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Production and profitability of yacon grown in different spatial arrangements

Arnaldo Henrique de Oliveira Carvalho[1]*, Fábio Luiz de Oliveira[2], Wallace Luís de Lima[3], Ariany Teixeira da Graça[4], Joab Luhan Ferreira Pedrosa[5], Magno do Carmo Parajara[6]

[1]Instituto Federal do Espírito Santo - Campus Ibatiba, Brazil
[2]Departamento de Agronomia - CCAE/UFES, Brazil
[3]Instituto Federal do Espírito Santo - Campus de Alegre, Brazil
[4]Doutorado em Produção Vegetal - CCAE/UFES, Brazil
[5]Doutorando em Produção Vegetal - CCAE/UFES, Brazil
[6]Graduando em Agronomia - CCAE/UFES, Brazil

***Corresponding author: acarvalho@ifes.edu.br**

Abstract

The interest in yacon has generated a demand for information that may enhance the production system. Among them are the studies on the different spatial arrangements of planting spacing. Therefore, the purpose of this study was to evaluate the production and yield of yacon cultivated in different arrangements, varying the spaces between the lines and the plants. The experimental design was a randomized complete block design, being the parcels composed by three spacing between lines (0.80, 1.0 and 1.20 meters) and the subplots by three spacing between plants within the lines (0.40, 0.50 and 0.60 meters), distributed in 9 treatments with four replications. At harvest time, evaluations on the accumulation of dry mass in the plant and tuber root production data (number, weight, total productivity, and per class) were made. Profitability indicators were estimated (Gross Income, Operational Profit and Benefit-Cost ratio). The arrangements of 0.80 x 0.40 m and 1.00 x 0.50 m produced higher tuberous roots yield (37.5 and 39.8 t ha^{-1}, respectively), but the arrangement 1.00 x 0. 50 m had a higher profit (US$ 13,854.91) and a better benefit-cost ratio (4.9), which is the most indicted.

Keywords: *Smallanthus sonchifolius*; spacing; plant population, profit.

Introduction

Yacon is a functional food with great potential for exploitation, since its composition has bioactive compounds that offer benefits to consumer health (Sousa et al., 2015). It is a plant with considerable nutritional value. The interest of food and pharmaceutical industries is mainly focused on its antidiabetic effect modulating the concentration of insulin in the blood plasma (Paula et al., 2015). Recent studies have associated the combination of yacon root with reduced glycemic index, due to the effects they have on health (Lachman et al., 2003; Sousa et al., 2015). Moreover, yacon has other interesting properties, such as antimicrobial and anti-inflammatory actions (Sousa et al., 2015), becoming an expressive culture due to its nutraceutical potential. These researches have increased the interest for the culture and, generated a demand for information on its cultivation, mainly in order to improve the production system. Among the demands, studies on the productivity and profitability of yacon from different spatial arrangements of planting are necessary. The study of spatial arrangement of plants will allow defining the best way of organizing plants in the spaces, besides reducing the competition for environmental resources, which may also contribute to a higher yield and efficiency of the crop (Bezerra et al., 2014). The greater efficiency in the use of the resources during cultivation, could be achieved with the ideal arrangement of planting. This could reflect directly to the crop yield and, in the profitability of the yacon crop. In this sense, there are reports that spatial arrangements have influenced productivity and profitability in taro cultivation (Herédia Zárate et al., 2012), beet (Herédia Zárate et al, 2008), cassava (Silva et al., 2013) and carrot (Resende et al, 2016). The yacon has been cultivated under different arrangements, ranging from 0.60 to 1.40 m between rows and from 0.45 to 0.90 m between plants (Doo et al., 2001; Amaya Robles, 2002; Tokita et al., 2015). Thus, there is still demand for adjustment in the ideal crop arrangement (Amaya Robles, 2002). This situation shows the need for research on the subject through the evaluation of the best arrangement of plants, which is, the line spacing and the distribution of plants in the line. This will allow defining the best distance between plants in the cultivation area (Herédia Zárate et al., 2008). There is a lack of study on profitability and the monitoring of costs for the yacon culture, which are essential for the success of its production as non-conventional vegetable, considering its applicable as an innovative kind of income and social interest to compose the agrosystems (Torales et al., 2015). Therefore, the objective of this study was to evaluate the production and profitability of yacon grown in different arrangements, varying the spacing between lines and within lines.

