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Planning of pomegranate (*Punica granatum* L.) orchards management for season December-July (*Ambe bahar*)

■ **A.D. BHAGAT AND P.G. POPALE**

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See end of the Paper for authors' affiliation

Correspondence to :

A.D. BHAGAT
Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, AHMEDNAGAR (M.S.) INDIA
Email : arunbhagat02@gmail.com

■ **ABSTRACT :** The study was carried out to evaluate the *Ambe bahar* of pomegranate for optimum production of pomegranate for Solapur district in the semi-arid zone of Maharashtra. Generally, for crop planning, rainfall analysis and water balance studies are required, to determine drought investigation, water requirement and water surplus/ deficit for better management of orchards. Rainfall is the major determinant of pomegranate production, especially in rain fed areas because the contribution of rain fed horticulture is almost half to the national production. Therefore, an attempt has been made to estimate the occurrence of drought. Data are classified into certain degrees of drought severity (Drought, normal and surplus) based on a number of truncation levels corresponding to specified mean values of the rainfall. Pomegranate evapotranspiration determined by the crop co-efficient (kc) approach where the effects of various weather conditions were incorporated into reference crop evapotranspiration and crop characteristics into crop co-efficient. The water to be applied through drip system at 90 per cent efficiency to pomegranate plantation spaced at 3 x 4.5 m.The water balance parameters and climatic shift in *Ambe bahar* of pomegranate for 14 stations of Solapur district were estimated.Thus, the study revealed that the average intensity of drought for all stations was higher in *Ambe* season (*bahar)* followed by *Hasta* and *Mrig* seasons (*bahars*) of pomegranate. For *Ambe bahar*, the total amounts of water to be applied is 1696 l/tree for the pomegranate tree of 5th year age at 70 per cent probability level for Solapur district. The average climate during season January-August (*Ambe bahar)* is arid with very poor moisture adequacy index but it is beneficial for quality and disease free production of pomegranate. The average moisture index was -78.31 per cent with highest and lowest moisture index were observed in Solapur (-72.77) and Mangalvedha (-81.96) stations, respectively. Thus, it concludes, good season for disease free, quality and more beneficial production of pomegranate when external source of water supply is available.

■ **KEY WORDS :** *Ambe bahar*, Drought, Water deficit, Surplus, Climate shift

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Drought analysis, water requirement and water balance studies are important aspects in the rain fed farming as well as in water resource planning, irrigation scheduling, irrigation system design, moisture deficit prediction, hydrological and climatic studies, management and allocation of irrigation water. The success or failure of crops, particularly under rain fed conditions is closely linked with the rainfall pattern.Drought is evaluated in a more meaningful manner by water balance approach taking into account the

rainfall pattern, evapotranspiration and moisture characteristics of soil. To explain the exact level of water balance in particular area, there is need of calculation for water surplus and deficit.But in drought area only water deficit is present.Water surplus works directly with plant engineering, environmental engineers and operation team to provide a comprehensive review of your water and chemical usage. Proper operation, monitoring and maintenance of your water treatment systems are critical for maximum return on your equipment investment. A water balance can be used to manage water supply and predict whether there may be water shortages. It is also used in irrigation and runoff assessment.

Pomegranate cultivation planning in water shortage area is based on conservation, utilization and management of rainwater. Due to frequent droughts and related socio-economic constraints, per hectare yield in rainfed areas, is very low (Rockstrom *et al.,* 2003). In this region, three flowering *bahars* are promoted for pomegranate production (NRCP, 2009). *Bahar* is a local word also widely used to express flowering seasons of horticulture crop and here it is for pomegranate. Thus, flowering seasons are defined as: *Ambe bahar* flowering period (January-February) and harvesting period (June-July), *Mrig bahar* flowering period (June-July) and harvesting period (December-January) and *Hasta bahar* flowering period (September-October) and harvesting period (January-February). In presentstudy, the drought is investigated as meteorological drought but expressed according to pomegranate season (*bahar)*, water requirement of mature pomegranate tree at different probability levels by considering best fit probability distributions and seasonal water balance are determined to aid pomegranate growers to increase pomegranate production.

Data collection :

The daily rainfall data of 33 years (1975–2007) were collected from Indian Metrological Department, Pune.

Meteorological data: Daily parameters (*i.e.* maximum temperature (T_{max},^{0}C) and minimum temperature (T_{min},^{0}C), maximum relative humidity (RH_{max}, %) and minimum relative humidity (RH_{min}, %), pan evaporation (E_{pan}, mm), wind speed (WS, kmhr^{-1}) at a height of 2.0 m, sun shine hours (SSHr, hr), rainfall (R, mm) etc.) also collected from Indian Meteorological Department, Pune.

METHODOLOGY

Evaluation of drought :

Ambe bahar wise weekly rainfall determined for each year and weekly events were classified as drought, normal and surplus weeks,suggested by the following criteria (Sharma *et al.,* 1979).

