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Influence of organic mulches and irrigation levels on growth, yield and water use efficiency of pomegranate (*Punica granatum* L.)

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ABSTRACT

A field experiment was carried out at Solapur, Maharashtra during 2015-2017 on 4 and 5 year old plants of pomegranate having treatments composing of 4 organic mulches (*i.e.*No mulch, wheat straw, sugarcane baggas and safflower straw) and 5 different irrigation levels (*i.e.* 0.30 to 0.80 * ET_r) through drip irrigation under split plot design. Amount of applied irrigation water for different treatments varied from 2597 to 9218 Liters per season per tree. The results indicated that organic mulches and irrigation level had significant effect on leaf area index, nos. of fruits, yield and water use efficiency. The highest water use efficiency was estimated with sugarcane baggas while the lowest WUE was estimated in no mulch.The mean maximum plant height, number of fruits, weight, growth, LAI,yield and WUE was evaluated at 0.50*ET_r and 0.60*ET_r irrigation level and sugarcane baggas mulch is the best for 4 and 5 old age pomegranate tree.

Keywords: Pomegranate, phenophase, reference crop evapotranspiration(ET_r), crop coefficient(K_c), organic mulches and water use efficiency (WUE).

Pomegranate (*Punica granatum* L.) is one of the foremost fruit crops of India due to its demand for internal and export potential. Pomegranate are fairly drought registant but require irrigation to produce good quality production; over and under irrigation results in craking, soft and poorly coloured fruit.In India, it is cultivated in Maharashtra, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka, Gujarat, Rajasthan, Madya Pradesh, Punjab and Haryana in over 1.13 lakh ha area with an annual production of 7.44 lakh tones and productivity of 6.6 tha^{1} is still low as compared to the major pomegranate producing countries (>40 tha^{-1}) (Pal *et al.,* 2014). The area under pomegranate in India is increasing at a faster rate due to its hardy nature, suitability to marginal land with poor fertility, rocky land with shallow depth,low maintenance cost, low water requirement, high yield potential, good keeping quality, extremes temperature (-12 to 44 ^{0}C) and versatile adaptability. However, regular irrigation is essential during the different phenological stages as moisture stress condition causes dropping of flowers and small fruits (Meshram *et al.,* 2011). Accurate estimates of evapotranspiration are helpful for proper irrigation planning and management (Smith *et al.,* 1991; Pandey and Mehta 2018).In the pomegranate growing area of Maharashtra, water is scarce resources and there is a need to apply water judiciously according to water requirement. Hence, the present investigation was undertaken to study the effect of organic mulches and irrigation scheduling on water requirement of pomegranate during various phenophases under drip irrigation system.

MATERIALS AND METHODS

The field experiment was conducted at ICAR-Research Farm of National Research Center on Pomegranate, Solapur in *hasta* season (September to April) of 2015-2016 and 2016-2017. The research farm is located at an altitude of 483.6 m above mean sea level and is intersected North latitude 17^0 10'' and East longitude by 74^{0}42''.The experiment was laid out in split plot design with main plot treatments of mulches (*i.e.* M_0-No mulch, M_1-wheat straw, M_2-sugarcane baggas, M_3-safflower straw) and subplot treatments of irrigation levels (*i.e.* I_0-0.30*ET_0; I_1-0.40*ET_0; I_2-0.50*ET_0; I_3-0.60*ET_0; I_4-0.70*ET_0 for 4 year old tree and 0.40*ET_0; I_1-0.50*ET_0; I_2-0.60*ET_0; I_3-0.70*ET_0; I_4-0.80*ET_0 for 5 year old tree). The plant to plant and row to row spacing was 4.5 x 4 m. The details of organic mulches 7-10 kg, 10 cm thick layer, 40-60 cm radius and 3-5 cm away from trunk diameter of pomegranate were used. The irrigation water was applied with four replications.The drip irrigation system consisted of polyethylene laterals of 16 mm in diameter with on-line drippers at 60 cm distance away from the steam of trees. The drippers had a discharge rate of 2.00 Lh^{-1} under an operating pressure of 1.0 $kgcm^{-2}$. The irrigation in drip system was applied at alternate day intervals for the required time to deliver the calculated quantity of water based on atmospheric demand.

