Phase VIII
(Part II)

Status Report

on

Crop Kc, Water Requirement of Kharif Cotton and Pigeon pea

for

Project on;

"Determination of Crop Coefficients for Major Crops by Lysimetric Studies"

at

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING,
DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH
AKOLA- 444104 (MAHARASHTRA)

Phase VIII (Part II)
Status Report on Crop Kc, Water Requirement of Kharif Cotton and pigeon pea

"Determination of crop coefficients for major crops by Lysimetric studies"

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

Title of the Project: Determination of crop coefficients for major crops by Lysimetric studies" at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

Location: **Department of Irrigation and Drainage Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola.**

Duration: **Three years.**

Total outlay: **Rs. 38.38 lakhs.**

Investigators:

Principal Investigator	:	Dr. M.M. Deshmukh, Head, Department of Irrigation and Drainage Engineering Dr. PDKV, Akola
Co-Principal Investigator	:	Dr. A.N. Mankar, Assistant Professor, Department of Irrigation and Drainage Engineering Dr. PDKV, Akola.
Coordinator for the project for three universities **(MPKV, Rahuri; Dr PDKV, Akola and VNMKV, Parbhani)**	:	Dr. S.D. Gorantiwar, PI CAAST-CSAWM and Director of Research, MPKV, Rahuri.

INTRODUCTION:

The Project is being executed at Department of Irrigation and Drainage Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. This project is undertaken for determination of crop coefficients of cotton and pigeon pea during Kharif season. As per schedule of reporting requirements, following are the details regarding the status of Kharif cotton and pigeon pea.

DETAILS OF WORK:

Cultivation of Kharif cotton and pigeon pea:

The cultivation of Kharif cotton and pigeon pea was started in the month of June 2023; the sowing of cotton (Variety- PDKV JKAL-116 BG) was done on 28th June 2023 and harvested on 12th December 2023. The sowing of pigeon pea (Variety- PDKV-Ashlesha) was done on 30th June 2023 and harvested on 28th December 2023.

Photographs taken during the cultivation of Cotton




Sowing of Cotton on 28th June 2023, in presence of Dr. Munjaji Bhosle, (Hydrologist, NDKSP, PoCRA, Mumbai), Er. Sagar Ghaymukte (Asst. Hydrologist, NDKSP, PoCRA, Mumbai) and PI, Co-PIs of the project


