Phase VII Status Report

On

Crop K_c, Water Requirement of *rabi* Gram along with Suitable Shading Factors with different Irrigation Practices

in

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

at

Mahatma Phule Krishi Vidyapeeth, Rahuri

Submitted to

Nanaji Deshmukh Krushi Sanjeevani Prakalp (PoCRA), Mumbai

Title of the project	:	Determination of Crop Coefficients for Major Crops by Lysimetric Studies
Location	:	CAAST-CSAWM Climate Smart Research Block and Experimental Field of AICRP on IWM, Mahatma Phule Krishi Vidyapeeth, Rahuri
Duration	:	2020-2024
Total Outlay	:	Rs. 31.43 Lakhs (Rs. Thirty one lakh fourty three thousand only)
Principal Investigator	:	Dr. A. A. Atre, Professor of SWCE, Dr. ASCAE&T and Procurement Officer, CAAST-CSAWM, and MPKV, Rahuri
Co-Principal Investigator	:	Dr. M. G. Shinde, Professor of SWCE and Co-PI CAAST- CSAWM, MPKV, Rahuri
	:	Dr. S. A. Kadam, Associate Professor of IDE and Member, CAAST-CSAWM, MPKV, Rahuri
Coordinator for the project for three universities (MPKV, Rahuri; Dr. PDKV, Akola and VNMKV, Parbhani)	:	Dr. S. D. Gorantiwar, Head, Dept. of Agril. Engg. and PI, CAAST-CSAWM and, MPKV, Rahuri

1. Introduction

The Project is being executed at Mahatma Phule Krishi Vidyapeeth, Rahuri. This project is undertaken for determination of crop coefficients of *kharif* Sesame, *rabi* Gram and Summer Fodder Bajra. In the second year experiment of *rabi* season, Gram was sown on 30th November, 2022 in the Lysimeter and surrounding area of 0.5 ha. The details Gram variety 'Phule Vikram'; which was sown for the experiment are shown in table 1.

Table 1. Details of Gram Crop.

Scientific Name	*Cicer arietinum L.*
Variety	Phule Vikram
Release year	2016
Name of Institute / University	Mahatma Phule Krishi Vidyapeeth, Rahuri
Soil type requirement	Well drained, medium to deep soils having 45 to 60 cm depth.
Climate requirement	Minimum temperature 10-15ºC, Maximum temperature 25 to 30ºC Rainfall 750 to 1000 mm Humidity 21-41 %.
Optimum Sowing Time / Planting period	Rainfed crop: 20th Sept to 10 Oct Irrigated crop: 20th Oct to 10 Nov Late sown: First week of December Duration: 105-110 Days
Crop Spacing	30 × 10 cm
Seed Rate	75 kg/ha
Productivity	Rainfed: Trial Yield: 16-18, Average yield: 16.00 q/ha Irrigated: Trial Yield: 40-42, Average yield: 22.00 q/ha Late sown: Trial Yield: 22-24, Average yield: 21.00 q/ha
Characters / features	Tall growth habit hence suitable for mechanical harvesting, medium size yellowish brown seeds, wilt resistant, suitable for rainfed, irrigated and late sown conditions, Released for Maharashtra.

2. Estimation of Reference Crop Evapotranspiration (ET_r) by Penman-Monteith Method

Reference crop evapotranspiration (ET_r) during the crop growing season is estimated by using the Penman-Monteith Method using Eqn (1).

$$ET_r = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \ldots (1)$$

Where,

ET_r = Reference evapotranspiration [mm/day],

R_n = Net radiation at the crop surface [MJ/m^2 day],

G = Soil heat flux density [MJ/ m^2 day],

T = Mean daily air temperature at 2 m height [°C],

u_2 = Wind speed at 2 m height [m/s],

e_s = Saturation vapour pressure [kPa],

e_a = Actual vapour pressure [kPa],

e_s - ea = Saturation vapour pressure deficit [kPa],

Δ = Slope vapour pressure curve [kPa/ °C],

g = Psychrometric constant [kPa /°C].

