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Improvement of water use efficiency in pomegranate (*Punica granatum*) cv. Bhagwa under micro-irrigation system

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ABSTRACT

A field experiment was conducted to evaluate the effect of different irrigation levels (10 to 50 and 20 to 60%) and mulches (No mulch, dry lawn mulch, dry lawn mulch + hydrogel and hydrogel alone) on growth and yield of Bhagwa pomegranate (*Punica granatum* L.). The actual pomegranate evapotranspiration in l/day/tree was estimated by using the reference crop evapotranspiration, pan coefficient, crop coefficient, wetted area, area occupied by one tree and micro-irrigation efficiency. The study revealed that mulch + hydrogel enhanced vegetative growth and yield contributing characteristics. However, 30 and 40% irrigation levels for three and four years pomegranate plants, respectively, produced results at par with respect to yield attributing traits, quality, juice content and TSS. Based on statistical analysis of vegetative and yield characteristics, it was inferred that the treatment combination comprising of dry lawn mulch + hydrogel and irrigation levels at 30 and 40% with alternate day irrigation resulted into higher yield with good quality fruits as compared to other treatments.

Key words: Pomegranate, Micro-irrigation, Dry mulch, Hydrogel, Water use efficiency

The area under pomegranate (*Punica granatum* L.) in India is increasing at a faster rate due to its hardy nature, low maintenance cost, low water requirement, high yield potential, good keeping quality and versatile adaptability (Singh *et al*. 2015). However, regular irrigation is essential during the different phenological stages as irregular moisture condition causes dropping of flowers and reduction in fruits size (Prasad *et al.* 2003, Meshram *et al.* 2011). The sudden change in soil moisture causes the moisture stress, which affects the fruit development adversely and leads to fruit cracking (Cheema *et al.* 1954).

Since, water resources are limited and depleting continuously, economic and efficient use of water is an essential feature of water management (Patil and Gorantiwar 2009). Success for production of pomegranate largely depends on the timing, quantity and quality of irrigation water used. Irrigation affects the performance of trees through the major mechanisms, i.e. stomatal conductance, assimilation rate, turgor and expansive growth (Lakso 2003). There are several ways of efficiently using water, these includes- appropriate irrigation scheduling, adoption of water saving irrigation methods such as drip, sub-surface drip, mulches and optimum allocation of land water resources. These options are not alternatives to each other but complimentary to each other. Most of these options call for the exact estimation of water requirement that varies with crops, their growth stages, climate, etc. (Michael 2008). In addition, these accurate estimates of evapotranspiration are helpful in proper irrigation planning and management.

Soil moisture in the feeder root zone can be conserved by increasing water holding capacity of the soil, mulching, growing cover crops and use of anti-transpirant and growth retardants. A mulch is a material spread on the ground surface to protect a plant or plant roots. Natural mulches such as dry leaf, straw, dead leaves, sugarcane trash, paddy husk, paddy straw, safflower, wheat straw and plastic mulch (i.e. black, white, pervious, silver and black, red etc.) have been found very effective in conserving soil moisture for minimizing the evaporation losses and maintaining soil temperature (Kar and Kumar 2007). The plastic mulch types are LLDPE, HDPE and flexible PVC mulches are effective in reducing reference crop evapotranspiration (ET_r) as crop coefficient values decrease by an areas of 10-30 % due to the 50-80% reduction in soil evaporation, evapotranspiration, environmental stress coefficient, etc. (Singh *et al.* 2003, Seidhom and Abd-El-Rahaman 2011). Considering the above facts, the present investigation was undertaken to study the effect of organic dry (American lawn grass) mulch with hydrogel at five irrigation levels on the yield, quality and water use efficiency of pomegranate cv. Bhagwa.

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MATERIALS AND METHODS

The field experiment was conducted at ICAR-National Research Center on Pomegranate Research Farm, Solapur, India during *hasta bahars*. The research farm is located at an altitude of 483.6 m above mean sea level and is intersected by North latitude 17^0 10" and East longitude by 74^0 42". The physical, hydraulic and chemical properties of the soil profile of the experimental site are given in Tables 1 and 2. The details of experiment was laid out with two factors in split plot design with main treatements of five irrigation levels (i.e. Factor B: 0.10 to 0.50 and 0.20 to 0.60 * ET_r of three and four years old pomegranate tree) and sub-treatments of mulch kept as 10 cm layers and 10 g of hydrogel kept at 4 places below drippers (i.e. Factor A: M_0-No mulch, M_1- Dry lawn mulch, M_2- Dry lawn mulch+Hydrogel and M_3-hydrogel). The electrical conductivity and residual sodium carbonate of the irrigation water used was 0.5 dS/m and 2.2 meql, respectively. The drip irrigation system consisted of plastic laterals of 16 mm diameter with on-line pressure compensating drippers at 60 cm distance away from trunk of the trees. The drippers had a discharge rate of 4.00 l/h under an operational pressure of 1.0 kg/cm^2. The irrigation through drip system was applied at alternate day for required time to deliver the calculated quantity of water based on atmospheric demand. The experiment were conducted on light texture soil with standard recommended doze of fertilizers and other management practices.

