ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.22, n.7, p.445-450, 2018
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v22n7p445-450

Carrot yield and water-use efficiency under different mulching, organic fertilization and irrigation levels

Daniel F. de Carvalho[1], Daniela P. Gomes[1], Dionizio H. de Oliveira Neto[2], José G. M. Guerra[3], Janaína R. C. Rouws[3] & Fábio L. de Oliveira[4]

[1] Universidade Federal Rural do Rio de Janeiro/Instituto de Tecnologia/Departamento de Engenharia. Seropédica, RJ. E-mail: carvalho@ufrrj.br (Corresponding author) - ORCID: 0000-0001-7629-9465; danielagomesagro@hotmail.com - ORCID: 0000-0003-1373-4604
[2] Agristar do Brasil. Santo Antonio de Posse, SP. E-mail: dionizioneto@yahoo.com.br - ORCID: 0000-0003-3000-4750
[3] Empresa Brasileira de Pesquisa Agropecuária/Embrapa Agrobiologia. Seropédica, RJ. E-mail: guilherme.guerra@embrapa.br - ORCID: 0000-0002-3532-9661; janaina.rouws@embrapa.br - ORCID: 0000-0003-1816-3505
[4] Universidade Federal do Espírito Santo/Centro de Ciências Agrárias e Engenharias/Departamento de Agronomia. Alegre, ES. E-mail: fabio.oliveira.2@ufes.br - ORCID: 0000-0002-1711-6988

Key words:
irrigation management
Gliricidia sepium
castor bean cake
Daucus carota L.
organic agriculture

A B S T R A C T
This study was carried out to evaluate the contributions to the optimization of water use in a carrot crop under different forms of mulch using *Gliricidia sepium*, fertilization with castor bean cakes and irrigation water depths. The experiment was conducted in Seropédica, RJ, Brazil (22° 46' S and 43° 41' W), from June to September 2010. The experiment was conducted using a split-split-plot scheme (5 x 3 x 2), with four replicates. The five plots had irrigation depths corresponding to 0, 43, 72, 100 and 120% of crop evapotranspiration (ETc); the three subplots contained the different forms of mulch (whole leaves (WL) and chopped leaves and branches (CLB)) and the absence of mulch (AM); and the two sub-subplots contained either the presence (PF) or absence of fertilization (AF). Using time domain reflectometry (TDR) in the irrigation management, water depths ranging from 67.8 to 285.5 mm were applied. The use of mulch in association with fertilization led to higher yields and water-use efficiency (WUE) of the carrot plants, and the mulch composed of WL performed best. The application of irrigation depths corresponding to 97% of ETc promoted the highest carrot yields, although the highest values of WUE were observed, with irrigation depths corresponding to a range from 51 to 68% of ETc.

Palavras-chave:
manejo da irrigação
Gliricidia sepium
torta de mamona
Daucus carota L.
agricultura orgânica

Produção de cenoura e uso eficiente da água sob cobertura morta vegetal, adubação orgânica e níveis de irrigação

R E S U M O
O trabalho foi realizado com o objetivo de avaliar a contribuição de formas de preparo de cobertura morta de *Gliricidia sepium*, da adubação com torta de mamona (em cobertura) e de lâminas de irrigação na otimização do uso da água no cultivo de cenoura. O experimento foi conduzido em Seropédica, RJ, Brazil (22° 46' S e 43° 41' W), de junho a agosto de 2010. O experimento foi em esquema de parcelas sub-sub-divididas (5 x 3 x 2), com quatro repetições. As parcelas foram caracterizadas pelas lâminas de irrigação correspondentes a 0, 43, 72, 100 e 120% da evapotranspiração da cultura (ETc); as sub-parcelas, pelas formas de preparo da cobertura morta (folhas inteiras e folhas e ramos tenros picados) e pela ausência de cobertura; e as sub-sub-parcelas, pela presença e ausência de adubação. Utilizando TDR no manejo da irrigação, foram aplicadas lâminas de 67,8 a 285,5 mm. O uso da cobertura morta associada à adubação proporcionou maior produtividade e eficiência de uso de água (EUA) da cenoura, sendo a cobertura constituída por folhas inteiras a que apresentou melhor desempenho. A aplicação de 97% da ETc proporcionou as maiores produtividades de cenoura, embora os maiores valores de EUA tenham sido obtidos com lâminas variando de 51 a 68% da ETc.