List of different constants and their values used for Rahuri are provided in table 2.

Table 2: Input data and constants required to calculate reference evapotranspiration using Penman-Monteith Method.

Sr. No	Parameter	Weather data as input	Data or constants as input in the absence of local data
1	R_n	R_a = Extra-terrestrial radiation	α = 0.23, a_s = 0.25 and b_s = 0.5
2	G	Mean Temperature	Soil heat capacity, c_s = 2.1 MJ m^{-3} °C^{-1} and Effective soil depth, ΔZ = 0.2m
3	μ_2	Wind speed at 2m height	-
4	T	Min. and Max. Temperature	-
5	e_s	Min., Max. and mean Temperature	-
6	e_a	Min., Max. Temperature and Min., Max. Humidity.	Air humidity correction factor, y = a-b √ea, where, a= 0.34 and b= 0.14

The daily variation of ET_r during crop growing season of Gram is shown in Figure 1. Values of reference evapotranspiration during the crop growing season (30-11-2022 to 18-03-2023) varied from 1.54 to 5.14 mm.

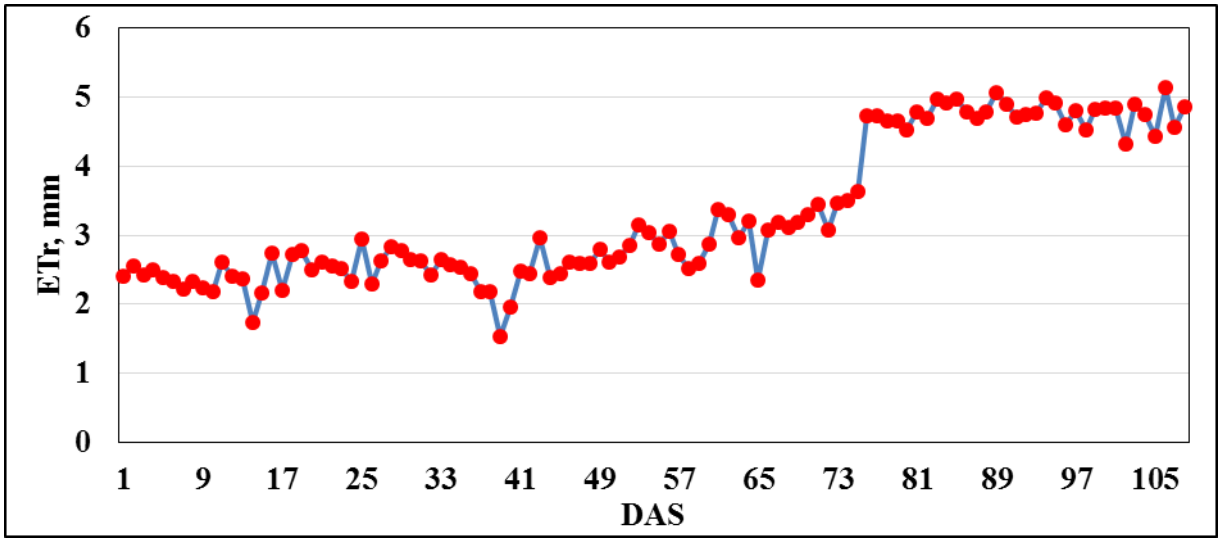

Figure 1: Daily variation of ETr during crop growth period of Gram

3. Crop Evapotranspiration of Gram

Lysimeter is used to measure crop evapotranspiration where the crop grows in isolated tanks filled with soil. Weighing Lysimeters measure crop water used by measuring the change in mass of an isolated volume of soil. Irrigation and precipitation add water and increase the weight of the soil volume and drainage and evapotranspiration removes water and decrease the weight. Water input and output is measured by Water Balance Method and then crop evapotranspiration is calculated. The crop evapotranspiration is estimated by using water balance equation given below.

$$ETc = P + I - \Delta S - D \quad \ldots (2)$$

Where,

ET_c = Crop Evapotranspiration, mm;

P = Precipitation, mm;

I = Irrigation, mm;

ΔS = Change in water storage, mm;

D = Drainage, mm.

