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Full Length Research Paper

Management of water content of soil in cultivation of greenhouse cucumber (*Cucumis sativus L,* Nasim variety) in Isfahan- Iran

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Measurement and control of water content of soil is an essential factor in irrigation management, to apply the best management practice for reducing water consumption and improving product quality. The water content of soil is an important factor in greenhouse where it is directly related to the total amount of water consumed for irrigation. Since cucumbers (*Cucumis sativus L,* Nasim variety) is considered as the main and much used summer crop in Iran, which are extremely sensitive to adverse conditions particularly water stress, determination and supply of water is vital for this plant. To this end, maximum allowable depletion (MAD) should be determined. This experiment was conducted in the research greenhouse (Plastic Covered) of Islamic Azad University in Khorasgan, Isfahan, during a period of five months. This project was implemented in the framework of three 40, 60, and 80 cm bar water suction treatments with three replications using tensiometer. Before treatment application, water content of soil was determined in weight. MAD in 40, 60, and 80 cm bar treatments was 22, 32 and 50%, respectively. Statistical results and mean comparison demonstrated that MAD of 22 and 32% led to a significant yield increase (P<0.001), while MAD of 50% had the least yield. The results reveal that there was a significant difference between MAD of 22 and 32% in increasing leaf area index (LAI) (P<0.001).

Key words: Maximum allowable depletion, greenhouse cucumber, tensiometer, leaf area index.

INTRODUCTION

Water availability is generally the most important factor limiting the development of agriculture in arid and semi-arid regions (Bozkurt and Mansurolu, 2011). New innovations for saving irrigation water and thereby increasing crop water use efficiency (WUE) are especially important in water-scarce regions (Gencoglan et al., 2006). In irrigation management discussion, measurement and control of water content of soil is regarded as an essential component to apply optimal management methods for the purpose of reducing water consumption and improving WUE.

Water content of soil is an important component in greenhouse, which has a direct impact on the amount of water used to irrigate crops. Greenhouse cultivation is of various types in many parts of the world and is considered as an expensive method to produce a number of products (Canakci and Akinci, 2003). Furthermore, the main goal of greenhouse development is to improve productivity and efficiency of water consumption (Hasandokht, 2005). To improve water productivity is possible in two ways: (1) keeping the production degree at the current level along with reducing water consumption and (2) increasing the yield (including product weight, product diameter, stem diameter, and leaf area index) in return for the consumptive water unit (Hasandokht, 2005). To be more precise, the degree of production is increased through protecting available water resources. As a result, what is considered in the greenhouse is to

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Abbreviations: MAD, Maximum allowable depletion; **LIA,** leaf area index.

increase the yield in return for the consumptive water unit.

Since cucumber(*Cucumis sativus L.*) is considered as the main and popular summer crop in Iran, and is extremely sensitive to adverse conditions particularly water stress, determination and supply of water need is vital for this plant (Hasandokht, 2005). To this end, it seems necessary to determine maximum allowable depletion (MAD) of soil. Part of the available water is easily absorbed into plant which is named readily available water (RAW). On the other hand, plant requires a lot of energy to absorb the rest of water which results in product reduction. As it is not favorable for the farmers, practically, they irrigate the field at a point between field capacity (FC) and Permanent Wilting Point (PWP). This potential point is called MAD, expressed in percent and dependent on the irrigation management and type of cultivation. Hence, it is called management allowable depletion (Alizadeh, 1999).

