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Abstract

Crop evapotranspiration (ETc) estimation is essential for many studies such as irrigation system design and management, crop yield simulation, and water resource planning and management. Field studies were conducted at MPKV Rahuri, Maharashtra from 2015 - 2016 and 2016 - 2017 (2 years) in clay soils to determine crop evapotranspiration and crop coefficients (Kc) of the potato crop. The experimental area was cultivated with irrigation applied at 7-days interval. The irrigation scheduling was based on the field water balance approach. The crop evapotranspiration was determined by the field water balance; reference evapotranspiration (ETo) by the Penman-Monteith method and crop coefficients were computed using the standard FAO-56 methodology. The total reference evapotranspiration (ETo) and crop evapotranspiration (ETc) were 226 and 240 mm for the year 2015–2016 and 248 and 250 mm for the year 2016–2017, respectively. The 2-year average reference evapotranspiration was 237 mm and the crop evapotranspiration was 245 mm. The average estimated Kc values for the semi-arid region during the vegetative, tuber development, and maturity stages for potato are 0.55, 1.11, and 1.01, respectively. The calculated values are slightly lower than those suggested by FAO-56 for the vegetative and tuber development stages and higher for the maturity stage of potato. The estimated values of crop coefficients for potato are 11.25% higher than those suggested by FAO-56. However, observed variation between values from the FAO-Kc and Kc calculated by the field water balance is not significant. So, these values can be used for irrigation scheduling of potato in the semi-arid region.

Keywords Crop coefficient · Crop evapotranspiration · Field water balance · Potato · Reference evapotranspiration

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Introduction

Potato is the fourth most important food crop after wheat, maize, and rice in terms of the amount produced and cultivated in many countries of the world. The annual average potato production in the world is 388.19 million tonnes and its production area is 19.30 million hectares and average yield per hectare is 20 t (FAOSTAT 2019). India is the second largest producer in the world with 48.85 million tonnes in potato production. Its production area is 2.18 million ha and average yield per hectare is 22.40 t (Anonymous 2018). Maharashtra ranks 14th with 0.536 million tonnes in potato production in India and its production area is 0.0208 million hectare and average yield per hectare is 25.76 t (Anonymous 2018). In Maharashtra, potato is one of the major cash crops and Pune and Satara districts are major potato-growing districts in Maharashtra state, which account for 72% of area and 76% of production (Nikam et al. 2008).

Potato is very sensitive to water stress and requires continuous supply of irrigation water throughout its growth cycle with differential phasic water requirement (Ingle 2007). Therefore, the relationship of crop yield with water requirement has been a major focus of agricultural research in the arid and semi-arid regions. Water requirements vary substantially during the growing stages of the crop mainly due to variation in crop canopy and climatic conditions (Doorenbos and Pruitt 1977). The knowledge of crop water requirements is an important practical consideration to improve water use efficiency in irrigated agriculture. Even though India is second of the major potato producing countries in the world, studies on water requirements of potato cultivated under semi-arid conditions are scarce. There is considerable scope for improving water use efficiency of potato by proper irrigation scheduling which is essentially governed by crop evapotranspiration (ETc). The estimation of crop evapotranspiration is therefore necessary for appropriate irrigation water management. The crop evapotranspiration varies as per crop, its growth stage, and prevailing weather conditions. Thus, crop evapotranspiration is a function of crop characteristics and weather characteristics. Reference crop evapotranspiration which is the evapotranspiration of reference crop that is fully grown and never short of water takes care of the weather characteristics. The crop evapotranspiration is then related to reference crop evapotranspiration through a factor called crop coefficient which varies as per crop and its growth period.

