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Economic analysis of crisp lettuce production in different planting spacing and soil cover

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Abstract: The objective of this study was to estimate and evaluate the economic indicators of lettuce production, cultivated using different soil cover and plant spacing. The experiment was conducted in subdivided parcels, with four replications. The treatments were composed by a combination of three soil cover (uncovered soil, straw and plastic cover) and three planting spaces (0.25 x 0.20, 0.25x0.25 and 0.25x0.30 m). The productivity and economic indicators were evaluated for a production area of 1000 m^2. For the different treatments, a total operating cost of USD 781.80 to USD 663.30 1000 m^{-2} was obtained. It was observed that for the cultivation of lettuce in soil covered by straw, from the rubbing, and spacing of 0.25x0.25 m the economic indicators were raised. With a productivity of 687.70 boxes 1000 m^{-2}, for this treatment was obtained gross revenue of USD 1,828.99, operating profit of USD 1,135.41 and a profitability index of 62.08%. Thus, lettuce cultivation provides positive profitability regardless of the spacing or type of cover used and the combination between the 0.25 x 0.25 m planting spacing and the use of straw as a soil cover culminates in higher monetary gains.

1. Introduction

The consumption of vegetables has been increasing continuously due to the dietary habits adopted by the population (Maziero *et al.*, 2017), which consequently influences the demand for higher yields (Silveira *et al.*, 2015). Among the products sought by consumers, lettuce is the world leader in terms of acceptance, increasing its importance to the productive sector due to the large volume of commercialization (Vieira and Barreto, 2006).

Considering the participation of family farms in the vegetable production scenario, one of the main productive obstacles is the investment required. Most of the costs are related to inputs purchase, as fertilizers, seedlings and seeds (Rezende *et al.*, 2005, 2009; Batista *et al.*, 2013). This burden of the production process is necessary, in order to obtain higher quality products, increasingly demanded by the consumer market.

Through the research, it is seeking the application of techniques that assist the rural producers in obtaining greater monetary returns, encouraging them to continue in the agricultural activity. Simple changes in management can be effective strategies for reducing production costs. In this sense, for the lettuce crop, it is observed that the use of straw as a cover is an effective way of preserving the soil physicochemical characteristics, favoring plants development and increasing the profitability (Vendruscolo *et al.*, 2017 a). In addition, due to intense soil movement applied to vegetable production (Ziech *et al.*, 2014), the cover contributes to the preservation of organic matter and erosion reduction (Cividanes, 2002; Souza and Resende, 2006).

Materials that are easily accessible to the rural producer, such as straw from grazing, can be used as mulch, replacing other materials such as plastic, for example, which has an effective participation in the costs of producing vegetables (Vendruscolo *et al.*, 2017 b), also representing a source for environmental contamination (Chang *et al.*, 2013). In this sense, it is important to generate information on the economic feasibility of techniques applied to agriculture, based on data with high reliability.

The presence of a superficial straw layer is beneficial from the point of view of soil quality maintenance (Cardoso *et al.*, 2012), favoring the development of plants of economic interest (Torres *et al.*, 2015; Vendruscolo *et al.,* 2017 a). It also favors the maintenance of soil moisture by controlling the direct evaporation of the surface (Carneiro *et al.*, 2014), reducing the need for large volumes of water in irrigation. The decrease in weed competition due to the suppression of spontaneous plants is another advantage of soil cover (Moraes *et al.*, 2013), which implies the less need for herbicides or even manual weeding. In this sense, it was verified, for the radish culture, that the maintenance of the cultural remains of silk flower on the soil surface increased the number of commercial roots produced (Oliveira *et al.*, 2015).

In addition to the soil cover, other management techniques can assist producers in obtaining higher yields and superior quality of their product. The plant population used in agricultural crops is decisive in creating an environment conducive to its development and should be established for the specific conditions of a given locality, in order to avoid excessive competition for resources such as water, light, nutrients and carbon dioxide essential to their development (Taiz *et al.*, 2017). In addition, the unnecessary expense of purchasing seedlings, one of the inputs with the largest share in production costs (Vendruscolo *et al.*, 2017 a).

Specifically for lettuce, it is observed that larger plant spacings can generate plants with higher weight (Vasconcelos *et al.*, 2017), which may be related to the broad development of the aerial part observed in commercial genotypes. It is also verified that population density variation can be an effective tool for controlling weeds in different crops (Carvalho and Guzzo, 2008; Bajwa *et al.*, 2017; Li *et al.*, 2018), decreasing spending on hand and acquisition of agrochemicals.

