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Water requirement of pomegranate (*Punica granatum* L.) plants upto five year age

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Abstract

The study was carried out to estimate reference crop evapotranspiration, develop crop coefficient, area factors and estimates of pomegranate evapotranspiration for Pune region of Maharashtra. The crop coefficient values were estimated on weekly basis from the concept of shaded area approach that is widely used for the deciduous crops. Shaded area was estimated at 12.00-13.00 h with the help of specially prepared plywood board of different sizes with grid marking of size 20 x 20 cm for 5 randomly selected pomegranate trees each from 2 orchards of different ages. The values of water to be applied to pomegranate plantation spaced at 4.5 x 3 m and irrigated by the drip irrigation system of 90 % efficiency were estimated for 1st, 2nd, 3rd, 4th and 5th year of pomegranate orchard for *Ambe Bahar*, *Mrig Bahar* and *Hasta Bahar*. The values of water to be applied presented in this paper would be useful for the appropriate irrigation water management of pomegranate.

Key words: Pomegranate, reference crop evapotranspiration (ET_r), actual evapotranspiration (ET_c), crop coefficient (k_c), area factor (Fa)

Introduction

Pomegranate (*Punica granatum* L.) is one of favourite fruit crops of tropical and sub-tropical regions. It is a high value crop and has great economic significance (Levin, 2006; Jalikop, 2007; Holland *et al.*, 2009). India is the largest producer of pomegranate (Jadhav and Sharma, 2007). It is commercially cultivated in Maharashtra followed by Karanataka, Andhra Pradesh and Gujarat. The total pomegranate production in the world is around 15 lakhs tonnes out of which India produces 8.28 lakhs tonnes, but exports only 33.4 thousand tones (Holland *et al.*, 2009).

At present, around more than 1.27 lakh ha area is covered in India under pomegranate cultivation of which around 1 lakh ha is in Maharashtra alone, producing about 67 % of total Indian production. The productivity level is still low (<6.7 t/ha) in India as compared to the major pomegranate producing countries like Israel, Iran, Spain, China, (>40 t/ha) etc. (Holland and Bar-Ya'akov, 2008). In Maharashtra, pomegranate is commercially cultivated in the regions of Solapur, Nasik, Ahmednagar, Pune, Sangli, Satara, Dhule, Aurangabad, Latur and Osmanabad. In the pomegranate growing area of Maharashtra, water is scarce and hence, there is a need to apply water according to water requirement of the crop. The water requirement of crop depends on age, season, location and management strategies (Allen *et al.*,1998).

There are many methods reported in the literature to estimate reference crop evapotranspiration. The important methods include: Penman, Modified Penman, Penman-Monteith, Hargreaves-Samani, Pan Evaporation, Blanney-Criddle, Radiation, Jensen-Haise, Priestly-Taylor, Thronthwaite and Christiansen. The excellent reviews on these methods have been provided by Doorenbos and Pruitt (1977) and Patil and Gorantiwar (2009). Some methods require huge data set but are considered accurate whereas other require less data and give approximate value. FAO Penman-Monteith method (Allen *et al.*, 1998) has been recommended as a standard. Therefore, in this study, estimates of ET_c for pomegranate were made by Penman-Monteith method.

Computation of water requirement needs the measurement of evapotranspiration (ET_c). However, evapotranspiration is not easy to measure. Specific devices and accurate measurements of various physical parameters or the soil water balance in lysimeters are required to measure evapotranspiration (Doorenbos and Pruitt,1977). These methods are often expensive and demanding in terms of accuracy of measurements and can only be fully exploited by well trained research personal. Although, the methods are inappropriate for routine measurements, they remain important for the evaluation of ET_r estimates obtained by indirect methods. However due to simplicity, indirect method use weather parameters for estimation of ET_r. The ET_c is then estimated by multiplying ET_r with k_c. The development of simple method to estimate seasonal k_c for different crops, including woody, perennial, horticultural crops would be of great benefit to the horticultural industry (Williams and Ayars, 2005). Hence, accurate estimation of ET_r and k_c are of paramount importance for proper irrigation scheduling.

