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Effect of irrigation timing on the eggplant performance under drip irrigation

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ABSTRACT

This study was carried out to evaluate the effect of night irrigation on the eggplant performance with regard to the irrigation adequacy levels and root temperature indicators. The research site was the Agricultural College of Ferdowsi University of Mashhad. Plant irrigation was conducted through drip irrigation and the soil texture was loam according to tests. Experiments were conducted in a randomized complete block design with three treatments and six replications. The results of statistical analysis showed that night irrigation was significant on the crop performance and water use efficiency (WUE) at 5% confidence level. The amount of consumed water in day and night irrigation was equal. However, the night irrigation performance at the levels of adequacy of 100, 75 and 50% was, respectively, 3.77, 3.69 and 3.07 kg in 2012, and 2.50, 1.95 and 1.60 kg in 2013 more than day irrigation. Irrigation timing (night and day) was affected by root temperature difference. In addition, the temperature after day irrigation increased, but decreased in night irrigation.

Key words : Drip irrigation, eggplant performance, night irrigation, SPSS, temperature

INTRODUCTION

Agriculture is one of the most important parts of our society as includes 18% of GDP, 25% of job creation, providing 85% of community food, 25% of non-oil exports, and providing 90% of raw materials used in the industry. Therefore, the growth and development in this sector is the basis of economic, social and industrial progress of the country (Irrigation Association, 2011).

Various factors affect the optimal production of agricultural crops. Among these factors, water is the most important factor that can have a huge impact on the production of crops such as eggplants with optimum management and consumption and providing control solutions. Eggplant is one of the most popular and most used crops due to the variety of consumption in a variety of foods and marinades. The cultivation area of this plant is increased every year and it is cultivated at vast areas. Iran was the fourth country as an eggplant producer in 2010 (FAO, 2010b). Considering the shortage of water in the country and the importance of cultivation in the province as well as the susceptibility of the eggplant to the water shortage compared to other crops and the vast uses of this plant for strategic use during war and famine in the form of conserving, research on the effects of different timing and adequacy level is essential on the performance of this crop.

Inappropriate irrigation time can result in agricultural water shortage, which consequently reduces the performance due to lack of water and nutrients (Ismail *et al.,* 2007). In addition, proper irrigation time is essential for the production quality of many vegetables. Inappropriate time of irrigation reduces the crop performance. Lack of moisture has a negative effect on the quality of production during the growing season, although the whole crop may not be affected.

Determining the proper irrigation time has an effective role in reducing evaporation. For example, night irrigation can improve the performance of the crop, as it allows water to penetrate into the deeper layers of the soil by reducing the amount of evaporation, which

increases the possibility of absorption by the root.

Abd-Zadeh Gohari *et al.* (2015) evaluated the possibility of reducing water consumption in eggplant by using the drip (tape) irrigation system. They determined the appropriate amount of nitrogen fertilizer and its effect on the crop performance. They also determined the production function and vegetation coefficient (Kc) as well as crop sensitivity to the coefficient moisture stress (Ky) in the form of a randomized complete block design with three replications in Astaneh Ashrafieh City in 2010. In this research, the plant height and the root height were not significant in the irrigation management and the crop diameter was not significant in the nitrogen fertilizer management, but the sensitivity of eggplant to irrigation and the amount of fertilizer and their interaction on performance and water use efficiency were significant. Abd Zadeh Gohari and Babaei Baskayei (2011) conducted a split plot experiment in a randomized complete block design with three replications in a field in Astaneh Ashrafieh, East of Guilan province in 2009 to evaluate the performance components of eggplant under different levels of irrigation and nitrogen fertilizer. In this research, the irrigation management was carried out including 12, 6 and 0 days irrigation as the main treatment and nitrogen fertilizer (from source of urea fertilizer) with amounts of 60, 120 and 180 kg N/ha as the sub-treatment. The results showed that the six days irrigation treatment and the fertilizer content of 120 kg/ N/ha with the yield of 12.25 t/ha had maximum yield. In addition, the irrigation management and nitrogen fertilizer had a significant effect on plant height, number of crops per square meter, and crop length and width. Doukkali (1997) evaluated the efficiency of night irrigation and suggested recommendations to improve the available networks.