In view of the information above, the objective of this study was to estimate and evaluate the economic indicators of lettuce cultivation, using different soil cover and plant spacing.

2. Materials and Methods

The study was conducted in an experimental area located at the Goiás Federal University, in Goiânia, Goiás, Brazil. For the locality the following average climatic indicators are verified: annual precipitation of 1,575 mm and average monthly temperature of 22.9°C, the predominance of Aw climate, characterized by a tropical climate with rainy season of October to April and a period with precipitations below 100 mm monthly between May and September. The average climatic parameters of air temperature and humidity were obtained at an evaporimetric station at 300 m distance from the experimental area (Fig. 1).

The soil was classified as Latossolo Vermelho, following the methodology proposed by Santos *et al.* (2013). The soil chemical analysis (depth of 0-0.2 m), before the implantation of the experiment revealed the following nutrient content: Ca^{2+}: 2.8 $cmol_c$ dm^{-3}, Mg^{2+}: 1.8 $cmol_c$ dm^{-3}, K^{+}: 0.37 $cmol_c$ dm^{-3}, P (Mehlich I): 25.8 mg dm^{-3}, organic matter: 3.0 g dm^{-3}, Al^{3+}: 0.0 $cmol_c$ dm^{-3}, H+Al: 2.8 $cmol_c$ dm^{-3}, pH ($CaCl_2$): 5.3, 7.8 $cmol_c$ dm^{-3} of CTC, 64.0% of V, according to Donagemma *et al.* (2011). The soil granulometric analysis, according to da Silva (2009), presented 44 g kg^{-1} of clay in 0-0.2 m layer (da Silva, 2009).

Previously to the planting, an initial fertilization was carried out, which consisted of the equivalent application of 320 kg ha^{-1} of simple superphosphate and liming in order to raise the bases saturation to 80%. The limestone was incorporated and the beds were confectioned with 1.00 m wide and spaced 0.50 m apart.

The experiment was conducted in a subdivided plots design, with four replications for each treatment. The treatments were composed by a combination of three soil cover (uncovered soil, straw and plastic cover) and three planting spaces (0.25x0.20, 0.25x0.25 and 0.25x0.30 m), making a total of nine treatments. Each plot had dimensions of 1.0x1.25 m (1.25 m^2). For evaluation, the central plants of the two internal lines were used and the remaining plants were used as a border.

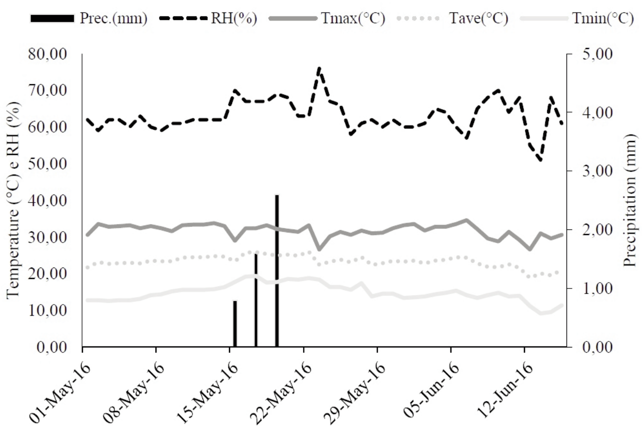

Fig. 1 - Summary of climatic conditions of relative air humidity and maximum, average and minimum temperature during the period of conduction of the study.

Irrigation was carried out by drippers spaced twenty centimeters apart in three polyethylene tapes suitable for this purpose, positioned between the planting lines. The acquisition of the drip tapes was included in the calculation of the costs, considering the implantation of this system in the production area and the useful life of this material. However, the amounts spent on the purchase of other materials, such as pumps, pipes and others irrigation materials were not considered.

After the irrigation tapes placement, the soil covers were installed according to the treatments. For that, a straw from the grass (*Zoysia japonica*) was distributed over the plots until a layer of 5 cm was obtained. The plastic cover consisted of the placement of double-sided polyethylene canvas (black and white), with the white face facing upwards.