The paper presents the methodology used for determination of ET_r, k_c, WR and the weekly values of water to be applied in *Ambe Bahar, Mrig Bahar* and *Hasta Bahar* for the pomegranate orchards of Pune region of Maharashtra in India.

Materials and methods

Determination of k_c values: The k_c values vary with the crop growth stages and the age of the crop. The determination of k_c values needs the measurement of ET_c and the estimation of ET_r. ET_c values need to be measured with help of lysimeters or soil moisture studies. As the pomegranate is a widely spaced fruit crop and stabilizes after 4-5 years, it is required to grow pomegranate for 4-5 years in large lysimeters. Such type of experimental set up is very expensive and takes lot of time to generate the information, though accurate. Hence in this study it was proposed to develop the k_c values with the help of shaded area approach that is adopted for many deciduous crops.

For this purpose, two commercial pomegranate orchards (*Mrig Bahar*) of 1st to 5th years were selected from the *Sangola Tehsil* and from each orchard 5 of representative plants were randomly selected. The shaded area was measured at solar noon hour with the help of specially prepared plywood boards of 1.5 x 1.5, 2.5 x 2.5, 3.5 x 3.5 m sizes with grid marking of size 20 x 20 cm. The total numbers grids occupied by shaded area were measured on a weekly basis for each selected plant.

The crop coefficient was then calculated by following equation developed for deciduous fruit crops (Williams and Ayars, 2005)

k_c=0.014x-0.08, Where, k_c = Crop coefficient, x = Percentage of shaded area, (%)

By using the above equation, the week wise crop coefficient values were developed for different phenological stages from June (*Mrig Bahar*) from 1st to 5th year age. The values so developed for *Mrig Bahar* were then appropriately transformed for *Ambe* and *Hasta Bahar*.

Estimation of ET_r: The Penman-Monteith method (Allen *et al.*, 1998) was used for the estimating reference crop evapotranspiration by following equation:

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

Where, ET_r = reference evapotranspiration (mmd^{-1}), G = soil heat flux density ($MJm^{-2}d^{-1}$), R_n = net radiation ($MJm^{-2}d^{-1}$), T = mean daily air temperature (^0C), γ = psychometric constant ($kPa/^0C$), Δ = slope of saturation vapour pressure function ($kPa/^0C$), 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})

This method needs the daily values of meteorological parameters *viz.*, maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, wind speed and sunshine hours. The daily records of these parameters were obtained from the Indian Meteorological Department, Pune region. The daily values of ET_r were estimated for all years. Daily ET_r values were summed up to obtain to weekly ET_r values.

Estimation of ET_c: The weekly values of ET_r and k_c were used to obtain weekly values of ET_c by following equation for *Ambe Bahar, Mrig Bahar* and *Hasta Bahar* for all the years.

$ET_c = ET_r \times k_c$, Where, ET_c= pomegranate evapotranspiration (mm d^{-1}), ET_r = reference crop evapotranspiration (mm d^{-1}), k_c = crop coefficient of pomegranate

Water requirement: The water requirement by the surface irrigation methods is equal to the crop evapotranspiration estimated by the equation. However water requirement by the drip irrigation method is less than the water requirement of the surface irrigation methods as in drip irrigation method unlike in surface irrigation method, it is possible to apply water to the effective root zone only. Hence water requirement in case of drip irrigation method was estimated by following equation:

$WR = ET_c \times Fa$, Where, WR = water requirement (mm d^{-1}), Fa = Area factor (fraction)

Area factor: Area factor is the proportion of the effective root zone with respect to the total area. The area factor hence varies with the crop growth period and the age of the crop. In general, it has been reported that for most of the deciduous crops, the effective root zone area below the soil surface is the area occupied by the canopy above the soil. The canopy area is the shaded area at solar noon hour and was measured weekly for all the tress under experimentation. Area factor was computed by using following relationship:

Fa = SA/AT, Where, Fa=Area factor, SA=Shaded area (m^2), AT=Area occupied per tree (m^2). Fa was calculated on weekly basis for the pomegranate trees up to the age of 5 years.

