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GREENHOUSE CRISPHEAD LETTUCE GROWN WITH MULCHING AND UNDER DIFFERENT SOIL WATER TENSIONS

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ABSTRACT: Proper irrigation management is important both to enable adequate water supply and to minimize problems with diseases, nutrient leaching and unnecessary water and power wastes. Thus, this study aimed at improving irrigation management in greenhouses. For that reason, we assessed the effect of various water tensions on yield performance of crisphead lettuce, Raider-Plus cv., grown with mulching. The experiment was conducted in greenhouse at the Federal University of Lavras. Treatments constituted five different soil water tensions, namely 12, 25, 35, 45, and 70 kPa. The results showed that irrigation must be carried out at water soil tension of around 12 kPa to reach satisfying commercial values for both total and commercial yield, 66 and 50 t ha^{-1}, as well as keeping good vegetable quality. At this tension, total water consumption was of 167.25 mm. The water use efficiency demonstrated quadratic response to treatments, with high water consumption efficiency found in intermediate treatments (35 and 45 kPa), achieving values of 579.87 and 471.71 kg ha^{-1}mm^{-1}, respectively.

KEYWORDS: *Lactuta sativa*, irrigation management, protected environment, soil covering.

PRODUÇÃO DE ALFACE-AMERICANA EM CULTIVO PROTEGIDO UTILIZANDO MULCHING, SOB DIFERENTES TENSÕES DE ÁGUA NO SOLO

RESUMO: O manejo correto da irrigação é importante não apenas por possibilitar que a irrigação supra adequadamente as necessidades hídricas das plantas e por minimizar problemas com doenças e lixiviação de nutrientes, mas também como gastos desnecessários com água e energia. Visando a definir critérios para o manejo da irrigação, este trabalho teve como objetivo avaliar o efeito de diferentes tensões de água no solo sobre o comportamento produtivo da alface-americana, cv. Raider-Plus, em ambiente protegido, com uso de mulching. O experimento foi conduzido em casa de vegetação na Universidade Federal de Lavras. Os tratamentos foram constituídos de cinco tensões de água no solo: 12; 25; 35; 45 e 70 kPa. Os resultados permitiram concluir que, para a obtenção de valores máximos de produtividade total e comercial, 66 e 50 t ha^{-1}, a reposição da lâmina evaporada deve ser realizada quando a tensão de água no solo atingir 12 kPa, representando consumo total de 167,25 mm. As variáveis altura de plantas e circunferência da cabeça comercial tiveram valores máximos alcançados quando se utilizou a tensão de 12 kPa. A eficiência no uso da água apresentou resposta quadrática aos tratamentos, sendo que a maior eficiência no consumo de água foi verificada nos tratamentos intermediários (35 e 45 kPa), atingindo valores de 579,87 e 471,71 kg ha^{-1}mm^{-1}, respectivamente.

PALAVRAS-CHAVE: *Lactuta sativa*, manejo da irrigação, ambiente protegido, cobertura do solo.

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INTRODUCTION

Lettuce is considered the most significant leaf vegetable in the Brazilian diet, which demonstrates its economic relevance and justifies its position as the top leaf vegetable in terms of marketing and consumption (SALA & COSTA, 2012).

According to SALA & COSTA (2012), a new group of curly-leafed lettuce, known as crisphead, were introduced to Brazil in the beginning of the 1980's. From the 1990's, this variety had an increased market demand in Brazil, rising from 9% in 1995, to more than 34% in 2010. Such growth was related to the rise of fast-food chains, which required this type of lettuce, mainly in large urban centers where a few regions stood out for growing this type of crop. Among these centers, Southern Minas Gerais was highlighted because of favorable weather for cultivation throughout the year, besides being conveniently located near three major consumer centers (Belo Horizonte, São Paulo and Rio de Janeiro).

As lettuce is a short-cycle and rapid-growth vegetable, it is very demanding in terms of climate conditions, water and nutrients supply; however, it provides fresh mass in rapid increments throughout its cycle. The strengthening of these needs can be better administered by cultivation in protected environments, in which vegetables can achieve outstanding productions with excellent product quality. It happens because these environments provide a more propitious climate for crop development throughout the year, lessen problems with pests and diseases, protect against climate changes, lower leaching and reduce fertilization costs, enabling thus greater production compared to open environments. However, it is of upmost importance the use of irrigation to reach highest yields (OLIVEIRA et al., 2011).