Results and Discussion

Effect of treatments on biomass accumulation

The accumulation of dry biomass in the aerial part and roots was influenced by the arrangements. There was no effect for the accumulation in rhizophores. In general, the plants presented biomass of rhizophores ranging from 0.48 to 0.80 t ha^{-1}. For the accumulation of biomass in the aerial part, we observed that spacing of 0.80 and 1.20 m between lines caused no difference. However, at 1.00 m between lines and 0.50 m between lines, the greatest accumulation of dry biomass in aerial part (2.58 t ha^{-1}) was found (Table 1). The accumulation of biomass in the roots presented a difference between the treatments. At 0.80 and 1.20 m spacing between the lines, a higher accumulation of root biomass was obtained when there was a 0.40 m distance between the plants on lines. However, at 1.00 m spacing between lines, the greatest accumulation of biomass in the roots is occurred at 0.50 m between plants spacing (3.73 t ha^{-1}) (Table 1). This treatment promoted accumulation of biomass among the studied spacings. It was the most ideal for yacon biomass production in certain conditions, and the one closest to the one recommended for cultivation, in the State of Espirito Santo 1.0 x 0.5 m and for the other producing regions, 1.0 x 0.6 m (Oliveira et al., 2013). This spacing (1.0 x 0.5 m) prevents tuberous roots from growing too much and exceeding the most accepted size in the market (Oliveira et al., 2013). This result shows that yacon plants can change their photoassimilate allocation, thus varying the accumulation of biomass in different organs according to their need. The distribution of plants per area, according to the different spatial arrangements, has possibly changed the photosynthetic efficiency of the plant, and consequently, which increased the production in the most comfortable situations for plants (Kvitschal et al., 2010). This is due to the ability of plants to allocate, as a matter of priority, resources for reproduction, survival, development, growth an defense are important adaptive features, defined within the principle of allocation of photo-assimilates, as explained by Fancelli and Dourado Neto (1996).

