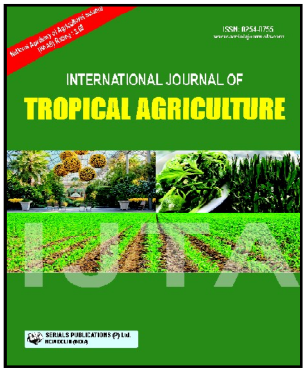

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SARIMA Model and Organic Mulches used for Improving Water use Efficiency in Pomegranate (*Punica granatum* L.)

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Abstract: The study was undertaken to develop and evaluate forecasting model for pomegranate (*Punica granatum* L.) fruit crop in *hasta bahar* at Solapur (*i.e.* North latitude 17° 10″, East longitude by 74°42″ and 483.5 m msl) and to quantify yield, quality and water use efficiency of pomegranate cultivar (*i.e.* Bhagawa). The best model *i.e.* SARIMA (1, 1, 0) $(1, 0, 1)_{52}$ amount of water applied with minimum 0.30 × *ETr* and maximum 0.70 × *ETr* through drip irrigation system for Sugarcane baggas, wheat and safflower under split plot design. Maximum plant height, flowers, branches, stem diameter and fruits was recorded in sugarcane baggas followed by safflower and wheat. The actual water applied in different organic mulches treatments is 30-70% age less than the actual water demand due to the reduced wet evaporative surface. The actual water requirement (WR) varied from 12-35 $lday^{-1}$ $tree^{-1}$ during different phenological stages (*i.e.* new leaf initiation period, crop development, crop maturity and harvesting) and 0.50 × *ETr* irrigation level was the best for sugarcane baggase mulch for 5 year old pomegranate tree. The study revealed that, the best SARIMA model for pomegranate evapotranspiration with Sugarcane baggase enhanced vegetative growth and yield contributing characteristics. However, 50% age irrigation levels for 5th year's pomegranate plants produced results at par with 50% age irrigation level respect to yield attributing traits, quality, juice content and TSS. Water management ensured increased crop yield, high water use efficiency, high water saving, energy consumption and minimal weed problems. It is concluded from the present study that, SARIMA (1, 1, 0) $(1, 0, 1)_{52}$ and 50% age irrigation level with 7-10 kg per plant sugarcane baggase is the better technological option for improving pomegranate productivity with higher benefit.

Keywords: Organic Mulches, Pomegranate, Reference Crop Eapotranspiration (*ETr*), SARIMA model, Yield and Water Use Efficiency (HUE).

INTRODUCTION

Water is the most limiting natural resource in arid and semi-arid areas for the economic development of the country. In most of the pomegranate growing regions the only water available is the rain and ground water that comes under this area, hence for sucusseful horticulture/agriculture, proper utilization of water is very essential which means to increase the water use efficiency of crop by adopting suitable water conservation measures. In this regions, water is a scarce resource and its efficient use has to be prioritized. Regular water supply through irrigation system is paramount essential for sustainable production of pomegranate. It is a major activity and is most intensively practiced operation throughout the seasons/*bahars*. Pomegranate thrives best under hot dry summer and cold winter provided optimum irrigation facilities. There are three main *bahars* flowering of *Ambea, Mrig* and *Hasta*. For maintaining productivity of the plants, generally one *bahar* is regulated, which depends upon market factors and availability of water [26]. Water applied in appropriate irrigation scheduling can influence its productivity and fruit quality [1].

In world, major pomegranate growing regions include Iran, India, China, Israel, Spain, Egypt, Tunisia, Turkey, Japan, USA, Russia, Australia, South Africa and Saudi Arabia [19]. In India, pomegranate is commercially cultivated in Maharashtra, Telangana, Tamil Nadu, Karnataka, Gujarat, Rajasthan and Madya Pradesh. At present in India over 1.31 lakh ha area is under pomegranate of with production of 13.45 lakh tonnes. About 80% of the productivity tones from Maharashtra [32]. In the pomegranate growing area of Maharashtra, water is scarce resources and there is a need to apply water judiciously according to water requirement.

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. However, regular irrigation is essential during the different phenological stages as irregular moisture condition causes dropping of flowers and reduction in fruits size [25]. The sudden change in soil moisture causes the moisture stress, which affects the fruit development adversely and leads to fruit cracking [9]. 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.* [40, 28].

