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Plant growth, nutrient uptake, water use efficiency and yield of pomegranate as affected by irrigation scheduling in loamy soils of semi-arid regions

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ABSTRACT

A field experiment was conducted on loamy soil of National Research Centre on Pomegranate, Solapur, Maharashtra for three consecutive years (2010 to 2013) to assess the water requirement of pre-bearing and bearing plants of pomegranate cv. Bhagwa. The treatments consisted of replenishment of irrigation water equivalent to 30, 40, 50, 60, 70, 80 and 90% of cumulative pan evaporation (CPE) on alternate day laid out in randomized block design with four replications. The results of the study showed that during pre-bearing year, maximum plant growth can be achieved with the application of irrigation equivalent to 60% of CPE, while during bearing period it should be 70% of CPE. In three-year-old plants, maximum fruit yield (6.79 kg/plant) and irrigation efficiency (0.473 t/ha-cm) was observed in 70% CPE treatment. Leaf content of N (2.25%), Cu (124.9 ppm) and Mn (80.7 ppm) was also highest in this treatment. Fruit cracking to the extent of 58.8, 45.3 and 37.7% was recorded from the plants supplied with 30, 40 and 50% of CPE irrigation, respectively which reduced fruit yield drastically.

Key words: Pomegranate, irrigation scheduling, plant growth, fruit yield, nutrient uptake.

INTRODUCTION

For marginal and degraded lands of semi-arid to arid regions, fruit crops like pomegranate (*Punica granatum* L.) assumes greater significance. In India, during last two decades, pomegranate cultivation has registered a high growth due to its hardy nature, export potential, low maintenance cost and good keeping quality and reached to 1.31 lakh ha with an annual production of 13.45 lakh tonnes (Pal *et al*., 12). Majority of the pomegranate cultivation is on undulating, shallow and light textured soils where water scarcity is a major constraint (Marathe *et al*., 11). Hence, it is imperative to adopt holistic strategies to harvest more crop per drop of water. It is reported that pomegranate can tolerate extreme dry conditions but for optimum growth and quality fruit production, irrigation is most essential. Earlier, Lawande and Patil (6) suggested surface irrigation equivalent to 0.8 and 1.0 IW /CPE ratio for fruit yield and vegetative growth, respectively for 'Muskat' pomegranate grown in black soils of Parbhani areas. But nowadays, in almost all the pomegranate orchards, irrigation is being provided through drip-irrigation system and in absence of scientific knowledge about irrigation schedules, farmers have tendency to provide excess irrigation. Application of inappropriate amount of irrigation water especially in light textured soils results into wastage of water through deep percolation or otherwise creating waterlogging, poor aeration and weed infestation (Marathe *et al*., 9). Recently, irrigation equivalent to 100% pan evaporation was suggested for pomegranate, grown under high density planting system (Haneef *et al*., 5). There were few recommendations, on the basis of climatic approach but recommendations on basis of field experimentation is lacking. In this perspective, the present investigation was undertaken to suggest irrigation schedules for pre-bearing and bearing pomegranate cv. Bhagwa orchards grown under semi-arid region of India.

MATERIALS AND METHODS

A field experiment was conducted during 2010 to 2013 at experimental farm of ICAR-NRCP, Solapur, Maharashtra, India. The site lies at 17°65" N latitude and 75°90" E longitude and 457 m above mean sea level receiving average annual rainfall of 472.8 mm. The soil was having loamy texture, 15.8% coarse fragments, montmorillonitic mineralogy, 60 cm deep with pH 7.66, electrical conductivity 0.18 dS/m, organic carbon 0.38% and calcium carbonate 6.24%. The available N, P and K_2O content of surface soil was 190.0, 11.5 and 238.4 kg/ha, respectively. The field capacity (33 kPa) and permanent wilting point (1.5 M Pa) of soil was 24.2 and 13.1%, respectively. Average monthly maximum and minimum temperature during

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the experimental period (January to July) varied from 29.9 to 40.2°C and 15.2 to 25.1°C, respectively. The daily pan evaporation ranged between 3.7 to 19.8 mm.