If 'm' is the mean weekly / monthly rainfall, then a week / month receiving rainfall less than $A_1$is defined as drought, in between A_1 and A_2 is normal month and above A_2 is surplus month, where A_1 = m / 2 (50 %) and A_2 = 2 m (200%). Also, if 'y' is the long term mean annual rainfall then the year is said to be classify as drought or normal or surplus as follows.

Drought year : If the year's is less than or equal to y – s amount.

Normal year: If the year's rainfall in between y + s and y - s amount.

Surplus year: If the year's rainfall is greater than or equal to y + s amount. Where's is the standard deviation of the annual rainfall series.

Probability distribution analysis :

The Gumbel, Weibull (Maxima) and Log normal distributions were selected for analysis and goodness of fit Chi-square test for testing is used.

Estimation of reference crop evapotranspiration (ETr) :

The weekly reference crop evapotranspiration estimated by using the standard method *i.e.* Penman-Monteith (Allen *et al.,* 1998).

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

where,

ETr = Reference crop evapotranspiration (mm/day),

G = Soil heat flux density (MJ/m^2/day),

R = Net radiation (MJ/m^2/day),

T = Mean daily air temperature (^{0}C),

Γ = Psychometric constant (kPa/^{0}C),

Δ = Slope of saturation vapour pressure function (kPa/^{0}C),

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 (m/

sec).

Crop co-efficient (Kc) :

The weekly crop co-efficient values were used (Meshram, 2010).

Pomegranate evapotranspiration (ETp) :

The weekly values of ETr and Kc were used to obtain weekly values of ETp by equation for *Ambe bahar*

ETp = ETr× kc × Crop spacing × Wetted area × Water application efficiency .... (2)

where,

ETp =Pomegranate evapotranspiration (mm/day)

ETr = Reference crop evapotranspiration (mm/day)

Kc = Crop co-efficient of pomegranate

Wetted area = 20 per cent of crop spacing

Water application efficiency = 90 per cent (for drip system).

Water balance :

The central concept of soil water balance is shown in Fig. A (Thornthwaite and Mather, 1955). Procedure for computation of different water balance elements is given below (Kerkides *et al.*, 1996).

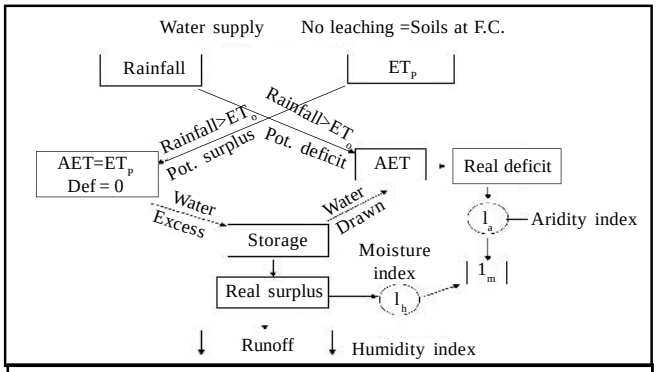

Fig. A : Generalized flow diagram of the climatic water balance

Weekly moisture excess and deficit (P-ETp) :

Difference between rainfall (P) and crop evapotranspiration (ETp) gives weekly moisture excess and deficit. A negative value of this difference indicates moisture deficit, which means the amount by which the rainfall fails to supply the potential water need of area. While positive difference is moisture excess, this is the amount of excess water available for soil moisture replenishment and also for a runoff.

Water deficit (DEF) :

The amount by which the actual evapotranspiration (AET) and crop evapotranspiration differ in any week is the water deficit (DEF). Water deficit only exists when (P-ETp) is negative and is calculated by the following equation.

$$\mathbf{AET = ETp - DEF} \quad \text{..... (3)}$$

Water surplus (SUR) :

The water surplus is the amount of positive (P-ETp) which remains in excess after recharging the soil to the field capacity by the following equation.

$$\mathbf{SUR = P - AET} \quad \text{.....(4)}$$

Climatological indices :

On the basis of above parameters climatological indices such as humidity index (I_h), aridity index (I_a), moisture index (I_m) and moisture adequacy index (I_{ma}) were computed by using the following expressions (Thornthwaite and Mather, 1955 and 1957).

$$\mathbf{I_h = \frac{SUR}{ET_0} \times 100} \quad \text{....(5)}$$

$$\mathbf{I_a = \frac{DEF}{ET_0} \times 100} \quad \text{....(6)}$$

$$\mathbf{I_{ma} = \frac{AET}{ET_o} x100} \quad \text{.....(7)}$$

$$\mathbf{I_m = I_h - I_n} \quad \text{....(8)}$$

Determination of climatic shift :

The annual moisture index represents the type of prevailing climate in an area. On the basis of moisture index, following criteria has been suggested by

Moisture index, %	Type of climate
> 100	A – Per humid
80 – 100	B_4 – Humid
60 – 80	B_3 – Humid
40 – 60	B_2 – Humid
20 – 40	B_1 – Humid
0 – 20	C_2 – Moist sub humid
-33.3 – 0	C_1 – Dry sub humid
-66.7 - -33.3	D – Semi-arid
-100 - -66.7	E – Arid

Subrahmanyam and Sastri (1969) to distinguish the climate:

Moisture adequacy index :

Krishnan (1979) has suggested following criteria for weekly soil moisture adequacy index:

$$MAI = \frac{AE}{PE} x100 \quad .....(9)$$

Classification of MAI on weekly basis are decided as follows :

– MAI >= 75 % -Excellent
– MAI = 50 to 74 % -Good (Adequate moisture)
– MAI = 49 to 24 % -Poor
– MAI < 24 % -Very poor moisture stress.