Effect of treatments on the agronomic performance of yacon

The production in tuberous roots reflected accumulation of dry biomass, which was observed at 0.80 m spacing between the lines. The highest yield of tuberous roots was observed in the smaller spacing between plants (0.40 m). At 1.00 m between the rows spacing, higher productivity was observed in the tuberous roots for the plant spacing of 0.50 m. There were no differences in the spacing of 1.20 m between rows (Table 2). Yacon productivity may change according to the spacing arrangement. Amaya Robles (2002), obtained a yield of 65.8 t ha^{-}1 of tuberous roots at 1.00 m spacing between rows and 0.80 m between plants (12,500 plants ha^{-1}). They achieved 45.3 t ha^{-1} using spacing of 1.40 m between rows and 1.00 m between plants (7,142 plants ha^{-1}). Sumyianto et al. (2012), cultivated three plants per linear meter (30,303 plants ha^{-1}) and obtained productivity of 26 t ha^{-1} of tuberous roots. Thus, the yields of tuberous roots in the arrangements of 0.80 x 0.40 m (31.250 plants ha^{-1}) (37.5 t ha^{-1}) and 1.00 x 0.50 m (20,000 plants ha^{-1}) (39.8 t ha^{-1}), would be within the range observed in this crop. This effect on productivity reflects the sensitivity of the plant to the medium which occurs due to competition for water, light and nutrients, or the increased availability of these features, along with the intrinsic genotype response of the species (Herédia Zárate et al., 1995). The plants show direct adaptation responses to the medium, which change the physiological indexes, such as the duration of the photosynthetically active leaf area; chlorophyll content. This may alter the light absorption capacity and the transfer of radiant energy to the reaction centers, representing a change in the productive capacity of the plants (Larcher, 2000). In general, it has been noted that the yield of yacon is varied, possibly due to the fact that species were still adapting to the environments outside the Andes; and therefore are still very sensitive to the conditions of cultivation. In the state of São Paulo, yields ranging from 30 to 62.5 t ha^{-1} were reported (Amaya Robles, 2002). In Espírito Santo, Silva et al. (2018a) observed variation in the production due to the edaphoclimatic conditions of cultivation, and 97.50 t ha^{-1} (in the mountainous region) and 60.65 t ha^{-1} (in the lowered region). Even these authors observed that in conditions of higher temperatures, maturity is advanced, and causes a decrease in the plant productivity. Silva et al. (2018b) showed the sensitivity of the plant to the soil cover, and the crop presented higher yields of tuberous roots when grown on covered soil with double-sided plastic (31.71 t ha^{-1}) and coffee grounds in the level (28.35 t ha^{-1}). This was related to the conditions of lower temperatures and higher soil moisture, and the suppression of the spontaneous plants, which favors yacon. It is important to understand influence of the arrangements on the categories of produced roots, since the market has preference. The behavior was similar to the total productivity. For the line spacing of 0.80 m, there was a greater amount of roots of class 2A and 3A (larger roots), when the spacing between plants of 0.40 m was adopted. The highest root numbers in the best classes (2A and 3A) were observed at 1.0 m between row spacing and plant spacing of 0.50 m. Only class 3A showed higher yields at 1.20 m line and 0.40 plant spacing (Table 3). It is noteworthy that the arrangements that showed higher total productivity also had higher productive yield in the classes of roots with higher commercial value. The arrangement of 0.80 m x 0.40 m had a yield of 48% and 38% in classes 2A and 3A, respectively. The same yield in the best classes (2A and 3A) was observed in the 1.00 x 0.50 m arrangement. This is an interesting result considering that these two categories of roots meet the market demand, since they are the ones with the highest commercial value. It is observed that the amount of roots produced in class 1A was lower than in the other classes, regardless of the arrangement adopted. The root productivity in class 1A practically does not change, due to the arrangements adopted, except for 1.20 m spacing between lines, which presented lower amount of roots in this class, when the spacing was 0.4 m between plants (Table 2). The lower root production in this category is economically interesting, especially for the "in natura" root market, since these are called "scrap" because of the low commercial value.

Table 1. Accumulation of dry biomass in aerial part and tuberous roots of yacon plants grown in different spacing between lines and between plants.

Spacing within lines (m)	Aerial part (t ha^{-1})		
	Spacing between lines (m)		
	0.80	1.00	1.20
0.40	2.47 a	2.13 b	1.93 a
0.50	2.15 a	2.58 a	1.63 a
0.60	2.23 a	2.18 b	1.83 a
CV% ²	10.23		
	Roots (t ha^{-1})		
Spacing within lines (m)	Spacing between lines (m)		
	0.80	1.00	1.20
0.40	3.23 a	2.08 b	2.25 a
0.50	1.93 b	3.73 a	2.00 b
0.60	1.40 b	1.90 b	1.43 b
CV%²	16.38		

¹Means followed by the same lowercase letter in the columns. do not differ by Tukey's test ($p \leq 0.05$).
²CV - coefficient of variation -%.

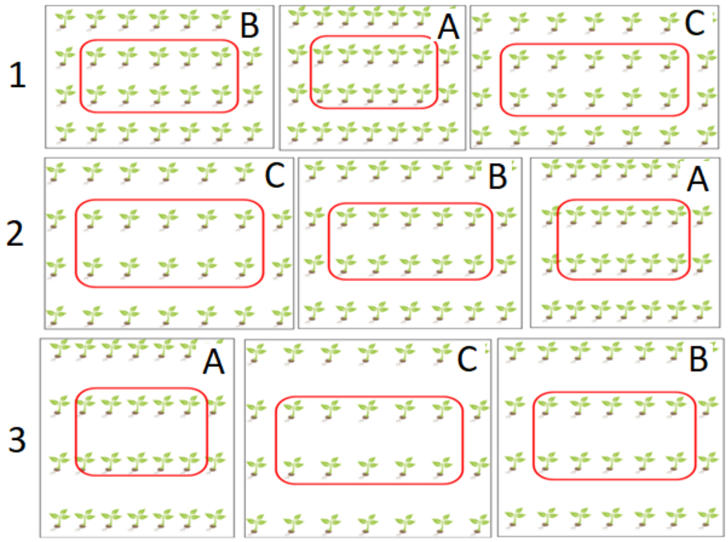

Fig 1. A sketch representing a block in the experimental area. Plots 1, 2 and 3 spacing between lines (0.8. 1.0 and 1.20 m. respectively). Sub-plots A. B and C spacing within lines (0.4; 0.5 and 0.6 m. respectively).

