Phase V Status Report

On

Crop Kc, 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

Title of the project	:	Determination of Crop Coefficients for Major Crops by Lysimetric Studies
Location	:	CAAST-CSAWM Climate Smart Research Block, Mahatma Phule Krishi Vidyapeeth, Rahuri
Duration	:	Three years (2020-2023)
Total Outlay	:	Rs. 31.43 Lakhs (Rs. Thirty one lakh fourty three thousand only)
Principal Investigator	:	Dr. A. A. Atre, Professor of SWCE and CAAST-CSAWM, Member and Dr. ASCAE&T, 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, 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 on "Determination of Crop Coefficients for Major Crops by Lysimetric Studies" 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 summer season after harvesting of *Rabi* Gram from only one Lysimeter and surrounding area, fodder Bajra was sown on 12th April, 2022 in the Lysimeter and surrounding area of 0.5 ha. Table 1 shows the various details of Fodder Bajra.

Table 1. Details of Fodder Bajra.

Scientific Name	*Pennisetum glaucum*
Variety	Giant Bajra
Release year	1980
Name of Institute / University	Mahatma Phule Krishi Vidyapeeth, Rahuri
Soil type	Light to medium well drained soil
Climate	*Kharif* and summer
Optimum Sowing Time / Planting period	Kharif: June- July, Summer: February- March
Seed Rate	10 kg/ha
Productivity	450 to 500 q/ha
Characters / features	Plant type - Tall plants (250-300cm) with profuse tillering Leaves - High leafiness Stem - Juicy Crude Protein: 8 to 9 %

2. Estimation of Reference Crop Evapotranspiration ETr Estimation by Penman-Monteith Method

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

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

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].

Values of reference evapotranspiration during the crop duration from 12-04-2022 to 23-07-2022 varied between 2.14 to 7.56 mm. The daily variation of ETr during crop period is shown in figure 1.

Table No. 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	$\alpha = 0.23$, $a_s = 0.25$ 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, $\Delta Z = 0.2$m
3	μ_2	Wind speed at 2m height	Data Collected from IMD observatory
4	T	Min. and Max. Temperature	Data Collected from IMD observatory
5	e_s	Min., Max. and mean Temperature	Data Collected from IMD observatory
6	e_a	Min., Max. Temperature and Min., Max. Humidity.	Air humidity correction factor, $y = a\text{-}b\sqrt{ea}$ where, a= 0.34 and b= 0.14

