Investigating the effect of partial root zone drying (PRD) and regulated deficit irrigation (RDI) on tomato leaf components 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 methods and different levels of deficit irrigation on indicators of fresh weight of leaves, dry weight of leaves, leaves water content, leaf area index (LAI), specific leaf area (SLA), leaf area ratio (LAR) and leaf number does not have a significant effect. The highest leaf components was observed in PRD85 treatments and the lowest in PRD70 treatments. According to the results, PRD85 treatment seems to be the best treatment for the formation of tomato leaves in hydroponic culture.
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1. Introduction

With the increase in population and rising water demand, sustainable water use can also be addressed, which certainly depends on adapting human behavior to the water cycle. In spite of the value and importance of water as a source of life and underpinned by growth and development, in many cases, it is wasting in vain and unknowingly. As long as the water limit was not created or its intensity was not as good as today, the conflict over the owner of water and the creation of moisture stress did not stand. Since water scarcity is the biggest barrier to development, planning to reduce dependency on water will be possible by optimizing water use. Plants with physiological and morphological changes such as decreasing leaf area index, osmotic pressure regulation, torsion and temporary leaf wilting and active absorption of salts by cells, limit the extent and intensity of transpiration, and they deal with dryness (Sepaskhah et al**,** 2006).

Shabani et al. (2009) investigated the effect of water stress on physiological characteristics of rapeseed plant, Licord cultivar. The results showed that water deficit reduced plant height (especially in rainfed treatment), dry weight of plants (especially in continuous water stress treatment in plant growth period), leaf area index, plant water potential, and increase of green plant temperature due to evapotranspiration reduction. Shah Nazari et al. (2007) investigated the effect of partial root zone drying on crop, tuber size and potato plant water consumption in field conditions. The results showed that leaf area index was not significantly different in different treatments. Lak et al. (2006) investigated the effects of water deficit stress on grain yield and corn nitrogen efficiency at different nitrogen and plant densities. The three levels of irrigation treatments were: favorable irrigation, mild drought stress and severe drought stress (respectively irrigation after 30, 40 and 50% of field capacity). The results showed that grain yield, dry matter, leaf area index and relative water content decreased with increasing drought stress. Sepehri et al. (2002) reported that "the phenological stages of corn growth, delayed by the effect of water deficit stress and different amounts of nitrogen consumed. The leaf area index decreases significantly with decreasing soil moisture and available nitrogen.

Rafiei et al. (2009) concluded that mild drought stress in maize plants reduced the area of upper leaves, while drought stress severely reduced the area of all leaves. Also, with increasing drought stress, the number of leaves decreased significantly and from 16 leaves to 15 and 14 leaves. Drought stress, if it occurs before flowering, reduces the corn leaf area, which reduces the absorption of sunlight and decreases yield, and stress after flowering decreases green leaf area durability (LAD). The leaf area index for Uncontrolled treatment was 4/4, and for soft and severe stress treatments it was 3.6 and 2.8, respectively. Grain yield increased linearly with increasing leaf area index. Khoramgah et al. (2008) investigated the effect of deficit irrigation on water use efficiency and grain yield of hybrid 704 corn. The results of this experiment showed that deficit irrigation treatments caused a significant decrease in leaf yield and biological weight of plant organs, which had an effect on the yield components and thereby decreased economic performance.

Sedaghatfar et al. (2011) In order to investigate the effect of shading and irrigation on the growth of tomato, a split plot experiment was conducted in randomized complete block design with three replications and with four levels of shading and three levels of irrigation. Shading treatments were 15%, 30%, 45% and complete sunlight, and irrigation treatments consisted of 60, 80 and 100% of water requirements. The plant's water requirement was calculated using Cropwat software and was placed on the plant by drip irrigation. The results showed that shading up to 15% increased pure metabolism, but increased shadowing reduced its amount. The effect of shading and irrigation on the leaf area index was meaningless. Liu et al. (2006) examined the effect of traditional deficit irrigation (DI) and partial root zone drying (PRD) on the morphology and physiology characteristics of potato plants. 9 days after treatment application, the leaf water potential was the same in all treatments, but 21 days after treatment application, leaf water potential was less in partial root zone drying treatments than traditional deficit irrigation and full irrigation (FI). Both partial root zone drying and deficit irrigation treatments were less biomass and leaf area than full irrigation. The water used in traditional deficit irrigation and partial root zone drying was 37% less than full irrigation.

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.

Measurement of leaf area was done every two weeks by using the ruler, so that the largest length and width of the leaf of the plant were measured and using the equation 1 (Blanco and Folegatti, 2002), the leaf area Calculated:

$$LA = 0.347 \times (L \times W) - 10.7 \quad (1)$$

LA: leaf area (cm^2), L: the largest leaf length (cm) and W: the largest leaf width (cm). The leaf area index (LAI) (the leaf area ratio of the plant to the farm surface occupied by a plant) is calculated using equation 2:

$$LAI = LA / A \quad (2)$$

LAI: leaf area index, LA: leaf area per plant (cm^2) and A: occupied by a plant (cm^2). The specific leaf area (SLA), which is the ratio of leaf area to leaf dry weight, and leaf area ratio (LAR), which is: the leaf area ratio to leaf and stem dry weight, is calculated using the said relationship.

