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RESPOSTA DA CULTURA DO RABANETE SOB CULTIVO ORGÂNICO AOS FATORES DE PRODUÇÃO ÁGUA E COBERTURA DO SOLO

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1 RESUMO

Em regiões com limitações de recursos hídricos, como semiárido cearense, o uso eficiente da água torna-se a cada dia imprescindível para a produção de hortaliças irrigadas nestas regiões. Neste sentido, a presente pesquisa teve como objetivo a avaliação técnica e econômica do efeito dos fatores de produção água e níveis de cobertura do solo da bagana de carnaúba sobre a produtividade da cultura do rabanete. A pesquisa foi conduzida no período de junho a agosto de 2018 em dois ciclos de produção em área pertencente ao Prece (Programa de Educação em Células Cooperativas), localizado no município de Pentecoste-CE. O experimento foi conduzido em um delineamento em blocos casualizados com quatro repetições. Os tratamentos foram constituídos por cinco lâminas de irrigação (50%; 75%; 100%; 125% e 150% da evapotranspiração das culturas localizada, ETc_{loc}) e cinco diferentes níveis de cobertura morta constituída de bagana de carnaúba: 25%; 50%; 75% e 100% além da testemunha com o solo sem cobertura 0%, totalizando 100 parcelas experimentais. Os resultados permitiram concluir que a bagana de carnaúba apresentou potencial para utilização como cobertura morta no cultivo de rabanete, proporcionando incremento no rendimento da cultura em condições de estratégia de irrigação com déficit para o uso de 16 t ha^{-1} de cobertura morta. A cultura rabanete responde de forma crescente às diferentes lâminas de irrigação até a ETc_{loc} de 100%, podendo-se obter ganhos econômicos quando associadas à utilização de cobertura morta no solo.

Palavras-chave: Cobertura do solo. Manejo da irrigação. Função de produção. *Raphanus sativus* L.

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RESPONSE OF RABANET CULTURE UNDER ORGANIC CULTIVATION TO PRODUCTION FACTORS WATER AND SOIL COVERAGE

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2 ABSTRACT

In regions with limited water resources, such as the semi-arid region of Ceará, the efficient use of water becomes indispensable every day for the production of irrigated vegetables in this region. In this sense, this research had as objective the technical and economic evaluation of the effect of the factors of production water and levels of the cover of the soil of the bagana on the productivity of the radish culture. The research was conducted in the period from June to August 2018 in two production cycles in area belonging to Prece (Cooperative Cell Education Program), located in the municipality of Pentecoste-CE. The experiment was conducted in a randomized block design with four replicates. The treatments consisted of five irrigation depth (50%, 75%, 100%, 125% and 150% of crop localized evapotranspiration, ET cloc) and five levels of ground cover consisting of carnauba bagana: 25%; 50%; 75% and 100% beyond the control with the soil without 0% coverage, totalizing 100 experimental units. The results allowed to conclude that the carnauba bagana presented potential for use as ground cover in the cultivation of radish, providing an increase in the yield of the crop under conditions of deficit irrigation strategy to use 16 t ha-1 of ground cover. The radish crop significantly responds to the different irrigation depth, up to 100% ET cloc, and economics gains can be obtained when associated with the use of ground cover in soil.

Keywords: Soil cover. Irrigation management. Production function. *Raphanus sativus* L.

3 INTRODUCTION

Irrigation is considered one of the main techniques for increasing productivity in several regions of the world; however, to remain sustainable in economic, social and environmental terms, it needs to be efficient in terms of the use of water and its efficiency, which is taken as the ratio between the amount of water actually used by the crop and the amount withdrawn from the source (OLIVEIRA, 2016).

On the other hand, increasing water use efficiency with a localized irrigation system requires a high initial cost from the farmer, compared with other systems, which signals to the farmer the cultivation of a high-value-added crop to recover the invested capital. Studies have demonstrated that under appropriate growing conditions and with appropriate management practices, the yield of organic farming systems matches conventional yields (SEUFERT; RAMANKUTTY; FOLEY, 2012).

