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Effect of organic mulches on yield, quality and WUE of Pomegranate (*Punica granatum* L.)

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ABSTRACT

A field experiment was carried out during 2013-2014 in *hasta bahar* at Solapur to quantify yield, quality and water use efficiency of pomegranate *cv.* Bhagawa at 4.5 x 4.0 m spacing. Three different types of organic mulches (*i.e.* wheat, sugarcane baggas and safflower) at different irrigation levels (*i.e.* 0.20 to 0.60* ET_0) were evaluated for their effects.

The physical, chemical and hydrological properties of the soil profile of experimental site have been evaluated before and after experimentations. The amount of water applied was minimum 0.20*ET_0 and maximum 0.60*ET_0 through drip irrigation for wheat, sugarcane baggas, safflower and control under split plot design. Maximum plant height, flowers, branches, stem diameter and fruits was recorded in sugarcane baggas mulch. Crop coefficient and wetted area were estimated ranged from 0.18-0.70 and 30-40%. The actual water applied in different organic mulches treatments 40-80% is less than the actual water demand due to the reduced wet evaporative surface. The actual Water Requirement (WR) varied from 7-40 Ld^{-1} t^{-1} during different phenological stages and 0.40*ET_0 irrigation level is the best for organic mulch (*i.e.* Sugarcane baggas) for 3rd old age of pomegranate tree.

1. INTRODUCTION

A Pomegranate is an important fruit crop of arid and semi-arid regions of the world. It has several salient peculiarities unique to its credit (*i.e*. ability to withstand harsh and hostile climate, buit-in capacity to withstand heat, drought and moisture deficit, versatile adaptability, hardy nature, low maintenance cost, high yields, better keeping quality, therapeutic, medicinal, nutritional values and the richest source of antioxidants) (Levin, 2006[a] and 2006[b]; Samadia and Pareek, 2006 and Jadhav and Sharma, 2007).

In world, major pomegranate growing regions includes Iran, India, China, Israel, Spain, Egypt, Tunisia, Turkey, Japan, USA, Russia, Australia, South Africa and Saudi Arabia (Holland *et al*., 2009 and Faria and Calhau, 2010). At present pomegranate is grown on more than 0.180 million hectares (m ha) area in India; of which, 0.087 m ha area is in the state of Maharashtra alone. Hence, Maharashtra is considered to be the pomegranate basket of India, contributing about 70% of the total area and production under pomegranate in India. It is also cultivated at commercial scale in Karnataka, Gujarat, Telangana, Madhya Pradesh, Tamil Nadu, Rajasthan, Punjab, H.P. and Haryana. Pomegranate is largely cultivated in marginal lands and *bahar* treatments are given for regulating flowering and fruiting. The productivity in India is still low (<6.7 t ha^{-1}) as compared to the major pomegranate producing countries (>40 t ha^{-1}) (Holland and Bar-Ya'akov, 2008). In the pomegranate growing area of Maharashtra, water is scarce resources and there is a need to apply water judiciously according to water requirement.

Water is the most important natural resource for agriculture/horticulture development and economic advancement of any country. But it is a major constraint to crop production in the arid and semi-arid regions of the world. Modern irrigation technologies, (*i.e.* surface, sub-surface drip and sprinkler irrigation) results in higher WUE as compared to traditional methods (Chopade and Gorantiwar, 1998; Chopade *et al.*, 2001 and Intrigliolo *et al.*, 2011). However, regular irrigation is essential during the different phenological stages as irregular moisture condition causes dropping of flowers and small fruits (Patil *et al.*, 2002; Prasad *et al.*, 2003; Meshram *et al.*, 2011 and Meshram *et al.*, 2012). 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). In addition to this accurate estimates of evapotranspiration are helpful for proper irrigation planning and management. Soil moisture in the feeder root zone can be conserved by increasing water holding capacity of the soil, growing cover crops and use of anti-transparent and growth retardants (Bangar and Kadam, 2002; Meti *et al.*, 2008 and Bhantana and Lazarovitch, 2010). Organic mulches help to reduce water consumed, improvement of growth, yield and minimizing the evaporation losses (Shukla *et al.*, 2000; Shirgure *et.al.*, 2003 and Keramat *et al.*, 2011). Mulches are effective in reducing reference crop evapotranspiration (ET_0) and crop coefficient values decrease by an areas of 10-30% due to the 50-80% reduction in soil evaporation, evpotranspirtion, environmental stress coefficient, fruit cracking, fruit split, fruit physical and chemical properties but crop growth rates, leaf nutrient content, fruit set, water use efficiency, irrigation interval and yields were increased (El-Kassas, *et al.*, 1992; Chattopadhyay and Patra, 1993; Gupta *et al.*, 1999; Melgarejo *et al.*, 2000; Singh *et al.*, 2003; Bakeer, 2009 and Seidhom and Abd-El-Rahaman, 2011).