Air temperature, relative humidity, sunshine hours, wind speed, evaporation and rainfall data were measured from an automatic weather station located in the same farm. Soil temperature at 15 cm depth was measured with stainless steel fisher brand bi-metal dial thermometers having a length of 30 cm, gauge diameter of 5 cm and accuracy of ± 1.0% of dial range at any point of the dial. The observation was recorded on alternate days at 2.00 pm (mulched and control).

Water requirement (WR_p)

Water to be applied and time of irrigation was estimated on daily basis for the pomegranate trees at 0.30 to 0.80*ET_r irrigation levels by using following equation

$$WR_p = \frac{(ET_r \times K_c \times A \times WA)}{IE}$$

Where,

WR_p - Water requirement($Ld^{-1}t^{-1}$); ET_r – Reference crop evapotranspiration(mm); K_c - Crop coefficient; WA- Wetted area; A = Area occupied by each tree(m^2);IE = Irrigation efficiency of the drip irrigation system.

The water requirement was computed on daily basis for each phenophase, *viz.,* new leaf initiation, crop development, maturity and harvesting of the crop.

Estimation of reference crop evapotranspiration (ET_r)

The monthly values of reference ET_r were estimated by following Penman-Monteith method (Allen *et al.,* 1998)

$$ET_r = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_{2(e_s-e_a)}}{\Delta + \gamma(1 + 0.34u_2)}$$

Where,

ET_r = Reference crop evapotranspiration ($mmday^{-1}$); G = Soil heat flux density ($MJm^{-2}\ day^{-1}$); R_n = Net radiation ($MJm^{-2}day^{-1}$); T = Mean daily air temperature (^0C); ³ = Psychometric constant (kPa^0C^{-1}); “ = Slope of saturation vapour pressure function (kPa^0C^{-1}); e_s = Saturation vapour pressure at air temperature T (kPa); e_a = Actualvapour pressure atdew point température (kPa); u_2 = Average daily wind speed at 2 m height ($msec^{-1}$).

Crop coefficient (K_c)

The values of crop coefficient (K_c) was estimated for different phenophases of the crop using the shaded area approaches. The crop coefficient was calculated following Gorantiwar *et al.,*(2011) method as given below

$$K_c = 0.014x + 0.08$$

Where,

K_c = Crop coefficient; x = Percentage of shaded area (%)

Water use efficiency (WUE)

From the observed data on yield,water requirement and the water use efficiency was calculated

$$WUE = \frac{\text{Yield } (kgha^{-1})}{\text{Season wise WR(Liters)}}$$

The water use efficiency (WUE) was expressed as kg $ha^{-1}L^{-1}$.

RESULTS AND DISCUSSIONS

Climate during crop growth period

The mean monthly temperature during *hasta* season (September to April) varied between 27.4 ^0C in December and 36.7 ^0C in April. Relative humidity varied between 51 to 78 %, while wind speed between 7.8 to 10.9 $kmhr^{-1}$. Rainfall of 184.2 mm was received in September, while 115.3 mm was recorded in October (Table 1). The soil temperature varied between 29.3 ^0C (January) and 35.2 ^0C in April. Under different mulches the soil temperatures were about 1 to 2 ^0C lower than the control (Table 2). This may be due to the fact that, the mulches insulate and protect soil direct sunlight and prevent it from hard setting and toughness by controlling rate of evaporation (Tolk *et al.,* 1999).

Reference crop evapotranspiration (ET_r) and water requirement (WR_p)

The average monthly reference crop evapotranspiration (ET_r) estimated by Penman-Monteith Method (Fig.1) reveals that ET_r was the highest in April (255.6 mm) and lowest in December (108 mm) in both the years.The average ET_r were 157.6 mm during new leaf initiation, 299.5 mm during development,538.5 mm during maturity and 535.1 mm during harvesting periods. The average annual reference crop evapotranspiration (ET_r) was 1530.6 mm. Malve *et al.* (2017) reported that the crop water requirement (ET_C) of wheat under drip irrigation was found to vary with irrigation levels.