Studies of Kramer and Boyer (1995) demonstrated that doubling the number of irrigation during the peak time of blooming of wheat led to a rise in productivity up to 25%. Moreover, studies to determine the index of MAD showed that it is possible to use MAD equal to 65% to determine the amount of water usable for the plant. In addition, Rouphael and Giuseppe (2005) agreed that water tension decrease the leaf area index (LAI) in greenhouse cucumber. Eiasu et al. (2009) in the experiment that was conducted for maximum allowable soil water depletion levels (MAD), 20, 40, 60 and 80% of the plant available soil water (ASW) in the top 0.8 m root zone, were applied as treatments. Plant roots extracted most soil water from the top 0.4 m soil layer. Increasing the soil water depletion level to 60% and higher resulted in a significant reduction in herbage mass and essential oil yield. An increase in maximum allowable depletion level generally resulted in a decrease in leaf area and an increase in leaf to stem fresh mass ratio. Up to 28% of irrigation water could be saved by increasing maximum allowable depletion level of ASW from 20 to 40%, without a significant reduction in essential oil yield. Wang et al. (2007a, b) demonstrated that the matric potential between 20 to 50 kpa led to maximum yield in tomato. Gontia and Tiwari (2008) have shown that their study was conducted to develop the relationship between canopy air temperature different and vapor pressure deficit for no stress condition of wheat crop. The MAD of the available soil water (ASW) of 10, 40, 60% and no irrigation were minted in the crop experiments. The canopy air temperature difference and VPD resulted linear relationship and the slop and intercept for lower baseline of pre-heading and post heading stages of wheat crop were found as m = -1.7466, c = -102546 and m = -11141, c = -2.0827, respectively. The CWSI was determined by using the developed empirical equation for three irrigation schedules of different MAD of ASW.

Shongwe et al. (2010) also reported parameters that were used with four water treatments (0.40, 0.60, 0.80, and 1.00 × FC). Parameters measured included leaf number per plant, plant height, chlorophyll content, canopy size, leaf width, leaf length, stem girth, dry mass, fresh mass, fruit length, and brix content. There were significant ($P<0.05$) increases in leaf number, plant height, chlorophyll content, canopy size, fresh and dry mass tops and fruit length at the highest moisture level (1.00×FC), followed by the second highest regime (0.80 × FC), whilst the lower water regimes resulted in lower increases in each of the parameters. LAI did not differ significantly across all treatments. In increasing order, the treatments 0.80 and 1.00 × FC gave higher yields, but in decreasing order lower brix and thus subsequent lower paprika quality. Bozkurt and Mansurolu (2011) studied the effects of different irrigation levels on yield, quality and water use characteristics of lettuce (*Lactuca sativa var. longifolia cv. Lital*) cultivated in a solar greenhouse in the Eastern Mediterranean region of Turkey. Five irrigation treatments (I) were based on adjustment coefficients (0.25, 0.50, 0.75, 1.0 and 1.25) of Class A pan evaporation. The results show that Irrigation levels had significantly ($P<0.01$) different effects on yield and yield components except for plant dry weight, plant height and head firmness. The results show that the highest yield was obtained from SDI10 (subsurface drip irrigation at 10 cm depth) × I100 treatment. The WUE and the irrigation water use efficiency (IWUE) increased as the irrigation was reduced.

Determination of quantity and direction of water flow is very important for sustainable land management (Sariyev et al., 2007). The aforementioned literature shows that water use efficiency and yield depends on soil water management and MAD, especially in a greenhouse condition, and it should be determined for greenhouse production.

The objectives of the present study were determination of (1) maximum allowable depletion coefficient in greenhouse condition and cucumber cultivation for a semi-arid region, and (2) yield and yield components of the condition.

MATERIALS AND METHODS

This experiment was conducted in the research greenhouse of Islamic Azad University, Khorasgan branch, Isfahan, Iran (Latitude: 32°37' N, Longitude: 51°40' E and Elevation: 1550.4 m) during a five-month's cultivation period starting from May 2008 to December 2008. Average annual temperature is about (16.2°C), and average annual precipitation is about 122.8 mm, which mainly concentrated from June to September. The dominant soil is silty-loam, with an average bulk density of 1.36 g/cm^3.

The total area of the greenhouse was 1377 m^2, with a useful area of 1050 m^2. The greenhouse was covered with a 45% UV Polyethylene and equipped with open-able ceilings and heating (heater) and cooling (fan and utility) systems. Drip irrigation system was used and drippers were put at the distance of approximately 40 cm.

Cucumber's seed (*Cucumis sativus L,* Nasim variety) were

Table 1. Properties of irrigation water.

EC (dS/m)	pH	SO_4 (meq/L)	Ca (meq/L)
0.31	7.8	½	1.6

Table 2. Physical properties of greenhouse soil.

Depth (cm)	Aw (%)	PWP (%)	F.C (%)	Sp (%)	ρ_b (g/cm^3)	Texture
0-30	17	10	27	48	1.36	Silty-loam

Aw, Available water; PWP, permanent wilting point; FC, field capacity.

Table 3. Chemical properties of greenhouse soil.

