Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani

Status Report III

Estimation of crop Kc based on normalized Kc using FAO calculations and water and irrigation requirement by different irrigation practices.

(For *Kharif* Soybean, *Kharif* Greengram, *Rabi* Sorghum, *Summer* Groundnut and Okra crop)

Title of the project	:	Determination of crop coefficients for major crops by Lysimetricstudies" at Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani.
Location	:	Department of Irrigation & Drainage Engineering, College of Agricultural Engineering Research Field, Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani
Duration	:	Three years
Total outlay	:	Rs. 38.38 lakhs
Investigators	:	
Principal Investigator	:	**Dr. U. M. Khodke** Associate Dean & Principal, College of Agricultural Engineering & Technology VNMKV Parbhani
Co-Principal Investigators	:	1) **Dr. H.W. Awari** Head, Deptt. of Irrigation & Drainage Engineering, CAET, VNMKV Parbhani 2) **Dr. V.K. Ingle** Assistant Professor, Deptt. of Irrigation & Drainage Engineering, CAET, VNMKV Parbhani
Coordinator for the project		**Dr. S.D. Gorantiwar** PI CAAST-CSAWM and Head, Deptt. of Agril. Engg., MPKV, Rahuri

MEMORANDUM OF UNDERSTANDING:

The Memorandum of Understanding between Nanaji Deshmukh Krishi Sanjeevani Prakalp (NDKSP), Government of Maharashtra earlier referred as Project on Climate Resilient Agriculture (PoCRA) a World Bank funded project and Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani was signed on January 17, 2020 at Mumbai by Project Director, PoCRA and PI of the project from VNMKV Parbhani in the presence of ADG (NRM), Director of Research, MPKV, Rahuri; NDKSP Authorities and PI of the project from MPKV, Rahuri.

This Project is being executed at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. During the current phae (III), activities related with estimation of crop Kc, and water and irrigation requirement by different irrigation practices for *Kharif* Soybean, *Kharif* Greengram, *Rabi* Sorghum, *Summer* Groundnut and Okra crop using FAO calculations,

IMPORTANCE OF THE EXPERIMENT:

Water is a critical natural input for agricultural production and plays a vital role in crop growth and development which directly or indirectly affects the yield and productivity of crops. But due to population growth, urbanization and climate change, the competition for water resources is expected to increase day by day with the negative impacts on agriculture. Currently, Indian farmers have to face different problems such as climate change, famines & droughts, extreme precipitation and flooding, hurricanes and dry spell, etc.

To overcome these problems, it is essential to adopt and develop climate resilient technologies according to the need of local climate. To obtain the potential yield and productivity from a unit area, it is essential to know the optimum water requirement of the crops to maintain the soil health, increase the production and productivity and to avoid the excess use of irrigation water. Excess or deficit amount of water has negative impacts on the crop growth. Crop evapotranspiration is essential parameter to determine the water requirement of the crops. Evapotranspiration (ET) corresponds to the sum of evaporation (E) and transpiration (T) processes in vegetated surfaces that occur simultaneously, and it is often difficult to separate these two physical processes. The knowledge of ET forms a fundamental basis for designing and managing irrigation systems including irrigation scheduling. With the help of lysimetric studies, we can directly estimate daily/ stage wise crop coefficients and ET which play major role in water requirement of the crops.

Usually average crop coefficients for different crops determined by FAO (Doorenbos and Pruitt, 1977) are being used by the researchers, planners and managers of water resource system across the world. Since these values are based on the average crop coefficient all over the world and are not lcation and crop specific, they lead to inappropriate application of water, resulting in under or over irrigation and finally either in decreased productivity and/or increased wastage of scarce water resources.

Althoght the available crop coefficient values of different crops determined by FAO are stage wise; many times, for planning, management and operation purposes the daily values of crop coefficients are required. Therefore, the equation of crop coefficients as a function of number of days since sowing/planting or crop coefficient curves is required. In actual situation, the crop growing season may vary according to location and crop variey. Therefore, while developing the functions for crop coefficient (Kc), instead of days since sowing/planting, the ratio of days since sowing/planting to total length of crop perod is considered. The equations for crop coefficient are also useful for computer programmes. Hence there is a need of regionalization of FAO crop coeffieinct values of major crops in Marathwada using the local weather data and growth stage wise plant height measurements.

