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Assessment of crop coefficient variations with leaf area index for cotton

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Abstract
The experiment was carried out to access the corelation between crop coefficient and leaf area index of cotton crop at Department of Irrigation and Drainage Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The meteorological data were obtained from the automatic weather station installed at the site. The crop coefficient values and leaf area index for cotton were monitored at 30 days interval. The results showed that the crop coefficient values increased steadily from 0.59 at 30 DAS when the LAI was at its lowest about 0.06, to a peak of 1.16 at 120 DAS matching the highest LAI of 1.02. There was a strong correlation found between Kc and LAI, with an R-squared value of 0.89, highlighting that as the cotton leaf area expands, the crop's water needs rise accordingly. The results highlights the importance of stage-specific Kc and LAI values for accurate irrigation scheduling and for improving water use efficiency in cotton cultivation.

Keywords: Cotton, crop coefficient, leaf area index, lysimeter

1. Introduction
Cotton is a soft, fluffy staple fibre that grows in a protective case, known as a boll, around the seeds of cotton plants belonging to the genus *Gossypium* in the mallow family *Malvaceae*. Cotton is a crucial cash crop in India, integral to both the economy and agriculture. Cotton is chiefly a tropical and sub-tropical crop. It requires uniformly high temperatures (21°C to 30°C) and grows well within the average annual rainfall range of 50-100 cm. It is a Kharif crop which requires 6 to 8 months to mature. A high amount of rainfall in the beginning (helps in the sprouting of seeds) and sunny and dry weather at ripening time (moist weather during ripening leads to pest attacks) are beneficial for a good crop.
Evaporation from soil and plant surfaces occurs due to atmospheric demand, which is mainly influenced by meteorological factors. Meanwhile, the availability of water at the evaporation site is determined by soil and plant characteristics. Therefore, evapotranspiration is influenced by a combination of meteorological, biological, and soil factors. Evapotranspiration (ET) is the total water loss from plants and soils, influenced by factors like water potential, humidity, soil availability, atmospheric moisture, and temperatures. Evapotranspiration can be measured using a lysimeter or a water balance approach. A lysimeter isolates soil from its surroundings, allowing for accurate measurements. Proper construction, installation, and operation are necessary for reliable measurements.
Lysimeters can be used to calculate crop coefficients (Kc), which are crucial for estimating crop evapotranspiration (ETc) from reference evapotranspiration (ETo). Crop coefficients (Kc) are essential for determining cotton's irrigation water requirements. They can be calculated daily and averaged monthly using lysimeters and reference evapotranspiration rates. Adopting the correct amount of water and applying it at the right time is crucial for scheduling irrigations and achieving optimal crop production (Mehta and Pandey, 2016). The Leaf Area Index (LAI) is characterized as the mean total leaf area (considering only one side) for every unit of ground surface area. This index is obtained through the collection of all vibrant, healthy leaves from plants that are indicative of the buffer zone. The measurement is facilitated by a leaf area meter. The experiment was conducted to determine the crop coefficient values and to access the relation between crop coefficient (Kc) and Leaf Area Index (LAI).

2. Material and Methods

2.1 Location of the experimental site

The experiment was carried out at Department of Irrigation and Drainage Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the period of 1st July, 2024 to 15th December, 2024. Akola is situated at 307.4 m above mean sea level at 20° 42' N latitude and 77° 02' E longitudes. The climate of Akola is semi-arid and characterized by three distinct seasons *viz*., hot, and dry summer from March to May, warm humid and rainy season from June to October and mild cold winter from November to February.

2.2 Weather Data

In order to measure evapotranspiration precisely, a pair of weighing lysimeters were utilized for the cotton crop, enabling the exact calculation of the crop coefficient. The weather data was collected from automatic weather station installed at the experimental site. Daily crop evapotranspiration and reference evapotranspiration were monitored to determine the Kc values.

Table 1: Experimental details for cotton crop

Sr. No.	Particulars	Specifications
1	Crop	Cotton
2	Scientific Name	*Gossypium arboreum*
3	Family	*Malvaceae*
4	Variety	Ajeet-199 BT
5	Season	Kharif
6	Seed Rate (Kg ha-1)	2-2.5 Kg/ha
7	Crop Spacing (cm)	90x60
8	Crop Period (Days)	168
9	Date of sowing	1stJuly, 2024
10	Date of harvesting	15th December, 2024
11	Crop Yield	13.24q/ha

2.3 Growth studies

The plant growth observations like height of plant, number of leaves, number of flowers, number of branches, number of bolls and Leaf Area Index were recorded at 30, 60, 90,120,150 DAS and at harvest of cotton crop.