Crop coefficient (Kc) is the key parameter commonly required in determining crop water requirement of the crop. To extrapolate the measurement of ETc for irrigation planning in regional scale, the crop coefficient (Kc) is often used. Kc is the ratio of the actual crop evapotranspiration (ETc) to a reference evapotranspiration (ETo) which can be calculated using the FAO-Penman-Monteith method. The Kc integrates the crop and soil conditions that make a given crop evapotranspiration more or less than the reference evapotranspiration. Doorenbos and Pruitt (1977) in FAO-24 and Allen et al. (1998) in FAO-56 suggested crop coefficient values for the potato crop under different climatic conditions that are commonly used in places where the local data are not available. However, the values documented by FAO are based on the average crop coefficient values all over the world and hence the need to develop crop coefficients under prevailing local climatic conditions (Kashyap and Panda 2001). Consideration of the global averages of the crop coefficient does not result in an appropriate estimation of crop evapotranspiration and hence leads to inappropriate application of water, resulting in under or over irrigation and finally decreased productivity and/or increased wastage of scarce water resources. FAO also cautioned to use the values documented by them carefully, as those values are averages of values over different regions of the world. Kc values developed by FAO are for global average climate conditions and due to weather and water requirement they change from region to region. Also, due to differences in albedo, crop height, variations in wind speed, aerodynamic resistance, and leaf and stomata properties of a particular crop, the crop coefficient varies during the crop growth period. Therefore, it is necessary to develop Kc values for semi-arid conditions for different crops of the semi-arid region considering local conditions for the estimation of accurate crop water requirement. The crop coefficients have not been developed for the potato crop under semi-arid climatic conditions in India. Hence, a study was conducted to determine the periodic crop coefficient values for the potato crop of the regions by the field water balance method. The Kc developed in the study will be useful for estimating crop water requirements for potato and the overall improvement of irrigation water management in the semi-arid regions.

Materials and Methods

Experimental Site, Soil, and Climate

The field experiment was carried out during the *Rabi* seasons of 2015–2016 and 2016–2017 at the Experimental Farm of Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri located in the semi-arid region and western part of Maharashtra state, India. The experimental site is situated at 19° 47′ N, 74° 37′ E at 657 m above mean sea level. Climatically, the study area falls under the semi-arid and subtropical zone with average annual rainfall of 520 mm. The distribution of rain is uneven and is distributed over 15 to 37 rainy days. The annual mean maximum and minimum temperature range is between 21.2 to 41.8 °C and 3.0 to 24.6 °C, respectively. The annual mean maximum and minimum relative humidity range is from 59 to 90% and 21 to 61%, respectively. The annual mean pan evaporation ranges from 2.3 to 14.9 mm day^{-1}. The daylight hours range from 7 to 9 h day^{-1}. The annual mean wind speed ranges from 3.2 to 13.09 km h^{-1}. Agro-climatically, the area falls under the scarcity zone of Maharashtra state. The local climate is semi-arid with subtropical. The soil characteristics of the experimental field were clay with 27.74% field capacity, 13.64% permanent wilting point, and 1.10 g cc^{-1} bulk density. The pH of soil was 8.34 and electrical conductivity was 0.71 dsm^{-1}. The available N, P, and K were 154, 19, and 775 kg ha^{-1}, respectively, indicating low potassium in the soil.

Crop Details

Potato (*Solanum tuberosum* L.), cultivar Kufri Pukraj, was planted at a spacing of 45 × 20 cm in a field of 40 m × 28.8 m size on November 27, 2015, and November 24, 2016, during the *Rabi* seasons of 2015–2016 and 2016–2017. The depth of planting was maintained at 10 cm. The recommended fertilizer, inter-culturing operations, pesticide and insecticide application, and other necessities were provided according to requirement. The irrigation was applied at an interval of 7 days based on the soil moisture balance approach. The crop was harvested on March 14, 2016, and March 15, 2017, during the *Rabi* seasons of 2015–2016 and 2016–2017, respectively.

Root Zone Depth

The root length was measured by using destructive plant sampling**.** For each moisture content observation, the effective root zone was determined by carefully uprooting one healthy plant (FAO 56). Doorenbos and Kassam (1979) reported a maximum root penetration of the potato plant of 60 cm, whereas most of the roots were concentrated in the top 40–60 cm of soil with only a few roots above 20 cm. Therefore, a root zone depth of 60 cm was considered when planning the observations.

Soil Moisture Content

The soil moisture content was determined by using the standard gravimetric method of Michael (2010). The soil water content was measured at 20 cm, 40 cm, and 60 cm depths during the potato-growing period before sowing, prior to irrigation and in-between two irrigations approximately at midpoint of irrigation interval during the whole crop season.