Objectives

Hence the study was proposed to determine the crop coefficients for the major crops of Marathwada region/ Maharashtra state by Lysimetric studies with following specific objectives.

1. To estimate the values of crop coefficients of important field crops over their growth periods by using lysimetric study,

2. To estimate water requirement of different field crops for efficient irrigation water requirement

About Staus Report III:

The procedure for development of Kc using lysimeter by adopting experimentation of allotted crops will require two to three years. Therefore until the development of Lysimeter Kc, it was decided to develop the Kc based on wether data and growth stage wise plant height data of widely adopted crop varieties of allotted crops viz., *Kharif* Soybean, *Khari*

Greengram, *Rabi* Sorghum, *Summer* Groundnut and Okra following FAO- 56 curve method and procedure.

METHODOLOGY

The crop coefficients for *Kharif* Soybean, *Khari* Greengram, *Rabi* Sorghum, *Summer* Groundnut and Okra crops were derived by following FAO- 56 curve number and standard procedure and guidelines suggested by Allen *et al.,* (1998). The weekly crop coefficients were derived by following the standard procedure.

Computation of week wise Kc initial, K_c mid and Kc end

1) Stage wise Kc and crop duration matching to climate and season of local station were recorded from FAO 56 and converted to Meteorological week wise Kc.
2) Considering, sowing date and total crop period ratio t/T (t= days since sowing and T is crop period) was determined and meteorological week Kc was computed.
3) The prepared Kc curve with polynomial equation having highest R^2 was selected.
4) The week wise Kc values for regional crops were derived using polynomial equation t/T (t= days since sowing and T total crop period of regional crop variety).
5) The week wise derived FAO Kc values were regionalized using local climatic data like minimum humidity and wind velocity.

For computing stage wise regionalized Kc, the week wise crop height data was used along with local climatic data for average wind velocity and minimum relative humidity.

Computation of Modified Crop coefficients

Computation of Kc initial

The crop coefficients for initial growth stage of each crop were estimated using FAO method in which the sowing time, crop duration and reference evapotranspiration of station was considered. Evapotranspiration during the initial stage is predominately in the form of evaporation. The value of Kc ini is affected by the evaporating power of the atmosphere, magnitude of wetting event and time interval between wetting events. The wetting event was considered with wetting depth as total reference crop evapotranspiration between wetting events. For deciding the Kc ini values, Fig 29 and Fig. 30b (fine and medium textured soils) from Allen et al. (1998) was used to estimate Kc ini in the following equation:

$$\text{Kc ini} = \text{Kc ini(Fig. 29)} + \frac{(\text{I}-10)}{(\text{I}-40)}[\text{Kc ini (Fig. 30)} - \text{Kc ini (Fig. 29)}] \quad \text{..... (Eq1.)}$$

Where,
Kc ini (Fig.29) = Value of Kc ini from Fig. 29

Kc ini (Fig.30) = Value of Kc ini from Fig.30

I = Average infiltration depth, mm

Development of modified Kcmid and Kc end

The Kc mid and Kc end values of FAO-56 are typical values expected for average Kc mid and K_c end under the standard climatic conditions. The K_c mid and K_c end values were determined using Eq2 and Eq3, respectively for Parbhani regional climate. The growth stage wise plant height measurements were collected from research experiments conducted in the University. For specific adjustment in climates where RH_{min} differs from 45% or where U_2 is larger or smaller than 2.0 m s^{-1}, the K_c mid values were determined by using the following equation:

$$\mathbf{K_c\ mid} = K_c\,(mid)_{FAO56} + [\,0.04\,(U_2-2) - 0.004\,(RH_{min}-45)]\,(h/3)^{0.3} \quad \text{..... (Eq.2)}$$