Table 2. Production of tuberous roots of yacon, total and per class, grown in different lines and spacing between plants.

Spacing within lines (m)	Spacing between lines (m)		
	0.80	1.00	1.20
	Total yield of tuberous roots (t ha^{-1})		
0.40	37.5 a¹	25.0 b	22.1 a
0.50	26.4 b	39.8 a	22.2 a
0.60	20.3c	20.9 b	18.5 a
CV% ²	13.15		
	Tuberous root production in Class 1 A (t ha^{-1})		
0.40	5.3 a	5.2 a	2.4b
0.50	4.3 a	5.3 a	4.4 to
0.60	4.7 a	4.5 a	3.4 ab
CV% ²	20.24		
	Tuberous root production in Class 2A (t ha^{-1})		
0.40	17.9 a	13.9 b	9.5 a
0.50	13.9 ab	19.3 a	11.6 a
0.60	10.3 b	10.2 b	10.2 a
CV% ²	19.51		
	Tuberous root production in Class 3A (t ha^{-1})		
0.40	14.2 a	5.9b	10.1 a
0.50	8.2b	15.2 a	6.3 b
0.60	5.3c	6.2b	4.8 b
CV% ²	11.72		

¹Means followed by the same lowercase letter in the columns. do not differ by Tukey's test ($p \leq 0.05$).
²CV - coefficient of variation -%.

Table 3. Production, gross income, production cost, profit and benefit-cost ratio of yacon commercial roots grown in different spacing between the line and between the plants.

Arrangements (m)	Nº of plants ha^{-1}	Production (t ha^{-1})	Gross Income[1] (US$)	Costs[2] (US$)	Profit (US$)	Benefit-Cost Ratio (BCR)
0.80 x 0.40	31.250	37.51	16.410.63	5.004.44	11.406.19	3.3
0.80 x 0.50	25.000	24.97	10.924.38	4.078.76	6.845.62	2.7
0.80 x 0.60	20.833	22.05	9.646.87	3.466.02	6.181.34	2.8
1.00 x 0.40	25.000	26.35	11.528.13	4.292.65	7.498.48	2.7
1.00 x 0.50	20.000	39.76	17.395.00	3.540.09	13.854.91	4.9
1.00 x 0.60	16.666	22.20	9.712.50	2.934.24	6.778.26	3.3
1.20 x 0.40	20.833	20.29	8.876.87	3.448.32	5.428.55	2.6
1.20 x 0.50	16.666	20.87	9.130.62	2.920.85	6.209.77	3.1
1.20 x 0.60	13.888	18.45	8.071.87	2.520.10	5.551.77	3.2

[1] Calculations based on R$1.75 kg^{-1} average values traded between January and February of 2018 at the Espírito Santo Supply Center (Ceasa/ES) in Brazil converted to dollar based on the exchange rate of the Brazilian currency on November 28 2018 . [2] Production Cost of one hectare of yacon constructed in Table 1.

Table 4. Estimated costs for yield per hectare of yacon grown in different spacing between line and between plants in Alegre. Espírito Santo. Brazil.