After studying the design principles and water distribution methods in modern irrigation and drainage networks of the country, he concluded that the flow in the main grid was generally followed a continuous stream with variable flow. The water delivery method in the sub-network is mainly based on a pre-determined program. According to Reddy *et al.* (1994), Wang *et al.* (1995) and Ming (2000), selection of delivery and distribution methods in the primary and secondary network make the night irrigation inevitable in some farms. Warren and Bilderback (2004) and Yeag *et al.* (1997) concluded that the proper irrigation hours to reduce irrigation water evaporation and wind damage could occur in the early hours of the morning before 10 O'clock. On the other hand, Ozawa (1998) showed that night irrigation may be better for the plant, since it further reduces the evaporation of irrigation water and gives the chance to water to penetrate more deeply, which causes increasing the water use efficiency. Yacoubi *et al.* (2014) conducted a study on the effects of day and night irrigation on irrigation performance and tomato performance in Tunisia. Field experiments were performed at the experimental station under two rectangular sprinkler spacings : 24 × 18 m and 18 × 18 m, denoted as plots M_1 and M_2, respectively. Simulation results indicate that night irrigation would greatly improve performance in comparison to day operation : WDEL decreased from 24 to 7%, while irrigation uniformity increased from 50 to 64% in M_1 and from 71 to 80% in M_2. Simulated results showed that night irrigation decreased relative yield losses (from 26 to 16% in M_1 and from 11 to 3% in M_2). Ismail *et al.* (2007) investigated the effect of irrigation frequency and irrigation timing on the water use efficiency and tomato yields by drip irrigation system in greenhouse.

The experiment was conducted in a greenhouse with two irrigation frequencies, 1 and 3 days and three irrigation timings, early morning (8 : 00 h), afternoon (14 : 00 h) and night (20 : 00 h). Soil water content at 0-60 cm and soil temperature at 15 cm depth were measured at 15 cm distance far from dripper by installing TDR sensors and thermocouples, respectively. The results of greenhouse experiment showed that the best irrigation frequency was 3-day with the average yield of 70 t/ha, while 63 t/ha in 1-day frequency. The effect of irrigation timing varied with irrigation frequency. For 3-day frequency, irrigation at early morning was better than afternoon and night irrigations. The average yield for irrigation at early morning was increased by 15 and 14% than irrigation at afternoon and night, respectively. For 1-day frequency irrigation at night increased the yield by 11 and 3% than irrigation at early morning and afternoon correspondingly. Rezvani and Dolati (2014)

conducted a study to evaluate the irrigation system at night using saline water in the warm and dry climatic conditions of Qom province. Since the study area is located in the desert regions, its water has a very high chlorine and sodium with undesirable quality. Nevertheless, the crops are obtained with a good performance due to night sprinkler irrigation for several years. In this research, the factors affecting this action have been considered in order to remove the barriers water resources limitations by spreading sprinkler irrigation and using saline water. Therefore, the present research was aimed at assessing the effect of irrigation timing of the performance of eggplant.

According to the mentioned issues, the present study has investigated the effect of irrigation at different times of the day in 2012 and 2013 on the eggplant performance in the adequacy levels of 50, 75 and 100%. Proper and timely use of water not only reduces water consumption, but also increases the crop yield and under cultivation area.

MATERIALS AND METHODS

This research was carried out on the meteorological site at Ferdowsi University of Mashhad in a land area of approximately 125 square meters. The irrigation water supply source on this site was a well, which transmitted the water through the pipe to the test site and irrigated the test blocks. The project was completed from the preparation of the land to the last stage of harvesting from May to September in 2012 and 2013. The site was sampled three times prior to the implementation of the plan and it was analyzed for determining the physical and chemical characteristics. Some physical and chemical properties of the soil can be seen in Table 1.