Vieira et al. (2016) emphasized that in recent years, growing concerns about the environmental impacts of conventional agricultural practices, combined with increased consumer demand for sustainably produced products, have led to the greater adoption of organic farming by producers. There was a 20% increase in revenue from these products, totaling R$4 billion in revenue in 2018 (MINISTRY OF AGRICULTURE, LIVESTOCK AND SUPPLY, 2019). Compared with the total area cultivated conventionally in Brazil, organic farming areas are small; however, the estimated annual growth of 30% may indicate a greater share of this sector in the food market in the future (DAROLT, 2002).

Plant productivity and water use efficiency involve the use of varying amounts of mulch on the soil surface, which, in turn, is influenced by the adopted soil management system. Mulching is a recommended practice, particularly in semiarid regions, and contributes to improved crop performance, reduced soil water loss, and reduced surface erosion (MELO et al., 2014). Bagana, a byproduct of carnauba wax production, is an excellent alternative among plant mulches. Despite deforestation, wax production remains an economic activity in the sertanejo (backwood) region. The use of this byproduct as mulch (ALMEIDA et al., 2020; SILVA et al., 2019) can be a valuable alternative for this residue, even when it is incorporated into the soil after cultivation.

Among the crops usually consumed by the population, radish (*Raphanus sativus* L.) is a short-cycle crop (30 to 35 days) used as a condiment in traditional dishes or as a component in salads (SILVA et al., 2012). For satisfactory vegetable production in semiarid regions, studies on economic viability, alternative sources of fertilizers and the evaluation of cultivars with adaptation potential are necessary, as such studies can reduce risks for small producers (SILVA et al., 2019).

In this sense, the present research aimed to technically and economically evaluate the effects of water production factors and the soil cover level of the bagana on the productivity of the radish crop in the municipality of Pentecoste-CE.

4 MATERIAL AND METHODS

The research was carried out from June to November 2018**,** two production cycles**.** The experiment was conducted in an area belonging to Prece (Cooperative Cell Education Program), located in the municipality of Pentecoste-CE, with geographic coordinates of 39°12'46" longitude and 03°55'20" latitude and 56 m above sea level. The climate of the region is of the BSw'h ' type, according to the Köeppen classification, characterized as hot semiarid, with irregular rainfall distributed from February to May, average annual rainfall of 860 mm and evaporation of 1,475 mm. The average air temperature during the experiment varied between 23.5 °C and 38.4 °C. The maximum temperatures observed were slightly above the temperature considered optimal for crop growth (MINAMI; TESSARIOLI NETTO, 1997); however, no significant problems were observed in terms of plant development.

The physical and chemical attributes of the soil (TEIXEIRA et al., 2017) in the 0–0.3 m layer are as follows: pH in water, 7.4; assimilable phosphorus, 290.0 mg kg $^{-1}$; potassium, 9.0 cmol $_c$ kg $^{-1}$; calcium, 10.3 cmol $_c$ kg $^{-1}$; magnesium, 7.9 cmol $_c$ kg $^{-1}$; sodium, 1.14 cmol $_c$ kg $^{-1}$; aluminum, 0.0 cmol $_c$ kg $^{-1}$; organic matter, 39.2 g kg $^{-1}$; C:N ratio, 11 g kg $^{-1}$; soil density, 1320 kg m $^{-3}$; particle density, 2510 kg m $^{-3;}$ and sandy loam texture.

