Report on Crop Kc, Water Requirement of Summer Sesame and Summer Greengram, 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:

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Co-Principal Investigator	:	Dr. A.N. Mankar, Assistant Professor, Department of Irrigation and Drainage Engineering Dr. PDKV, Akola.
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INTRODUCTION:

The Project is being executed at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. As per schedule of reporting requirements, following are the details regarding the crop coefficient of summer greengram and summer sesame also the water requirement for Summer Greengram, Summer Sesame, cotton and pigeon pea.

DETAILS OF WORK:

Cultivation of Summer Green Gram and Summer Sesame:

As it was planned to cultivate Summer Green Gram and Summer Sesame, the sowing of summer sesame (CV- PDKV NT-11) was done on 11th February 2022 and the sowing of Greengram (CV- Pusa Vaishakhi) was done on 28th March 2022. Whereas, the harvesting of the Sesame was done on 25th May 2022 and Greengram on 3rd June 2022.

Following images shows the different field practices done during the entire growing period of Sesame and Greengram.

Sowing

Irrigation

Germination

Thinning and Weeding

Spraying Pesticides and Insecticides

Harvesting

Cultivation of Summer Sesame

Sowing

Irrigation

Germination

Weeding

Spraying Pesticides and Insecticides

Harvesting

Cultivation of Summer Greengram

Plant Protection Measures

An unhealthy and diseased plant greatly affects the evapotranspiration of the crop. For healthy and disease free plants, the spraying of insecticides and pesticides were done at different stages of crop according its requirement. Following are the details of insecticides, fungicides and pesticides applied during the growth period for healthy growth of Sesame and Greengram.

Table 1. Plant Protection Measures in Summer Sesame

Sr. No.	Date of Application	Insecticide/ Fungicide/ Pesticide	Quantity
1	07/03/2022	Profenofos 50 % EC	15 ml/10 lit. water
2	15/03/2022	Quinalphos 25 % EC	20 ml/10 lit. water
3	21/03/2022	Azadirachtin 300 ppm 0.03 %	50 ml/ 10 lit. water
4	25/03/2022	Pyriproxyfen 10 % EC	8 ml/ 10 lit. water
5	29/03/2022	Azadirachtin 300 ppm 0.03 %	50 ml/ 10 lit. water
6	09/04/2022	Flonicamid 50 % WG	3 gm/ 10 lit. water
7	16/04/2022	Flonicamid 50 % WG	3 gm/ 10 lit. water

Table 2. Plant Protection Measures in Summer Greengram

Sr. No.	Date of Application	Weedicide/ Insecticide/ Fungicide/ Pesticide	Quantity
1	29/03/2022	Pendimethelene 38.7 % CS	40 ml/10 lit. water
2	11/04/2022	Flonicamid 50 % WG	3 gm/ 10 lit. water
3	16/04/2022	Flonicamid 50 % WG	3 gm/ 10 lit. water
4	20/04/2022	Propaquizop 10 % EC	15 ml/ 10 lit. water
5	23/04/2022	Monocrotophos 3.6 % SL	8 ml/ 10 lit. water
6	30/04/2022	Monocrotophos 3.6 % SL	8 ml/ 10 lit. water
7	03/05/2022	Propaquizop 10 % EC	20 ml/ 10 lit. water
8	14/05/2022	Chlorantraniliprole 18.5 % W/W SC	7 ml/ 10 lit. water.

Plant Growth Observations

During the process of planting and growing the crops, there were several observations made regarding growth and yield of crops. Observations were made by selecting 10 random plants form the lysimeter in different intervals i.e. for sesame at 30 days after sowing, 60 days after sowing, 90 days after sowing and at the time of harvest. Also for Greengram at 15 days interval i.e., 15 days after sowing, 30 days after sowing, 45 days after sowing and 60 days after sowing. The overall observations were focused around height of crop, number of branches, number of leaves, number of flowers, number of capsules/pods and yield. Following table illustrates an overall detail about the growth parameters of summer Sesame and summer Greengram during the growing period.

