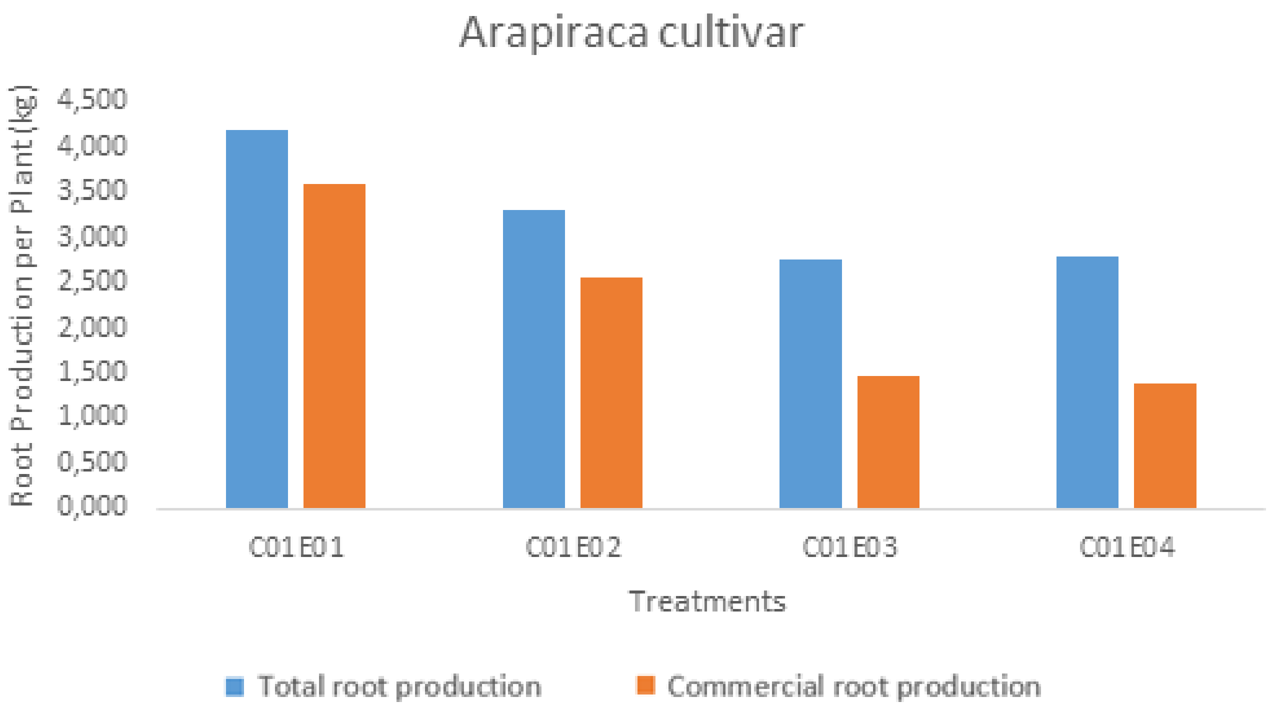


Figure 5: Average production of total and commercial roots per plant for the “Saracura” cultivar.