In addition to these accurate estimates of evapotranspiration are helpful in proper irrigation planning and management. The pomegranate cv. 'Bhagwa' growing under high density planting system (spacing 2.0 × 2.0 m) irrigation at 100% pan evaporation rate at alternate days through drip irrigation significantly increased vegetative growth, fruit quality, yield and leaf N, P, K content [17]. For future estimation of crop evapotranspiration, the study of forecasting of hydrological model is very essential. Several time series models have been developed in past for modeling of hydrological data *i.e.* runoff, temperature, humidity, river flow, evaporation *etc.* These include autoregressive (AR) models of different orders[10, 35, 13, 36, 22, 42], moving average (MA) models for different orders [16, 44], autoregressive moving average (ARMA) models of different orders [43] for annual stream flow. For monthly or intra-seasonal flows, seasonal or periodic autoregressive integrated moving average (ARIMA) model [4, 29]and fractionally difference ARIMA models [29, 30] were used. The models used for generation and forecasting of the annual runoff, reference crop evapotranspiration and evaporation series were AR, MA and ARMA models of different orders. The models SARIMA, PARMA and FARIMA were used for seasonal and periodic runoff, reference crop evapotranspiration and evaporation series. The time series models were successfully used for the generation of the synthetic sequence of runoff, reference crop evapotranspiration and evaporation. The SARIMA models showed the ability to forecast other hydrological events such as runoff, reference crop evapotranspiration and evaporation and finally the appropriate SARIMA model was found for the forecast of *ETr*.

Pomegranate being an important fruit crop of India. 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-transparent 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 [5, 11, 24, 21, 38, 23]. The plastic mulch types are LLDPE, HDPE and flexible PVC these mulches are effective in reducing reference crop evapotranspiration (*ETr*) as crop coefficient values decrease by an areas of 10-30% due to the 50-80% reduction in soil evaporation, evpotranspirtion, environmental stress coefficient, *etc.* [12, 7, 1, 15, 16, 27, 39, 3, 33, 37]. In view of the above circumstances, the present research was undertaken to study the effect of forecasted water requirement at five different irrigation levels and organic mulches (*i.e.* sugarcane baggase, wheat and safflower) on the yield, quality and water use efficiency of pomegranate *cv.* Bhagawa.

MATERIALS AND METHODS

Study Area

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° 10" and East longitude by 74° 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 mulch kept as 10 cm layers (*i.e.* Factor A: M_0-No mulch, M_1-Wheat, M_2-Sugarcane baggase and M_3-Safflower) and sub-treatments of five irrigation levels (*i.e.* Factor B: 0.30 to 0.70 × *ETr* of fifth years old pomegranate tree). The irrigation water was applied with five replications. The electrical conductivity and residual sodium carbonate of the irrigation water used was 0.5 dSm^{-1} and 2.2 $meql^{-1}$, respectively. The drip irrigation system consisted of polyethylene 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^{-1} 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 by using Penman Monteith

Table 1
Physical and hydraulic properties of the soil profile at the experimental site.

Depth (cm)	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Texture*	*BD (Mgm^{-3})*	*HC (mmh^{-1})*
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

Table 2
Chemical properties of the soil profile at the experimental site.

Depth (cm)	*pH*	*EC(dS m^{-1})*	*OC (%)*	*NH_4-N, ($kgha^{-1}$)*	*NO_3-N, ($kgha^{-1}$)*
0-15	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

method. The experiment were conducted on light texture soil with standard recommended doze of fertilizers and other management practices.

Climtic Parameters

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°C, 20.5°C, 73%, 42%, 7.6 hrs, 7.5 kmphr, 6.9 mm and 441.20 mm in *hasta bahar* taking from August to April (Figure 1) in 2015-2016.

Development of SARIMA Model

The basic ARIMA model in its seasonal form is described as [18,6] a straightforward extension of the non-seasonal ARMA and ARIMA models. A time series involving seasonal data will have relations at a specific lag *s* which depends on the nature of the data, *e.g.* for monthly data *s* = 12 and weekly *s* = 52. Such series can be successfully modeled only if the model includes the connections with the seasonal lag as well. Such models are known as multiplicative or seasonal ARIMA (SARIMA) models.The different styles involved in fitting of SARIMA models to historical hydrological series as suggested by [18 and 6] are

(i) Standardization and normalization of time series variables;

(ii) Identification of the models;

(iii) Determination of the parameters of selected models;

(iv) Diagnostic checking and

(v) Selection of the model.