Germination of Cotton

Cotton plants inside and around lysimeter 30 days after sowing

Cotton plants inside and around lysimeter 60 days after sowing

Cotton plants inside and around lysimeter 90 days after sowing

Cotton plants inside and around lysimeter 120 days after sowing

Cotton plants inside and around lysimeter at Harvest

Photographs taken during the cultivation of pigeon pea

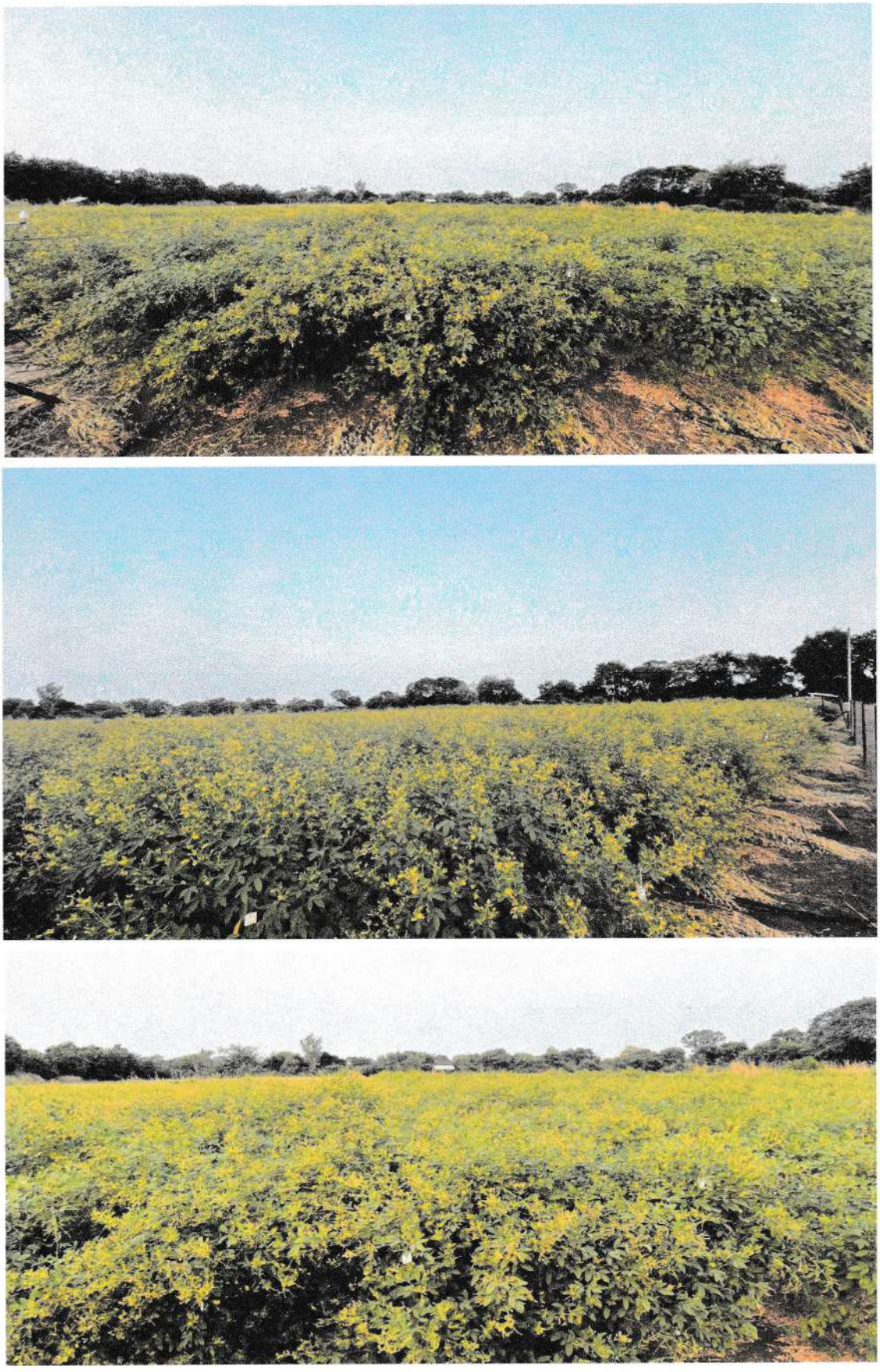
Sowing of pigeon pea on 30th June 2023

Germination of pigeon pea

Pigeon pea plants inside and around lysimeter 30 days after sowing

Pigeon pea plants inside and around lysimeter 60 days after sowing

Pigeon pea plants inside and around lysimeter 90 days after sowing



Pigeon pea plants inside and around lysimeter 120 days after sowing

Pigeon pea plants inside and around lysimeter 150 days after sowing

Pigeon pea plants inside and around lysimeter at Harvest

Plant Protection Measures

For healthy and disease free plants, the spraying of insecticides, herbicides and pesticides were done at different stages of crop according to its requirement. Following are the details of insecticides, fungicides and pesticides applied during the growth period for healthy growth of cotton and pigeon.

Table 1. Plant protection measures in cotton

Sr. No.	Date of Application	Weedicide/ Insecticide/ Fungicide/ Pesticide	Quantity
1	29-06-2023	Pendimethelene 38.7 % CS	40 ml/10 lit. water
1	10-07-2023	Chloropyriphos 20 EC	30 ml/ 10 lit. water
2	15-07-2023	Benfurocarb 3% G (IIL Tadakhi)	Soil Application
4	04-08-2023	Dimethoate 30% EC + 100 gm 19:19:19 + Gibberellic Acid (10 ppm)	20 ml/ 10 lit. water
5	08-08-2023	Pyrithiobac Sodium 6% + Quizalofop ethyl 4% MEC (Hitweed Max)	25 ml / 10 lit. water
6	29-08-2023	Profenophos 50% EC + 00:52:34	30 ml + 75 gm / 10 lit. water
7	30-09-2023	Indoxacarb 14.5 SC	10 ml / 10 lit. water
8	07-10-2023	Fipronil 15% + Flonicamid 15% (Apache)	06 gm / 10 lit. water
9	17-10-2023	Amister Top (Azoxystrabin 18.2% + Difenoconazole 11.4% SC)	10 ml / 10 lit. water
10	29-10-2023	SAAF (Carbendazim 12% + Mancozeb 63% WP)	25 gm / 10 lit. water