Item	Un.	Value Unit. (US$)[1]	Costs by population arrangement - US$[1]					
			0.80 x 0.40 m		0.80 x 0.50 m		0.80 x 0.60 m	
			Amount	Total	Amount	Total	Amount	Total
1-Inputs								
Bovine manure	t	17.5	15	262.50	15	262.50	15	262.5 0
Seedlings	un.	0.05	31.250	1.562.50	25.000	1.250.00	20.833	1.041.65
2-Services								
Plowing/Harrowing	H/T	15.00	6	90.00	6	90.00	6	90.00
Planting	D/H	12.50	42	525.00	34	425.00	28	350.00
Weeding	D/H	12.50	34	425.00	28	350.00	23	287.50
Fertilizing	D/H	12.50	47	587.50	38	475.00	31	387.50
Harvest	D/H	12.50	42	525.00	34	425.00	28	350.00
Ranking	D/H	12.50	42	525.00	34	425.00	28	350.00
Irrigation	D/H	12.50	10	125.00	10	125.00	10	125.00
EOC				4.627.00		3.827.50		3.244.15
3-Charges								
Social contribution		2.3% of GI		377.044		251.26		221.88
TOC				5.004.44		4.078.76		3.466.02
Item	Un.	Value Unit. (US$)[1]	Costs by population arrangement - US$ [1]					
			1.00 x 0.40 m		1.00 x 0.50 m		1.00 x 0.60 m	
			Amount	Total	Amount	Total	Amount	Total
1-Inputs								
Bovine manure	t	17.5	15	262.50	15	262.50	15	262.50
Seedlings	un.	0.05	25.000	1.250.00	20.000	1.000.00	16.667	833.35
2-Services								
Plowing/Harrowing	H/T	15.00	6	90.00	6	90.00	6	90.00
Planting	D/H	12.50	34	425.00	27	337.50	23	287.50
Weeding	D/H	12.50	28	350.00	22	275.00	18	225.00
Fertilizing	D/H	12.50	38	475.00	30	375.00	25	312.50
Harvest	D/H	12.50	34	425.00	27	337.50	23	287.50
Ranking	D/H	12.50	34	425.00	27	337.50	23	287.50
Irrigation	D/H	12.50	10	125.00	10	125.00	10	125.00
EOC				3.827.50		3.140.00		2.710.85
3-Charges								
Social contribution		2.3% of GI		265.15		400.09		223.39
TOC				4 292.65		3.540.09		2.934.24
Item	Un.	Value Unit. (US$)[1]	Costs by population arrangement - US$[1]					
			1.20 x 0.40 m		1.2 0 x 0.50 m		1.20 x 0.60 m	
			Amount	Total	Amount	Total	Amount	Total
1-Inputs								
Bovine manure	t	17.5	15	262.50	15	262.50	15	262.50
Seedlings	un.	0.05	20.833	1.041.65	16.667	833.35	13.889	694.45
2-Services								
Plowing/Harrowing	H/T	15.00	6	90.00	6	90.00	6	90.00
Planting	D/H	12.50	28	350.00	23	287.50	19	237.50
Weeding	D/H	12.50	23	287.50	18	225.00	15	187.50
Fertilizing	D/H	12.50	31	387.50	25	312.50	21	262.50
Harvest	D/H	12.50	28	350.00	23	287.50	19	237.50
Ranking	D/H	12.50	28	350.00	23	287.50	19	237.50
Irrigation	D/H	12.50	10	125.00	10	125.00	10	125.00
EOC				3.244.15		2.710.85		2.334.45
3-Charges								
Social contribution		2.3% of GI		204.17		210.00		185.65
TOC				3.448.32		2.920.85		2.520.10

[1]Amount based on the Brazilian dollar exchange rate.

However, they can be destined for industry or animal feed (Amaya Robles, 2002).

Effect of treatments on gross income and the benefit/cost ratio

In a complementary way, information was generated on the profitability of the culture in the different arrangements. Therefore, the cost of production was estimated in order to produce 1.0 hectare of yacon in Alegre. There was a variation of US$ 2,484.84 in the total production cost, while the lowest cost was US$ 2,520.10, corresponding to the arrangement of 1.20 m x 0.60 m. The highest cost (US$ 5,004.94) corresponded to the arrangement of 0.8 x 0.40 m (Table 3).

The highest percentage of the total production cost of the yacon crop was invested in labor services. However, without significant difference between the arrangements, varying from 54-57% of the total production cost. The most influential factor on was propagation costs, corresponding to the acquisition of rhizophores (propagation material-seedlings). This represented 27.5% of the production cost for the arrangement with fewer plants per area (1.20 x 0.60 = 13.888 plants ha^{-1}) and 32% for the arrangement with greater number of plants (0.80 x 0.04 = 31.250 plants ha^{-1}) (Table 3).