The best model used for forcasting of reference crop evapotranspiration for determing the water requirement of pomegranate.

Estimation of Reference Crop Evapotranspirtion (mm)

The Penman-Monteith method has strong likelihood of correctly predicting *ETr* in a wide range of location and climates [1]. The daily values of reference *ETr* were estimated by equation (1).

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

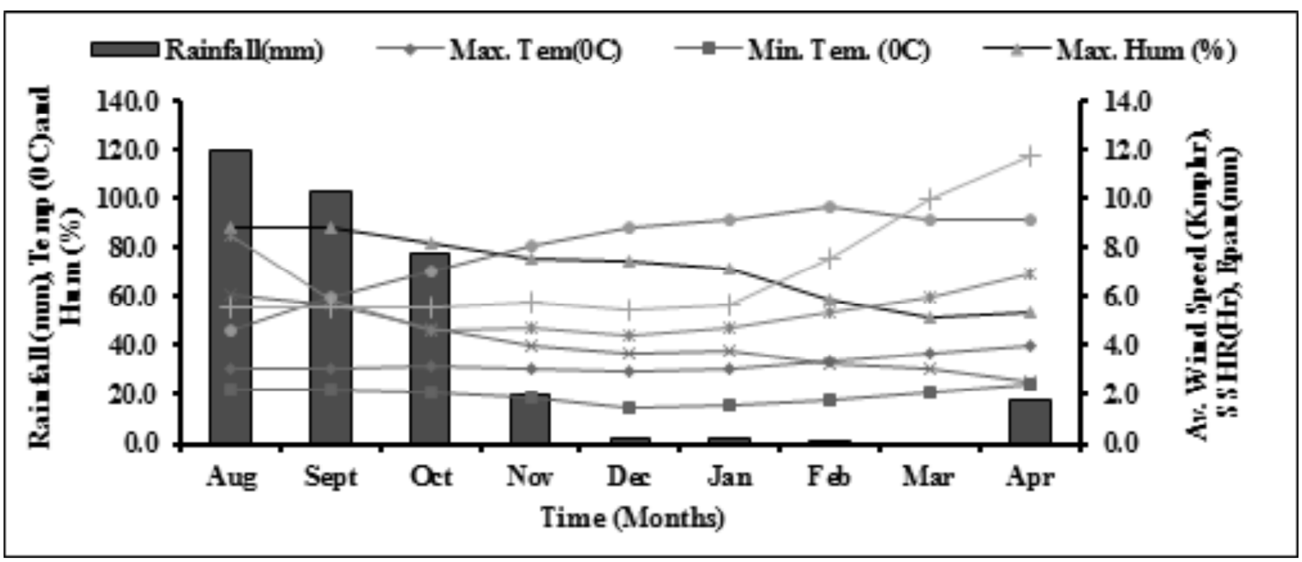

Figure 1: Average weather parameters from 1983 to 2016

Where,

ETr = 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, (°C);

γ = Psychometric constant, (kPa°C^{-1});

Δ = Slope of saturation vapour pressure function, (kPa°C^{-1});

e_s = Saturation vapour pressure at air temperature T, (kPa);

e_a = Actual vapour pressure at dew point température, (kPa);

u_2 = Average daily wind speed at 2 m height, (msec^{-1})

Water Requirement (Lday^{-1}tree^{-1})

The information on water to be applied in Ld^{-1}t^{-1} 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 dialy basis for the pomegranate trees at 0.30 to 0.70 *ETr levels for fifth years old pomegranate orchards by using the equation (1) and (2).

$$WR = \frac{\left(ET_r \times k_c \times k_{pan} \times A \times WA\right)}{IE} \qquad (2)$$

Where,

WR = Water requirement, Ld^{-1}t^{-1};

ETr = 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)

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 (Ld^{-1}t^{-1}) of pomegranate [14, 20]. For computation of water use efficiency (WUE), the fresh fruit yield per hectare were divided by the water expense and expressed as kg ha^{-1}L^{-1}.