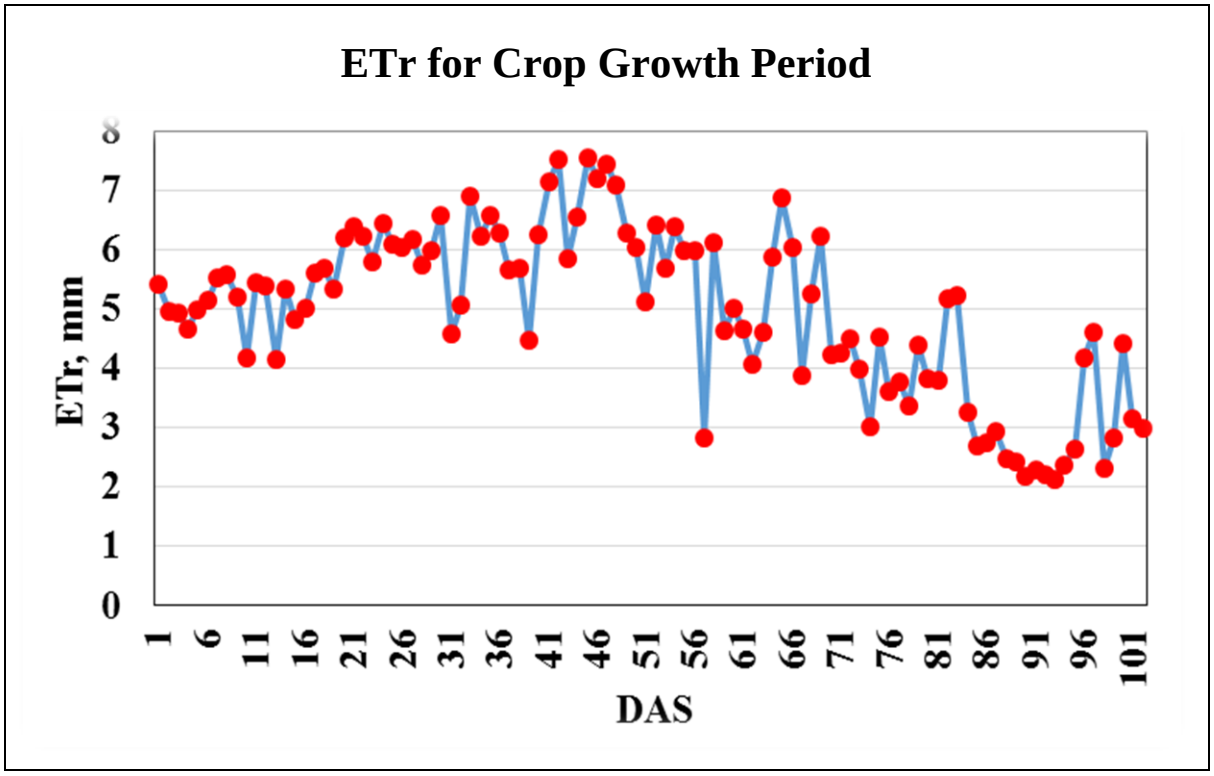

Figure 1: Daily variation of ETr during crop growth period of Fodder Bajra

3. Crop Coefficient (K_c) of Gram

Lysimeter is used to measure crop evapotranspiration where the crop grows in isolated tanks filled with either disturbed or undisturbed 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 water output is measured by water balance method and then crop evapotranspiration is calculated. The crop coefficient K_c is defined as the ratio of actual crop evapotranspiration to reference crop evapotranspiration.

$$ETc = P + I - \Delta S - D \qquad \text{Eqn… (2)}$$

Where,

P = Precipitation, mm; ΔS = Change in water storage, mm;
I = Irrigation, mm; D = Drainage, mm.

Daily variation of crop water requirement (mm) of Fodder Bajra is shown in the figure 2. Weekly crop evapotranspiration was calculated by addition of daily crop evapotranspiration (mm) from lysimeter. Table 3 shows weekly crop water requirement and reference crop evapotranspiration for Fodder Bajra and K_c values computed using them.