The experiment was arranged in randomized block design with 4 replications having 2 plants per unit. There were 7 treatments consisting of application of irrigation water equivalent to 30 (T_1), 40 (T_2), 50 (T_3), 60 (T_4), 70 (T_5), 80 (T_6) and 90 (T_7) % of cumulative pan evaporation (CPE). Cumulative irrigation was provided on every alternate day through drip system of irrigation, having four (4 lph) drippers placed on four sides of each plant at a distance of 30 cm during first year and 50 cm afterwards. The crop water requirement of pomegranate crop was computed on daily basis using the following equation.

$$V = E_p \times K_p \times K_c \times S_c \times W_p$$

Where, V = volume of water (litres/ day/ plant), E_p = open pan evaporation (mm/day), K_p = pan coefficient, K_c = crop coefficient, S_c = crop spacing (plant to plant × row to row in metre) and W_p = wetting factor. Irrigation efficiency of drip was considered as 90%. The effective rainfall was calculated by balance sheet method from the actual rainfall received and was used for daily water requirement of crop. Measured quantity of irrigation water was provided to the plants using water meters and separate pipeline for every treatment.

In all the treatments, 150-day-old air-layered saplings of pomegranate cv. Ganesh were planted during January 2009 and maintained by adopting similar cultivation practices. During 2010, various treatments were imposed on one-year-old plant from 10th February to 11th June 2010. Due to severe infestation of bacterial blight disease, as a management practice, plants were cut to ground level during October 2010. All plant debris were literally swept from soil surface of entire farm and disinfected by spraying bleaching powder on the surface. Again plants were allowed to grow and treatments were imposed from December 2011 to June 2012 and again during December 2012 to June 2013.

A representative leaf samples were collected (Marathe and Babu, 7) from individual plants and processed for nutrient analysis. The samples were digested (Chapman and Pratt, 1) in di-acid mixture (H_2SO_4:$HClO_4$ in 1:2.5). Nitrogen was determined by using micro-Kjeldhal steam distillation method, phosphorus by Vanadomolybdo phosphoric acid method, potassium by flame photometer and Ca^{2+} + Mg^{2+} by versenate titration method. All micronutrients (Fe, Zn, Mn and Cu) were determined using atomic absorption spectrophotometer (Perkin Elmer, USA make Analyst 400).

Vegetative growth in terms of plant height and plant spread was recorded in each year. Data on male and hermaphrodite flowers were taken by counting the flowers dropped on the ground and set on plants. The fruit yield data was recorded both in terms of number count and fruit weight basis during the year 2013. Cracked fruits were harvested separately and counted in terms of numbers. Chlorophyll content in the leaves as indicated by SPAD values was measured during 2012 using chlorophyll meter (Konica Minolta SPAD-502). The data obtained were subjected to statistical analysis such as analysis of variance (ANOVA) using online software (WASP 2.0) developed by ICAR Research Complex, Goa.

RESULTS AND DISCUSSION

It was observed that for pomegranate, supplemental irritation is required only during summer season of the year. Accordingly, treatments were imposed during December to June months of the years as per the crop requirements. Quantity of irrigation water applied during the period largely varied from 187.8-563.5, 527.6-1582.7 and 614.7-1844.1 litres / plant, during the year 2010, 2011-12 and 2012-13, respectively (Table 1). Quantity of irrigation water was highest during the month of May followed by April and was lowest in the month of June. It was low during the year 2010 due to low vegetative growth of the plant and increased afterwards with the increase in plant canopy.

Soil moisture content during fruiting period varied from 16.9 to 21.0, 16.0 to 22.1 and 14.9 to 23.0 at 0-15, 15-30 and 30-45 cm vertical depth, respectively amongst different treatments (Table 2). Soil moisture content in 0-15 cm depth showed non-significant variation during all the months, mainly due to evaporation and percolation losses in surface layer. Moisture content was found to increase with the increasing quantity of irrigation water. During most of the period higher soil moisture was recorded in 90% CPE treatment. In 30 and 40% CPE treatments, it was very low in 30-45 cm depth, indicating that the quantity of irrigation water was not sufficient to percolate below 30 cm depth, inducing water stress to the plants.

Per cent increase in plant height and plant spread showed significant variation during all the years (Table 3). During first year (2010) maximum increase in plant height and plant spread was under 60 and 70 CPE treatments, respectively but no fixed trend was observed. During the year 2011-12, highest increase in plant height and plant spread was in 90 and 80% CPE treatments, respectively. The increase might be due to constant supply of ample water to the plant. This maintains the soil moisture at optimum level eliminating water stress to the plants resulted in greater vigor. For optimum plant growth, Lawande

Table 1. Quantity of irrigation water applied to the experimental plants during different years.