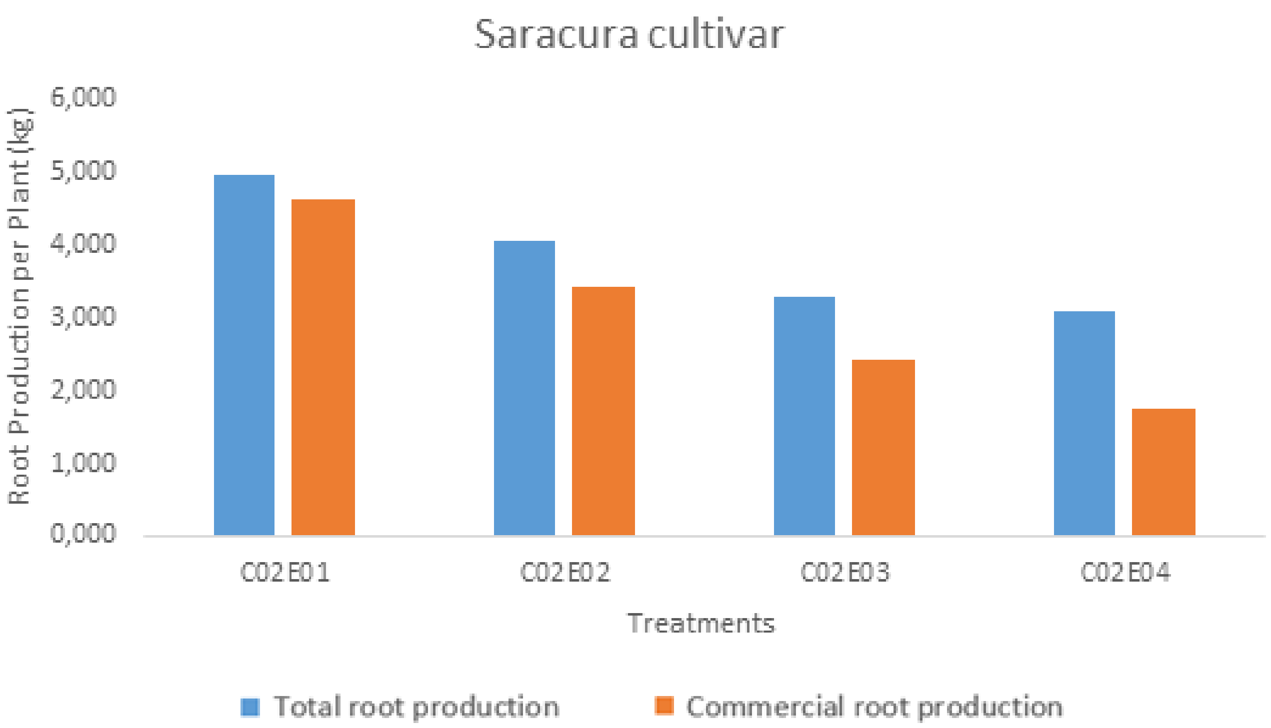


Figure 6: Productivity per hectare, "Arapiraca" cultivar.

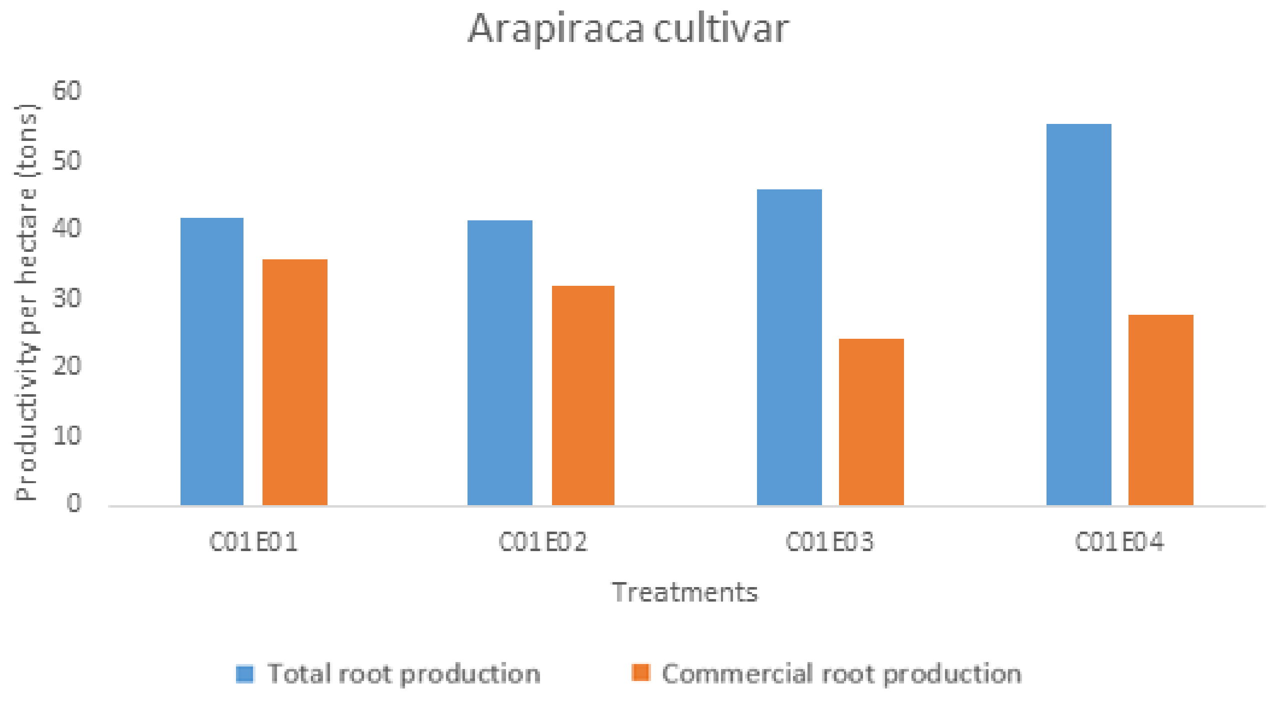
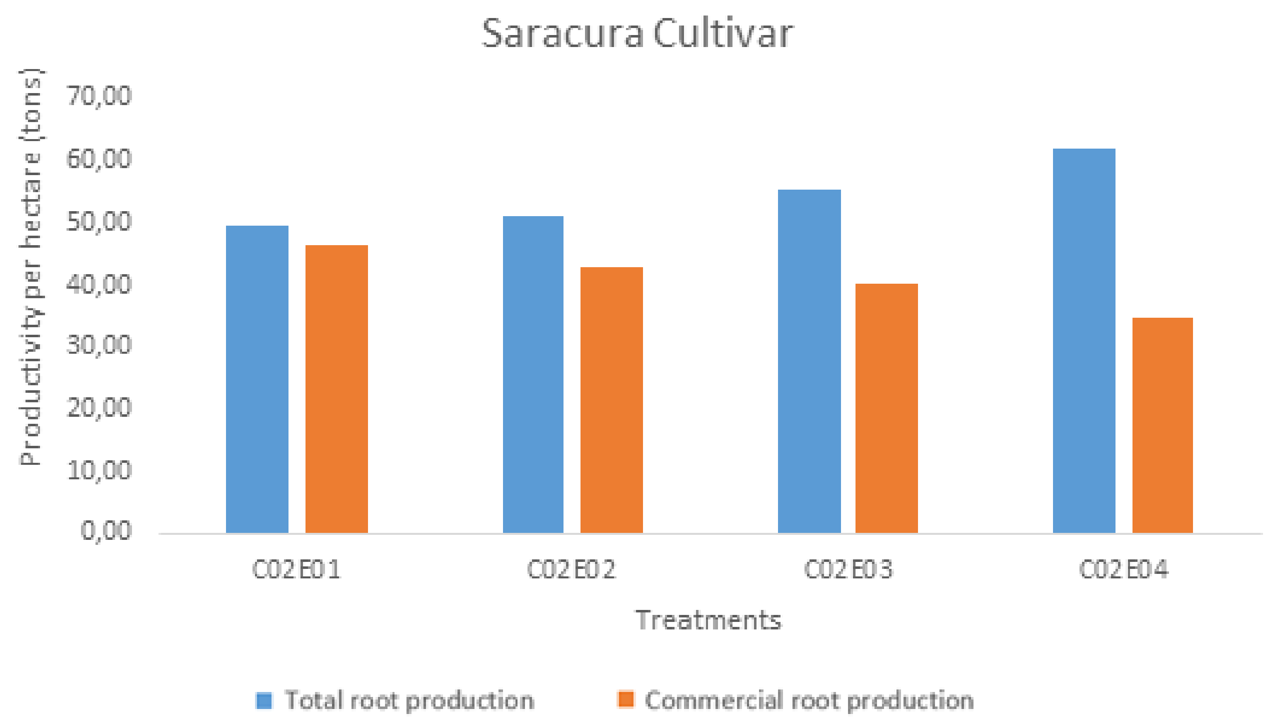