Ref. 181970 – Received 28 Jun, 2017 • Accepted 08 Feb, 2018 • Published 28 May, 2018

Introduction

Carrots (*Daucus carota* L.) are one of the most consumed vegetables in the world, and they are the root vegetable with the highest economic value in Brazil (Resende et al., 2016). In addition to controlling the amount of water applied, appropriate management of fertilizer positively affects the production of roots, especially in organic agricultural systems, which are needed to ensure the availability of nitrogen (N) to achieve adequate yields (Dawson et al., 2008).

The management practices employed in organic agriculture, such as the use of mulch and organic fertilizers, can increase the yield of crops without impacting production costs (Kang et al., 2008). Therefore, these practices favor agricultural activities, which are characterized by a minimal use of external inputs and a limited amount of mineral fertilizers, on small properties (Egodawatta et al., 2012).

The use of the leguminous species *Gliricidia sepium* for mulch has resulted in gains in yields (Moura et al., 2010) because of its capacity to provide nutrients to the crops (Welch et al., 2016), especially N (Omari et al., 2016). However, mulch preparation, for later deposition onto soil, can influence its decomposition rate and consequently affect both the supply and the rate of release of its nutrients. Castor bean cake is another material that has been used as an organic fertilizer, and it has become an ideal option for meeting the nutritional requirements of crops (Lima et al., 2011).

Irrigation water management is a tool that must be used, especially in organic production systems, to fulfill the need to produce foods with the minimum environmental impact. Using irrigation water management with mulch and organic fertilizers promotes higher water-use efficiency (WUE) in crops (Igbadun & Oiganji, 2012).

Thus, this study aimed to evaluate the contribution of different forms of mulch preparations using *Gliricidia sepium*, fertilization with castor cakes and irrigation water depths for the optimization of water use in a carrot crop, under organic management.

Materials and Methods

The experiment was conducted in Seropédica-RJ, Brazil (22º 46` S and 43º 41` W), in a Red-Yellow Argisol (22% clay, 8% silt and 70% sand). The climate of the region is classified as Aw according to Köppen's classification, with precipitation and high temperatures in the summer and a dry winter with mild temperatures.

The meteorological data (global radiation, wind speed, air temperature, air relative humidity and rainfall) were obtained from an automatic weather station, installed close to the experimental area, allowing the estimation of reference evapotranspiration through the Penman-Monteith FAO-56 method (Allen et al., 1998). During the cultivation period, the reference evapotranspiration (ETo) and rainfall were 286.3 and 81.0 mm, respectively.

The soil was prepared with one plowing and two harrowings, with the latter raising the beds (1.0 m wide and 0.20 m high). According to methodologies recommended by EMBRAPA (1997) the soil chemical analysis was performed and indicated no need for soil correction: pH: 5.9; Al: 0 $cmol_c\ dm^{-3}$; Ca: 28.0 $cmol_c\ dm^{-3}$; Mg: 11.0 $cmol_c\ dm^{-3}$; K: 104 mg dm^{-3}; P: 69.8 mg dm^{-3}.

On 16 June 2010, carrot plants (cv. 'Brasília') were sown directly in the soil following the longest direction of the bed, at a spacing of 0.25 m between rows and 0.05 m between plants. Immediately after sowing, bovine manure (3 Mg ha^{-1}) was applied in the planting rows to cover the seeds. The harvest was performed on 13 September 2010 (89 days after sowing, DAS).

The experiment was set in a split-split-plot scheme (5 x 3 x 2) with 4 replicates. The applied irrigation depths characterized the five experimental plots and corresponded to 43 (L2), 72 (L3), 100 (L4) and 120 (L5) % of crop evapotranspiration (ETc), with an additional treatment L1 (0% of ETc), which received only the irrigation depth applied during the period of crop establishment and the effective rainfall that occurred during the cultivation period. The three subplots were characterized by the presence of Gliricidia mulch prepared in two different ways, whole leaves (WL), which was mulch composed of only whole leaves, and chopped leaves and branches (CLB), which was mulch composed of chopped leaves and tender branches, and one plot received a treatment without mulching (AM). The two sub-subplots were characterized by the presence (PF) and absence (AF) of fertilization with castor bean cakes in an area of 0.383 m^2 with 30 plants, of which only the 14 central plants were used for evaluation.

The different irrigation depths were obtained using flow-regulated drippers of different nominal flow rates equivalent to 3.9 (L2); 6.5 (L3); 9.0 (L4) and 10.8 (L5) L h^{-1}. Two irrigation lines were installed (16-mm-diameter polyethylene pipes) on each bed, with emitters spaced by 0.125 m.