Irrigation Scheduling

The irrigation scheduling was based on soil moisture content in the root zone of the potato crop. The irrigation for potato was initiated when soil water in the root zone approached, but never depleted more than 35% (FAO 56) of available soil moisture content and refilled the profile to field capacity. The depth of water applied was calculated using the following formula:

$$d_t = \sum_{i=1}^{n} (\theta f_t \times Z_t \times BD_t - \theta_t \times Z_t \times BD_t) - Rf_e$$

$$\text{When } Rf_e \leq (\theta f_t \times Z_t \times BD_t - \theta_t \times Z_t \times BD_t)$$

$$d_t = 0$$

$$\text{When } Rf_e \geq (\theta f_t \times Z_t \times BD_t - \theta_t \times Z_t \times BD_t)$$

$\theta f_t = \sum_{i=1}^{n} \theta f_i$; $\theta_t = \sum_{i=1}^{n} \theta_I$; $Z_t = \sum_{i=1}^{n} Z_I$; $BD_t = \sum_{i=1}^{n} BD_{i.}$ where d_t is the depth of irrigation water to be required in the active root zone at t^{th} day of irrigation event (mm), θf_t is the field capacity (%), $\theta_t$is the soil water contents before irrigation for i^{th} layer of the root zone on t^{th} day (%), Z_t is the root zone depth at t^{th} day (mm); i is the incremental root depth (150 mm) and n is number of i^{th} layers; Rf_e is the effective rainfall (mm); and BD_t is bulk density on t^{th} day (g cc^{-1}).

Irrigation Interval

FAO-56 has suggested that the soil water balance method can only give evapotranspiration estimates over long periods of the order of week-long or 10-day periods. Therefore, the interval between two successive soil moisture measurements was maintained at 7 days (Allen et al. 1998).

Soil Water Storage

The change in soil water storage was determined by considering the soil layers from the surface down to the depth of the effective root zone of the potato crop. The change in soil water storage (ΔS_t) was determined for two successive observation days (i.e. soil water storage at the previous observation day minus soil water storage at next observation day) as:

$$\Delta S_{\mathrm{t}} = (\theta_{t-1} \times Z_{t-1} - \theta_t \times Z_{t-1}) \times \ \mathrm{BD}_{\mathrm{t-1}}$$

$$\theta_{t-1} = \sum_{i=1}^{n} \theta_i \qquad Z_{t-1} = \sum_{i=1}^{n} Z_i \qquad \mathrm{BD}_{t-1} = \sum_{i=1}^{n} \mathrm{BD}_i$$

where θ_{t-1} is the previous day (t-1) moisture content (%), and θ_t is the successive day (t) moisture content (%), Z_{t-1} is the previous day depth of effective root zone at t-1 day (mm), i is the incremental root depth (150 mm), and n is a number of i^{th} layers and BD_{t-1} is bulk density of effective root zone at t-1 day (g cc^{-1}).

Determination of Soil Water Balance

The field water balance, expressed in terms of depletion at the end of consecutive soil water measurement days, was calculated by the following equation given by FAO 56:

$$\mathrm{ETc} = I + R_{\mathrm{e}} - \mathrm{RO} - \mathrm{DP} + \mathrm{CR} \pm \Delta \mathrm{SF} \pm \Delta \mathrm{S}$$

where ETc is the crop evapotranspiration, I the is depth of irrigation applied, R_{e} is the effective rainfall, RO is the runoff from the soil surface, DP is the deep percolation below the root zone, CR is the capillary rise (case of a shallow water table), ΔSF is the horizontal subsurface flow in or out of the root zone, and ΔS is the change in soil profile water storage, respectively. All parameters were expressed in mm. Effective rainfall was computed by Dastane (1972) criteria (FAO 22). Surface runoff was neglected as the experimental site had flat topography. Similarly, CR was assumed to be zero.

Crop Evapotranspiration

The field water balance method was used to estimate crop evapotranspiration (ETc) in the root zone between two consecutive soil moisture measurements as:

$$\sum_{t-1}^{t} \mathrm{ETcj} = (\theta_{t-1} - \theta_t) \times (Z_{t-1} \times \mathrm{BD}_{t-1}) + I_{t-1} + \sum_{t-1}^{t} R_e$$

where ETcj is the crop evapotranspiration from the active root zone (mm) between t-1 and t^{th} day time interval, R_e the effective rainfall (mm) between t-1 day and t^{th} day time interval, and I_{t-1} the supplemental irrigation (mm) given on the t-1 day.