Daily weather data was collected from Agro-Met Observatory located at the same research farm. The average maximum, minimum temperature, maximum, minimum relative humidity, sunshine hours, wind speed, evaporation and total rainfall were 33.3^{0}C, 20.5^{0}C, 73%, 42%, 7.6 hr, 7.5 kmphr, 6.9 mm and 321.6 mm in *hasta bahar* taking average period of two years from August to April in 2013-2014 and 2014-2015.

The information on water to be applied in L/d/t and time in hours for each pomegranate tree is need to calculated in order to come out with a recommendation. Water to be applied and time of irrigation was estimated on daily basis for the pomegranate trees at 0.10 to 0.50 and 0.20 to 0.60 *ET_r levels for three and four years old pomegranate orchards by using the equation (1), (2) and (3).

$$WR = \frac{(ETr \times kc \times kpan \times A \times WA)}{IE} \quad (1)$$

where, WR - Water requirement, L/d/t; ET_r — Reference crop evapotranspiration, mm; k_c — Crop coefficient, fraction; k_{pan} — Pan coefficient, fraction; WA- Wetted area, fraction; A = Area occupied by each tree, m^2; IE = Irrigtion efficiency of the drip irrigation system (fraction).

$$IT = \frac{WR}{DC} \quad (2)$$

where, IT —Irrigation time (hr);WR— Water requirement (L/d/t); DC-Dripper discharge capacity (L/hr).

The Penman-Monteith method has strong likelihood

Table 1 Effect of mulching and irrigation levels on morphological parameters in pomegranate during *hasta bahar*

Treatment	Plant height (cm)										LAI									
	3rd year					4th year					3rd year					4th year				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
I_0	173.25	179.00	192.75	183.75	182.18	175.75	182.50	202.50	190.50	187.81	2.22	1.92	2.43	1.98	2.14	2.36	2.31	2.67	2.19	2.38
I_1	165.75	183.25	197.00	189.75	183.93	168.50	187.50	202.75	197.75	189.12	2.39	2.62	2.55	2.22	2.45	2.65	2.68	3.39	2.91	2.91
I_2	209.00	211.50	215.50	211.25	211.81	211.75	213.25	217.25	212.00	213.56	2.29	2.66	3.32	2.99	2.81	2.45	3.07	3.69	3.65	3.22
I_3	180.75	180.75	212.25	184.00	189.43	173.00	174.25	218.00	196.25	190.37	2.23	2.45	3.66	3.13	2.87	2.40	2.81	3.88	3.72	3.20
I_4	176.00	172.75	204.50	181.25	183.62	178.75	177.75	218.25	192.25	191.75	2.17	2.67	3.72	3.43	2.99	2.40	2.65	3.91	3.60	3.14
Mean	180.95	185.45	204.4	190.00		181.55	187.05	211.75	197.75		2.26	2.46	3.14	2.75		2.45	2.70	3.51	3.21	
CD	Irrigation=9.71					Irrigation=5.36					Irrigation=0.23					Irrigation=0.28				
(P=0.05)	Mulching=9.30					Mulching=8.59					Mulching=0.22					Mulching=0.22				
	Irrigation × Mulching=20.78					Irrigation × Mulching=19.22					Irrigation × Mulching=0.50					Irrigation × Mulching = 0.48				

I_0 - I_4: 10 to 0.50 * ET_r for 3rd year tree and I_0 - I_4: 0.20 to 0.60 * ET_r for 4th year tree

Table 2 Effect of mulching and irrigation levels on fruit quantitative parameters in pomegranate during *hasta bahar*