Table 2. Plant protection measures in pigeon pea

Sr. No.	Date of Application	Weedicide/ Insecticide/ Fungicide/ Pesticide	Quantity/10 lit. water
1	01-07-2023	Pendimethelene 38.7 % EC	40 ml/10 lit. water
2	07-07-2023	Imazethapyr 10% SL	20 ml/ 10 lit. water
3	07-07-2023	Trichoderma Powder	Soil Application
4	15-07-2023	Imazamox 35% + Imazethapyra 35% Wg (Odessy)	2 gm / 10 lit. water
5	04-10-2023	Fipronil 15% + Flonicamid 15% (Apache)	06 gm / 10 lit. water
6	05-10-2023	Emamectin Benzoate 5 SG	2.5 gm / 20 lit. water
7	09-12-2023	Coragen – Chlorantraniliprade 18.5% W/W)	8 ml / 20 lit. water

Plant Growth and Yield Observations

During the process of planting and growing the crops, there were several observations made regarding growth of crops. Observations were made from inside and outside the lysimeter at different intervals i.e., 30 days after sowing, 60 days after sowing, 90 days after sowing, 120 days after sowing, 150 days after sowing and at harvest for cotton and pigeon pea. The overall observations taken were height of crop, number of branches, number of leaves, number of flowers, and number of bolls/pods and yield observations were taken from lysimeters as well as by selecting random plants from the plot and by selecting the random plots of size 2 m x 2 m. Following table illustrates overall details about the growth parameters of cotton and pigeon pea.

Table 3. Average plant growth parameters of Cotton from Lysimeter 1 and 2

Parameters	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest
Height (cm)	18.50	56.72	106.58	129.62	134.91	135.80
Branches	0.00	6.135	20.47	24.97	27.61	28.66
Leaves	8.34	53.94	124.27	137.87	88.99	53.90
Flowers	0.00	11.84	37.92	32.21	0.00	0.00
Bolls	0.00	0.00	14.07	28.48	45.65	31.33
Yield	14.56 q/ha					

Table 4. Average plant growth parameters pigeon pea from Lysimeter 1 and 2

Parameters	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest
Height (cm)	24.17	100.43	158.06	198.69	219.75	220.98
Branches	0.00	8.00	21.31	27.52	36.45	37.39
Leaves	20.26	229.88	366.82	460.14	644.88	354.65
Flowers	0.00	0.00	0.00	44.49	45.58	26.13
Pods	0.00	0.00	0.00	15.83	145.77	172.87
Yield	23.45 q/ha					

Daily observations of crop evapotranspiration and other parameters were taken from each lysimeter for cotton and pigeon pea. Two lysimeters were used for each crop to get daily crop evapotranspiration observations. After harvesting crops, crop coefficient values and water requirement for cotton and pigeon pea was determined.

CROP COEFFICIENTS (KC) FOR COTTON AND PIGEON PEA

The weekly values of crop coefficients were computed as the ratio of weekly crop evapotranspiration and weekly reference evapotranspiration. The meteorological data like maximum temperature, minimum temperature, rainfall, wind speed, relative humidity and

bright sunshine hours were taken from Automatic Weather Station installed at the experimental site. Weekly crop evapotranspiration was obtained from lysimeters by growing crop in lysimeters. Penmen Monteith method was used to estimate the reference crop evapotranspiration. The ratio of crop evapotranspiration and reference crop evapotranspiration is called as crop coefficient.