Table 3. Plant Growth Parameters and yield of Sesame (Summer)

Parameters (Average)	30 DAS	60 DAS	90 DAS	At Harvest
Height (cm)	18.1	65.7	92.6	107.4
Branches	3.5	4.1	4.1	4.1
Leaves	28.7	43.6	127	104.8
Flowers	0	5.5	13.5	2
Capsules	0	11	52.6	56.8
Avg. Yield				9.82 q/ha

Table 4. Plant Growth Parameters and yield of Greengram (Summer)

Parameters (Average)	15 DAS	30 DAS	45 DAS	60 DAS
Height (cm)	7.95	15.9	42.85	59.3
Branches	0	5	10.4	11.2
Leaves	6.4	15.75	33.55	34.8
Flowers	0	0	5.1	2.2
Pods	0	0	9.65	18.7
Avg. Yield				12.09 q/ha

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 $°C^{-1}$)
T = Mean air temperature (°C)
γ = Psychrometric constant (kPa $°C^{-1}$)
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 COEFFICIENTS (KC) FOR SUMMER GREENGRAM AND SESAME:

The weekly value of crop coefficients was 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 Agro-meteorology observatory, Department of Agronomy, Dr. PDKV, Akola. Weekly crop evapotranspiration was obtained from lysimeters by growing crop in lysimeters. For Greengram, two lysimeters was used and the crop evapotranspiration values were measured for both lysimeters and the obtained crop coefficient values was averaged over both the lysimeters to avoid errors in measurement. Whereas for Sesame (summer) one lysimeter was used to measure the crop evapotranspiration to obtain the crop coefficient values. 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. Following tables represents the values of crop coefficient for summer Greengram and sesame.

Table 5. Weekly Crop Coefficient (Kc) Values for Greengram (Summer)

Crop Week	Weekly Kc by lysimeter 1	Weekly Kc by Lysimeter 2	Average Kc	Crop Growth Stages	Stagewise Kc Values
1	0.49	0.48	0.48	Initial (15 Days)	0.57
2	0.58	0.59	0.59		
3	0.70	0.74	0.72		
4	0.84	0.90	0.87	Deve. (25 Days)	0.96
5	0.97	1.04	1.01		
6	1.08	1.17	1.12	Mid (25 Days)	1.17
7	1.15	1.24	1.20		
8	1.17	1.26	1.21		
9	1.11	1.20	1.16	End (15 Days)	0.81
10	0.97	1.04	1.01		
11	0.73	0.77	0.75		

Table 6. Weekly Crop Coefficient (Kc) Values for Sesame (Summer)

Crop Week	Weekly Kc by Lysimeter	Crop Growth Stages	Stagewise Kc Values
1	0.43	Initial (20 Days)	0.54
2	0.54		
3	0.67		
4	0.80	Deve. (35 Days)	1.02
5	0.93		
6	1.05		
7	1.15		
8	1.23		
9	1.29	Mid (45 Days)	1.23
10	1.31		
11	1.31		
12	1.27		
13	1.19		
14	1.07		
15	0.91	End (20 Days)	0.67
16	0.71		
17	0.47		

The computed Kc values for Greengram (summer) during initial, development, mid and end stage were 0.57, 0.96, 1.17 and 0.81 respectively and for sesame (summer) were 0.54, 1.02, 1.23 and 0.67 in respective stages. The average weekly Kc values for Greengram ranges between 0.48 (Initial stage) and 1.21 (Mid stage) during the crop growth period. Whereas for sesame (summer) it ranges between 0.43 (Initial stage) and 1.31 (Mid stage) during the growth period. The maximum values of crop coefficients were estimated during the mid-stage mainly because of higher canopy. Following figures 1 and

2 represents the variation in Weekly Crop Coefficient (Kc) values during the growth period for summer Greengram and Sesame.