The seedlings of crisp lettuce, cv. Vanda, were purchased in a commercial seedling producer, with a surplus of 10% of the quantity required for the replacement of dead plants. The seedlings transplanting proceeded on May 1, 2016. For this purpose, pits were opened amidst the covers, with sufficient size for seedling insertion.

Cover fertilization was carried out in three applications during the cycle, based on the recommendations for the crop (Trani *et al.*, 2014), applying 60 kg ha^{-1} of urea (45% N) and 50 kg ha^{-1} KCl (60% K_2O). During the lettuce cultivation, there was no application of fungicides, insecticides or herbicides. Plants were harvested at 45 days after transplanting.

Treatments were considered as commercial crops with the purpose of determining the production costs of a productive cycle of crisp lettuce. In this way, the total operational cost (TOC) structure was obtained as proposed by Martin *et al.* (1998) by adding up the effective operating cost (EOC), which is composed of the expenses of the operations and inputs used, other expenses involved (OE), and costing interest per year (CIY). A rate of 5% of total EOC expenses was considered for other expenses (OE) that involves costs with administration, technical assistance and other fees to be paid for the activity, while costing interest (CIY) used was 6.5% per year, over 50% of EOC, estimated as an annual interest rate (Martin *et al.*, 1998).

Before the calculation of TOC, the base total operating cost (TOC base) was obtained, for which the costs related to the experimental variables were not considered, remaining constant for all treatments. For monetary amounts, the presentation was made in Reais (R$) and US dollars (USD). The conversion was made considering the quotation on June 15, 2018 (USD 1.00 = R$ 3.76). Each economic data was based on a single production mean, which was composed by the four replications.

The average prices, received by the producers, were obtained from the Goiás State Supply Centers (2018) website. The average price paid to producers in the first half of June of 2018 was USD 2.66 per box of 4.8 kg, for calculation purposes, the same was used in the present study.

The average region labor force in 2018 was USD 18.62 day^{-1}. Thus, labor costs were obtained through the index generated by the need for manual operations for each operation, multiplied by the daily value. For inputs, the cost was calculated based on the average product value in the region, obtained in the first half of 2018, and the amount of material used.

The profitability of each treatment was obtained through estimates of gross revenue, obtained multiplying the quantity produced (4.8 kg boxes) for the average price received by the producers, the difference between gross revenue and total operating cost represents the profitability index: the proportion of the gross revenue that represents the final amount after covering the production total operational cost. Equilibrium price was also obtained as the minimum price necessary to be obtained to cover the TOC at a given level of production total operating cost, considering the average productivity obtained by the producer, and the equilibrium productivity, given the minimum productivity required to cover TOC at a given level of production total operating cost.

3. Results and Discussion

The production of crisp lettuce in an area equivalent to 1000 m^2 presented a base total operating cost (TOC base) of USD 454.64 (Table 1), which was formed by the cost of mechanized operations (68.02%), manual operations (20.47%), inputs (3.88%), other expenses (4.62%) and interest expenses (3.00%). The effective participation of mechanized operations was due to the acquisition of dripping tapes, which had a 96.75% participation in this item and 65.81% over TOC base. In addition, manual operations and inputs had a share of 20.47% and 3.88%, respectively, in the TOC base.

The small inputs participation is due to the non-insertion of the seedlings acquisition value. However, when this cost is added to the inputs amount, the participation on the TOC and the TOC itself increases (Table 2). The seedlings value also have a participation of 42.47%, 38.84% and 36.47% for treatments composed of 0.25x0.20 m, 0.25x0.25 m and 0.25x0.30 m of planting spacing, respectively. These results related to the seedlings acquisition corroborate with those obtained by Rezende *et al.* (2005), who verified a participation of 55.20% of the inputs on TOC and by Rezende *et al.* (2009), which obtained a burden of approximately 49.30% on TOC due to expenditures on inputs and other materials.

