Effect of deficit irrigation on greenhouse cucumber root distribution and root tolerance index in hydroponics cultivation

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Abstract: The current research was done in a hydroponic culture during fall and winter in 2016 in a research greenhouse in Shahid Chamran Agricultural university of Ahwaz. The purpose of the study was to understand the effect of water stress on root distribution and root tolerance index of greenhouse cucumber including root length, root width, root volume, and root tolerance index. The irrigation was done by drip irrigation. The applied irrigation treatments were included three water need levels of 100%, 85% and 70% which were performed in a randomized complete design. The results showed that water stress has a significant effect on root length, root width and root tolerance index in the level of 1%, but has no significant effect on the volume of the root. Deficit irrigation is not recommended for the greenhouse cucumber because of the sensitivity of greenhouse cucumber to water deficit and significant decrease of length and width against deficit of irrigation water. When the water deficit is more serious in the region it is better that deficit irrigation was done after yielding or was done in a way that has the least effect on performance.

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1. Introduction

Greenhouse cucumber is a fast growth plant which grows in wet and warm weather. Sufficient water in soil is necessary for vegetative growth and consequently for photosynthetic capacity (Ortega & Kishman, 1982). Among cucurbits, cucumber is in the group of cash products in the classification of crops. Thus produced cucumber is supplied as the end product in the market and its period of return of capital is very short (Sadrghaen, 2002). In addition, considering the extensive facilities of production and processing of this crop in Iran, the crop is economically important and also attracts agricultural officials' attraction, because it causes importing of currency in the country (Mehrabi, 2008). Irrigation management is easily performed in greenhouse culture because of using pressurized irrigation and control of weather parameters. Irrigation management is very important for plant growth and also for control of salinity level of the soil (Pessarakli & Szabolcs, 1999). Dried and semi-dried regions face to water shortage for producing crops. Thus, correct usage of water and water saving is necessary. Agricultural experts need to change their attitude toward the concept of "development" and use "advanced technological system", sustainable consumption of water and energy, maintaining ecosystem and landscaping in dried and semi-dried areas. To achieve optimized yield in dried and semi-dried areas, understanding and applying new irrigation methods is one of the modern options. Because using new technologies leads to suitable increase of water use efficiency and better yield, and also prevents the accumulation of salt in root. On the other hand, irrigation management as an important tool for optimal production of crops has been considered all over the world. Some researches should be done in such regions in regard with applying the methods of deficit irrigation to understand their effects and consequences as a suitable alternative for water efficiency increase, yield and balance of drought conditions.

Liang et al, (2014) studied the effect of output water and salt from soil on root growth and fruit yield and concluded that length, weight, level, diameter and volume of the room reduced by water stress. Mardani Nejad et al, (2014) studied the effect of different amount of soil on the root of green pepper. Results showed that high amount of irrigation water has an increasing effect on weight, volume, level and length of the root and low amount of irrigation water has a decreasing effect on the above components. Dehghan et al, (2015) investigated the root growth and yield of tomato in dry stress in four irrigation treatments including 100, 70, 60 and 40 percent water need. Yield, weight, diameter, number of fruits, dry weight of aerial organs, root volume, root wet weight, root dry weight, root length and root level reduced under dry stress. In addition, root volume shows the highest correlation with yield of tomato. To define the effects of dry stress on growth and yield of cucumber, Najarian et al, (2015) did an experiment in three levels of 100 control and 80% and 60% in a culture containing soil, cocopeat and perlite. They express that stem diameter, fruit weight; number of leaves, dry material of bush and wet and dry weigh of the root reduce under dry stress.

2. Material and Methods

The research has been done in research greenhouse of Chamran Agricultural University, Ahwaz during fall and winter in 2016 to investigate the effect of water stress on the distribution of the root of greenhouse cucumber such as root length, root width, root volume and root tolerance index in hydroponic culture. The experiment was performed in randomized complete design with employing of 3 irrigation treatments and 5 replications. Since the losses such as evaporation, depth penetration and… are low, irrigation treatments were performed in three water need levels of 100% (I_{100}) as the control, 85% (I_{85}) and 70% (I_{70}).

2.1 Seed bed and Fertilizer

the used pots were plastic and white with the large and small diameters of 24cm and 20cm and height of 25cm. An equal amount of gravel was poured on the bottom of the pots (for drainage) and then pots were filled with cocopeat and perlite with ratio of 50:50.

The nutrient solution used in this research was provided based on the rash nutrient formula (table 1). Before planting, cucumber seeds were soaked in petri dish containing filter paper in the room temperature and after 24 hours were planted in small pots of 120cc (paper cups) in cocopeat perlite cultures (50:50). After 10 days, seedlings were transplanted to the pots. The pruning was done to let the length growth and produce high quality fruit near the main stem and also improve the air conditioning and facilitate the harvest. The pruning was in form of one shoot and subshrubs were eliminated gradually. Thus, all the produced energy of the plant is used for the growth of leaf and stem and consequently the plant will be strong. Deficit irrigation treatments were performed on the bushes on November 6th in 2016.