If MAI = 0 to 49, during active growth stages of the crop, it is considered as drought. Where, AE and PE are actual and potential evapotranspiration for the period.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Weekly drought investigation :

The data of 33 years (1975-2007) analysed, *bahar* includes 8 specific month (35 weeks of the year) and total week considers for analysis are 1155 (35week of specific bahar ×33 year).

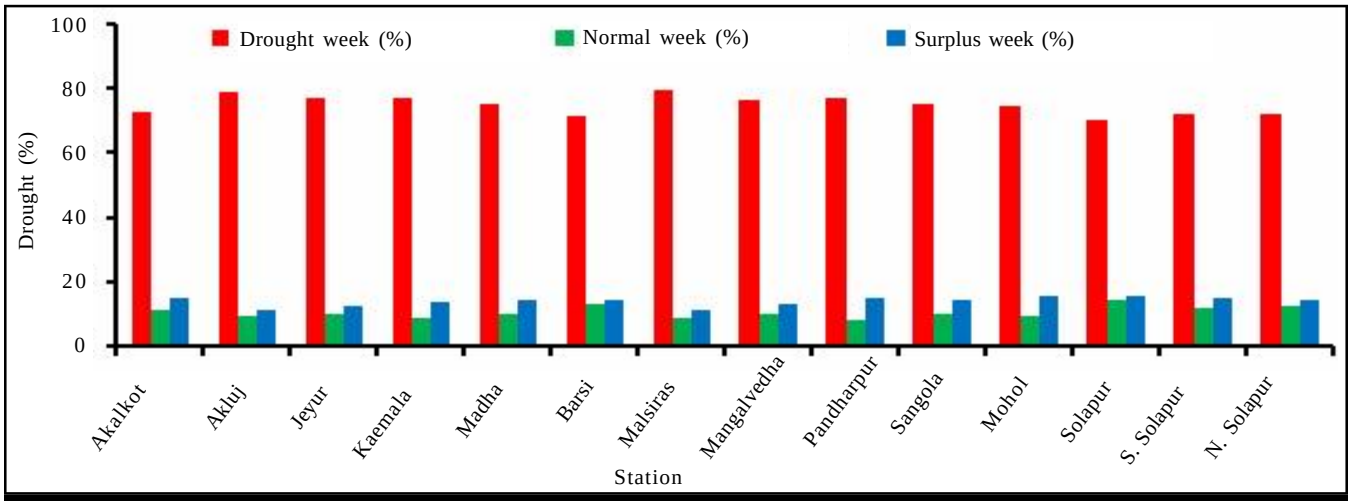

Fig. 1 : Weekly drought variation curves of *Ambe bahar* for all stations in Solapur district

Table 1 : Weekly drought investigations of *Ambe bahar* for all stations of Solapur district

Sr. No.	Station	No. of drought week	No. of normal week	No. of surplus week	% of drought week	% of normal week	% of surplus week	Co-eff. of variance in %
1.	Akalkot	843	135	177	72.99	11.69	15.32	103.17
2.	Akluj	914	112	129	79.13	9.70	11.17	119.01
3.	Jeyur	943	126	156	76.98	10.29	12.73	113.46
4.	Karmala	890	107	158	77.06	9.26	13.68	113.79
5.	Madha	920	128	177	75.10	10.45	14.45	108.68
6.	Barsi	829	155	171	71.77	13.42	14.81	99.90
7.	Malsiras	919	103	133	79.57	8.92	11.52	120.18
8.	Mangalvedha	881	118	156	76.28	10.22	13.51	111.68
9.	Pandharpur	888	95	172	76.88	8.23	14.89	113.59
10.	Sangola	866	119	170	74.98	10.30	14.72	108.40
11.	Mohol	864	109	182	74.81	9.44	15.76	108.16
12.	Solapur	760	157	168	70.05	14.47	15.48	95.39
13.	S. Solapur	785	134	166	72.35	12.35	15.30	101.47
14.	N. Solapur	786	139	160	72.44	12.81	14.75	101.65

Weekly drought investigation for *Ambe bahar* (December-July) :

Table 1 revealed the average weekly drought of *Ambe bahar*. In the 33 (1975-2007) years, total drought weeks highest in Akluj were 943 weeks with 76.98 per cent and lowest in Solapur 760 weeks with 70.05 per cent. The total normal weeks highest in north Solapur is 157 weeks with 14.47 per cent and lowest in Pandharpur is 95 weeks with 8.92 per cent. Similarly, the total surplus weeks highest in Mohol are 182 weeks with 15.32 per cent and lowest in Akluj is 129 weeks with 11.17 per cent. The per cent co-efficient of variation between