The mulch was prepared with material from the pruning of adult Gliricidia plants. The mulch was processed from whole leaves (WL) detached from the branches and dried in the shade and leaves and tender branches (CLB) ground in a disintegrator machine (using a flat bottom sieve for forage) and dried in the shade. The amount of straw used was 1.8 kg m^{-2}. The top-dressing fertilizer used castor bean cake (1.5 Mg ha^{-1}) that was applied in the row at 30 DAS.

During the pruning, the material used as mulch was collected for the determination of its macronutrient contents, and the results were the following: N: 33.1; Ca: 8.5; Mg: 2.5; K: 13.1 and P: 1.3 g kg^{-1} (EMBRAPA, 2000). The castor bean cake used in the top-dressing fertilizer was also analyzed, and the analysis provided the following results: N: 58.1; Ca: 12.95; Mg: 6.55; K: 8.50 and P: 2.42 g kg^{-1}.

Irrigation management was performed through the time-domain reflectometry technique (Topp et al., 1980), using a TDR 100 (Campbell Scientific, Logan-Utah), properly calibrated for the experimental area. The probes had a length of 0.15 m and were horizontally installed at depths of 0.05, 0.10 and 0.20 m in the plots corresponding to L1 and L4, in the AM and AF, totaling 24 probes.

In the TDR calibration process and after moistening of a portion of the area, the soil moisture (θ) corresponding to field capacity was determined (θ_{fc} = 0.181 $cm^3\ cm^{-3}$), with θ as the constant value, while the surface was covered with plastic to avoid soil water evaporation. The calibration equations obtained were $\theta_{0\text{-}0.10} = 0.0316ka - 0.2182$ ($R^2 = 0.91$) and $\theta_{0.10\text{-}0.20} = 0.0333ka - 0.1599$ ($R^2 = 0.85$) for layers 0-0.10 and 0.10-0.20 m, respectively. With the field capacity value, the irrigation depth was determined in the control treatment (100% of ETc), using the value of soil moisture (θ_a) obtained from mean values of the dielectric constant (ka) from the four replicates. Based on crop growth, the following effective depths of the root system were considered: 5 cm (until 20 DAS), 10 cm (from 21 to 48 DAS) and 20 cm (from 49 DAS to harvest).

The irrigation depth applied through micro-irrigation was calculated also considering the location coefficient, which considers the percentage of wet area from the emitter (PWA) and the percentage of area shaded by the crop (PSA).

For the first 20 days after sowing, the experimental area was irrigated by sprinklers (water depth was applied in the period of crop establishment), using sectorial sprinklers with 3.2-mm nozzles. After the evaluation of uniformity, the system showed a mean uniformity coefficient (CUC) of 86%. Then, the different irrigation depths were applied through micro-irrigation, which exhibited a mean distribution uniformity coefficient (DUC) of 90%.

The evaluated production variables were total yield and marketable yield of roots. Marketable roots were considered as those longer than 10 cm with no defects.

Water-use efficiency (WUE) values were obtained based on the ratio between the marketable yield of roots and the applied water depth (Lovelli et al., 2007).

The data were subjected to analysis of variance and when the results were significant for F test, the irrigation depth was subjected to a regression analysis, and the forms of mulch preparation were subjected to the Scott-Knott test at a 0.05 significance level.

Results and Discussion

The total water depths (irrigation depth applied during the period of crop establishment + effective rainfall + irrigation depths of the treatments) resulted in values of 67.8 (L1), 130.9 (L2), 188.9 (L3), 244.4 (L4) and 285.5 (L5) mm (Table 1).

Under severe conditions of water stress (67.8 mm), the use of mulch had no significant effect on the total yield of carrots (Table 1). With a higher water intake (130.9 and 188.9 mm), the use of the mulch influenced the total yield of carrots. With 130.9 mm, the WL mulch provided the highest total yield, followed by the CLB and AM, but with 188.9 mm, the CLB mulch did not differ significantly from the AM. These results were independent of the absence or presence of fertilization. With the application of 100% of the crop water requirement (244.4 mm), no significant differences were observed between the types of mulch independent of fertilization, but the PF provided the highest total yield in the AM. With the application of 285.5 mm (120% of ETc) of water, the use of mulch had a beneficial effect on the total yield in the presence of fertilization, and no significant differences were observed between the types of mulch. In the absence of fertilization, the WL mulch provided the highest total yield, followed by the CLB mulch and AM treatment.

The higher irrigation depths favored the transformation of organic matter derived from mulch and organic fertilization due to the best levels of soil moisture, resulting in better development of the plants (Brito et al., 2008).

