Phase VIII Status Report

On

Crop K_c, Water Requirement of Summer Fodder Bajra 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 and Head, Deptt. of SWCE, Dr. ASCAE&T, MPKV, Rahuri
Co-Principal Investigator	:	Dr. M. G. Shinde, Professor of SWCE, Dept. of Agril. Engg., MPKV, Rahuri
	:	Dr. S. A. Kadam, Associate Professor of IDE, Dept. of Agril. Engg., MPKV, Rahuri
Coordinator for the project for three universities (MPKV, Rahuri; Dr. PDKV, Akola and VNMKV, Parbhani)	:	Dr. S. D. Gorantiwar, Director of Research and Head, Dept. of Agril. Engg., 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 summer season, Fodder Bajra was sown on 23rd March, 2023 in the Lysimeter and surrounding area of 0.5 ha. The details of Fodder Bajra variety 'Giant Bajra'; sown for the experiment are given in Table 1.

Table 1. Details of Fodder Bajra Crop.

Common Name	Fodder Bajra
Scientific Name	*Pennisetum glaucum L.*
Variety	Giant Bajra
Release year	1980
Name of Institute / University	Mahatma Phule Krishi Vidyapeeth, Rahuri
Soil type requirement	Light to medium well drained soil
Climate requirement	*kharif* and summer
Optimum Sowing Time / Planting period	*kharif*: June- July, Summer: February- March
Crop Duration	1st cut: 50 to 55 days after sowing 2nd cut: 40 to 45 days after first cut
Seed Rate	10 kg/ha
Productivity	45 to 50 t/ha
Characters / features	Plant type - Tall (250-300 cm height) with profuse tillering Leaves - High leafiness Stem - Juicy Crude Protein: 8 to 9 %

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 [Eq (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].

The daily variation of ET_r during crop growing season of fodder Bajra is shown in Figure 1. Values of reference evapotranspiration during the crop growing season (23-03-2023 to 22-06-2023) varied from 3.24 to 8.21 mm with average ETr of 5.55 mm.

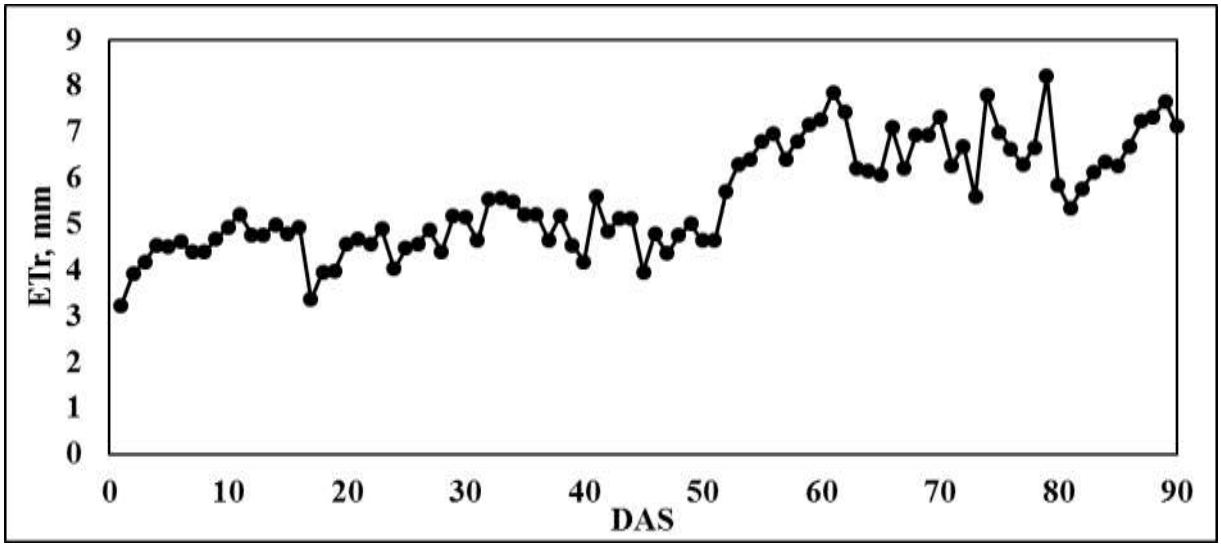

Figure 1: Daily variation of ETr during crop growth period of Fodder Bajra

3. Crop Evapotranspiration of Fodder Bajra

Lysimeter is used to measure crop evapotranspiration where the crop is grown 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 using water balance method [Eq. (1)].