The total crop evapotranspiration was estimated as:

$$\mathrm{ETc} = \sum_{j=1}^{n} \mathrm{ETc_j}$$

where j is the period for which ETc measured between two successive moisture content observation events (from t-1 to t), and n is the total number of two successive events in the entire growth period.

Reference Evapotranspiration

The reference evapotranspiration (ETo) was estimated using the Penman-Monteith method proposed by Allen et al. (1998) using daily weather parameters for the crop growth period as:

$$\mathrm{ETo} = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where ETo is the reference evapotranspiration (mm day^{-1}), R_n is the net radiation at the crop surface (MJ m^{-2} day^{-1}), G is the soil heat flux density (MJ m^{-2} day^{-1}), T is the mean daily air temperature at 2 m height (°C), u_2 is the wind speed at 2 m height (m s^{-1}), e_s is the saturation vapour pressure (kPa), e_a is the actual vapour pressure (kPa), Δ is slope of vapour pressure curve (kPa ^{0}C^{-1}), and γ is the psychrometric constant (kPa ^{0}C^{-1}).

Estimation of Crop Coefficients

The crop coefficient (Kc) values were estimated for potato crop as a ratio of crop evapotranspiration to the reference evapotranspiration using the following equation proposed in FAO-56.

$$\mathrm{Kc} = \frac{\mathrm{ETc}}{\mathrm{ETo}}$$

where ETc is the crop evapotranspiration values obtained from the field water balance method by monitoring the soil moisture balance in the crop root zone and corresponding ETo values were estimated by Penman-Monteith Method using climate data.

Regression Equations for Kc

The polynomial equations of the following orders were developed to estimate the daily values of crop coefficients with Kc as the dependent variable and (t/T) as the independent variable. Regression coefficients squared (R^2) were estimated and tested for significance to decide upon the validity of the particular polynomial equation.

$$\mathrm{Kc_t} = a_2\left(\frac{t}{T}\right)^2 + a_1\left(\frac{t}{T}\right)^1 + a_o\left(\frac{t}{T}\right)^0$$

$$\mathrm{Kc_t} = a_3\left(\frac{t}{T}\right)^3 + a_2\left(\frac{t}{T}\right)^2 + a_1\left(\frac{t}{T}\right)^1 + a_o\left(\frac{t}{T}\right)^0$$

$$\mathrm{Kc_t} = a_4\left(\frac{t}{T}\right)^4 + a_3\left(\frac{t}{T}\right)^3 + a_2\left(\frac{t}{T}\right)^2 + a_1\left(\frac{t}{T}\right)^1 + a_o\left(\frac{t}{T}\right)^0$$

$$\mathrm{Kc_t} = a_5\left(\frac{t}{T}\right)^5 + a_4\left(\frac{t}{T}\right)^4 + a_3\left(\frac{t}{T}\right)^3 + a_2\left(\frac{t}{T}\right)^2 + a_1\left(\frac{t}{T}\right)^1 + a_o\left(\frac{t}{T}\right)^0$$

where $\mathrm{Kc_t}$ is the crop coefficient of t^{th} day, a_5, a_4, $a_{3,}$ $a_{2,}$ a_1, and a_0 are constants of equations, t is the day considered, and T is the total crop growth period from planting to harvesting (days).

Results and Discussion

Average Soil Moisture

The moisture content found increased with an increase in soil layer depth down to 40 cm and thereafter it slightly decreased at 60 cm with the lowest moisture content observed after 60 cm depth. The average soil moistures during different growth stages of potato for the years 2015–2016 and 2016–2017 are presented in Figs. 1 and 2. Figures 1 and 2 revealed that growth stage greatly influenced the average moisture content of the soil. The soil moisture content increased with an increase in crop evapotranspiration during the growth period. In the initial stage, the soil moisture content was low and increased in the tuber development and maturity stages as depth

