ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.22, n.2, p.107-112, 2018
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v22n2p107-112

Marketable yield of onion under different irrigation depths, with and without mulch

Daniel F. de Carvalho[1], Eduardo C. Ribeiro[2] & Daniela P. Gomes[1]

[1] Universidade Federal Rural do Rio de Janeiro/Instituto de Tecnologia/Departamento de Engenharia. Seropédica, RJ. E-mail: carvalho@ufrrj.br (Corresponding author); danielagomesagro@hotmail.com
[2] Instituto Federal de Educação Ciência e Tecnologia do Tocantins/Campus Avançado Pedro Afonso/Coordenação dos Cursos Técnicos em Agropecuária. Pedro Afonso. TO. E-mail: eduardo.ribeiro@ifto.edu.br

Key words:
crop coefficient
water requirement
Allium cepa L.
vegetable grass residues

ABSTRACT
The objectives of this study were to obtain the onion crop coefficients and evaluate the influence of different irrigation depths (0, 22, 45, 75 and 100% of crop evapotranspiration) on marketable yield and quality of onion bulbs cultivated with and without mulch of elephant grass. The experiment was carried out in Seropédica, RJ, Brazil, from May to September 2012, in a Red Yellow Argisol. The experimental design was in randomized blocks in split plots, with 10 treatments and seven replicates. Irrigation management was performed through soil water balance using the Time Domain Reflectometry technique, with probes installed horizontally at 7.5 and 22.5 cm depths. The use of mulch allowed the application of smaller irrigation depths, leading to lower crop coefficient (18% in stage II and 3% in stage III) in comparison to the crop without mulch. Irrigation depths associated with the use of mulch influenced the evaluated production variables, proving to be an alternative to increase marketable yield and quality of onion bulbs, with lower irrigation depth.

Palavras-chave:
coeficiente de cultivo
necessidade hídrica
Allium cepa L.
resíduos vegetais de gramíneas

Produtividade comercial da cebola sob diferentes lâminas de irrigação, com e sem cobertura do solo

RESUMO
Objetivou-se neste estudo obter os coeficientes de cultivo para a cultura da cebola e avaliar a influência de diferentes lâminas de irrigação (0, 22, 45, 75 e 100% da evapotranspiração da cultura) na produtividade comercial e na qualidade de bulbos de cebola, cultivada com e sem cobertura vegetal morta de capim-elefante no solo. O experimento foi realizado em Seropédica, RJ, Brasil, entre maio e setembro de 2012, em um Argissolo Vermelho-Amarelo. O delineamento experimental adotado foi em blocos casualizados em parcelas subdivididas, com10 tratamentos e sete repetições. O manejo da irrigação foi realizado por meio do balanço de água no solo utilizando a técnica da Reflectometria no Domínio do Tempo, a partir de sondas instaladas horizontalmente a 7,5 e 22,5 cm de profundidade. A utilização da cobertura morta permitiu a aplicação de menores lâminas de irrigação, proporcionando coeficientes de cultivo inferiores (18% no estágio II e 3% no estágio III) ao cultivo sem cobertura do solo. A lâmina de irrigação associada ao uso da cobertura vegetal morta no solo influenciou as variáveis de produção avaliadas, demonstrando ser uma alternativa para elevar a produtividade comercial e a qualidade de bulbos de cebola com menor lâmina de irrigação.

Ref. 178421 – Received 11 Apr, 2017 • Accepted 19 Sep, 2017 • Published 22 Dec, 2017

Introduction

Onion (*Allium cepa* L.) stands out among the other cultivated vegetables, for its volume of production and consumption and economic value (Oliveira et al., 2013). In 2015, an area of 56.4 thousand hectares was harvested in Brazil, generating a production of 1.42 million tons (IBGE, 2016).

Onion cultivation is normally conducted under irrigation, which is considered an essential instrument to increase its yield, if carried out according to technical criteria. While the mean national production is approximately 16 t ha^{-1}, irrigated plantations show yield higher than 25 t ha^{-1} (Marouelli et al., 2005). In general, the knowledge on the total water demand by the crop alone does not guarantee an efficient irrigation management, thus requiring the application of water according to crop water demands in each phenological stage or phase (Souza et al., 2011). Crop water demand (crop evapotranspiration - ETc) is normally estimated using information on reference evapotranspiration (ETo) (Zanetti et al., 2008) and crop coefficient (Kc) appropriate for each crop and climatic condition.