Drip irrigation method was used to irrigate the crop. The dimensions of each block were 2.5 × 1.25 m. The length of the irrigation tape was 1.5 m and the distance of the emitters was 30 cm. The discharge of each oven was at a pressure of 0.5 bar and the system operation pressure was 2 liters per hour. Therefore, the row spacing in each block was 0.75 m and three rows were cultivated in each block. The space of plants in each row was 30 cm from each other, and a total of 15 plants per block were tested.

In this research, the effect of irrigation timing (day and night) factors on different levels of adequacy was considered. Accordingly, the experiments were carried out to compare the parameters in two levels of daily irrigation (D_1) and overnight (D_2), as well as irrigation levels of 100% (I_1), 75% (I_2) and 50% (I_3) adequacy levels with six replications in order to investigate the interactions of treatments in a completely randomized block design. The total amount of irrigation water consumption in different treatments at of each six replicates in 2012 and 2013 is presented in Table 2. The collected data were analyzed in the form of a randomized complete block design with three treatments and six replications using SPSS software.

RESULTS AND DISCUSSION

Effect of Irrigation Timing on Eggplant Performance

The effect of different irrigation times (night and day) on the performance of eggplant was investigated according to water consumption in each year. 1_I, I_2 and I_3 are, respectively, the adequacy levels of irrigation water. Figs. 1 and 2 compare the performance of eggplant in terms of kilograms.

As can be seen, the crop performance increases with the constant volume of irrigation water by increasing the level of adequacy. In addition, the crop performance in night irrigation in this case is more than daily

Table 1. Physical and chemical properties of the tested soil

Test No.	pH	EC (dS/m)	Organic carbon (%)	N (%)	P absorbable (mg/kg)	K absorbable (mg/kg)	$CaCO_3$ (%)	Saturation percentage	Soil texture
1	7.5	2.387	0.968	0.074	18.4	240	17.12	32.32	Loam
Balanced limit	6-7	<5	1.5-2	0.1-0.15	25.0	350	<15	35.00	
2	7	1.427	0.825	0.063	15.2	190	16.58	32.32	Loam
Balanced limit	6-7	<5	1.5-2	0.1-0.15	25.0	350	<15	35.00	
3	7.70	2.177	0.592	0.045	2.4	80	18.45	40.84	Clay loam
Balanced limit	6-7	<5	1.5-2	0.1-0.15	25.0	350	<15	35.00	

Table 2. Water consumption (V) during growing season in different irrigation treatments

Treatment	Time	Adequacy levels (%)	Water consumption (V) (cubic meter)	
			1392	1391
I_1	–	100	0.905	0.831
I_2		75	0.679	0.623
I_3		50	0.452	0.415

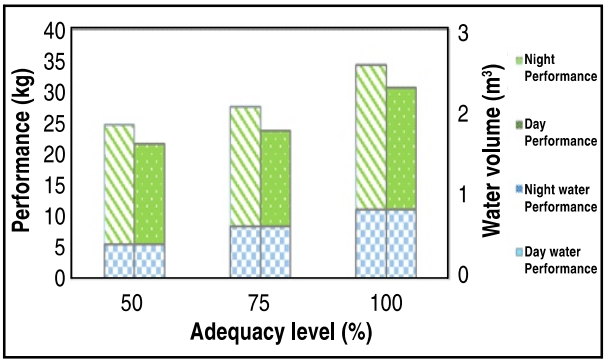

Fig. 1. Comparison of eggplant performance under different irrigation times (daily and nightly) according to the consumed water volume during 2012.