Penman Monteith Method

The FAO Penman Monteith Method has been recommended as the sole standard method for calculating reference crop evapotranspiration. It is a method with strong likelihood of correctly predicting ETr in a wide range of locations (Allen et. al., 1998). By defining the reference crop as a hypothetical crop with assumed height of 0.12 m having a surface resistance of 70 s m^{-1} and an albedo of 0.23, closely resembling the evaporation of an extensive surface of green grass of uniform height, actively growing and adequately watered the FAO Penman Monteith Method was developed as presented by following equation.

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

Where,

ET_o = Reference evapotranspiration (mm day^{-1})

Δ = Slope of saturation vapour pressure curve (kPa $^oC^{-1}$)

T = Mean air temperature (^oC)

γ = Psychrometric constant (kPa $^oC^{-1}$)

R_n = Net radiation at the crop surface (MJ m^{-2} day^{-1})

G = Soil heat flux density (MJ m^{-2} day^{-1})

u_2 = Wind speed at 2.0 m height (ms^{-1})

e_a = Actual vapour pressure (kPa)

e_s = Saturation vapour pressure (kPa)

e_s- e_a = Saturation vapour pressure deficit (kPa)

Crop Coefficient (Kc) Values for Cotton:

Table 5 represents the values of weekly crop coefficient measured using lysimeter for cotton.

Table 5. Weekly Crop Coefficient (Kc) Values for Cotton

Crop Week	Weekly Kc by Lysimeter 1	Weekly Kc by Lysimeter 2	Average Weekly Kc Values	Crop Growth Stages	Stagewise Kc Values
1	0.54	0.58	0.56	22 days -Initial Stage	0.60
2	0.55	0.64	0.59		
3	0.59	0.7	0.64		
4	0.65	0.77	0.71	38 days- Development stage	0.89
5	0.72	0.85	0.78		
6	0.8	0.92	0.86		
7	0.88	0.99	0.94		
8	0.96	1.06	1.01		
9	1.03	1.11	1.07	59 days- Mid season stage	1.18
10	1.1	1.16	1.13		
11	1.14	1.2	1.17		
12	1.18	1.23	1.2		
13	1.19	1.25	1.22		
14	1.19	1.25	1.22		
15	1.18	1.24	1.21		
16	1.14	1.21	1.18		
17	1.1	1.18	1.14		
18	1.04	1.13	1.08	48 days - End stage	0.87
19	0.97	1.07	1.02		
20	0.89	0.99	0.94		
21	0.82	0.91	0.86		
22	0.75	0.82	0.78		
23	0.69	0.73	0.71		
24	0.64	0.63	0.63		

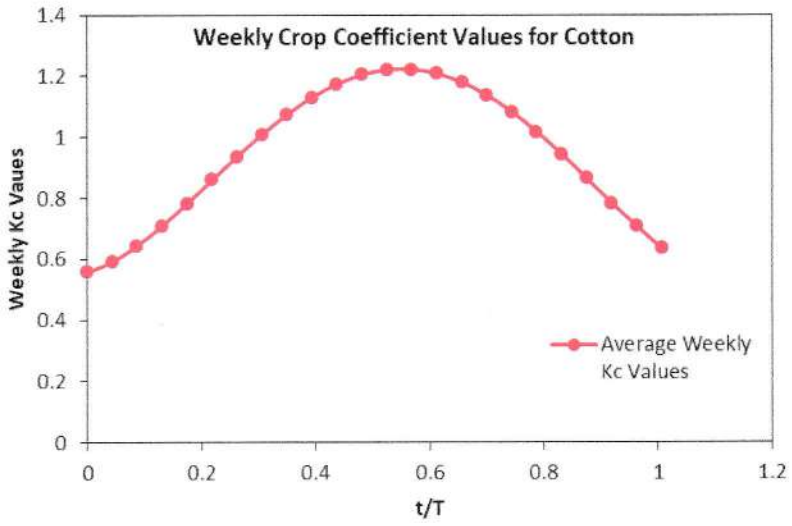


Figure 1. Weekly crop coefficient values for cotton

The obtained weekly Kc values for cotton were plotted against crop weeks and are represented in figure 1. Equation No. 1 and 2 given below are obtained from weekly K_c values for cotton against 't/T' to derive daily K_c values for lysimeter 1 and 2 respectively.