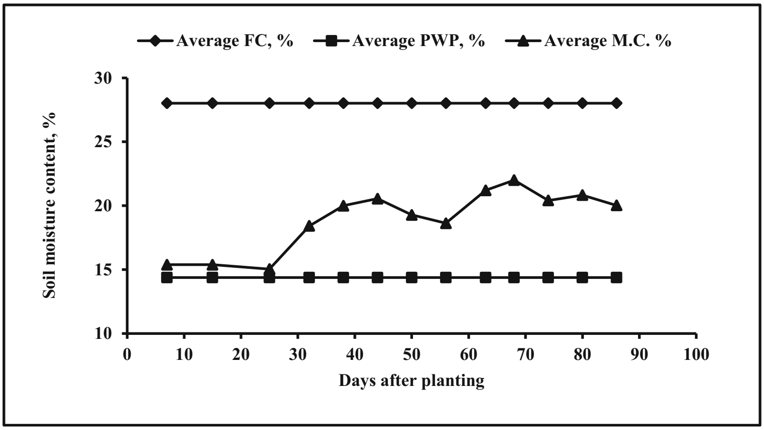

Fig. 1 Average soil moisture content in 2015–2016 growing season of potato

of irrigation increased. However, during the maturity stage, the crop water use was largely reduced which resulted in high soil moisture content in the soil root zone.

Irrigation Water Applied

The irrigation depth differed for a particular growth stage in a season due to differences in crop water use and duration of the stage. Total depth of irrigation water applied during crop growth period was 240 mm and 250 mm in 2015–2016 and 2016–2017, respectively. Invariably in both seasons, the tuber development stage was identified as a high water requirement stage due to its long duration (26–85 days). In both seasons, the lowest irrigation water was applied for the maturity stage among all stages. This happened because of a decline in crop water use with crop maturity.

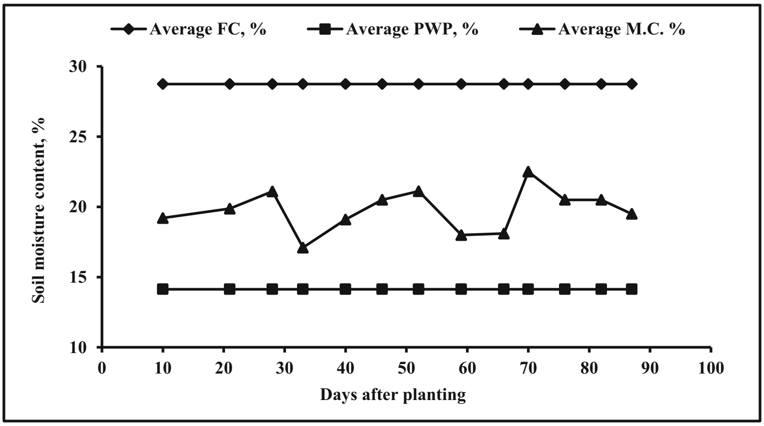

Fig. 2 Average soil moisture content in 2016–2017 growing season of potato

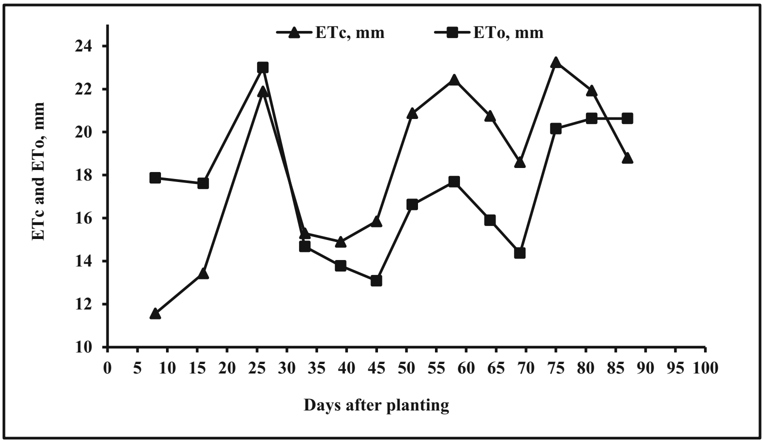

Fig. 3 Crop evapotranspiration (ETc) and reference evapotranspiration (ETo) in and reference evapotranspiration in season 2015–2016

Crop Evapotranspiration and Reference Evapotranspiration

The crop evapotranspiration (ETc) and reference evapotranspiration (ETo) values for the entire crop seasons of 2015–2016 and 2016–2017 are depicted in Figs. 3 and 4. The total ETo estimated over the entire crop season was 226 mm in the 2015–2016 season and 248 mm in the 2016–2017 season with an average of 237 mm. The total ETc estimated over the entire crop growth season was 240 mm in the 2015–2016 season and 250 mm in the 2016–2017 season with an average of 245 mm.