Depth (cm)	EC (dS/m)	pH	N (%)	P (meq/kg)	K (meq/kg)
0-30	1.5	7.8	0.16	0.4	0.7

directly planted into the soil at the distance of 40 cm in a row and 1.5 m row's distance. Properties of the irrigation water, physical properties of the soil, and chemical properties of the soil are shown in Tables 1, 2 and 3, respectively.

Methods

Agronomic measures such as fertilizing, pruning, layering and weed and pests control were equally taken in all treatments. The statistical design used was the Randomized Complete Block Design (RCBD), which was implemented in the framework of three 40, 60, and 80 cm bar water suction treatments with three replications (named T40, T60 and T80, respectively). The control treatment was irrigated every other day (traditional use of water in the region). Before treatment application, water content of soil was measured in weight. A number of tensiometers were used in the soil to measure water content of soil and at the same time, water content of soil by weight (Baybordi, 2003) and the soil matric potential were measured through standard methods (Baybordi and Naderi, 2001).

The relation between water content of soil and soil matric potential, and water content and time were obtained through Curve Expert Software and its diagram was drawn. To determine MAD for each treatment and the amount of available water, Equations 1 and 2 were used respectively (Baybordi, 2003).

$$MAD_i = \frac{\Delta \theta_i}{\theta_{AW}} \quad (1)$$

$$\theta_{AW} = (\theta_{FC} - \theta_{PWP}) \quad (2)$$

Where, θ_{Aw} is the soil available water (%); θ_{FC} is the soil moisture in field capacity (%); θ_{PWP} is the soil moisture in permanent witling point (%); $\Delta\theta_i$ is the difference of peaks in moisture-time diagram for each treatment and MAD_i is the maximum allowable depletion for each treatment.

Soil water tension data was daily recorded by tensiometer. When the data was below the target soil matric potential, irrigation was then initiated. Cucumber yield indexes were measured including: weight of product measured by a digital scale, diameter of stem and length and diameter of the fruit measured by a caliper, and LAI measured by a planimeter (Rossini and Dejesus, 2004). For this purpose, six bushes were randomly selected from each replication in each treatment.

Statistical analysis, including analysis of variance and mean comparison by Duncan's multiple range test, were performed at 5% level of significance using SPSS Software (Statistics Package for Social Science), version 14.

RESULTS AND DISCUSSION

The depth of water for each irrigation event of all treatments is shown in Figure 1. The number of irrigation events varied from 10 events in the lowest soil matric potential treatment (treatment 80) to 34 events in the highest soil matric potential treatment (treatment 40). It shows that the irrigation amount varied from 78 (control) to 34 cm (treatment 80). The number of irrigation events and total irrigation amount reduced as target soil matric potential decreased (Figure 1). The duration of each irrigation interval differed between treatments. Treatment 40 got the most frequent irrigation and irrigation occurred almost 4 days, while treatment 80 got lest irrigation frequency and the average irrigation was 13 days (Figure 1).

Table 4 shows the calculated MAD using Equations 1 and 2. There are three levels of MAD ranging from 22 to 50%. Figure 2 shows the water content of soil variation vs. time in each treatment. The result shows there is a highly significant difference between the treatments in

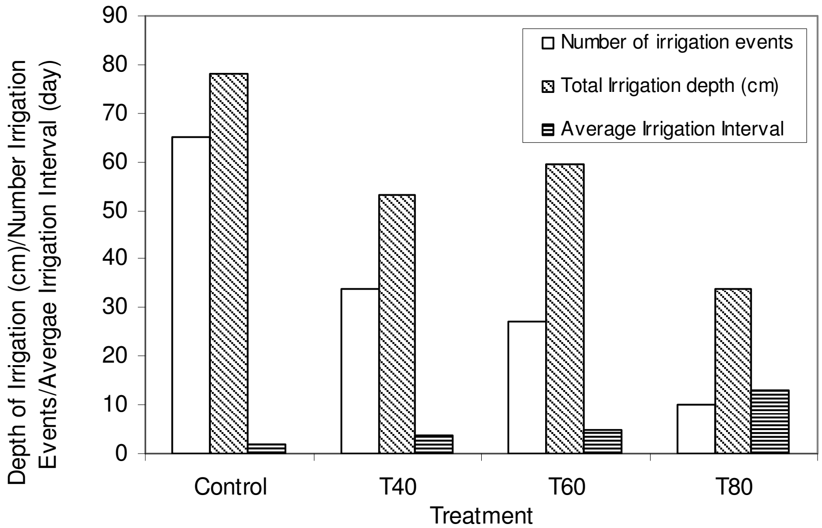

Figure 1. Cumulative irrigation amount under different treatments.