Where,

K_c $(mid)_{FAO56}$	=	value of K_c mid derived from FAO-56,
U_2	=	Mean value for daily wind speed at 2m height,
RH_{min}	=	Mean value for daily minimum relative humidity the mid-season growth stage
h	=	Mean plant height during mid-season(m)

$$\mathbf{K_c\ end} = K_c\,(end)_{FAO56} + [\,0.04\,(U_2-2) - 0.004\,(RH_{min}-45)]\,(h/3)^{0.3}) \quad \text{..... (Eq.3)}$$

Where,

K_c $(end)_{FAO56}$	=	value of K_c end derived from FAO-56,
U_2	=	Mean value for daily wind speed at 2m height,
RH_{min}	=	Mean value for daily minimum relative humidity the mid-season growth stage
h	=	Mean plant height during end-season(m)

Polynomial equation for Kc

The following polynomial equations were used for developing the functions for crop coefficients and the best fit equation was selected.

$$Kc_t = a_0\left(\frac{t}{T}\right)^0 + a_1\left(\frac{t}{T}\right)^1 + a_2\left(\frac{t}{T}\right)^2$$

$$Kc_t = a_0\left(\frac{t}{T}\right)^0 + a_1\left(\frac{t}{T}\right)^1 + a_2\left(\frac{t}{T}\right)^2 + a_3\left(\frac{t}{T}\right)^3$$

$$Kc_t = a_0\left(\frac{t}{T}\right)^0 + a_1\left(\frac{t}{T}\right)^1 + a_2\left(\frac{t}{T}\right)^2 + a_3\left(\frac{t}{T}\right)^3 + a_4\left(\frac{t}{T}\right)^4$$

$$Kc_t = a_0\left(\frac{t}{T}\right)^0 + a_1\left(\frac{t}{T}\right)^1 + a_2\left(\frac{t}{T}\right)^2 + a_3\left(\frac{t}{T}\right)^3 + a_4\left(\frac{t}{T}\right)^4 + a_5\left(\frac{t}{T}\right)^5$$

Where,

Kc_t - crop coefficients of t^{th} day.

a_0, a_1, a_2 - constants of equations

t - day considered

T - total period of crop growth from sowing to harvesting (days)

In order to compute the daily Kc of crop, the best fit polynomial equation from above having highest R^2 (coefficient of regression) was selected which can be used in Dicision Support System (DSS) models.

Computation of Reference Crop Evapotanspiration

Refernce evapotranspiration (ETo) was estimated by Penman-Monteith method (FAO-56) using fifty one years (1970-2021) climatic data of Minimum Temperature, Maximum Temperature, Minimum relative humidity, Maximum relative humidity, Wind speed and Sunshine hours using following equation.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \text{..... (Eq.4)}$$

where,

ET_o - potential evapotranspiration (mm day^{-1}),

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

G - soil heat flux density (MJ m^{-2} day^{-1}),

T - mean daily air temperature at 2 m height (°C),

u_2 - wind speed at 2 m height (m s^{-1}),

e_s - saturation vapour pressure (kPa),

e_a - actual vapour pressure (kPa),

$e_s - e_a$ - saturation vapour pressure deficit (kPa),

Δ - slope of vapour pressure curve (kPa $°C^{-1}$),

γ - psychrometric constant (kPa $°C^{-1}$).

The daily ETo estimated using above equation was converted to metereological weekwise ETo.

Comupation of crop evapotranspiration

The crop evapotranspiration of selected crop was computed by following equation:

$$ET_c = K_c \times ET_o \quad \text{.....(Eq.5)}$$

Where,

ETc = Crop evapotranspiration, mm

Kc = Crop coefficient

ETo= Reference evapotranspiration (mm)

The crop evapotranpiration of specifi crop (Soybean, Greengram, Rabi Sorghum, Groundnut and Okra) were calculated using the average weekly reference crop evapotranspiration and developed modified crop coeffieicnt.