Crop Coefficient of Potato

In this study, the Kc values were estimated for potato by the field water balance method. The crop evapotranspiration (ETc) values were obtained from the field method

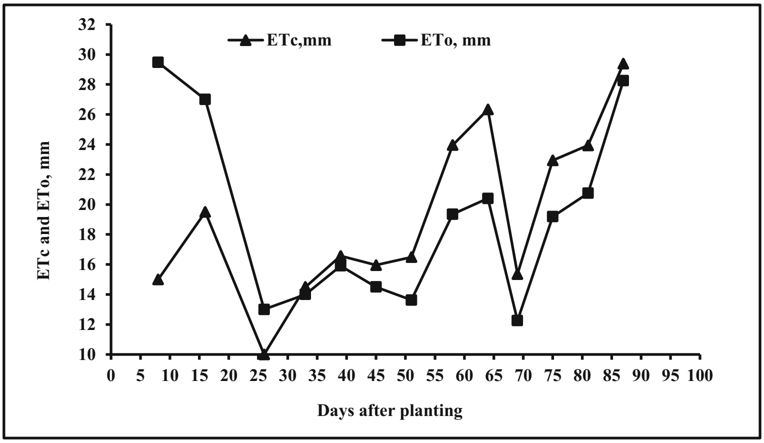

Fig. 4 Crop evapotranspiration (ETc) and reference evapotranspiration (ETo) in and reference evapotranspiration in season 2016–2017

Table 1 Crop evapotranspiration, reference evapotranspiration, and crop coefficient (Kc) of the potato crop in 2015–2016 and 2016–2017 and an average of 2015–2016 and 2016–2017

Period, days	2015–2016			2016–2017			Average		
	ETc, mm	ETo, mm	Kc	ETc, mm	ETo, mm	Kc	ETc, mm	ETo, mm	Kc
1–8	11.57	17.87	0.65	15.00	29.47	0.51	13.29	23.67	0.56
9–16	13.43	17.61	0.76	19.50	27.00	0.72	16.47	22.31	0.74
17–26	21.89	23.00	0.95	10.00	13.00	0.77	15.95	18.00	0.89
27–33	15.29	14.68	1.04	14.50	14.00	1.04	14.90	14.34	1.04
34–39	14.90	13.78	1.08	16.57	15.91	1.04	15.74	14.85	1.06
40–45	15.85	13.09	1.21	15.96	14.50	1.10	15.91	13.80	1.15
46–51	20.88	16.63	1.26	16.49	13.63	1.21	18.69	15.13	1.23
52–58	22.44	17.69	1.27	23.96	19.35	1.24	23.20	18.52	1.25
59–64	20.75	15.90	1.31	26.33	20.40	1.29	23.54	18.15	1.30
65–69	18.60	14.37	1.29	15.36	12.26	1.25	16.98	13.32	1.28
70–75	23.25	20.16	1.15	22.94	19.19	1.20	23.10	19.68	1.17
76–81	21.93	20.63	1.06	23.94	20.75	1.15	22.94	20.69	1.11
82–87	18.80	20.63	0.91	29.39	28.26	1.04	24.10	24.45	0.99

by monitoring the soil moisture in the crop root zone and corresponding ETo values were estimated using climatic data by the Penman-Monteith method. The weekly values of crop coefficients were then computed for the potato crop as the ratio of weekly crop evapotranspiration and weekly reference evapotranspiration. Furthermore, these Kc values were represented in the form of a polynomial equation, with respect to the ratio of days to total crop period. The crop evapotranspiration, reference evapotranspiration, and crop coefficient for *Rabi* potato crop during 2015–2016 and 2016–2017 and an average of 2015–2016 and 2016–2017 are shown in Table 1.