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

Where,

ET_c = Crop Evapotranspiration, mm;

P = Precipitation, mm;

I = Irrigation, mm;

ΔS = Change in water storage, mm;

D = Drainage, mm.

Daily variation of crop evapotranspiration (mm) of Fodder Bajra is shown in Figure 2.

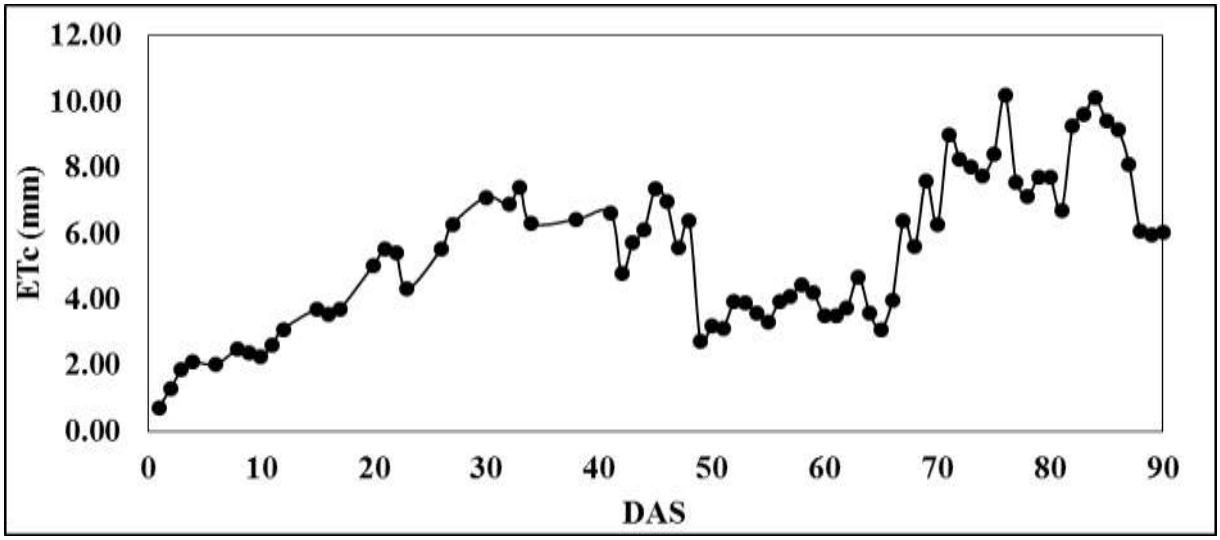

Figure 2: Daily variation of ETc during crop growth period of Fodder Bajra

4. Crop Coefficient of Fodder Bajra and development of Kc curve

The daily Kc values were estimated for Fodder Bajra as the ratio of crop evapotranspiration (ETc) to the reference evapotranspiration (ETr) estimated by Penman-Monteith method over crop growth period using Eq (3).

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

Where,

K_c = Crop Coefficient

ET_c = Crop Evapotranspiration

ET_r = Reference Crop Evapotranspiration

The polynomial equations of second, third, fourth and fifth orders are 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 is selected based on maximum R^2.

The different forms of second, third, fourth and fifth order polynomial equation are as below:

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

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

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

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

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 crop growth period from sowing to harvesting (days)

In this experiment, involving the 'Giant Bajra' variety, two cuts were taken. The first cut was taken at 49 days after sowing, while the second cut was made at 42 days after the first cut. Two crop coefficient (Kc) curves were developed for this Fodder Bajra variety, considering standard harvesting time and protocol.

Figure 3 and 4 shows the Kc curves along with polynomial equation before first cut (1 to 49 DAS) and after first cut (50 to 90 DAS), respectively. Forth order polynomial equations with R^2 of 0.92 and 0.90 were fitted to estimate Kc values before the first cut (Eqn. 4) and after the first cut (Eq. 5), respectively. Daily Kc values derived by using these polynomial equations are given in the Appendix – A.

$$K_{ct} = 92.687(t/T)^4 - 133.21(t/T)^3 + 53.696(t/T)^2 - 3.3898(t/T) + 0.4131 \quad \text{.....(4)}$$

$$K_{ct} = -69.479(t/T)^4 + 145.09(t/T)^3 - 88.213(t/T)^2 + 9.0508(t/T) + 4.478 \quad \text{.....(5)}$$

