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Mulch bed system for improving water use efficiency of Pomegranate (*Punica granatum* L.) on a light texture soil in Deccan Plateau

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ABSTRACT

A field experiment was carried out during two successive seasons (2019 and 2020) at Solapur, Maharashtra, India in *hasta bahar* with Bhagawa pomegranate cultivar, which corresponded to trees 6th and 7th years-old to study the effect of different irrigation levels and inorganic mulching on vegetative growth and productivity. The experiment consisted of main treatments of five irrigation levels for each year of pomegranate tree (*i.e.* 50 to 90 and 60 to 100% *pomegranate evapotranspiration (ET_p) for 6th and 7th year-old tree, respectively) and sub-treatments of different inorganic mulches (*i.e.* M_0-no mulch (control), M_1-black mulch, M_2-black and white mulch and M_3-previous/weed mat mulch). The actual water applied in different mulching treatments is 50-10% less than the actual water demand due to the reduced wet evaporative surface. The actual and deficit water requirement (WR) ranged from 18.50 to 35.50 and 22.60 to 45.20 $Lday^{-1}tree^{-1}$ at various phenological stages. Maximum plant height, leaf area index (LAI), plant canopy spread (E-W and N-S), no. of fruits per tree and fruit weight was the best at irrigation levels of 70% and 80%$^*ET_p$ for 6th and 7th years old tree, respectively.

The study revealed that inorganic mulch (*i.e.* previous/weed mat) enhanced vegetative growth and yield contributing characteristics. Based on a statistical analysis of yield contributing characteristics, it was inferred that the treatment combination comprising of previous/weed mat mulch and irrigation levels of 70% and 80% $^*ET_p$ with alternate day irrigation resulted in higher yield and WUE as compared to other treatments for 6th and 7th years old age pomegranate trees, respectively. The previous/weed mat mulch with drip irrigation treatment was found to be a more effective method in improving WUE and increasing pomegranate yield. It is concluded from the study that, inorganic mulch (*i.e.* previous/weed mat) is the better technological option for improving crop productivity.

1. INTRODUCTION

Pomegranate has been cultivated throughout the Mediterranean region continuously since 3000 BCE (Stover and Mercure, 2007). Though, the crop is best suited for drought-prone areas as it requires light texture soil and low rainfall of 180-550 mm (Levin, 2006; Holland *et al.,* 2009). The performance of the trees *i.e.* yield, fruit size, fruit quality, storability and long term productivity are highly dependent on an adequate supply of water through irrigation (Rodriguez *et al.,* 2012). For maintaining good productivity of the plants, generally one of the three *bahars* (flowering) is regulated, which depends upon market factors and the availability of water resources (Meshram *et al.,* 2012). However, regular irrigation is essential during the different phenological stages as irregular moisture condition causes the dropping of flowers and a reduction in production (Prasad *et al.,* 2003; Meshram *et al.,* 2011). The sudden change in soil moisture causes moisture stress, which affects fruit development adversely and leads to fruit cracking (Cheema *et al.,*1954). The area under pomegranate 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). In Maharashtra, pomegranate is predominately cultivated in *Solapur, Ahmednagar, Pune, Nasik, Sangli, Satara* and *Osmanabad*. In these parts of Maharashtra availability of irrigation water is limited and hence there is a need to apply water judiciously as per the water requirement of the crop. The water requirement of the pomegranate crop depends on the type of soil, age of the plants, *bahars*, atmospheric demand, location, management strategies and water applied as per appropriate irrigation scheduling can influence pomegranate productivity and fruit quality (Allen *et al.,* 1998).

In field conditions, judicious use of water is essential for the increasing area under pomegranate production with a limited water supply. Therefore, the uses of moisture conservation measures are essential in such a situation. Mulching has been advocated as an effective means of conserving soil moisture (Khurshid *et al.,* 2006; Seyfi and Rashidi, 2007; Jat *et al.,* 2014). Soil moisture in the feeder root zone can be conserved by increasing the water holding capacity of the soil through mulching, growing cover crops, irrigation levels and the use of anti-transpirant and growth retardants (Keramat *et al.,* 2011; Kasirajan and Ngouajio, 2012). Despite the fact that, the pomegranate is characterized as fairly drought resistant, still requires regular irrigation to maintain good productivity and various reports indicated that, the drought stress could have significant negative effects on fruit quality and quantity of pomegranate (Bray, 1997; Mellisho *et al.,* 2012; Mena *et al.,* 2013).