Weekly crop evapotranspiration was calculated by summation of daily crop evapotranspiration (mm) from Lysimeter. Weekly variation of crop evapotranspiration (mm) of Gram is shown in Table 3.

Table 3: Weekly Crop Evapotranspiration (ET_c) observed from Lysimeter

Meteorological Week	Crop Week	ET_c, mm
48	1	4.55
49	2	4.30
50	3	6.32
51	4	10.17
52	5	13.43
1	6	13.47
2	7	14.50
3	8	16.64
4	9	22.75
5	10	26.71
6	11	26.97
7	12	26.00
8	13	25.34
9	14	16.19
10	15	7.10
11	16	4.84
Total		**239.3**

4. Crop Coefficient of Gram

The crop coefficient K_c is estimated as the ratio of actual crop evapotranspiration to reference crop evapotranspiration using Eqn (3). Table 4 shows the values of weekly K_c computed by taking ratio of crop evapotranspiration to reference evapotranspiration.

$$K_c = ET_c / ET_r \quad \ldots (3)$$

Where,

K_c = Crop Coefficient

ET_c = Crop Evapotranspiration

ET_r = Reference Crop Evapotranspiration

Table 4: Crop Coefficients of *rabi* Gram

Meteorological Week	Crop Week	Weekly ETr (mm)	Weekly ET_c (mm)	Weekly K_c
48	1	17.22	4.55	0.26
49	2	16.1	4.30	0.26
50	3	15.89	6.32	0.39
51	4	18.06	10.17	0.56
52	5	18.27	13.43	0.73
1	6	17.99	13.47	0.74
2	7	16.52	14.50	0.87
3	8	18.13	16.64	0.91
4	9	19.53	22.75	1.16
5	10	21.42	26.71	1.24
6	11	23.66	26.97	1.14
7	12	26.67	26.00	0.97
8	13	33.04	25.34	0.76
9	14	33.46	16.19	0.48
10	15	32.76	7.10	0.21
11	16	28.64	4.84	0.17

5. Development of Polynomial Equation to derive Daily K_c

The weekly K_c values were estimated for Gram as the ratio of crop evapotranspiration (ET_c) to the reference evapotranspiration (ET_r) estimated by Penman-Monteith method over crop growth period.

The polynomial equations of second, third, fourth and fifth orders can be fitted to calculate daily K_c, with K_c as the dependent variable and (t/T) as the independent variable. The best fit polynomial equation can be selected based on maximum R^2.

Forms of second, third, fourth and fifth order polynomial equation are:

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

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

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

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

Where,

Kc_t =crop coefficient of t^{th} day.

a_0, a_1, a_2…..= constants of equations.

t = day considered after sowing.

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

Thus, by considering weekly K_c values given in the table 4, K_c curve was developed by using methodology as discussed above. Figure 2 shows the K_c curve of polynomial equation of fourth order having coefficient of determination (R^2) equal to 0.95. Daily K_c values derived by using the developed K_c curve are given in the Appendix – A.

