Evaluation of deficit irrigation methods on root components of tomato in hydroponic culture

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Abstract: This research was carried out in the greenhouse complex of agriculture in shahid chamran university of ahvaz in 2016. This study has investigated the effects of regulated deficit irrigation (RDI) and partial root zone drying (PRD) on tomato under hydroponic culture conditions. The treatments of experiment consisted of five treatments: RDI irrigation at 85 and 70% of plant water requirement and PRD irrigation at 85 and 70% of the plant water requirement, and control treatment was carried out in a completely randomized design with four replications. The results showed that different methods and levels of deficit irrigation have a significant effect on fresh and dry weight of root, root water content, root volume, root length and width. The highest rates of the mentioned indices were observed in the control treatment and the lowest were observed in RDI85. According to the results, it seems that the control treatment is the best treatment for the formation of root components of tomato plants in greenhouse conditions.

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1. Introduction

Regarding water resource constraints, it is recommended that deficit irrigation be considered as an efficient option to increase the efficiency of irrigation water. deficit irrigation is "deliberate and wisely-used water consumption, in order to increase production in the covered lands". One of the objectives of deficit irrigation is to increase water use efficiency by reducing the amount of irrigation water versus low yield (Kirda, 2002). Water scarcity increases root development towards deep and wet soil sections. It can be said that growth of root to wet soil is considered as the second line of defense against dryness. Water stress causes loss of roots and increasing deep roots (kafi and Mahdavi Damghani, 2002).

Tomato is one of the most important Vegetables in all parts of the world (Bocian and Holubowicz, 2008). The root of the tomato plant is deep and sometimes even penetrates more than one meter in the soil. Tomato produce a lot of roots (Qeshm and Kafi, 1999).

Mashouri et al. (2010) to study four levels of nitrogen (0, 30, 60 and 90 mg / kg) from Urea fertilizer source and two levels of irrigation (4 and 6 days) showed that nitrogen and irrigation levels had a significant effect on yield, fresh and dry weight of aerial parts and roots of tomato plants, and with increasing nitrogen levels, yield was increased. The highest yield was obtained from 90 mg / kg nitrogen with irrigation intervals of 4 days. The highest fresh and dry weights of the aerial parts and root were obtained from 60 mg / kg nitrogen plus 4 days irrigation.

Raiesi et al. (2014) by investigation two methods of drip irrigation and furrow irrigation, and three levels of irrigation of 100, 75 and 50% of the water requirement of tomato plants, reported that the fresh weight of the root decreased with decreasing irrigation water volume. Also, in each level of irrigation, the fresh weight of the root by the furrow method is always higher than the fresh weight of the root by the drip method. Stikic et al. (2003) by investigation on tomato concluded that root dry weight was higher in full irrigation treatment (control treatment) compared to partial root zone drying of deficit irrigation treatments.

Nourmahnad et al (2006) by investigation two irrigation methods of partial root zone drying (PRD) and regulated deficit irrigation (RDI) and three levels of 75, 100 and 50% of water requirement, they said that the highest length of root, root volume and root dry weight were obtained in control treatment, but the lowest root length was observed in RDI 75 treatment and the lowest root dry weight and root volume in RDI50 treatment.

Molavi et al. (2011) by investigation three treatments of full irrigation, one among fixed and one among variables of furrow irrigation on tomato plants they said that the effect of root length and root dry weight was significant at 1% level. The highest root length and root dry weight were observed in full irrigation treatments and the lowest in one among variables treatment.

2. Material and Methods

In order to investigate the effect of regulated deficit irrigation (RDI) and partial root zone drying (PRD) on greenhouse tomato plants in a hydroponic culture system, an experiment was carried out in 2016 with three levels of irrigation of 100, 85 and 70% of plant water requirement with Four replications at the greenhouse of the Faculty of Agriculture, Shahid Chamran University of Ahvaz, with a geographical range of 31 degrees, 18 minutes and 22 seconds north latitude, 48 degrees and 39 minutes 30 seconds Eastern length and 18 meters above sea level. This experiment was conducted in a completely randomized design. The planting method was manual. The spacing of the rows was 100 cm and the distance between the pots was 50 cm. 52 vases were prepared in a volume of 9.8 liters and a pot was planted per plant. To plant the seeds in the tray, we first mixed the peatmoss with water and then placed in the tray. We put 105 tomato seeds of Valora variety in tray cavities at a depth of 4 to 5 mm of soil surface. In this study, Peatmoss was used for tomato plants.