In Western Maharashtra, water is a scarce resources for pomegranate optimum production. The present investigation was undertaken to study the effect of organic mulches and different irrigation levels on the yield, quality and WUE of pomegranate.

2. MATERIALS AND METHODS

Study Area

The field experiment was conducted at ICAR-Research Farm of National Research Center on Pomegranate, Solapur, India in *hasta bahar*. The research farm is located at an Altitude of 483.5 m msl and is intersected North Latitudes $17^0 10^{''}$ and East Longitude by $74^0 42^{''}$. The physical, hydraulic and chemical properties of the soil profile of the experimental site are given in Table 2 and Table 3. The experiment was laid out in split plot design with main plot treatements of mulches (*i.e.* M_0-No mulch, M_1-wheat straw, M_2-sugarcane baggas, M_3-safflower straw) and sub plot treatments of irrigation levels (*i.e.* I_0-0.20*ET_0, I_1-0.30*ET_0, I_2-0.40*ET_0, I_3-0.50*ET_0, I_4-0.60*ET_0). The details of organic mulches 5-7 kg, 10 cm thick layer, 40-60 cm radious and 3-5 cm away from trunk diameter of pomegranate was used. The mulches and irrigation water was applied with four replications. The electrical conductivity and residual sodium carbonate of the irrigation water used was 1.5 dS m^{-1} and 2.2 meq l^{-1}, respectively. The drip irrigation system consisted of polyethylene laterals of 16 mm in diameter with on-line drippers at 60 cm distance away from steam of trees. The drippers had a discharge rate of 4.00 l h^{-1} under an operational pressure of 1.0 kg cm^{-2}. The irrigation in drip system was applied at alternate day intervals for required time to deliver the calculated quantity of water based on atmospheric demand.

Climatic Parameters

Daily weather data was collected from Agro-Met Observatory situated in the same 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 hrs, 7.5 km hr^{-1}, 6.9 mm and 334.6 mm, respectively in *hasta bahar* taking period from August, 2013 to March, 2014 (Table 1).

Water Requirement (Litres day^{-1} $tree^{-1}$)

Farmers need the information on water to be applied ($Ld^{-1} t^{-1}$) and duration for running the drippers to each pomegranate tree. Water to be applied and time of irrigation was estimated on daily basis for the pomegranate trees at 0.20 to 0.60*ET_0 levels by using the eq. 1, 2 and 3.

$$WR = \frac{\left(ET_0 \ x \ k_c \ x \ A \ x \ WA\right)}{IE} \quad ...(1)$$

Where, WR - Water requirement, Ld^{-1} t^{-1}; ET_0 - Reference crop evapotranspiration, mm day^{-1}; k_c -