Mulching is the process or practice of covering the soil/ground to make a more favourable condition for plant growth, development and efficient crop production. Plastic mulches were first noted for their ability to increase soil temperature in 1950 (Emmert, 1957). Due to the monetary benefits of many horticultural crops, it is beneficial to adjust soil micro-climate to prolong the growing season and increase plant growth (Tarara, 2000). Moreover, inorganic mulches such as plastic mulches (*i.e.* black, transparent, white, previous, yellow, silver and black, blue, red etc.) have been found very effective in conserving soil moisture, reducing evaporation losses, warming the soil, soil solarization, control weeds, crop clean, promotes early growth, improved soil micro-climate,improved quality and yield (Kasperbaur, 2000; Lal *et al.,* 2003; Shirgure *et al.,* 2005; Zhang *et al.,* 2007; Singh *et al.,* 2009; McCann *et al.,* 2007; Kher *et al.,* 2010; Haneef *et al.,* 2014; Iqbal *et al.,* 2015; Kader *et al.,* 2017; Laulina and Hasan, 2018). However, an effective in reducing reference crop evapotranspiration (ET_r) as a crop coefficient (K_c) values decrease by an area 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). These plastic mulches have been used as agricultural mulch in many parts of the world for more than 50 years (Ham *et al.,*1993; Espi *et al.,* 2006; Bhattacharya *et al.,* 2018). The plastic mulches are generally made from LDPE, LLDPE, HDPE and flexible PVC (Kasirajan and Ngouajio, 2012; Paul *et al.,* 2013; Steinmetz *et al.,* 2016; Patel and Tandel, 2017). Further, reported that mulching boosts the yield by 50-60% and saved water by 24-26% over no mulching under rainfed situations (Dilip Kumar *et al.,*1990; Li *et al.,* 2003; Shirgure *et al.,* 2005; Maji and Das, 2008; Mark *et al.,* 2015). Keeping this in the background, the present investigation was undertaken to study the response of inorganic mulches and irrigation levels on the growth, quality, yield and WUE of pomegranate.

2. MATERIALS AND METHODS

Study Area

The field trial was conducted at ICAR-National Research Center on Pomegranate Research Farm, Solapur, India (17°10"N, 74°42"E and an altitude of 483.60 m above mean sea level) in *hasta bahar* during two consecutive seasons (2019 and 2020) with the Bhagawa pomegranate cultivar, which corresponded to trees 6^{th} and 7^{th} years-old. The experiment was laid out with two factors in split-plot design with main treatments of five irrigation levels each year for pomegranate tree (*i.e.* Factor A: I_0-50%$^*ET_p$; I_1-60%$^*ET_p$; I_2-70%$^*ET_p$; I_3-80%$^*ET_p$; I_4-90%$^*ET_p$ for six year old tree and I_0-60%$^*ET_p$; I_1-70%$^*ET_p$; I_2-80%$^*ET_p$; I_3-90%$^*ET_p$; I_4-100%* ET_p for seven year old tree) and sub-treatments of mulch (*i.e.* Factor B inorganic mulch: M_0-no mulch (control), M_1-black mulch, M_2-black and white mulch and M_3-previous / weed mat mulch). The electrical conductivity and residual sodium carbonate of the irrigation water used were 0.5 dS m^{-1} and 2.2 meq l^{-1}, respectively. The laterals were laid below the mulch and 4 drippers of 2.0 lph under an operational pressure of 1.0 kg cm^{-2} had been given to each tree. The drip irrigation system consisted of plastic laterals of 16 mm diameter with on-line pressure compensating drippers at a 60 cm distance away from the trunk of the trees and 100-micron thickness mulch was used in the present study. The irrigation through a drip system was applied on alternate day for the required time to deliver the calculated quantity of water based on atmospheric demand. The experiment was conducted on light texture soil with a standard recommended dose of fertilizers and other management practices.

Cultivation

The orchard used in the study was planted in the first week of July 2013 at a spacing 4.5 m × 4.0 m. The plants are almost 6^{th} years-old during the installation of the test. Every successive four months, training and pruning have been done and all flowers, new fast-growing branches and suckers were regularly removed for two years. After two years of plant growth, heavy pruning was done and ethereal @ 0.2% alongwith 0.5% DAP was sprayed for leaf drops to maintain the ideal C:N ratio in plants for good flower induction. Within 15 days, 90% of leaves were fall and proper stress was maintained in plants, then irrigation was resumed and fertilizer dose was applied. The liquid fertilizer was used with water at the rate of 100 L / 20 kg, stored for 48 hrs and subsequently injected into the lateral geometry irrigation network through Netaject fertigation unit using a fertigation programme at rates of 30, 60 and 120 kg ha^{-1}. The various phenological growth stages of the plants were identified for irrigation scheduling between new leaf initiations to the harvesting period (Melgarejo *et al*., 1997).

Climatic Parameters

Daily weather data was collected from Agro-Met. Observatory is located at the same research farm. The phenophase wise mean monthly climatic parameters in *hasta bahar* taking an average of two years from September to April during 2019 and 2020 are depicted in Table 1. The mean monthly maximum and minimum temperature varied between 33.3 to 40.8°C and 21.5 to 32.5°C, respectively. The mean monthly maximum and minimum relative humidity varied between 65.4 to 88.2% and 37.5 to 67.4%, respectively while sunshine hours varied between 8.7 to 10.1 hr. Wind speed varied between 7.8 to 10.9 km hr^{-1}. Rainfall of 180.2 mm was received in September, while 7.9 mm was recorded in November.