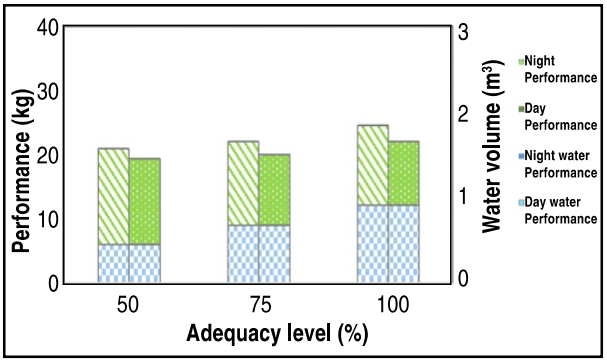

Fig. 2. Comparison of eggplant performance under different irrigation times (daily and nightly) according to the consumed water volume during 2013.

irrigation. Day and night irrigation volume at levels of 100, 75 and 50% was 0.831, 0.623 and 0.415 cubic meters in 2012, and 0.905, 0.672 and 0.452 in 2013, respectively. However, the difference in performance at the levels of adequacy of 100, 75 and 50% was 3.77, 3.69 and 3.07 kg in 2012, and respectively 2.50, 1.95 and 1.60 kg in 2013. In other words, the eggplant performance with night irrigation was 12.3, 15.5 and 14.2% in 2012, and 12, 10 and 8% in 2013 more than day irrigation. Therefore, the performance of the plant increased with the increase of the level of adequacy, but their difference was not necessarily upward. The purpose of statistical analysis in this section is to examine the significance of the difference in the performance of eggplant by analyzing variance at different irrigation times (daily and nightly) and the levels of adequacy on the basis of the recorded data.

The results of analysis of variance and water use efficiency in 2012 and 2013 are presented in Tables 3 and 4. As can be seen, the effect of irrigation adequacy levels in both the years was significant at 5% level on the performance of eggplant. Regarding efficiency, the effect of irrigation levels was significant at 5% level in 2012 and 1% level in 2013. Therefore, the performance results with different levels of irrigation adequacy were significant in both the years. The effect of irrigation timing levels was significant at 1% level on the performance and 5% level efficiency in both the years. In other words, irrigation timing had a significant effect on the

Table 3. Analysis of variance of eggplant performance at different irrigation times (day and night) and adequacy levels in the year 2012

Sources of changes	d. f.	Mean square of performance (kg/ha)	Sig.	Mean square water efficiency (kg/m^3)	Sig.
Block (repeat)	5	668.708^{ns}	0.057	0.036^{ns}	0.105
Adequacy levels	2	5110057.049*	0.019	0.386*	0.013
Error (block)	6	0.11		0.25	
Irrigation time	1	47555756.49**	0.004	0.129*	0.019
Irrigation time × Level of adequacy	2	138496.928*	0.027	0.002*	0.024
Error (block × irrigation time × adequacy level)	10	0.001		0.03	

*,**Indicate non-significant and significant levels at P=0.05 and P=0.01, respectively. NS : Not Significant.

Table 4. Analysis of variance of eggplant performance at different irrigation times (day and night) and adequacy levels in the year 2013

Sources of changes	d. f.	Mean square of performance (kg/ha)	Sig.	Mean square water efficiency (kg/m^3)	Sig.
Block (repeat)	5	756.617^{ns}	0.056	0.107^{ns}	0.234
Adequacy levels	2	4906999.792*	0.034	0.463*	0.007
Error (block)	6	0.09		0.07	
Irrigation time	1	5806464.397**	0.004	0.034*	0.021
Irrigation time × Level of adequacy	2	97957.565*	0.038	0.192*	0.042
Error (block × irrigation time × adequacy level)	10	0.004		0.02	

*,**Indicate non-significant and significant levels at P=0.05 and P=0.01, respectively. NS : Not Significant.

performance of the eggplant. The interaction of irrigation timing and adequacy levels was significant at 5% level on the performance of the plant. The interaction of irrigation volume and adequacy levels was significant at 5% level on the performance of the plant. In terms of efficiency, the interaction of irrigation volume and adequacy levels was significant at 5% level in 2012 and at 1% level in 2013.

Water Use Efficiency

The results of water use efficiency with regard to night and day water irrigation, and the adequacy levels of 100, 75 and 50% are presented in Figs. 3 to 6.