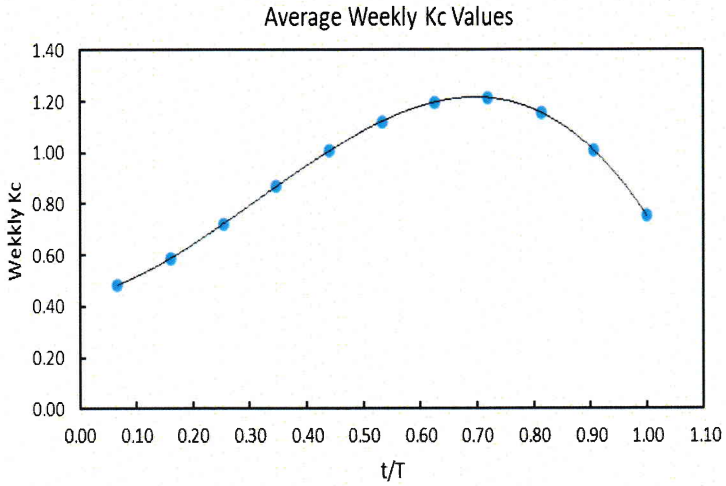

Figure 1. Weekly Crop Coefficient Values for Summer Greengram

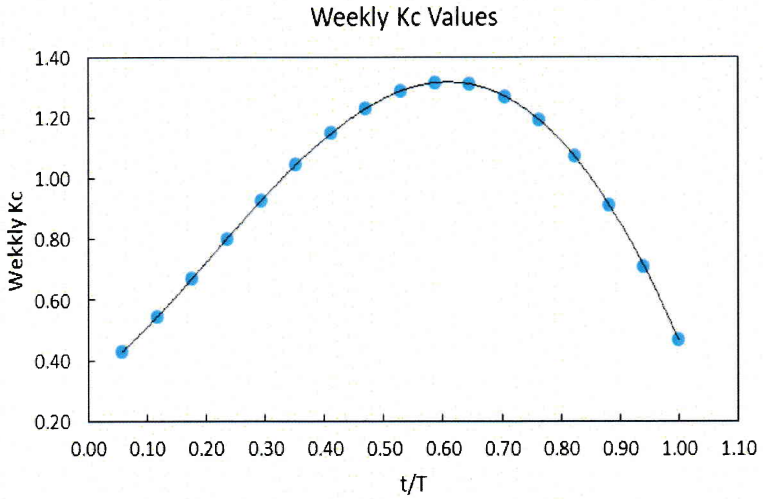

Figure 2. Weekly Crop Coefficient Values for Summer Sesame

PROGRESSIVE WORK:

Crop Planning:

The sowing of two Kharif crops (Cotton and Pigeon Pea) in the month of June under is done under this project. The crop intercultural practices and farm management practices are in progress. Following are the details of varieties of the crops which were planned to cultivate.

Cotton:

General Information about Crop:

Cotton is the Kharif crop that is sown from June to July and harvested from October to January. Cotton is a soft fluffy, staple fiber that grows in a boll or protective case, around the seeds of the cotton plant. Raw cotton or seed cotton is called Kapas and when the cotton fiber is separated from the seed cotton it is called Lint. Usually, Lint

cotton separated from cottonseed is pressed in the form of full pressed bales with a standard weight of 170 kg. The process of separating cotton fibres from cottonseed is called Ginning. Cottonseed is crushed to make cottonseed cake, which is used in livestock feed and cottonseed oil.

Economic Importance:

India's textile industry is predominantly cotton based and cotton plays a vital role in our country's economy. This sector contributes around 5% to the country's gross domestic product (GDP), 14% to industrial production, and 11% to total export earnings. We are also one of the largest producers as well as exporters of cotton yarn.

Table 7. Summary of Cotton Variety of Crop

Sr. No.	Particulars	Specifications
1	Crop	Cotton
2	Scientific Name	*Gossypium herbaceum*
3	Family	*Malvaceae*
4	Variety	PDKV JKAL-116 BG
5	Season	Kharif
6	Optimum Temperature	35-40 ^{0}C.
7	Optimum pH	6.0-8.5
8	Seed Rate (Kg/ha)	2 – 2.5
9	Sowing Time	Between 15 to 30 June
10	Crop Spacing (Cm)	50 x 90
11	Crop Period (Days)	160 Days

Length of Crop Development stages of Cotton Crop.

Sr. No.	Growth Stage	Length of Growth Stages (Days)
1	Initial	20
2	Development	35-40
3	Mid	45-50
4	Late	50

Pigeon Pea:

General Information about Crop:

Pigeon pea (Cajanus cajan), also known as red gram, arhar and tur in India, is an important pulse crop of the country. It is grown under a wide range of cropping systems. Traditionally, long-duration (180–260 days) crop was grown in a mixture with cereals. Pigeonpea is predominantly a crop of tropical areas mainly cultivated in semi-arid regions of India. Pigeonpea can be grown with a temperature ranging from 26^{0}C to 30^{0}C in the rainy season (June to October). Pigeonpea is very sensitive to low radiation at pod development, therefore flowering during the monsoon and cloudy weather, leads to poor pod formation.