Table 4. MAD in each treatment.

Treatment suction (Bar)	40	60	80
Maximum water content of soil (%,w/w)	16.5	16.5	16.5
Minimum water content of soil (%, w/w)	12.6	11	8
Δθ (%)	3.9	5.5	8.5
θ FC (%)	27	27	27
θ PWP (%)	10	10	10
θ Aw (%)	17	17	17
MAD(%)	22	32	50

θ_{FC} = soil moisture in field capacity; θ_{PWP} = soil moisture in permanent witling point; θ_{Aw} = soil available water; MAD_i = maximum allowable depletion for each treatment.

increasing LAI (P<0.001) (Figure 3). It showed that no significant difference was found between MAD of 22 (T40) and 32% (T60). Figure 3 shows the LAI in three sizes of large, medium and small in three treatments. The results of comparison of mean using Duncan's multiple range test in small and medium leaves indicated that the size of small leaf in MAD of 22 and 32% and the control had no significant difference (P>0.05), while there was a significant difference (P<0.01) between these three treatments and MAD of 50%. It is evident that minimum LAI was observed in MAD of 50%. Furthermore, from among the three applied treatments, MAD of 22 and 32% provided the most LAI and the most suitable condition for the greenhouse cucumber growth. This is due to the high water content of soil (less water stress) in the MAD of 22 and 32%. Comparing the mean, it was found that there was a significant difference (P<0.01) between each treatment of MAD of 22, 32 and 50% regarding the large size of leaf, but the MAD of 22% had the maximum LAI and had no significant difference (P>0.05) with the control. This means that the larger sizes of the leaf are more sensitive to water stress than medium and small size.

Figure 4 shows the comparison of mean for the fruit yield. Statistical analysis results, as well as mean comparison, revealed that MAD of 22 and 32% led to a significant increase of fruit yield at P<0.001, while MAD of 50% had the least yield. Comparing the results with the control, irrigation treatment confirms this fact. Peyvast (2006) declared that yield, LAI, and stem diameter in tomato had no significant difference (P>0.05) under different irrigations. Eiasu et al. (2007) examined the impact of four levels of MAD (25, 40, 55 and 70%) on potato and came to the conclusion that MAD of 25 and 40% increased the growth and yield of potato tuber, while MAD of 50 and 70% decreased the yield. Kounsoukeh et al. (2003) explained that water stress in a Japanese persimmon tree led a decrease in fruit and stem diameter. Fasehun (1978) concluded that leaf area, number of leaf, and plant weight would be mainly decreased by a rise in soil suction (from 0.1 to 0.72, 10 kpa). Moreover, Mao et al. (2003) concluded that the