To prepare the pots we wanted to apply PRD treatment on them, aluminum sheet was used to divide the pot into two equal parts. The aluminum sheet was placed in the direction of a small oval diameter and placed at a distance of 5 cm above the pot. This spacing of 5 cm was considered for planting and its root in the potted soil. After complete preparation of the pots, the peatmass bed, well combined with water was placed inside the pots. Irrigation system of the treatments was carried out using drip irrigation. Pipes from the reservoir up to the beginning of the lateral tubes of polyethylene and 0.75 in diameter, as well as lateral tubes were made of polyethylene and 16 mm in diameter. To provide the required power for transferring water, using a pump with a power of 0.5 horsepower. Also, partial root zone drying (PRD) treatments were used from two lateral tubes that each of the laterals, irrigated one side of the plant and alternately and daily, a lateral opening and irrigation was performed, while the other lateral was closed, and the next day it was transported and the other lateral, irrigation was carried out.

The water requirement of the plant was determined by measuring the evaporation rate from the class A evaporation pan located in the greenhouse and multiplying it at the plant shadow area. Solubility round was set using the timer. Due to the very low storage capacity of bed Cultivate, the irrigation was done 12 times a day. To feed the plants, the nutrient solution was used (Table 1), which contains macro and micro nutrients for plant growth which is presented in the table, name and concentration of the elements. It was used to prepare a solution of urban water with EC = 1.8 ms / cm. After the end of the growth period, Indicators such as root fresh weight, root dry weight, root water content, root volume, root length and root width were measured.

3. Results and Discussions

Data was analyzed using SPSS16.0 software. In this study, analysis of variance and Duncan tests were used to compare the studied traits. In the tables for analysis of variance, the two groups are as follows for comparison of the traits: Group 1: partial root zone drying (PRD) and regulated deficit irrigation (RDI) treatments at 85% level of plant water requirement (PRD85 and RDI85). Group 2: partial root zone drying (PRD) and and regulated deficit irrigation (RDI) treatments at 70% level of plant water requirement (PRD70 and RDI70).

Table 1 - Nutrition Solution of Resh

High Consumption elements	Element concentration (ppm)	Low Consumption elements	Element concentration (ppm)
N	140	Mn	0.8
P	50	Cu	0.07
K	325	Zn	0.1
Mg	50	B	0.3
Ca	180	Mo	0.03
S	168	Fe	20

Root volume

Among treatments and in group 1 (PRD85 and RDI85), root volume had a significant difference at 1% level, but there was no significant difference in group 2 (PRD70 and RDI70). The highest root volume in control treatment was observed at 110 cubic centimeters. Also, the lowest amount of root volume in RDI85 treatment was observed at 70 cubic centimeters, which shows a decrease of 36% compared to control treatment. In group comparisons, at a level of 85% of the plant's water requirement, partial root zone drying (PRD) treatment produced more root volume than regulated deficit irrigation (RDI) treatment (107.5 and 70 cubic centimeters respectively). By decreasing the amount of irrigation water up to level of 70% of the plant's water requirement partial root zone drying (PRD) treatment increased the root volume than regulated deficit irrigation (RDI) treatment (95 and 80 cubic centimeters respectively).

Noormahnad et al. (2006) believed that the cause of root increase in partial root zone drying (PRD) treatments rather than regulated deficit irrigation (RDI) may be due to the fact that in this type of deficit irrigation the same amount of water has infiltration in less volume of soil, therefore, they can moisturize the more depth of soil than ordinary irrigation at each irrigation, and according to the theory that in each part of the soil, where water exists, the root grows at the same point, and that's the reason in treatments with higher levels of water, more root can be produced.

Root fresh weight

Root fresh weight was significantly different between treatments and in group 1 with 99% confidence, but no significant differences were observed in group 2. Accordingly, the highest fresh weight of the roots was measured in the control treatment at 116.68 gr. Also, the lowest value was observed in RDI85 treatment at 77.20 g, which shows a decrease of 34% compared to control treatment. In group comparisons, with a 15% reduction in irrigation water volume compared to control treatment, partial root zone drying (PRD) treatment produces a higher root fresh weight than regulated deficit irrigation (RDI) treatment (respectively, 113/65 and 77/20 g). By decreasing the volume of irrigation water by 30% compared to the control treatment, partial root zone drying (PRD) treatment again increased more root fresh weight than the regulated deficit irrigation (RDI) treatment (respectively, 107/20 and 92/07 g). Haghighi (2010) reported that application of partial root zone drying (PRD) method compared to conventional irrigation method, produces less root fresh weight, which does not conform to the results ofthisresearch.