Period	Water applied (litres / plant / day)						
	30% CPE	40% CPE	50% CPE	60% CPE	70% CPE	80% CPE	90% CPE
February 2010	0.67	0.90	1.12	1.35	1.57	1.80	2.02
March 2010	1.41	1.88	2.35	2.82	3.29	3.76	4.23
April 2010	1.72	2.29	2.86	3.43	4.01	4.58	5.15
May 2010	1.86	2.48	3.09	3.71	4.33	4.95	5.57
June 2010	0.54	0.72	0.90	1.08	1.26	1.44	1.62
Total during 2010	187.8	250.4	313.1	375.7	438.3	500.9	563.5
December 2011	1.41	1.88	2.35	2.82	3.29	3.76	4.23
January 2012	1.75	2.33	2.91	3.49	4.08	4.66	5.24
February 2012	2.29	3.05	3.82	4.58	5.34	6.10	6.87
March 2012	2.90	3.87	4.84	5.81	6.78	7.75	8.71
April 2012	3.01	4.01	5.01	6.01	7.02	8.02	9.02
May 2012	3.36	4.48	5.60	6.72	7.84	8.96	10.08
June 2012	2.63	3.51	4.39	5.26	6.14	7.02	7.89
Total during 2011-12	527.6	703.4	879.3	1055.2	1231.0	1406.9	1582.7
December 2012	1.93	2.58	3.22	3.86	4.51	5.15	5.80
January 2013	2.19	2.92	3.65	4.38	5.11	5.84	6.57
February 2013	2.60	3.46	4.33	5.19	6.06	6.92	7.79
March 2013	3.22	4.29	5.36	6.43	7.51	8.58	9.65
April 2013	4.50	6.00	7.51	9.01	10.51	12.01	13.51
May 203	4.98	6.64	8.30	9.96	11.62	13.28	14.94
June 2013	2.27	3.03	3.79	4.55	5.30	6.06	6.82
Total during 12-13	614.7	819.6	1024.5	1229.4	1434.3	1639.2	1844.1

Table 2. Moisture content in the root zone of pomegranate as affected by irrigation scheduling treatment.

Treatment	March			April			May		
Soil depth (cm)→	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
30% CPE	16.9	17.5	15.6	17.0	17.5	14.9	16.5	16.5	14.3
40% CPE	17.0	18.0	16.2	16.8	16.5	15.0	17.0	16.0	14.6
50% CPE	17.5	18.8	18.0	17.3	17.0	17.2	16.5	17.2	15.8
60% CPE	18.2	18.4	18.8	18.6	18.9	19.0	17.6	18.4	19.5
70% CPE	18.8	19.5	20.3	19.0	19.5	20.3	18.2	19.2	19.8
80% CPE	19.2	19.8	21.4	18.9	19.8	20.9	18.5	19.0	21.0
90% CPE	20.4	21.4	22.7	21.0	22.0	23.0	20.4	22.1	22.5
CD (p = 0.05)	NS	NS	2.85*	NS	2.82*	3.25*	NS	2.62*	2.01*

NS = Non-significant, *significant at 1% level

and Patil (6) suggested irrigation water equivalent 1.0 IW/CPE ratio for Muskat pomegranate using surface system of irrigation on black soils. During bearing period (2012-13), highest increase in plant height and plant spread was in 80 and 70% CPE treatments, respectively. The statistical analysis showed that significantly at par growth can also be obtained with the application of 60 and 70% of CPE water in pre-bearing and bearing plants, respectively. Plant growth was drastically reduced in 40 and 30% CPE treatments, receiving very less quantity of irrigation.

Table 3. Vegetative growth of pomegranate as affected by irrigation scheduling.