Economic Importance:

India is the largest producer and consumer of Pigeon pea in the world. Pigeonpea accounts for about 20 per cent of the total production of pulses in the country. Pigeon pea is grown in the tropical and subtropical regions and about 90% of the world production is from the Indian subcontinent.

Table 8. Summary of Pigeon Pea Variety of Crop

Sr. No.	Particulars	Specifications
1	Crop	Pigeon Pea
2	Scientific Name	*Cajanus cajan (L.)*
3	Family	*Fabaceae*
4	Variety	PDKV Ashlesha
5	Season	Kharif
6	Optimum Temperature	26-30 ^{0}C.
7	Optimum pH	7.0-8.5
8	Seed Rate (Kg/ha)	2-2.5
9	Sowing Time	Between 15 to 30 June
10	Crop Spacing (Cm)	50 x 90
11	Crop Period (Days)	180 Days

Length of Crop Development stages of Pigeon Pea Crop.

Sr. No.	Growth Stage	Length of Growth Stages (Days)
1	Initial	25
2	Development	45-50
3	Mid	55-60
4	Late	50

COMPUTATION OF WATER REQUREMENT USING MODIFIED FAO KC VALUES FOR VIDARBHA REGION

Crop water requirement (ETc) was determined by the crop coefficient approach whereby the effect of the various weather conditions are incorporated into reference crop evapotranspiration (ETo) and the crop characteristics into the crop coefficient (Kc):

$$ETc = Kc \times ETo$$

Crop water requirement for major crops i.e. Summer Greengram, Summer Sesame, Cotton and Pigeon Pea were determined using the historical meteorological data of 30 years. Daily meteorological data were downscaled and downloaded for the period 1992 - 2021 (30 years) for 118 tehsils of Vidarbha from website (power.larc.nasa.gov) of The POWER Project supported by NASA Earth Science for prediction of worldwide energy resources. Data pertaining to maximum temperature (^{o}C) at 2 m (Tmax), minimum temperature (^{o}C) at 2 m (Tmin), relative humidity (%) at 2 m (RH), wind speed (ms^{-1}) at 2 m (WS) and all sky surface shortwave downward irradiance (MJ m^{-2} day $^{-1}$) i.e. Solar radiation (Rs) are available free to download from that website and data of these parameters was downloaded. Then, mean weekly averages of all above meteorological

data was determined, by averaging it, according to standard meteorological weeks. Other parameters like geographic locations viz., latitude, longitude and altitude were also obtained.

I) Reference Crop Evapotranspiration

Weekly reference crop evapotranspiration was determined by converting daily climatic data into weekly, according to standard meteorological weeks (SMW). Estimation of weekly reference evapotranspiration (ETo, mm day^{-1}) was carried out by using FAO Penman-Monteith method for all eleven districts of Vidarbha region. The mathematical expression FAO Penman Monteith method to estimate the reference evapotranspiration (ETo) is as follows;

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

where,

ETo	-	Reference Evapotranspiration (mm day^{-1})
Δ	-	Slope of saturation vapour curve (kPa $^0C^{-1}$)
R_n	-	Net radiation at the crop surface (MJ m^{-2} day^{-1})
G	-	Soil heat flux density (MJ m^{-2} day^{-1})
γ	-	Psychometric constant (kPa $^0C^{-1}$)
T	-	Mean air temperature (^0C)
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)

The determined weekly reference crop evapotranspiration (ETo) for 30 years (1992-2021) was averaged to get average weekly ETo for 52 standard meteorological weeks for each station (Tehsil) of all eleven districts in Vidarbha region. The obtained ETo values for each taluka were used to extract district wise and Tehsil wise ET average ETo values for respective tehsil and district using GIS software. The extracted ETo values for each district and taluka were used to determine the crop water requirement for the respective station by multiplying crop coefficient values.

II) Modified Crop Coefficients

FAO has given the crop coefficient values for various crops and climatic conditions, these values can be used to calculate the crop evapotranspiration after modifying according to our local climatic conditions. Crop coefficient values were determined by modifying the FAO crop coefficients for local climatic conditions to determine the crop evapotranspiration. The Kc values were modified for the four crops i.e. summer sesame, summer greengram, cotton and pigeon pea. The calculation modification of FAO crop coefficients consists of:

1. Identifying the crop growth stages, determining their lengths, and computing the corresponding crop coefficients;
2. Constructing the crop coefficient curve (To predict Kc values from graph plotted for the growing period); and
3. Calculating ETc as the product of ETo and Kc.