Table 2 : Pomegranate evapotranspiration (ETp) of *Ambe bahar* (lit/day/tree) for 5th year (mature) pomegranate tree

M W	Probability levels								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
49	3.82	4.05	4.23	4.38	4.54	4.69	4.87	5.08	5.39
50	5.95	6.30	6.57	6.81	7.04	7.28	7.54	7.86	8.33
51	9.04	9.42	9.71	9.97	10.21	10.46	10.74	11.06	11.54
52	11.10	12.02	12.56	13.00	13.36	13.70	14.02	14.37	14.80
1	11.72	12.54	13.12	13.64	14.14	14.67	15.25	15.96	17.00
2	14.10	14.83	15.38	15.87	16.35	16.83	17.38	18.03	18.95
3	14.10	14.83	15.38	15.87	16.35	16.83	17.38	18.03	18.95
4	20.01	21.33	22.34	23.25	24.12	25.03	26.04	27.27	29.08
5	24.64	25.94	26.93	27.80	28.63	29.49	30.45	31.60	33.27
6	28.54	30.14	31.35	32.43	33.47	34.54	35.73	37.17	39.25
7	31.14	33.20	34.72	36.04	37.30	38.60	39.99	41.66	44.05
8	34.58	37.32	39.48	41.43	43.35	45.39	47.66	50.49	54.68
9	39.60	42.94	45.51	47.85	50.14	52.53	55.21	58.53	63.47
10	46.85	50.40	52.86	54.90	56.74	58.50	60.27	62.18	64.52
11	52.53	55.18	57.17	58.93	60.62	62.36	64.27	66.59	69.93
12	50.50	56.50	60.24	63.11	65.56	67.79	69.97	72.29	75.15
13	56.41	59.69	62.15	64.33	66.42	68.55	70.88	73.66	77.51
14	55.60	62.33	66.54	69.76	72.50	74.99	77.43	80.05	83.27
15	59.36	62.99	65.72	68.14	70.56	73.14	75.86	79.19	84.04
16	66.49	71.31	74.32	76.64	78.60	80.38	82.14	84.01	86.31
17	66.71	70.03	72.52	74.72	76.84	79.03	81.42	84.34	88.54
18	70.06	73.25	75.64	77.75	79.77	81.83	84.11	86.84	90.79
19	67.99	71.64	74.38	76.80	79.14	81.56	84.22	87.44	92.14
20	66.66	70.83	74.00	76.82	79.56	82.38	85.52	89.35	94.96
21	60.42	64.67	67.92	70.83	73.65	76.59	79.87	83.88	89.79
22	53.19	57.92	61.70	64.94	68.31	71.69	75.60	80.33	87.62
23	39.78	44.18	47.37	50.10	52.64	55.16	57.81	60.81	64.74
24	38.08	41.55	44.25	46.70	49.10	51.63	54.48	58.01	63.31
25	35.29	38.54	41.16	43.53	45.77	48.14	50.88	54.25	59.36
26	31.28	34.27	36.61	38.72	40.81	43.01	45.49	48.58	53.22
27	31.52	34.14	36.17	37.99	39.79	41.66	43.85	46.37	50.22
28	26.95	29.57	31.61	33.47	35.30	37.24	39.43	42.16	46.25
29	23.37	28.36	31.47	33.86	35.88	37.73	39.55	41.48	43.85
30	23.90	25.96	27.56	29.00	30.41	31.91	33.57	35.63	38.71
31	22.96	25.47	27.41	29.19	30.96	32.82	34.94	37.61	41.64
(l/y/tree)	1281	1378	1450	1512	1571	1631	1696	1774	1886

drought, normal and surplus weeks for every station found highest in Malsiras station is 120.18 per cent and lowest in Solapur is 95.39 per cent. Also the weekly drought variation curves of *Ambe bahar* for every *station* presented in Fig. 1.

The results of the *bahar* wise weekly drought investigation at different stations revealed that, there is a small variation in drought, normal and surplus weeks of rainfall in the district. Similar drought analyses of rainfall have been carried out by Vladislava and Zoran (2010) climatological stations in Serbia; Rafiuddin (2011) over 4 sub-regions of the Bangladesh country.

Pomegranate evapotranspiration (ETp) of *Ambe bahar* at different probability level :

Weekly values of pomegranate ETp at different probability levels are presented in Table 2 for 5th year's (mature) tree for *Ambe bahar*. It is seen from the table that the weekly values of pomegranate evapotranspiration (ETp) are low during initial stage and tends to increase during crop development stages. It is observed from the table that, at 70 pe cent probability level weekly pomegranate evapotranspiration (ETp) ranges from 4.87 to 85.52 lit./day/tree. Maximum values of pomegranate evapotranspiration (ETp) are observed in 20th week. These values are 89.35, 85.52, 79.56 and 70.83 lit./day/tree at probability levels 80 per cent, 70 per cent, 50 per cent and 20 per cent, respectively. Minimum values of the pomegranate evapotranspiration (ETp) are observed in 31st week and it is 5.08, 4.87, 4.54 and 4.05 lit./day/tree at probability levels 80 per cent, 70 per cent, 50 per cent and 20 per cent, respectively. The total pomegranate evapotranspiration (ETp) at 70 per cent probability level over a period of 35 weeks of phenological stages in *Ambe bahar* is 1696.42 lit./year/tree.