Despite the relevance of protected environment cultivation in Brazil, there is a lack of research on subsidization and potential exploitation of this technology at different climatic regions, especially with regards to irrigation management (SANTOS & PEREIRA, 2004; BANDEIRA et al., 2011; VILAS BOAS et al., 2012). Such studies could optimize irrigation water use, enhancing crop yields and quality, especially for cultivars of high productive capacity.

Soil coverage is another technique highly used in modern agriculture to reduce water losses through evaporation, control weeds, facilitate harvesting and improve post-harvest quality, boosting commercialization. TOSTA et al. (2010) evaluated the effects of different soil covers on lettuce production, “Babá de Verão” cultivar in Cassilândia – MS; they observed improved results for black plastic cover for all evaluated variables. According to the same authors, one of the advantages of mulching is superficial root proliferation within topsoil as a consequence of a biologically improved microclimate.

In spite of the importance of mulching for the Brazilian vegetable growing, there is a lack of research to support a potential exploitation of this technology at different climatic regions, especially concerning appropriate irrigation management. In this respect, weather effects on soil water tensions that are able to promote optimum yields must be quantified, and such information is indispensable to establish an irrigation control.

Therefore, the aim of this study was to evaluate the effect of different soil water tensions on crisphead lettuce productive performance, using Raider-Plus cv., grown in greenhouse with plastic covering, double-sided mulching, in Lavras - MG, Brazil; thus, aiming to define criteria for proper irrigation management.

MATERIAL AND METHODS

The experiment was conducted between July and September in a greenhouse located at the experimental area of the Engineering Department of the Federal University of Lavras (UFLA). UFLA in located in Lavras, south of Minas Gerais state, in Brazil. It is at an average altitude of 910m, 21°14’ south latitude and 45°00’ west longitude. In accordance with the Köeppen's classification (DANTAS et al., 2007), the region has a Cwa climate, which is characterized as mild temperate, rainy, with dry a winter, average temperature of the coldest month bellow 18ºC and above 3ºC, and summers with an average temperature in the hottest month above 22 ºC.

The greenhouse was built with an arced metallic structure, with an ordinary ceiling height of 2.5m and a high point of 4m, length of 13m and width of 7m, covered with low-density transparent polyethylene film, with an anti-UV additive of 150 μm thickness and sides closed with an anti-aphid mesh.

The soil was originally classified as dystroferric Red Latosol (Oxisol). Samples were collected within a depth range from 0 to 0.25m to determine the characteristic curve of soil water and. After achieved, values were adjusted with tension of 10 kPa at field capacity humidity. We used a model proposed by GENUCHTEN (1980), based on Eq. 1, which was adjusted for the studied soil:

$$\theta = 0.263 + \frac{(0.458)}{\left[1 + (0.686 \times |\psi|)^{1.528}\right]^{0.345}} \tag{1}$$

In which,

θ – current humidity ($cm^3 . cm^{-3}$), and

Ψ – water tension in soil (kPa).

A randomized block design (RBD) was used with five treatments and four repetitions. The treatments consisted of five soil water tensions (12, 25, 35, 45 and 70 kPa), as an index of irrigation need. We assembled a set of five tensiometers per plot to monitor the tensions (three at 12.5cm and two at 25cm depth), for two of the four repetitions. This equipment was settle on crop rows, between two plants and 30-cm distant from each other.

Readings were carried out twice a day, at 9:00 am and at 3:00 pm, with the aid of a puncture digital tensiometer. Tension values were measured and irrigations were conducted when at least 4 sensors, installed at 12.5cm (decision tensiometer), indicated the target tension for the treatment. The experimental plots presented dimensions of 1.2 m in width and 2.4 m in length, totaling an area of $2.88m^2$.

Four plant lines spaced in 0.3m between lines and 0.3m between plants were used, totaling 32 plants per plot. The plants within central lines were considered useful while the two plants at the beginning and the two at the end of each plot were discarded (useful plot with $0.72m^2$ and 8 plants). Dripping irrigation was employed, with side lines composed by emitters with flow of 1.76 L h^{-1}, 16mm DN and 0.3m distance from each other, placed in the plot to assist two plant lines, operating with pressure of around 18 mca, which was regulated through a pressure valve inserted in the control drophead.

The side lines were connected to polyethylene derivation lines (PEBD DN 16 mm), which were connected to main lines (PVC DN 35 mm; PN 40 kPa) that included at their beginnings, electric control valves (solenoids) located at the control drophead exit. For each treatment, one valve was used and was activated through a programmable controller, working for as long as was necessary to replace the depth indicated by the humidity sensors (tensiometers). In all irrigations, it was aimed to elevate the soil humidity up to field capacity.

