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Evaluation of Crop Coefficient for Cotton under Akola Region

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ABSTRACT:
The study has been undertaken to determine crop coefficient for cotton. Climatic parameters (Maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, bright sunshine hours, wind speed and rainfall), during the growing period of cotton crop (kharif) were collected from agricultural metrological observatory of Dr. PDKV,Akola. Reference evapotranspiration (ET_0) was determined by using FAO 56 Penman montheith method. Soil moisture storage was then determined using Thornthwaite and Mather equation. From soil moisture storage, change in soil moisture storage was calculated. The change in soil moisture was compared with actual evapotranspiration measured in the field with the help of lysimeter. The crop coefficients were determined by comparing change in soil moisture storage with the actual evapotranspiration. The maximum Kc value is observed during the initial stage which gradually increases till full growth of the cotton crop and then afterwards it gradually decrease. The Kc values for cotton on daily basis varies from 0.01 to 1.78 similarly on weekly basis the lowest Kc value was found during 26^{th} SMW and highest Kc value was observed during 40^{th} SMW. Crop coefficients during various growth stages of cotton crop was minimum 0.25 for square formation to flowering stage and maximum 0.77 for boll setting to ball bursting and boll bursting to first picking stage.

Keywords*: cotton, reference evapotranspiration, Crop coefficient*

1. Introduction

Cotton is the king of cash crops. It is also known as white gold because of its high market value. Cotton is the major crop of Vidherbha region of Maharashtra (India). It is grown mainly in western and central Vidherbha region having annual rainfall ranging from 700 – 1000 mm. In Vidherbha region land under cotton cultivation is about 16 – 17 lakh.ha. this is 60 percent of cotton cultivated in Maharashtra.

In production rating India lags behind in the world because of its low productivity. The average productivity of cotton in India is mainly 213 kg/ha against the global average of 656 kg/ha. (Khatua & Gajaria, 1997). In India only 35.8 % of area under cotton crop is irrigated (Yadav & Kumar, 2002). In Akola district cotton is essentially grown as kharif crop. A fundamental requirement for accurate irrigation scheduling is the determination of actual crop evapotranspiration (ETc) for each day during the growing period. A practical and extensively applied method for estimating ETc is the crop coefficient (Kc) approach (Doorenbos and Pruitt 1977; Jensen and Allen 2000), in which an experimentally developed dimensionless Kc is multiplied by reference evapotranspiration (traditionally grass or alfalfa) to compute ETc. Values of Kc determined for most agricultural crops will typically vary in relation to changes in vegetative growth until effective full cover is attained. After full cover, the Kc will tend to decline, the extent of which is primarily dependent on the particular growth characteristics of the crop (Jensen et al. 1990) and the irrigation management during the late season (Allen et al. 1998).

A crop coefficient curve is the seasonal distribution of Kc, often expressed as a smooth continuous function in time or some other timerelated index, such as thermal units (Jensen et al. 1990). Increased soil evaporation can cause Kc values to deviate significantly from the empirically determined Kc function for several days following irrigation or heavy rainfall. To account for the effects of soil evaporation, the Food and Agriculture Organization (FAO) Irrigation and Drainage paper no. 56 (FAO-56), Crop evapotranspiration (Allen et al. 1998), presented dual crop coefficient procedures to allow computation of more precise estimates of daily ETc for days following irrigation or rain.

For the FAO-56 dual crop coefficient approach, the single Kc is separated into two coefficients, a basal crop coefficient, Kcb (primarily crop transpiration), and a wet soil evaporation coefficient, Ke, to quantify the individual contributions for the two components of ETc. The dual procedures also include a water stress coefficient (Ks) to quantify the effects of soil water stress on ETc. Several recent studies conducted in Texas and Arizona have shown that the FAO-56 dual crop coefficient procedures can provide good estimates of daily ETc for fully-irrigated grain sorghum (Tolk and Howell 2001), cotton (Hunsaker 1999; Howell et al. 2002), and alfalfa (Hunsaker et al. 2003).

The irrigated crop is sown in May and rainfed crop in June – July with the commencement of monsoon. Total land under cotton cultivation in Akola district is about 2, 25,955 ha. Out of which only about 0.60 lakh ha. is under irrigated cotton. The productivity of cotton in Akola district is 90- 100 kg / ha. Reason for this has been reported as lack of irrigation facilities, poor control of insect pest and diseases and lack of mechanization.

2. Material And Methods

This chapter is broadly encompasses the methodology adopted in set of objective in light of basic background data, the location of experimental site & its characteristics features & other relevant components of the study.

2.1. General description of study area

The metrological station Akola located at region of Vidherbha was selected for study which represents the western & central Vidherbha.

2.1.1. Akola

Akola is situated in subtropical zone (Agro climatic zone VII) at 20°40' N latitude and 77° 02' E longitude at an altitude of 307. 415 m above mean sea level. The average annual rainfall is 750 mm.