1. Identifying the crop growth stages and their lengths for local varieties of respective crops:

Identifying and determining the length of growth stages was done by selecting the general lengths for the four distinct growth stages and the total growing period for local climatic conditions. This information is summarized in Table 7.

Table 9. Length of growth Stages for selected crops

Sr. No.	Name of Crop	Length of Growth Stage (Days)				
		Initial	Development	Mid	End	Total
1	Summer Greengram	10	21	26	13	70
2	Summer Sesame	15	28	42	20	105
3	Cotton (Kharif)	22	38	52	48	160
4	Pigeon Pea (Kharif)	24	52	58	46	180

Determination of Crop coefficient for the initial stage (Kc ini)

The crop coefficient for the initial growth stage was derived by taking reference of FAO, irrigation and drainage paper No.56. FAO has given the procedure to select the initial Kc value by graphical method. The average reference crop evapotranspiration values were used to determine the Kc initial using FAO graphical method. Whereas the wetting events for determining the Kc initial for all four crops were selected by general irrigation intervals during summer for greengram and sesame and during Kharif for cotton and pigeon pea. Figure 3. is given by FAO-56 which is used for heavy wetting events when infiltration depths are greater than 40 mm, such as for when wetting is primarily by periodic irrigation such as by sprinkler or surface irrigation.

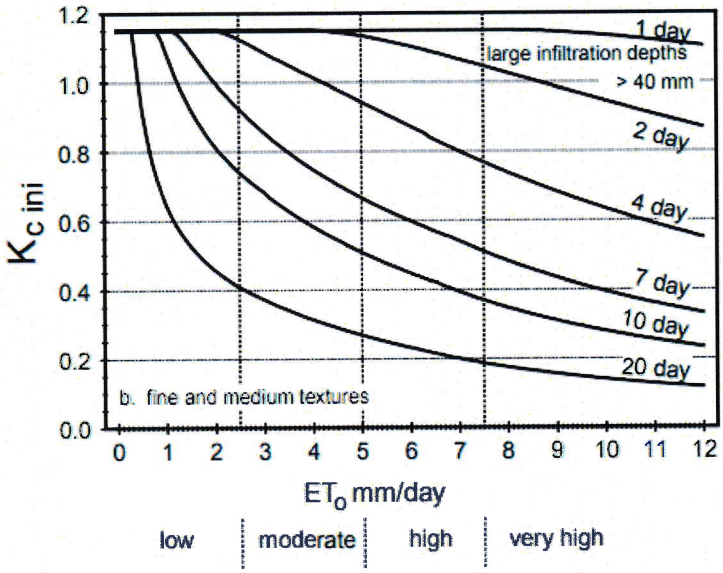

Figure 3. Average Kc ini as related to the level of ETo and the interval between irrigations greater than or equal to 40 mm per wetting event, during the initial growth stage for a) coarse textured soils; b) medium and fine textured soils

Determination of Crop coefficient for the mid stage (Kc Mid)

The computation of Kc mid was done for specific adjustment in climates where mean value of daily minimum relative humidity during mid-stage of growth stage and mean daily wind speed during the mid-stage of growth stage was considered by following the procedure given by FAO, Irrigation and drainage paper. The mean plant height and mean relative humidity during the mid-season stage for all four crops were collected from previous experimental data of university for determining Kc mid as well as Kc End. The mean daily wind speed value was used to determine both Kc mid and Kc end. Following equation was used to estimate Kc mid:

$$K_C \text{ mid} = K_{C \text{ mid (FAO)}} + [0.04(u_2 - 2) - 0.004\ (RH_{min} - 45)]\ (h/3)^{0.3}$$

Where,

$Kc_{\text{mid (FAO)}}$ -	Value for Kc mid taken from FAO-56,
u_2 -	Mean value for daily wind speed at 2 m height (m/s),
RH_{min} -	Mean value for daily minimum relative humidity during the mid-season growth stage (%),
h -	Mean plant height during the mid-season stage (m)

Determination of Crop coefficient for the end stage (Kc end)

The computation of Kc end is similar to Kc Mid where mean value of daily minimum relative humidity during end-stage of growth stage and mean daily wind speed during the end-stage of growth stage was considered by following the procedure given by FAO, Irrigation and drainage paper. Following equation was used to estimate Kc end:

$$K_C \text{ mid} = K_{C \text{ End (FAO)}} + [0.04(u_2 - 2) - 0.004\ (RH_{min} - 45)]\ (h/3)^{0.3}$$

