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Physiological and yield response of almond to different drip irrigation regimes under temperate conditions

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ABSTRACT

An experiment was conducted eight-year-old almond (*Prunus dulcis* Mill.) cv. Shalimar plants to determine the effect of different irrigation levels *vis-à-vis* various phenological stages on growth and yield parameters. The study revealed that irrigation applied at different phenological stages improved yield and yield contributing attributes of almond significantly. Highest nut yield (2.69 kg/tree) was recorded at 100% Etc (I_1) during the first year of experimentation, which rose to the tune of (2.91 kg/tree) at the same irrigation level during the subsequent year. The leaf nutrient status (N, P & K) of almond increased significantly with irrigation. Similarly, the leaf Relative Water Content (RWC) increased significantly with increase in the irrigation level. However, Water Use Efficiency (WUE) decreased with increase in the irrigation level. Maximum WUE (0.60 kg m^{-3}) was observed at 0% ETc (I_0) level of irrigation followed by 50% ETc (I_3) level (0.46 kg m^{-3}), which was statistically at par with 75% ETc (I_2). The highest yield attributes, leaf nutrient concentration and RWC of almond recorded at 100% ETc (I_1) level of irrigation and found to be statistically at par with 75% ETc level, when applied throughout the growth stages.

Key words: Evapo-transpiration, microirrigation, *Prunus dulcis* Mill., regulated deficit irrigation, yield.

INTRODUCTION

Almond (*Prunus dulcis* Mill.) is one of the major and oldest nut tree crops known to the mankind with wide spread popularity throughout the world. Almond is grown mainly for its kernels which are concentrated source of energy rich in fat, protein, various minerals and vitamins. The lack of water resources is one of the major limiting factor of agricultural production particularly in arid and semi-arid regions. The water needs of the fruit trees vary with species and even within species during different stages of the growing season. The areas where water is scarcely available, different strategies are being applied to improve water use efficiency. One of the most promising methods applied in almonds to improve irrigation efficiency has been the application of Regulated Deficit Irrigation (RDI) strategies (Romero *et al.*, 14), reducing applied water in the low water stress sensitivity periods to obtain a beneficial horticultural response. If almond trees are under irrigated during stress sensitive periods, important tree processes get adversely affected. For commercial production, therefore, almond needs to be irrigated during the entire growing season (Goldhamer and Viveros, 7). A very high percentage of almond orchards in India and particularly in the valleys of Kashmir are lacking irrigation facilities and rainfall is the only source of moisture and that very meagre amount of rainfall (about 600-700 mm) coupled with its erratic distribution, which usually is not enough to cater the demands of fruit growth and development and due to which productivity is low. Keeping the above mentioned facts in view, an attempt has been made to study the response of almond cv. Shalimar to various levels of irrigation.

MATERIALS AND METHODS

The present investigation was conducted at Central Institute of Temperate Horticulture (CITH), Srinagar on eight-year-old almond (*Prunus dulcis* Mill.) plantation during 2008-09 to 2009-10. The study was undertaken on cv. Shalimar trees (4 m × 4 m) on soil with sandy loam textural class. The experiment carried out in RBD with four replications, consisting of four different irrigation levels, *viz*., 0% ETc (I_0), 100 % ETc (I_1), 75% ETc (I_2) and 50 % ETc (I_3), applied at four different crop phenological stages of growth and development, *viz*., fruit growth stage (C_1), kernel filling stage (C_2), pre-harvest stage (C_3) and throughout the growth stage (C_4). The irrigation was applied through drip and irrigation scheduling was programmed daily through pressure compensated drippers @ 4 lph discharge capacity per tree depending upon the level of irrigation with respect to ETc. The four drippers were placed equidistant in east, west, north and south direction at 50% distance of canopy radius.

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Crop evapo-transpiration (ETc) was estimated by using evaporation data recorded with the help of locally installed class-A evaporation pan and crop-coefficients (Kc) for mature almond trees, adjusted for canopy size based on orchard floor shaded area. The Kc was taken as 0.38 for the month of March, 0.52 for April-May, 0.60 for June, July, August and 0.54 for the month of September. The daily and monthly weather data was recorded at the meteorological observatory located at Rambagh, Srinagar and pan evaporimeter, installed in the experimental field during the period of study have been depicted in (Table 1). The NPK fertilizers doses were given as per the recommended package of practices during the course of study through urea (750 g), SSP (200 g) and MOP (900 g) per tree. The quantum of irrigation was estimated by following Food and Agriculture Organization (FAO) methodology (Allen *et al*., 1).