As can be seen in the figures, the water use efficiency was reduced by increasing water requirements every two years, whether in night irrigation or day irrigation. In other words, the efficiency of water consumption at the level of adequacy of 50% was more than 75 and 100%. The highest water use efficiency in 2012 was 2.92 kg per cubic meter of night irrigation with a level of adequacy of 50%. The lowest water use efficiency was 1.82 per cubic meter of day irrigation with a level of adequacy of 100%. The highest water use efficiency in 2013 was 2.29 kg per cubic meter of night irrigation with a level of adequacy of 50%. The lowest water use efficiency was 1.20 per cubic meter of day irrigation with a level of adequacy of 100%. The crop performance was reduced considering the water use efficiency in Figs. 4 and 6 with increasing the level of adequacy, while the performance was increased. In addition, the plant performance and the water use efficiency in night irrigation in both the years were more than day irrigation. The results of statistical analysis of the interactions between irrigation timing (day and night) and the adequacy of

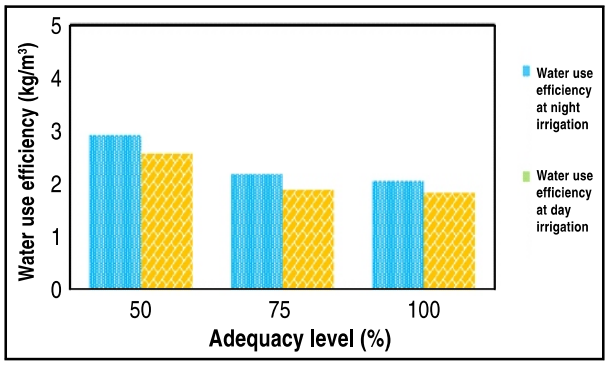

Fig. 3. Comparison of water use efficiency under day and night irrigation during 2012.

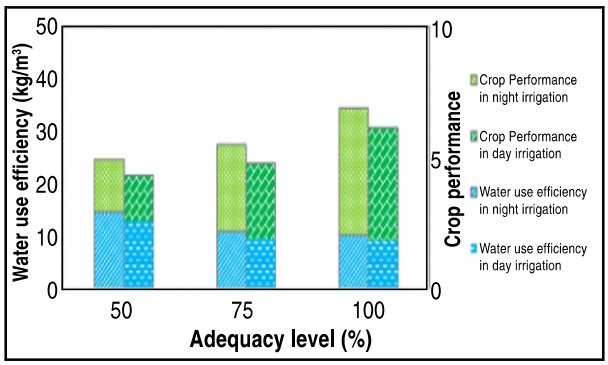

Fig. 4. Performance comparison with respect to water use efficiency in 2012.

irrigation water for both the years are presented in Table 5.

The mean comparison of interactions between irrigation timing (day and night) and the level of irrigation water adequacy is presented in Table 5. In this experiment, the interactions irrigation time (day and night) and irrigation water adequacy level were significant on the plant performance and water use efficiency ($P<0.05$). The highest plant performance in 2012 at the level of 100% adequacy in night irrigation was 37.34 and the lowest plant performance in 2013 at the level of 50% adequacy in day irrigation was 19.4.

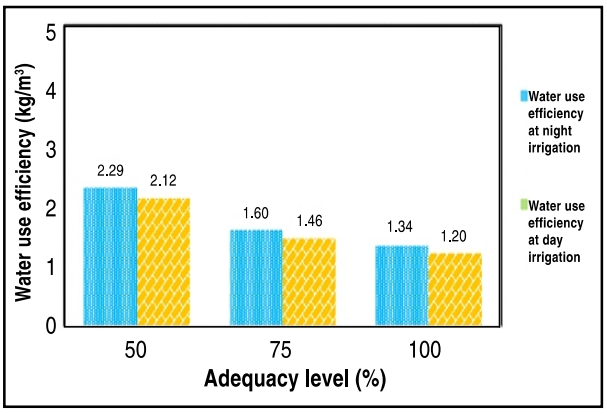

Fig. 5. Comparison of water use efficiency under day and night irrigation in 2013.