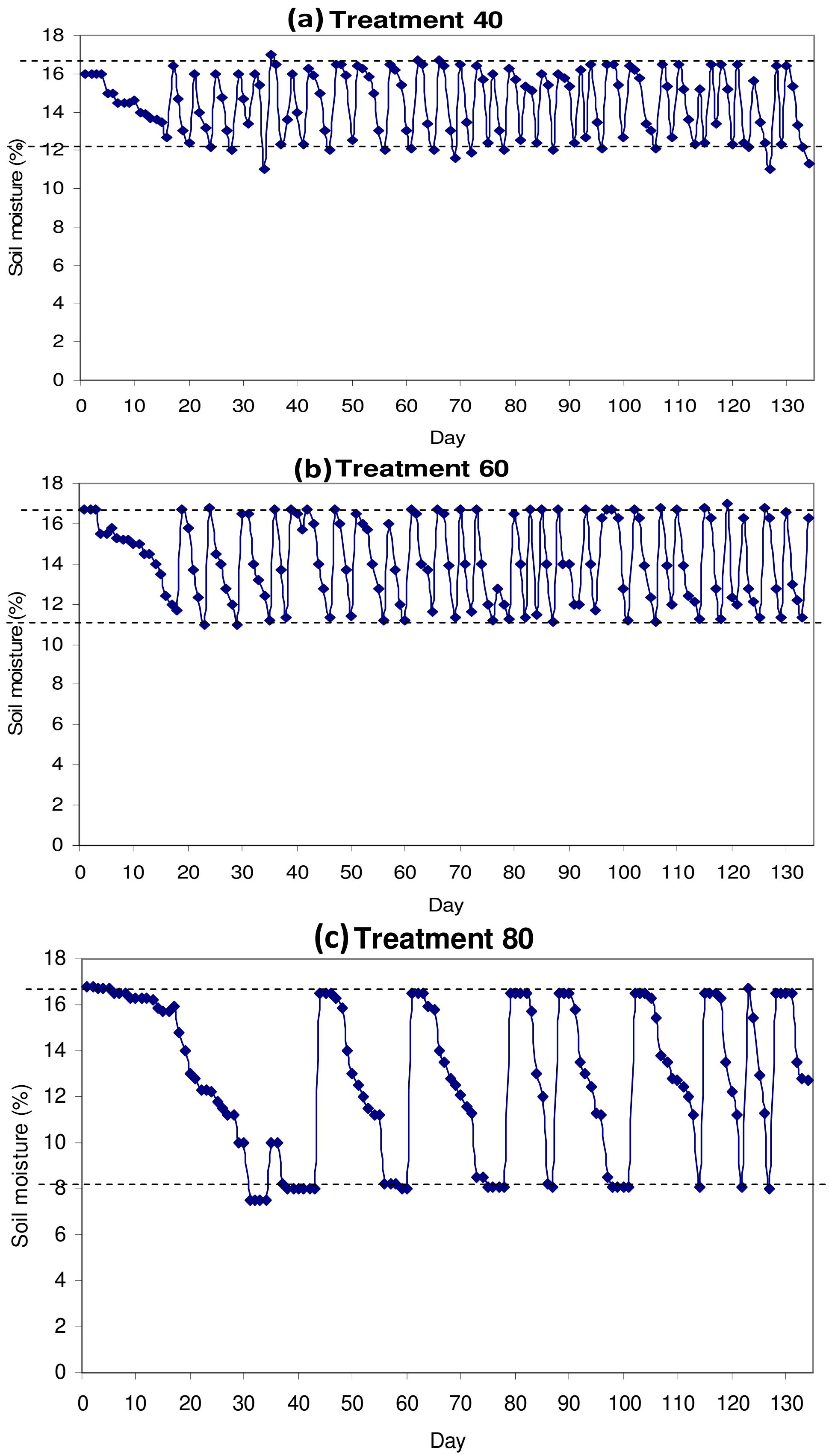

Figure 2. Water content of soil vs. time in the three treatments (a, b, and c).

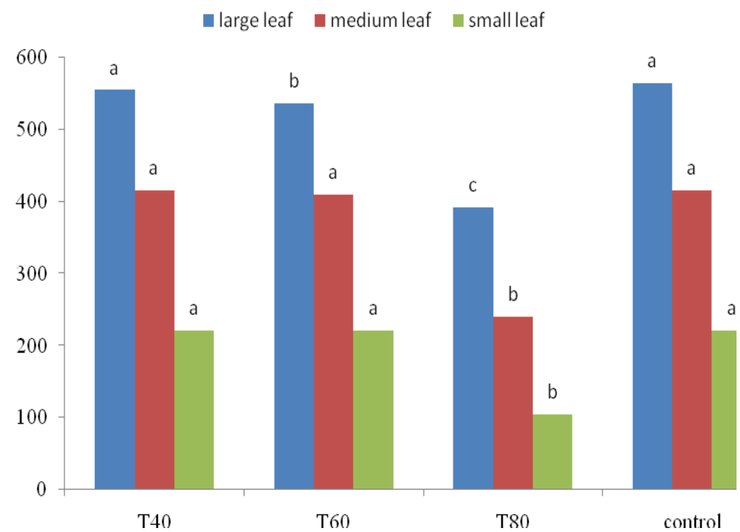

Figure 3. Comparison of LAI mean in applied treatments. Different letters show a significant difference, while similar letters demonstrate no significant difference in the level of 5% using Duncan's test.