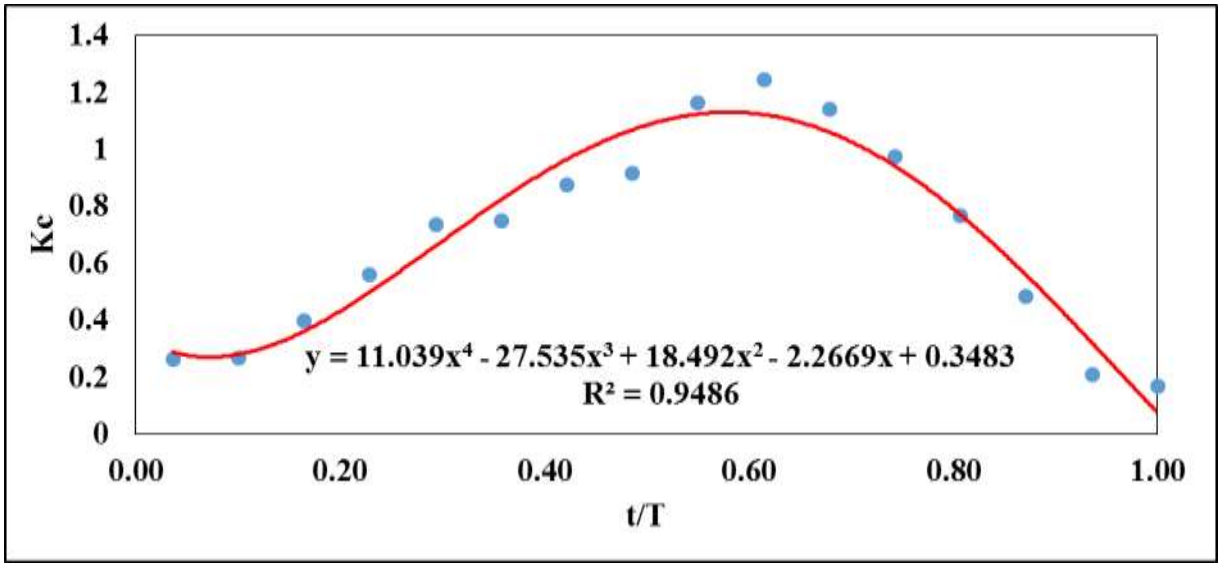

Figure 2. Crop Coefficient Curve developed using weekly crop coefficients for Gram

Daily K_c values were converted into stage wise K_c values as given in the Table 5 below. The calculated K_c values for Gram during initial, development, mid and end stage were 0.34, 0.81, 1.09 and 0.28 respectively. Whereas stage wise K_c values calculated according to FAO-56 are 0.4, 0.7, 1.00 and 0.35 for respective stages.

Table 5: Stage wise FAO-56 Kc values and Local Kc values derived from polynomial equation

Stage	Local Kc	Kc Derived from FAO - 56
Initial	0.34	0.40
Development	0.81	0.70
Mid	1.09	1.00
End	0.28	0.35

6. Irrigation water requirement using locally derived Kc values for Gram for Western Maharashtra Region

To calculate crop and irrigation water requirement of Gram using weekly K_c values for western Maharashtra, meteorological data for 22 Agricultural Research Stations was used for estimation of reference crop evapotranspiration by Hargreaves - Samani Method. As the data of minimum and maximum temperature were available for all these stations (Table 6). Reference evapotranspiration was calculated by using Phule Jal with minimum and maximum temperature and latitude of these stations as input parameter.

After the calculations of reference evapotranspiration for 22 weather stations, weekly values were interpolated over entire Western Maharashtra by Inverse Distance Weight (IDW) method using ArcMap which were then multiplied by respective crop coefficients obtained from Lysimetric Studies. As a result, weekly maps of crop water requirement were produced for Western Maharashtra from which taluka wise weekly crop water requirement was extracted using Geo-statistical Analysis tool in ArcMap. As Gram is close growing row crop, the shading factor is considered as 1.

Taluka wise weekly crop water requirement is converted into irrigation water requirement for surface irrigation by considering 40, 50 and 60 per cent efficiency, by sprinkler irrigation 80 and 85 per cent efficiency and by drip irrigation 90 and 95 per cent efficiency. Taluka wise crop water requirement and irrigation water requirement of 10 districts of Western Maharashtra *Viz*. Ahmednagar, Dhule, Jalgaon, Kolhapur, Nandurbar, Nashik, Pune, Sangli, Satara and Solapur are given in Appendix-B.