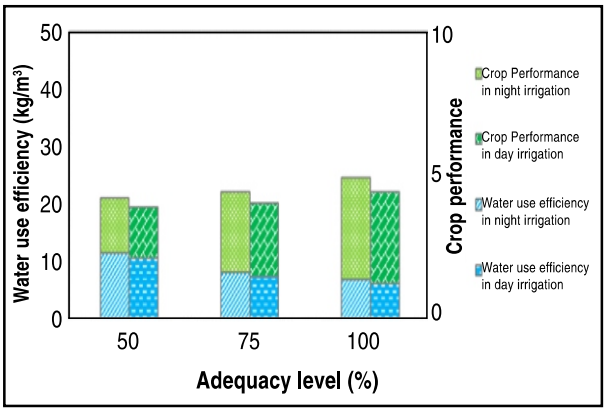

Fig. 6. Performance comparison with respect to water use efficiency during 2013.

The highest water use efficiency in 2012 at the level of 50% adequacy in night irrigation was 2.92 kg/m^3 and the lowest water use efficiency in 2013 at the level of 100% adequacy in day irrigation was 1.20 kg/m^3. With increasing the average water consumption, the crop performance increased but the water use efficiency decreased. The performance and the water use efficiency in 2012 at 50 and 75% levels were not significantly different (P>0.05), but there was a difference at the level of adequacy 100% (P<0.05). This case was true for night irrigation, and the crop performance was only significant at all three levels (P <0.05).

CONCLUSION

The mean comparison of eggplant performance in different harvesting and 100, 75 and 50% adequacy levels at different irrigation timings (nights and days) in 2012 and 2013 indicated that the average weight of the harvested crop in night irrigation was generally more than day irrigation. According to the results, the night irrigation treatments at the level of adequacy of 100%, using 0.831 m^3 of water, and producing 37.34 kg per area in 2012 had the highest performance during the growing season. This was recommended for farmers with no water resources limitation to achieve maximum yield. If there is a limitation of water resources during the growing season, a drip irrigation system at the level of adequacy of 75% is recommended. In 2103, the drip irrigation treatment at the level of adequacy of 100% of night irrigation using 0.905 m^3 of water and producing 24.55 kg per area was better than other treatments. The plant's performance at the level of 75% was also in the next level and it reached its lowest level at the level of 50%. The statistical tests also showed that plant performance in day and night irrigation was significant at different levels of cultivation in both the years. It can be concluded that the results of night irrigation are significant on the plant performance at different levels of irrigation. The results of statistical analyses in 2012 indicated that irrigation timing had a significant relationship with the performance. This was true for the statistical analyses in

Table 5. Mean comparison of the performance and the water use efficiency between irrigation timings (day and night) and the adequacy of irrigation water in 2012 and 2013

Time	Level of adequacy	2012		2013	
		Performance (kg)	Water use efficiency (kg/m^3)	Performance (kg)	Water use efficiency (kg/m^3)
Day	50% water requirement	21.56a	2.25a	19.4a	2.12a
	75% water requirement	23.83a	1.88a	20.05a	1.46a
	100% water requirement	30.60b	1.81b	22.05b	1.20b
Night	50% water requirement	24.64a	2.92a	21.00a	2.29a
	75% water requirement	27.52b	2.18a	22.00a	1.60a
	100% water requirement	37.34c	2.04b	24.55b	1.34b

Figures in a column followed by the same letter are not significantly different at P=0.05 level of significance based on LSD test.

2013. These results are consistent with the results of Bievre *et al.* (2003). Ozawa (1998) also acknowledged that night reduced the amount of irrigation water evaporation, giving it a chance to penetrate more deeply. The results of Ismail *et al.* (2007) were also consistent with the results of this research during a one-day irrigation run. In addition, the results of this research are aligned with the results of Rezvani and Dolati (2014).

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