The use of mulch favored the production of carrot roots at the length accepted by the consumer market (marketable yield), even under severe conditions of water stress (67.8 mm), and there were no significant differences among the different types of mulch. With the application of water depths of 130.9 and 188.9 mm in the presence of fertilization, there were significant differences between the WL and CLB mulches, but there was no significant difference from the AM. In the absence of fertilization, the mulches significantly influenced the marketable yields, with the WL mulch providing the highest marketable yield, followed by the CLB mulch and AM treatment. With a water depth of 244.4 mm, mulch resulted in significant differences in the marketable yields, and the CLB and WL mulches did not present significant differences, regardless of the presence or absence of fertilization. The same results were obtained with a water depth of 285.5 mm for the

Table 1. Total and marketable yields and water-use efficiency (WUE) of carrots, at the different irrigation levels and forms of mulch preparation (whole leaves - WL, chopped leaves and branches – CLB, and absence of mulch - AM) and in the presence (PF) and absence of fertilization (AF)

Water depth (mm)	Mulching	Total yield (Mg ha^{-1})		Marketable yield (Mg ha^{-1})		WUE (kg m^{-3})	
		PF	AF	PF	AF	PF	AF
67.8	CLB	32.43 aA	32.00 aA	22.50 aA	21.52 aA	33.16 aA	31.72 aA
	WL	36.08 aA	30.45 aA	24.76 aA	18.52 aA	36.49 aA	27.29 bA
	AM	30.43 aA	30.71 aA	14.93 aB	15.34 aA	22.01 aB	22.60 aB
130.9	CLB	58.98 aB	55.23 aB	51.47 aB	49.74 aB	39.31 aB	37.99 aB
	WL	66.17 aA	66.49 aA	61.55 aA	58.37 aA	47.01 aA	44.58 aA
	AM	52.38 aC	47.50 aC	45.39 aB	40.61 aC	34.67 aC	31.02 aC
188.9	CLB	65.86 aB	57.15 bB	61.32 aB	51.93 bB	32.47 aB	27.50 bB
	WL	74.61 aA	67.64 bA	73.50 aA	63.93 bA	38.91 aA	33.85 bA
	AM	62.99 aB	52.93 bB	58.16 aB	44.25 bC	30.79 aB	23.43 bB
244.4	CLB	73.91 aA	71.82 aA	71.17 aA	60.76 bA	29.12 aA	24.86 bA
	WL	75.67 aA	73.43 aA	74.27 aA	67.82 aA	30.38 aA	27.74 aA
	AM	68.87 aA	62.72 bB	63.74 aB	47.93 bB	26.08 aA	19.61 bB
285.5	CLB	71.58 aA	64.40 bB	69.32 aA	54.73 bB	24.28 aA	19.17 bB
	WL	75.92 aA	72.48 aA	71.47 aA	70.02 aA	25.03 aA	24.52 aA
	AM	62.07 aB	53.21 bC	53.67 aB	42.87 bC	18.80 aB	15.01 aB

Means followed by the same letter do not differ ($p > 0.05$), uppercase letter in the column and lowercase letter in the row for respective water depths and yields and WUE total and marketable yields, when fertilization with a castor bean cake was used.

The water-use efficiency was higher with the use of the mulches under the water depth of 67.8 mm, and the WL mulch did not differ significantly from the CLB mulch (Table 1). With the application of the water depths of 130.9 and 188.9 mm, the use of mulch influenced the water-use efficiency. With a water depth of 130.9 mm, the WL mulch provided the highest value, followed by the CLB mulch and AM treatment, but with a water depth of 188.9 mm, the CLB mulch did not differ significantly from the AM treatment. These results occurred regardless of fertilization with castor bean cakes. For the irrigation depth of 244.4 mm, higher WUE values were obtained with PF, independent of using mulch, and AF with the WL mulch. For the irrigation depth of 285.5 mm, the highest values of WUE were obtained with mulch and PF. In the AF treatment, the WL mulch showed the highest value of WUE, while with the CLB mulch, the WUE value was not significantly different from that with the AM treatment.

The results show that the use of mulch increases the total and marketable yields, consequently increasing the WUE of carrots under conditions of water stress (up to 43% of ETc for total productivity), with a water supply of 100% (except in the presence of fertilization) and at 120% of ETc. The gains obtained with the use of mulch from leguminous species are possibly related to the benefits caused by the organic matter in the system, such as soil protection against the main agents that cause degradation (Moura et al., 2015), the maintenance of moisture (Moura et al., 2010), the decrease in maximum temperature and thermal amplitude of the soil (Silva et al., 2016) and specifically the supply of nutrients to the crop, released through the decomposition of residues (Moura et al., 2010). Ambrosano et al. (2013) demonstrated the capacity of leguminous species to contribute to the increase in N content in the soil, which is readily mineralized during the decomposition of its residues and preserved in the organic matter of the soil.