Table: 1
Average weather parameters during the crop growing period

Months/Climatic parameters	Max. Temp. (^0C)	Min. Temp. (^0C)	Max. Hum. (%)	Min. Hum. (%)	AWS (Km hr^{-1})	Sshr (Hr)	E_{pan} (mm)
August	30.8	21.7	88.2	60.8	8.5	4.6	5.6
September	30.9	21.6	88.4	56.8	5.9	6.0	5.5
October	31.9	20.8	81.7	47.6	4.7	7.0	5.6
November	30.8	19.2	75.8	39.8	4.7	8.1	5.8
December	29.7	14.7	74.6	37.2	4.4	8.8	5.5
January	30.6	15.5	71.3	37.8	4.7	9.2	5.7
February	33.4	17.6	58.7	33.0	5.3	9.6	7.6
March	36.8	20.6	51.9	30.8	6.0	9.2	10.0

Table: 2
Physical and hydraulic properties of the soil profile of the experimental site

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	BD (Mg m^{-3})	HC (mm h^{-1})
Before experiment						
0-30	80.0	14.5	8.5	Loamy sand	1.68	9.7
30-60	73.5	18.5	11.0	Silt	1.75	5.7
60-90	67.8	21.0	12.3	Silt	1.49	14.8
After experiment						
0-30	65.0	15.43	8.9	Loamy sand	1.26	9.3

BD - Bulk density; HC - Hydroulic conductivity

Table: 3
Chemical properties of the soil profile of the experimental site

Depth (cm)	pH	EC (dS m^{-1})	OC (%)	NH_4-N (kg ha^{-1})	NO_3-N (kg ha^{-1})
Before experiment					
0-30	8.8	0.366	0.420	17.65	23.52
30-60	8.5	0.332	0.150	15.68	39.20
60-90	8.8	0.303	0.090	3.92	27.44
After experiment					
0-30	8.08	0.278	0.900	18.78	25.62

EC - Electrical conductivity; OC - Organic carbon

Crop coefficient, fraction; WA- Wetted area, fraction; A - Area occupied by each tree, m^2; IE - Irrigtion efficiency of the drip irrigation system (fraction).

Irrigation Time (hrs)

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

Where, IT - Irrigation time (hr); WR - Water requirement (Ld^{-1} t^{-1}); DC - Dripper discharge capacity (L hr^{-1}).

Estimation of Reference Crop Evapotranspirtion (mm)

The Penman-Monteith method has strong likelihood 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 eq. 3.

$$Et_0 = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T + 273}\right)u_{2\,(e_s - e_a)}}{\Delta + \gamma\,(1 + 0.34u_2)} \quad \text{...(3)}$$

Where, ET_0 = Reference crop evapotranspiration, (mm day^{-1}); G = Soil heat flux density, (MJ m^{-2} day^{-1}); R_n = Net radiation, (MJ m^{-2} day^{-1}); T = Mean daily air temperature, (^0C); γ = Psychometric constant, (k Pa^0C^{-1}); Δ = Slope of saturation vapour pressure function, (k Pa^0C^{-1}); e_s = Saturation vapour pressure at air temperature T, (k Pa); e_a= Actual vapour pressure at dew point température, (k Pa); u_2= Average daily wind speed at 2 m height, (m sec^{-1}).

The other parameters (*i.e.* crop coefficient (k_c), pan coefficient (k_p), Wetted Area (WA) and Irrigation Efficiency (IE) for estimating water requirements ($Ld^{-1} t^{-1}$) of pomegranate were used, which was published by Gorantiwar *et al.*, 2011.

For computation of fresh fruit yield per hectare and WUE were divided by the water expense and expressed as kg $ha^{-1}L^{-1}$.

3. RESULTS AND DISCUSSION

The daily climatic data of 211 days at the experimental site of ICAR-NRCP, Solapur covering the period of August, 2013 to March, 2014 were analyzed for the calculating reference crop evapotranspiration (ET_0) by Penman-Month method. The average daily values of ET_0 by Penman-Monteith method are shown in Fig. 1. It is revealed that, the trend of the estimated ET_0 values over the days are in different due to variation in climatic parameters. The water to be applied through drip system at 90% efficiency for *hasta bahar* ranged from 7 to 40 $Ld^{-1} t^{-1}$ for 3rd years of pomegranate tree at different phenological stages. The values in the Fig. 1 would be useful for irrigation scheduling of pomegranate by drip irrigation method.