Computation of crop water requirement

The meteriological week wise crop water requirement was calculated for each crop for different talukas in Marathwada region using the following equation.

$$WR = (ETc - Er) \times Af \quad \text{.....(Eq.6)}$$

Where,

WR = Water to be applied, mm

ETc = Crop evapotranspiration, mm

Er = Effective rainfall, mm

Af = Area factor

(Area factor = 1.0 for surface and 0.8 for drip)

Computation of irrigation water requirement

The irrigation water requirement was obtained by dividing the water requirement by efficiency of particluar irrigation system:

$$IWR = WR/\eta \quad \text{.....(Eq.7)}$$

Where,

WR = Water to be applied, mm

IWR = Irrigation water to be applied, mm

Ƞ= Efficiency of the irrigation system

RESULTS:

Using the standard crop stage wise Kc developed by FAO-56, meteriolocal weekwise Kc were derived for each crop under study. The derived Kc were regionalized according to the sowing period, growth stages, crop period and suitable crop varieties (Soybean, Greengram, Rabi Sorghum, Groundnut and Okra) for Marathwada under Parbhani condition and termed as modified Kc. Similalrly, the best fitted polynomial equations for computation of Kc were developed.

Crop coefficients for major Crops

The metereological week wise crop coefficients for *Kharif* Soybean**,** *Kharif* Greengram, *Rabi* Sorghum, *Summer* Groundnut and Okra crops is presented in Table 1 to 5,

Crop coefficients for *Kharif* Soybean

The modified Kc value for *Kharif* Soybean (Table 1) ranges between 0.49 to 1.27 whereas the highest modified Kc value was 1.27 during 37th MW and the lowest (0.49) during 26th MW. The weekly Kc values demonstrated in initial stage of crop growth (1to 4 WAS) were low and edid not show much variation. The modified Kc was higher during 34th to 37th MW, and lateron lowered down to 0.58 in the 41st MW (Fig. 1). In general the modified crop coefficients for soybean were higher as compared to corp coefficients given in FAO-56.

Table 1: Week wise Kc values of *Kharif* Soybean considering crop period 26th to 42th MW (26th Jully to 19th October)

MWWeek No.	Week after sowing	Days	Avg.U_2 Km/hr	Rh min %	Crop height cm	Modified Kc
26	**0**	1	11.90	50.96	-	0.49
27	**1**	7	11.20	53.92	0.08	0.61
28	**2**	14	10.61	56.77	0.13	0.62
29	**3**	21	10.44	57.52	0.18	0.63
30	**4**	28	10.12	59.17	0.22	0.66
31	**5**	35	9.90	61.79	0.27	0.72
32	**6**	42	9.98	61.22	0.32	0.83
33	**7**	49	9.68	60.62	0.38	0.95
34	**8**	56	8.90	60.71	0.43	1.07
35	**9**	63	8.64	60.67	0.46	1.18
36	**10**	70	7.97	59.24	0.49	1.25
37	**11**	77	7.53	57.65	0.52	1.27
38	**12**	84	6.18	55.87	0.53	1.22
39	**13**	91	5.63	53.38	0.53	1.12
40	**14**	98	5.93	50.60	0.53	0.82
41	**15**	105	5.05	44.21	0.53	0.58
42	**16**	110	5.20	39.92	0.53	0.51