Table 2 - Analysis of variance of the indicators measured

Sources of changes	df	Root volume	Root fresh weight	Root dry weight	root water content	Root length	Root width
Treatment	4	1200**	1089/61**	20/76**	832/17**	68/57*	21/93**
Group 1	1	2812/50**	2657/20**	50**	1987/20**	231/12*	8 n.s
Group 2	1	450 n.s	457/53 n.s	0/10 n.s	471/24**	2 n.s	19/53 n.s
Error	15	131/66	191/32	3/72	148/88	21/80	2/61
c.v		20/41	19/24	21/36	19/29	11/62	17/98

ns: is not statistically significant, **: significant at the one percent level, *: significant at the five percent level

Table 3 – Comparison of root meanings with Duncan test

Treatment	Root volume (cm^3)	Root fresh weight (g)	Root dry weight (g)	root water content (cm^3)	Root length (g)	Root width (g)
Control	110^{a}	116/68^{a}	15/22^{a}	101/45^{a}	46/25^{ab}	17/5^{a}
PRD 85	107/5^{a}	113/65^{a}	14/45^{a}	99/20^{a}	53/25^{b}	13/75^{bc}
RDI 85	70^{c}	77/20^{b}	9/45^{b}	67/75^{b}	42/5^{a}	11/75^{c}
PRD 70	95^{ab}	107/20^{ab}	11/97^{ab}	95/22^{a}	49/5^{ab}	16^{ab}
RDI 70	80^{bc}	92/07^{ab}	12/20^{ab}	79/87^{ab}	50/5^{ab}	12/87^{bc}

Treatments with at least one common letter are not have a significant difference

Root dry weight

Root dry weight was significantly different between treatments and in group 1 at 1% level, but no significant differences were observed in group 2. The highest root dry weight (15.22 g) was observed in the control treatment and the lowest value was 9.95 g in RDI70 treatment, which showed a 38% reduction compared to the control treatment. In group comparisons, by decreasing the irrigation water volume to 85% of the plant's water requirement, partial root zone drying (PRD) treatment has a higher root dry weight than the regulated deficit irrigation (RDI) treatment (respectively, 14.45 and 9.45 g). but with a further reduction of irrigation water volume to 70% of the water requirement of the plant, the regulated deficit irrigation (RDI) treatment provides more root dry weight than partial root zone drying (PRD) treatment (12.20 and 11.97 g, respectively). Mohammadi et al. (2011) they said that increasing drought stress leads to a reduction in the dry weight of tomato roots, which is consistent with the results of this study.

Root water content

Among treatments and in group 1, root water content had a significant difference at 1% level, but in group 2, no significant difference was observed between the two treatments. The highest root water content was measured in control treatment at a rate of 101.45 cc. Also, the lowest value was observed in RDI85 at 67.75 cc, which shows a 33% reduction compared to the control treatment. in group 1, partial root zone drying (PRD) treatment maintains more water in the root than the regulated deficit irrigation (RDI) treatment (99.20 and 67.75 cc respectively). Also, in group 2, partial root zone drying (PRD) treatment maintains more water volume in the root than regulated deficit irrigation (RDI) treatment (95.22 and 79.87 cc respectively).

Root length

In the study of the effects of different levels of irrigation on root length, according to Table 3 in Group 1, partial root zone drying (PRD) treatment has a larger root length than regulated deficit irrigation (RDI) treatment (respectively, 53.25 and 42.5 cm), which each treatment is ranked in a group and means that they have a significant difference in the level of 5%, but in the group 2, regulated deficit irrigation (RDI) treatment has a greater root length than partial root zone drying (PRD) treatment (50.5 and 49.5 cm respectively), both of which are ranked in the same group, which means that there is no significant difference between treatments in this group. In between treatments, root length had a significant difference at 5% level. The highest root length was observed in PRD85 treatment at 53.25 centimeters, which shows a 15% increase compared to control treatment. Also, the least amount of root length was measured at 42.5 cm in RDI85 treatment, which showed a decrease of 8% compared to control treatment. Noormahnad et al. (2006) stated that deficit irrigation has a significant effect on root length of tomato plant that is consistent with the results of this study.

Root width

Root width was significantly different between treatments at 1% level, but no significant difference was observed in groups. Maximum root width was observed in control treatment at 17.5 cm. Also, the lowest value was measured in RDI85 at a rate of 11.75 cm, which showed a decrease of 33% compared to control treatment. In group comparisons, at a level of 85% of the plant's water requirement, partial root zone drying (PRD) treatment has a higher root width than the regulated deficit irrigation (RDI) treatment (13.75 and 11.75 cm respectively). Also, at 70% level of plant water requirement, partial root zone drying (PRD) treatment has more root width than regulated deficit irrigation (RDI) treatment (16 and 12.87 centimeters, respectively).

4. Conclusion

In this research, the effect of partial root zone drying (PRD) and regulated deficit irrigation (RDI) on greenhouse tomato root components was investigated in hydroponic culture. The results showed that fresh and dry weight of root, root water content, root volume and root width were highest in control treatment, which seems to be the best method for making root components of tomato. If we apply low irrigation, by decreasing irrigation water volume to 85% and 70% of the water requirement of the plant, partial root zone drying (PRD) treatment produces more root components than the regulated deficit irrigation (RDI) treatment.

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