Water to be applied: Water to be applied was estimated on weekly basis up to the age of 5th year by using the equation given bellow:

WA = WR * A/eff, Where, WA = water to be applied to each tree (L d^{-1}), A = area occupied by each tree (m^2), eff. = efficiency of the drip irrigation system (fraction)

Results and discussion

The average ET_r values estimated by Penman-Monteith method are depicted in Fig. 1. It is revealed from the figure that, ET_r is the highest in May (19-20 MW) and lowest in the month of December (49-52 MW). The weekly values of ET_r are useful for obtaining the crop evapotranspiration of any crop for which the crop coefficient values are known. It is noted at this juncture that in lack of locally developed values of stage wise k_c, the values proposed by FAO (Doorenbos and Pruitt, 1977) are being widely used. The mean yearly values of ET_r as obtained by Penman-Monteith method are 1428.00 mm estimated for Pune region.

The monthly values of SA and k_c are presented in Table 1 for *Mrig Bahar* and transformed values for *Ambe Bahar* and *Hasta Bahar* for the pomegranate tree of different ages. It is apparent from the table that the shaded area increased from new leaf initiation to maturity period in the range from 0.84 to 10.60 m^2. During harvesting period shaded area decreased from 10.60 to 7.25 m^2 due to leaf drop, less amount of irrigation, removing of water sprout, luxur and harvesting of fruit.

The monthly crop coefficient values of pomegranate tree of

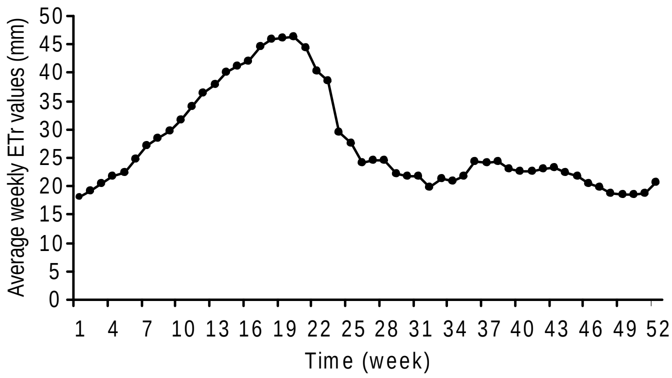

Fig. 1. Average weekly ETr values for Pune region from 1987 to 2009.

different ages for *Mrig Bahar* shown in Table 1 can be used for the estimation of pomegranate evapotranspiration provided the values of reference crop evapotranspiration are known.

According to important phenological stages of mature pomegranate tree (Table 2), the period of new leaf initiation to 10 % ground cover of tree is 21 days, the crop development period *i.e.* up to 60 to 80 % ground cover of the tree is 77 days, the maturity period is 56 days and harvesting period is 105 days. During the period from the new leaf initiation to crop development, the crop coefficient values increased from 0.22 to 1.10 and during maturity period, the k_c values were around 1.2. At harvesting, the value of k_c went on decreasing from 1.14 to 0.65 due to leaf drop, removing of water sprout, foliage breakdown and harvesting of fruits. The average shaded area per plant and wetted area for pomegranate tree are presented in Table 3.

The water to be applied to the pomegranate plantation irrigated by surface irrigation methods can be calculated by using the ET_r values (Fig.1) and k_c values (Table 1). The water to be applied to the pomegranate plantation irrigated by drip irrigation method can be calculated by using the ET_r values (see materials and methods) and k_c and SA values (Table 1), if the efficiency of the drip irrigation method and the area covered by the pomegranate tree are known.