RESULTS AND DISCUSSIONS

The daily climatic data of from the period of (*i.e.* 1983 to 2016) at the experimental site of ICAR-NRCP, Solapur were analyzed on daily basis for estimating reference crop evapotranspiration (ETr) by using Penman-Month method. The computer program in FORTRAN was developed to estimate the daily values of ETr by using Penman-Monteith method which was then added up to obtaining the weekly values. The weekly values of ETr by Penman-Monteith method are shown in Figure 2. It is revealed that the trend of the estimated ETr values over the days were different due to variation in climatic parameters.

The water to be applied at different phenological stages for fifth years pomegranate trees (*i.e. New leaf initiation period, crop development period, crop maturity and harvesting period*) through drip system at 90% age irrigation efficiency for *Hasta bahar* ranged from 22.2 to 46.8 mm week^{-1}. The values in the Figure 3 would be useful for irrigation scheduling of pomegranate by drip irrigation method.

The results revealed that sugarcane baggase mulch with irrigation levels had significant effect on vegetative characteristics like plant height, canopy spread, leaf area index and leaf nutrient status (Table 3). Among various irrigation levels at 0.50 × ETr showed higher plant height (2.20 m), plant spread (1.98 m E-W × 1.97 m N-S), leaf area index (3.10) and leaf nutrient status. 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 sugarcane

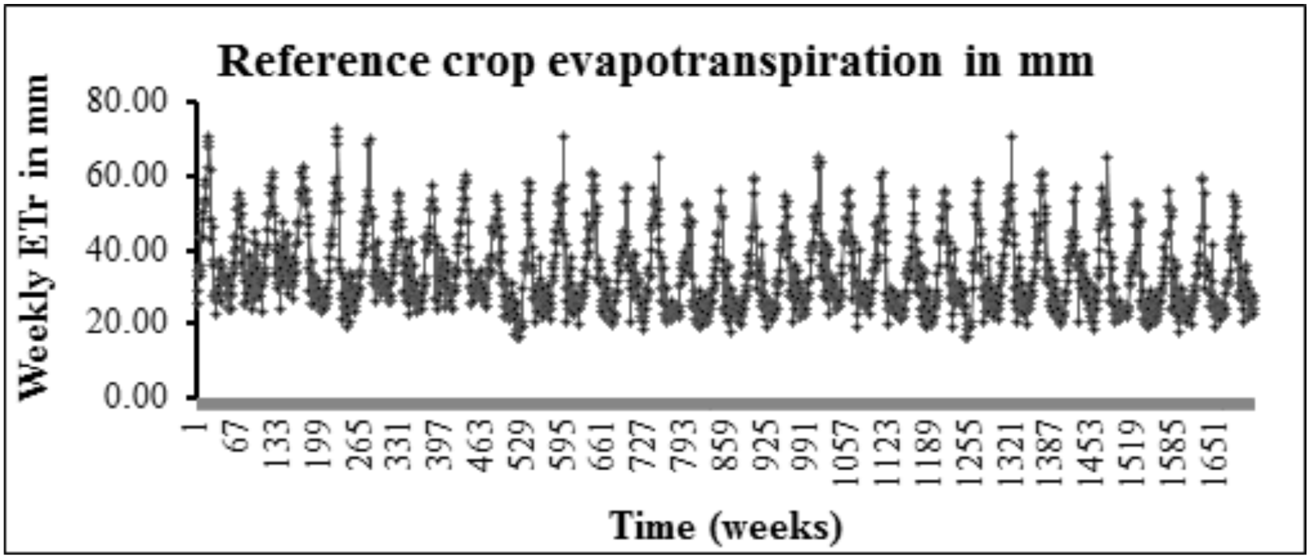

Figure 2: Weekly reference crop evapotranspiration series from 1983 to 2016.