2.2. Data collection (Meteorological parameter)

Daily metrological data Viz., Maximum temperature (T_{max}), Minimum temperature (T_{min}), bright sunshine hours (BSH), wind speed (Ws), morning relative humidity (RH-I), evening relative humidity (RH-II) and actual crop evapotranspiration (ETc) were collected from agricultural metrological observatory of Akola for cotton growing season. From daily metrological data mean weekly & mean seasonal data were calculated according to their periods. Other parameters like geographic locations viz., latitude, longitude & altitude were also obtained. Actual crop evapotranspiration observations were taken with the lysimeter apparatus. Air temperature data were obtained from maximum and minimum thermometers housed in Stevenson screen dry and wet bulb thermometers located in Stevenson screen are used to provide relative humidity values. Wind speed is measured by anemometer installed at height of 2m above the ground. Bright sunshine hours are measured with the help of sunshine recorder. The recorder is positioned over a concrete piller at a hight of 3m from ground & at places where there is no obstacle to obstruct the sun rays at any time of day during whole day.

2.3. Available water holding capacity of soil (AWC)

Information regarding soil type & soil depth ranges in different tahsils was obtained from district soil survey office Akola. Estimating average available water holding capacity using following relationship.

$$AWC = \frac{(FC-PWP) \times Bd \times D}{100} \quad \text{---------- (1)}$$

Where,
AWC = Available water holding capacity equivalent to the depth of water, (cm).
FC = Field capacity, (%)
PWP = Permanent wilting point, (%)
Bd = Bulk density (gm / cm^3), &
D = Depth of soil column (cm).

2.4. Determination of reference evapotranspiration.

Daily, weekly & seasonal reference evapotranspiration for Akola was calculated using FAO- 56 penman- monteith model expressed as

$$ETo = \frac{0.408\,\Delta\,(Rn-G) + \gamma\,\{900/(T+273)\}\,u_2\,(e_s-e_a)}{\Delta + \gamma\,(1+0.34\,u_2)} \quad \text{---------- (2)}$$

Where,
ETo = Reference evapotranspiration (mm day^{-1})
Rn = Net radiation at crop surface (MJ m^{-2} day^{-1})
G = Soil heat flux density (MJ m^{-2} day^{-1})
T = Main daily air temperature at 2m height (° C)
u_2 = Wind speed at 2m height (ms^{-1})
e_s = Saturation vapour pressure (Kpa)
e_a = Actual vapor pressure (Kpa)
(e_s-e_a) = Saturation vapor pressure deficient (Kpa)
Δ = Slope of vapour pressure curve (Kpa°C^{-1})
γ = Psychometric content (Kpa°C^{-1})

2.5. Soil moisture storage (STOR)

As a soil dries due to evapotranspiration taking place from its surface, the rate of evapotranspiration also decreases according to Throntwaite & Mather (1957) the release of moisture is an exponential function. Considering the above principle following formula was used for computing the soil moisture storage at the end of each week.

$$STOR = AWC.e^{\frac{ACC\ (P-ETo)}{AWC}} \quad \text{---------- (3)}$$

Where
STOR = Actual storage of soil moisture, mm.
AWC = Moisture storage capacity of soil, mm.
ACC (P-ETo) = Accumulated values of (P-ETo), mm
P = Weekly rainfall, mm
When soil moisture remains a field capacity level for two weeks, the change of actual storage from week to week (Δ STOR) will be zero when Δ STOR reaches a value less than the field capacity, then Δ STOR will be calculated as the subtraction of STOR, of present week from STOR of the previous week. The Δ STOR can be negative, which implies extraction of water from the soil to be used for evapotranspiration. The Δ STOR can be positive which implies infiltration of water in the soil & it is addition to the soil moisture storage.

2.6. Determination of crop coefficient

The computed daily, weekly & seasonal ETo values are used to compute crop coefficient by using Throntwaite & Mather (1957) equation.

$$Kc = \frac{ETc}{\Delta\ STOR} \quad \text{---------- (4)}$$

Where,
Kc = Crop coefficient
ETc = Actual crop evapotranspiration, (mm day $^{-1}$)
Δ STOR = Change in a soil moisture storage, (mm day $^{-1}$)
For determing the crop coefficients for cotton crop, the cotton variety AKA-7 was grown on the field of dry land agriculture scheme, Dr. PDKV, Akola. The crop was grown under dryland condition & lysimeter is installed in this field. Hence by using above equation the crop coefficients on weekly & growth stages basis were evaluated for cotton under dryland condition.

3. Results And Discussion

The present study is an attempt to develop & evaluate crop coefficient for cotton under the prevailing climatological conditions of Akola & for this study, the metrological data in respect of actual crop evapotranspiration, Maximum temperature (T_{max}), Minimum temperature (T_{min}), bright sunshine hours (BSH), wind speed (Ws), Maximum relative humidity (RH-I), Minimum relative humidity (RH-II) for the growth period of cotton during the kharif season were collected.
The soil moisture balance was calculated using the procedure given by Throntwaite & Mather (1957). The change in soil moisture storage was compared with that of actual evapotranspiration (ETc) obtained through the lysimeter reading. The weighing type lysimeter was installed in the cotton field crop with variety AKA-7 Tr. The crop coefficients were computed on daily basis, weekly basis and for different growth stages of cotton.