A randomized complete block design was adopted, with four replicates. The treatments consisted of five irrigation depths based on crop evapotranspiration, 50%, 75%, 100%, 125%, and 150% of the ETc_{loc}, and five levels of mulch consisting of Carnauba bagana, 25%, 50%, 75%, and 100%, in addition to the control treatment with 0% Bagana (i.e., soil without cover). Notably, the 100% level is equivalent to 16 t ha $^{-1,}$ as used by Sousa et al. (2017). The experimental plot had an area of 6 m2 (1.0 m × 6.0 m), and the subplot had an area of 1.20 m2 (1.0 m × 1.20 m). Each subplot had 18 plants, and the plot had a total of 90 plants, which was above the optimal amount according to Silva et al. (2012). A spacing of 0.15 m between plants and 0.2 m between rows was used, totaling 100 experimental plots.

To prepare the area, the crop was cleared and cleared of plant debris. Afterward, 3 kg of organic compost was distributed per square meter 30 days before the crop was planted in the field. This was followed by soil turnover to incorporate the compost and break up the soil. The compost was incorporated to a depth of 0.10 to 0.30 m.

Ridges were built manually with agricultural tools to establish the crop, measuring 6 m long by 0.7 m wide and spaced 0.30 m apart. Fertilization was carried out according to the recommendations of Vitti et al. (2007), with 30,000 kg ha^{-1} organic compost applied at planting. Sowing was direct, with three rows of plants inserted in each plot. After germination, the plots received mulch with bagasse equivalent to the levels proposed in the research. Thinning occurred seven days after sowing (DAS).

At fifteen DAS, soil aeration and hilling were performed. The top dressing was supplemented with a previously characterized biofertilizer (pH -8.3; Na - 2.89 mg dm^{-3}; Mg - 4.0 $cmol_c$ dm^{-3}; Ca -8.7 $cmol_c$ dm^{-3}; K - 8.59 mg dm^{-3}; P - 1.6 mg dm^{-3}) and was applied at a ratio of 1:5, corresponding to 500 mL per plant, at intervals of seven DAS.

The irrigation system used was a drip with 16 mm diameter self-compensating drip tape emitters spaced 0.20 m apart, with a flow rate of 2.21 L h^{-1} and a service pressure of 10 mca. Irrigation was based on data obtained from a class "A" tank installed 5 m from the experiment, where the ETc_{LOC} was determined by the product of the evaporation measured in the tank (ECA), the tank coefficient (Kt), the total crop coefficient (Kc) of the radish for each development stage, according to Allen et al. (1998), and the location coefficient (KL), according to Bernardo et al. (2019). To ensure uniform plant development at the beginning of the cycle, all the treatments received the irrigation depth required by the crop in the first seven days after transplanting.

The irrigation time was obtained as the product of localized crop evapotranspiration, the spacing between rows and drippers in relation to system efficiency, the number of emitters per plant and the emitter flow rate according to equation 1.

$$Ti = \frac{ETc_{Loc}\ x\ E1\ x\ E2}{Ea\ x\ n\ x\ q} \quad (1)$$

where Ti is the irrigation time in hours;
ETc_{LOC} – Localized crop evapotranspiration
E1 – Spacing between rows in meters;
E2 – Spacing between drippers in meters;
Ea – System efficiency (%);
n – Number of drippers;
q – emitter flow rate in L h^{-1}.

Crop productivity was based on the fresh mass of tubers measured on a commercial scale with an accuracy of 0.01 g and the area of the plot.

To obtain the production function, regression analysis was used between crop productivity and water application level, adjusted by a polynomial model for each mulch level. Net revenue or profit from production was obtained from the difference between the total monetary value of production, the costs of water application, and the fixed costs of the production system, including the irrigation system and soil mulch levels (FRIZZONE, 2007).

The product price (Py) was the average price obtained by rural producers in Serra da Ibiapaba/CE from November 2018 to January 2019. The cost of irrigation, considering that application costs are included in crop production costs, was considered equal to the value of the electricity tariff according to equation 2.

$$CE = 0{,}7557\ x\ Pot\ x\ Tf\ x\ Pkwh \quad (2)$$

where:
CE – cost of electricity during the crop cycle, in R$;
0.7457 – conversion factor from hp to kW;
Pot – engine power, in hp;
Tf – system operating time required to replenish ETc, in hours, considering an irrigated area of 1.0 ha;
Pkwh – price of kwh, in R$.