We observed that even with the lowest productivity (18.45 t ha^{-1}), the arrangement of 1.20 x 0.60 m showed a benefit-cost ratio (BCR) very close to the arrangement 0.80 x 0.40 m (second highest productivity. 37.51 t ha^{-1}), with BCR of 3.2 and 3.3, respectively (Table 3).

This result is attributed mainly to the lower investment in propagation, which the arrangement of 1.20 x 0.60 demanded. This shows that the number of plants directly influences the production cost of the crop, whereas the greater quantity of plants demands a greater quantity of seedlings and labor, altering the production and consequently the benefit/cost ratio.

This is a common feature in vegetatively propagated crops, where expenditures on propagating material represent a good part of the total production cost of the crop. This requires attention to this component of production. In the cultivation of arracacha, the cost of acquisition of propagative material represented 36% of the total production (Torales et al., 2015). In the production of taro, the cost with propagating material, considering only the variable costs was 45% of the total production (Herédia Zárate et al., 2012).

The best benefit-cost ratio (BCR) was achieved with the 1.00 x 0.50 m arrangement (4.9), showing the highest rate of return. It reached US$ 4.90 for every US$ 1.00 invested. Furthermore, it was the most profitable arrangement. with total return of US$ 13,854.91 (Table 3). The higher yields were achieved in this arrangement, together with a median seedling cost (20.000 plants ha^{-1}), contributing significantly to these BCR values and to the observed profitability. Huaycho et al. (2016) observed that the BCR yacon crops can vary depending on the varieties used. They found that highest value was 4.53 in areas with farmers in the inter-Andean valleys of Bolivia.

It should be noted that all the spatial arrangements used presented a benefit-cost ratio (BCR) above 1, showing an economic return under different intensities. Thus, yacon cultivation is possible using several arrangements by varying the spacing between plants and between rows. However, there is a need to define adequate spacing in order to potentiate not only the growth and production of plant but also benefit-cost ratio (BCR) and crop profitability for these study conditions. The recommended arrangement would be planting at a spacing of 1.00 x 0.50 m.

Materials and Methods

Experimental area

The study was developed in the experimental area of the Federal Institute of Education, Science and Technology of Espírito Santo (Ifes), Campus, Alegre, located in the district of Rive (Alegre-ES) coordinates 20°45' south latitude and 41°27' longitude West. The site is 120 m altitude and located in the valley of Rio Itapemirim, which is a hot tropical micro-region (lowland) with higher temperatures. During the experimental period, the maximum temperatures varied between 26.5 and 35.1°C and a minimum of 14.9 and 21.2°C with accumulated precipitation of 850 mm (data acquired from the automatic meteorological station of the National Institute of Meteorology of Brazil (INMET, Alegre/ES), located next to the experiment. The soil of the experiment was classified as Red-Yellow Latosol, medium texture (EMBRAPA. 2014). The samples were collected in the layers of 0-20 cm deep and a soil analysis showed the following characteristics: pH (H_2O) 5.9; phosphorus Mehlich 1 (P): 39.80 mg dm^{-3}; potassium (K): 69mg dm^{-3}; aluminum (Al): 0.0 $cmol_c$ dm^{-3}; hydrogen + aluminum (H + Al): 1.80 $cmol_c$ dm^{-3}; calcium (Ca): 1.35 $cmol_c$ dm^{-3}; magnesium (Mg): 0.49 $cmol_c$ dm^{-3}; base sum (BS): 1.97 $cmol_c$ dm^{-3}; V% 52.25; Cation Exchange Capacity (CEC): 3.77; organic matter (OM): 14 g kg^{-1}. The soil was prepared by plowing followed by harrowing and liming was not carried out at the planting sites.

Agronomic practices

Yacon planting was conducted in holes of about 15 cm (depth and diameter), using seedlings with three pairs of leaves, approximately 10 cm high prepared in plastic bags (10 x 18 cm) filled with substrate with ravine soil and bovine manure in the ratio 2:1. The seedlings were produced from rhizophores originating from the same genotype (Lorenzoni et al., 2017). Organic fertilization was carried out using tanned bovine manure in the amount of 15 t ha^{-1}. The application was divided into three equal period. The first was carried out in the day of planting; the second, 30 days after planting and the third, 60 days after planting. Throughout the crop cycle, manual control of spontaneous plants and irrigation by conventional spraying were performed.