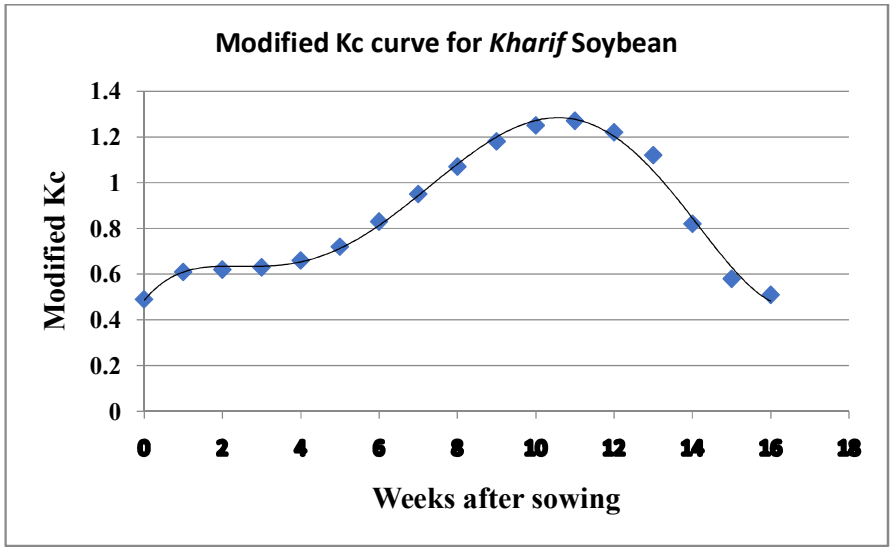

Fig.1: Modified K_c for *Kharif* Soybean

Crop coefficients for *Kharif* Greengram

The meteriological week wise crop coefficients for *Kharif* Greengram are presented in Table 2.

Table 2: Week wise Kc values of *Kharif* Greengram considering crop period 29th to 39th MW (16thJuly to 30thSepteber)

MWWeek no.	Week after planting	Days	Avg.U_2 Km/hr	Rh min %	Crop height cm	Modified Kc
29	**0**	1	8.49	50.63	-	0.58
30	**1**	7	7.88	56.80	3.0	0.62
31	**2**	14	7.54	56.92	7.5	0.62
32	**3**	21	7.64	56.50	13.0	0.82
33	**4**	28	7.54	56.98	17.5	1.01
34	**5**	35	7.46	56.94	22.0	1.15
35	**6**	42	7.15	59.56	26.0	1.20
36	**7**	49	6.77	58.77	30.0	1.18
37	**8**	56	6.23	57.25	33.0	1.06
38	**9**	63	5.93	58.37	35.5	0.83
39	**10**	70	5.58	55.49	38.0	0.45

The modified Kc value of *Kharif* Greengram increased till mid season stage and thereafter it was uniform during mid-season stage. At the end of season it gradually decresed to 0.45 (Fig. 2).

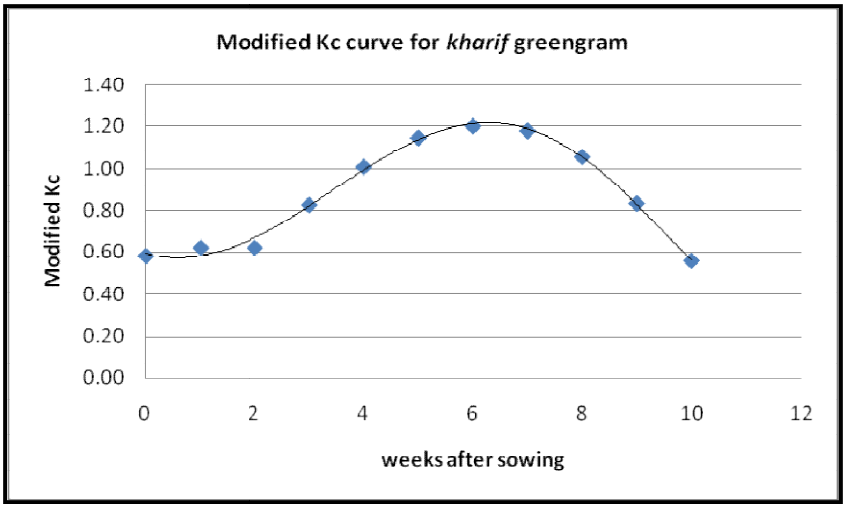

Fig.2: Modified K_c for Kharif Greengram

Crop coefficients for *Rabi* Sorghum:

The week wise crop coefficients for *Rabi* Sorghum are presented in Table 3. From table kc values, it is revealed that FAO derived Kc values were differ than to that of modified crop coefficients for *Rabi* Sorghum which were ranges from 0.40 to 1.31 (Fig. 3).

