Annals of Arid Zone 49(2): 107-111, 2010

Water Requirement of Pomegranate (*Punica granatum* L.) Orchards in Semi-arid Region of Maharashtra, India

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Abstract: The study was carried out to estimate reference crop evapotranspiration, develop crop coefficient, area factor and estimate evapotranspiration of pomegranate for Nasik district of Maharashtra. The crop coefficient values were estimated on weekly basis from the concept of shaded area approach. Shaded areas were estimated at mid-day with the help of plywood board having 20 x 20 cm grid. Pomegranate evapotranspiration was determined on monthly basis using crop coefficient and reference crop evapotranspiration. The water to be applied through drip system at 90% efficiency to pomegranate plantation spaced at 3 x 4.5 m ranged from 1.4-4.3, 3.1-10.7, 2.6-30.4, 3.9-40.7 and 4.4-50.1 L day^{-1} tree^{-1} for 1st to 5th years. The values of reference crop evapotranspiration, crop coefficient, area factor, water requirement and water to be applied would be useful for the irrigation water management of pomegranate.

Key words: Pomegranate (*Punica granatum* L.), reference crop evapotranspiration (ET_r), crop evapotranspiration (ET_c), crop coefficient (K_c), area factor, water requirement.

In India, pomegranate is commercially cultivated in Maharashtra, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka, Gujarat, Rajasthan, Punjab and Haryana. The total pomegranate production in the world is 1.15 MT out of which India produces 0.5 MT. (Holland *et al.*, 2009). At present in India over 0.13 Mha area is under pomegranate, of which 0.087Mha area is in Maharashtra, producing about 85% of total Indian production (Jadhav and Sharma, 2007). The productivity in India is still low (<11.2 t ha^{-1}) as compared to the major pomegranate producing countries like Israel, Iran, Morocco, Egypt, Afghanistan, Spain, Turkey, China, Greece, Japan, France, Italy (40 t ha^{-1}) (Holland and Bar-Ya'akov, 2008). In the pomegranate growing area of Maharashtra, water is scarce commodity and there is a need to apply water judiciously according to water requirement. As evapotranspiration is an important component of the water requirement and varies with the climate, there is a need to estimate evapotranspiration for different regions/ districts. To consider the variation of water requirement with respect to different stages/ages of pomegranate plantation, it is also necessary to know crop coefficients for pomegranate accordingly to its growth stages/ages. Therefore, there is a need to develop crop coefficient and determine water requirement of pomegranate.

The main objective of this study was to quantify water to be applied to pomegranate during different months for Nasik District of Maharashtra.

Materials and Methods

The experiment was conducted in commercial pomegranate orchard during 2008-2009 (Latitude 18° 33″ and 20° 53″ north latitude, 73°16″ and 75°16″ east longitude and altitude 608.0 m above mean sea level) at northwest part of Maharashtra state. 1st to 5th years pomegranate orchards were planted in the year of 2007, 2006, 2005, 2004 and 2003 near Malegaon of Nasik district.

It is important to know the values of K_c and ET_r to estimate ET_c and eventually water requirement of pomegranate (WR). K_c values of most of the crops are not available locally and hence in irrigation water management of these crops, the K_c values reported by FAO are often used. So is the case with pomegranate too. Hence in this study K_c values were determined locally and then used for estimation of pomegranate evapotranspiration (ET_c) by knowing reference crop evapotranspiration (ET_r). ET_r and K_c values were estimated by climatological and shaded area approaches. The following sections describe the

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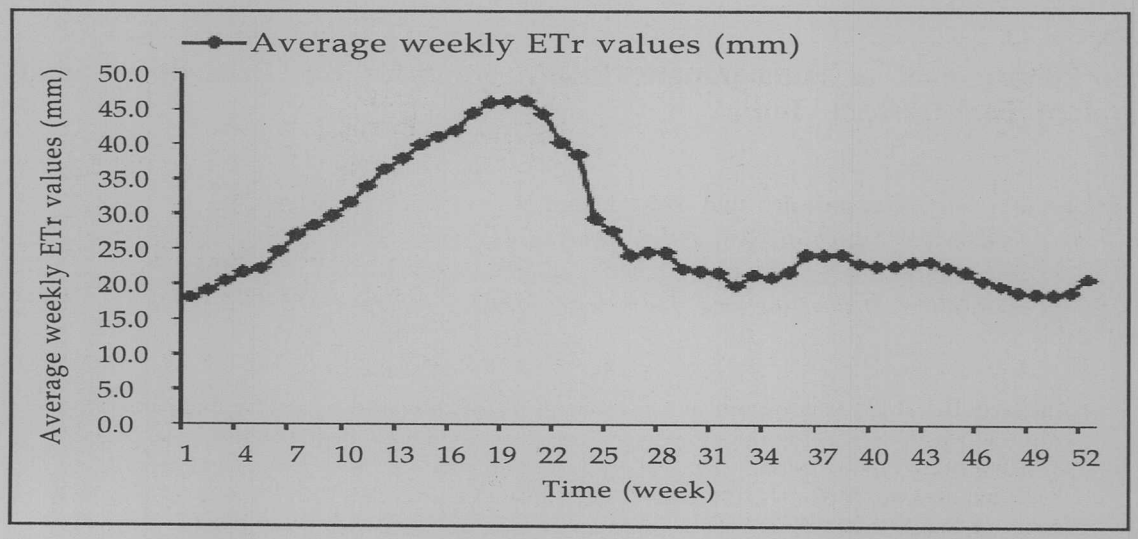

Fig. 1. Average weekly ET_r values for Nasik District from 1985 to 2007.

methods used for the determination of K_c and ET_r values.