Table 1: Mean climatic parameters during the study period (Sept. 2015 to April, 2017)

Phenophase	Months/Climatic parameters	T_{mean} (^{0}C)	RH_{mean} (%)	WS($kmhr^{-1}$)	SSh(hr)	E_{pan} (mm)	Rainfall (mm)
Initial	September	30.0	77.8	9.5	8.7	6.8	184.2
Development	October	30.2	74.2	7.9	8.8	5.8	115.3
	November	28.6	70.4	9.9	9.2	9.8	5.9
	December	27.4	67.2	7.8	9.2	5.0	0
Maturity	January	27.6	71.6	8.4	8.8	6.0	0
	February	31.0	70.5	10.9	10.1	6.6	0
Harvesting	March	30.7	51.4	10.6	10.0	10.4	6.05
	April	36.7	62.1	10.6	10.1	14.4	0

Table 2: Soil temperature (^{0}C) under various organic mulches during the crop growing period at various phenophase

Phenophase	Months	Control (M_0)	Wheat (M_1)	Sugarcane baggas (M_2)	Safflower (M_3)
Initial	September	30.8	30.0	29.7	30.1
Development	October	31.3	30.4	30.0	30.5
	November	29.8	28.6	28.2	29.0
	December	30.0	28.8	28.2	29.2
Maturity	January	29.3	28.1	27.4	28.7
	February	31.1	30.2	29.2	30.2
Harvesting	March	32.6	31.1	30.8	31.6
	April	35.2	34.7	33.3	34.0

Table 3: Phenophase wise number of days, wetted area and crop coefficient for 4 and 5 year old pomegranate

Phase	Phenophase Indicators	Av.Days	Wetted area		Crop coefficient	
			4th year	5th year	4th year	5th year
New leaf Initiation	Start of new leaves to 10% ground cover	25	0.30	0.40	0.24	0.28
Development	10% ground cover to effective full cover, about 60-70% coverage crops	65	0.35	0.45	0.65	0.71
Maturity	Effective full cover to maturity, indicated by yellowing of leaves, leaf drop and browning of fruit	85	0.50	0.60	0.80	0.90
Harvesting	Maturity to harvest indicated ripe fruits start falling on the ground	65	0.45	0.55	0.70	0.80

The water requirement (WR_p) was also highest in April (2297.2 $Lphase^{-1}tree^{-1}$) and lowest in December (302.4 $Lphase^{-1}tree^{-1}$) in both the years. The water to be applied through drip irrigation system at 90 per cent irrigation efficiency ranged from 10.5-24.5 and 18.6-37.20 $Lday^{-1}$ $tree^{-1}$ for 4 and 5year pomegranate trees due to the variation in reference crop evapotranspiration, crop coefficient and wetted area values (Meshram *et al.,*2012). Due to well-distributed rainfall during September and October, the irrigation given was very less in that period. The total values

