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Response of almond (*Prunus dulcis*) to different drip irrigation levels vis-à-vis various phenological stages on flowering and yield of almond cv. Shalimar*

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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. It is grown mainly for its kernels which are concentrated source of energy, rich in fat (54.0 g), protein (19.0 g), various minerals and vitamins. The kernels and their oil (Rogne-Badam) are known for their medicinal values and are important meteria-medica in Ayurvedic and Unani system of medicine.

Of all the materials used by the fruit trees for growth, water is taken up in the largest amount. The performance of deciduous trees with respect to crop yield, fruit size, fruit quality, storability and long-term productivity are highly dependent on irrigation and different species respond differently to irrigation (Naor 2001).

The lack of water resources is one of the major limiting factor of agricultural production, particularly in arid and semi-arid regions. It has been known for a long time that drought lowers productivity in fruit trees. What is now beginning to be understood is that water use is directly related to productivity even under conditions when the trees are not visibly stressed from drought. 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.* 2004), reducing applied water in the low water stress sensitivity periods to obtain a beneficial horticultural response.

Almond is considered a drought-tolerant plant and is often grown as a rainfed crop (Girona *et al.* 1993). However, drought tolerance does not mean that almond requires little water for optimal growth. The well known drought tolerance of almond refers to its ability to survive under water-stress conditions, but never means that trees will grow normally or have high productivity if irrigated poorly. For commercial production, almond needs to be irrigated during the growing season It has been found that almond trees can utilise water at a fast rate; much faster than any other fruit and nut trees. If almond trees are underirrigated during stress sensitive periods, important tree processes get adversely affected.

A very high percentage of almond orchards in India and particularly in the valley of Kashmir are lacking irrigation facilities and rainfall is the only source of moisture and that very meagre amount of rainfall (about 700 mm) coupled with its erratic distribution (Ahmad *et al* 2010) which usually is not enough to cater to the demands of fruit growth and development and due to which productivity is low. On the other hand, traditional irrigation system, i e flooding is still practised by a majority of orchardists resulting in wastage of a scarce commodity like water besides its ill effects on fruit quality.

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 applied through drip at various phenological stages of growth and development.

The present investigation was conducted at Central Institute of Temperate Horticulture, Srinagar on eight-year old almond (*Prunus dulcis* Mill) plantation during 2008 and 2009. The study was undertaken to determine the effect of different irrigation levels vis-à-vis various phenological stages on flowering and yield of mature almond cv. Shalimar trees, spaced (4m × 4m on soil with sandy loam textural class. The experiment was carried out in RBD with four replications,

*Short note

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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), preharvest stage (C_3) and through out the growth stage (C_4).

The irrigation was applied through drip and irrigation scheduling was programmed daily through pressure compensated drippers @ 4 lph discharge. The four drippers were placed equidistant in east, west, north and south direction at 50% distance of canopy radius. Crop evapotranspiration (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 (Synder and Pruitt 1989, Fereres and Goldhamer 1990). 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 September. The meteorological data with regard to rainfall received and evaporation recorded is presented in Fig 1.

The quantum of irrigation was estimated by using the following equation of Food and Agriculture Organization (FAO) methodology (Allen *et al*. 1999)

$$ETc = \frac{E_{pan} \times K_p \times K_c \times AA \times AC}{IE}$$

Where, ETc = Crop evapotranspiration

E_{pan} = Daily pan evaporation data (mm)

K_c = Crop efficient

K_p = Pan coefficient (taken as 0.8)

AA = Area allotted/plant (m^2)

AC = Area shaded by canopy at noon (%)

IE = Irrigation efficiency of system (85%) taken as decimal

∴ Irrigation amount (litres/tree/day) = [ETc – Effective rainfall]

Bloom intensity and fruit set of each experimental tree which also received post harvest irrigation during the preceeding year was measured on four branches/tree. For bloom intensity each selected branch was located midway up the canopy and 60 cm lengths were monitored (Westwood 1993). Similarly, fruit set was calculated after final drop on the same selected limbs used for estimation of bloom intensity in terms of percentage. Nut yield of almond was recorded after harvesting from each experimental tree and were weighed after air dried to 3.8 to 5.2% moisture level and expressed in kg/tree.