The WL mulch promoted a better performance in terms of carrot yield compared to the CLB mulch (irrigation depths of 130.9 and 188.9 mm, in the presence and absence of fertilization and at the irrigation depth of 285.5 mm in the absence of fertilization), which may have been influenced by the decomposition of the material. The WL mulch is composed only of leaves of Gliricidia, which is a material that is more easily decomposed; on the other hand, the CLB mulch is composed of leaves and branches of Gliricidia, and when it is compared to the WL mulch, it takes more time to decompose. Coelho et al. (2006) found 50 and 69% of remaining dry matter at 15 and 176 days after planting, respectively, for mulches of Gliricidia with leaves and chopped leaves and branches. The authors observed that the yield of the branches and leaves from the pruning of the Gliricidia shoots was equal to 3:1 and that the N contents in the branches and leaves were 6.2 and 43.3 g kg^{-1}, respectively.

The decomposition of plants used as soil cover is also influenced by the content of lignin, which affects their decomposition rates (Hobbie, 2000; Silva et al., 2008). The molecule lignin interacts with the cell wall, promoting mechanical protection of the cellulose against degradation, thus delaying its decomposition (Mafongoya et al., 1997). Silva et al. (2008) and Souza et al. (2010) found lignin contents of 74 and 163 g kg^{-1} for mulches of Gliricidia composed of leaves and chopped leaves and branches, respectively.

The use of the WL mulch promoted a better yield of the carrot crop, in addition to demanding less labor in terms of preparing the material and not needing a device for chopping. However, the material composed of only Gliricidia leaves had a lower yield, corroborating the results of Coelho et al. (2006).

Regardless of the type of mulch used, there were also gains in the total and marketable yields of the carrot crop associated with organic fertilization with castor bean cakes and the application of the irrigation depths. There was a maximum response yield as a function of the applied irrigation depths, with higher values in the PF (Figure 1), corroborating the results that the presence of organic matter and adequate irrigation management can promote gains in the total and marketable yields of a carrot crop. The adjusted equations and their respective determination coefficients for the total and marketable yields are presented in Table 2.

The irrigation depths corresponding to 237.0 and 237.23 mm were responsible for the highest total yields 72.5 (PF) and 66.4 (AF) Mg ha^{-1}, respectively. For marketable yields, the depths of 233.4 and 229.0 mm were responsible for 69.6 (PF) and 59.3 (AF) Mg ha^{-1}, respectively. Imtiyaz et al. (2000) and Nagaz et al. (2012) also obtained gains in carrot yields with an increase in irrigation depth. Based on Nagaz et al. (2012), the

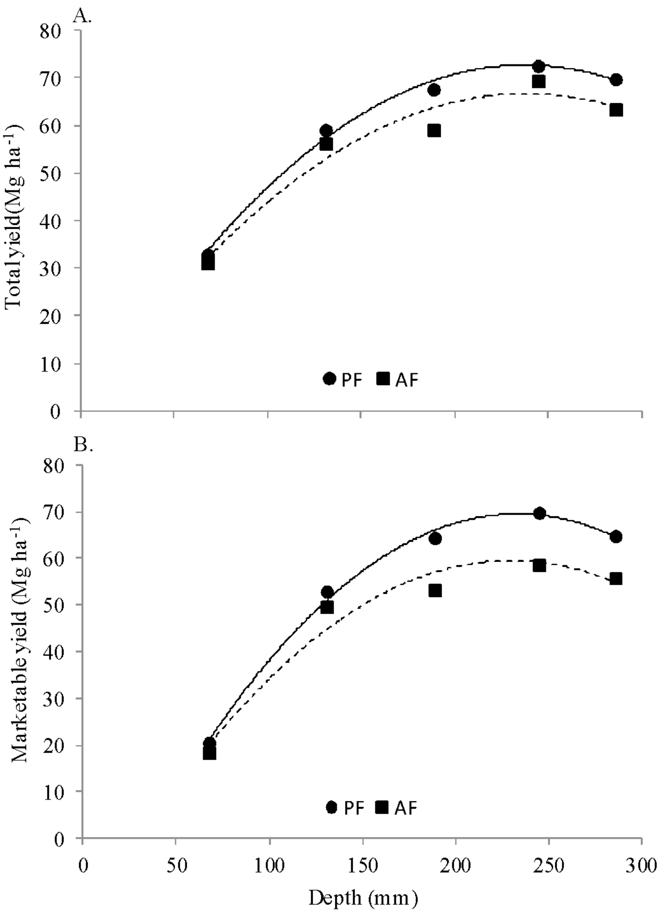

Figure 1. Total (A) and marketable (B) yield of carrots in the presence (PF) and absence of fertilization (AF), as a function of irrigation depth