When the plastic cover was used, it was verified that the acquisition of the cover added to its placement, participated in an average of 9.63%, while the straw had a participation around 2.66%, relative to its distribution on the beds. During the lettuce cycle, weed control burdened in 7.76% and 2.66%, respectively, the treatments without cover and straw cover,

Table 1 - Estimated base total operational cost for crispy lettuce in 1,000 m^2

Description	Specification	Quantity	Unit cost R$	Cost R$	Unit cost USD	Cost USD
A - Mechanized operations						
Tillage	HM Tp 65cv. 4x2 + grade aradora 14 x 26"	0.30	52.95	15.89	14.08	4.22
Disk harrow	HM Tp 65cv. 4x2 + grade niveladora 28x22"	0.10	52.43	5.24	13.94	1.39
Beds preparation	HM Tp 65cv. 4x2 + roto-encanteirador	0.35	47.75	16.71	12.70	4.44
Irrigation	Irrigation equipment	1.00	1,125.00	1,125.00	299.20	299.20
Subtotal A				1,162.84	0.00	309.27
B - Manual operations						
Beds preparation	Man-day	0.50	70.00	35.00	18.62	9.31
Seedling transplant	Man-day	1.00	70.00	70.00	18.62	18.62
Fertirrigation	Man-day	3.00	70.00	210.00	18.62	55.85
Harvest	Man-day	0.50	70.00	35.00	18.62	9.31
Subtotal B				350.00	0.00	93.09
C - Inputs						
Limestone	kg	13.00	0.09	1.16	0.02	0.31
Single superphosphate	kg	32.00	1.34	42.88	0.36	11.40
KCl (60% K_2O)	kg	5.00	2.00	10.00	0.53	2.66
Urea (45% N)	kg	6.00	2.05	12.30	0.55	3.27
Subtotal C (R$)				66.34	0.00	17.64
Effective Operational Cost (A+B+C)				1,579.10		419.99
D - Other expenses				78.96		21.00
E - Costing Interest per year				51.32		13.65
Base Total Operating Cost (A+B+C+D+E)				1,709.46		454.64

respectively (Table 2).

The acquisition costs and placement of the plastic cover, together with the greater seedlings acquisition costs caused by the smaller planting spacing, resulted in the higher TOC. This was 15.15% higher than the lowest TOC, obtained with the combination of straw coverage and larger planting spacing (0.25x0.30 m) (Table 2).

According to the average price received by producers during the first half of June 2018 (USD 2.66 box 4.8 kg^{-1}), it was found that gross revenue, operating profit and profitability index obtained varied according to the planting spacing and cover used (Table 3).

Treatment composed of the straw cover and planting spacing of 0.25x0.25 m resulted in higher values for the three variables. This result is due to the lower straw cost and its action on the maintenance of the physical and chemical quality of the soil (Collier *et al.*, 2011; Cardoso *et al.*, 2012), as well as weed control through suppression of their development (Moraes *et al.*, 2013). In contrast, the lowest profitability index was obtained using the plastic cover and the planting spacing of 0.25x0.20 m. Under these conditions, the low productivity in addition to the cover value were the main factors that contributed to the variables decrease in 23.44%, 45.53% and 28.85% of gross revenue, operating profit and profitability index, respectively, compared with the best treatment.

The lower equilibrium yield was obtained for the treatment composed by 0.25x0.30 m planting spacing and straw cover. This result was 15% below the treatment composed of a plastic cover and 0.25x0.20 m planting spacing, for which the highest equilibrium production was verified (Table 4). For this treatment, the highest equilibrium price was also obtained with an increase of 47.23%, compared to the lowest equilibrium price, obtained with the use of straw and planting spacing of 0.25x0.25 m.

In general, the use of straw as soil cover favors the economic return with the lettuce crop. In addi-

Table 2 - Participation of the cost variation factors over the total operational cost, in 1,000 m^2, for the cultivation of crisp lettuce in different planting spacing and soil cover

Cover	Planting spacing (m)	Cost in R$						Cost in USD					
		Seedlings cost	Cover cost	Cover placement	Weed control	OE + CIY	TOC	Seedlings cost	Cover cost	Cover placement	Weed control	OE + CIY	TOC
Control	0.25x0.20	870.00	0.0	0.00	210.00	89.10	2,878.50	231.40	0.00	0.00	55.90	23.70	765.60
Control	0.25x0.25	690.00	0.0	0.00	210.00	74.30	2,683.60	183.50	0.00	0.00	55.90	19.70	713.70
Control	0.25x0.30	585.00	0.0	0.00	210.00	65.60	2,570.00	155.60	0.00	0.00	55.90	17.40	683.50
Straw	0.25x0.20	870.00	0.0	70.00	70.00	83.30	2,802.70	231.40	0.00	18.60	18.60	22.20	745.40
Straw	0.25x0.25	690.00	0.0	70.00	70.00	68.50	2,607.90	183.50	0.00	18.60	18.60	18.20	693.60
Straw	0.25x0.30	585.00	0.0	70.00	70.00	59.80	2,494.20	155.60	0.00	18.60	18.60	15.90	663.30
Plastic	0.25x0.20	870.00	196.40	70.00	0.00	93.80	2,939.60	231.40	52.20	18.60	0.00	24.90	781.80
Plastic	0.25x0.25	690.00	196.40	70.00	0.00	78.90	2,744.70	183.50	52.20	18.60	0.00	21.00	730.00
Plastic	0.25x0.30	585.00	196.40	70.00	0.00	70.20	2,631.10	155.60	52.20	18.60	0.00	18.70	699.70