Irrigation level	% increase during 2010		% increase during 2011-12		% increase during 2012-13	
	Plant height	Plant spread	Plant height	Plant spread	Plant height	Plant spread
30% CPE	19.4	27.2	14.2	14.7	13.5	17.7
40% CPE	20.0	25.3	13.9	14.3	14.9	18.5
50% CPE	20.9	31.2	17.1	16.7	18.0	20.1
60% CPE	30.2	33.7	17.8	18.0	20.9	25.0
70% CPE	25.5	34.4	17.8	18.4	23.0	31.0
80% CPE	27.0	31.2	17.2	19.4	23.4	27.9
90% CPE	24.2	28.6	18.0	19.0	21.9	27.5
CD (p = 0.05)	4.69*	4.05*	1.86*	1.66	3.05*	2.35*

NS = Non-significant, *significant at 1% level

The scheduling of irrigation had marked effect on major (N and K) and micro (Cu and Mn) nutrient contents in the leaves (Table 4). The leaf N, Cu and Mn contents was significantly higher with the application of 70% CPE irrigation water. Moderate level of irrigation water might have maintained good aeration and sufficient moisture content in soil, which resulted in higher uptake of these nutrients by the plants. Leaf K content was highest in 90% CPE treatment. The increased nutrient content due to higher moisture content in mulching treatment was reported by Chattopadhyaya and Patra (3) in pomegranate. Significantly lowest contents of N and K were recorded in 30% CPE treatment due to lack of sufficient moisture required for nutrient absorption. This finding is in close conformity with the findings of Marathe *et al.* (8) who reported decreased uptake of N, P, K and Fe in pomegranate with low moisture contend in higher irrigation interval treatments.

The leaf chlorophyll content was highest in 80% CPE followed by 90% CPE treatment (Fig. 1), indicating better photosynthetic capacity of the plants. This might be due to better nutrient uptake and ample water availability to the plants. Lowest chlorophyll content was recorded in 30% CPE treatment due stress conditions of the plant. Leaf temperature recorded during different period of fruit development increased with the increase in ambient temperature (Fig. 2). It was highest in the May followed by April and March. Minimum leaf temperature was in 70 to 90% CPE treatments receiving higher quantity of irrigation water. Cool canopy was found to be an important physiological principle for tolerance to high temperature stress. During all the months, higher leaf temperature was recorded in 30% CPE followed by 40% CPE treatments, indicating maximum stress conditions. As soil water becomes limited, transpiration got reduced and leaf temperature increased.

Number of hermaphrodite flowers were significantly highest in the plants supplied with 30% CPE followed by 50% CPE irrigation (Table 5). In general, flowering intensity increased with decreasing quantity of irrigation water. This indicated that moisture

Table 4. Leaf nutrient content of pomegranate as affected by irrigation scheduling.

Irrigation level	Macronutrient (%)					Micronutrient (ppm)			
	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
30% CPE	1.86	0.146	0.49	2.06	0.57	106.6	28.3	115.6	78.2
40% CPE	2.09	0.147	0.55	2.21	0.50	109.1	29.7	119.9	70.5
50% CPE	2.15	0.158	0.61	2.19	0.50	105.8	27.6	123.0	66.7
60% CPE	2.19	0.159	0.65	2.38	0.59	105.2	28.1	129.3	60.3
70% CPE	2.25	0.148	0.63	2.00	0.49	124.9	27.9	118.1	80.7
80% CPE	2.11	0.155	0.64	2.19	0.53	119.7	28.7	112.3	70.5
90% CPE	2.06	0.144	0.67	1.81	0.61	109.3	28.8	114.3	72.5
CD (p = 0.05)	0.15*	NS	0.07*	NS	NS	13.1	NS	NS	8.7*

NS = Non-significant, *significant at 1% level

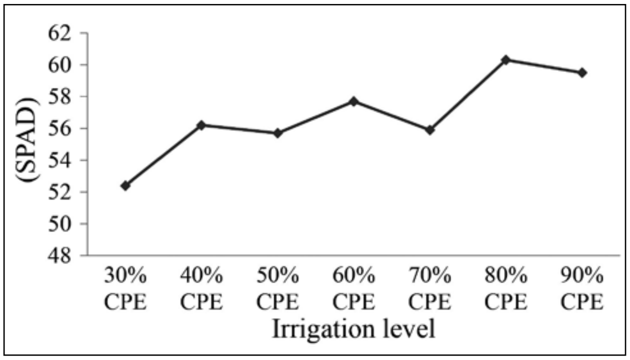

Fig. 1. Leaf chlorophyll content (SPAD) as affected by irrigation scheduling.