Where,

$Kc_{\text{end (FAO)}}$ -	Value for Kc end taken from FAO-56,
u_2 -	Mean value for daily wind speed at 2 m height (m/s),
R_{Hmin} -	Mean value for daily minimum relative humidity during the end-season growth stage (%),
h -	Mean plant height during the end-season stage (m)

2. Constructing the crop coefficient curve (To determine Kc values for weekly crop coefficient during the growing period)

The calculated crop coefficient values were plotted against time of season (days) for respective crop growth stages to get weekly Kc values for all four crops and eleven districts of Vidarbha region. Only three point values of Kc are required to describe and to construct the Kc curve. The curve was constructed using the following three steps:

1. Divided the growing period into four general growth stages that describe crop phenology or development (initial, crop development, mid-season, and late season stage), determined the lengths of the growth stages, and identified the three Kc values that correspond to Kc ini, Kc mid and Kc end.

2. After plotting horizontal and diagonal curve for all growth stages, the possible best fitting soft curve has been drawn manually on graph paper for whole growing season of respective crop and for respective district. Then the weekly Kc values has been read from that soft curve for the whole growing season.

3. Constructed a curve by connecting straight line segments through each of the four growth stages. Horizontal lines were drawn through Kc ini in the initial stage and through Kc mid in the mid-season stage. Diagonal lines were drawn from Kc ini to Kc mid within the course of the crop development stage and from Kc mid to Kc end within the course of the late season stage.

4. The obtained weekly Kc values for all four crops were plotted against crop weeks in Microsoft Excel to determine the daily values of crop coefficient by obtaining curve fitting equation. Then estimated daily Kc values were averaged to get modified weekly crop coefficients more exactly.

Following tables 10, 11, 12 and 13 represents the modified Kc values for summer greengram, summer sesame, cotton and pigeon pea respectively.

Table 10. Modified Crop Coefficient values for Summer Greengram

Week No.		Akola	Amravati	Bhandara	Buldhana	Chandrapur	Gadchiroli	Gondia	Nagpur	Wardha	Washim	Yavatmal
MW	CW											
11	1	0.52	0.50	0.54	0.53	0.54	0.54	0.54	0.54	0.53	0.53	0.52
12	2	0.62	0.60	0.64	0.64	0.64	0.60	0.64	0.64	0.64	0.63	0.63
13	3	0.79	0.77	0.80	0.79	0.79	0.70	0.80	0.81	0.79	0.79	0.79
14	4	0.95	0.95	0.96	0.95	0.95	0.82	0.96	0.97	0.95	0.95	0.96
15	5	1.08	1.09	1.09	1.08	1.07	0.91	1.09	1.09	1.07	1.08	1.10
16	6	1.16	1.17	1.16	1.15	1.14	0.95	1.16	1.16	1.15	1.15	1.17
17	7	1.17	1.18	1.18	1.17	1.15	0.92	1.17	1.17	1.16	1.16	1.18
18	8	1.11	1.12	1.12	1.12	1.10	0.83	1.11	1.11	1.10	1.10	1.12
19	9	0.99	0.99	0.99	1.00	0.97	0.67	0.99	0.98	0.98	0.97	0.99
20	10	0.78	0.80	0.78	0.81	0.77	0.43	0.78	0.78	0.78	0.77	0.80
21	11	0.76	0.78	0.76	0.79	0.75	0.42	0.76	0.76	0.76	0.76	0.78