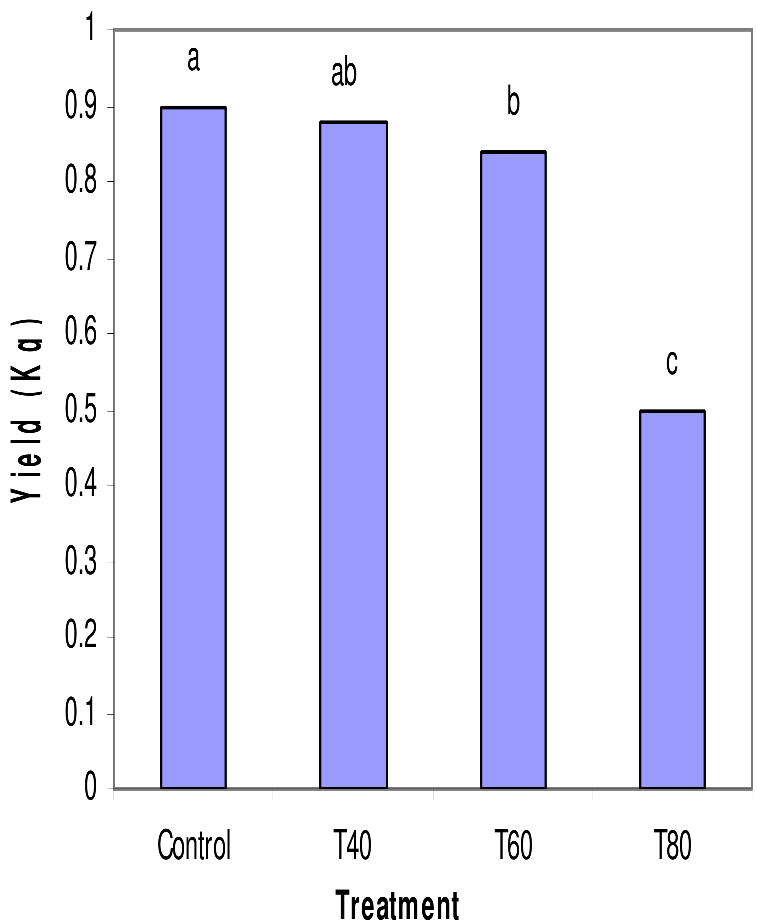

Figure 4. Weight of fruit in applied treatments. Different letters show a significant difference while similar letters demonstrate no significant difference in the level of 5% using Duncan's test.

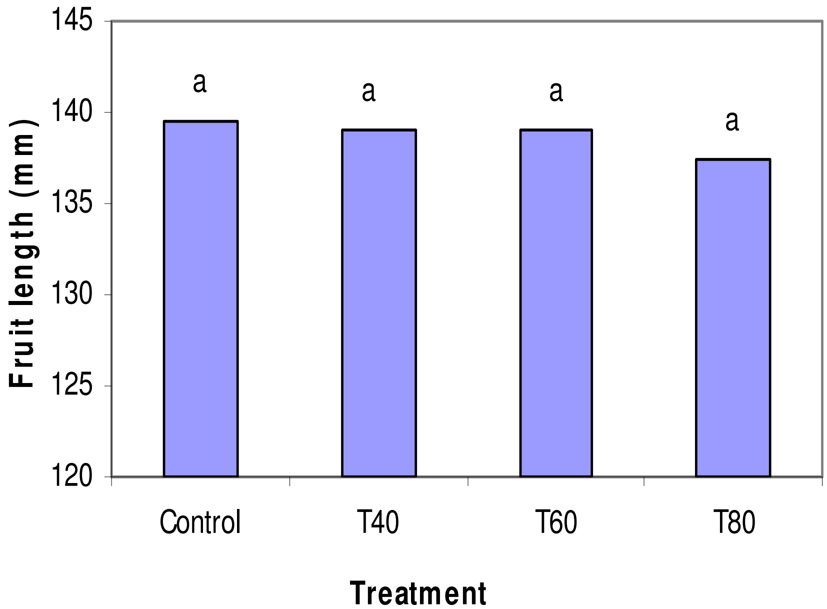

Figure 5. Comparison of length of fruit mean in applied treatments.