Table 3: Week wise Kc values of *Rabi* Sorghum considering crop period 42nd to 7th MW (15th October to 18th Feb.)

MWWeek no.	Week after planting	Days	X= t/T	Avg.U_2 Km/hr	Rh min %	Crop height cm	Modified Kc
42	**0**	1	0.01	4.23	39.38	-	0.40
43	**1**	7	0.06	3.88	36.28	4	0.44
44	**2**	14	0.12	4.43	33.72	6	0.50
45	**3**	21	0.18	4.28	32.14	10.5	0.51
46	**4**	28	0.23	4.22	34.57	16	0.65
47	**5**	35	0.29	3.92	35.52	35	0.80
48	**6**	42	0.35	4.00	32.47	59	0.97
49	**7**	49	0.41	4.06	33.04	79	1.10
50	**8**	56	0.47	3.88	31.89	95	1.20
51	**9**	63	0.53	3.93	30.35	114	1.28
52	**10**	70	0.58	3.91	31.27	129	1.31
1	**11**	77	0.64	3.28	31.90	140	1.27
2	**12**	84	0.70	3.39	30.84	152	1.27
3	**13**	91	0.76	3.49	29.21	159	1.24
4	**14**	98	0.82	3.57	28.18	162	1.19
5	**15**	105	0.88	4.02	25.78	166	1.15
6	**16**	112	0.93	4.20	25.86	167	0.9
7	**17**	119	1.00	4.37	25.21	167	0.6

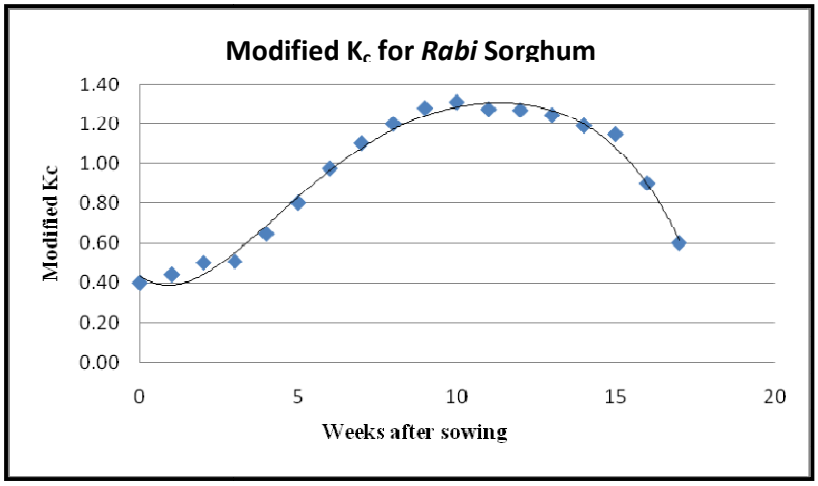

Fig.3: Modified K_c for *Rabi* Sorghum

As general the Kc at mid-season stage was highest during 49th to 3rd MW (1.09 to 1.31), which gradually decreased to 0.6 in 7th MW at the end of crop season.

Crop coefficients for *Summer* Groundnut:

The meteriological week wsie modified crop coefficients for *Summer* Groundnut are presented in Table 4. The weekly modified Kc values for *Summer* Groundnut remain constant in initial stage of crop growth and increased to 1.41 in 16th MW. Thereafter it decreases to 0.98 at the end of season.