Determination of Kc values

Two commercial pomegranate orchards (Mirg Bahar) 1 to 5-year-old orchard were selected and in each orchard five plants were randomly selected. Plywood boards of 1.5 x 1.5 m, 2.5 x 2.5 m and 3.5 x 3.5 m sizes with grid marking at 20 x 20 cm were prepared for the estimation of shaded area. The total number of grids occupied by shaded area were measured on a weekly basis for each selected plant.

The crop coefficient value was calculated following the equation (1), developed for deciduous fruit crops (Williams and Ayars, 2005).

$$KC = 0.014x + 0.08 \quad ...(1)$$

where, K_c = Crop coefficient, X = Percentage of shaded area

The week-wise crop coefficient values were developed for different phenological stages i.e., new leaf initiation, crop development, crop maturity and crop harvesting for the orchards pruned in the month of June (Mirg Bahar) for ages from 1st to 5th year. The values so developed for Mirg Bahar were then appropriately

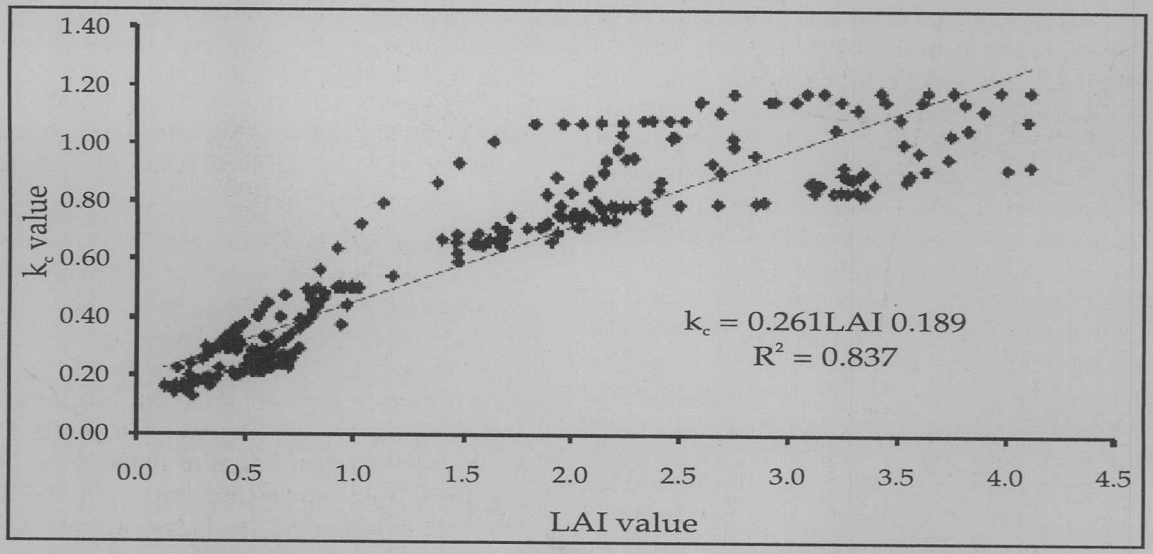

Fig. 2. Relationship between LAI and k_c values for pomegranate trees of all the ages together.

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

Months	Age of pomegranate tree (year)									
	1st		2nd		3rd		4th		5th	
	SA	Kc	SA	Kc	SA	Kc	SA	Kc	SA	Kc
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

transformed in to Ambe and Hast Bahar. Three flowering seasons are promoted for pomegranate production (NRCP 2009a). Thus, flowering seasons are defined as: Ambe Bahar (January to February), Mirg Bahar (June to July) and Hasta bahar (September to October).

Determination of ETr values

The Penman-Monteith method of estimation of ET_r were considered for the reference crop evapotranspiration. The ET_r method which is considered as the most accurate and proposed by FAO, Irrigation and Drainage Paper -56 (Allen *et al.*, 1998) for use was considered for the pomegranate evapotranspiration

Results and Discussion

The ET_r was maximum in May (19-20 MW) and minimum in December (49-52 MW) (Fig. 1). The relationship between k_c and LAI for the pomegranate tree for all the ages together are presented in Figure 2. The relationship is Kc= 0.261 LAI + 0.189 (R^2 = 0.837). As r^2 were more than 0.60, this relationship would also provide the k_c values for know values of leaf area index (LAI). A similar correlation between K_c and LAI (R^2 = 0.89) and (R^2 = 0.90) has been observed in apple and grapevine (Gong *et al.*, 2007; Netzer *et al.*, 2009). A good correlation has also been found between the K_c and canopy cover for various deciduous fruit crops (Wang *et al.*, 2007).