Nut yield of almond was recorded after harvesting from each experimental tree and were weighed after having air-dried to 3.8 to 5.2% moisture level and expressed in kg/tree. Leaf nutrient status with regard to N, P and K were recorded from 20 fully matured leaves which were collected in the month of July from each treatment all around the tree. Nutrient estimation for total nitrogen was estimated by micro-Kjeldhal method and results were expressed in per cent nitrogen on the basis of dry weight in leaves. Total phosphorus was determined by vanadomolybdo-phosphoric yellow colour method. Potassium content was estimated by flame photometer and results were expressed in percent. The leaf relative water content, determined as per the normal international standards in vogue. The observations were recorded monthly from 1st week of May to last week of September during the course of study. Water use efficiency was calculated by dividing the yield with the water consumed/depleted through evapo-transpiration and expressed in kg per cubic metre (kg/m^3). The statistical methods described by (Gomez and Gomez, 8) were followed to analyze and interpret the data. The experimental design was RBD and test of significance was made with 5 per cent level. The data clearly depicts that the variation existing in the two year data is because of carry over effect of the irrigation in the consecutive years.

RESULTS AND DISCUSSION

For maximum growth, yield, crop quality and orchard longevity, almond trees should receive a full water requirement. Water stress reduces vegetative growth, causing a subsequent reduction in nut load and yield. Nut size is reduced in the year stress occurs. Thus, irrigation is necessary for enhancing the yield parameters in almond. The present investigation reveals that irrigation improved almond yield significantly (Fig. 1). A significantly higher nut yield (2.42 kg/tree) was recorded at 100% ETc (I_1) as compared to (1.69 kg/tree) at 0% Etc (I_0) in the first year, which rose to the tune of 2.91 kg/tree in the second year. However, the yield obtained at (I_1) irrigation level was statistically at par with yield obtained at 75% Etc (I_2) in both the years. The nut weight, nut size, kernel weight, and kernel size also recorded a significant increase at 100 and 75% ET_C levels of irrigation over 0 and 50% ET_C levels (not

Table 1. Meteorological data (monthly av. values) during the experimental years.

Month	Ist year					2nd year				
	Temp. (°C)		RH (%)	Rainfall (mm)	Evaporation (mm)	Temp.(°C)		RH (%)	Rainfall (mm)	Evaporation (mm)
	Max.	Min.				Max.	Min.			
January	4.84	-2.61	88.35	84.50	6.10	8.20	0.09	92.01	86.50	10.90
February	8.15	-1.86	90.10	102.40	9.00	10.42	1.02	87.21	103.80	13.20
March	18.97	3.76	70.25	2.30	70.00	15.65	3.79	81.93	48.00	56.10
April	19.41	6.28	77.56	114.00	78.20	19.91	6.93	79.30	108.30	88.20
May	24.97	9.73	76.70	39.10	138.20	24.95	8.84	74.26	52.20	124.50
June	29.47	16.45	78.73	29.70	154.70	27.48	11.12	80.35	70.60	136.70
July	29.50	17.24	77.74	84.00	150.00	29.70	14.98	81.64	46.60	165.50
August	29.51	17.78	76.74	45.50	142.90	31.57	16.45	76.41	22.20	170.55
September	26.55	11.25	76.13	30.50	88.60	28.98	10.71	83.76	29.00	119.60
October	22.93	6.91	79.51	32.00	69.40	22.89	3.74	86.16	4.00	74.10
November	14.69	0.37	89.71	57.90	32.14	14.08	0.17	85.03	48.20	34.10
December	9.69	0.20	91.00	51.60	16.70	10.09	-1.08	89.64	15.50	17.75

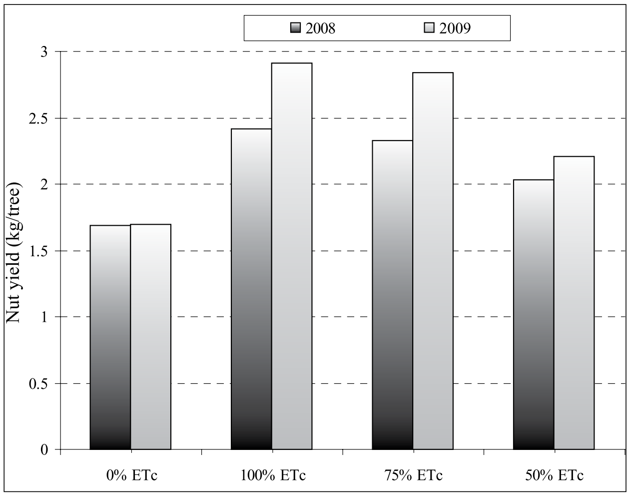

Fig. 1. Effect of irrigation levels on nut yield (kg/tree) in almond cv. Shalimar.