Organic agriculture is a cultivation system that has gained social, political and scientific recognition worldwide because it is based on the application of agroecological strategies, using local inputs, increasing the added value of the products and promoting a fairer marketing chain (Ríos et al., 2016). The use of mulch, a common practice in this cultivation system, reduces the natural water losses through evaporation on soil surface, thus leading to an increment in water productivity by the crop (Carvalho et al., 2011).

Given the above, this study aimed to estimate crop coefficients (Kc) for onion in organic cultivation, with and without grass mulch on the soil, and evaluate the effect of different irrigation depths and mulching on the marketable yield and quality of onion bulbs.

Material and Methods

The experiment was carried out from May to September 2012, in the Agroecological Production Integrated System (SIPA), in Seropédica, RJ, Brazil (22° 48' S; 43° 41' W; 33 m). The soil of the studied area was classified as moderate-A dystrophic Red Yellow Argisol, with sandy loam texture (EMBRAPA, 2006). A weather station installed in the experimental area provided the mean values of air temperature, relative humidity, wind speed, solar radiation and rainfall, for the different crop growth stages (Table 1).

Table 1. Mean air temperature (Tm), mean relative air humidity (RH), wind speed (U_2), global solar radiation (Rs) and rainfall for the different crop growth stages

Stage	Tm (°C)	RH (%)	U_2 (m s^{-1})	Rs (MJ m^{-2} d^{-1})	Rainfall (mm)
I*	21.9	76.9	0.74	11.66	49.0
II**	20.4	74.6	0.82	12.13	81.4
III***	20.9	69.5	1.08	17.38	24.7
IV****	23.3	67.9	1.52	15.89	62.6

* I - From seedling transplantation to initial establishment of plants; ** II - From initial establishment to beginning of bulb formation; *** III - Beginning of bulb formation to beginning of maturation; ***** IV - Beginning of bulb maturation to harvest

The onion cultivar 'Alfa Tropical' was sown on 288-cell polystyrene trays, maintained in a greenhouse and daily irrigated. After 40 days from sowing, seedlings were transplanted at spacing of 0.25 m between rows and 0.1 m between plants. Weeds were controlled through manual weeding at 15, 40 and 70 days after transplantation (DAT). Fertilization at planting was performed using bovine manure at dose of 25 t ha^{-1}. Top-dressing fertilization used 100 kg ha^{-1} of N, split into two applications (30 and 50 DAT), in the form of castor bean cake. At 124 DAT, plants were harvested and maintained for 15 days in the shade (curing period).

The experimental design was randomized blocks in split plots, with 10 treatments and 7 replicates (Figure 1). Treatments consisted of five irrigation depths (plots), corresponding to 0 (L0), 22 (L1), 45 (L2), 75 (L3) and 100% (L4) of crop evapotranspiration (ETc) and the use of mulch on the soil: absence of mulch (AM) and presence of mulch (PM) (subplots). Subplots were composed of 4 planting rows with length of 1.0 m, considering the 20 plants from the central rows for evaluation.

During the period of seedling establishment in the field, the experiment was irrigated using a conventional sprinkler system and irrigation depth was estimated by Class A pan evaporation, adopting tank coefficient (Kp) of 0.8 (Carvalho et al., 2006) and crop coefficient (Kc) of 1.0 (Marouelli et al., 2005). From 23 DAT on, seedlings were irrigated by drip irrigation, using two lateral lines per bed, with actual flow rates of 2.4 (L1), 4.9 (L2), 8.1 (L3) and 10.8 L h^{-1} (L4) (water depth applied by the treatments), promoting distribution uniformity coefficients above 95%.

Irrigation management was performed using the Time Domain Reflectometry (TDR) technique (Soncela et al., 2013), by monitoring soil water content in the 14 subplots corresponding to the water depth L4 (100% ETc). For adequate use of TDR, the device was previously calibrated in the studied area, according to Carvalho et al. (2011), and the soil moisture corresponding to field capacity was determined in the 0-0.15 m layer (0.214 cm^3 cm^{-3}). Readings of apparent dielectric constant (Ka), obtained through TDR probes, were taken every two days, immediately before irrigations and for both soil cover conditions. The probes were composed of three parallel stainless-steel rods spaced by 0.015 m, with diameters of 0.003 m and length of 0.18 m. In total, 28 TDR probes were installed horizontally at depths of 7.5 and 22.5 cm, in the subplots with and without mulch.