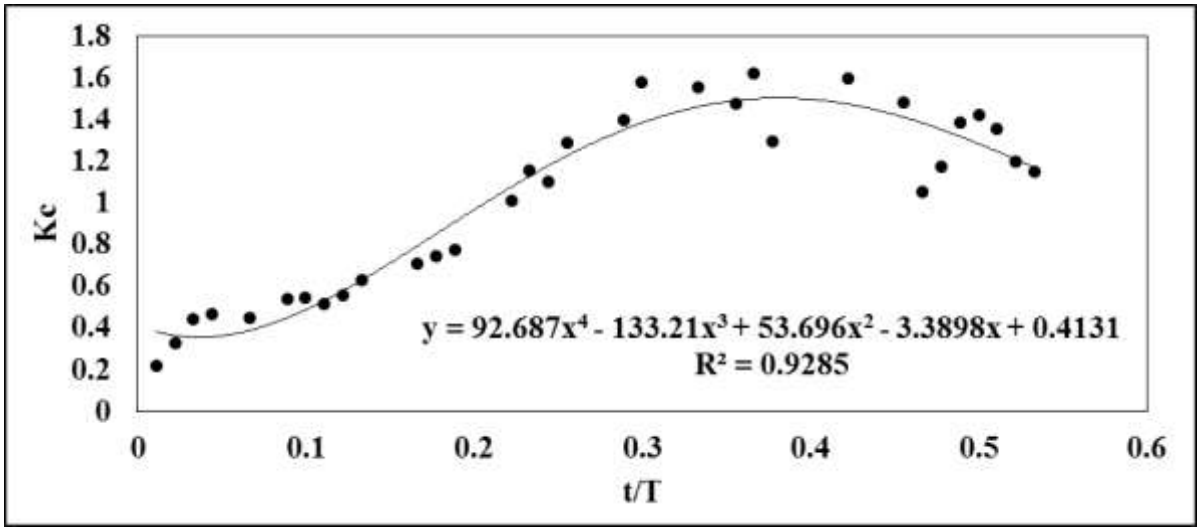

Figure 3. Kc curve for Fodder Bajra before first cut (i.e. 1 to 49 DAS)

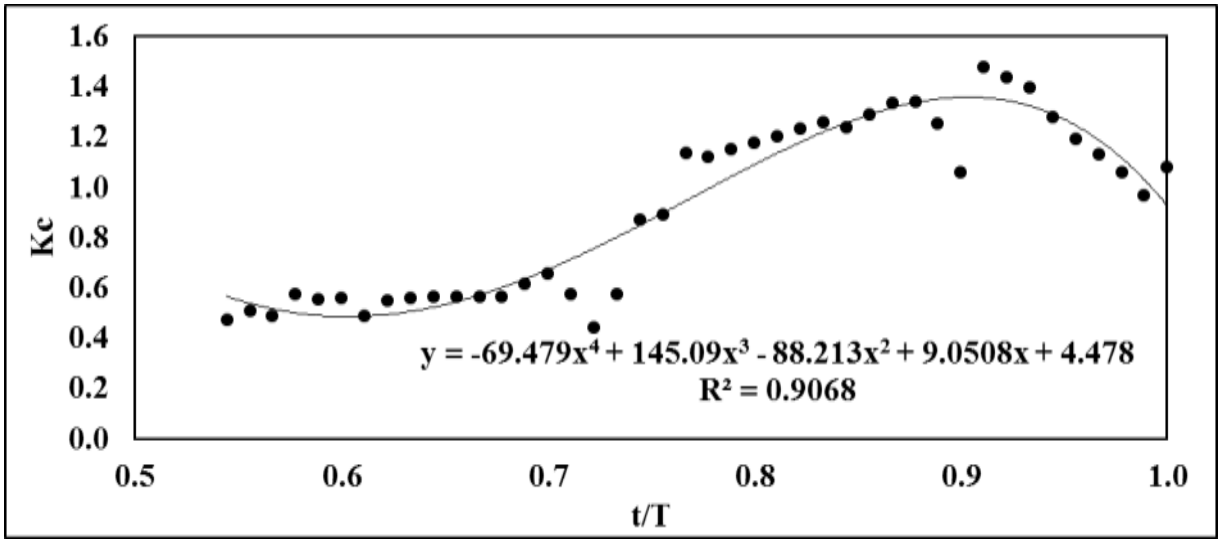

Figure 4. Kc curve for Fodder Bajra after first cut (i.e. 50 to 90 DAS)

5. Estimation of weekly crop coefficient and crop water requirement

Weekly Kc and crop water requirement (mm) are given Table 2 and stage wise Kc values are given in Table 3.