The readings conducted with the puncture digital tensiometer were provided in “bar” and subsequently, transformed into kPa and applied in Eq. 2 to determine water tension in soil, corrected for the desired depth.

$$\Psi = L - 0.098\,h \tag{2}$$

In which,

Ψ – water tension in soil (kPa);

L – tensiometer reading transformed into kPa (positive signal), and

h – tensiometer length (15 cm).

The observed tensions allowed calculation of the corresponding soil humidity through characteristic curve of soil water (Eq. 1). Irrigation system operating time was calculated through gross depth, in accordance with CABELLO (1996), considering an effective depth of root system equal to 0.25m. We also adopted an irrigation efficiency of 90%.

We used a crisphead lettuce of Raider-Plus cultivar. Foundation fertilization was conducted twenty-one days before transplanting and topdressing was split in accordance with the crop cycle. The topdressing was entirely conducted through fertigation and following soil chemical analysis requirements. Fertilizations were carried with potassium nitrate, calcium nitrate and magnesium sulfate. Foundation and topdressing provided to the crop, in kg ha^{-1}, amounts of 115.34 of N; 79.20 of P; 173.76 of K; 115.46 of Ca; 12.20 of Mg and 15.60 of S.

The seedbeds were mulched with 1.5-m-wide double-sided plastic film (white-on-black) of 25-micron thickness and with anti UV additive.

From transplantation on August 8 2007 to the beginning of treatment differentiation, irrigations were carried out for eight days in all five treatments, totaling a depth of 15 mm. This procedure aimed to increase seedling survival and standardization at the initial development.

Harvesting was conducted on September 29 2007, when plants reached maximum vegetative development. This occurs when crisphead lettuce heads are full of leaves and compact. Evaluations were made immediately upon harvesting the useful plots.

The analyzed variables were total and commercial yield, plant height, commercial head circumference and water use efficiency, which was assessed for the total yield (kg ha^{-1}) and the total amount of water consumed (mm) by each treatment during the entire cycle. Data underwent variance analysis using the F test and regression at 5% and 1% probability, using the SAS software.

RESULTS AND DISCUSSION

During the experiment, average temperature and air relative humidity inside greenhouse were 21.8 °C and 54.7%, respectively. The referred temperature is close to the optimum range recommended by SANTANA et al. (2009), standing within 15 and 20 ºC for great lettuce development; however, it is still reported that, when cultivated in warm and sunlit regions, this plant does not reach its full genetic potential.

The previously applied water depths (Init.), after the beginning of treatment differentiation (Irrig.), as well as total water provided to the crop (Total) and the number of irrigations computed since treatments differentiations (NI) are all presented in Table 1.

In this study, we can note that the total applied depths were higher in treatments close to the field capacity (10 kPa), adopted in this experiment, demonstrating a linear performance with water consumption per treatment. Thus, the highest depths were detected in treatments with tensions of 12 and 25 kPa. Based on irrigation management through tensiometry in greenhouse, using AF 1743 and OGR 326 cultivars, in the Juazeiro, state of Bahia - Brazil, BANDEIRA et al. (2011) achieved total consumption of 280 mm, replacing the evaporated depth every time that tension reached 30 kPa. This water intake is above the finding of this study, a fact that is justified by the use of mulching, which reduces the water evaporation rate.

TABLE 1. Established soil water tension, applied water depths before treatment differentiation (Initial**),** applied water depths after treatment differentiation (irrigation), total water depth applied (Total) and number of irrigations (NI). UFLA, Lavras, MG, in 2007.

Tension	Depth (mm)			NI
(kPa)	Initial	Irrigation	Total	
12	15	152.25	167.25	35
25	15	131.60	146.60	7
35	15	119.25	134.25	5
45	15	108.52	123.52	4
70	15	96.09	111.09	3

According to variance analysis (Table 2), significant effects were verified at 1% and 5% probability for total yield, commercial head yield, plant height, commercial head circumference and water use efficiency regarding soil water tensions.

TABLE 2. Summary of variance analysis total yield (TY), commercial head yield (CHY), plant height (PH), commercial head circumference (CHC) and water use efficiency (WUE) under different soil water tensions.

Variation Source	**D.L.**	**Q.M.**				
		TY (t ha^{-1})	**CY (t ha^{-1})**	**PH (cm)**	**CHC (cm)**	**WUE (kg.ha^{-1}.mm^{-1})**
Block	3	50.85 ^{ns}	31.96 ^{ns}	0. 10 ns	3.24 ns	2926.90 ns
Tensions	4	144.87 **	109.27 *	1. 25 **	18.83 **	5433.07 *
Residue	12	21.07	20.99	0. 21	2,75	1347.90
C.V. (%)	-	7.70	10.38	3.26	3.27	8.35
[1]Pr < W	-	0.69	0.85	0. 25	0.99	0.67

1 –Shapiro-Wilk. Normality test** and* significant at 1% and 5% of probability by the F test, respectively. ^{ns} not significant.