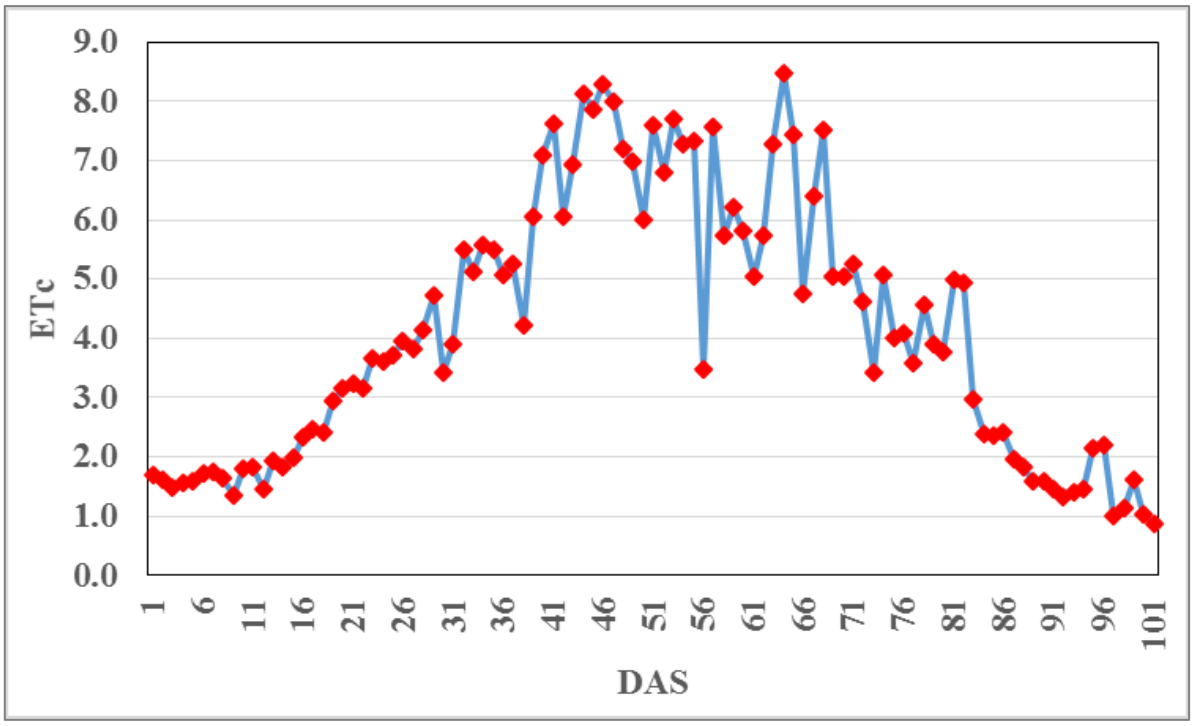

Figure 2: Daily variation of ETc of Fodder Bajra obtained from Lysimeter

Table 3: Weekly ETc, ETr and Kc values of Fodder Bajra during 12/04/2022 and 23/07/2022.

CW	Weekly Crop Water Requirement, ETc (mm)	Reference Crop Evapotranspiration, ETr (mm)	Local Kc Values
CW1	11.37	35.64	0.32
CW2	12.10	35.29	0.34
CW3	17.92	39.09	0.45
CW4	26.21	42.56	0.62
CW5	33.49	41.94	0.80
CW6	41.79	43.02	0.97
CW7	53.27	47.99	1.11
CW8	50.12	41.63	1.20
CW9	39.61	31.93	1.24
CW10	46.61	38.39	1.21
CW11	31.05	27.69	1.12
CW12	27.98	29.06	0.97
CW13	13.59	17.79	0.76
CW14	10.27	20.48	0.51
CW15	3.38	13.4	0.33
CW16	11.37	35.64	0.32

***CW: Crop Week**

The calculated K_c values for Fodder Bajra during initial, development, mid and end stage were 0.37, 0.87, 1.15 and 0.53, respectively. Whereas stage wise K_c values calculated according to FAO-56 are 0.30, 0.64, 1.01 and 0.64 for respective stages. The average weekly K_c values for Fodder Bajra ranged between 0.32 (initial stage) and 1.24 (mid stage) during its crop growth period. The maximum values of crop coefficient were estimated during mid-stage mainly because of higher canopy. Figure 3 represents the weekly Kc values during crop growth period of Fodder Bajra.