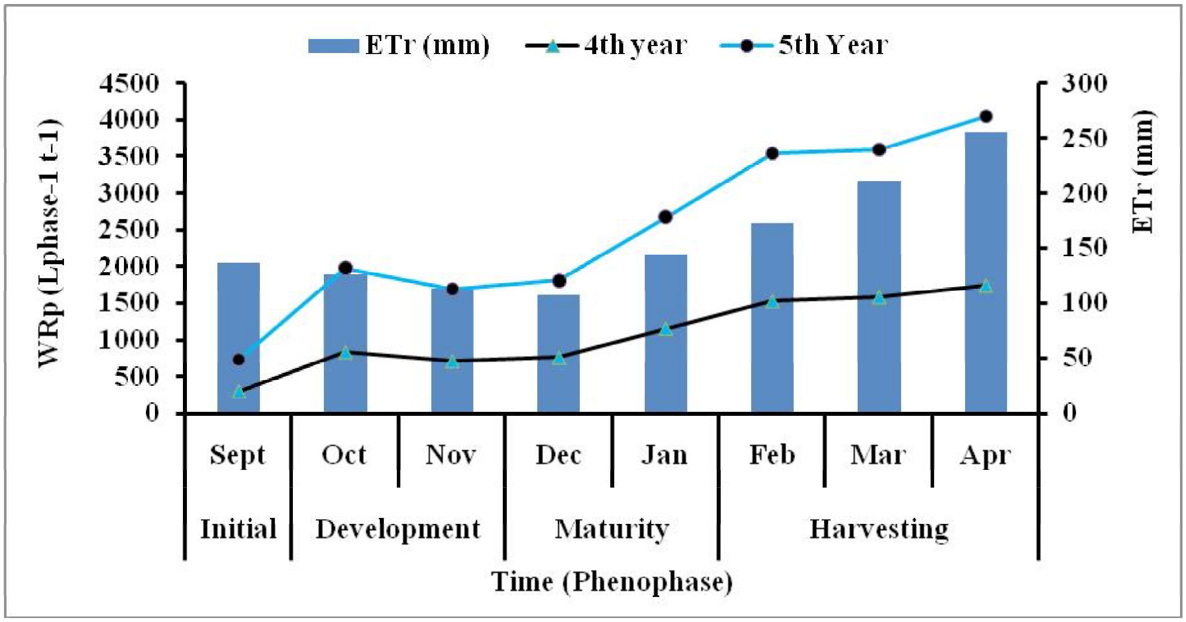

Fig.1: Average monthly ET_r and actual water demand values in $Lphase^{-1}t^{-1}$ for 4 and 5 year old pomegranate tree