3.1. Metrological data

The weekly metrological data in respect of Maximum & Minimum temperature, bright sunshine hours, wind speed, Maximum & Minimum relative humidity & rainfall were collected from the metrological department of Dr. Panjabrao Deshmukh Krushi Vidypeeth Akola.

- **Air Temperature**
  Maximum temperature ranges between 27 ° C to 34.9° C during the standard metrological week of 52nd &41st respectively. Also the minimum temperature ranges between 8.3 ° C to 24.5° C during the SMW of 52nd & 28th respectively for the growth period of cotton during the kharif season.
- **Relative humidity**
  Maximum relative humidity (RH-I) varies from 68.7 % to 93.2 % during the SMW of 50th & 36th respectively. It is also observed that the minimum relative humidity (RH-II) varies from 19.4 % to 83.4 % during the growth period of cotton during kharif season. The mean relative humidity (RHm) observed in the range of 45.2 % to 87.4 % during the growth of crop.
- **Bright sunshine hours**
  Bright sunshine hour varies from 0.8 hrs. to 9.3 hrs. in 26th SMW & 47th SMW respectively.
- **Wind speed**
  Maximum wind speed was found 13.9 kmph in 27th SMW & minimum wind speed was found in 0.7th kmph in 46th SMW during the kharif season.

3.2. Depletion in soil moisture storage

- **Available water holding capacity**
  Available water holding capacity was found to be 240.7 mm.
- **Reference evapotranspiration (ETo)**
  It is seen from the data that reference evapotranspiration for cotton was found maximum during 15th July (5.95 mm) & minimum reference evapotranspiration was found during 15th October (1.59 mm).
- **Soil moisture storage**
  It is seen from the data that the soil moisture storage varies from minimum of 215.13 mm to maximum of 768.89 mm. The variation in storage is due to evapotranspiration & rainfall.
- **Change in soil moisture storage**
  It is seen from the data that the negative values shown the depletion in storage due to evapotranspiration. While the positive value indicate the gain in storage due to rainfall.

3.3. Actual evapotranspiration (ETc)

Actual evapotranspiration varies from 0.2 to 10.8 mm. The minimum actual evapotranspiration was observed in the month of December while Maximum evapotranspiration was observed during the month of October. This may be due to the foliage of the crop along with the climatic condition.

3.4. Crop coefficients (Kc)

The crop coefficients were computed on daily basis, weekly basis & for different growth stages of cotton.

- **Daily crop coefficient**
  The daily Kc values for cotton vary from 0.01 to 1.78.
- **Weekly crop coefficient**
  From table 1 it is seen that the week wise values of Kc are varies from 0.08 to 0.89 during growth of the crop. The minimum Kc values are observed during initial stage, that gradually increases till full growth of the cotton crop then afterwards it gradually decreases.

SMW	Kc	SMW	Kc
26	0.08	40	0.89
27	0.35	41	0.74
28	0.36	42	0.63
29	0.38	43	0.76
30	0.25	44	0.57
31	0.09	45	0.53
32	0.12	46	0.48
33	0.16	47	0.43
34	0.20	48	0.27
35	0.20	49	0.13
36	0.39	50	0.14
37	0.52	51	0.25
38	0.44	52	0.27
39	0.54		

Table 1: Weekly crop coefficients estimated for Akola

- **Crop coefficients during various growth stages**
  According to phonological stages of crops, six stages were defined during the growth of crop viz. seeding to square formation, square formation to flowering, flowering to boll setting, boll setting to boll bursting, boll bursting to first picking & first picking to last picking.

From table 2 it is seen that crop coefficients during various growth stages of cotton crop was minimum 0.25 for square formation to flowering stage & maximum 0.77 for boll setting to boll bursting & boll bursting first picking stage.

Sr.No.	Phonological stages of crop	Crop coefficients
1	Seeding to square formation [26 (4) to 33 (2) SMW]	**0.34**
2	Square formation to flowering [33 (5) to 36 (4) SMW]	**0.25**
3	Flowering to boll setting [36 (3) to 40 (1)SMW]	**0.47**
4	Boll setting to boll bursting [40 (6) to 40 (1) SMW]	**0.77**
5	Boll bursting to first picking [43 (5) SMW]	**0.77**
6	First picking to last picking [43 (2) to 48 (6) SMW]	**0.48**

Table 2: Seasonal crop coefficients estimated for Akola

Note: Figures in parenthesis indicates the number of days in that standard metrological week as traction of weeks.

4. Conclusion

- For Akola, daily crop coefficients were obtained in the range of 0.01 to 1.78 during the growth of dry land cotton crop.
- For Akola weekly Crop coefficients were found in the range of 0.08 to 0.89 minimum 0.08 during 26th SMW & maximum 0.89 during 40th SMW.
- For Akola Crop coefficients were obtained according to phonological stages of cotton crops such as seeding to square formation 0.34, square formation to flowering 0.25, flowering to boll setting 0.47, boll setting to boll bursting 0.77, boll bursting to first picking 0.77& first picking to last picking 0.48.

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