Table 2. Adjusted equations and their respective determination coefficients for total (Ty) and marketable yields (My), in the presence (PF) and absence of fertilization (AF), as a function of irrigation depth (D)

Fertilization	Equation	R^2
	Total yield	
PF	$Ty = -0.00136D^2 + 0.64464D - 3.86078$	0.993
AF	$Ty = -0.00120D^2 + 0.56936D - 1.10596$	0.952
	Marketable yield	
PF	$My = -0.00176D^2 + 0,82171D - 26.32798$	0.996
AF	$My = -0.00151D^2 + 0.69169D - 19.88148$	0.963

decrease in carrot yield with the increase in irrigation depth is associated with the lower number and weight of roots, because of the water stress during the period from fruiting to harvest.

There was a significant interaction among the irrigation depths, forms of mulch preparations and fertilization for WUE (Figure 2). The adjustment equations and their respective determination coefficients for WUE are presented in Table 3. In the presence of fertilization (PF), the highest values of WUE (WL - 42.7 kg m^{-3}; AM - 33.4 kg m^{-3}) were obtained at the irrigation depths of 151.4 and 166.6 mm, respectively. Without fertilization with castor bean cakes (AF), the irrigation depths of 159.0, 124.8 and 140.1 mm were responsible for the highest WUE (CLB - 38.6 kg m^{-3}; WL - 34.0 kg m^{-3}; AM - 27.3 kg m^{-3}, respectively). Igbadun & Oiganji (2012) found a higher WUE for an onion crop when using mulch compared to the treatment

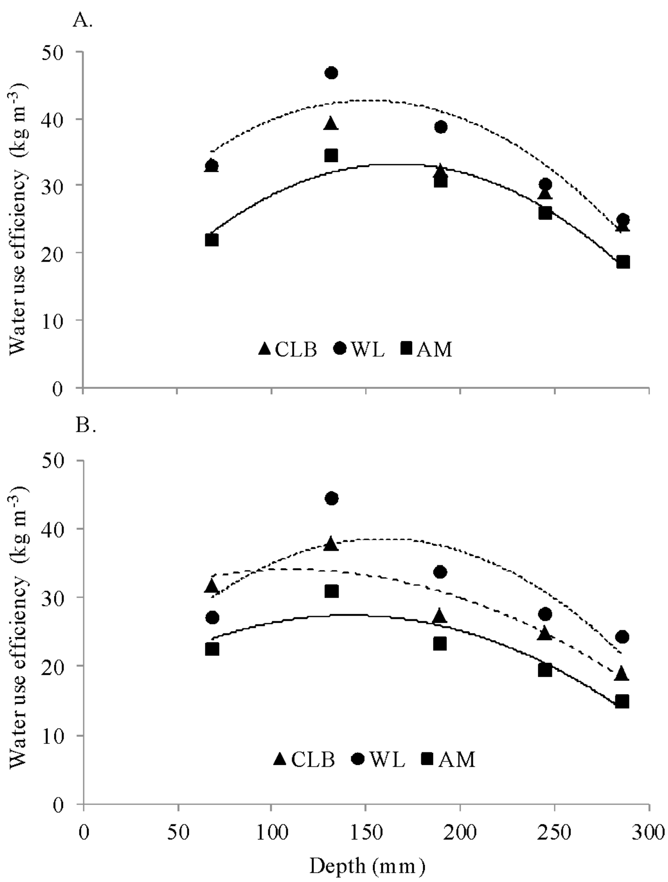

Figure 2. Water use efficiency (WUE) of carrots under different types of mulch (whole leaves - WL, chopped leaves and branches - CLB and absence of mulch - AM) and in the presence (PF) (A) and absence of fertilization (AF) (B), as a function of the irrigation depths

Table 3. Adjusted equations and their respective determination coefficients for WUE, as a function of irrigation depth (D)