Weekly water surplus/deficit in *Ambe bahar* for mature (5th year) pomegranate tree

The number of deficit weeks highest in Akluj is 1013 weeks with 93.55 per cent and lowest in South Solapur is 96.8 weeks with 89.68 per cent. The number of surplus weeks highest in South Solapur is 112 weeks with 10.32 per cent and lowest in Akluj is 70 weeks with 6.45 per cent. The weekly drought variation patterns of *Ambe bahar*mature pomegranate (5th year) tree for every station given in Table 3 and graphically presented in Fig. 2.

Moisture status under different stations of Solapur district :

The concept of climatic water balance has come to be understood universally as a basis for understanding the moisture status of a place (Kerkides *et al.*, 1996). The weekly water balance elements for all the stations of Solapur district have been computed by Thornthwaite and Mather (1955) method. Normal weekly water balance for different stations under study was

Table 3 : Weekly water balance of *Ambhe bahar* of V th year (mature) pomegranate tree

Sr. No.	Name of tehsil	No. of deficit week	No. of surplus week	% of deficit week	% of surplus week
1.	Akalkot	978	107	90.14	9.86
2.	Akluj	1015	70	93.55	6.45
3.	Jeyur	1012	73	93.27	6.73
4.	Karmala	1008	77	92.90	7.10
5.	Madha	1003	82	92.44	7.56
6.	Barsi	995	90	91.71	8.29
7.	Malsiras	1013	72	93.36	6.64
8.	Mangalvedha	1009	76	93.00	7.00
9.	Pandharpur	988	97	91.06	8.94
10.	Sangola	999	86	92.07	7.93
11.	Mohol	996	89	91.80	8.20
12.	Solapur	975	110	89.86	10.14
13.	S. Solapur	973	112	89.68	10.32
14.	N. Solapur	983	102	90.60	9.40

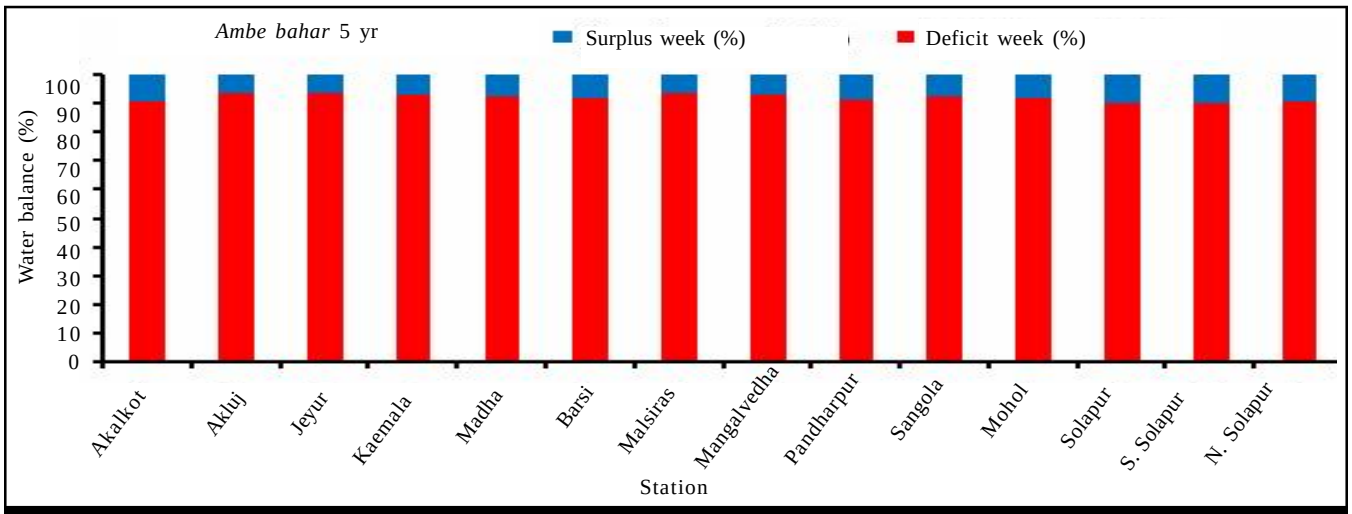

Fig. 2 : Weekly water balance pattern of *Ambe bahar* for 5th year (mature)pomegranate tree

determined. The water balance of the different stations of the district has been used to study moisture status in the district (Kothari *et al.*, 2006).