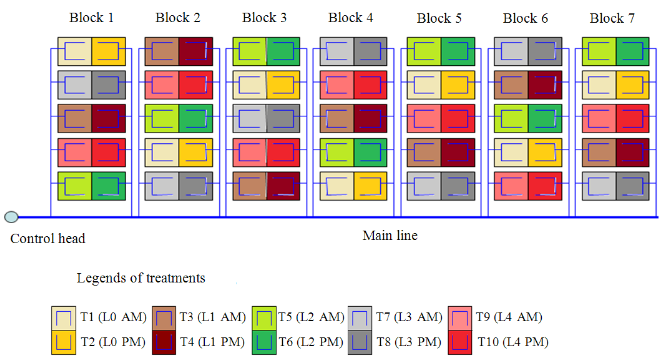

Figure 1. Scheme of the adopted experimental design

Besides the water depths applied during the establishment period and by the treatments, effective rainfall (Pef) was quantified, considered as the precipitated water depth (mm) that increased water content in the plots to the soil moisture corresponding to field capacity (Carvalho et al., 2011).

After the period of seedling acclimation, crop evapotranspiration (ETc) was estimated through soil water balance (Andrade et al., 2014), which divided by reference evapotranspiration (ETo), obtained through FAO-56 Penman-Monteith method (Allen et al., 1998), allowed to determine Kc in different crop growth stages, as follows: I (from seedling transplantation to initial establishment of plants); II (from initial establishment to beginning of bulb formation); III (from beginning of bulb formation to beginning of maturation); and IV (from beginning of bulb maturation to harvest).

Mulch consisted of straw of elephant grasss (*Pennisetum purpureum* Schum, *cv*. Cameron) shoots, chopped and dried in the shade, at dose of 2.5 kg m^{-2} of dry matter (Oliveira et al., 2008), placed on the soil at 22 DAT.

The evaluated production variables were marketable yield - bulbs with diameter greater than 35 mm (t ha^{-1}), mean diameter of marketable bulbs (mm) and percentage of bulbs in the classes established by CEAGESP (2001) (Table 2).

The data were subjected to analysis of variance and, when significant by the F test, the factor water depth was subjected to regression analysis at 5% significance level.

Table 2. Classification of onion bulbs according to diameter

Class (C)	Diameter (mm)
C1	≥ 35
C2	35 < D ≤ 50
C3	50 < D ≤ 60
C4	60 < D ≤ 70
C5	70 < D ≤ 90

Results and Discussion

The irrigation depths corresponding to 0, 22, 45, 75 and 100% ETc applied in the treatments AM and PM were equal to 0, 155.0, 220.6, 320.5 and 372.7 mm, and 0, 145.5, 207.6, 285.0 and 351.4 mm, respectively. The data of estimated ETo, ETc and crop coefficient (Kc) calculated for both soil cover conditions are presented in Table 3.

The highest Kc values were obtained in stage III, when the crop demands greater volume of water due to the formation of bulbs. Similar responses were reported by Marouelli et al. (2005) and Oliveira et al. (2013), who observed this same trend. In the present study, the use of mulch, which according to Marouelli et al. (2005) decreases soil exposure to evaporation, promoted lower Kc values, with reductions of 18% in stage II and 3% in stage IV, compared with the AM (Table 3). Oliveira Neto et al. (2011) also found lower Kc values for the beet crop, using mulch of elephant grass, compared with the treatment without mulch, and these differences were equal to 61.8, 33.1 and 33.3%, for the initial, intermediate and final stages, respectively. The variation found in the results of Kc confirms the importance of conducting field tests to determine the water demand of various crops in different environments and management conditions (Doorenbos & Pruitt, 1977; Allen et al., 1998).

Table 3. Reference evapotranspiration (ETo), crop evapotranspiration (ETc) and crop coefficient (Kc) in the different growth stages of onion, in the presence (PM) and absence (AM) of mulch

Stage	Duration (days)	ETo (mm)	Soil cover			
			AM	PM	AM	PM
			ETc (mm)		Kc	
I	21*	36.3	65.7	65.7	1.0**	1.0**
II	37	75.9	73.0	60.7	0.8	0.6
III	45	137.7	164.7	159.6	1.0	1.0
IV	21	77.6	69.3	65.3	0.8	0.7

* Beginning with seedling transplantation; ** Kc previously fixed for stage I due to the use of acclimation irrigations with fixed interval of 1 day, as recommended by Costa et al. (2002) and Marouelli et al. (2005)

Marketable yield (Figure 2A) and marketable mean diameter (Figure 2B) of onion bulbs were influenced by the irrigation depths, under both soil cover conditions. The highest marketable yields (42 t ha^{-1} without mulch and 56 t ha^{-1} with mulch) were obtained with water depth corresponding to 100% ETc. Bandeira et al. (2013) also obtained highest marketable yield of onion bulbs applying water depth corresponding to 100% ETc, compared with 75% ETc, performing irrigation management with Class A pan and without using mulch. Similar effect of different irrigation depths on onion bulb yield have also been observed by Olalla et al. (2004), Enciso et al. (2009), Ramalan et al. (2010) and Igbadun et al. (2012).