The price per kWh was obtained from Enel (Ceará Energy Company), considering that the system operated during peak hours. The price per millimeter of water (Pw) applied (R$ mm^{-1}) was obtained by dividing the cost of electricity (R$) by the water depth applied in the period (mm) and adding it to the price of K_2 (water tariff charged in the Baixo Acaraú Irrigation Perimeter, in 2016).

The marginal physical productivity (PFMa) of the variable factor constitutes the increase in the physical product resulting from the use of an additional unit of the variable factor and is expressed by the first derivative of the response function Y (dy/dx).

Water use efficiency was assessed via crop water productivity (WP), which was estimated by the relationship between the total productivity (kg ha^{-1}) and the respective amount of water applied in each treatment. Economic water productivity (EWP) was estimated by the relationship between the monetary value of total production (R$) and the respective amount of water applied (m^3) in each treatment.

The unit price of the product to determine the production values ($Y_{\$}$) was obtained from the historical wholesale prices of the Supply Center - Ceasa in the city of Maracanaú-CE in 2016. After the results were obtained, statistical analysis was performed via the Sisvar program (FERREIRA, 2014) through analysis of variance (ANOVA), and when the results were significant according to the F test, the regression models were adjusted to the 5% significance level ($p < 0.05$).

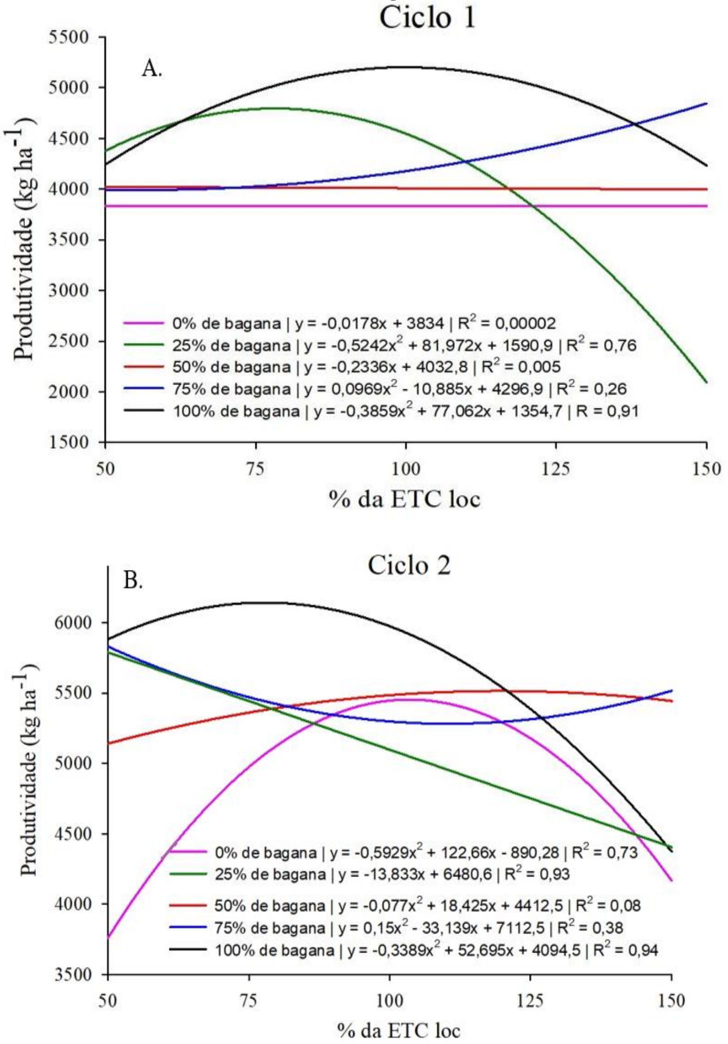
5 RESULTS AND DISCUSSION

During the first crop cycle, the sums of the applied water depths resulted in accumulations of 53, 66, 80, 93 and 107 mm, and 56, 71, 86, 101 and 116 mm for the second cycle, corresponding to replacement rates of 50, 75, 100%, 125 and 150% of the ETc loc, respectively. These values correspond to the total volume of water applied after the beginning of the differentiation of irrigation levels. Importantly, before the beginning of the differentiation of the depths, a total of 13.8 mm was applied in all the experimental units.

With the exception of the curves for the conditions without cover (0%) and 50% cover, which did not present an adequate fit ($p > 0.05$) to the studied models, the other curves were fitted ($p < 0.05$) to a quadratic model (Figure 1A). The highest average crop yields, both under water deficit and excess conditions, were observed for the treatment with 100% mulched soil cover. The estimated depths equivalent to 100.5, 78.2, 97.1, 56.2 and 99.8 mm provided the maximum commercial productivities, corresponding to 3801.34, 4795.50, 4062.01, 3991.22 and 5201.84 kg ha^{-1} of radish cv. I were associated with the following factors without coverage: 25%, 50%, 75% and 100% bagasse coverage, respectively.