$$Kc_t = 9.5436\left(\frac{t}{T}\right)^4 - 20.625\left(\frac{t}{T}\right)^3 + 11.829\left(\frac{t}{T}\right)^2 + 0.6656\left(\frac{t}{T}\right) + 0.5436 \quad \text{.....(1)}$$

$$Kc_t = 3.5727\left(\frac{t}{T}\right)^4 - 8.6178\left(\frac{t}{T}\right)^3 + 4.0106\left(\frac{t}{T}\right)^2 + 1.0766\left(\frac{t}{T}\right) + 0.5506 \quad \text{.....(2)}$$

Crop Coefficient (Kc) Values for Pigeon Pea:

Table 6 represents the values of weekly crop coefficient measured using lysimeter for pigeon pea.

Table 6. Weekly Crop Coefficient (Kc) Values for Pigeon Pea

Crop Week	Weekly Kc by Lysimeter 1	Weekly Kc by Lysimeter 2	Average Weekly Kc Values	Crop Growth Stages	Stagewise Kc Values
1	0.55	0.51	0.53	24 -Initial Stage	0.55
2	0.56	0.52	0.54		
3	0.58	0.55	0.57		
4	0.63	0.59	0.61	52 days - development stage	0.84
5	0.68	0.65	0.67		
6	0.74	0.72	0.73		
7	0.81	0.79	0.8		
8	0.87	0.86	0.87		
9	0.94	0.93	0.93		
10	1.00	0.99	1.00		
11	1.05	1.05	1.05	60 days - Mid season stage	1.12
12	1.09	1.1	1.09		
13	1.13	1.13	1.13		
14	1.15	1.16	1.15		
15	1.16	1.17	1.16		
16	1.15	1.17	1.16		
17	1.14	1.15	1.15		
18	1.11	1.13	1.12		
19	1.07	1.09	1.08		
20	1.02	1.03	1.03	46 days - End stage	0.81
21	0.96	0.97	0.97		
22	0.9	0.91	0.9		
23	0.83	0.83	0.83		
24	0.76	0.76	0.76		
25	0.69	0.68	0.68		
26	0.62	0.61	0.61		

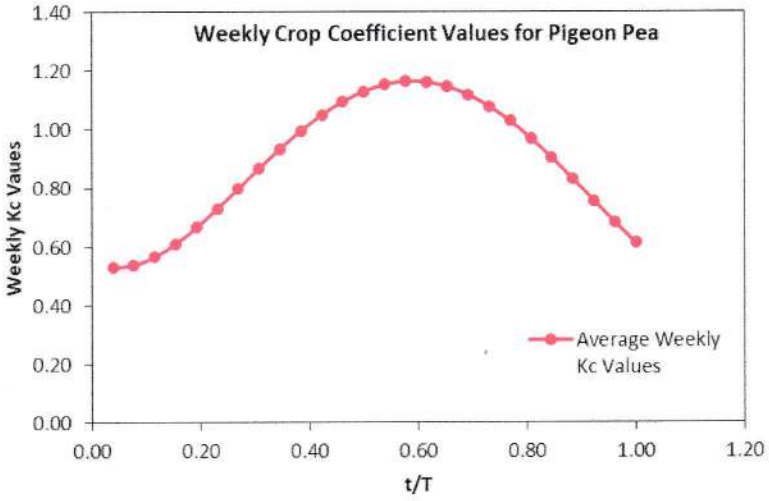


Figure 2. Weekly crop coefficient values for pigeon pea

Equation No. 1 and 2 given below are obtained from weekly K_c values for pigeon pea against 't/T' to derive daily K_c values for lysimeter 1 and 2 respectively.

$$Kc_t = 6.844\left(\frac{t}{T}\right)^4 - 15.864\left(\frac{t}{T}\right)^3 + 9.5597\left(\frac{t}{T}\right)^2 + 0.5033\left(\frac{t}{T}\right) + 0.5535 \quad \text{.....(1)}$$

$$Kc_t = 7.3416\left(\frac{t}{T}\right)^4 - 17.105\left(\frac{t}{T}\right)^3 + 10.424\left(\frac{t}{T}\right)^2 - 0.6022\left(\frac{t}{T}\right) + 0.5202 \quad \text{.....(2)}$$