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

The water to be applied and time of irrigation was estimated on daily basis for the pomegranate trees at 50% to 100%*ET_r irrigation levels for 6th and 7th year-old age pomegranate tree orchards by using the eq's. 1 and 2.

$$WR = \frac{(ET_r \text{ x } K_c \text{ x } K_{pan} \text{ x } A \text{ x } WA)}{IE} \quad ...(1)$$

Where, WR - water requirement, L day^{-1} $tree^{-1}$; 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 - irrigation efficiency of the drip irrigation system, fraction.

Irrigation Time (hrs)

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

Where, IT - irrigation time, hr; WR - water requirement, L day^{-1} $tree^{-1}$; DC - dripper discharge capacity, L hr^{-1}.

Estimation of Reference Crop Evapotranspiration (mm)

The Penman-Monteith method has a strong likelihood of correctly predicting ET_r in a wide range of locations and climates (Allen *et al.,* 1998). The daily values of ET_r were estimated by eq. 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^{-1}; G - soil heat flux density, MJ m^{-2} day^{-1}; R_n - net radiation at the crop surface, MJ $m^{-2}day^{-1}$; T - mean daily air temperature, ^{0}C; 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^{-1}.

Crop Coefficient (K_c)

The values of K_c have been estimated for different phenophases of the crop by using the shaded area approaches. The K_c was calculated by eq. 4, which is developed for deciduous fruit crops (Ayars *et al*., 2003; Gorantiwar *et al*., 2011).

$$K_c = 0.014x + 0.08 \quad ...(4)$$

Where, K_c - Crop coefficient; x - Shaded area, %

By using the above-stated equation, the phenophase wise K_c values were developed (*i.e.* new leaf initiation, development, maturity and harvesting).

The other parameters *i.e.* crop coefficient (K_c), pan coefficient (K_{pan}), wetted area (WA) and irrigation efficiency (IE) was used for estimating the water requirement (L day^{-1} $tree^{-1}$) of pomegranate (Ayars *et al.,* 2003; Gorantiwar *et al.,* 2011; Intrigliolo *et al.,* 2011; Meshram *et al.,* 2019).

Water Use Efficiency (WUE)

From the observed data, yield and daily water requirement were worked out and WUE was calculated by using the eq. 5.

$$WUE = \frac{\text{Yield (kg)}}{\text{Water requirement } (m^3)} \quad ...(5)$$

Leaf Area Index (LAI) Method

LAI was estimated by harvesting green healthy small, medium and large size leaves from the representative plants of selected tree/plantation and measuring their area without petiole by using LI - 3000 Licor that uses an electronic method of rectangular approximation. The total leaf areas were estimated by multiplying the average leaf area of each range (*i.e.* small, medium and large) by the number of leaves in those ranges. The LAIs are estimated as the ratio of total leaf area to shaded area at solar noon hour or area occupied by a tree. The indirect LAI was evaluated treatment wise. The indirect LAI is calculated by the eq. 6.

$$LAI_{pom} = \frac{LA_A \times N}{SA_{SN}} \text{ or } \frac{LA_A \times N}{APP} \quad ...(6)$$

Where, LAI_{pom} - leaf area index of the pomegranate tree, dimensionless; LA_A - average leaf area of small, medium and large harvested leaves, m^2; N - total number of leaves of the tree; SA_{SN} - shaded area of tree at solar noon hour, m^2; APP - area occupied by tree, m^2.

Statistical Analysis

The data in the present study were statistically evaluated using Web Agri Stat Package, version 2.0 (WASP - 2.0) and the differences between the means of the best treatment were considered significant at 5% confidence level by using Tukey test. Standard deviations (SD) were calculated using Excel plus software of the Office 2013® suite.

3. RESULTS AND DISCUSSION

Weather Conditions and Water Consumptions (ET_r)

The daily climatic data of 480 days at the experimental site covering the period of September 2019 to April 2020 were analyzed for the calculating reference crop evapotranspiration (ET_r) by the Penman-Monteith method. It was observed that the trend of the estimated ET_r, rainfall and water demand of atmospheric values over the days are different due to variation in climatic parameters. The rainfall distribution was higher than the water demand in the month of September (*i.e.* new leaf initiation) which affects the vegetative growth and flowering of trees during the study period. However, rainfall quanta were low in the month of November to April (*i.e.* development, maturity and harvesting period). The average *hasta bahar* rainfall was 307.5 mm. The water to be applied at different phenological stages for 6th and 7th years-old age pomegranate trees (*i.e.* new leaf initiation, crop development, crop maturity and harvesting period) through drip system at 90% irrigation efficiency was ranged from 18.50-35.50 and 22.60 - 45.20 $Lday^{-1}tree^{-1}$, respectively.