Experimental design

The experimental design was a randomized complete block design divided into three spacing between lines (0.80. 1.00 and 1.20 meters) and the subplots with three spacing within lines (0.40. 0.50 and 0.60 meters) distributed in 9 treatments with four replications (Figure 1).

Each experimental plot consisted of 4 lines with 7 plants in each line, totaling 28 plants per plot, considered as “useful plants” for the evaluations of the 10 most central plants, arranged in the two central lines and the others considered as a border. The total experiment area comprised of approximately 400 m².

Harvest and evaluation

210 days after planting (DAP) was considered as the "closing point" of the cycle due to the beginning of the flowering stage and the decay of the plant aerial part. Evaluations related to the crop production of the crop were carried out as following:

1. Root development: tuberous root production (number, weight, diameter and length). The number was obtained by counting all useful plants in the plots and the average number of roots per plant. The mass was obtained by weighing all useful plants in the plots by averaging the root weight.
2. Accumulation of dry mass in the plant. The plant aerial part was detached from the root system. The root system was separated into rhizophores and tuberous roots (excluding the fibrous roots) and both weighed separately to obtain the accumulation of dry mass in each part. The samples were dried in an oven with forced air circulation at 65ºC. The dry matter mass was obtained on a digital scale with an accuracy of 0.01 g.

The tuberous roots were selected and classified into: 1A (<130g, 7 to 13 cm in length); 2A (between 130 and 250g, 13 to 18 cm in length) and 3A (> 250g; > 18 cm in length) according to Oliveira (2016).

With the production data, an economic analysis of each spatial arrangement was performed. Data and information regarding prices and technical coefficients of all production costs were done by setting up the experiment, consulting the sales center and farmers. The methodology used to calculate the production cost and the analysis and profitability indicators results used were the same ones presented by Furlaneto and Esperancini (2010).

The structures considered in the production system were the effective operational cost (EOC), involving the expenses incurred with labor, machinery/equipment operations and materials consumed throughout the growing cycle. In this study, the total operational cost (TOC) was the EOC plus only the social security contribution (2.3% on gross income).

The indicators of profitability analysis were:

Gross Income (GI): expected revenue to determine the production per hectare or $GI = \Pr x\, Pu$; where Pr= yacon production per unit area and Pu = unit kg price of yacon (US$/kg); Real-Based Calculations R$ 1.75 kg^{-1} (average values traded between January and February 2018, in the central supply of Espírito Santo (Ceasa/ES) in Brazil. The costs were converted to US dollars based on the dollar exchange rate in November 28, 2018.

- Operating Profit (OP): difference between gross income and operating cost per hectare ($OP = GI - TOC$; where TOC is the total operating cost);
- Benefit-Cost Ratio (BCR) is the relation between the gross income and operating cost. i.e. $BCR = \frac{GI}{TOC}$.

For production costs, the amount paid by farmers regarding the unit value of each rhizophore was estimated. The dollar price (value based on the dollar exchange rate to Brazilian currency of R$4.00/US$1.00 on November 28,2018) also was estimated US$ 0.05 dollars (five cents) for a unit of 50g. The calculation of the labor cost was estimated based on the equivalent of 27 labor days (D/H) to implant one hectare (1ha) with 20.000 plants, spacing 0.80 x 0.50m according the information obtained from farmers. The cost of the organic fertilizer was estimated based on the study of Garcia and Souza (2015). For each population, planting arrangement costs was estimated, which are presented in Table 4.

Statistical analysis

The data were submitted to analysis of variance and when there was an interaction between the factors the subplots were split into a plot. The means of the treatments were compared by the Tukey's test at 5% of probability, when significant by Test F.

Conclusions

The arrangement of the plants in the spacing of 1.00 m between lines and 0.50 m within the lines (population of 20.000 plants) provided greater production, higher gross income, higher income and a better benefit-cost ratio compared to other arrangements population, being the most suitable for this cropping conditions.

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