Kumar et al. (2007) demonstrated that a greater water comfort to the onion crop is obtained when the soil is maintained close to field capacity (100% ETc), promoting

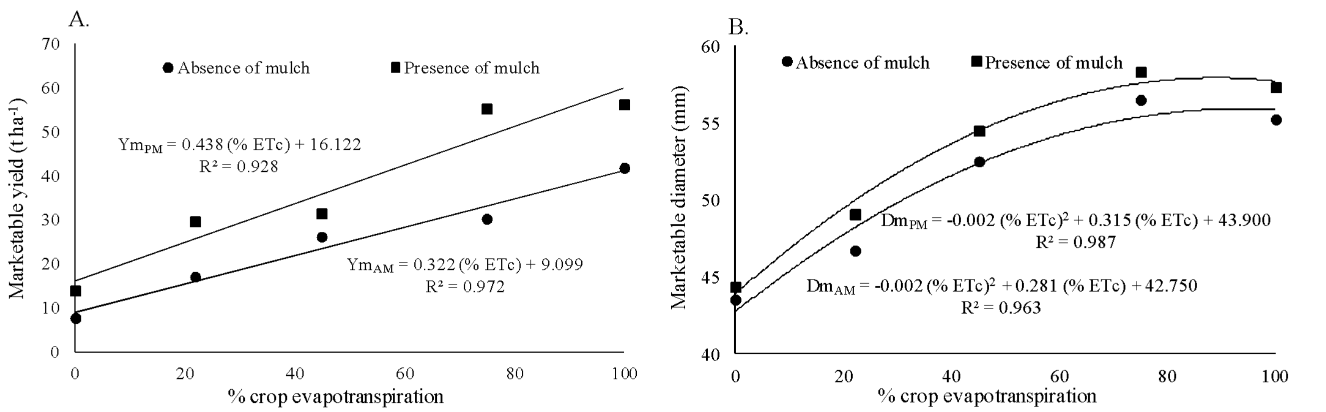

Figure 2. Marketable yield (A) and marketable mean diameter (B) of onion bulbs as a function of irrigation depths, in the presence (PM) and absence (AM) of mulch

maximum values of marketable yield. Water replacement to the soil lower than 100% ETc causes the crop to use more energy in water absorption, thus not using it for bulb filling (Rajput & Patel, 2006).

Cultivation in covered soil with replacement of about 58.9% ETc (approximately 207 mm) led to marketable bulb yield (42.0 t ha^{-1}) similar to that obtained in the cultivation in exposed soil with the application of 100% ETc (372.7 mm) (Figure 2A).

The highest values of marketable mean diameter (56.5 mm without mulch and 58.4 with mulch) were obtained with the application of water depths corresponding to 75% ETc (Figure 2B), and were considered as acceptable by the consumers for organic cultivation (Araújo et al., 2004).

Irrigation depths influenced the percentages of bulbs in the classes C1, C3, C4 and C5, regardless of the use of mulch (Figures 3A, C, D and E). However, the percentage of bulbs in the C2 class was only influenced by the irrigation depths when mulch was used (Figure 3B).

The percentages of unmarketable bulbs (C1) and C2 bulbs were higher with the applications of irrigation depths corresponding to 0 and 22% ETc, respectively, and lower with the application of irrigation depths corresponding to 75 and 100% ETc, respectively, with and without mulch (Figure 3A and B). The percentage of bulbs in the C3 class was lower with the application of irrigation depths corresponding to 0 and 22% ETc, reaching maximum values of 32% without mulch and 40% with mulch, respectively, at water depths corresponding to 100 and 45% ETc (Figure 3C).

The highest percentage of bulbs in the C4 class was found with the application of irrigation depths corresponding to 45% ETc, without mulch, and to 100% ETc, with mulch. Irrigation depths corresponding to 75% ETc, without mulch, and 100% ETc, with mulch, were responsible for the higher percentage of bulbs in the C5 class (Figures 3D and E).