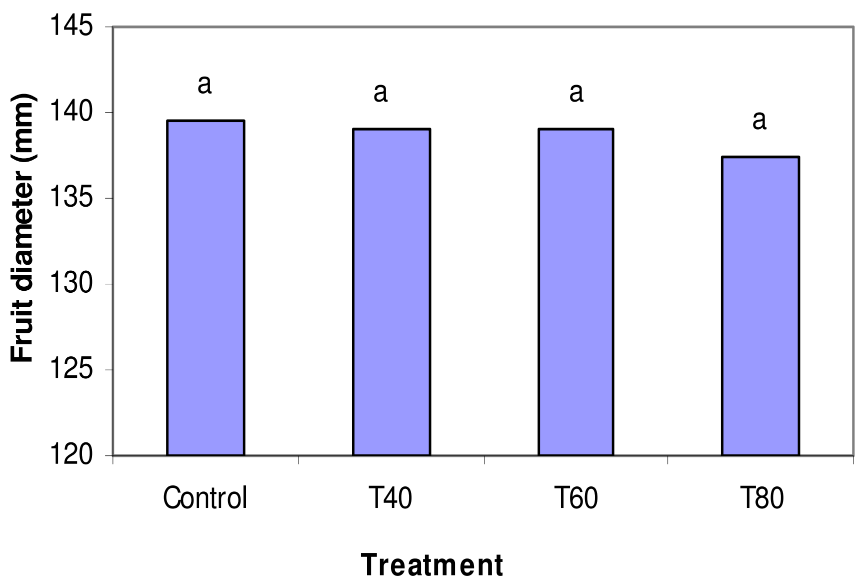

Figure 6. Comparison of fruit diameter mean in applied treatments.

yield of greenhouse cucumber (weight, bush height, LAI, fruit and stem diameter) was affected by the volume of consumptive water in all growth stages. In addition, Xing et al. (2007) agreed that the best soil matric potential for the optimal yield of potato was 25 kpa. They demonstrated that the matric potential between 20 to 50 kpa led to maximum yield in tomato. Alizadeh (1999) estimated the MAD of cucumber with root depth of 0.7 to 1.2 m to be 5%.

There was however, no significant difference (P>0.05) between other growth indexes including length of fruit, diameter of fruit, and stem, and other in demand properties of greenhouse cucumber among three treatments and the control (Figures 5, 6, and 7).

Conclusion

On the basis of the results of this research, the following conclusions are drawn:

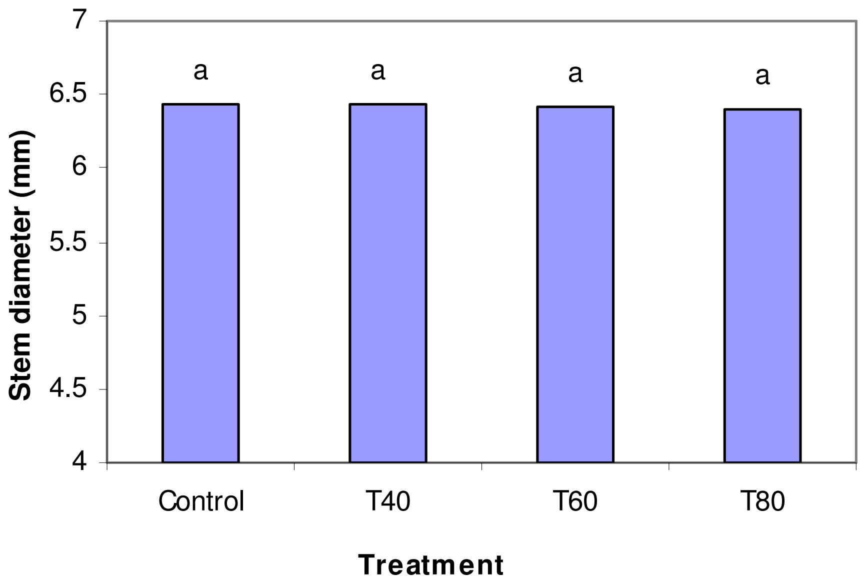

Figure 7. Comparison of stem diameter mean in applied treatments.

(a) MAD of 32% has the best effect on the weight of plant and appearance of cucumber (fruit length, fruit and stem diameter).
(b) Considering LAI, MAD of 22 and 32% has the best effect on it.
(c) Irrigation to MAD of 50% led to a decrease in yield, fruit length, fruit and stem diameter, and leaf area index.