Mulch	Equation	R^2
	Presence of fertilization	
CLB	$WUE = -0.04885D + 40.62977$	0.591
WL	$WUE = -0.00110D^2 + 0.33316D + 17.49642$	0.847
AM	$WUE = -0.00106D^2 + 0.35329D + 3.93263$	0.920
	Absence of fertilization	
CLB	$WUE = -0.00104D^2 + 0.33080D + 12.25750$	0.669
WL	$WUE = -0.00051D^2 + 0.11273D + 27.83456$	0.843
AM	$WUE = -0.00065D^2 + 0.18217D + 14.55050$	0.829

in the absence of mulch, which implies that the use of mulch significantly affects the water productivity of this crop. Nagaz et al. (2012) found WUE values for carrots of 7.6, 7.8 and 7.5 kg m^{-3} applying 100, 80 and 60% of ETc, respectively. Imtiyaz et al. (2000) obtained WUE values ranging from 13.4 to 9.7 kg m^{-3} with increases in the irrigation depths from 121 to 369 mm. In addition, it was also observed that the highest WUE values were obtained with fertilization. Working with a tomato crop, Badr et al. (2016) obtained WUE values from 11 to 18 kg m^{-3} in response to an increase in an N dose.

Conclusions

1. The mulch from *Gliricidia sepium* that was composed of whole leaves combined with fertilization using castor bean cakes led to higher yields and water-use efficiency values of the carrot crop.

2. The application of an irrigation depth corresponding to 97.0% of ETc promoted the highest yields of carrots, although the highest values of WUE were obtained with irrigation depths ranging from 51 to 68% of ETc.

Literature Cited

Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M. Crop evapotranspiration: Guidelines for computing crop water requeriments. Rome: FAO, 1998. 308p. Irrigation and Drainage Paper, 56

Ambrosano, E. J.; Cantarella, H.; Ambrosano, G. M. B.; Dias, F. L. F.; Rossi, F.; Trivelin, P. C. O.; Muraoka, T. The role of green manure nitrogen use by corn and sugarcane crops in Brazil. Agricultural Sciences, v.4, p.89-108, 2013. https://doi.org/10.4236/as.2013.412A008

Badr, M. A.; Abou-Hussein, S. D.; El-Tohamy, W. A. Tomato yield, nitrogen uptake and water use efficiency as affected by planting geometry and level of nitrogen in an arid region. Agricultural Water Management, v.169, p.90-97, 2016. https://doi.org/10.1016/j.agwat.2016.02.012

Brito, L. M.; Amaro, A. L.; Mourão, I.; Coutinho, J. Transformação da matéria orgânica e do nitrogênio durante a compostagem da fração sólida do chorume bovino. Revista Brasileira de Ciência do Solo, v.32, p.1959-1968, 2008. https://doi.org/10.1590/S0100-06832008000500017

Coelho, R. A.; Silva, G. T. A.; Ricci, M. dos S. F.; Resende, A. S. de. Effect of gliricídia (*Gliricidia sepium*) in nitrogen nutrition on coffee plants (*Coffea canephora*) intercropped with banana trees in organic system of production. Coffee Science, v.1, p.21-27, 2006.

Dawson, J. C.; Huggins, D. R.; Jones, S. S. Characterizing nitrogen use efficiency in natural and agricultural ecosystems to improve the performance of cereal crops in low-input and organic agricultural systems. Field Crops Research, v.107, p.89-101, 2008. https://doi.org/10.1016/j.fcr.2008.01.001

Egodawatta, W. C. P.; Sangakkara, U. R.; Stamp, P. Impact of green manure and mineral fertilizer inputs on soil organic matter and crop productivity in a sloping landscape of Sri Lanka. Field Crops Research, v.129, p.21-27, 2012. https://doi.org/10.1016/j.fcr.2012.01.010

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Manual de métodos de análise de solo. 2.ed. Rio de Janeiro: Embrapa Solos, 1997. 212p.

EMBRAPA- Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Métodos de análise de tecidos vegetais utilizados na Embrapa Solos. Rio de Janeiro: Embrapa Solos, 2000. 41p.

Hobbie, S. E. Interactions between litter lignin and nitrogenitter lignin and soil nitrogen avaiability during leaf litter decomposition in a Hawaiian Montane Forest. Ecosystems, v.3, p.484-494, 2000. https://doi.org/10.1007/s100210000042

Igbadun, H. E.; Oiganji, E. Crop coefficients and yield response factors for onion (*Allium cepa*. L) under deficit irrigation and mulch practices in Samaru, Nigeria. African Journal of Agricultural Research, v.7, p.5137-5152, 2012. https://doi.org/10.5897/AJAR12.689

Imtiyaz, M.; Mgadla, N. P.; Manase, S. K.; Chendo, K.; Mothobi, E. O. Yield and economic return of vegetable crops under variable irrigation. Irrigation Science, v.19, p.87-93, 2000. https://doi.org/10.1007/s002710050005