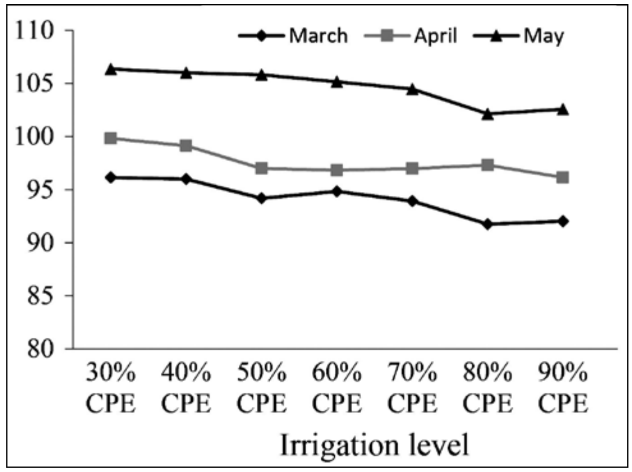

Fig. 2. Leaf temperature (°F) during different months as affected by irrigation scheduling.

stress encouraged reproductive phase, *i.e.* flowering intensity, might be due to the assimilation of more carbohydrates during moisture stress. The present findings are in conformity with the findings of Sharma *et al*. (13) and Marathe *et al*. (10) who reported that soil moisture deficit promotes early and more intense flowering in mango and Nagpur mandarin, respectively.

Fruit yield in terms of number and weight of the fruits was significantly higher in the plants supplied with irrigation water equivalent to 0.70 CPE followed by 0.80 CPE (Table 5). The increase in yield could be attributed to better plant growth, balanced nutrient uptake, bigger fruit size and least fruit cracking under these treatments. The results are in accordance with the findings of Lawande and Patil (6) who suggested IW/CPE ratio of 0.8 for higher fruit yield of Muskat pomegranate. Drastic reduction in fruit yield was recorded in the plants supplied with 30, 40 and 50% CPE irrigation. In these treatments, fruit cracking was as high as 58.8, 45.3 and 37.7%, respectively. The cracking was mainly due to water stress at the time of fruit maturity. Fruit cracking to the extent of 72% was reported under extreme arid climate of western Rajasthan (Charan, 2). The experimental results revealed that the cracking problem could be overcome by supplying optimum irrigation water equivalent to 70% CPE during fruiting period. Plants supplied with irrigation equivalent to 60 to 90% CPE produced good quality fruits but no fixed trend was observed with regard to different quality parameters (Data not shown). Fruit quality was drastically reduced in the treatments receiving less quantity of irrigation water (30 and 40% CPE) mainly due to shrinkage and cracking of the fruits.

It can be concluded that in light textured soils of semi-arid regions, 5.15, 5.84, 6.92, 8.58, 12.01, 13.28 and 6.06 l of water / day / plant should be provided through drip system of irrigation during the months of December, January, February, March, April, May and June, respectively to the bearing plants (height and canopy spread of 1.95 m). In water scarcity areas, pomegranate can be grown with supplemental irrigation only during summer season. In pre-bearing

Table 5. Flowering, fruit yield and water use efficiency as affected by irrigation scheduling.

Irrigation level	Male flowers/ plant	Hermaphrodite flowers/ plant	No. of fruits (per plant)	Yield (kg/ plant)	Fruit cracking (%)	WUE (t/ha-cm)
30% CPE	235.5	140.3	9.0	1.64	58.8	0.266
40% CPE	224.5	128.0	12.0	2.29	45.3	0.280
50% CPE	210.0	135.1	15.0	2.91	37.7	0.284
60% CPE	215.1	117.8	28.0	5.27	9.7	0.429
70% CPE	225.0	125.2	35.1	6.79	0.8	0.473
80% CPE	217.9	110.0	33.0	6.53	0.0	0.399
90% CPE	200.0	112.3	31.0	6.48	0.0	0.351
CD (p = 0.05)	NS	10.28*	3.47*	0.44*	2.78*	0.033*

NS = Non-significant, *significant at 1% level periods, variation in quantity of irrigation water do not have much adverse effects on plant growth. It is advisable to make irrigation recommendations on the basis of plant canopy instead of age of the plants.

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