The analyzed variables were influenced by soil water tensions and represented by regression in Figure 1. The results on TY, CY, PH and CHC demonstrated a linear response with decreasing values as water tensions increased. TY and CY maximum values were reached at 12 kPa, being of 66 and 50 t ha^{-1}, respectively (Figure 1A). In this treatment, the total irrigation depth was of 167.25 mm. Aiming to maximize crisphead lettuce yield of Raider-Plus cultivar in greenhouse without mulching, LIMA JÚNIOR et al. (2010) noted that depths between 203.9 and 204.3 mm reached the highest CY and TY, respectively. Possibly, our study reduction in hydric consumption is related to the double-sided mulching. VILAS BOAS et al. (2007) achieved maximum values of 36.5 and 33.2 t ha^{-1} for crisp lettuce without mulching by drip irrigating with 249.1 and 244.9 mm, respectively. This same inverse relationship between yield reduction and level of tension was verified for several different crops, corroborating with LIMA et al. (2013) who studied cayenne pepper and CARVALHO et al. (2012) with peas in protected cultivation with different soil water tensions. This reduction supports mulching, since it favors microclimate for root growth and absence of competition with weeds. Still, these advantages are directly associated to energy reduction during irrigation pumping, which is fundamental for decreasing the total variable cost in pressured irrigation systems as preconized by LIMA JÚNIOR et al. (2014), SILVA et al. (2013) and VILAS BOAS et al. (2011), who performed studies on the economic feasibility of drip irrigated crops.