In the second cycle (Figure 1B) of the crop, all curves fit a quadratic model, with the exception of the treatment with 25% bagasse cover. For the 50% mulch cover, no adequate fit was observed ($p>0.05$). The estimated depths of 103.4, 43.0, 119.6, 110.5 and 77.7 mm provided the maximum commercial yields, corresponding to 5453.74, 5844.54, 5514.71, 5282.18 and 6142.86 kg ha^{-1} of radish cv. Cometo for the factors without cover and 25%, 50%, 75% and 100% bagasse cover, respectively.

Figure 1. Productivity of radish cv. Cometo grown in soil with different amounts of bagasse and subjected to different levels of irrigation.



Several factors, acting in an interrelated manner, may have influenced the achievement of such results. Among these factors, it is worth highlighting the possibility of less variation and greater retention of soil moisture, less heating and thermal amplitude of the soil, conditions that are favorable for better plant development (FERREIRA et al., 2013; SILVA et al., 2019). In this same context, Mukherjee Kundu and Sarkar (2010) highlighted that soil cover reduces weed populations, causing a reduction in competition for water and nutrients. Orrillo et al. (2016) and Rossi et al. *Similarly,* (2013) highlighted that soil cover creates a physical barrier, reducing water loss from the soil to the atmosphere.

According to the regression equation adjusted for productivity as a function of irrigation depth, the maximum productivity of radish grown in soil without coverage was obtained at a depth of 107.1 mm, with the same productivity in cultivated soil covered with bagasse being obtained at a depth of 99.4 mm, thus requiring less water to obtain a significantly higher level of productivity, as shown in Table 1. A similar response was obtained by Oliveira Neto et al. (2011), who grew beetroot in soil covered with cameroon grass or gliricidia, resulting in a 53% reduction in evapotranspiration compared with cultivation without coverage.

Table 1. Optimal blades obtained under different soil cover conditions and their respective productivities in the first cycle of the radish cv. Cometo crop.

Soil Cover (% bagana)	Optimal Blade (mm)	Productivity (kg ha $^{-1}$)
0	107.1	3802.42
25	77.9	4795.45
50	93.3	4081.39
75	57.8	3991.49
100	99.4	5201.84

In the second cycle, the blades that provided the best productivity under the different soil cover conditions are shown in Table 2. The maximum productivity of the radish grown in soil without mulch was obtained with a blade of 103.1 mm, with this productivity being very close to that in the cultivation in soil covered with bagasse, where it was obtained with the application of a blade of 77.3 mm, thus requiring less water to obtain a significantly higher level of productivity, as shown in Table 2.