Figure 7: Productivity per hectare, "Saracura" cultivar.



In the evaluation of the general indices for total root productivity, the behavior of both cultivars is the opposite for the production of commercial roots, presenting the best productivity averages in treatments with greater planting density. Although the average production per plant is lower compared to less dense planting spacings, this increase in productivity is justified by the greater number of plants per area (Streck et al., 2014).

Based on results obtained, it could be concluded that treatments T1 and T2 ("Arapiraca" cultivar) as well as treatments T5 and T6 ("Saracura" cultivar), corresponding to less dense spacing, 1.0 m X 1.0 m and 1.0 m X 0.8 m, respectively, they presented greater number of weeds at 75 days after planting (DAP), thus requiring a third weeding, which increases production costs in cassava cultivation. On the other hand, less dense spacings T3, T4 for the "Arapiraca" cultivar (1.0 m m X 0.6 m and 1.0 m X 0.5 respectively) and treatments T7 and T8 for the "Saracura" cultivar (1.0 m X 0.6 m and 1.0 m X 0.5 m respectively), obtained satisfactory soil coverage results, which favored the cultural control of weeds, with no need for a third weeding.

In relation to cultivars, "Arapiraca" presented, at 75 DAP, lower number of weeds in all treatments compared to the "Saracura" cultivar, even though, in both, there was no need for mechanical or chemical control. This is due to the morphology and phenology of the shoots of these cultivars, in which "Arapiraca" has greater soil coverage capacity. This weed control study helps producers make decisions when choosing the best cultivar for certain areas with large weed infestations.

With regard to root production per plant, in both cultivars, less dense treatments showed greater production, since competition between cassava plants is less than in denser planting spacings. The production of commercial roots for fresh consumption was also greater in larger planting spacings due to less competition for space. The "Saracura" cultivar showed higher production compared to "Arapiraca" cultivar, and this may be an factor intrinsic to the cultivar. As for productivity per area, denser planting spacings stood out due to the greater number of plants.

It could be concluded that, for the production of commercial roots, even requiring a third weeding, less dense planting spacings are the most recommended due to their better quality, as well as the greater amount of roots produced. As for production destined for industry (flour mills and starch factories), denser spacings are the most recommended due to greater productivity per area, increasing farm revenue and reducing production costs, due to the smaller number of weedings to control weeds.

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