Table 4: Week wise Kc values of *Summer Groundnut* considering crop period 5th to 22nd MW (29th January to 3th June)

MWWeek no.	Week after planting	Days	Avg.U_2 Km/hr	Rh min %	Crop height cm	Modified Kc
5	**0**	1	4.02	25.78	2.00	0.62
6	**1**	7	4.20	25.86	3.20	0.62
7	**2**	14	4.37	25.21	4.90	0.63
8	**3**	21	4.36	22.77	6.40	0.65
9	**4**	28	4.54	19.22	8.20	0.70
10	**5**	35	4.72	20.17	9.80	0.82
11	**6**	42	4.75	20.93	11.80	0.96
12	**7**	49	4.80	17.72	13.20	1.09
13	**8**	56	4.84	15.72	14.80	1.21
14	**9**	63	5.08	15.34	16.00	1.30
15	**10**	70	5.30	15.83	17.40	1.37
16	**11**	77	5.71	14.95	18.60	1.41
17	**12**	84	5.87	14.53	19.80	1.41
18	**13**	91	6.38	15.45	20.80	1.38
19	**14**	98	7.02	17.67	21.80	1.32
20	**15**	105	8.31	19.85	22.60	1.25
21	**16**	112	8.60	18.88	23.20	1.00
22	**17**	119	9.14	25.99	23.40	0.98

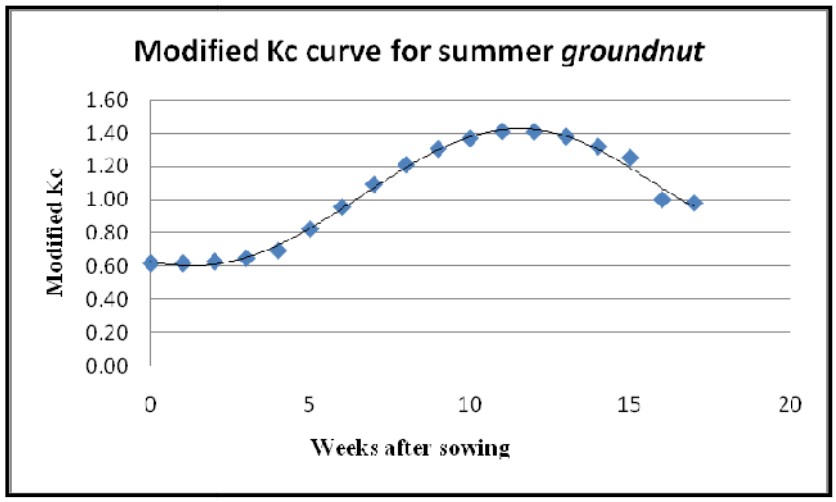

Fig. 4: Modified K_c for *Summer* Groundnut

Crop coefficients for *Summer* Okra:

The meteriological week wise crop coefficients for *Summer* Okra are presented in Table 5. The modified crop coefficients for *Summer* Okra were in the range of 0.61 to 1.41.

Table 5: Week wise Kc values of *Summer* Okra considering crop period 5th to 21st MW (29th January to 27th May)

MW	Week after planting	Days	Avg.U_2 Km/hr	Rh min %	Crop height meter	Modified Kc
5	**0**	1	4.02	25.78	0	0.61
6	**1**	7	4.02	25.86	2	0.64
7	**2**	14	4.02	25.21	6	0.69
8	**3**	21	4.02	22.77	11	0.81
9	**4**	28	4.02	19.22	17	0.96
10	**5**	35	4.02	20.17	26	1.09
11	**6**	42	4.02	20.93	35	1.20
12	**7**	49	4.02	17.72	43	1.31
13	**8**	56	4.02	15.72	56	1.38
14	**9**	63	4.02	15.34	65	1.41
15	**10**	70	4.02	15.83	79	1.40
16	**11**	77	4.02	14.95	95	1.35
17	**12**	84	4.02	14.53	97	1.28
18	**13**	91	4.02	15.45	102	1.18
19	**14**	98	4.02	17.67	108	1.06
20	**15**	105	4.02	19.85	111	0.96
21	**16**	112	4.02	18.88	118	0.64