Table 2. Optimal blades obtained under different soil cover conditions and their respective productivities in the second cycle of the radish cv. Cometo crop.

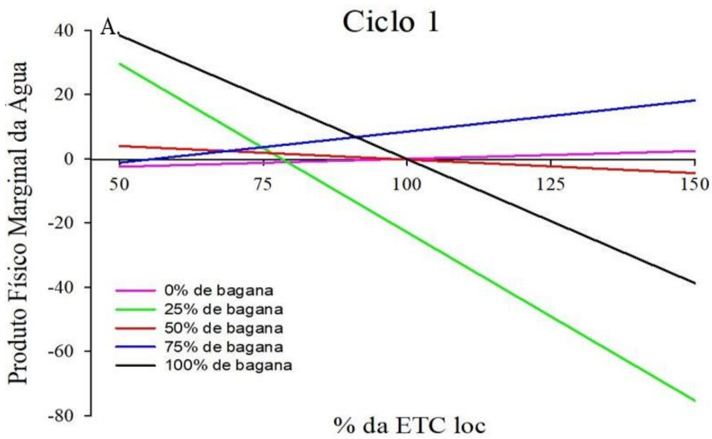
Soil Cover (% bagana)	Optimal Blade (mm)	Productivity (kg ha $^{-1}$)
0	103.1	5453.69
25	43.0	5844.54
50	117.5	5514.37
75	111.5	5282.35
100	77.3	6142.79

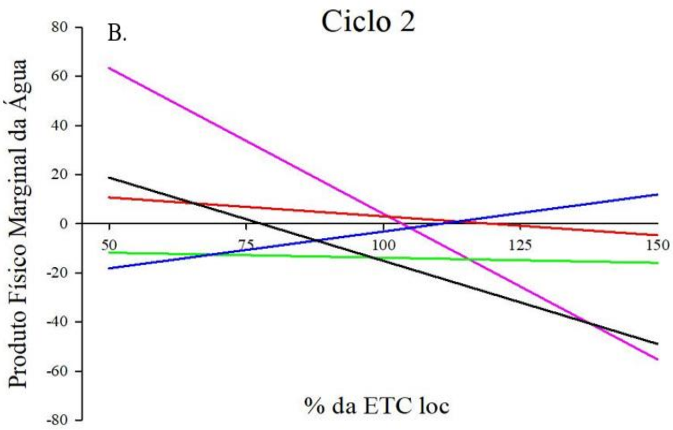
The positive effect of mulch on organic radish productivity can be seen in Ferreira et al. (2011), where the authors used mulch from spontaneous plants and obtained higher productivity than the no-tillage condition with living mulch from spontaneous plants. A similar result for productivity was also reported by Melo et al. (2014) studied the effects of carnauba straw mulch plus cattle manure on radish cultivation.

The optimal irrigation depths, from an economic point of view, were calculated by equating the expression of the marginal physical product of water (PFMa) to the price ratio of the variable water factor (Pw) and the radish product. In the first cycle, PFMa (Figure 2A) is initially positive and decreases as the water depth increases. When the PFMa value reaches zero, this corresponds to depths of 100.5, 78.2, 97.1, 56.2 and 99.8 mm in bare soil, with 25%, 50%, 75% and 100% bagasse cover, respectively, meaning that the applied depths provide maximum physical productivity. From the point at which PFMa presents a negative value, a decrease in productivity occurs with increasing depth, indicating that continued water application is uneconomical.

The optimal economic water depths (Figure 2B) and the water depths that provided the best physical yield in the second cycle were similar, indicating that the water depth that maximizes production is the same one that provides the maximum economic return. Therefore, applying a water depth that maximizes physical production may be sufficient to achieve economically viable production, demonstrating that irrigation management must ensure that crop water needs are met under optimal conditions (ALMEIDA et al., 2020). Other authors have reported similar behavior in various crops, such as roses and cherry tomatoes (OLIVEIRA, 2016; SILVA et al., 2019).