Treatment	No. of fruits/plant										Fruit wt (g)									
	3rd year					4th year					3rd year					4th year				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
I_0	66.25	38.50	81.00	40.00	56.44	62.50	43.00	59.50	67.25	58.06	292.50	301.25	332.50	328.25	313.62	272.25	275.00	317.50	277.00	285.43
I_1	36.25	42.25	48.50	48.25	43.81	36.00	60.75	74.25	51.75	55.69	276.50	316.25	338.75	330.00	315.37	271.50	297.50	352.00	303.75	306.18
I_2	71.00	71.75	76.25	72.75	72.94	72.50	75.25	79.50	71.25	74.63	320.25	326.00	368.75	320.75	333.93	312.50	319.75	363.25	330.00	331.38
I_3	35.50	37.00	53.00	73.25	49.69	39.25	39.50	73.75	59.50	53.00	304.00	265.00	341.25	375.75	321.50	279.25	272.00	345.00	302.50	299.68
I_4	36.00	45.25	44.75	43.00	42.25	40.00	50.00	76.75	55.00	55.44	290.75	272.50	353.25	310.50	306.75	299.25	272.50	345.00	336.25	313.25
Mean	49.00	46.95	60.70	55.45		50.05	53.70	72.75	60.95		296.8	296.2	346.9	333.00		286.90	287.30	344.50	309.90	
CD	Irrigation=10.47					Irrigation=10.25					Irrigation=29.50					Irrigation=25.35				
(P=0.05)	Mulching=10.21					Mulching=12.62					Mulching=24.90					Mulching=24.20				
	Irrigation × Mulching =22.82					Irrigation × Mulching=28.23					Irrigation × Mulching=55.68					Irrigation × Mulching=54.11				

I_0 - I_4: 10 to 0.50 * ET_r for 3rd year tree and I_0 - I_4: 0.20 to 0.60 * ET_r for 4th year tree

of correctly predicting ET_r in a wide range of location and climates (Allen *et al.* 1998). The daily values of reference ET_r were estimated by equation (3).

$$ET_r = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e_a)}{\Delta + \gamma(1+0.34u_2)} \quad (3)$$

where, ET_r = Reference crop evapotranspiration (mm/day); G = Soil heat flux density ($MJ/m^2/day$); R_n = Net radiation ($MJ/m^2/day$); T = Mean daily air temperature (^0C); γ = Psychometric constant (kPa^0C^{-1}); Δ = Slope of saturation vapour pressure function (kPa^0C^{-1}); e_s = Saturation vapour pressure at air temperature T (kPa); e_a= Actual vapour pressure at dew point temperature (kPa); u_2= Average daily wind speed at 2 m height (m/sec).

The other parameters, i.e. crop coefficient (k_c), pan coefficient (k_p), wetted area (WA) and irrigation efficiency (IE) were used for estimating water requirement (L/d/t) of pomegranate (Gorantiwar *et al.* 2011). For computation of water use efficiency (WUE), the fresh fruit yield/ha were divided by the water expense and expressed as kg/ha/L.

RESULTS AND DISCUSSION

The daily climatic data of 484 days (i.e. August, 2013 to April, 2015) at the experimental site of ICAR-NRCP, Solapur were analyzed on daily basis for estimating reference crop evapotranspiration (ET_r) by using Penman-Monteith method. The average of two *hasta bahars* monthly values of ET_r by Penman-Monteith method are shown in Fig 1. It is revealed that the trend of the estimated ET_r values over this period were different due to variation in climatic parameters. The water to be applied at different phenological stages for three and four years pomegranate trees (i.e. New leaf initiation period, crop development period, crop maturity and harvesting period) through drip system at 90% irrigation efficiency for *hasta bahar* ranged from 7 to 48 L/d/t. The values in the Fig 1 would be useful for irrigation scheduling of pomegranate by drip irrigation method.

The results revealed that mulch and hyrdogel along with irrigation levels had significant effect on vegetative characteristics namely, plant height and leaf area index (Table 1). Among various irrigation levels, irrigation at 0.30*ET_r for 3rd year and 0.40*ET_r for 4th year produced

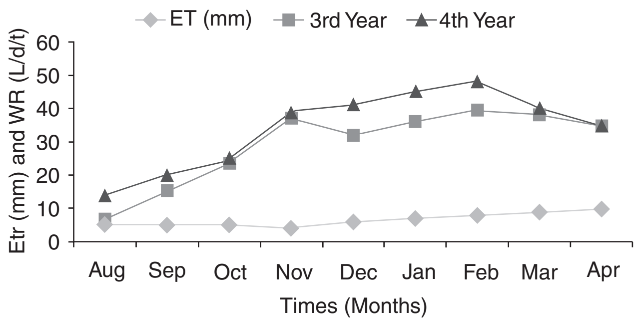

Fig. 1 Average monthly ET_r (mm/day) and water applied to the trees (L/d/t) values during August, 2013 to April, 2015

tallest plants (211.81 and 213.56 cm, respectively). However, independent of irrigation levels dry lawn mulch with hydrogel resulted into plants with significantly better height. It might be due to application of needful irrigation at different phenological stages and good moisture regime in the root zone by application of required quantity of dry lawn mulch with hydrogel resulting into better environment for nutritional uptake by plants. Chauhan and Chandel (2008) while working with kiwifruit found that the leaf nutrient contents and morphological characters were significantly higher under organic mulches as compared to recommended doses of fertilizers.