The results revealed that mulches with irrigation levels had significant effect on vegetative characteristics like plant height, leaf area index and leaf nutrient status (Table 4). Among various irrigation levels at 0.40*ET_0 showed higher plant height (2.07 m), leaf area index (2.6) and leaf nutrient status (1.7, 0.21, 1.26). It might be due to application of needful irrigation with proper phenological stages (*i.e.* new leaf initiation period, crop development, crop maturity and harvesting periods) and organic mulches to better nutritional environment in the root zone as well as in plant system. Major nutrients (*i.e.* nitrogen, phosphorus and potassium) and micro-nutrients (*i.e.* ferrous, magnisium, sulphur, calcium) are most essential of all mineral nutrients for growth and development of the plant. Earlier, Chauhan and Chandel (2008) on kiwifruit found that leaf nutrient contents were significantly higher under organic mulches compared to recommended doses of fertilizers.

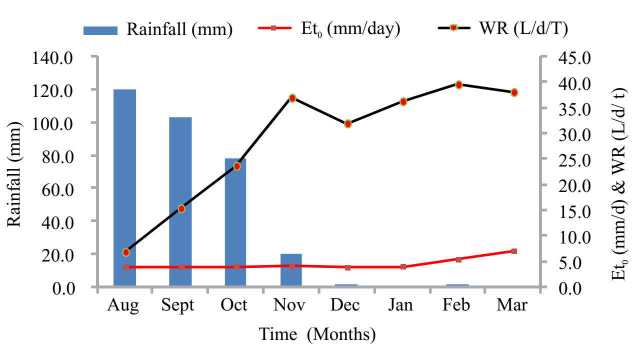

Fig. 1. Monthly rainfall (mm), daily ET_0 (mm day^{-1}) and water applied to the trees ($Ld^{-1}t^{-1}$) values during the crop growing period

The data revealed that pomegranate fruit yield responded differently to different quantities and qualities of water applied through drip irrigation system with two laterals with four drippers (Table 5). The influence of mulches with irrigation on fruit yield and quantity of irrigation applied is envisaged form the fact that, yield increment of pomegranate to the tune of 25-45% was recorded in double lateral with four drippers and organic mulches with 60% saving irrigation water applied and highest water use efficiency (0.034) in sugarcane baggas. Similarly, the corresponding increase over alternate day irrigation was 30.0% saving in water Ayars *et al.* (2001) also reported that yield in drip irrigated pomegranate was higher than other methods of irrigation system. The quality of irrigation water singnificantly influenced the furit yield which is evident from the fact that generally in poor quality irrigation and mulches, the mean fruit yield in absolute quantites was considerably reduced in comparison to other irrigation methods. Application of irrigation level I_2 (40%) during experiment effectively increased vegetative growth parameters and leaf nutrient status. The favorable influence of I_2 (40%) on plant height, leaf area index and leaf nutrient status may be due to excess moisture in the soil through drip irrigation. The increase in the plant height and canopy in drip irrigation might be due to the constant supply of water to the plant. This maintains the soil moisture at optimum level eliminating water stress to the plant resulting in greater vigour (Subramanian *et al.*, 1997). Earlier, Rana *et al.* (2005) also observed leaf N, P and K contents of peach was influenced with different irrigation levels and discharge rates and they found that higher irrigation levels increased the nitrogen, phosphourus and potassium content in leaves.

It is evident from the data presented in the Table 5, that mulches and irrigation levels had significant

Table: 4

Effect of organic mulches and irrigation levels on growth and leaf nutrient status of pomegranate