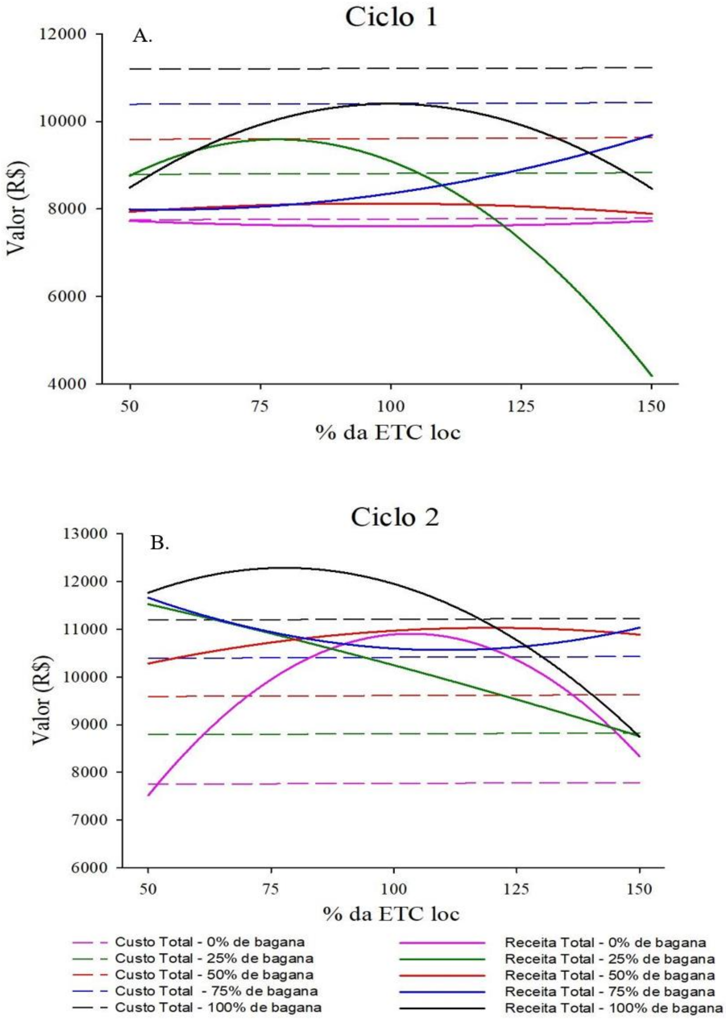
Figure 2. Marginal physical product of water (PFMa) for different irrigation depths applied in soils with different levels of bagasse.





The proximity observed for the economic optimum and physical maximum water depths can be explained by factors such as the high economic value of the crop, low water cost and, above all, the high efficiency of the localized irrigation system (BERNARDO et al., 2019). For both the first cycle (Figure 3A) and the second cycle (Figure 3B), using the economically optimal water depth, the profit for each crop was obtained considering the price per kg of radish (Py) at R$ 2.00. The costs of the factors considered fixed and variable in experiment (C) were estimated at 7,718.13, 8,758.13, 9,558.13, 10,358.13 and 11,158.13 RS ha $^{-1;}$ for the conditions of 0, 25, 50, 75 and 100% soil cover, respectively, the price of water (Pw) was 0.650 R$ mm $^{-1}$ for the second cycle.