Table 1. compound of proposed rash nutrient solution (2005) of greenhouse cucumber

Consuming elements	Element concentration (ppm)	low consumption elements	Element concentration (ppm)
N	140	Mn	0.8
P	50	CU	0.07
K	350	Zn	0.1
Mg	50	B	0.3
Ca	200	MO	0.03
S	150	Fe	3

2.2 Greenhouse condition and measuring tools

Cucumber grows in warm seasons and is sensitive to cold weather especially to temperature under 15°C. Thus, the relative moisture and temperature inside and outside of the greenhouse measured daily. Table 2 presents maximum, minimum and average temperature and also the relative moisture inside the greenhouse.

To measure the length and depth of the root, we put the roots on a flat surface and measure them by a ruler. Root volume was measured by liquid movement. For doing so, first an exact volume of water was poured in the beaker, and then the root was put in the beaker, the amount of water which rose is considered as the root volume. Root tolerance index was calculated as follows based on the root dry weight in stress and without stress condition (Maiti et., al 1996).

$TI = \frac{W1}{W2}$ (1-1) TI: root tolerance index

W_1: root dry weight in stress condition

W_2: root dry weight in without stress condition

Table 2. temperature variables and relative moisture inside the greenhouse

Variable / month	relative moisture	Temperature (°C)		
		Average	Maximum	Minimum
October	46.15	26.07	35	17
November	45.86	21.23	30.67	11.69
December	50.8	22.59	31	14.18
January	46.83	22.37	31.08	13.68
February	47.64	22.5	30.6	14.4

2.3 Irrigation management

An automatic irrigation system was designed for doing the experiment. For doing the irrigation and transferring the nutrient solution, three polyethylene 100 liter capacitors were used for making salt water which was connected to polyethylene 3/4 tube by metal socket and connector. 0/5 pump was used for transferring water and then, 3/4 tube was connected to the pump by polyethylene 3/4connector and the pump was balanced. Solenoid valve used for pump output in order that nutrient solution outflows just at the time of irrigation and water enters the system just when is necessary. After the output of solenoid valve, an output returns to the reservoir to set the pressure. Netafim drip pan and 16 mm tube were used for setting the irrigation volume and avoiding higher pressure. Water output was divided in to three separated lines by metal connectors to do the irrigation treatments and transferred to each line by using plastic 1/2 valve of drip irrigation to polyethylene lateral 16 mm tube and Netafim drip pan. Drip pans were placed on laterals in the distance of 0.5m. Irrigation started by command of timer to solenoid valve and pump, and the volume of irrigation was set by regulating the return valve and the valves of each lateral line. To determine the output water volume, a dish was put under each drip pan to shows the amount of poured water and also the pressure on each drip pan on that time. Then, pots put under laterals in a way that drip pans were backed to bushes to avoid direct pouring of nutrient solution into the bushes and also damaging the bushes.

2.4 data analysis

The design of the data was in form of split plot experiment and randomized complete design. Data were analyzed by SPSS software and Duncan test in the level of 5%. Excel software was used for depicting the diagrams.

3. Results

Table 3 shows the variance analysis results of deficit irrigation effect on studied characteristic of cucumber.

Table 3. analysis results of deficit irrigation effect

S.O.V	df	Mean of Squares			
		Root length	root width	root volume	root tolerance index
Deficit irrigation	2	1.0217**	0.1569**	0.1886n.s	0.016**
Error	12	0.0205	0.0098	1.1869	0.0008
CV %		2.29	2.75	6.64	3.12

**,* and n.s show the meaningfulness in the level of 1% and 5% and meaningless, respectively.

3.1 Effect of water stress on root length

The effect of different levels of irrigation on root length is meaningful on the statistic level of 1% (table 3). Figure 1 indicates that average difference of root length among different levels of irrigation is meaningful at the level of 5%. figure 1 shows that there's a significant difference among control treatment and the two other treatment in the level of 5%, because reproductive organs of the plane need more nutrients and water. Thus, more water and nutrition are transferred from root to reproductive organs and aerial parts and consequently the speed of root growth will decrease. Xue et al, (2003) reported the decrease of root growth. Liang et al., (2014) expressed that decrease of consumable water leads to the decrease of root length of cucumber. It corresponds to the results of the current research. In addition the results of the research of Dehghan et al, (2015) on tomato correspond to the results of the current research.

3.2 Effect of water stress on root width

As shown in table 3, the effect of irrigation on root width is meaningful at the level of 1 %. Increase of the level of water stress leads to a significant decrease of root width. So that the control bushes have the highest root width of I_{100} and plants treated with 70% water need have the lowest root width of I_{70}. Figure 2 shows that regarding with average, there's a significant difference between control treatment and the treatment of 185 in the level of 5%, but there's no significant difference between treatments of I85 and I_{70}.