The favorable influence of I_2 (30% and 40%) on plant height, plant spread (E-W and N-S), leaf area index and leaf nutrient status may be due to optimum moisture in the soil through drip irrigation resulting in greater vigour (Subramanian *et al.* 1997).

It is evident from the Table 2 that dry lawn mulch with hydrogel and irrigation levels had significant effect on the yield attributes. Dry lawn mulch with hydrogel (M_2) and irrigation level (I_2) recorded the maximum number of fruits (79.50 nos.) on 4th year tree, average fruit weight (368.75 and 363.25 g on 3rd and 4th year tree, respectively), yield (14.17 kg/plan). Interestingly, juice contents were at par across the irrigation levels in 3rd and 4th year orchard but 4th year pomegranate tree mulched with organic mulch + hydrogel produced fruits with significantly higher juice content (40.30%). Exactly similar trend was reflected in case of total soluble solids. Drip irrigation at 30 and 40% levels (I_2) recorded better quality parameters because drip irrigation provides a consistent moisture regime in the soil due to which root remains active thoughout the season resulting in optimum availability of nutrients and proper translocation of food materials for accurate fruit growth and development of quality charcters in fruits. The increase in juice content might be because of more absorption of water and minerals of mulch from the soil under the influence resulting into increased juice content (Nath *et al.*1999).

The data revealed that the yield attributing traits responded differently to different quantities of water applied through drip irrigation system having two laterals with four drippers at different irrigation levels during both the *hasta bahars* (Table 2 and 3). The influence of mulch+hydrogel with optimum irrigation on fruit yield is envisaged from the fact that the increment in yield attributing triats (fruit weight and number of fruits) in pomegranate to the tune of about 15-40 % were recorded as compared to no mulch and lower levels of irrigation.

Yield attributing traits were significantaly higher in mulch with hydrogel at 30 and 40% irrigation level for three and four year old pomegranate cv. Bhagwa under micro-irrigation. Based on statistical analysis of vegetative and yield characteristics, the mulch with hydro-gel and irrigation level at 30 and 40% giving alternate day irrigation resulted in higher number of fruits/tree along with increase fruit weight with quality. Henceforth, water management ensure

Table 3 Effect of mulching and irrigation levels on fruit qualitative parameters in pomegranate during *hasta bahars*

T	Juice content (%)								TSS (°Brix)							
	3rd year				4th year				3rd year				4th year			
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
I_0	30.50	35.00	39.50	39.25	36.06	30.00	34.75	40.50	38.00	35.81	15.36	16.54	16.55	16.36	16.20	15.01	16.04	17.00	16.19	16.06
I_1	31.00	34.50	38.25	37.25	35.25	29.50	34.25	40.00	38.00	35.44	14.98	17.12	16.37	16.05	16.13	14.84	17.13	17.52	16.86	16.59
I_2	31.25	33.25	40.00	38.75	35.81	29.00	34.00	39.75	39.50	35.56	15.39	16.68	16.51	16.40	16.25	13.65	16.97	17.53	16.36	16.13
I_3	30.75	34.25	40.25	38.00	35.81	29.75	34.25	41.00	38.50	35.88	15.32	17.59	17.28	17.95	17.03	15.34	16.91	17.50	17.41	16.79
I_4	30.00	33.50	39.00	40.00	35.63	30.25	32.75	40.25	38.75	35.50	15.20	16.86	18.05	16.41	16.63	15.20	16.74	18.30	15.73	16.49
Mean	30.70	34.10	39.40	38.65		29.70	34.00	40.30	38.55		15.25	16.95	16.95	16.63		14.80	16.75	17.57	16.51	
CD	Irrigation=0.94					Irrigation=1.04					Irrigation=0.50					Irrigation=0.72				
(P=0.05)	Mulching=0.88					Mulching=1.11					Mulching=0.47					Mulching=0.68				
	Irrigation × Mulching=1.96					Irrigation × Mulching=2.48					Irrigation × Mulching=1.05					Irrigation × Mulching=1.51				

I_0 - I_4: 10 to 0.50 * ET_r for 3rd year tree and I_0 - I_4: 0.20 to 0.60 * ET_r for 4th year tree.

increased crop yield, high water use efficiency, high water saving, energy consumption and minimal weed problems. It is concluded from the present study that, mulch with hydrogel is the better technological option for improving crop productivity.

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