Table 6: List of Agricultural Research Station for which meteorological data was obtained

Sr. No.	Zone	Name of Agricultural Research Station and Location
1.	Western Ghat Zone	Zonal Agricultural Research Station, Igatpuri Dist. Nashik
2.		Agricultural Research Station, Lonavala Dist. Pune
3.		Agricultural Research Station, Radhanagari, Dist. Kolhapur
4.		Regional Wheat Rust Research Station, Mahabaleshwar, Dist. Satara
5.	Sub-Montane Zone	Zonal Agricultural Research Station, Shenda Park, Kolhapur
6.		Agricultural Research Station, Karad
7.		Agricultural Research Station, Vadgaon Maval
8.		Agricultural Research Station, Gadhinglaj
9.	Plain Zone	Zonal Agricultural Research Station, Ganeshkhind, Pune
10.		Agriculture Research Station Niphad, Dist. Nashik
11.		Agriculture Research Station Kasbe Digraj, Dist. Sangli
12.		Agriculture Research Station, Pimpalgaon Baswant, Dist. Nashik
13.		College of Agriculture, Pune
14.	Scarcity Zone	Zonal Agriculture Research Station, Solapur
15.		Central Sugarcane Research Station, Padegaon
16.		Agriculture Research Station, Mohol
17.		Pulse and Oilseed Research and Training Center, Pandharpur
18.		Agriculture Research Station, Jeur
19.		Agriculture Research Station, Savalvihir
20.		Agriculture Research Station, Chas
21.		Agriculture Research Station, Dhule
22.	Central Plateau Zone	Oil Seed Research Station, Jalgaon

7. Photographs taken during experiment (30th November, 2022 to 18th March, 2023).

Gram Crop at Initial Growth Stage

Gram Crop at Development Stage

View of Gram in Field in and around Lysimeter

Gram in Lysimeter before Harvesting

8. Yield Data of Gram

The total yield obtained from the experiment is 510 kg from 0.5 ha with rate of production 10.2 q/ha. The Gram produced in the experiment was provided to CAAST-CSAWM, MPKV, Rahuri on gratis.

9. Expenditure statement till 30th September, 2023

Table 7: Expenditure statement till 30th September, 2023

Sr. No.	Head wise Expenditure	Amount, Rs.
1.	**Human Resources**	
a)	SRF	445610.00
b)	Field Assistant	175277.00
	Subtotal	**620887.00**
2.	**Recurrent Expenditure**	
a)	Farm input	51069.00
b)	Travelling	14760.00
c)	Stationery and other contingencies	21131.00
d)	Contractual labours	162015.00
	Subtotal	**248975.00**
	Total expenditure till 30th September, 2023	**869862.00**
	Released Grant	**1420070.00**
	Balance	**550208.00**

Appendix – A

Daily K_c Values for *rabi* Gram Derived from Kc Curve

DAS	K_c	DAS	K_c	DAS	K_c
1	0.327	41	0.859	81	0.959
2	0.311	42	0.880	82	0.938
3	0.298	43	0.900	83	0.917
4	0.288	44	0.920	84	0.894
5	0.280	45	0.939	85	0.871
6	0.275	46	0.957	86	0.846
7	0.272	47	0.975	87	0.821
8	0.271	48	0.992	88	0.794
9	0.272	49	1.008	89	0.767
10	0.276	50	1.023	90	0.739
11	0.281	51	1.037	91	0.710
12	0.288	52	1.051	92	0.680
13	0.296	53	1.063	93	0.649
14	0.306	54	1.075	94	0.618
15	0.318	55	1.085	95	0.586
16	0.331	56	1.095	96	0.553
17	0.345	57	1.103	97	0.520
18	0.361	58	1.110	98	0.487
19	0.377	59	1.117	99	0.453
20	0.395	60	1.122	100	0.418
21	0.413	61	1.126	101	0.383
22	0.433	62	1.129	102	0.348
23	0.453	63	1.130	103	0.312
24	0.474	64	1.131	104	0.277
25	0.495	65	1.130	105	0.241
26	0.517	66	1.129	106	0.205
27	0.539	67	1.126	107	0.169
28	0.562	68	1.121	108	0.133
29	0.585	69	1.116	109	0.098
30	0.608	70	1.109	110	0.062
31	0.631	71	1.102		
32	0.655	72	1.093		
33	0.678	73	1.082		
34	0.702	74	1.071		
35	0.725	75	1.058		
36	0.748	76	1.045		
37	0.771	77	1.030		
38	0.793	78	1.014		
39	0.816	79	0.997		
40	0.837	80	0.978		