Usually the pomegranate is spaced at 4.5 x 3 m and the drip irrigation systems are designed for 90 % efficiency. Hence, the values of water to be applied to pomegranate in different seasons for different stations were estimated for the tree spacing of 4.5 x 3.0 m and drip irrigation efficiency of 90 %. The values of water to be applied in liter/day on weekly basis are presented in Table 4 for *Ambe*, *Mrig* and *Hasta bahar*s. However, this period can be up to 2 months depending on the climate and soils. After the stress period is over, it is necessary to bring the moisture content in the root zone to the field capacity. For this purpose, it is proposed to operate the drip irrigation sysem continuously for 24 to 48 hours. The values in the table would be useful for irrigation scheduling of pomegranate by drip irrigation method. The values of reference crop evapotranspiration were estimated by the Penman-Monteith method and is presented in this paper on weekly basis for the Pune region and would be useful to estimate the pomegranate evapotranspiration, if the values of crop coefficient are known. The area factor values developed in this study would be useful to estimate the water requirement of pomegranate trees of different ages in combination with the crop coefficient values. The values of water to be applied to pomegranate (spaced at 4.5 x 3 m) irrigated by drip irrigation method (efficiency=90%) on weekly basis for Pune region (Maharashtra) would be useful for the irrigation planning, optimum and efficient utilization of irrigation water.

Table 1. Monthly shaded area (SA) and crop coefficient (k_c) values of 1st to 5th year pomegranate trees for *Mrig Bahar*

Month	Age of pomegranate tree (year)									
	1st		2nd		3rd		4th		5th	
	SA	k_C	SA	k_C	SA	k_C	SA	k_C	SA	k_C
July	0.84	0.16	1.68	0.22	1.35	0.13	1.72	0.14	2.07	0.15
August	1.00	0.17	2.43	0.25	4.09	0.21	4.82	0.26	5.26	0.30
September	1.16	0.18	3.30	0.32	7.53	0.48	8.32	0.54	8.46	0.59
October	1.28	0.20	4.05	0.41	9.54	0.83	10.30	0.91	10.55	0.92
November	1.37	0.21	4.13	0.49	9.63	1.06	10.44	1.13	10.60	1.16
December	1.49	0.22	3.44	0.51	8.21	1.08	9.41	1.15	9.73	1.18
January	1.66	0.23	2.65	0.44	7.14	0.94	8.12	1.05	8.91	1.09
February	1.60	0.25	2.01	0.35	6.11	0.78	6.85	0.92	7.73	1.00
March	1.47	0.25	2.01	0.29	5.54	0.68	6.41	0.79	7.25	0.88
April	1.56	0.23	2.16	0.29	5.72	0.65	6.57	0.74	7.58	0.83
May	1.65	0.24	2.34	0.30	5.94	0.67	6.73	0.77	7.77	0.87
June	1.79	0.25	2.50	0.32	6.14	0.69	6.88	0.78	8.02	0.89

Table 2. Important phenological stages of matured pomegranate tree under Pune conditions

Phenological stage	Meteorlogical week	Periods
Initial	31st to 33rd	21 days
Crop development	34th to 44th	77 days
Mid season	45th to 52nd	57 days
Late season	01st to15th	105 days
Rest period	16th to 30th	105 days

Table 3. Year wise area factor of pomegranate tree

Year	Age of pomegranate tree				
	1st	2nd	3th	4th	5th
Shaded area (m^2)	2.65	4.05	5.40	6.75	8.10
Area per plant (m^2)	13.5	13.5	13.5	13.5	13.5
Wetted area (Fraction)	0.20	0.30	0.40	0.50	0.60

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Table 4. Water to be applied (L d^{-1} t^{-1}) for 1st to 5th year pomegranate tree for *Ambe Bahar, Mrig Bahar* and *Hasta Bahar*