shown), applied at fruit growth and throughout the growth stages. The better performance of the crop at higher evaporation replenishment is probably a result of the better maintenance of internal water balance by the plants and an improved utilization of water and nutrients thereby increasing the amount of carbohydrates available for fruit growth. A significant reduction occurs in leaf photosynthesis of almond when trees were met with partial water requirement (Esparza *et al*., 3). The other possible explanation of low yield at low irrigation levels could be due to the significant reduction in photosynthesis that would result in a lower canopy volume, carbon gain and carbohydrate accumulation, reducing the necessary reserves for shoot growth in the following year. Since, almond besides spurs, bears fruit buds on one year old shoots and that the vigorous shoot growth occurs during early fruit growth stages. Water deficit reduces canopy development and thus decreases yield. The carry over effect of a few consecutive years of deficit irrigation reduces the capacity to accumulate dry matter in the kernel thereby influencing cropping efficiency (Girona *et al*., 5). The present findings are also in line with those of Mousavi and Alimohamadi (12), who observed that deficit irrigation of 40% ET_C level and drought at fruit growth stage significantly reduced fruit size .The significant decrease in almond yield by reducing water to 50% ET_C level and low yield was due to decrease of canopy size and weight of fruit as well as number of flowers (Hutmacher *et al*., 10). Significantly higher yield with irrigation in peach has also been reported by Bryla *et al*. (2), in plum by Naor *et al.* (13) and in tomato by Kaushik *et al*. (11).

As is evident from the (Table 2) the RWC of leaves under various ET_C values registered a significant increase with the increase in the irrigation level. The trees receiving 100% cent ET_C level of irrigation applied throughout the growing season recorded maximum RWC followed by trees receiving irrigation at 75% ET_C level at the same phenological stages, which were statistically at par with each other. The RWC of leaves in trees receiving irrigation at 50 and 0% ET_C levels and when applied during other phenological stages of growth and development was significantly lower. Turgidity of leaves is often associated with higher photosynthetic activity. The present findings are also in conformity with those of Romero *et al*. (14), who reported that RWC of deficit irrigated almond leaves was less as compared to fully irrigated almond leaves. Leaf nutrients of almond showed a significant increase with the increase in irrigation level. The leaf N, P and K contents of almond recorded a significant increase with irrigation applied at various phenological stages of growth and development. In the present study the almond leaves receiving the irrigation at 100% ET_C level recorded maximum concentration of N, P and K contents as

Table 2. Effect of different irrigation levels at various phenological stages on relative water content (%) of almond.

Irrigation / Phenology	Ist year					2nd year				
	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
C_1	78.06	89.72	89.29	83.90	85.24	77.81	89.72	89.20	83.67	85.10
C_2	77.90	88.68	87.63	83.37	84.39	77.68	88.98	87.53	83.16	84.33
C_3	77.32	88.19	87.21	83.32	84.01	77.10	88.39	87.10	83.10	83.92
C_4	77.46	89.86	89.45	84.36	85.28	77.22	89.88	89.41	84.14	85.16
Mean	77.68	89.11	88.40	83.74		77.45	89.24	88.31	83.52	
$CD_{0.05}$	I = 0.92					I = 0.90				
	C = 0.92					C = 0.90				
	I × C = 1.84					I × C = 1.80				

C_1 = Fruit growth stage (April-May); C_2 = Kernel growth stage (1st week of June-1st week of July); C_3 = Pre-harvest stage (1st week of July-Mid August); C_4 = Throughout growth stage (March-September); I_0 = 0 % ETc; I_1 = 100 % ETc; I_2 = 75 % ETc; I_3 = 50 % ETc compared to unirrigated trees (Tables 3, 4 & 5). In fact, the movement of mineral nutrients through the soil to the plant roots is dependent on mass flow of soil solution as a result of water uptake. In contrast, when soil dries, the amount of nutrients to the roots is inhibited, both by difficulty in movement along the soil profile and reduction of mass flow due to stomatal closure, which restricts transpiration.