After the end of the growth period, indicators such as leaf fresh weight, leaf dry weight, leaf area content, leaf area index (LAI), special leaf area (SLA), leaf area ratio (LAR) and leaf number were measured.

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

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).

Fresh leaf weight

The fresh weight of the leaf was measured after harvesting. According to Table 2, there was no significant difference between treatments and in comparison groups. The highest fresh weight of leaf was observed in PRD85 treatment at 317.50 g, which shows a 28% increase compared to control treatment. Also, the lowest fresh weight of leaf was measured in PRD70 treatment at 167.5 g, which decreased by 32% compared to control treatment. In group 1, at 85% of the plant's water requirement, partial root zone drying method (PRD) produced more fresh leaf weight, but in group2, at 70% level of plant water requirement, regulated deficit irrigation method (RDI), Created more fresh leaf weight. Probably because of the stress caused by deficit irrigation and partial root zone drying in PRD85 treatment, the plant retains more water volume than the control treatment.

Leaf dry weight

The results showed that leaf dry weight was not significantly different between treatments and in group comparisons. Table 3 shows that the highest leaf dry weight was measured in RDI70 at 34.25 g, which is 20% higher than the control treatment. Also, the lowest value of 20.25 g was observed in PRD70 treatments, which decreased by 29% compared with control treatment.

In group 1, at 85% of the plant's water requirement, partial root zone drying (PRD) treatment was 33.50 gr and the regulated deficit irrigation (RDI) treatment was 32.25, which showed very little difference, but, in group 2, in the level of 70% of the plant's water requirement, the difference between the two irrigation treatments was regulated deficit irrigation and partial root zone drying was increased to 34.25 g and 25.25 g, respectively, indicating a difference of 14 g.

Leaf water content

In the study of the effects of different levels of irrigation on leaf water content, according to Table 3, the highest amount of leaf water was observed in PRD85 treatment at 270.50 cubic centimetres, which shows a 31% increase compared to the control treatment. Also, it lowest was measured in PRD70 treatment at 133.75 cubic centimetres, indicating a 35% reduction compared to control treatment. Both treatments were ranked in a group, which means that there is no significant difference between treatments.

Leaf water content were not significantly different in group comparisons. By decreasing the irrigation water volume by 15% compared to the control treatment, partial root zone drying (PRD) treatment maintained a higher water content than the regulated deficit irrigation (RDI) treatment (respectively, 270.50 and 205.75 cubic centimetres). However, with a further reduction of irrigation water volume by 30% compared to the control treatment, the regulated deficit irrigation treatment (RDI), as compared to partial root zone drying (PRD), maintains greater water volume in the leaf (225 and 133. 75 cubic centimetres respectively).

Leaf Area Index (LAI)

LAI is important in determining the percentage of solar radiation absorbed by each plant. Therefore, affect on plant growth and final yield dry matter (koochak and banayan aval, 1994). Table 2 shows that leaf area index (LAI) is not significantly different between treatments and in group comparisons. According to Table 3, the highest level of leaf area index was observed in PRD85 treatment at 3.48, which shows a 1% increase compared to control treatment. Also, the lowest leaf area index was observed to be 2.58 in PRD70 treatments, which showed a 25% reduction compared to control treatment. In group comparisons, at 85% of plant's water requirement, partial root zone drying (PRD) treatment has a higher leaf area index than a regulated deficit irrigation (RDI) (3.48 and 3.16 respectively). but, in the level of 70% of the plant's water requirement, the regulated deficit irrigation (RDI) treatment produces a higher leaf area index than PRD (3.07 and 2.58, respectively). Cox and Jolliff (1986) stated that in conditions of water stress, LAI is the most sensitive factor among physiological indices in the plant's vegetative stage. Rezaei Estakhrouieye et al. (2012) reported that with decreasing irrigation water volume, the LAI index decreases, which is consistent with the results of thisresearch.