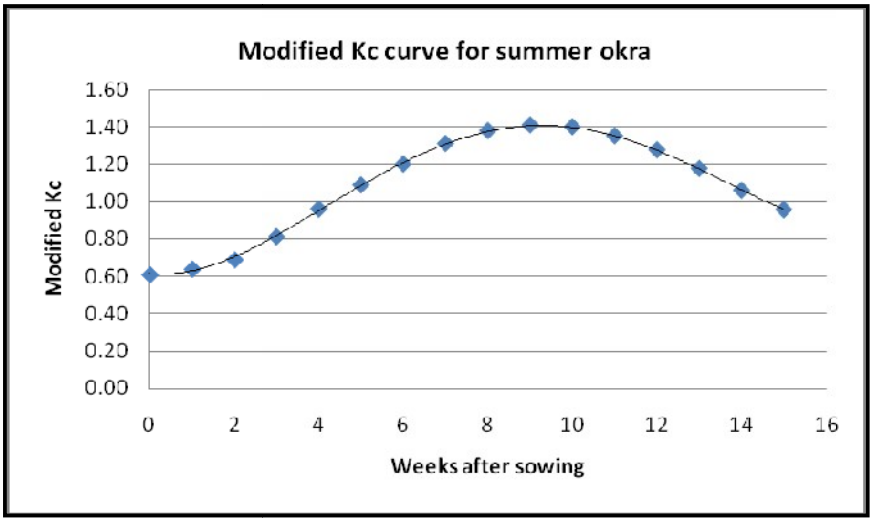

Fig.5: Modified K_c for *Summer* Okra

Polynomial equations for modified crop coefficient:

The crop coeffiecent curves for modified crop coefficient were developed for *Kharif* Soybean, *Kharif* Greengram, *Rabi* Sorghum, *Summer* Groundnut and Okra based on the data gerenerated. The developed polynomial equations for allotted crops are as under:

Table 6: The best fit polynomial equations for crop coefficients

Sr. No.	Crop	Polynomial Equation	R^2
1	*Kharif* Soybean	$Y = 10.39(t/T)^5 - 32.28(t/T)^4 + 29.27(t/T)^3 - 8.845(t/T)^2 + 1.549(t/T) + 0.501$	0.98
2	*Kharif* Greengram	$Y = 5.551(t/T)^5 - 8.438(t/T)^4 - 3.202(t/T)^3 + 6.934(t/T)^2 - 0.889(t/T) + 0.603$	0.99
3	*Rabi* Sorghum	$Y = -71.76(t/T)^6 + 200.4(t/T)^5 - 201.9(t/T)^4 + 81.81(t/T)^3 - 9.282(t/T)^2 + 0.827(t/T) + 0.401$	0.99
4	*Summer* Groundnut	$Y = -81.57(t/T)^6 + 234.0(t/T)^5 - 251.0(t/T)^4 + 116.9(t/T)^3 - 19.58(t/T)^2 + 1.178(t/T) + 0.607$	0.99
5	*Summer* Okra	$Y = -14.35(t/T)^5 + 40.33(t/T)^4 - 43.89(t/T)^3 + 19.38(t/T)^2 - 1.418(t/T) + 0.636$	0.99

Where Y- Crop Coefficient, t = days after sowing/planting and T = Crop Period

Irrigation water requirement of greengram

The estimation of crop Kc, water and irrigation requirement by different irrigation practices for *Kharif* Soybean, *Kharif* Greengram, *Rabi* Sorghum, *Summer* Groundnut and Okra based on modified Kc is completed. The crop water requirement and irrigation water requirement of *Kharif* Soybean, *Kharif* Greengram, *Rabi* Sorghum, *Summer* Groundnut and Okra crop ignoring effective rainfall by surface irrigation (efficiency: 60, 50 and 40%), sprinkler irrigation at (efficiency: 85 and 80%) and drip irrigation methods (efficiency: 95 and 90%) was calculated for all tehsils and districts of Marathwada region are given in **Annexure I to V**.

Crop planning:

As per the crop planning cultivation of first set of summer crops (Groundnut and Okra) were cultivated in the month of February 2022 and second set of crops Soybean (Sowing date: 20/06/2022, Harvesting date: 13/10/2022) and Green gram (Sowing date: 20/06/2022, Harvesting: 13/09/2022) is completed. The rabi sorghum experimentation is in the filed at present (Sowing date: 26/10/2022).

Investigators:

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