These results show that the application of lower irrigation depths led to higher onion bulbs classified as C1 and C2 and

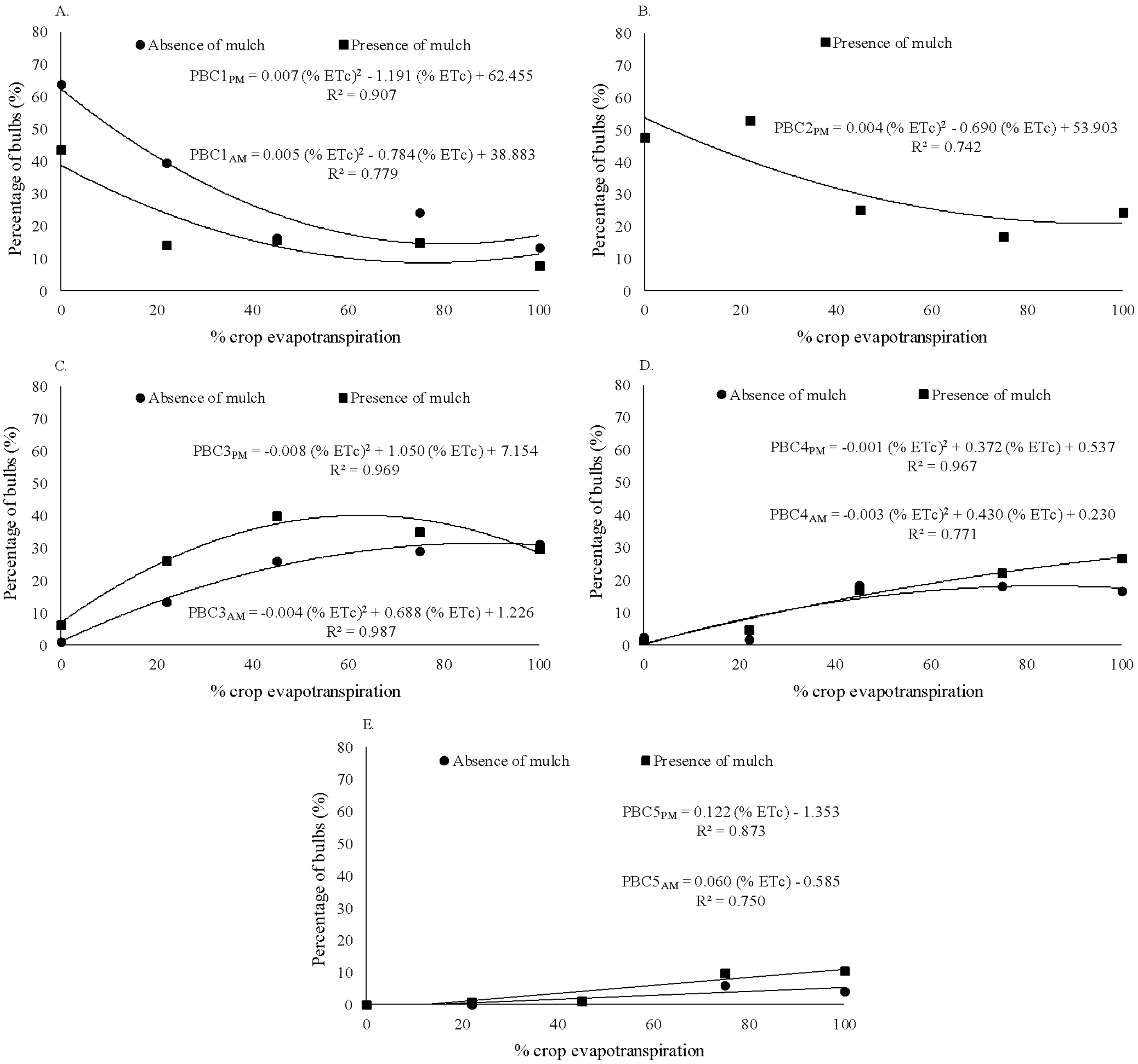

Figure 3. Percentage of onion bulbs (PB) in the classes C1 (A), C2 (B), C3 (C), C4 (D) and C5 (E) as a function of the irrigation depths, in the presence (PM) and absence (AM) of mulch

Table 4. Marketable yield (MY), marketable mean diameter (MMD) and percentage of onion bulbs in the different diameter classes in the presence (PM) and absence (AM) of mulch