Crop Phenology (CP)

240 days were taken to attain the total phenological event from new leaf initiation to the harvesting period in *hasta bahar* during each successive season (Table 2). In the two years of study, the average number of days taken for new leaf initiation was 25 days (10% ground cover of tree), the crop development period was 65 days (60 to 80% ground cover of the tree), maturity to yellowish of leaves was 85 days and harvesting period when ripe fruits start falling on the ground or birds and squirrels start nibbling the fruits, which are ripe was 65 days. Bhagawa being the late maturing variety took more than 200 days from new leaf initiation to harvesting. Similar studies on pomegranate, apple, and peaches on duration across the phenological stages were reported by Melgarejo *et al.,* 1997 and Boland *et al.,* 2002.

Crop Coefficient (K_c) and Wetted Area (WA)

The K_c and WA values for different growth stages of pomegranate are given in Table 2. On average K_c values

Table: 1
The mean monthly climatic parameters during the study period

Phenophase	Months	T_{max} (°C)	T_{min} (°C)	RH_{max} (%)	RH_{min} (%)	SSh (hr)	WS (km hr^{-1})	E_{pan} (mm)	Rainfall (mm)
Initial	September	35.3	24.6	88.2	67.4	8.7	9.5	6.8	180.2
Development	October	35.0	25.5	83.2	65.2	8.8	7.9	5.8	111.3
	November	34.0	23.2	87.4	50.1	9.2	9.9	9.8	7.9
	December	33.3	21.5	79.0	57.2	9.2	7.8	5.0	0.0
	January	33.5	21.6	85.4	57.8	8.8	8.4	6.0	0.0
Maturity	February	36.6	25.4	81.2	59.9	10.1	10.9	6.6	0.0
	March	37.2	24.3	65.4	37.5	10.0	10.6	10.4	8.1
Harvesting	April	40.8	32.5	77.7	46.5	10.1	10.6	14.4	0.0

T_{max} - Maximum temperature; T_{min} - Minimum temperature; RH_{max} - Maximum relative humidity; RH_{min} - Minimum relative humidity; SSh - Bright sunshine hours ; WS - Wind speed; E_{pan} - Pan evaporation

Table: 2
Phenophase wise number of days, wetted area and crop coefficient for 6th and 7th year-old pomegranate tree

Phase	Phenophase indicators	Average no. of days	Wetted area (%)		Crop coefficient (K_c)	
			6th year	7th year	6th year	7th year
New leaf initiation	Start of new leaves to 10% ground cover	25	0.40	0.50	0.25	0.35
Development	10% ground cover to effective full cover, about 60-70% coverage crops	65	0.50	0.55	0.75	0.80
Maturity	Effective full cover to maturity, indicated by yellowing of leaves, leaf drop and browning of fruit	85	0.65	0.70	0.85	0.90
Harvesting	Maturity to harvest, indicated by ripe fruit starts falling on the ground	65	0.50	0.60	0.65	0.70

varied in the range 0.25 - 0.85 and 0.35 - 0.90 for 6th and 7th year-old pomegranate trees during new leaf initiation to the harvesting period, respectively. Variation in K_c with phenophase wise after pruning to the harvesting of a pomegranate tree had been seen. It was observed that K_c values were low during the initial stage of growth and follow the rising trend during the development phase. The estimated values of phenophase wise K_c indicated that the values of 6th and 7th year-old pomegranate trees increased from 0.25 to 0.80 and 0.35 to 0.90, respectively. However, the K_c values of the 6th and 7th year-old pomegranate tree showed the four distinct phases of K_c. Initially, the K_c values increase from 0.25 to 0.80 for 6th and 0.35 to 0.90 for 7th year old tree. The K_c values are then almost constant upto crop maturity *i.e.* 0.80 and 0.90. The gradually declining trend was observed in K_c values during the harvesting stage. During the harvesting period, K_c decreased from 0.85 to 0.65 and 0.90 to 0.70 for 6th and 7th year-old trees, respectively due to leaf drop, less amount of irrigation, removal of water sprout and harvesting of fruit. Lower K_c values represent slower plant growth and lower plant canopy cover, indicating lower water requirement. K_c values attain the peak (0.85 and 0.90) during the maturity phase. It means the climatic demand for water is high during development and maturity when the crop is in a good state of health. The trend observed in K_c values of pomegranate during different phases of growth were comparable to those given by Gorantiwar *et al.,* 2011 and agreed fairly well. Phenophase wise WA was computed and it showed that the average WA for various phenophase (*i.e.* new leaf initiation to harvesting) was ranged from 0.40 to 0.65 and 0.50 to 0.70 for 6th and 7th year-old pomegranate tree, respectively.