*MW = Meteorological Week

*CW = Crop Week

Table 11. Modified Crop Coefficient values for Summer Sesame

Week No.		Akola	Amravati	Bhandara	Buldhana	Chandrapur	Gadchiroli	Gondia	Nagpur	Wardha	Washim	Yavatmal
MW	CW											
6	1	0.58	0.57	0.61	0.59	0.60	0.64	0.63	0.60	0.59	0.60	0.58
7	2	0.63	0.63	0.67	0.64	0.65	0.69	0.68	0.66	0.65	0.65	0.64
8	3	0.72	0.72	0.75	0.73	0.74	0.76	0.76	0.75	0.73	0.73	0.73
9	4	0.83	0.83	0.85	0.84	0.84	0.85	0.86	0.85	0.83	0.83	0.83
10	5	0.94	0.95	0.96	0.95	0.94	0.94	0.96	0.96	0.94	0.94	0.95
11	6	1.05	1.06	1.06	1.06	1.05	1.04	1.06	1.06	1.04	1.04	1.06
12	7	1.15	1.16	1.15	1.16	1.14	1.12	1.15	1.16	1.13	1.13	1.15
13	8	1.22	1.23	1.22	1.23	1.20	1.18	1.22	1.23	1.20	1.20	1.23
14	9	1.26	1.27	1.26	1.27	1.24	1.21	1.26	1.27	1.23	1.24	1.27
15	10	1.26	1.27	1.27	1.28	1.24	1.21	1.26	1.27	1.24	1.25	1.27
16	11	1.22	1.23	1.23	1.23	1.20	1.17	1.22	1.23	1.19	1.21	1.22
17	12	1.13	1.13	1.13	1.14	1.11	1.08	1.13	1.13	1.10	1.12	1.13
18	13	0.98	0.99	0.99	1.00	0.96	0.94	0.98	0.98	0.96	0.97	0.98
19	14	0.78	0.78	0.78	0.80	0.75	0.73	0.77	0.78	0.76	0.76	0.78
20	15	0.52	0.52	0.50	0.53	0.49	0.46	0.48	0.50	0.49	0.49	0.52
21	16	0.50	0.50	0.48	0.51	0.46	0.44	0.46	0.48	0.47	0.46	0.50

Table 12. Modified Crop Coefficient values for Cotton

Week No.		Akola	Amravati	Bhandara	Buldhana	Chandrapur	Gadchiroli	Gondia	Nagpur	Wardha	Washim	Yavatmal
MW	CW											
25	1	0.47	0.47	0.51	0.45	0.51	0.54	0.53	0.51	0.49	0.51	0.41
26	2	0.50	0.49	0.53	0.48	0.53	0.56	0.55	0.52	0.51	0.53	0.44
27	3	0.55	0.54	0.58	0.53	0.58	0.60	0.59	0.57	0.55	0.57	0.49
28	4	0.61	0.60	0.63	0.60	0.64	0.66	0.65	0.63	0.61	0.62	0.56
29	5	0.68	0.68	0.70	0.68	0.71	0.72	0.72	0.70	0.68	0.68	0.64
30	6	0.76	0.76	0.78	0.76	0.78	0.79	0.79	0.77	0.76	0.75	0.73
31	7	0.84	0.84	0.85	0.84	0.85	0.86	0.86	0.85	0.84	0.81	0.82
32	8	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.91	0.86	0.91
33	9	0.98	0.99	0.98	0.99	0.98	0.97	0.98	0.98	0.97	0.91	0.98
34	10	1.04	1.04	1.03	1.04	1.03	1.02	1.03	1.04	1.02	0.95	1.05
35	11	1.08	1.09	1.07	1.09	1.07	1.05	1.07	1.08	1.06	0.98	1.09
36	12	1.11	1.12	1.09	1.11	1.09	1.07	1.09	1.11	1.09	1.00	1.12
37	13	1.12	1.13	1.10	1.12	1.10	1.08	1.10	1.12	1.10	1.00	1.14
38	14	1.12	1.12	1.10	1.12	1.09	1.08	1.09	1.11	1.09	0.98	1.13
39	15	1.10	1.10	1.08	1.10	1.07	1.06	1.07	1.09	1.07	0.95	1.11
40	16	1.07	1.07	1.05	1.06	1.04	1.03	1.04	1.06	1.04	0.92	1.08
41	17	1.06	1.06	1.04	1.05	1.03	1.02	1.03	1.05	1.03	0.91	1.07
42	18	1.02	1.02	1.00	1.01	0.99	0.98	0.99	1.01	0.99	0.86	1.02
43	19	0.97	0.96	0.94	0.95	0.93	0.92	0.94	0.95	0.93	0.80	0.96
44	20	0.90	0.89	0.88	0.89	0.87	0.86	0.88	0.89	0.86	0.73	0.89
45	21	0.84	0.82	0.82	0.82	0.80	0.80	0.81	0.82	0.80	0.66	0.82
46	22	0.72	0.70	0.70	0.70	0.68	0.68	0.70	0.69	0.67	0.51	0.70
47	23	0.68	0.67	0.66	0.66	0.63	0.63	0.65	0.65	0.63	0.46	0.67
48	24	0.68	0.66	0.65	0.66	0.62	0.63	0.65	0.65	0.63	0.45	0.66