The aim of economic irrigation is to maximise the financial return per unit of water applied. Water use efficiency was lower with increase in the amount of water applied. Water use efficiency was maximum with 0% ET_C level followed by 50% ET_C, which was statistically at par with 75% ETC level of irrigation (Table 6). This significantly lower water use efficiency in almond at higher evaporation replenishment may have been caused by greater transpiration of trees which did not undergo any water stress. The occurrence of water stress might have reduced transpiration rate because of the inhibitory effect of water stress on stomatal opening. Under dry conditions, irrigation upto 50% ET_C resulted in markedly higher water use efficiency in almond, probably due to increased rate of leaf net CO_2 assimilation and low net transpiration rate. Similarly, the findings of Goldhamer and Beede (6) confirmed that water use efficiency of mature pistachio was significantly higher in regulated deficit irrigation (RDI) regimes as compared to fully irrigated trees. Similar results have also been noted by Garcia *et al.* (4) who recorded higher water use efficiency with regulated deficit irrigation as compared to fully irrigated (control) trees. Significantly higher water use efficiency at low moisture levels in capsicum has also been reported by (Gupta *et al.*, 9). However, Yadukumar and Balasimha (15) did not find any noticeable effect in cashew due to irrigation and interaction effect of irrigation and fertilizer.

Thus, it can be concluded that for commercial production, almond trees need to be irrigated for optimal growth and development during the growing season. Furthermore, irrigation is necessary for

Table 3. Effect of different irrigation levels at various phenological stages on nitrogen content (%) of almond.

Irrigation / Phenology	Ist year					2nd year				
	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
C_1	1.90	2.17	2.08	1.98	2.03	1.88	2.20	2.10	1.99	2.04
C_2	1.88	2.12	2.00	1.95	1.99	1.85	2.16	2.08	1.97	2.01
C_3	1.88	2.10	1.99	1.92	1.97	1.85	2.12	2.05	1.93	1.99
C_4	1.92	2.20	2.15	2.00	2.07	1.90	2.25	2.16	2.08	2.09
Mean	1.89	2.15	2.05	1.96		1.87	2.18	2.09	1.99	
$CD_{0.05}$	I = 0.10 C = 0.10 I × C = 0.20					I = 0.09 C = 0.09 I × C = 0.18				

C_1 = Fruit growth stage (April-May); C_2 = Kernel growth stage (1st week of June-1st week of July); C_3 = Pre-harvest stage (1st week of July-Mid August); C_4 = Throughout growth stage (March-September); I_0 = 0 % ETc; I_1 = 100 % ETc; I_2 = 75 % ETc; I_3 = 50 % ETc

Table 4. Effect of different irrigation levels at various phenological stages on phosphorus content (%) of almond.

Irrigation / Phenology	Ist year					2nd year				
	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
C_1	0.16	0.20	0.19	0.18	0.18	0.15	0.22	0.21	0.20	0.20
C_2	0.16	0.19	0.17	0.17	0.17	0.16	0.19	0.18	0.18	0.18
C_3	0.17	0.18	0.17	0.16	0.17	0.15	0.18	0.18	0.17	0.17
C_4	0.15	0.20	0.20	0.19	0.19	0.16	0.24	0.22	0.20	0.21
Mean	0.16	0.19	0.18	0.17		0.15	0.21	0.20	0.19	
$CD_{0.05}$	I = NS C = NS I × C = NS					I = 0.04 C = 0.04 I × C = 0.08				

C_1 = Fruit growth stage (April-May); C_2 = Kernel growth stage (1st week of June-1st week of July); C_3 = Pre-harvest stage (1st week of July-Mid August); C_4 = Throughout growth stage (March-September); I_0 = 0 % ETc; I_1 = 100 % ETc; I_2 = 75% ETc; I_3 = 50% ETc, NS = Non-significant

Table 5. Effect of different irrigation levels at various phenological stages on potassium content (%) of almond.

Irrigation / Phenology	Ist year					2nd Year				
	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
C_1	1.32	1.60	1.54	1.41	1.47	1.28	1.64	1.58	1.42	1.48
C_2	1.29	1.50	1.46	1.37	1.40	1.25	1.56	1.48	1.39	1.42
C_3	1.32	1.44	1.41	1.34	1.38	1.30	1.50	1.43	1.36	1.40
C_4	1.34	1.62	1.56	1.43	1.49	1.33	1.68	1.60	1.46	1.52
Mean	1.32	1.54	1.49	1.39		1.29	1.59	1.52	1.41	
$CD_{0.05}$	I = 0.09 C = 0.09 I × C = 0.18					I = 0.07 C = 0.07 I × C = 0.14				

C_1 = Fruit growth stage (April-May); C_2 = Kernel growth stage (1st week of June-1st week of July); C_3 = Pre-harvest stage (1st week of July-Mid August); C_4 = Throughout growth stage (March-September); I_0 = 0 % ETc; I_1 = 100 % ETc; I_2 = 75 % ETc; I_3 = 50 % ETc

Table 6. Effect of different irrigation levels at various phenological stages on water use efficiency (kg m^{-3}) of almond.