Water Requirement (Wr_p)

Phenophase wise actual and water to be applied to pomegranate trees during two years studies are furnished in Fig's. 1 and 2. Considerable variation was noted in water demand which is due to dissimilar weather experiences and stages of the pomegranate trees. The applied irrigation to the pomegranate trees was estimated and presented in Fig's. 1 and 2 at various irrigation levels during the new leaf initiation to harvesting period in *hasta bahar.* The water to be applied through a drip irrigation system at 90% irrigation efficiency was ranged from 18.50 - 35.50 and 22.60 - 45.20 Lday^{-1}tree^{-1} for 6th and 7th year-old pomegranate trees due to the variation in ET_r, K_c and WA values (Chopade and Gorantiwar, 1998; Meshram *et al.,* 2012). In general, there was well-distributed rainfall (*i.e.* 291.50 mm) during Sep and Oct, the irrigation given was very less for that period. The total values of water to be applied to the pomegranate tree are 9017.35 and 9037.78 liters per *bahar* per tree at 70 and 80%*ET_p for the 6th and 7th-old-age tree, respectively, the similar result reported by Intrigliolo *et al.,* 2011.

Effect of Irrigation Levels and Inorganic Mulching on Vegetative Growth

The data pertaining to the vegetative growth of trees before and after start of experiment presented in Table's 3 and 4 indicate that these parameters are significantly influenced by the various irrigation levels and mulching treatments. The average plant height (m), LAI and plant canopy spread (m) in all the irrigation and mulching treatments were significantly higher in 7th year-old pomegranate trees than in 6th year-old. These differences depended on the age of the plants. For 6th year-old pomegranate tree, the higher plant height (2.12 m) was recorded in the I_2 treatment, which was significantly different from the treatments I_0 (1.97 m), I_1 (1.98 m), I_3 (2.04 m) and I_4 (2.04 m). Similarly, the higher plant height (2.23 m) for 7th year-old tree was registered in treatment I_2, which was statistically different from the treatments I_0 (2.07 m), I_1 (2.08 m),

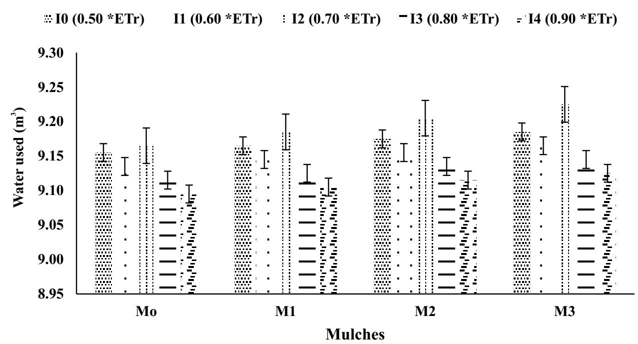

Fig. 1. Water used by 6th year-old pomegranate tree

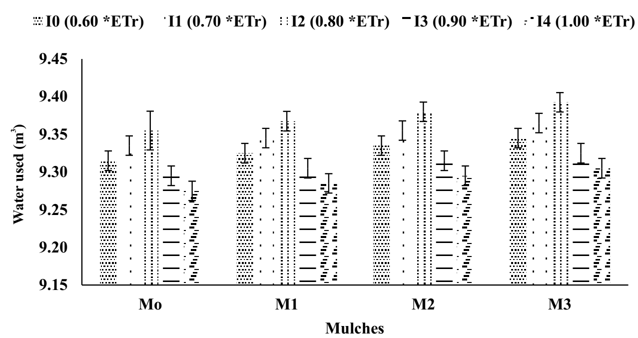

Fig. 2. Water used by 7th year-old pomegranate tree

Table: 3
Status of plant growth parameters before the start of experiment

Treatments	Plant height (m)	LAI	Plant spread (m)	
			E-W	N-S
M_0-No Mulch	1.82	2.98	1.52	1.68
M_1-Black mulch	1.89	2.30	1.55	1.72
M_2-Black and White	1.98	3.08	1.57	1.82
M_3-Previous/weed mat	2.10	3.10	1.83	1.91
CD (P=0.05)	0.025	0.094	0.025	0.020

Table: 4
Effect of irrigation levels and inorganic mulches on vegetative growth of 6th and 7th year-old pomegranate tree