Annual moisture status and its parameters of *Ambe bahar* of pomegranate :

The elements of annual water balance for different rainfall years have been computed. The Table 4 reveal that maximum and minimum value of rainfall, evapotranspiration (ET), actual evapotranspiration (AET), water deficit, water surplus, humidity index (I_h), aridity index (I_a), moisture index (I_m), moisture adequacy index (I_{ma}) during the years (1977-2007) in all the *stations* of Solapur district for *Ambe bahar*. In all *stations* the highest maximum value of rainfall, actual evapotranspiration (AET), water deficit, water surplus, humidity index (I_h), aridity index (I_a), moisture index (I_m), moisture adequacy index (I_{ma}) are occurred in Akalkot (1132.5), Solapur (352.37), Mohol (1369.82), Akluj (947.46), Akluj (86.26), North Solapur (98.44), Akalkot (3.31) and Mohol (30.81), respectively. Similarly, minimum value occurred in North Solapur (17), North Solapur (17.1), Solapur (791.43), Akluj (0), Jeyur (0), Solapur (69.19), North Solapur (-98.44) and North

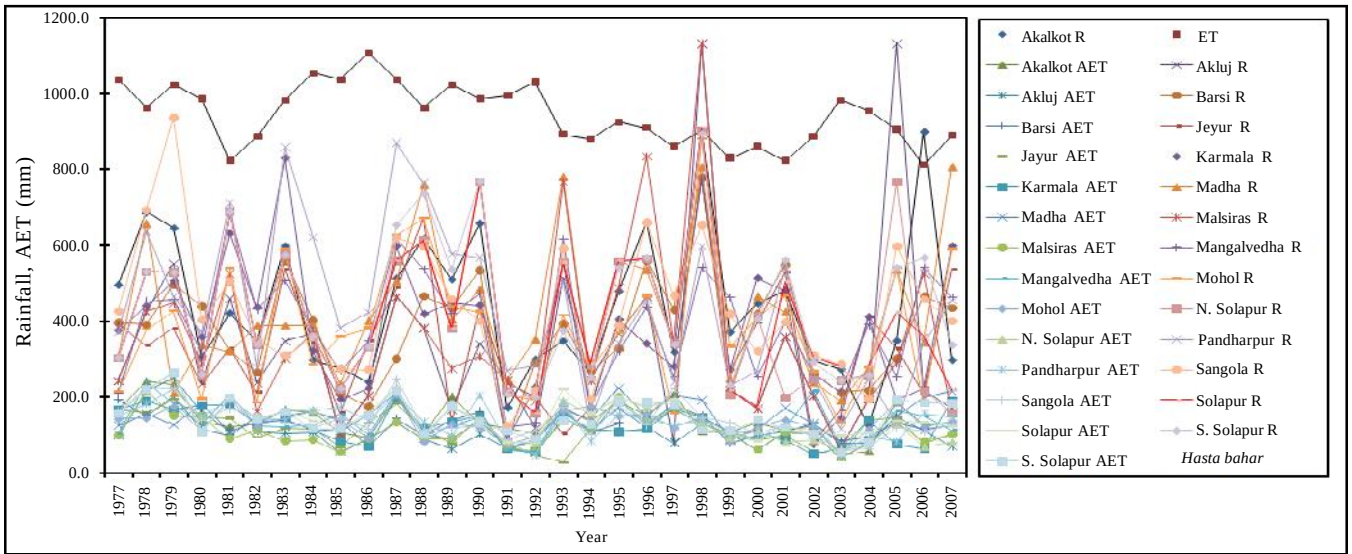

Fig. 3 : Seasonal water balance in different stations of Solapur district for *Ambe bahar*

Solapur (1.56), respectively.

Above results and Fig. 3 reflect that the high water deficit prevails during summer season (January-February) and surplus water remains high during rainy season (after month May to August) and probably no surplus occurs in before month may due to high temperature without rainfall. *Bahar* wise water surplus always occurs after weekly water deficit in all the stations of Solapur district. It also indicates the high heterogeneity of water surplus and deficit in different stations. The figure also indicates that probability or percentage of safe crop growing year in different stations. The rainfall data also reveal that the weekly water deficit increases from month January to May. Thereafter, it decreases sharply during June and then again decreases during monsoon season (July - August).

Climatic shift in *Ambe bahar* :

The moisture index, which is the basis for climatic classification (Kothari *et al.*, 2006) has been studied based on seasonal change in climate. Fig. 4 indicates the fluctuation of moisture index (I_m) in different years of study period. It is observed that from Table 5, the climate at Malsiras, Mangalvedha, Pandharpur and Mohol represents high arid condition (93.5%) while at Solapur, North Solapur and South Solapur it is low arid condition