Evaluated variables		Mulching	% ETc				
			0	22	45	75	100
Marketable yield	(t ha^{-1})	AM	7.6a	17.1a	26.3a	30.4b	32.0b
		PM	14.0a	30.0a	31.4a	55.5a	56.2a
Marketable mean diameter	(mm)	AM	43.5a	46.7a	52.5a	56.5a	55.2a
		PM	44.4a	49.1a	54.5a	58.4a	57.3a
C1 (≤ 35)	(%)	AM	64a	40a	17a	24a	13a
		PM	44b	14b	16a	15a	8a
C2 (35 < D ≤ 50)		AM	32b	44a	37a	22a	33a
		PM	48a	53a	25a	17a	24a
C3 (50 < D ≤ 60)		AM	1 a	14 b	26b	29 a	32 a
		PM	6 a	26 a	40a	35 a	30 a
C4 (60 < D ≤ 70)		AM	3a	2a	19a	18a	17a
		PM	2a	5a	17a	22a	27a
C5 (70 < D ≤ 90)		AM	0a	0a	1a	6a	4b
		PM	0a	1a	1a	10a	11a

Means followed by the same letter in the column do not differ significantly by F test at 0.05 probability level

that the application of higher irrigation depths led to greater production of bulbs in the classes C4 and C5. Lack of water reduces turgor pressure and, consequently, sap flow through the conducting vessels (Taiz & Zeiger, 2009), tending to decrease cell elongation and, therefore, bulb growth and development. The results also demonstrate the effect of mulching on the production of bulbs classified as C1 and C2, and increase in the production of bulbs classified as C4 and C5. Hence, the application of water depth corresponding to 100% ETc associated with the use of mulch promotes increments in the marketable yield and quality of onion bulbs. Production of higher-class onion bulbs leads to higher commercial profitability and greater acceptance in the Brazilian market (Bandeira et al., 2013), considered by Reghin et al. (2006) as an indicator of the high production quality achieved.

Table 4 shows the values of marketable yield, marketable mean diameter and percentage of onion bulbs under both soil conditions, for the different irrigation depths. The use of mulch led to gains in marketable yield when irrigation depths corresponding to 75 and 100% ETc were used. This result indicates that the use of mulch becomes a promising alternative to obtain better yields with reduction in water consumption. Igbadun et al. (2012) also found gains in the marketable yield of onion using mulch of rice and black polyethylene plastic.

Marketable mean diameter was not influenced by the use of mulch (Table 4). However, the use of mulch decreased the percentage of bulbs in the C1 class (unmarketable), when irrigation depths corresponding to 0 and 22% ETc were applied. In the class C2, the use of mulch led to increase in the percentage of bulbs in the treatment without irrigation (0% ETc) and, in the C3 class, the use of mulch caused increments in the percentage of bulbs when irrigation depths corresponding to 22 and 45% ETc were applied. In the C5 class, mulching promoted higher percentage of bulbs when the irrigation depth corresponding to100% ETc was applied (Table 4).

The obtained gains may be related to the sum of the possible beneficial effects of soil cover by plant residues, such as reduction of water evaporation from soil surface, maintenance of moisture and reduction in soil temperature (Santos et al., 2012), reduction in soil exposure to the direct impact of rain drops and increase of carbon stock in the soil (Loss et al., 2014), increase in water productivity (Mota et al., 2010), reduction in the incidence of weeds (Silva et al., 2009) and supply of nutrients to the soil (Carvalho et al., 2011). The use of other types of mulch compared with the treatment without mulch also proved to be efficient to increase onion yield, such as the straw of bamboo or gliricidia (Santos et al., 2012).

Conclusions

1. The use of mulch promoted reduction of water consumption in the production of onion bulbs, with decrease of 18% (stage II) and 3% (stage III) in the Kc values, in comparison to those obtained without mulch.

2. Irrigation depth associated with the use of mulch on the soil influenced onion bulb yield and quality.

3. Cultivation in covered soil led to marketable yield of onion bulbs similar to that obtained in the cultivation in exposed soil (42.0 t ha^{-1}) with a 41.1% lower irrigation depth (207 mm).

4. Application of higher irrigation depths promoted higher production of bulbs in the classes C4 and C5.

Literature Cited

Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M. Crop evapotranspiration: Guidelines for computing crop water requirements. Rome: FAO, 1998. 308p.