Treatment combinations	Plant height (m)		LAI		Plant canopy spread (m)			
	6th	7th	6th	7th	6th		7th	
					E-W	N-S	E-W	N-S
Irrigation								
I_0	1.97±15.24c	2.07±16.68c	3.04±0.21b	3.52±0.09d	1.57±0.04d	1.73±0.04c	1.65±0.05d	1.70±0.07e
I_1	1.98±13.54c	2.08±13.60bc	3.04±0.16b	3.63±0.14c	1.62±0.04c	1.75±0.05b	1.60±0.06e	1.71±0.04d
I_2	2.12±8.60a	2.23±13.21a	3.16±0.18a	3.86±0.21a	1.75±0.08a	1.85±0.06a	1.77±0.07a	1.80±0.07a
I_3	2.04±14.77b	2.10±13.62bc	3.06±0.23b	3.81±0.15b	1.63±0.06b	1.73±0.03c	1.67±0.05b	1.73±0.06b
I_4	2.04±13.67b	2.12±13.03b	3.07±0.21b	3.84±0.19ab	1.54±0.02e	1.75±0.03b	1.65±0.04c	1.72±0.06c
Mulching								
M_0	1.92±7.87c	1.98±6.36d	2.83±0.08d	3.57±0.10d	1.61±0.05c	1.75±0.03c	1.61±0.05d	1.67±0.04d
M_1	1.92±10.07c	2.04±10.00c	2.98±0.08c	3.65±0.12c	1.58±0.07d	1.73±0.06d	1.65±0.06c	1.75±0.03b
M_2	2.06±7.17b	2.15±10.28b	3.16±0.07b	3.77±0.19b	1.64±0.08b	1.76±0.07b	1.67±0.09b	1.71±0.07c
M_3	2.20±7.42a	2.30±6.18a	3.32±0.06a	3.94±0.19a	1.67±0.11a	1.79±0.07a	1.73±0.07a	1.80±0.05a

I_0 (50 and 60% $^*ET_p$); I_1 (60 and 70% $^*ET_p$); I_2 (70 and 80% $^*ET_p$); I_3 (80 and 90% $^*ET_p$); I_4 (90 and 100% $^*ET_p$); M_0-No Mulch; M_1-black; M_2-black and white; M_3-previous/weed mat; LAI-Leaf area index; I-Irrigation; M-Mulching; Means ± std. deviations followed by a different letter within the columns were significantly different at p ≤ 0.05, according to the Tukey test

and I_3 (2.10 m) and I_4 (2.12 m). However, independent of irrigation levels previous / weed mat mulch resulted in plants with significantly better height. It might be due to the application of needful irrigation at different phenological stages and a good moisture regime in the root zone by application of the required quantity of inorganic mulch resulting in a better environment for nutritional uptake by plants. The increase in growth of the plant was possible due to an increase in the availability of soil moisture, nutrients and moderate evaporation from the soil surface (Shirgure *et al.,* 2003). When talking about mulching treatments, the highest plant height for 6th year-old tree was reported in M_3 (2.20 m) treatment, which was significantly different from the M_o (1.92 m), M_1 (1.92 m) and M_2 (2.06 m) treatments. It might be due to the essential organic mulches for a better nutritional environment in the root zone as well as in the plant system.

The highest value of LAI in 6th and 7th year-old pomegranate tree was recorded in I_2 (3.16 and 3.86, respectively) treatment. For 6th year-old tree, the irrigation level treatment I_2 was significantly different from I_0 (3.04), I_1 (3.04), I_3 (3.06) and I_4 (3.07) treatments while in turn, for 7th year-old tree, it was not significantly different from I_4 (3.84) treatment but statistically different from I_0 (3.52), I_1 (3.63) and I_3 (3.81) treatments. Similarly, mulching treatment M_3 (3.32 and 3.94) recorded the highest LAI for 6th and 7th year-old pomegranate trees, respectively. The M_3 treatment was statistically different from M_0 (2.83 and 3.57), M_1 (2.98 and 3.65) and M_2 (3.16 and 3.77) treatments in both years, respectively.

The higher E-W and N-S plant canopy spread for 6th-year-old tree were found in treatment I_2 (1.75 m and 1.85 m, respectively) which was significantly different from I_0 (1.57 m and 1.73 m, respectively), I_1 (1.62 m and 1.75 m, respectively), I_3 (1.63 m and 1.73 m, respectively) and I_4 (1.54 m and 1.75 m, respectively) treatments. Similarly, for 7th year-old tree, the higher E-W and N-S plant canopy spread was registered in treatment I_2 (1.77 m and 1.80 m, respectively) which was statistically different from I_0 (1.65 m and 1.70 m, respectively), I_1 (1.60 m and 1.71 m, respectively), I_3 (1.67 m and 1.73 m, respectively) and I_4 (1.65 m and 1.72 m, respectively) treatments. Mulching treatment M_3 (1.67 m and 1.79 m) recorded higher E-W and N-S plant canopy spread for 6th year-old tree which was significantly different from M_0 (1.61 m and 1.75 m, respectively), M_1 (1.58 m and 1.73 m, respectively) and M_2 (1.64 m and 1.76 m, respectively) treatments. Similarly, in 7th year-old pomegranate tree, the highest E-W and N-S plant canopy spread was found in mulching treatment M_3 (1.73 m and 1.80 m, respectively) which was significantly different from M_0 (1.61 m and 1.67 m, respectively), M_1 (1.65 m and 1.75 m, respectively) and M_2 (1.67 m and 1.71 m, respectively) treatments.