The computed stage wise Kc values for cotton during initial (22 Days), development (38 days), mid (59 Days) and end stage (48 Days) were 0.60, 0.89, 1.18 and 0.87 respectively. However, stage wise Kc values for pigeon pea during initial (24 Days), development (52 days), mid (60 Days) and end stage (46 Days) were 0.55, 0.84, 1.12 and 0.81 in respective stages. The maximum values of crop

coefficients were estimated during the mid-stage mainly because of higher canopy and higher water requirement during the flowering stage.

Comparison between Lysimetric and FAO Modified Kc values for Cotton:

Lysimetric Kc values were found as 0.60, 0.89, 1.18 and 0.87 for initial, development, midseason and end stages of cotton respectively. Whereas the FAO modified Kc values are 0.56, 0.96, 1.12 and 0.83 for initial, development, mid-season and late season stage. Table 7 shows the comparison between lysimetric and FAO modified Kc values for cotton.

Table 7. Comparison between lysimetric and FAO modified Kc values for Cotton

Growth Stages	1st lysimeter Kc	2nd lysimeter Kc	Average Lysimetric Kc	FAO Kc	FAO modified Kc
Initial season stage	0.56	0.64	0.60	0.35	0.51
Development Stage	0.83	0.94	0.89	-	0.79
Mid-season stage	1.15	1.21	1.18	1.15	1.08
Late season stage	0.83	0.90	0.87	0.70	0.85

Figure 3 shows the comparison between polynomial curves obtained from lysimetric and FAO modified K_c values for cotton. The polynomial equation obtained for FAO Kc values for cotton is as follows;

$$Kc_t = 7.5945\left(\frac{t}{T}\right)^4 - 16.439\left(\frac{t}{T}\right)^3 + 9.2161\left(\frac{t}{T}\right)^2 - 0.1751\left(\frac{t}{T}\right) + 0.4698 \quad \text{.....(4)}$$

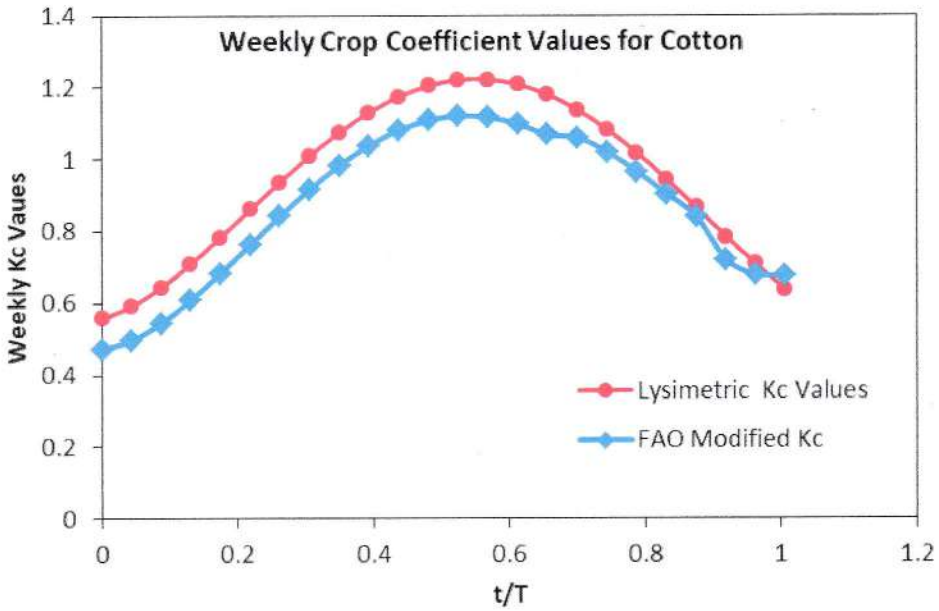


Figure 3. Comparison between lysimetric and FAO modified Kc values for cotton

Comparison between Lysimetric and FAO Modified Kc values for Pigeon pea:

Lysimetric Kc values were found as 0.55, 0.84, 1.12 and 0.81 for initial,

development, midseason and end stages of pigeon pea respectively. Whereas the FAO modified Kc values are 0.50, 0.78, 1.08 and 0.76 for initial, development, mid-season and late season stage. Table 8 shows the comparison between lysimetric and FAO modified Kc values for pigeon pea.