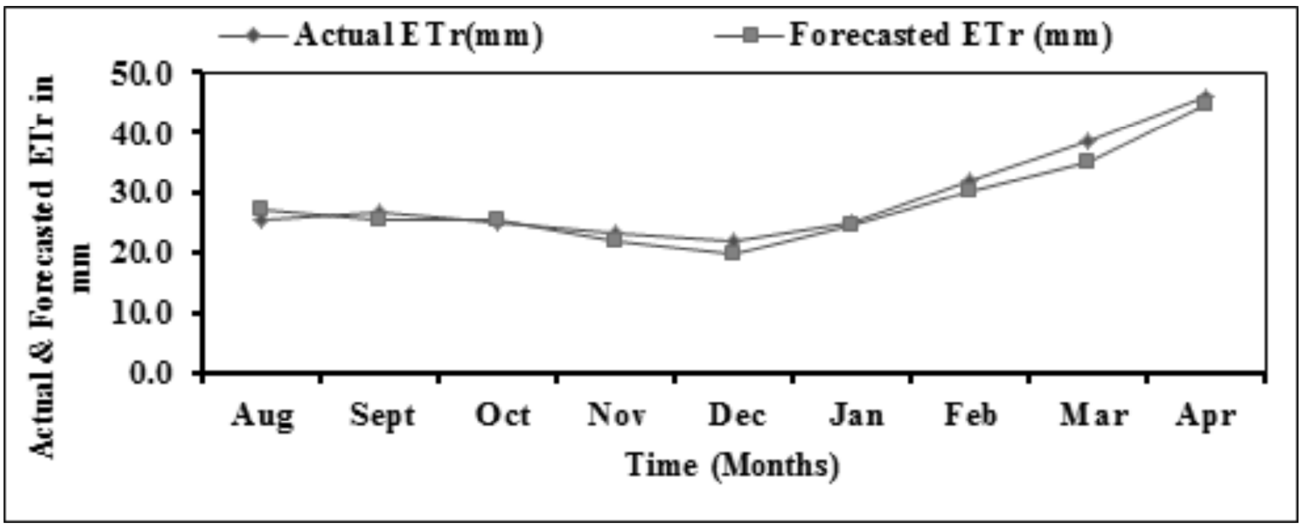

Figure 3: Comparision of actual and forecasted *ETr* values in mmweek^{-1}

baggase mulch resulting into better environment for nutritional uptake by plants. [8] while working on kiwifruit found that leaf nutrient contents were significantly higher under organic mulches compared to recommended doses of fertilizers.

The data revealed that pomegranate fruit yield responded differently to different quantities and qualtites of water applied through drip irrigation system having two laterals with four drippers at different irrigation levels during *hasta bahars* (Table 4 and 5). The influence of sugarcane baggase mulch with irrigation on fruit yield is envisaged form the fact that, the yield increment of pomegranate to the tune of 25-37% age were recorded in double lateral with four drippers and organic mulches water irrigation 40% age saving. The same combination recorded the heighest water use efficiency (0.042). [2, 17] also reported that yield in dirp irrigated pomegranate was higher than other methods of irrigation system. The quality of irrigation water singnificantly influenced the furit yield which is

Table 3
Effect of organic mulch and irrigation levels on growth and leaf nutrient status of pomegranate.

		Plant spread (m)			*Leaf nutrient status (%)*		
Treatments	*Plant height (m)*	*E-W*	*N-S*	*LAI*	*N*	*P*	*K*
Organic Mulches and Irrigation levels (0.30 to 0.70 × ET_r)							
M_0	1.95	1.53	1.56	2.56	1.67	0.18	1.20
M_1	2.05	1.84	1.78	2.67	1.79	0.20	1.22
M_2	2.20	1.98	1.97	3.10	1.88	0.25	1.35
M_3	1.78	1.78	1.92	2.78	1.87	0.18	1.31
CD (*P* = 0.05)	0.040	0.05	0.020	0.096	0.048	0.029	0.038

evident the fact that generally in poor quality irragiton and mulches, the mean fruit yield in absolute quantites was considerably reduced in comparison to other irrigation methods. Application of irrigation level I_2 (50% age) during experiment effectively increased the vegetative growth and leaf nutrient status. The favorable influence of I_2 (50% age) 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 [20, 41]. Earlier, [34] 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 form the data presented in the Table 6 that sugarcane baggase mulch and irrigation levels had significant effect on the yield attributes. Sugarcane baggase mulch with irrigation level (I_2) recorded the maximum number of fruits (66 nos.), average fruit weight (305 g), yield (20.13 kg plant^1), juice content (38.10% age), organoleptic rating (9.6). However, maximum TSS: acid ratio (18.30) along with minimum rind thickness (2.60 mm) was recorded in $M_2 \times I_2$ accumulation of more carbohydrates into the fruit further, during the subsequent fruit development. Similarly, different irrigation levels of drip 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 50% age 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 to accurate the fruit growth and development of quality charcters in the fruits during fifth year of pomegranate plants. The increase in juice content might be because of more absorption of water and minerals from the soil resulting into increased juice content [31].