The favourable influence of I_2 (70 and 80%) treatment on plant height, LAI, and plant canopy spread (E-W and N-S) may be due to optimum moisture in the soil through drip irrigation resulting in greater vigour (Subramanian *et al.,* 1997). The higher soil moisture availability, addition of nutrients and less weed growth associated with mulches can be attributed to the higher extension of growth under mulching treatments. More or less similar results have been reported by Autio *et al.,* 1991; Borathakur and Bhattacharya, 1992; Pande *et al.,* 2005.

Effect of Irrigation Levels and Inorganic Mulching on Yield Attributes

The results revealed that no. of fruits/tree, fruit weight, yield and WUE responded differently to different irrigation levels through drip irrigation levels and mulching treatments and it is presented in Table 5. For 6th year-old pomegranate tree, irrigation treatment I_2 recorded the highest no. of fruits/tree (80.75) which was statistically different from I_0 (69.74), I_1 (73.69), I_3 (76.25) and I_4 (75.13) treatments. A similar result for 7th year-old tree was obtained, treatment I_2 registered a maximum no. of fruits/tree (85.38) which was again significantly different from I_0 (72.13), I_1 (76.13), I_3 (77.63) and I_4 (77.63) treatments. Comparing the influence of mulching material used, for 6th year-old tree, treatment M_3 reported the highest no. of fruits/tree (87.90) followed by M_1 (76.40) treatment. Similarly, treatment M_3 also reported the highest no. of fruits/tree (88.70) followed by M_1 (78.60) treatment in the case of 7th year-old pomegranate tree.

The maximum fruit weight was observed in irrigation treatment I_2 (292.06 g) which was statistically different from I_0 (281.56 g), I_1 (279.25 g), I_3 (281.81 g) and I_4 (285.81 g) for 6th year-old tree while mulching treatment M_3 (292.50 g) recorded the highest fruit weight for same old age tree. Incase of 7th year-old tree, the highest fruit weight was seen in irrigation treatment I_2 (296.38 g) and mulching treatment M_3 (298.55 g).

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 registered in irrigation levels of 70 and 80% (23.62 and 25.38 kg tree^{-1}, respectively). 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 levels. When compared with the irrigation level treatment I_0 (50 and 60%$^*ET_p$), the yield increment in I_2 (70 and 50%$^*ET_p$) treatment was 19.78 and 23.80 kg tree^{-1} for 6th and 7th year-old pomegranate tree, respectively. As seen in the case of growth parameters and yield contributing attributes (no. of fruits per tree and fruit weight), the M_3 treatment (previous/weed mat mulch) produced significantly higher yield (25.72 and 26.51 kg tree^{-1}) when compared with other and no mulch treatments (Table 5). The increment of yield in previous/weed mat mulch treatment was 38.43 and 34.09% over no mulch treatment for 6th and 7th year-old pomegranate tree, respectively. Similar results were observed by Keramat *et al.,* 2011; Julian *et al.,* 2012; Larco *et al.,* 2013; Strik and Vance, 2017 and Strik *et al.,* 2017.

Effect of Irrigation Levels and Inorganic Mulching on Water Used and WUE

The Fig's 1 and 2 and Table 5 clearly indicates that different irrigation level with inorganic mulch had a significant effect on water used (WU) and WUE of pomegranate trees. As regards different irrigation levels, the mean maximum WU was 9.20 and 9.37 m^3 for 6th and 7th year-old pomegranate trees at 70 and 80%$^*ET_p$ irrigation levels, respectively. In terms of different mulching treatments used, the treatment M_3 (previous/weed mat) reported higher WU (9.17 and 9.35 m^3) for 6th and 7th year-old trees, respectively compared with the M_0, M_1 and M_2 (9.13, 9.15, 9.16 and 9.32, 9.33, 9.34 m^3, respectively) treatments (Fig's 1 and 2). There was a significant WUE difference between both irrigation and mulching treatments. The irrigation levels 70 and 80%$^*ET_p$ had the higher WUE (Table 5). WUE had its highest value in the treatment I_2 (2.57 and 2.71 kg m^{-3}) compared to I_0, I_1, I_3, and I_4 (2.15, 2.25, 2.35, 2.36 and 2.20,

Table: 5
Effect of irrigation levels and inorganic mulches on yield attributes and water use efficiency for 6th and 7th year-old age pomegranate tree