Table 4 : Seasonal water balance and its different parameters of *Ambe bahar*

Station *(Ambe bahar)*	Cate-gory	Rain-fall, (mm)	ET (mm)	AET (mm)	Water Deficit (mm)	Water Sur-plus (mm)	Humi-dity Index (I_h)	Ari-dity Index (I_a)	Mois-ture Index (I_m)	Moisture adequacy Index (I_{ma})
Akalkot	Max.	611.0	1455.02	283.84	1328.9	334.6	26.49	94.50	-50.53	22.98
	Min.	78.40	1096.21	72.08	912.95	6.32	0.48	77.02	-94.02	5.50
Akluj	Max.	1132.	1455.02	216.93	1359.0	947.4	86.26	96.72	3.31	19.79
	Min.	42.20	1096.21	42.20	879.28	0.00	0.00	80.21	-96.72	3.28
Jeyur	Max.	447.2	1455.02	310.33	1371.7	253.5	23.08	95.45	-59.29	25.26
	Min.	74.00	1096.21	51.99	854.48	0.00	0.00	74.74	-94.22	4.55
Karmala	Max.	552.0	1455.02	285.67	1344.1	329.2	28.78	95.40	-51.74	21.60
	Min.	54.40	1096.21	54.40	904.67	0.00	0.00	78.40	-95.24	4.60
Madha	Max.	424.2	1455.02	262.13	1379.8	206.1	18.77	94.83	-63.51	22.62
	Min.	75.20	1096.21	75.20	896.72	0.00	0.00	77.38	-94.83	5.17
Barsi	Max.	463.3	1455.02	291.95	1310.4	244.1	20.07	90.77	-62.07	21.74
	Min.	145.8	1096.21	119.84	861.32	0.00	0.00	78.26	-89.10	9.23
Malsiras	Max.	1132.	1455.02	199.32	1359.0	947.4	86.26	96.72	3.11	17.23
	Min.	42.20	1096.21	42.20	913.33	0.00	0.00	82.77	-96.72	3.28
Mangal-	Max.	512.5	1455.02	304.42	1317.8	260.6	22.80	93.67	-55.64	26.27
vedha	Min.	87.30	1096.21	85.76	854.42	0.00	0.00	73.73	-93.48	6.33
Pandhar-pur	Max.	497.0	1455.02	321.08	1264.6	274.3	24.00	92.78	-56.53	27.71
	Min.	140.5	1096.21	94.04	837.77	0.70	0.06	72.29	-89.29	7.22
Sangola	Max.	554.2	1455.02	328.14	1283.8	278.2	19.12	93.79	-58.01	28.70
	Min.	88.00	1096.21	71.01	815.13	0.00	0.00	71.30	-92.63	6.21
Mohol	Max.	415.5	1455.02	283.91	1369.2	215.2	17.43	94.11	-67.65	24.50
	Min.	86.40	1096.21	80.87	874.94	5.53	0.42	75.50	-93.41	5.89
Solapur	Max.	550.6	1455.02	352.37	1302.9	299.6	24.26	90.04	-54.70	30.81
	Min.	130.6	1096.21	130.60	791.43	0.00	0.00	69.19	-90.04	9.96
S. Solapur	Max.	523.2	1455.02	311.61	1302.9	250.7	20.30	96.33	-57.64	24.00
	Min.	48.10	1096.21	48.10	903.03	0.00	0.00	76.00	-96.33	3.67
N. Solapur	Max.	550.6	1455.02	311.61	1302.9	299.6	24.26	98.44	-56.94	24.27
	Min.	17.10	1096.21	17.10	830.14	0.00	0.00	75.73	-98.44	1.56

(67.7, 74.2 and 80.6%, respectively). The data also indicate that the climatic conditions at Solapur, North Solapur and South Solapur highly shifted from arid to semi-arid condition in 32.3, 25.8 and 19.4 per cent years, respectively, whereas climatic conditions at Malsiras, Mangalvedha, Pandharpur and Mohol low shifted from semi arid to arid in 6.5 per cent years. The climatic conditions of none of station shifted to dry sub-humid. The climatic conditions at Akalkot, Akluj, Jeyur, Karmala, Madha, Barsi and Sangola shows swing between semi-arid and arid conditions.

The characterization of climate is an important tool for crop planning. The study on predominant shift in climate of *Ambe bahar* of pomegranate in different stations reveal that two types of micro climatic conditions prevails in the district *viz.*, arid, having arid climate for more than 80 per cent years (>26 years); semi arid climate, having semi arid climate for more than 32.3 per cent years (>10 years) and arid to semi arid, having swing from arid to semi arid climate in different years. Thus,