Treat-ments	Plant height (cm)					LAI (m^2 m^{-2})					Leaf nutrient status (%)														
											N					P					K				
	M_o	M_1	M_2	M_3	M	M_o	M_1	M_2	M_3	M	M_o	M_1	M_2	M_3	M	M_o	M_1	M_2	M_3	M	M_o	M_1	M_2	M_3	M
I_o	186	190	200	189	191	2.2	1.9	2.3	1.9	2.2	1.40	1.64	1.84	1.78	1.4	0.17	0.17	0.19	0.18	0.17	1.18	1.2	1.2	1.2	1.24
I_1	196	185	205	189	193	2.4	2.5	2.6	2.2	2.4	1.52	1.63	1.89	1.82	1.5	0.17	0.17	0.19	0.18	0.17	1.17	1.2	1.3	1.3	1.25
I_2	200	205	216	205	207	2.9	2.8	3.3	3.5	2.6	1.70	1.63	1.88	1.88	1.7	0.17	0.17	0.21	0.20	0.17	1.18	1.1	1.3	1.3	1.26
I_3	194	195	213	191	198	2.2	2.3	3.5	2.9	2.2	1.95	1.84	1.77	1.86	1.9	0.18	0.18	0.22	0.20	0.18	1.22	1.2	1.3	1.2	1.26
I_4	199	187	211	192	197	2.2	2.6	3.5	3.3	2.2	1.85	1.89	1.83	1.74	1.8	0.18	0.17	0.23	0.21	0.18	1.19	1.1	1.3	1.2	1.25
Me	195	193	209	193		2.2	2.4	3.0	2.6		1.68	1.73	1.84	1.82		0.17	0.17	0.21	0.20		1.19	1.2	1.3	1.3	
CD	Irrigation=7.45					Irrigation=0.28					Irrigation=0.162					Irrigation=0.012					Irrigation=0.046				
(p=0.05)	Mulching=7.12					Mulching=0.21					Mulching=0.129					Mulching=0.020					Mulching=0.039				
	Irrigation*Mulching=15.14					Irrigation*Mulching=0.55					Irrigation*Mulching=0.258					Irrigation*Mulching=0.040					Irrigation*Mulching=0.078				

Table: 5

Effect of organic mulches and irrigation levels on quality, yield attributes and water use efficiency of pomegranate

Treat-ments	Juice content (%)					TSS: Acid ratio (%)					Organoleptic rating					Rind (mm)	No. of fruits/tr.	Av. FW (g)	Yield (kg ha^{-1})	WR (Lb^{-1} t^{-1})	WUE (kg ha^{-1} l^{-1})
	M_o	M_1	M_2	M_3	M	M_o	M_1	M_2	M_3	M	M_o	M_1	M_2	M_3	M						
I_o	30	35	39	39	35.7	14	16	16	16	15.5	6.7	6.8	6.9	7.0	6.8	1.89	39	255	6.5	2401	0.0026
I_1	31	34	37	37	34.7	15	16	16	16	15.7	8.4	8.6	8.7	8.7	8.6	2.33	48	265	7.6	3601	0.0021
I_2	31	33	39	38	35.2	16	16	17	16	17.3	9.9	9.7	9.7	9.5	9.7	2.70	62	325	16.2	4802	0.0034
I_3	30	34	40	37	35.3	15	17	17	18	16.7	8.6	8.7	8.6	8.6	8.6	2.59	52	310	14.2	6002	0.0025
I_4	29	33	38	40	35.0	15	16	18	16	16.2	8.9	8.9	9.0	8.9	8.9	2.68	50	305	15.1	7203	0.0021
Mean	30	33	39	38		15	17	16	16		8.5	8.6	8.6	8.5		2.43	50.2	292	12.0	4802	0.0025
CD	Irrigation=1.14					Irrigation=0.559					Irrigation=0.324					Irrigation=3.35			Irrigation=0.829		
(p=0.05)	Mulching=0.91					Mulching=0.490					Mulching=0.341					Mulching=5.26			Mulching=0.750		
	Irrigation*Mulching=1.83					Irrigation*Mulching=0.981					Irrigation*Mulching=0.682					Irrigation*Mulching=18.25			Irrigation*Mulching=1.501		