M	*Ambe Bahar*					M	*Mrig Bahar*					M	*Hasta Bahar*				
W	1st	2nd	3rd	4th	5th	W	1st	2nd	3rd	4th	5th	W	1st	2nd	3rd	4th	5th
1	1.25	2.59	1.98	3.02	3.39	31	1.50	3.10	2.37	3.62	4.06	36	1.67	3.47	2.65	4.05	4.55
2	1.34	2.93	2.70	4.49	5.48	32	1.39	3.04	2.80	4.65	5.68	37	1.69	3.71	3.42	5.68	6.93
3	1.46	3.35	3.66	6.18	7.65	33	1.52	3.50	3.82	6.46	7.98	38	1.73	3.98	4.34	7.34	9.07
4	1.59	3.76	5.03	8.46	10.43	34	1.53	3.62	4.85	8.16	10.06	39	1.67	3.97	5.31	8.93	11.01
5	1.67	4.10	6.27	10.26	12.63	35	1.62	4.00	6.11	9.99	12.31	40	1.69	4.16	6.36	10.41	12.82
6	1.89	4.86	8.46	13.37	16.01	36	1.85	4.77	8.30	13.11	15.69	41	1.73	4.46	7.76	12.27	14.68
7	2.11	5.61	11.14	17.24	20.55	37	1.88	5.01	9.95	15.39	18.36	42	1.80	4.80	9.53	14.74	17.58
8	2.27	6.25	13.66	20.80	24.37	38	1.94	5.33	11.66	17.75	20.80	43	1.86	5.10	11.15	16.98	19.89
9	2.42	6.91	16.23	24.91	28.50	39	1.87	5.32	12.51	19.19	21.96	44	1.82	5.20	12.22	18.75	21.45
10	2.62	7.69	19.57	29.33	33.58	40	1.87	5.49	13.97	20.94	23.97	45	1.80	5.28	13.43	20.13	23.05
11	2.87	8.78	23.11	34.88	38.66	41	1.92	5.86	15.42	23.27	25.79	46	1.73	5.28	13.91	20.99	23.26
12	3.13	9.70	27.00	40.67	44.56	42	1.99	6.16	17.14	25.83	28.30	47	1.69	5.24	14.60	22.00	24.10
13	3.31	10.91	30.30	45.66	49.90	43	2.02	6.67	18.53	27.93	30.52	48	1.64	5.41	15.02	22.64	24.74
14	3.54	12.16	34.49	50.89	56.97	44	1.98	6.82	19.35	28.56	31.97	49	1.65	5.66	16.06	23.70	26.53
15	3.68	13.07	37.60	55.20	61.83	45	1.95	6.92	19.92	29.24	32.75	50	1.65	5.87	16.90	24.81	27.79
16	3.81	13.44	38.43	56.67	63.39	46	1.86	6.55	18.75	27.64	30.92	51	1.71	6.03	17.25	25.44	28.45
17	4.09	14.34	40.78	60.09	67.28	47	1.81	6.35	18.07	26.64	29.82	52	1.91	6.69	19.03	28.05	31.40
18	4.28	14.91	42.28	62.12	69.61	48	1.75	6.10	17.30	25.43	28.49	1	1.68	5.87	16.63	24.44	27.39
19	4.35	15.00	42.43	62.31	69.88	49	1.75	6.05	17.12	25.14	28.20	2	1.80	6.21	17.57	25.81	28.94
20	4.36	15.08	42.80	62.42	70.07	50	1.74	6.02	17.09	24.93	27.98	3	1.93	6.67	18.95	27.64	31.02
21	4.23	14.51	41.09	59.93	67.33	51	1.80	6.16	17.44	25.44	28.58	4	2.07	7.10	20.13	29.36	32.98
22	3.88	13.22	37.31	54.42	61.19	52	2.00	6.82	19.23	28.05	31.54	5	2.15	7.32	20.65	30.12	33.87
23	3.77	11.68	34.03	50.82	56.52	1	1.77	5.49	15.98	23.86	26.54	6	2.42	7.50	21.85	32.62	36.28
24	2.91	8.57	24.73	37.67	42.20	2	1.89	5.56	16.06	24.47	27.40	7	2.68	7.88	22.75	34.66	38.83
25	2.78	7.76	22.29	34.22	38.59	3	2.05	5.74	16.49	25.32	28.55	8	2.86	7.98	22.94	35.21	39.71
26	2.46	6.54	18.61	28.96	32.83	4	2.22	5.89	16.77	26.10	29.59	9	3.04	8.08	22.99	35.78	40.56