Bloom intensity of almond responded positively to various levels of irrigation, applied at various phenological stages of growth and development. The data presented in Table 1 revealed that bloom intensity and fruit set of almond increased significantly with irrigation. Highest bloom intensities (39.72 and 45.42%) and fruit set (34.45 and 38.36%) were recorded at highest evaporation replenishment (I_1), whereas control recorded lowest bloom intensities (28.31 and 26.02%) and fruit set (19.03 and 15.03 %) during first and second years respectively. The bloom intensity and fruit set recorded at I_2 in both the years was statistically at par

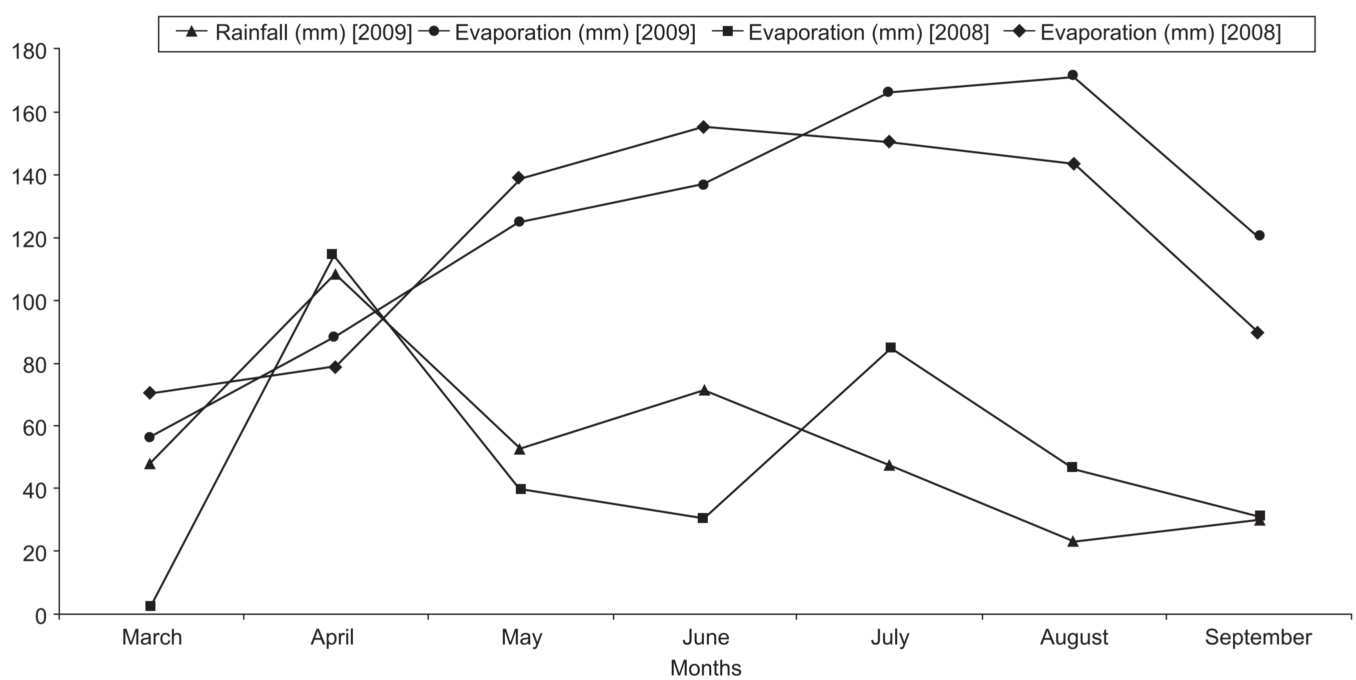

Fig 1 Meterological data (monthly values) during the growing season for the years 2008 and 2009