Irrigation / Phenology	Ist year					2nd year				
	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
C_1	0.59	0.32	0.41	0.47	0.45	0.60	0.31	0.41	0.48	0.45
C_2	0.61	0.31	0.40	0.46	0.44	0.57	0.30	0.40	0.47	0.44
C_3	0.60	0.33	0.38	0.45	0.44	0.60	0.31	0.39	0.46	0.44
C_4	0.60	0.30	0.41	0.48	0.45	0.58	0.32	0.42	0.49	0.45
Mean	0.60	0.31	0.40	0.46		0.59	0.31	0.40	0.48	
$CD_{0.05}$	I = 0.06 C = NS I × C = 0.12					I = 0.08 C = NS I × C = 0.16				

C_1 = Fruit growth stage (April-May); C_2 = Kernel growth stage (1st week of June-1st week of July); C_3 = Pre-harvest stage (1st week of July-Mid August); C_4 = Throughout growth stage (March-September); I_0 = 0% ETc; I_1 = 100% ETc; I_2 = 75% ETc; I_3 = 50% ETc, NS = Non Significant

enhancing the fruiting characteristics of mature almond plantation and for long term productivity. 75% ETc level of irrigation seems to be the best irrigation regime wherein highest yield potential besides a saving of 25% water is achieved.

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REFERENCES

1. Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. 1999. Crop evapotranspiration – Guidelines for computing crop water requirements. *FAO Irrigation and Drainage Paper*, **56**: 22-43.

2. Bryla, D.R., Trout, T.J. and Ayars, J.E. 2003. Growth and production of young peach trees irrigated by furrow, microjet, surface drip or subsurface drip systems. *HortSci.* **38**: 1112-16.

3. Esparza, G., Dejong, T.M., Weinbaum, S.A. and Klein, I. 2001. Effects of irrigation deprivation during the harvest period on the yield determinants in mature almond trees. *Tree Physiol.* **21**: 1073-79.

4. Garcia, J., Romero, P., Botia, P. and Garcia, F. 2004. Cost-benefit analysis of almond orchard under regulated deficit irrigation (RDI) in SE Spain. *Spanish J. Agric. Res.* **2**: 157-65.

5. Girona, J., Mata, M. and Marsal, J. 2005. Regulated deficit irrigation during the kernel filling period and optimal irrigation rates in almond. *Agric. Water Mgmt.* **75**: 152-67.

6. Goldhamer, D.A. and Beede, B.H. 2004. Regulated deficit irrigation effects on yield, nut quality and water use efficiency of mature pistachio trees. *J. Hort. Sci. Biotech.* **79**: 538-45.

7. Goldhamer, D.A. and Viveros, M. 2000. Effects of pre-harvest irrigation cut off durations and post harvest water deprivation on almond tree performance. *Irrig. Sci.* **19**: 125-31.

8. Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research* (2nd Edn.), John Wiley and Sons, New York.

9. Gupta, A.J., Feza, M.A. and Bhat, F.N. 2010. Studies on yield, quality, water and fertilizer use efficiency of capsicum under drip irrigation and fertigation. *Indian J. Hort.* **67**: 213-18.

10. Hutmacher, R.B., Nightingale, H.I., Rolston, D.E., Biggar, J.W., Dale, F., Vail, S.S. and Peters, D. 1994. Growth and yield responses of almond (*Prunus amygdalus*) to trickle irrigation. *Irrig. Sci.* **14**: 117- 26.

11. Kaushik, N., Kaushik, R.A., Kumar, S., Sharma, K.D. and Dhankhar, O.P. 2011. Comparative performance of some agri-silvi-horti systems with drip irrigation under arid regions. *Indian J. Hort*. **68**: 12-17.

12. Mousavi, A. and Alimohamadi, R. 2006. Effects of deficit irrigation and drought during different phenological stages of fruit growth and development in almond production. *Acta Hort.* **726**: 489-94.

13. Naor, A., Peres, M., Greenblat, Y., Gal, Y. and Ben Arie, R. 2004. Effects of pre-harvest irrigation regime and crop level on yield, fruit size distribution and fruit quality of field grown 'Black Amber' Japanese plum. *J. Hort. Sci. Biotech.* **79**: 281-88.

14. Romero, P., Botia, P. and Garcia, F. 2004. Effects of regulated deficit irrigation under subsurface drip irrigation conditions on water relations of mature almond trees. *Pl. Soil*, **260**: 155-68.

15. Yadukumar, N. and Balasimha, D. 2006. Effects of drip irrigation and fertilizer levels on photosynthesis in cashew. *Indian J. Hort*. **63**: 310-15

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