27	2.55	6.31	18.13	28.69	33.08	5	2.32	5.72	16.45	26.03	30.02	10	3.29	8.13	23.38	37.01	42.68
28	2.60	6.00	17.50	27.83	32.43	6	2.61	6.03	17.60	28.00	32.62	11	3.59	8.29	24.21	38.50	44.86
29	2.38	5.18	15.25	24.41	29.01	7	2.90	6.31	18.57	29.73	35.34	12	3.91	8.50	25.02	40.05	47.60
30	2.38	4.87	14.25	23.20	27.95	8	3.10	6.34	18.54	30.19	36.38	13	4.14	8.46	24.75	40.29	48.55
31	2.39	4.62	13.74	22.22	27.29	9	3.29	6.35	18.91	30.56	37.54	14	4.42	8.52	25.36	41.00	50.36
32	2.22	3.97	12.05	19.61	24.46	10	3.55	6.36	19.30	31.40	39.17	15	4.60	8.23	25.00	40.68	50.74
33	2.43	3.93	12.64	20.15	25.22	11	3.87	6.25	20.13	32.08	40.16	16	4.77	7.71	24.82	39.57	49.54
34	2.05	3.74	11.87	19.04	22.18	12	3.57	6.51	20.64	33.11	38.58	17	4.35	7.94	25.18	40.39	47.07
35	2.14	3.91	11.99	18.82	23.07	13	3.73	6.83	20.96	32.88	40.30	18	4.52	8.27	25.38	39.82	48.81
36	2.39	4.39	13.42	21.12	25.82	14	3.95	7.24	22.12	34.80	42.55	19	4.55	8.36	25.53	40.17	49.11
37	2.40	4.41	13.48	21.16	25.82	15	4.08	7.50	22.90	35.94	43.86	20	4.59	8.43	25.77	40.44	49.36
38	2.43	4.50	13.61	21.33	25.96	16	4.19	7.78	23.53	36.87	44.86	21	4.43	8.23	24.88	38.99	47.45
39	2.30	4.33	12.92	20.24	24.61	17	4.46	8.39	25.05	39.23	47.69	22	4.04	7.59	22.68	35.52	43.19
40	2.28	4.30	12.79	20.04	24.33	18	4.63	8.75	26.00	40.72	49.46	23	3.88	7.33	21.78	34.12	41.44
41	2.32	4.35	12.91	20.19	25.08	19	4.71	8.83	26.24	41.04	50.99	24	3.00	5.63	16.74	26.18	32.52
42	2.40	4.49	13.26	20.75	25.70	20	4.78	8.96	26.47	41.41	51.30	25	2.86	5.36	15.84	24.78	30.69
43	2.42	4.56	13.41	21.09	25.90	21	4.63	8.70	25.61	40.28	49.49	26	2.52	4.73	13.92	21.90	26.90
44	2.36	4.47	13.05	20.63	25.19	22	4.25	8.04	23.44	37.05	45.26	27	2.59	4.90	14.30	22.60	27.61
45	2.31	4.41	12.74	20.01	24.56	23	4.09	7.82	22.57	35.44	43.49	28	2.61	4.99	14.40	22.61	27.75
46	2.19	4.21	12.06	18.73	23.28	24	3.15	6.06	17.34	26.93	33.46	29	2.38	4.58	13.10	20.35	25.28
47	2.13	4.11	11.76	18.15	22.53	25	2.99	5.77	16.49	25.45	31.60	30	2.36	4.56	13.04	20.12	24.98
48	2.06	3.99	11.31	17.41	21.61	26	2.63	5.11	14.49	22.30	27.69	31	2.37	4.59	13.01	20.02	24.86
49	2.08	3.98	11.27	17.28	21.57	27	2.74	5.26	14.88	22.81	28.48	32	2.21	4.23	11.98	18.38	22.94
50	2.09	4.00	11.21	17.21	21.56	28	2.78	5.32	14.94	22.93	28.72	33	2.41	4.63	12.98	19.92	24.95
51	2.16	4.15	11.56	17.63	22.12	29	2.55	4.89	13.64	20.81	26.11	34	2.41	4.62	12.87	19.63	24.63
52	2.42	4.63	12.89	19.58	24.68	30	2.55	4.88	13.57	20.61	25.98	35	2.53	4.85	13.49	20.49	25.83