Table-1 Effect of different irrigation levels at various phenological stages on bloom intensity, fruit set and yield of almond (cv. Shalimar)

Irrigation	Bloom intensity (%)									
	First year					Second year				
Phenology	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
C_1	28.41	40.66	39.56	32.79	35.35	25.87	45.80	45.53	36.69	38.47
C_2	28.10	39.10	38.91	32.53	34.66	26.20	45.08	44.45	36.35	38.00
C_3	28.45	38.13	38.60	32.30	34.37	25.99	44.65	43.86	36.15	37.66
C_4	28.30	40.97	39.88	33.20	35.59	26.01	46.16	45.95	37.23	38.84
Mean	28.31	39.72	39.24	32.70		26.02	45.42	44.95	36.60	
CD (P=0.05)		I = 0.55					I = 0.49			
		C = 0.55					C = 0.49			
		I × C = 1.10					I × C = 0.98			
	Fruit set (%)									
C_1	18.95	34.98	34.62	27.01	28.89	15.05	38.67	38.52	31.63	30.97
C_2	19.05	33.41	33.42	26.94	28.21	15.05	37.92	37.28	30.91	30.29
C_3	19.12	33.39	33.17	26.79	28.12	14.99	37.76	36.96	30.68	30.10
C_4	19.00	36.02	34.79	27.14	29.23	15.03	39.09	38.84	31.78	31.18
Mean	19.03	34.45	34.00	26.97		15.03	38.36	37.90	31.25	
CD (P=0.05)		I = 0.48					I = 0.47			
		C = 0.48					C = 0.47			
		I × C = 0.96					I × C = 0.94			
	Nut yield (kg/tree)									
C_1	1.70	2.48	2.35	2.04	2.14	1.70	2.98	2.92	2.27	2.46
C_2	1.68	2.30	2.27	1.98	2.05	1.70	2.83	2.78	2.12	2.35
C_3	1.66	2.24	2.22	1.88	2.00	1.69	2.74	2.65	2.00	2.27
C_4	1.73	2.68	2.50	2.24	2.29	1.72	3.10	3.00	2.44	2.56
Mean	1.69	2.42	2.33	2.03		1.70	2.91	2.84	2.21	
CD (P=0.05)		I = 0.26					I = 0.28			
		C = 0.26					C = 0.28			
		I × C = 0.52					I × C = 0.56			

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

with bloom intensity and fruit set recorded at I_1 during respective years. Similarly, a significant effect on bloom intensity and fruit set was noticed at various phenological stages. Maximum bloom intensities (35.59 and 38.84%) and fruit set (29.23 and 31.18 %) were recorded at C_4 crop phenological stage during first and second years respectively. However, the bloom intensity and fruit set recorded at C_4 stage were found statistically at par with C_1 stage of crop growth and development in both the years.

The interaction effect of different irrigation levels and phenological stages was found significant on almond bloom intensity and fruit set. Highest bloom intensity (40.97 and 46.16 %) and fruit set (36.02 and 39.09%) were recorded with I_1C_4 during the first and second years of study respectively. However, bloom intensity and fruit set recorded with I_1C_4 in the first year was found at par with I_1C_1 and I_2C_4. Likewise the bloom intensity and fruit set recorded with I_1C_4 during the second year was found to be statistically at par with I_1C_1, I_2C_4 and I_2C_1.

This significant improvement in bloom intensity and fruit set is primarily because of the fact that almond is more sensitive to irrigation at a later stage of season due to the late reproductive bud differentiation and water stress at this stage might result in underdevelopment of primordial flower parts of this nut crop and/or accelerate the emergence of the stamens during bloom, thus decreasing their pollen receptivity. Moisture deprivation at this stage also results in delayed development of flower parts, as reported by Ruiz-Sanchez *et al.* (1988). The present findings clearly reveal that water stress can affect almond orchards not only in the year in which stress occur, but also in the following season. These results are in agreement with the earlier reports of Goldhamer and Viveros (2000). Whereas, increased flower bud density in almond with 100 and 80% ET_C levels of irrigation have been observed. In contrary, the results of Esparza *et al.* (2001) and Romero *et al.* (2004) pointed out that irrigation deprivation had no effect on the percentage of spurs that flowered or set fruit during subsequent years.