effect on the yield attributes. Sugarcane baggas (M_2) and irrigation level (I_2) recorded the maximum number of fruits (62 nos.), average fruit weight (325 g), yield (16.20 kg plant[1]), juice content (39.38%), organoleptic rating (9.7) and this level was at par with M_2*I_2. However, maximum TSS: acid ratio (17.33) along with maximum rind thickness (2.70 mm) was recorded in M_2*I_2 and this level was at par with maximized the growth of the plant and facilitated in accumulation of more carbohydrates into the fruit further, during the subsequent fruit development. Similarly, in irrigation levels of drip irrigation different irrigation had significant effect on the yield attributes (number of fruits, av. Fruit weight) yield and quality components (juice content, TSS: acid ration rind thickness and organoleptic rating). Drip irrigation at 40% level (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 which accelerated the fruit growth and development of quality characters in the fruits. The increase in juice content might be because of more absorption of water and minerals from the soil resulting into increased juice content (Nath *et al.*,1999 and Kumar, 2016).

The net profit per hectare ranged form ₹ 1.02 to 6.17 lakhs (Table 6). The highest profit (6.17 lakhs) was obtained with sugarcane baggas at 40% irrigation level (I_2*M_2) followed by safflower with 50% drip irrigation (I_3*M_3). The 20% irrigation level and no mulch (M_0I_0) gave the least net profit of ₹ 1.02 lakhs, followed by 30% irrigation level and no mulch (M_0*I_1). The benefit:cost ratio ranged from 0.34 to 2.14 depending upon the treatments and it was found to be the highest (2.14) with 40% irrigation level with sugarcane baggas .

4. CONCLUSIONS

Drip irrigation and mulching technologies is beneficial to the farmers for higher production and

Table: 6
Relative economics and benefit :cost ratio from plantation to fruiting of different mulches and irrigation levels in pomegranate at spacing 4.5 x 4.0 m

Treatment combination	Total cost of production (lakhs ha^{-1})	Total marketable yield (t ha^{-1})	Gross return (lakhs ha^{-1})	Net return (lakhs ha^{-1})	B:C ratio
M_0I_0	2.98	5.33	4.00	1.02	0.34
M_0I_1	2.98	5.60	4.20	1.22	0.40
M_0I_2	2.98	6.67	5.00	2.02	0.67
M_0I_3	2.98	6.80	5.10	2.12	0.71
M_0I_4	2.98	7.17	5.37	2.39	0.80
M_1I_0	2.94	5.96	4.47	1.53	0.52
M_1I_1	2.94	6.04	4.53	1.59	0.54
M_1I_2	2.94	6.24	4.68	1.74	0.59
M_1I_3	2.94	6.28	4.71	1.77	0.60
M_1I_4	2.94	6.39	4.79	1.85	0.62
M_2I_0	2.87	10.34	7.75	4.88	1.70
M_2I_1	2.87	10.67	8.00	5.13	1.78
M_2I_2	2.87	12.06	9.04	6.17	2.14
M_2I_3	2.87	11.37	8.53	5.66	1.97
M_2I_4	2.87	11.72	8.79	5.92	2.06
M_3I_0	2.93	7.57	5.67	2.74	0.95
M_3I_1	2.93	7.97	5.98	3.05	1.04
M_3I_2	2.93	8.06	6.04	3.11	1.06
M_3I_3	2.93	8.59	6.44	3.51	1.19
M_3I_4	2.93	8.67	6.50	3.57	1.21
CD (P=0.05)	0.039	NS	0.88	1.20	

M_0I_0 to M_0I_4 – Treatment for No Mulch; M_1I_0 to M_1I_4 – Treatment for Wheat straw; M_2I_0 to M_2I_4 – Treatment for Sugarcane baggas; M_3I_0 to M_3I_4 – Treatment for Safflower)

quality of fruits. The water to be applied through drip system ranged from 7 to 40 Ld^{-1} t^{-1} at different phenological stages and water saved 60% due to organic mulch and drip irrigation technique. Drip irrigation including mulching techniques ensure increased crop yield, high water use efficiency, reduced water and energy consumption and minimal weed problems. It is concluded from the present study that, organic mulch and drip irrigation is the better technological option for improving crop as well water productivity.

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