Kang, H.; Shannon, D. A.; Prior, S. A.; Arriaga, F. J. Hedgerow pruning effects on light interception, water relations and yield in alley-cropped maize. Journal of Sustainable Agriculture, v.31, p.115-137, 2008. https://doi.org/10.1300/J064v31n04_08

Lima, R. de L. S. de; Severino, L. S.; Sampaio, L. R.; Sofiatti, V.; Gomes, J. A.; Beltrão, N. E. de M. Blends of castor meal and castor husks for optimized use as organic fertilizer. Industrial Crops and Products, v.33, p.364-368, 2011. https://doi.org/10.1016/j.indcrop.2010.11.008

Lovelli, S.; Perniola, M.; Ferrara, A.; Tommaso, T. di. Yield response factor to water (Ky) and water use efficiency of *Carthamus tinctorius* L. and *Solanum melongena* L. Agricultural Water Management, v.92, p.73-80, 2007. https://doi.org/10.1016/j.agwat.2007.05.005

Mafongoya, P. L.; Giller, K. E.; Palm, C. A. Decomposition and nitrogen release patterns of tree prunings and litter. Agroforestry Systems, v.38, p.77-97, 1997. https://doi.org/10.1023/A:1005978101429

Moura, E. G. de; Aguiar, A. das C. F.; Piedade, A. R.; Rousseau, G. X. Contribution of legume tree residues and macrofauna to the improvement of abiotic soil properties in the eastern Amazon. Applied Soil Ecology, v.86, p.91-99, 2015. https://doi.org/10.1016/j.apsoil.2014.10.008

Moura, E. G. de; Serpa, S. S.; Santos, J. G. D. dos; Costa Sobrinho, J. R. S.; Aguiar, A. das C. F. Nutrient use efficiency in alley cropping systems in the Amazonian periphery. Plant and Soil, v.335, p.363-371, 2010. https://doi.org/10.1007/s11104-010-0424-0

Nagaz, K.; Masmoudi, M. M.; Mechlia, N. B. Impacts of irrigation regimes with saline water on carrot productivity and soil salinity. Journal of the Saudi Society of Agricultural Sciences, v.11, p.19-27, 2012. https://doi.org/10.1016/j.jssas.2011.06.001

Omari, R. A.; Aung, H. P.; Hou, M.; Yokoyama, T.; Onwona-Agyeman, S.; Oikawa, Y.; Fujii, Y.; Bellingrath-Kimura, S. D. Influence of different plant materials in combination with chicken manure on soil carbon and nitrogen contents and vegetable yield. Pedosphere, v.26, p.510-521, 2016. https://doi.org/10.1016/S1002-0160(15)60061-3

Resende, G. M.; Yuri, J. E.; Costa, N. D.; Mota, J. H. Yield of carrot cultivars in organic farming system at high temperature. Horticultura Brasileira, v.34, p.121-125, 2016. https://doi.org/10.1590/S0102-053620160000100018

Silva, D. M. N. da; Oliveira, F. L. de; Teodoro, R. B.; Fávero, C.; Quaresma, M. A. L. Temperature and humidity of soil covered with perennial herbaceous legumes in the semiarid region of Minas Gerais, Brazil. Bioscience Journal, v.32, p.11-19, 2016. https://doi.org/10.14393/BJ-v32n1a2016-26241

Silva, G. T. A.; Matos, L. V.; Nóbrega, P. de O.; Campello, E. F. C.; Resende, A. S. de. Chemical composition and decomposition rate of plants used as green manure. Scientia Agricola, v.65, p.298-305, 2008. https://doi.org/10.1590/S0103-90162008000300010

Souza, A. P. de; Lima, M. E. de; Carvalho, D. F. de; Guerra, J. G. M.; Andrade, I. P. de S.; Rocha, H. S. da. Influence of the decomposition of vegetable residue subjected to irrigation in the behavior of spontaneous vegetation. Acta Scientiarum. Agronomy, v.32, p.317-324, 2010.

Topp, G. C.; Davis, J. L.; Annan, A. P. Electromagnetic determination of soil water content: Measurements in coaxial transmission lines. Water Resources Research, v.16, p.574-582, 1980. https://doi.org/10.1029/WR016i003p00574

Welch, R. Y.; Behnke, G. D.; Davis, A. S.; Masiunas, J.; Villamil, M. B. Using cover crops in headlands of organic grain farms: Effects on soil properties, weeds and crop yields. Agriculture, Ecosystems and Environment, v.216, p.322-332, 2016. https://doi.org/10.1016/j.agee.2015.10.014