Table 2. Analysis of variance of the indicators measured

Sources of changes	df	Fresh leaf weight	Leaf dry weight	Leaf water content	Leaf Area Index (LAI)	Specific leaf area (SLA)	Leaf Area Ratio (LAR)	Leaf number
Treatment	4	n.s30/12056	n.s37/132	n.s92/9720	n.s524/0	a98/652	n.s71/1752	n.s42/2
Group 1	1	n.s50/8320	n.s12/3	n.s12/453628	n.s205/0	a84/646	n.s99/403	n.s125/0
Group 2	1	n.s23762	n.s392	n.s12/16653	n.s466/0	a37/499	n.s12/3522	n.s125/0
Error	15	20/15368	21/187	28/11425	94/32101658	02/647a	35/1034	61/4
c.v		01/48	55/44	56/50	13/19	54/635a	17/30	43/7

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	Fresh leaf weight (g)	Leaf dry weight (g)	Leaf water content (cm^3)	Leaf Area Index (LAI)	Specific leaf area (SLA) (cm^2/g)	Leaf Area Ratio (LAR) (cm^2/g)	Leaf number
Control	a247	28/50a	205/25a	3/44a	a98/652	a72/116	a29
PRD 85	a50/317	33/50a	270/50a	3/48a	a84/646	a40/134	a27
RDI 85	253a	32/25a	205/75a	3/16a	a37/499	a19/120	a28
PRD 70	167/50a	20/25a	133/75a	2/58a	02/647a	a66/120	27a
RDI 70	276/50a	34/25a	225a	3/07a	54/635a	a69/78	a27

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

Specific leaf area (SLA)

The specific leaf area indicates the thickness of the leaves of the plant. Any value of this attribute is less Indicates the thickness of the leaf. In the study of the effects of different levels of irrigation on the specific leaf area index, according to Table 3, the highest amount of specific leaf area was observed at 652.98 cm^2 / g for control treatment. Also, the lowest level of specific leaf area in RDI85 treatment was observed to be 499.37 cm^2 / g, which showed a 24% decrease compared to control treatment. Both treatments were ranked in a group, which means that there is no significant difference between treatments.

Rezaei Estakhrouieye et al. (2012) reported that the highest specific leaf area was observed in control treatment. Also, the plant under full irrigation has a thinner leaf and plants under drought stress have thicker leaves. Therefore, it can be said that the plant thickens the leaves to cope with drought stress.

There were no significant differences in group comparisons. By decreasing irrigation water volume by 15% compared to control treatment, partial root zone drying (PRD) treatment provides a higher level of specific leaf area than RDI (646.84 and 499.37 cm^2/g, respectively). By decreasing the amount of irrigation water by 30% compared to control treatment, partial root zone drying (PRD) treatment provides a higher level of specific leaf area than RDI (647.02 and 635.54 cm^2 / g, respectively).

Leaf Area Ratio (LAR)

There was no significant difference in leaf area ratio index between treatments and in group comparisons. The highest leaf area ratio in PRD85 treatment was observed at 134.40 cm2 / g, which shows a 15% increase compared to control treatment.

Also, the lowest rate in RDI70 was measured at 78.69 cm2 / g, which shows a decrease of 32% compared to control treatment.

In group comparisons, by decreasing irrigation water levels up to 85% of the water requirement of the plant, partial root zonedrying (PRD) treatment produces a higher leaf area ratio than the regulated deficit irrigation (RDI) (134.40 and 120.19 cm2 / g, respectively). By decreasing the amount of irrigation water levels up to 70% of the plant's water requirement, unlike previous parameters, partial root zone drying (PRD) treatment again has a greater leaf area ratio than RDI (120.66 and 78.69 cm2 /g, respectively).

Leaf number

According to Table 2, there was a significant difference between treatments and in group comparisons. The highest leaf number in control treatment was observed at 29 leaves. Also, the lowest in PRD85 and PRD70 and RDI70 treatments was observed at 27 leaves, which showed a decrease of 7% compared to control treatment. Mousavi Rahimi et al. (2014) reported the highest number of leaves in tomato plants observed in control treatment, which is consistent with the results of this study. In group comparisons, at a level of 85% of the plant's water requirement, the regulated deficit irrigation (RDI) treatment produces more leaves than partial root zone drying (PRD) treatment (28 and 27 leaves, respectively), but at the level 70% of the water requirement of the plant, no difference was observed in the number of leaves between the two treatments of partial root zone drying (PRD) treatment and regulated deficit irrigation (RDI) treatment (both treatments were 27 leaves). Rezaei Estakhrouieye et al. (2012) reported that reducing the volume of irrigation water, reduces the number of plant leaves that are consistent with the results of the research.

4. Conclusion

In this research, the effect of partial root zone drying (PRD) and regulated deficit irrigation (RDI) on greenhouse tomato leaf components in hydroponic culture was investigated. The results showed that fresh leaf weights, leaf water content, leaf area index (LAI) and leaf area ratio (LAR) had the highest values in PRD85 treatment, while leaf area index (SLA) and leaf number in Control treatments and leaf dry weight were highest in RDI70 treatment. Due to low differences in leaf area (SLA), leaf number and leaf dry weight in PRD85 treatment with the highest amount of this indicator, PRD85 treatment seems to be the best treatment for the development of leaf component indices. At the level of 85% of the plant's water requirement, partial root zone drying (PRD) treatment produces more leaf components than the regulated deficit irrigation (RDI) treatment. but, there is no particular superiority between the two treatments at 70% of the plant's water requirement, and in some indices partial root zone drying (PRD) treatment and in some other indicators, regulated deficit irrigation (RDI) treatment, cause more weight.

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