Table 3 - Productivity, gross revenue, operating profit and profitability index, obtained with the cultivation of crisp lettuce in different planting spacings and soil cover, in 1,000 m^2

Cover	Planting spacing (m)	Produtivity (Boxes 4.8 Kg)	Gross revenue		Operation profit		Profitability index (%)
			R$	USD	R$	USD	
Control	0.25x0.20	592.96	5,929.57	1,577.01	3,051.09	811.46	51.46
Control	0.25x0.25	640.17	6,401.70	1,702.58	3,718.07	988.85	58.08
Control	0.25x0.30	641.27	6,412.66	1,705.49	3,842.69	1,021.99	59.92
Straw	0.25x0.20	663.33	6,633.27	1,764.17	3,830.57	1,018.77	57.75
Straw	0.25x0.25	687.70	6,877.01	1,828.99	4,269.15	1,135.41	62.08
Straw	0.25x0.30	553.92	5,539.20	1,473.19	3,045.01	809.84	54.97
Plastic	0.25x0.20	526.50	5,265.02	1,400.27	2,325.46	618.47	44.17
Plastic	0.25x0.25	564.50	5,644.95	1,501.32	2,900.25	771.34	51.38
Plastic	0.25x0.30	557.81	5,578.11	1,483.54	2,947.06	783.79	52.83

tion, it can be easily acquired in the rural property by scrubbing areas with grasses and acts in the prevention of physical and chemical soil erosion (Cardoso *et al.*, 2012), as well as acting on inhibition of weed development (Moraes *et al.*, 2013), favoring the development of the culture of interest.

These facts are supported by a study about the lettuce cultivation on the vegetal residue of different species, which demonstrates that plants cultivated on sorghum and millet straw favor the crop profitability indexes. In this study, it was also observed the importance of choosing the species that will compose the straw cover, since there are effects of allelopathy (Vendruscolo *et al.*, 2017 a, b). The straw deposition on the soil surface, in the cultivation of American lettuce and cabbage, also favored the development of these crops, especially when using *Brachiaria* or millet straw (Torres *et al.*, 2015).

4. Conclusions

The insertion of these techniques, with the use of vegetal soil cover, in addition to culminating in higher financial returns, due to lower production costs and increased productivity, also represents a technique of greater environmental viability. It is observed that crops with high demand for technologies tend to generate large amounts of slow degradation residues, such as plastics, inferring in environmental contamination (Chang *et al.*, 2013). Thus, we concluded that the crisp lettuce crop provides positive profitability, regardless of the planting spacing or cover type used. For the conditions observed during this study, the combination of the 0.25x0.25 m planting spacing and the straw as a soil cover culminates in higher financial returns.

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Table 4 - Production and equilibrium price obtained with lettuce cultivation in different spacing and soil cover, in an area of 1,000 m^2

Cover	Planting spacing (m)	Production (Boxes 4.8 kg)	Equilibrium price	
			Boxes 4.8 kg^{-1} (R$)	Boxes 4.8 kg^{-1} (USD)
Control	0.25x0.20	287.85	4.85	1.29
Control	0.25x0.25	268.36	4.19	1.11
Control	0.25x0.30	257.00	4.01	1.07
Straw	0.25x0.20	280.27	4.23	1.12
Straw	0.25x0.25	260.79	3.79	1.01
Straw	0.25x0.30	249.42	4.50	1.20
Plastic	0.25x0.20	293.96	5.58	1.48
Plastic	0.25x0.25	274.47	4.86	1.29
Plastic	0.25x0.30	263.10	4.72	1.25

* In each variable, data followed by the same letters (small letters for interactions and capital letters for means) are not significantly different using LSD at 5% level. Data represent the mean value ± S.D. the mean of four replicates.

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