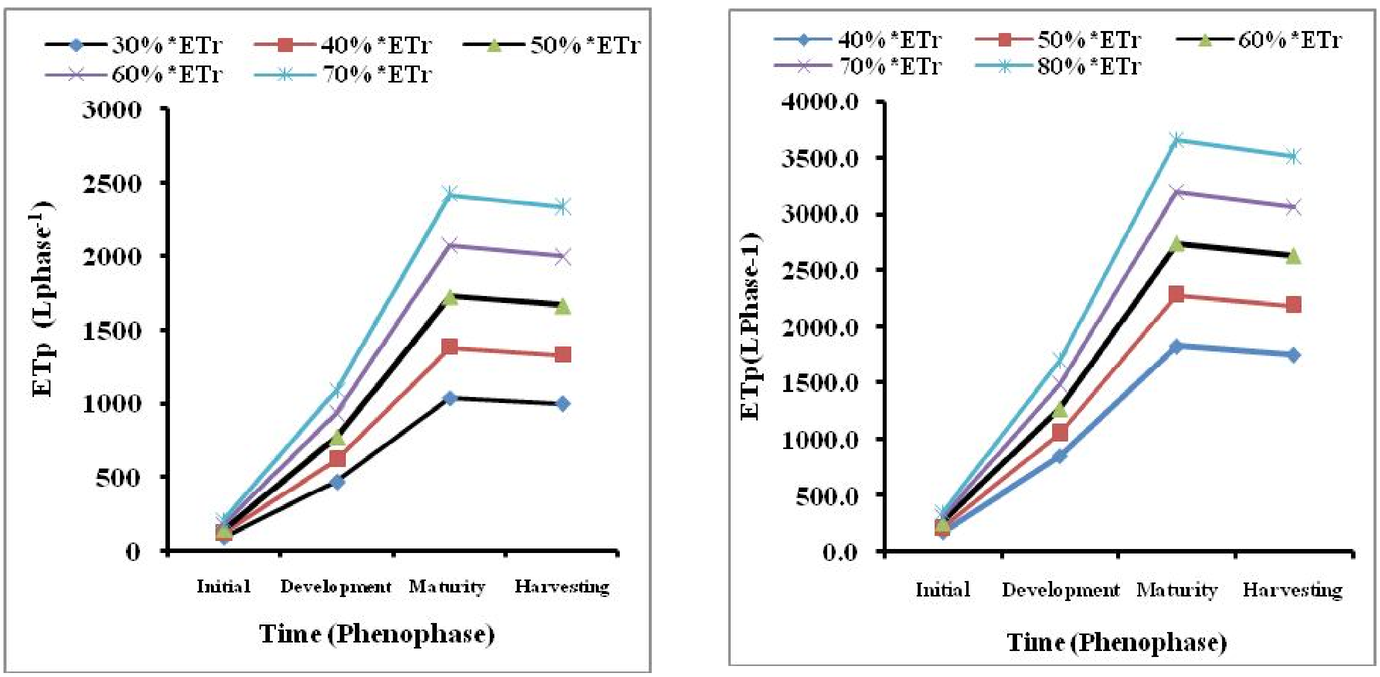

Fig.2: Water applied ($Lphase^{-1}t^{-1}$)at various irrigation levels for 4 and 5 year old pomegranate tree

of water to be applied to pomegranate tree were 4,329.6 and 6,914.8 Liters per season per tree at 0.50 and 0.60 *ET_r for 4 and 5 old age tree.

Crop coefficient (K_c) and wetted area (WA)

The crop coefficient values for different growth stages (*i.e.* new leaf initiation, development, maturity and harvesting period) of pomegranate are given in Table 3 during crop growth period. On an average crop coefficient (K_c) values varied from 0.24 to 0.80 and 0.28 to 0.90 for 4 and 5 old age pomegranate trees respectively. K_c values were low during the initial stage of growth and follow the rising trend during the development phase. The K_c values were higher in 5 year pomegranate tree than that of 4 year old tree. The trend observed in K_c values of pomegranate during different phases of growth are similar to those given by Gorantiwar *et al.,*(2011). Mehta and Pandey (2016) also reported that the K_c values varies with age and height of the crops.

Table 4: Effect of organic mulches and irrigation levels on vegetative growth and attributes yield of pomegranate

Treatment combinations	Plant height (cm)		LAI		No. of fruits/plants		Fruit wt. (gm)	
	4th year	5th year	4th year	5th year	4th year	5th year	4th year	5th year
Mulching								
No Mulch (M_0)	182	184	2.67	2.69	53	56	294	279
Wheat straw (M_1)	188	190	2.71	2.78	62	69	286	283
Sugarcane bagas(M_2)	211	213	3.26	3.18	70	83	330	322
Safflower straw (M_3)	199	203	2.58	2.6	50	64	314	299
Irrigation								
I_0 (0.30 & 0.40*ET_r)	190	192	2.38	2.46	59	69	298	284
I_1 (0.40 & 0.50*ET_r)	190	192	2.62	2.77	64	71	303	307
I_2 (0.50 & 0.60*ET_r)	216	215	3.08	3.07	67	74	308	315
I_3 (0.60 & 0.70*ET_r)	191	196	2.99	2.93	59	67	297	293
I_4 (0.70 & 0.80*ET_r)	190	193	2.92	2.86	52	60	295	280
CD (P=0.05)	I=0.23	I=0.25	I=0.23	I=0.25	I=12.47	I=11.93	I=32.1	I=33.10
	M=0.20	M=0.23	M=0.20	M=0.23	M=8.19	M=5.7	M=27.98	M=24.05
	I*M=0.52	I*M=0.55	I*M=0.52	I*M=0.55	I*M=16.3	I*M=11.4	I*M=55.9	I*M=48.4

Table 5: Effect of organic mulches and irrigation levels on yield and water use efficiency of pomegranate