Table 2: Weekly Crop Coefficients and crop water requirement (mm) of Fodder Bajra at Rahuri

Before First Cut				After First Cut			
CW	**ETr (mm)**	**Kc**	**ETc (mm)**	**CW**	**ETr (mm)**	**Kc**	**ETc (mm)**
1	29.4	0.376	11.0	8	41.5	0.503	20.8
2	33.7	0.585	19.7	9	49.2	0.580	28.5
3	30.3	0.964	29.2	10	46.8	0.851	39.8
4	31.8	1.304	41.5	11	46.3	1.173	54.3
5	36.8	1.481	54.4	12	44.3	1.340	59.3
6	34.2	1.449	49.6	13	49.4	1.133	56.0
7	33.1	1.164	38.6				

Table 3: Stage wise Kc values derived from polynomial equation

Stage	**Duration (Days)**	**Crop Coefficients**	
		Before first Cut	**After First Cut**
Initial	21	0.64	-
Development	28	1.34	0.77
Mid	14	-	1.24
End*	-	-	-

* Bajra was harvested as green fodder, and was not allowed to dry. Therefore end stage was not considered in this experiment.

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

To calculate crop and irrigation water requirement of Fodder Bajra 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 4). Reference evapotranspiration was calculated by using Phule Jal with minimum and maximum temperature and latitude of these stations as input parameters.

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 to obtain from Lysimetric Studies. As a result, weekly maps of crop water requirement were developed for Western Maharashtra from which taluka wise weekly crop water requirement was extracted using Geo-statistical Analysis tool in ArcMap. As Fodder Bajra is close growing row crop, the shading factor is considered as 1 while calculating crop water requirement.

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 4: 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 (23rd March, 2023 to 22nd June, 2023).

Fodder Bajra Crop at Initial Growth Stage

Fodder Bajra Crop at Development Stage

Fodder Bajra in Lysimeter at the time of first cut

Fodder Bajra immediately after first cut

Growth of Fodder Bajra after first cut

Growth of Fodder Bajra at the time of second cut

8. Yield Data of Fodder Bajra

The production of Fodder Bajra was produced is 1.3257 t from Lysimeter and surrounding area. The Fodder Bajra produced was provided to Organic Farming Research and Training Centre, MPKV, Rahuri on gratis, as cattle feed.

9. Expenditure statement till 31st December, 2023

Table 5: Expenditure statement till 31st December, 2023

Sr. No.	Head wise Expenditure	Amount, Rs.
1.	**Human Resources**	
a)	SRF	5,48,790/-
b)	Field Assistant	2,09,944/-
	Subtotal	**7,58,734/-**
2.	**Recurrent Expenditure**	
a)	Farm input	1,43,288/-
b)	Travelling	14,760/-
c)	Stationery and other contingencies	48,731/-
d)	Contractual labours	2,39,719/-
	Subtotal	**4,46,498/-**
	Total expenditure till 31st December, 2023	**12,05,232/-**
	Released Grant	**19,84,743/-**

Appendix – A

Daily K_c Values for summer Fodder Bajra Derived from Kc Curve

DAS 1 to 49: Before first Cut				DAS 50 to 90: After First Cut			
DAS	**Kc**	**DAS**	**Kc**	**DAS**	**Kc**	**DAS**	**Kc**
1	0.011	26	0.289	50	0.540	75	1.219
2	0.022	27	0.300	51	0.517	76	1.256
3	0.033	28	0.311	52	0.501	77	1.288
4	0.044	29	0.322	53	0.491	78	1.315
5	0.056	30	0.333	54	0.487	79	1.336
6	0.067	31	0.344	55	0.488	80	1.350
7	0.078	32	0.356	56	0.495	81	1.357
8	0.089	33	0.367	57	0.507	82	1.355
9	0.100	34	0.378	58	0.524	83	1.344
10	0.111	35	0.389	59	0.545	84	1.323
11	0.122	36	0.400	60	0.571	85	1.290
12	0.133	37	0.411	61	0.602	86	1.246
13	0.144	38	0.422	62	0.636	87	1.188
14	0.156	39	0.433	63	0.673	88	1.116
15	0.167	40	0.444	64	0.714	89	1.030
16	0.178	41	1.410	65	0.757	90	0.927
17	0.189	42	1.383	66	0.802		
18	0.200	43	1.352	67	0.849		
19	0.211	44	1.319	68	0.897		
20	0.222	45	1.284	69	0.945		
21	0.233	46	1.247	70	0.994		
22	0.244	47	1.209	71	1.043		
23	0.256	48	1.169	72	1.090		
24	0.267	49	0.568	73	1.135		
25	0.278			74	1.179		