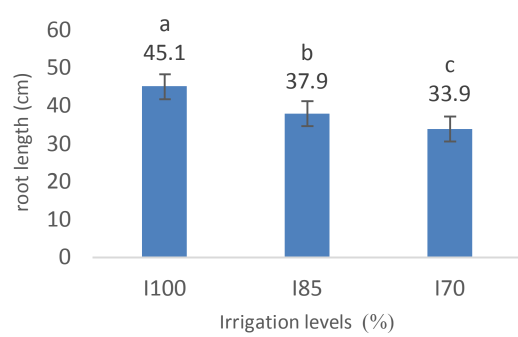

Figure 1. root lenght in deficit irrigation treatments

In each turn of irrigation there's lower moisture around and in the area of root development in treatments with deficit irrigation. This increases the mechanical resistance of soil against root development and thus leads to decrease of length and density of root in deficit irrigation treatments. Therefore, in treatments without deficit irrigation, there's more water around the root and the plant uses water to make the root dense. Thus, these treatments used water more suitable than deficit irrigation treatments. William et al., (1998) also reported the decrease of roots growth and their confinement to the upper layers of the soil because of water shortage. Give et al., (1999) asserted that roots developed under suitable moisture condition are smaller and have less branches and their penetration depth is also lower. While in wet condition, root depth will be more.

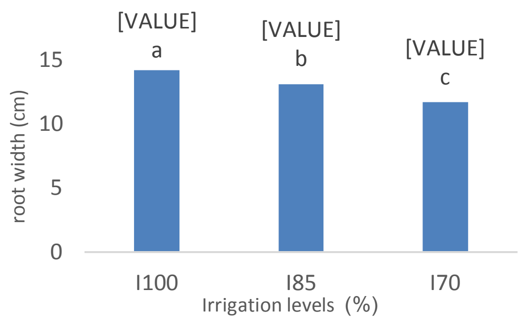

Figure 2. root width in deficit irrigation treatments

3.3 Effect of water stress on root volume

The results of variance analysis of the effect of different levels of water stress showed that different amount of water stress has no significant effect on root volume (table 3). Root volume decreased because of water stress but the reduction was not significant (figure 3). There's no significant difference among different levels of irrigation regarding root volume. Shafi et al, (2010) showed that salt stress reduce the total volume of the root which contradict obtaining results, probably because salinity affects root length not root volume.

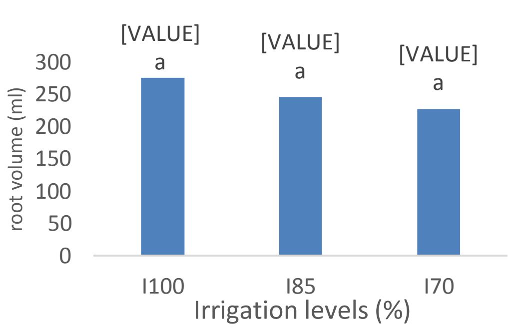

Figure 3. root width in deficit irrigation treatments

3.4 Effect of water stress on root tolerance index

As observed in table 3 the effect of simple irrigation on root tolerance index was significant in the level of 1%. Increase of the level of water stress led to significant decrease of root tolerance index. So that control bushes have the highest root tolerance index of I_{100} and plants treated with 70% water need have the lowest root tolerance index of I_{70}. There was a significant difference among different levels of irrigation in the level of 5% (figure 4).

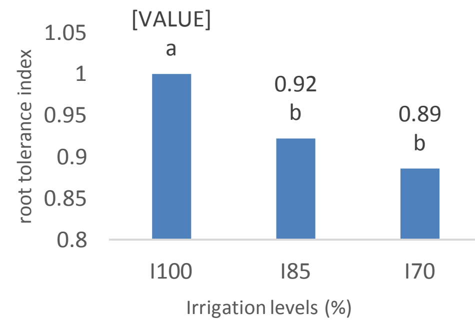

Figure 4. root tolerance index in deficit irrigation treatments

4. Discussions

The research was done under hydroponic system in rash culture to determine the effect of deficit irrigation on root distribution and root tolerance index of cucumber. The results showed that deficit irrigation treatments had significant effect on root length and width and also on root tolerance index in the level of 1% but had no significant effect on root volume. Generally, control treatment had the highest length, width and root tolerance index and I70 treatment had the lowest root distribution and root tolerance index. Deficit irrigation is not recommended for greenhouse cucumber because of the sensitivity of greenhouse cucumber to water shortage and significant reduction of length and width against deficit irrigation. But when water shortage is more serious in the region, it is better to do deficit irrigation after cropping period or do it in a way that has the minimum effect on yield.

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