Regression Equations for Estimation of Daily Crop Coefficient

The polynomial equations of different orders were developed between the crop coefficient and the ratio of days (t) to total crop period (T). These equations will give the daily values of the crop coefficient for the total crop duration. The best fit polynomial type of Kc equations for season 2015–2016 and 2016–2017 and an average of the two seasons are represented in Table 2.

Table 2 Crop coefficient equations for potato (2015–2016, 2016–2017 and average over 2015–2016 and 2016–2017) where Kc_t is the crop coefficient on tth day, t is the number of days since planting, and T is the total crop growth period

Year	Crop coefficient equations
2015–2016	$Kc_t = 14.901\left(\frac{t}{T}\right)^5 - 36.657\left(\frac{t}{T}\right)^4 + 29.07\left(\frac{t}{T}\right)^3 - 10.429\left(\frac{t}{T}\right)^2 + 3.2121\left(\frac{t}{T}\right)^1 + 0.4382$
2016–2017	$Kc_t = -5.1145\left(\frac{t}{T}\right)^5 + 14.507\left(\frac{t}{T}\right)^4 - 17.988\left(\frac{t}{T}\right)^3 + 8.8307\left(\frac{t}{T}\right)^2 + 0.1185\left(\frac{t}{T}\right)^1 + 0.3953$
Average	$Kc_t = -0.457\left(\frac{t}{T}\right)^5 + 1.9252\left(\frac{t}{T}\right)^4 - 5.642\left(\frac{t}{T}\right)^3 + 3.2692\left(\frac{t}{T}\right)^2 + 1.1969\left(\frac{t}{T}\right)^1 + 0.3753$

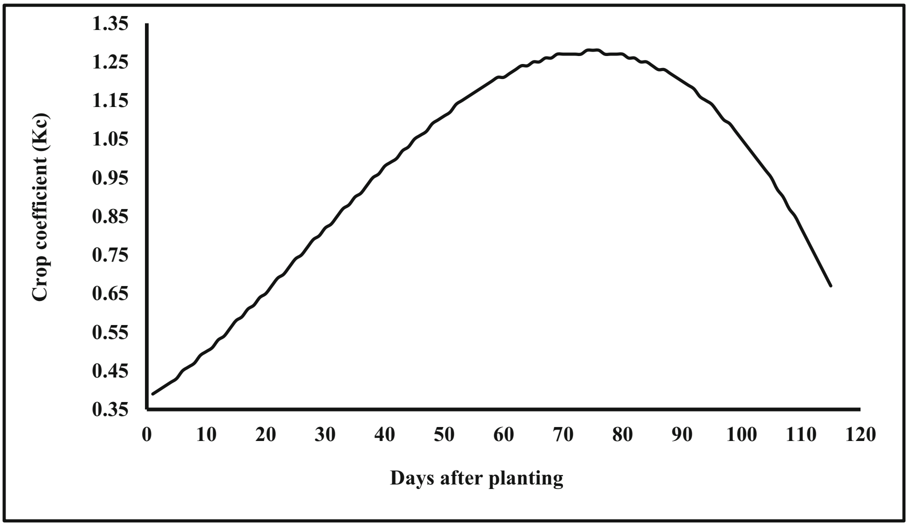

Fig. 5 Crop coefficient curve for potato

The average crop coefficient (Kc) equation can be used to derive the daily Kc values for any period within the potato-growing season and hence potato crop water requirement on a daily basis.

The daily Kc values estimated using the average best fit polynomial equation are presented by the Kc curve in Fig. 5. The crop coefficient curve represents the changes in the potato vegetation and ground cover during plant development and maturation and hence crop water requirement. From the curve, the daily Kc factor can be derived for any period within the potato-growing season. These Kc values can be used for the estimation of crop water requirement of potato on a daily basis during the crop growth period.