Treatment combinations	No. of fruits/tree		Fruit weight (gm)		Yield (kg tree^{-1})		WUE (kg m^{-3})	
	6th	7th	6th	7th	6th	7th	6th	7th
Irrigation								
I0	69.94±9.38e	72.13±7.67d	281.56±12.13c	284.00±11.41d	19.72±3.04d	20.50±2.56e	2.15±0.33d	2.20±0.27e
I1	73.69±10.90d	76.13±8.97c	279.25±8.08d	282.25±8.05e	20.60±3.31c	21.51±2.84d	2.25± 0.36c	2.30±0.30d
I2	80.75±10.13a	85.38±9.58a	292.06±3.79a	296.38±8.50a	23.62±3.24a	25.38±3.54a	2.57±0.35a	2.71±0.37a
I3	76.25±6.42b	77.63±5.98b	281.81±6.62c	284.75±7.39c	21.52±2.22b	22.14±2.19c	2.35±0.24b	2.38±0.23c
I4	75.13±9.83c	77.63±8.79b	285.81±7.29b	289.31±8.44b	21.49±3.02b	22.49±2.96b	2.36±0.33b	2.43±0.31b
Mulching								
M0	65.60±4.21d	69.40±3.73d	283.20 ±3.94c	284.80 ±3.49c	18.58±1.32d	19.77±1.22d	2.03±0.14d	2.12±0.13d
M1	76.40±3.19b	78.60±3.32b	274.10 ±9.87d	276.80 ±8.56d	20.96±1.41b	21.77±1.44b	2.29±0.15b	2.33±0.15b
M2	70.70±8.44c	74.40±9.38c	286.60±5.28b	289.20±6.12b	20.29±2.71c	21.56±3.13c	2.22±0.29c	2.31±0.33c
M3	87.90±4.09a	88.70±4.92a	292.50 ±3.62a	298.55 ±6.06a	25.72±1.38a	26.51±1.96a	2.80±0.14a	2.84±0.20a

I_0 (50 and 60% $^*ET_p$); I_1 (60 and 70% $^*ET_p$); I_2 (70 and 80% $^*ET_p$); I_3 (80 and 90%$^*ET_p$); I_4 (90 and 100% $^*ET_p$); M_0-No Mulch; M_1-black; M_2-black and white; M_3-previous/weed mat;WUE-Water use efficiency; I-Irrigation; M-Mulching; Means ± std. deviations followed by a different letter within the columns were significantly different at $p \leq 0.05$, according to the Tukey test

2.30, 2.38, 2.4 kg m^{-3}, respectively) treatments for 6th and 7th year-old pomegranate tree. It increased about 19.53% and 23.18% in I_2 when compared with I_0. In mulching treatment M_3 (previous/weed mat), for 6th and 7th year-old trees, the higher WUE (2.80 and 2.84 kg m^{-3}, respectively) was reported. Compared to control treatment M_0 (No mulch), the increase of WUE in treatment M_3 was 37.93 and 33.96% for 6th and 7th year-old trees, respectively. Earlier, Zhang *et al.,* 2007 mentioned that inorganic mulching increased WUE due to a reduction in evaporation, enhanced transpiration and deep percolation, leading to increased WUE.

4. CONCLUSIONS

The ET_r, K_c, and WA values varied in the range from 4.58-9.95 mm, 0.25-0.85 and 0.35-0.90, 0.40-0.65 and 0.50-0.70 during new leaf initiation, development, maturity and harvesting phase, respectively. Yield attributing traits (number of fruits/tree and fruit weight) were significantly higher in previous/weed mat mulch at 70 and 80%$^*ET_p$ irrigation levels for 6th and 7th year-old pomegranate *cv.* Bhagawa under micro-irrigation. Based on a statistical analysis of vegetative growth and yield attributing characteristics, the previous/weed mat mulch and irrigation levels at 70 and 80%, giving alternate day irrigation resulted in a higher number of fruits per tree along with increased fruit weight, yield and WUE. Henceforth, water management ensures increased crop yield, high WUE, high water saving, energy consumption and minimal weed problems. On average pomegranate fruit crop consumed about 9.20 and 9.37 m^{-3} water at 70 and 80%$^*ET_p$ irrigation levels, respectively and previous/weed mat consumed 9.17 and 9.35 m^{-3}. Maximum WUE was 2.57 and 2.71 kg m^{-3} for 6th and 7th year-old pomegranate tree at 70 and 80%$^*ET_p$ irrigation levels, respectively and 2.80 and 2.84 kg m^{-3} in previous/weed mat treatments. WUE does not depend only on the total amount of water consumed by the crop but also on its distribution during the various growth stages of the crop. Water conserved technologies ensure increased crop yield, high WUE, reduced water, and energy consumption. Drip irrigation with irrigation level is effectiveness of pomegranate cultivated in the previous/weed mat mulch was higher than with no mulched. It is concluded from the present study that, previous/weed mat mulch is the better technological option for improving crop production as well as WUE in pomegranate cultivation in light texture soil in Deccan Plateau.

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