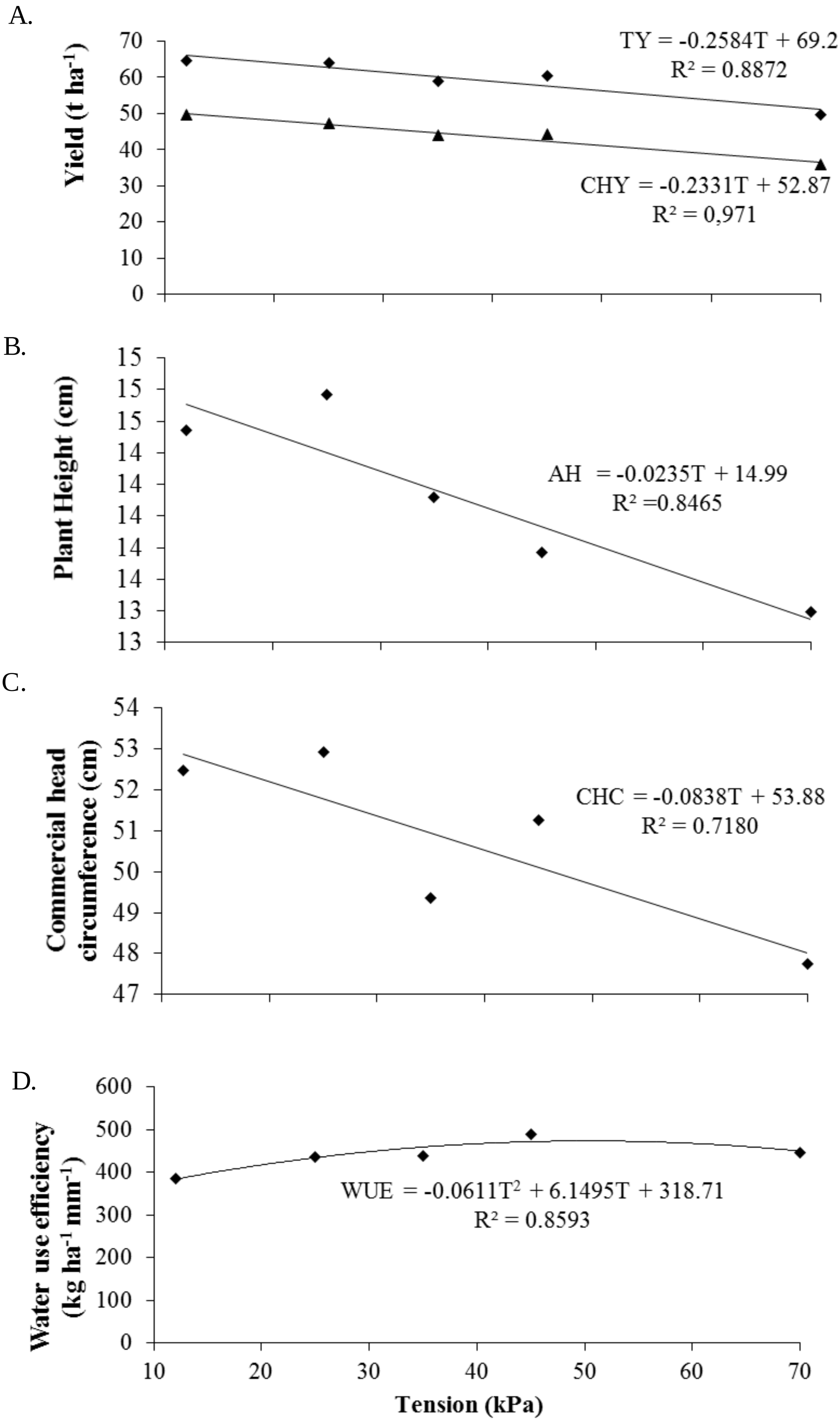

FIGURE 1. Observed and estimated average values of yield, plant height, commercial head circumference, and water use efficiency, according to different water tensions. UFLA, Lavras, MG, in 2007.

Through the equations in Figures 1B and 1C, we noted that an increase of one unit in tension would lead to a reduction of 0.0235cm in PH and 0.0838cm in CHC, within the studies interval (12 kPa a 70 kPa). In the same research line and with the same cultivar but without mulching, SANTOS & PEREIRA (2004) evidenced a decrease of 0.0852cm in PH within an interval of 15 to 89 kPa. In other words, the closer the tension corresponding to the soil field capacity, the more the lettuce plants will grow. Thus, the soil humidity seems to directly favor vegetative crop development.

CHC is one of the basic parameters in consumer choice; therefore, this characteristic can be used as selection index when purchasing with suppliers. LIMA JÚNIOR et al. (2012a) established a quadratic effect for CHC in lettuce of Laureau cultivar, with a maximum value of 58.35 cm, being reached by a total water depth of 103 mm. This depth value is below our study for 12 kPa, which in accordance with the equation in Figure 1C, we obtained a maximum of 52.87 cm. This difference was possibly influenced by the genetic potential of each cultivar, with the Laureau cultivar demonstrating greater efficiency in transforming inputs into photo-assimilated compounds. It was also observed that all of these evaluated variables were near field capacity (10 kPa) and safe from negative effects of water deficit. Thus, it is possible to assume that exposing plants to hydric stress induces water potential decline in leaves, stomatal conductance and CO_2 flow, resulting in an adverse impact on photo-assimilated compound accumulations and as consequence crop yield (BANDEIRA et al., 2011). Regarding hydric stress, each species has survival mechanisms that might include changes in stomatal responses, osmotic adjustment and major movement of photo-assimilates to the roots, consuming metabolic energy and affecting plant production and commercial quality.

Water use efficiency (WUE) states the relationship between crop yield and water consumption. Regarding the crisphead lettuce, a quadratic regression can explain the variations in WUE throughout different soil water tensions (Figure 1D). The variance analysis detected significant differences among treatments, which could be explained by the quadratic regression at 5% probability (Table 2). From Figure 1D, we can note that the highest WUE was in intermediate treatments, which means, tension between 35 and 45 kPa, reaching values of 579.87 and 471.71 kg ha^{-1}mm^{-1}, respectively. The extreme tensions (12 and 70 kPa) obtained the lowest efficiencies with values of 383.7 and 449.78 kg ha^{-1} mm^{-1}, respectively. Some studies in specialized literature, conducted with other vegetables, demonstrate that an increase in water tension and/ or decrease of applied water depth leads to growing efficiency values (LIMA JÚNIOR et al., 2012b; VILAS BOAS et al., 2011); however, in this study, it was observed up to 45 kPa.

CONCLUSIONS

Upon completion and analysis of this experiment using crisphead lettuce crop, we could conclude that:

1- The greatest t

2- otal and commercial yield, 66 and 50 t ha^{-1}, were estimated with evaporated depth reposition when soil water tension reached 12 kPa, representing a total consumption of 167.25 mm.

3- Plant height and commercial head circumference reached maximum values when a 12 kPa tension was used.

4- The water use efficiency showed quadratic response to treatments, once the greatest efficiency in water consumption was verified for 50.32 kPa, achieving a maximum value of 473.44 kg ha^{-1} mm^{-1}.

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