It is therefore recommended that with regards to drought and texture of soil and depth of root development, greenhouse cucumber could be irrigated with MAD of 32%.

REFERENCES

Alizadeh A (1999). Relation of Water, Soil & Plant. Imam Reza University Press, Mashhad. p. 353.

Baybordi M (2003). Soil physics. Tehran university press, p. 671.

Bozkurt S, Mansurolu GS (2011). The effects of drip line depths and irrigation levels on yield, quality and water use characteristics of lettuce under greenhouse condition. Afr. J. Biotechnol. 25 April, 2011. 10(17): 3370-3379.

Canakci M, Akinci I (2003). Energy use pattern analyses of greenhouse vegetable Prod. Energy J. 31: 1243-1256.

Eiasu BK, Soundy P, Hammes PS (2007). Response of potato (Solanum tuberosum) tuber yield components to gel-polymer soil amendments and irrigation regimes. New Zealand. J. Crop. Horticult. Sci. 35(1): 25-31.

Eiasu B.K. Steyn J.M. Soundy P. (2009). Rose-scented geranium (Pelargonium capitatum × P. radens) growth and essential oil yield response to different soil water depletion regimes. Agricultural Water Management, 96(6):991-1000.

Fasehun FE (1978). Effect of soil matric potential on leaf water potential, diffusive resistance, growth and development of *Gmelina arborea* L. seed. Biol. Planta. J. 21(2): 100-104.

Gencoglan C, Altunbey H, Gencoglan S (2006). Response of green bean (P. Vulgaris L.) to subsurface drip irrigation and partial rootzone-drying irrigation. Agric. Water Manage. 84(3): 274-280.

Gontia NK, Tiwari KN (2008). Development of crop water stress index of wheat crop for scheduling irrigation using infrared thermometry. Agricultural Water Management, 95(10): 1144-1152.

Hasandokht M (2005). Greenhouse Management (Production Technology of Greenhouse Products). Marz Danesh Press, p. 320.

Kounsoukeh F, Ito J, Mohapatra PK, Hirofumi S, Kei L, Heilil K, Kawai K, Ohkura K (2003). Circadian rhythm of stem and fruit diameter dynamics of Japanese persimmon (Diospyrus kaki Thunb.) is affected by deficiency of water in saline Environ. Functional Plant Biol. J. 30(7): 747-754.

Kramer PJ, Boyer JS (1995). Water relation of plants and soils, Academic press, San Diego, Calif. USA.

Mao X, Liu M, Wang X, Liu C, Hou Z, Shi J (2003) Effects of deficit irrigation on yield and water use of greenhouse grown cucumber in the North China Plain. Agricultural Water Management 61(3):219-228.

Shongwe VD, Magongo BN, Masarirambi MT, Manyatsi AM (2010) Effects of irrigation moisture regimes on yield and quality of paprika (Capsicum annuum L). Physics and Chemistry of the Earth, Parts A/B/C, 35(13-14):717-722.

Peyvast G (2006). Effect of different irrigation scheduling of tomato leaf area in mound culture. Proceeding of the 4th Intenational Symposium on Protected Cultivation in Mild Winter Climates. Kissimmee, Florida, USA. Acta Hortic. 569: 663-670.

Rossini A, Dejesus T (2004). Leaf area prediction models for Zinnia elegans Jacq. Zinnia haageana regel and 'profusion cherry. Sci. Agric. (Piracicaba, Braz.). 61(1): 47-52.

Rouphael Y, Giuseppe C (2005). Radiation and water use efficiencies of greenhouse zucchini squash in relation to different climate parameters. Eur. J. Agron. 23(2):183-194.

Sarıyev A, Polat V, Mujdeci M, Yusufova M, Akça E (2007). Mathematical modelling of soil hydraulic properties and numerical analyses of moisture dynamic. Asian J. Chem. 19(4): 3125-3131.

Wang D, Kang Y, Wan S (2007). Effect of soil matric potential on tomato yield and water use under drip irrigation condition. Agric. Water Manage. J. 87(2): 180-186.

Wang FX, Kang Y, Liu SP, Hou XY (2007). Effects of soil matric potential on potato growth under drip irrigation in the North China Plain. Agric. Water Manage. J. 88(1-3): 34-42.