2.4 Calculation of crop coefficient (Kc)

In this experiment, crop coefficient was determined with ratio of ETc, as derived from the soil water balance equation using lysimeter and ETo calculated using the FAO Penman-Monteith equation. The equation for soil water balance method is as follows;

$$ETc = R + I - Dp \pm \Delta S$$

Where,

ET_c	=	Crop Evapotranspiration, mm;
R	=	Rainfall, mm;
I	=	Irrigation water applied, mm;
Dp	=	Deep percolation loss i.e. drain water from lysimeter, mm;
ΔS	=	Change in water storage inside the lysimeter, mm.

Crop Coefficient provides an indication of the crop's water usage relative to a standardized reference condition. The calculation of the crop coefficient (Kc) is based on the following equation,

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

Where, ETc is the actual crop evapotranspiration (mm day^{-1}) ETo is the reference crop evapotranspiration (mm day^{-1}).

2.5 Leaf area index (LAI)

Leaf Area was determined at 30, 60, 90, 120, 150 DAS and at harvest. Three leaves samples of random observation plants were taken as big, medium, and small to measure average the leaf area. The total leaf area of a plant was calculated by multiplying average leaf area by average number of leaves per plant for respective growth stage. The Leaf Area Index was determined using following formula,

$$LAI = \frac{\text{Total LA}}{\text{Ground Area}}$$

2.6 Yield parameters

Yield for plants inside lysimeter were taken. Harvesting was done at 168 DAS. Total number of bolls picked per plant for each picking were counted from selected plants and the average was taken.

3. Results and Discussion

3.1 Growth and Yield Observations

Table 3.1 shows the detail growth observations taken of cotton crop throughout the growth period until harvest.

Table 1: Average plant growth parameters and yield of cotton crop

Parameters	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest
Height (cm)	19.95	37.66	63.46	84.41	101.87	102.18
Branches	0.00	10.42	14.98	16.94	19.04	18.74
Leaves	8.74	29.23	49.13	58.78	37.91	26.09
Flowers	0.00	0.25	2.28	16.35	12.68	7.82
Bolls	0.00	2.08	7.12	12.85	14.13	13.47
Yield	13.24q/ha					

From Table 3.1 it is observed that the plant height was maximum at harvest i.e.102.18 cm while the maximum rise was during the period of 61-90 DAS. Similarly, the number of branches were highest at 150 DAS i.e. 19.04 and maximum rise observed during period of 61-90 DAS. The number of leaves were maximum at 120 DAS i.e. 58.78. It is observed the there is an increasing trend in number of leaves till 120 DAS and then number of leaves starts decreasing. The number of flowers and bolls were maximum at 120 DAS and 150 DAS respectively.

The crop yield recorded from the both lysimeters and field plot area. The average yield of cotton was found to be 13.24q ha^{-1}.

3.2 Crop Coefficient (Kc) of cotton (monthly)

The monthly Kc calculated using ETc, and the ETo calculated using the FAO Penman-Monteith equation is given below in the Table 3.2.

Table 2: Crop Coefficient (Kc) of cotton (monthly)

DAS	Average Kc
0-30	0.59
31-60	0.86
61-90	1.11
91-120	1.16
121-150	0.96
151-168	0.68

The Kc obtained was maximum during period of 91-120 DAS i.e. 1.16.

3.3 Leaf Area Index of Cotton crop

The monthly leaf area obtained with the help of Leaf Area Meter is given in Table 3.3

Table 3: Leaf Area of Cotton

DAS	Big	Medium	Small	Average
30	38.36	14.72	5.71	19.59
60	101.51	60.17	16.87	59.69
90	101.19	51.16	11.38	54.57
120	70.04	50.43	19.97	46.81
150	69.44	38.82	14.71	40.99
168	75.39	28.55	17.91	40.61

This Leaf Area obtained is then multiplied by the average number of leaves. Then, the average of total leaf area obtained is divided by total number of samples of each size. Now, put the obtained leaf area into formula and then the obtained Leaf Area Index is given in Table 3.4.