Andrade, I. P. de S.; Carvalho, D. F. de; Almeida, W. S. de; Silva, J. B. G.; Silva, L. D. B. da. Water requirement and yield of fig trees under different drip irrigation management. Engenharia Agrícola, v.34, p.17-27, 2014. http://dx.doi.org/10.1590/S0100-69162014000100003

Araújo, J. F.; Costa, N. D.; Lima, M. A. C. de; Pedreira, C. M.; Santos, C. dos; Leite, W. de M. Avaliação de genótipos de cebola em cultivo orgânico. Horticultura Brasileira, v.22, p.420-424, 2004.

Bandeira, G. R. L.; Queiroz, S. O. P. de; Aragão, C. A.; Costa, N. D.; Santos, C. A. F. Desempenho agronômico de cultivares de cebola sob diferentes manejos de irrigação no submédio São Francisco. Irriga, v.18, p.73-84, 2013. https://doi.org/10.15809/irriga.2013v18n1p73

Carvalho, D. F. de; Oliveira Neto, D. H. de; Ribeiro, R. de. L. D.; Guerra, J. G. M.; Rouws, J. R. C. Manejo da irrigação associada a coberturas mortas vegetais no cultivo orgânico da beterraba. Engenharia Agrícola, v.31, p.269-277, 2011. https://doi.org/10.1590/S0100-69162011000200007

Carvalho, D. F. de; Silva, L. D. B.; Folegatti. M. V.; Costa, J. R.; Cruz, F. A. Avaliação da evapotranspiração de referência na região de Seropédica-RJ utilizando lisímetro de pesagem. Revista Brasileira de Agrometeorologia, v.14, p.97-105, 2006.

CEAGESP - Companhia de Entrepostos e Armazéns Gerais de São Paulo. Classificação da cebola (*Allium cepa* L.). São Paulo: CEAGESP, 2001. 2p. Disponível em: <http://http://www.ceagesp.gov.br/wp-content/uploads/2015/07/cebola.pdf> Acesso em: 24 Mar. 2017.

Costa, E. L. da; Marouelli, W. A.; Camboim Neto, L. de F.; Silva, W. L. C. Irrigação da cebola. Informe Agropecuário, v.23, p.57-66, 2002.

Doorenbos, J.; Pruitt, W. O. Guidelines for predicting crop water requirements. Rome: FAO, 1977. 156p.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Sistema brasileiro de classificação de solos. 2.ed. Brasília: Embrapa; Rio de Janeiro: Embrapa, 2006. 312p.

Enciso, J.; Weidenfeld, B.; Jifon, J.; Nelson, S. Onion yield and quality response to two irrigation scheduling strategies. Scientia Horticulturae, v.120, p.301-305, 2009. https://doi.org/10.1016/j.scienta.2008.11.004

IBGE - Instituto Brasileiro de Geografia e Estatística. Confronto das safras de 2015 e 2016 (1. Área e 2. Produção). Brasília: CONAB, 2016. Disponível em: <http://www.ibge.gov.br/home/estatistica/indicadores/agropecuaria/lspa/defaulttab.shtm> Acesso em: 04 Ago. 2016.

Igbadun, H. E.; Ramalan, A. A.; Oiganji, E. Effects of regulated deficit irrigation and mulch on yield, water use and crop water productivity of onion in Samaru, Nigeria. Agricultural Water Management, v.109, p.162-169, 2012. https://doi.org/10.1016/j.agwat.2012.03.006

Kumar, S.; Imtiyaz, M.; Kumar, A.; Singh, R. Response of onion (*Allium cepa* L.) to different levels of irrigation water. Agricultural Water Management, v.89, p.161-166, 2007. https://doi.org/10.1016/j.agwat.2007.01.003

Loss, A.; Ribeiro, E. C.; Pereira, M. G.; Costa, E. M. Atributos físicos e químicos do solo em sistemas de consórcio e sucessão de lavoura, pastagem e silvipastoril em Santa Teresa, ES. Bioscience Journal, v.30, p.1347-1357, 2014.

Marouelli, W. A.; Costa, E. L.; Silva, H. R. Irrigação da cultura de cebola. Brasília: Embrapa, 2005. 17p.