Comparison of Crop Coefficients with FAO Crop Coefficients

Kc values developed for potato during this study and those suggested by FAO-56 are represented with respect to different crop growth stages for seasons 2015–2016 and 2016–2017 and an average of the two seasons in Table 3. The generalized stage-wise

Table 3 Values of the crop coefficient (Kc) for each crop growth stage of potato based on FAO-56 methodology (Allen et al. 1998) and soil water balance (SWB)

Growth stage	FAO-Kc	2015–2016	% variation	2016–2017	% variation	Average	% variation
Vegetative	0.50	0.69	+ 38.0	0.51	+ 2.00	0.55	+ 10.0
Tuber development	1.15	1.16	+ 0.87	1.08	− 6.09	1.11	− 3.48
Maturity	0.75	0.88	+ 17.33	1.06	+ 41.33	1.01	+ 34.67
Average	0.80	0.91	+ 14.00	0.88	+ 0.10	0.89	+ 11.25

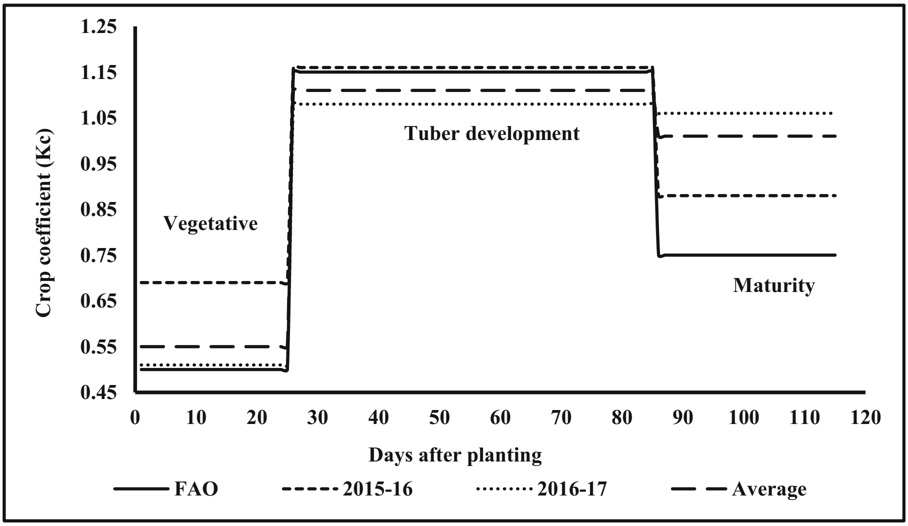

Fig. 6 Generalized crop coefficient curve for potato

crop coefficient curves for potato are presented in Fig. 6. The crop coefficient values derived from the field water balance method during the vegetative stage (1–25 days), tuber development stage (26–85 days), and maturity stages (86–115 days) for potato in the semi-arid region are 0.55, 1.11, and 1.01, respectively. The corresponding values of FAO-56 are 0.50, 1.15, and 0.75, respectively.

The Kc values estimated for the semi-arid region for potato were higher for vegetative stage (10%) and maturity stage (34.67%) but lower (3.48%) at tuber development stage as compared to Kc values given by FAO. This may be due to the conditions of the study area as Kc from FAO was developed for global climatic conditions. In practice, results reported here showed that FAO-Kc could lead to underestimation in irrigation water requirement of potato in semi-arid conditions, as Kc values based on soil water balance are slightly higher than recommended by FAO-Kc. The result is consistent with previous studies that conditions of higher wind speed will have higher values for Kc and vice-versa (Allen et al. 1998). The effect of the difference in aerodynamic properties between the grass reference surface and agricultural crops is not only crop specific but also varies with climatic conditions. This is because the results of these studies are obtained either for semi-arid climate conditions or for potato.

Conclusion

The study evaluated the crop evapotranspiration and applicability of the crop coefficient for potato in a semi-arid region, Maharashtra, India, and compared the developed Kc by the field water balance method with crop coefficients given in FAO-56. The average crop evapotranspiration of potato by the field water balance method for semi-arid conditions was estimated as 245 mm. The estimated Kc values for this region during the vegetative, tuber development, and maturity stages for potato are 0.55, 1.11, and 1.01, respectively. The calculated values are slightly lower than those suggested by FAO-56 for the vegetative and tuber development stages and higher for the maturity stage of potato. The estimated values of crop coefficients for potato are 11.25% higher than those suggested by FAO-56. However, observed variation between values from the FAO-Kc and Kc calculated by the field water balance is not significant. So, these values can be used for irrigation scheduling of potato in the semi-arid region.

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