Table 4: Leaf Area Index of Cotton crop

DAS	LAI
0-30	0.06
31-60	0.64
61-90	0.99
91-120	1.02
121-150	0.58
151-168	0.48

From, Table 3.4 it was observed that the LAI is minimum in period of 0-30 DAS i.e. 0.06 and the maximum LAI was in period of 90-120 DAS i.e. 1.02. The LAI increases in the period 0-120 DAS and then starts decreasing.

3.4 Comparison between Monthly Kc and LAI

The following Table 3.5 shows the monthly average LAI and Kc obtained for cotton.

Table 5: Monthly average LAI and Kc obtained for cotton

DAS	LAI	Average Kc
0-30	0.06	0.59
31-60	0.64	0.86
61-90	0.99	1.11
91-120	1.02	1.16
121-150	0.58	0.96
151-168	0.48	0.68

The crop coefficient (Kc) value is continually increasing at this stage as a result of an increase in crop evapotranspiration, which is caused by an increase in the leaf area of the transpiring leaf. Leaf Area Index of 1.02 was highest at 90-120 DAS and at average Kc of 1.16.

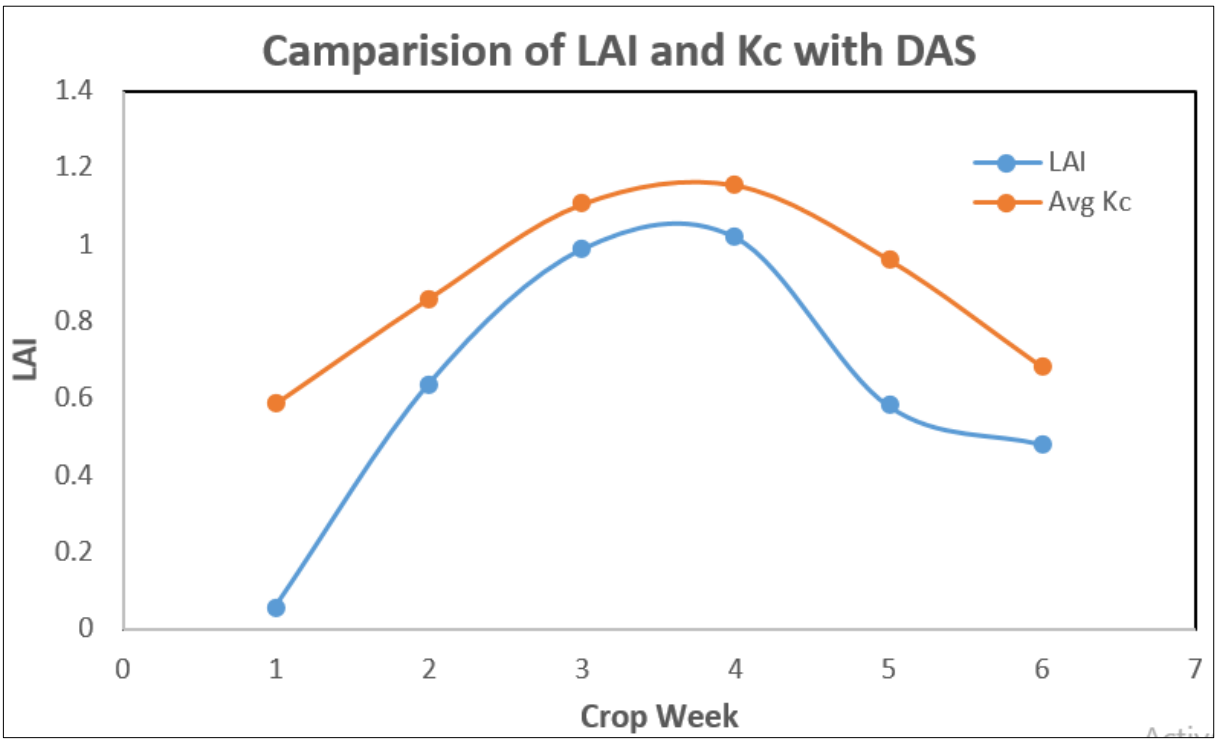

Fig 1: Comparison between Monthly Crop Coefficient and Leaf Area Index

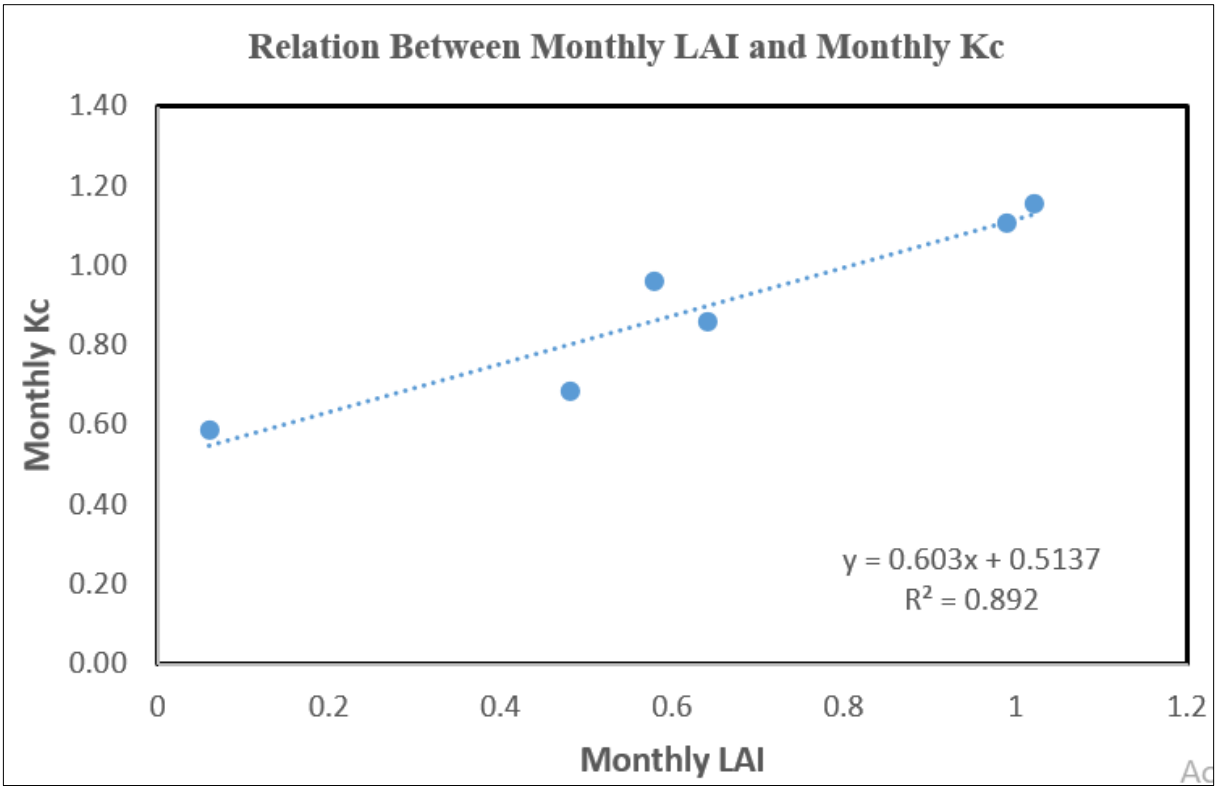

Fig 2: Correlation between monthly Kc and LAI for cotton

Crop Coefficient (Kc) is an important variable used to estimate crop evapotranspiration and its relationship for cotton with Leaf Area Index (LAI) as function of phenological growth stage emphasises the importance of canopy development in water relation processes. At low LAI, evaporation from bare soil dominates evapotranspiration (ET). As the crop matures, however, LAI increases dramatically improves canopy cover and changes ET composition to mostly transpiration (transpiration contributes more than 90% of ET in 90-120 DAS). The increase in Kc values (1.16 average during 90-120 DAS) with a peak on LAI 1.02 represents this transition. Table 3.5 and Figures 3.1 & Figure 3.2 together further demonstrate this general trend from mid-season Kc maxima to lower late season values as well of LAI. The following equation obtained with comparison of monthly Kc and LAI which shows the significant relation in Kc during the entire growing period due to increase in canopy cover and water requirement of cotton. The R^2 value obtained was 0.892 which shows that, the relation is significant.

$$y = 0.603x + 0.5137$$

$$R^2 = 0.892$$

4. Summary and Conclusion

The monthly Leaf Area Index (LAI) was measured to evaluate canopy development and its impact on water consumption. The results showed that the crop coefficient (Kc) values increased steadily from 0.59 at 30 days after sowing (DAS), when the LAI was at its lowest 0.06, to a peak of 1.16 at 120 DAS, matching the highest LAI of 1.02. There was a strong correlation between Kc and LAI, with an R-squared value of 0.89, highlighting that as the cotton leaf area expands, the crop's water needs rise accordingly. This information is vital for accurate irrigation scheduling.

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