Mota, J. C. A.; Libardi, P. L.; Brito, A. dos S.; Assis Júnior, R. N. de; Amaro Filho, J. Armazenagem de água e produtividade de meloeiro irrigado por gotejamento, com a superfície do solo coberta e desnuda. Revista Brasileira de Ciência do Solo, v.34, p.1721-1731, 2010. https://doi.org/10.1590/S0100-06832010000500024

Olalla, F. M. de S.; Domínguez-Padilla, A.; López, R. Production and quality of the onion crop (*Allium cepa* L.) cultivated under controlled deficit irrigation conditions in a semi-arid climate. Agricultural Water Management, v.68, p.77-89, 2004. https://doi.org/10.1016/j.agwat.2004.02.011

Oliveira, F. F. de; Guerra, J. G. M.; Almeida, D. L. de; Ribeiro, R. de L. D.; Espíndola, J. A. A.; Ricci, M. dos S. F.; Ceddia, M. B. Avaliação de coberturas mortas em cultura de alface sob manejo orgânico. Horticultura Brasileira, v.26, p.216-220, 2008. https://doi.org/10.1590/S0102-05362008000200017

Oliveira, G. M. de; Leitão, M. M. V. B. R.; Bispo, R. de C.; Santos, I. M. S.; Lima, C. B. de A.; Carvalho, A. R. P de. Coeficiente de cultura e produtividade da cebola submetida a diferentes lâminas de irrigação. Revista Brasileira de Engenharia Agrícola e Ambiental, v.17, p.969-974, 2013. https://doi.org/10.1590/S1415-43662013000900009

Oliveira Neto, D. H.; Carvalho, D. F. de; Silva, L. D. B. da; Guerra, J. G. M.; Ceddia, M. B. Evapotranspiração e coeficientes de cultivo da beterraba orgânica sob cobertura morta de leguminosa e gramínea. Horticultura Brasileira, v.29, p.330-334, 2011. https://doi.org/10.1590/S0102-05362011000300012

Rajput, T. B. S.; Patel, N. Water and nitrate movement in drip-irrigated onion under fertigation and irrigation treatments. Agricultural Water Management, v.79, p.293-311, 2006. https://doi.org/10.1016/j.agwat.2005.03.009

Ramalan, A. A.; Nega, H.; Oyebode, M. A. Effect of deficit irrigation and mulch on water use and yield of drip irrigated onions. WIT Transactions on Ecology and the Environment, v.134, p.39-50, 2010. https://doi.org/10.2495/SI100041

Reghin, M. Y.; Otto, R. F.; Olinik, J. R.; Jacoby, C. F. S. Produção de cebola sobre palhada a partir de mudas obtidas em bandejas com diferentes números de células. Horticultura Brasileira, v.24, p.414-420, 2006. https://doi.org/10.1590/S0102-05362006000400004

Ríos, I. de los; Rivera, M.; García, C. Redefining rural prosperity through social learning in the cooperative sector: 25 years of experience from organic agriculture in Spain. Land Use Policy, v.54, p.85-94, 2016. https://doi.org/10.1016/j.landusepol.2016.02.009

Santos, S. da S.; Espíndola, J. A. A.; Guerra, J. G. M.; Leal, M. A. de A.; Ribeiro, R. de L. D. Produção de cebola orgânica em função do uso de cobertura morta e torta de mamona. Horticultura Brasileira, v.30, p.549-552, 2012. https://doi.org/10.1590/S0102-05362012000300032

Silva, A. C. da; Hirata, E. K.; Monquero, P. A. Produção de palha e supressão de plantas daninhas por plantas de cobertura, no plantio direto do tomateiro. Pesquisa Agropecuária Brasileira, v.44, p.22-28, 2009. https://doi.org/10.1590/S0100-204X2009000100004

Soncela, R.; Sampaio, S. C.; Vilas Boas, M. A.; Tavares, M. H. F.; Smanhotto, A. Construction and calibration of TDR probes for volumetric water content estimation in a distroferric Red Latosol. Engenharia Agrícola, v.33, p.919-928, 2013. https://doi.org/10.1590/S0100-69162013000500004

Souza, A. P. de; Pereira, J. B. A.; Silva, L. D. B. da; Guerra, J. G. M.; Carvalho, D. F. de. Evapotranspiração, coeficientes de cultivo e eficiência do uso da água da cultura do pimentão em diferentes sistemas de cultivo. Acta Scientiarum. Agronomy, v.33, p.15-22, 2011. https://doi.org/10.4025/actasciagron.v33i1.5527

Taiz, L.; Zeiger, E. Fisiologia vegetal. Porto Alegre: Artmed, 2009. 819p.

Zanetti, S. S.; Sousa, E. F.; Carvalho, D. F. de; Bernardo, S. Estimação da evapotranspiração de referência no estado do Rio de Janeiro usando redes neurais artificiais. Revista Brasileira de Engenharia Agrícola e Ambiental, v.12, p.174-180, 2008. https://doi.org/10.1590/S1415-43662008000200010