Table 8. Comparison between lysimetric and FAO modified Kc values for pigeon pea

Growth Stages	1st lysimeter Kc	2nd lysimeter Kc	Average Lysimetric Kc	FAO Kc	FAO modified Kc
Initial season stage	0.53	0.57	0.55	0.40	0.50
Development Stage	0.83	0.85	0.84	-	0.78
Mid-season stage	1.13	1.12	1.12	1.15	1.08
Late season stage	0.81	0.81	0.81	0.55	0.76

Figure 4 shows the comparison between polynomial curves obtained from lysimetric and FAO modified K_c values for pigeon pea. The polynomial equation obtained for FAO Kc values for cotton is as follows;

$$Kc_t = 6.3079\left(\frac{t}{T}\right)^4 - 15.341\left(\frac{t}{T}\right)^3 + 9.6189\left(\frac{t}{T}\right)^2 - 0.5745\left(\frac{t}{T}\right) + 0.4895 \quad \text{.....(5)}$$

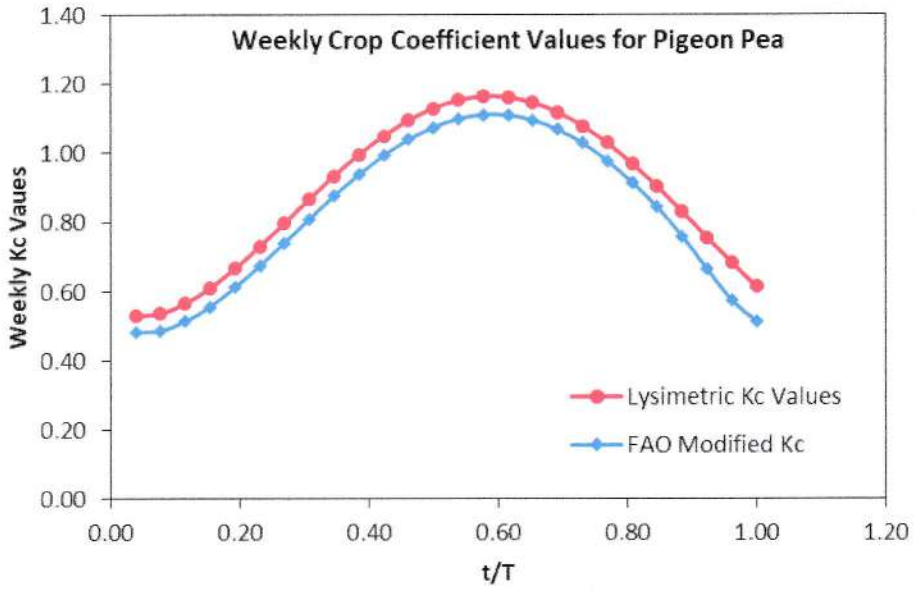


Figure 4. Comparison between lysimetric and FAO modified Kc values for pigeon pea

Water Requirement for Cotton and Pigeon Pea Crops:

Taluka wise crop water requirement (mm/day) was determined using lysimetric Kc values obtained for cotton and pigeon pea by ignoring the effective rainfall for talukas in Vidarbha region. Also the irrigation water requirement was determined by considering the crop water requirement at different irrigation efficiencies. It was calculated for surface irrigation at 40%, 50% and 60% irrigation efficiency, for drip irrigation at 90% and 95% irrigation efficiency and for sprinkler irrigation at 80% and 85% irrigation efficiency. The taluka wise water requirement for cotton and pigeon pea are given in Annexure for above mentioned irrigation efficiencies.

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