Table 4
Effect of mulch and irrigation levels on yield and quality of pomegranate during *hasta bahars*

Treatments	*No. of fruits/plant*	*Av. Fruit weight (g)*	*Yield/plant (kg)*	*Juice content (%)*	*TSS: acid ratio*	*Organoleptic rating*
Mulch and Irrigation levels (0.30 to 0.70 × ET_r)						
M_0	43	280	12.04	31.13	14.00	6.3
M_1	49	287	14.06	34.80	15.78	8.5
M_2	66	305	20.13	40.73	16.36	9.9
M_3	47	295	13.86	39.42	15.45	8.5
CD (*P* = 0.05)	1.31	0.99	0.27	1.39	2.12	0.083

Table 5
Effect of mulch and irrigation levels on production and water use efficiency of pomegranate during *hasta bahars*

	5th Year		
Treatments (IL)	*WR ($Lba^{-1}t^{-1}$)*	*Yield (kg)*	*WUE ($kgha^{-1}L^{-1}$)*
$I_0 = 0.30 \times ET_r$	1520	12.04	0.0029
$I_1 = 0.40 \times ET_r$	3210	14.06	0.0041
$I_2 = 0.50 \times ET_r$	4879	20.13	0.0042
$I_3 = 0.60 \times ET_r$	5872	13.86	0.0023
$I_4 = 0.70 \times ET_r$	7844	14.50	0.0018

Note: $Lba^{-1}t^{-1}$–Litres per bahar per tree; kg–Kilogram; $kgha^{-1}L^{-1}$–Kilogram per hectare per liter.

Yield obtained during *hasta bahars* significantaly higher in sugarcane baggase mulch with at 50% age irrigation level for fifth year pomegranate cv. Bhagawa under micro-irrigation. Based on statistical analysis of vegetative and yield characteristics, the sugarcane baggase with irrigation level at 50% age giving alternate day irrigation resulted in higher yield with quality fruits. Henceforth, water management ensure increased crop yield, high water use efficiency, high water saving, energy consumption and minimal weed problems.

The reference crop evapotranspiration (*ETr*) time series pertaining to experimental site has been investigated in this paper. The SARIMA (1, 1, 0) $(1, 0, 1)_{52}$ gave the lower values of RMSE and hence is the best Seasonal ARIMA model for generation and forecasting of weekly *ETr* values. Seasonal ARIMA model can successfully used for forecasting of reference crop evapotranspiration and forecasting performance of the seasonal ARIMA model was found to be satisfactory with suagarcane baggase at 50% age irrigation level is the better technological option for improving crop productivity. Henceforth, it is concluded from the present study that, SARIMA (1, 1, 0) $(1, 0, 1)_{52}$ and 50% age irrigation level with 7-10 kg per plant sugarcane baggase is the better technological option for improving pomegranate productivity with higher benefit.

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Table 6
Effect of mulch and irrigation levels on growth, yield and quality components of pomegranate

Treatment combination	*Plant height (m)*	*Plant spread (m)* E-W	N-S	*Fruit wt. (g)*	*Yield/plant (kg)*	*Juice content (%)*	*TSS: acid ratio*	*Organolptic rating*
M_0 (I_0 to I_4)	1.95	1.53	1.56	280	12.04	32.8	16.8	6.7
M_1 (I_0 to I_4)	2.05	1.84	1.78	287	14.06	33.5	17.3	8.8
M_2(I_0 to I_4)	2.20	1.98	1.97	305	20.13	38.1	18.3	9.6
M_3 (I_0 to I_4)	1.78	1.78	1.92	295	13.86	40.3	15.4	8.8
CD ($P = 0.05$)	0.044	0.049	0.085	NS	NS	1.24	NS	0.17

Note: M_0–No Mulch; M_1–Wheat; M_2–Sugarcane baggase; M_3–Safflower; I_0–0.30 × *ETr*; I_1–0.40 × ET_r; I_2–0.50 × ET_r; I_3–0.60 × ET_r; I_4–0.70 × ET_r).

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