Treatment combinations	Yield ($kgha^{-1}$)		WR($Lseason^{-1}tree^{-1}$)		WUE($kgha^{-1}l^{-1}$)	
	4th year	5th year	4th year	5th year	4th year	5th year
Mulching						
No Mulch (M_0)	11474	11632	4329	6914	0.0039	0.0024
Wheat straw (M_1)	12212	16344	4329	6914	0.0040	0.0033
Sugarcane bagas(M_2)	12497	19131	4329	6914	0.0041	0.0039
Safflower straw (M_3)	10040	14182	4329	6914	0.0034	0.0030
Irrigation						
I_0(0.30& 0.40*ET_r)	8970	13666	2597	4609	0.0042	0.0028
I_1 (0.40 & 0.50*ET_r)	11910	15588	3463	5761	0.0043	0.0032
I_2 (0.50 & 0.60*ET_r)	14171	17971	4329	6914	0.0045	0.0035
I_3 (0.60 & 0.70*ET_r)	11869	15865	5194	8066	0.0031	0.0027
I_4 (0.70 & 0.80*ET_r)	10858	13523	6060	9218	0.0024	0.0020
CD (P=0.05)	I=728	I=1050	I=7.19	I=8.25	I=4.78	I=4.95
	M=513	M=573	M=7.15	M=8.55	M=4.57	M=4.88
	I*M=1026	I*M=1147	I*M=14.34	I*M=16.80	I*M=9.55	I*M=9.83

Effects of mulches on growth and fruit attributes

The growth parameter (plant height and LAI) and yield attributes (No. of fruits per plant and fruit weight) as influenced by the mulches and irrigation treatments are presented in Table 4,while yield, water use and water use efficiency as influenced by the treatments are presented in Table 5. It may be seen that all the growth and yield parameters were significantly influenced by the organic mulches treatments. The highest plant height (211 and 213 cm), LAI(3.26 and 3.18). Number of fruits per plant (70883) and fruit weight (330 and 322 g) were observed under mulch treatments M_2 (Sugarcane bagas) and lowest under no mulch. Irrigation treatment I_2 (0.50 ET_r and 0.60 E_r) significantly higher growth and yield attributes (Table 4). This may be due to the application of essential mulch and proper irrigation level in phenological stages to the better nutritional environment in the root zone as well as in plant system. The increase in plant height and spread was recorded highest in sugarcane baggas, closely followed by safflower and wheat straw. The increase in growth of plant was possible due to increase in availability of soil moisture, nutrients and moderate evaporation from the soil surface and lowest growth of plant was recorded under control (No mulch).Drip irrigation at 50 and 60 per cent level (I_2) and organic mulch (M_2) recorded better quantity parameters because irrigation and organic mulch provide a consistent moisture regime in the soil due to which root remains active throughout the phase resulting in optimum availability of moisture and proper translocation of food materials, which accelerated the fruit growth and development of quality characters in the fruits.

Effect of Irrigation on yield and water use efficiency

As seen in case of growth and yield attributes, the M_2 treatment (Sugarcane bagas mulch) produced significantly highest yield (12497 and 19131 leq ha^{-1}) in comparison to other treatments and no mulch (Table 5).The pomegranate yield responded differently to different quantities of water applied through drip irrigation. The influence of the quantity of irrigation water applied on yield increment of pomegranate was recorded drip irrigation of 50 and 60 per cent up to level (I_2). The irrigation water significantly influenced the mean yield which is evident from the fact that, the mean yield in absolute quantities was considerably reduced in comparison to other irrigation level.The table clearly indicates that different irrigation level with organic mulch had a significant effect on water use efficiency of pomegranate. As regards different irrigation level with organic mulch, mean maximum water use efficiency was 0.0043 and 0.0037 kgha^{-1}L^{-1} for 4 and 5 year pomegranate tree at 0.50 and 0.60*ET_r irrigation level. Ghosh and Behra (2015) has mentioned that irrigation and organic mulch increased fruit yield and water use efficiency due to a reduction in evaporation, enhanced transpiration and deep percolation, leading to increased yields and water use efficiency.

CONCULSION

It may be concluded from the present study that, organic mulch of sugarcane baggas and irrigation levels of 0.50 and 0.60* ET_r is the better technological option for improving crop production as well as water productivity in pomegranate cultivation.

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