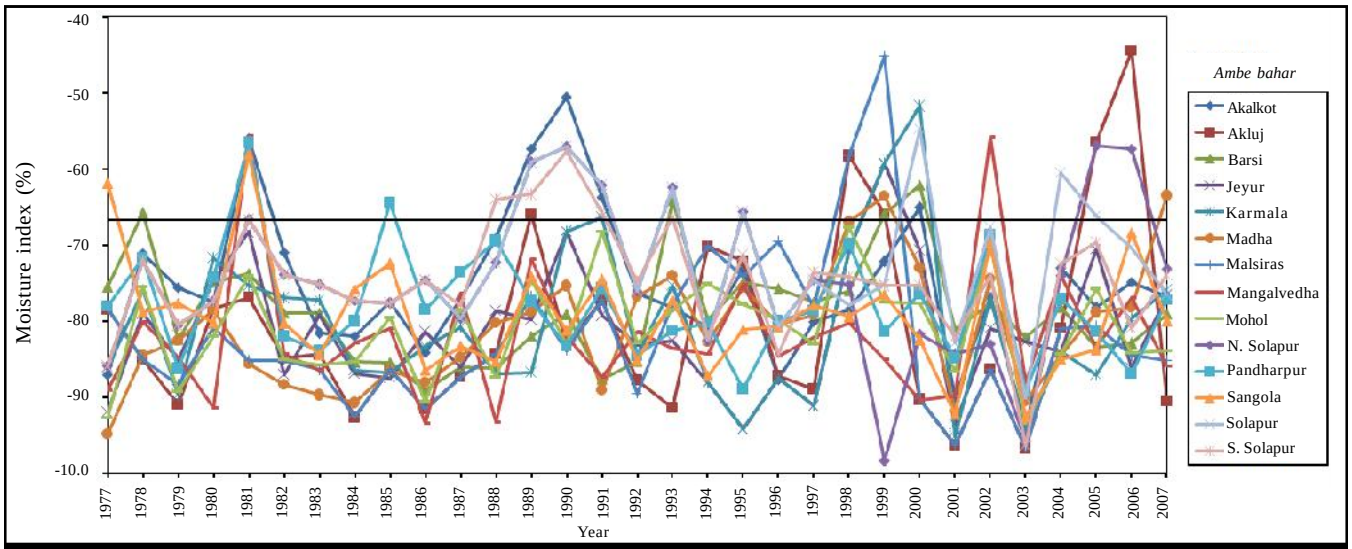

Fig. 4 : Climatic shift in *Ambe bahar* for different rainfall stations of Solapur district

Table 5 : Climatic conditions of *Ambe bahar* under different stations for Solapur district

Stations, Ambe	Number of years of shift out of 31 years			Arid (%)	Semi-arid (%)
	Arid	Semi-arid	Dry sub- humid		
Akalkot	26	5	0	83.9	16.1
Akluj	26	5	0	83.9	16.1
Jeyur	28	3	0	90.3	9.7
Karmala	27	4	0	87.1	12.9
Madha	28	3	0	90.3	9.7
Barsi	27	4	0	87.1	12.9
Malsiras	29	2	0	93.5	6.5
Mangalvedha	29	2	0	93.5	6.5
Pandharpur	29	2	0	93.5	6.5
Sangola	28	3	0	90.3	9.7
Mohol	29	2	0	93.5	6.5
Solapur	21	10	0	67.7	32.3
S. Solapur	25	6	0	80.6	19.4
N. Solapur	23	8	0	74.2	25.8

the predominant climate for *Ambe bahar* of pomegranate at every stations of Solapur district is arid. The complete arid climate is good for pomegranate tree also disease free production. In arid climate, temperature and humidity are good for pomegranate production but due to unavailability of rainfall, there is need of external irrigation facility to fulfill water requirement.

Conclusion :

The greater intensity of weekly drought for *Ambe bahar* is found in Malsiras followed by Akluj and Karmala and lowest intensity of weekly drought is found in Solapur and Barsi for all the weeks. The monitoring of drought using meteorological indicators are time consuming, laborious and not on real time but using this data reliable and economical monitoring of drought is possible compared to any other improved techniques.

Water requirement at 70 per cent probability of *Ambe bahar* is 1696.42 lit./year/tree for mature (5^{th} year) pomegranate tree.

The per cent maximum water deficit weeks observed in Malsiras fallowed by Akluj and that of maximum surplus weeks observed in Solapur fallowed by South Solapur for every pomegranate *bahar* for mature (5^{th} years) pomegranate trees. The per cent water surplus weeks always lower than the per cent water deficit weeks for all the stations of Solapur district for entire study period (1977-2007). From weekly water deficit and surplus results, it is clear that area under go arid to semi-arid region.

The climate at Malsiras, Mangalvedha, Pandharpur and Mohol stations represents high arid condition (93.5%) in years. The climatic conditions at Solapur, North Solapur and South Solapur stations highly shifted from arid to semi-arid condition in 32.3 per cent, 25.8 per cent and 19.4 per cent years, respectively, whereas climatic conditions at Malsiras, Mangalvedha, Pandharpur and Mohol stations low shifted from semi-arid to arid in 6.5 per cent years.

The moisture index data in Solapur district reveal that the climate in *Ambe bahar* is completely arid with average moisture index (-78.31) per cent. Highest and lowest moisture index are observed in Solapur (-72.77) and Mangalvedha (-81.96) stations, respectively.

The abrupt changes, large variation from mean values of meteorological parameters are occurred in *Ambe bahar* but the average climate, for *Ambe bahar* is arid and very poor moisture adequacy index. This is good for disease free and high quality production of pomegranate when external source of water supply is available.

Authors' affiliations:

P. G. POPALE, Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, AHMEDNAGAR (M.S.) INDIA

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