The yield of almond also recorded a significant improvement with irrigation applied at various phenological stages of growth and development (Table 1). Maximum yield of 2.42 and 2.91 kg/tree were recorded with 100% ET_C (I_1) level of irrigation, whereas 0% ET_C (I_0) level of irrigation registered lowest yields (1.69 and 1.70 kg/tree) during first and second years, respectively. The maximum nut yield of almond achieved at 100% ET_C (I_1) level of irrigation was found to be statistically at par with 75% ET_C (I_2) level of irrigation in both the years. Similarly, the yield of almond showed a significant difference at various phenological stages of growth and development. Maximum nut yield of 2.29 and 2.56 kg/tree were recorded for C_4 stage, where irrigation was applied throughout the growth stage in the respective years. However, it was found to be statistically at par with that achieved for C_1 and C_2 phenological stages in both the years.

The interaction effect of irrigation and phenological stages also had a significant influence on nut yield of almond. Maximum nut yield of 2.68 and 3.10 kg/tree were obtained with 100% ET_C level of irrigation applied throughout the growth stage (I_1C_4) during first and second years of the study respectively. However, the nut yield obtained with I_1C_1, I_1C_2, I_2C_1 and I_2C_4 were not significantly different from I_1C_4 during respective years.

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 utilisation 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 (Marsal *et al.* 1997, Esparza *et al.* 2001). The other possible explanation of low yield at low irrigation levels could be due to the significant reduction of photosynthesis that would result in a lower canopy volume, carbon gain and carbohydrate accumulation, thus reducing the necessary reserves for shoot growth in the following year (Romero *et al.* 2004, Lampinen *et al* 2007). Similarly, the application of full water requirement throughout the growth stage helps the reproductive bud differentiation to get completed positively, the increase in yield and yield contributing factors at these phenological stages of growth and development with irrigation thus seems to be obvious.Water stress affects more tree and crop development processes during the early season from leafing out through shoot growth and development of terminal and lateral buds. During this period rapid vegetative development is necessary for canopy development and fruiting positions for the following season.(Goldhamer *et al.* 2006) 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 and Marshal 2005). It is therefore concluded that for commercial production, almond need to be irrigated for its optimal growth and development during the growing season. Furthermore, irrigation is necessary for enhancing flowering and fruiting characteristics of mature almond plantation and for long-term productivity. 75% Etc level seems to be the best irrigation level wherein highest yield potential besides a saving of 25% water is achieved. Moreover, flowering and early fruit growth stage of almond seems to be the critical stages of irrigation in almond wherein water stress can adversely affect this nut crop and that the post-harvest irrigation in almond may prove to be beneficial in increasing the subsequent year flowering and fruit set.

SUMMARY

Experiment was conducted to assess the effect of different irrigation levels vis-à-vis various stages of flowering, fruit set and yield of almond (*Prunus dulcis* Mill.) plantation cv. Shalimar. The results revealed that irrigation applied at various stages of growth and development improved flowering, fruit set and yield of almond significantly. Maximum bloom intensity, fruit set and yield were recorded with highest evaporation replenishment of 100 ETc applied throughout the season during first and second year respectively. The study further confirmed that highest flowering and yield attributes of almond recorded at 100% ETc level of irrigation were found to be statistically at par with measured parameters recorded at 75% ETc level of irrigation when applied at fruit growth stage and throughout the growth stage. The results revealed clearly that flowering and early fruit growth stages are the most critical stages of irrigation in almond and that post-harvest irrigation may prove to be beneficial.

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