The shaded area increased from new leaf initiation to maturity from 0.87 to 1.79 and 1.68 to 4.13 during first and second year, respectively (Table 1). During 3rd, 4th and 5th year, the shaded area increased from 1.35 to 9.63, 1.72 to 10.44 and 2.07 to 10.60 m^2 due to increase in number of leaves and fruit size. At harvest the shaded area decreased from 9.63 to 5.54, 10.44 to 6.41 and 10.60 to 7.25 m^2 due to leaf drop and harvesting of fruit. Lower K_c values represent slower plant growth and lower plant canopy cover, indicating lower ET_c. The values of the monthly shaded area shown in this table for the pomegranate trees of different ages can be used to estimate the water requirement for the pomegranate plantation under drip irrigation, once the values of pomegranate crop evapotranspiration are estimated. The initial values of water use are 1.4-1.6, 3.1-3.4, 2.6-4.0, 3.9 and 4.4-6.8 L day^{-1} $tree^{-1}$ for 1st to 5th year-old pomegranate trees in Ambe, Mirg and Hasta Bahar seasons. It gradually increases or decreases during different phenological development stages of pomegranate (i.e. new leaf initiation, crop development, crop maturity, harvesting and rest period of the tree). The water to be applied through drip irrigation system at 90% efficiency for Ambe, Mirg and Hasta Bahar seasons ranged from 1.4-4.3, 3.1-10.7, 2.6-30.4, 3.9-40.7 and 4.4-50.1 L day^{-1} $tree^{-1}$ for 1st to 5th year-old pomegranate tree due to variation of reference crop evapotran- spiration, crop coefficient and area factor values for 1st to 5th year-old. The seasonal values of water to be applied to pomegranate tree ranged from 912 to

Table 2. Water to be applied (L day^{-1} tree^{-1}) to 1 to 5-year-old pomegranate tree for Ambe, Mirg and Hasta Bahar

Months	Age of pomegranate tree (year)				
	1st	2nd	3rd	4th	5th
Ambe Bahar					
January	1.5	3.4	4.0	6.0	8.0
February	2.0	5.5	11.4	16.0	20.6
March	2.5	7.7	20.7	28.4	34.5
April	3.0	10.7	30.4	40.7	50.1
May	3.1	10.7	30.2	40.2	49.6
June	3.0	8.5	24.5	34.2	42.5
July	3.3	7.0	20.5	30.0	39.4
August	2.6	4.6	14.5	21.1	28.4
September	1.9	3.5	10.6	15.1	20.2
October	2.0	3.7	10.9	15.6	21.1
November	2.1	4.1	11.8	16.6	22.7
December	3.0	5.7	16.0	22.1	30.5
Total (L/Y/T)	912	2284	6250	8699	11181
Mirg Bahar					
July	1.6	3.3	2.6	3.9	4.4
August	1.6	3.6	4.2	6.9	8.4
September	2.0	5.3	11.1	17.1	20.1
October	2.2	6.8	18.4	27.7	30.7
November	2.1	7.4	21.0	30.9	34.6
December	2.0	6.9	19.6	28.6	32.1
January	2.3	6.4	18.5	28.5	32.3
February	3.4	7.1	21.0	33.8	40.5
March	4.3	7.6	23.7	37.9	46.3
April	3.9	7.2	21.7	34.0	41.4
May	3.2	6.2	17.8	27.6	34.2
June	3.6	6.8	19.2	29.3	36.7
Total	979	2269	6047	9314	11002
Hasta Bahar					
September	1.4	3.1	3.4	5.1	6.8
October	1.5	4.1	8.4	11.8	15.3
November	1.7	5.3	14.1	19.3	23.6
December	2.2	7.8	22.4	29.9	36.9
January	2.0	6.9	19.4	25.8	31.9
February	2.6	7.2	20.8	29.1	36.2
March	3.3	7.0	20.5	30.0	39.5
April	3.5	6.2	19.4	28.2	38.0
May	3.2	6.0	18.2	25.9	34.7
June	3.1	5.9	17.3	24.6	33.4
July	3.3	6.3	18.1	25.5	34.8
August	2.8	5.5	15.5	21.2	29.2
Total	931	2169	6007	8407	10959

979, 2168 to 2284, 6007 to 6250, 8704 to 9313 and 10959 to 11181 L year^{-1} for 1st, 2nd, 3rd, 4th and 5th year in Ambe, Mirg and Hasta Bahar seasons (Table 2). The values in the table would be useful for irrigation scheduling of pomegranate by drip irrigation method.

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