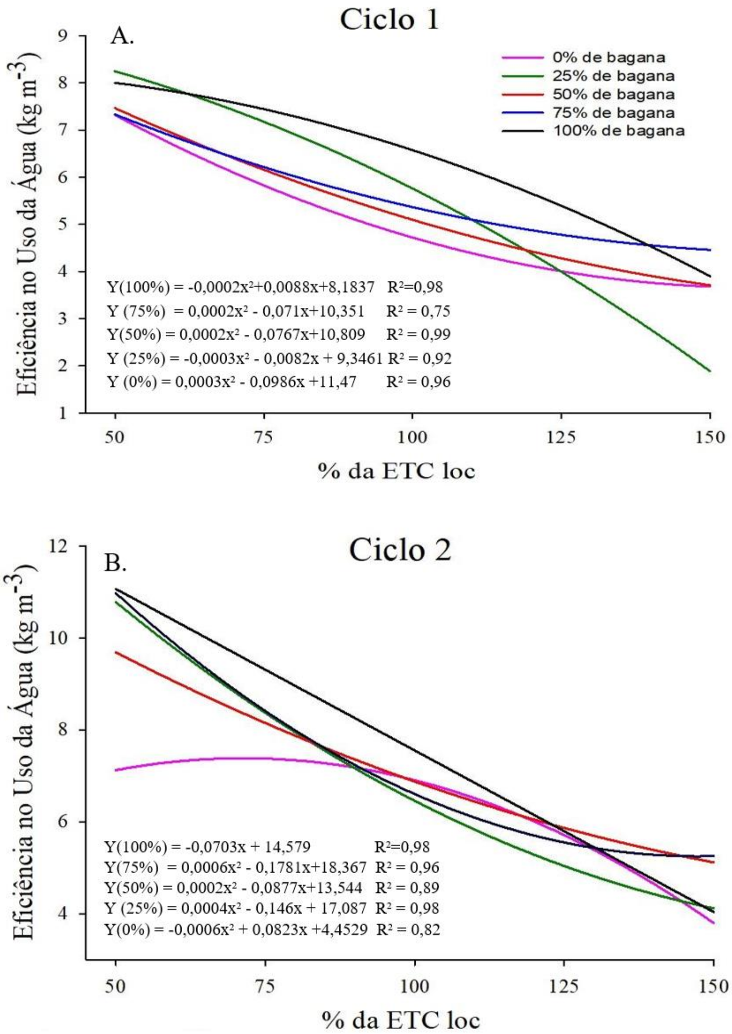
Figure 3. Cost and value of radish production cv. Cometo according to irrigation depth for the month of August 2018.



The water use efficiency variable was significant ($p<0.05$) for the irrigation depth factor (ETc_{loc}) within each soil mulch factor. Importantly, the curves under all the soil cover conditions were fitted with quadratic models for the first cycle and most of the second cycles, except for the 100% mulch factor.

With respect to water use efficiency, the soil with 100% bagasse cover presented the best results, being superior at the lowest applied water depths (Figure 4A) for most values. The maximum efficiency, in the first crop cycle, was observed at the 50% ETc_{depth} with 100% bagasse cover, where a water use efficiency of 7.85 kg m^{-3} was reached. Similar behavior was observed in the second crop cycle (Figure 4B), with a value of 11.06 kg m^{-3}.

Figure 4. Water use efficiency of radish cv. Cometo with different water levels and soil cover crops.



The results indicate that the water use efficiency obtained in crops where soil cover was used was significantly greater than the efficiency observed in the soil condition without cover; that is, the use of soil cover enables greater root productivity with a smaller amount of water applied.

Teófilo et al. (2012) reported that water productivity (the relationship between crop yield and water consumption) can be improved through procedures such as improved management practices, fertilization, and, especially, more efficient irrigation practices that can significantly reduce water losses, as well as techniques that promote water storage and infiltration into the soil, thus reducing evaporation rates. In the present study, a similar behavior was observed, with greater water use efficiency observed in the presence of soil cover. The authors also emphasized that the use of soil cover reduces water losses through evaporation and increases water use efficiency.

6 CONCLUSION

Carnauba bagasse has potential for use as mulch in radish cultivation, providing an increase in crop yield under deficit irrigation strategy conditions for the use of 16 t ha $^{-1}$ of mulch.

Radish crops respond increasingly to different irrigation depths up to 100% ETc, and economic gains can be obtained when associated with the use of mulch on the soil.

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