Table 13. Modified Crop Coefficient values for Pigeon Pea

Week No.		Akola	Amravati	Bhandara	Buldhana	Chandrapur	Gadchiroli	Gondia	Nagpur	Wardha	Washim	Yavatmal
MW	CW											
25	1	0.48	0.49	0.51	0.47	0.51	0.58	0.54	0.51	0.50	0.53	0.44
26	2	0.49	0.49	0.51	0.48	0.52	0.58	0.55	0.52	0.50	0.54	0.44
27	3	0.51	0.52	0.54	0.51	0.55	0.60	0.57	0.55	0.53	0.56	0.47
28	4	0.56	0.56	0.58	0.55	0.58	0.63	0.60	0.59	0.56	0.59	0.51
29	5	0.61	0.61	0.63	0.61	0.63	0.67	0.65	0.64	0.61	0.64	0.57
30	6	0.67	0.67	0.69	0.67	0.69	0.72	0.70	0.70	0.67	0.69	0.64
31	7	0.74	0.74	0.75	0.73	0.75	0.77	0.76	0.76	0.73	0.75	0.71
32	8	0.81	0.81	0.81	0.80	0.81	0.83	0.82	0.82	0.79	0.81	0.78
33	9	0.88	0.87	0.87	0.87	0.87	0.88	0.87	0.88	0.86	0.87	0.85
34	10	0.94	0.93	0.93	0.93	0.92	0.93	0.93	0.94	0.91	0.93	0.92
35	11	0.99	0.99	0.98	0.98	0.97	0.98	0.98	0.99	0.96	0.98	0.98
36	12	1.04	1.03	1.03	1.03	1.01	1.01	1.02	1.03	1.01	1.02	1.03
37	13	1.07	1.07	1.06	1.06	1.05	1.04	1.05	1.07	1.04	1.05	1.07
38	14	1.10	1.09	1.08	1.09	1.07	1.06	1.07	1.09	1.07	1.08	1.10
39	15	1.11	1.10	1.10	1.10	1.08	1.07	1.08	1.10	1.08	1.09	1.11
40	16	1.11	1.10	1.09	1.10	1.08	1.07	1.08	1.09	1.08	1.09	1.11
41	17	1.10	1.09	1.08	1.09	1.07	1.05	1.06	1.08	1.06	1.07	1.10
42	18	1.07	1.06	1.05	1.06	1.04	1.03	1.04	1.05	1.04	1.05	1.07
43	19	1.03	1.02	1.01	1.02	1.00	0.99	1.00	1.01	1.00	1.01	1.03
44	20	0.98	0.97	0.96	0.97	0.95	0.94	0.95	0.96	0.95	0.96	0.98
45	21	0.91	0.91	0.90	0.91	0.89	0.88	0.89	0.90	0.88	0.89	0.91
46	22	0.84	0.84	0.83	0.84	0.82	0.81	0.82	0.83	0.81	0.82	0.84
47	23	0.76	0.75	0.74	0.75	0.73	0.72	0.74	0.74	0.72	0.73	0.75
48	24	0.66	0.65	0.64	0.65	0.62	0.62	0.64	0.64	0.62	0.62	0.65
49	25	0.57	0.55	0.54	0.56	0.52	0.51	0.55	0.54	0.51	0.51	0.55
50	26	0.51	0.48	0.48	0.49	0.44	0.44	0.49	0.48	0.44	0.44	0.49
51	27	0.51	0.48	0.47	0.48	0.43	0.43	0.48	0.47	0.44	0.43	0.48
52	28	0.50	0.47	0.46	0.48	0.43	0.43	0.47	0.46	0.43	0.42	0.47

3. Calculating ETc as the product of ETo and Kc.

The FAO crop coefficient values were modified for local climatic and crop conditions. The district wise ETo and as well as modified Kc values for all four crops and eleven districts were used to calculate the crop evapotranspiration (ETc) for all tehsils of corresponding district.

III) Water Requirement for Major Crops:

Taluka wise crop water requirement (mm/day) for summer greengram, summer sesame, cotton and pigeon pea was determined by ignoring the effective rainfall for all districts and 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 and district wise water requirement for summer greengram, summer sesame, cotton and pigeon pea are given in Annexure I to V for above mentioned irrigation efficiencies.

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