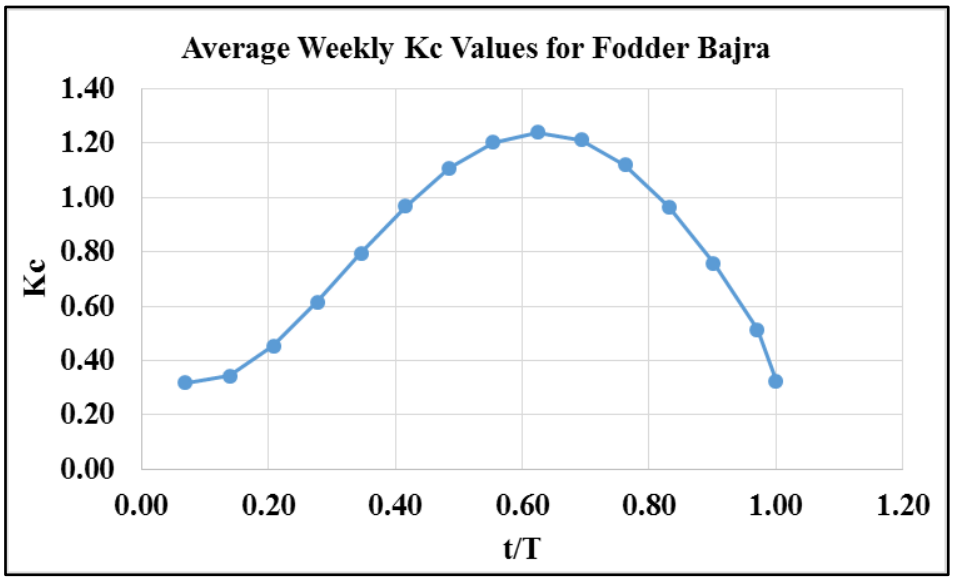

Figure 3: Weekly Kc values of Fodder Bajra during crop growth period

Table 4: Weekly local and FAO derived Kc values of Gram

CW	Weekly Kc from lysimeter	Crop growth stages	Stage wise Local Kc Values	Stage Wise FAO Kc Values
1	0.32	Initial - 21 Days	0.37	0.3
2	0.34			
3	0.45			
4	0.62	Crop Development - 28 days	0.87	0.64
5	0.80			
6	0.97			
7	1.11			
8	1.20	Mid-Season - 35 Days	1.15	1.01
9	1.24			
10	1.21			
11	1.12			
12	0.97			
13	0.76	End Season - 21 Days	0.53	0.64
14	0.51			
15	0.33			

4. Development of Polynomial Equation to derive Daily K_c

The Kc values were estimated for fodder bajra as the ratio of crop evapotranspiration (ET_c) under no water stress condition to the reference evapotranspiration (ET_r) estimated by Penman Monteith method over a specified period.

$$K_c = ET_c / ET_r \qquad \text{Eqn… (3)}$$

The polynomial equations of third, fourth and fifth orders were fitted with K_c as the dependent variable and (t/T) as the independent variable. These are:

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

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

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

Where,

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

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

t = day considered.

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

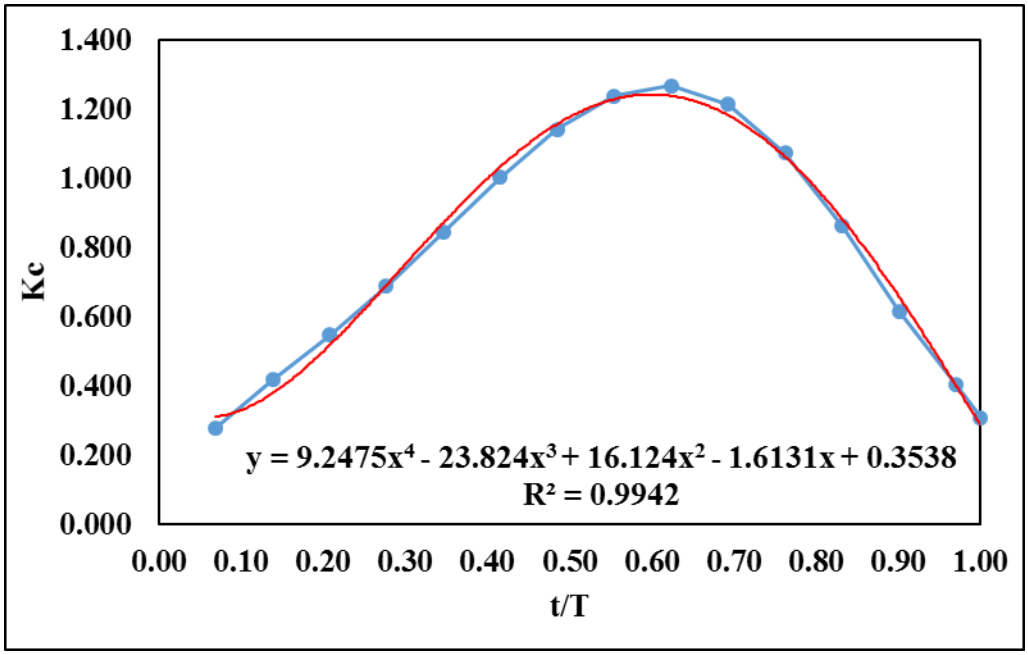

Figure 4. Polynomial Curve obtained from weekly K_c values

Equation No. 5 given below and also shown in figure 4 is obtained from weekly K_c values against 't/T' with coefficient of determination (R^2) equal to 0.99 was used to derive daily Kc values. The daily values of crop coefficient of Fodder Bajra are given in Appendix A.

$$y = 9.2475x^4 - 23.824x^3 + 16.124x^2 - 1.6131x + 0.3538 \quad \text{Eqn… (5)}$$

Figure 5 shows the comparison between polynomial curve obtained from local and FAO K_c values. Clearly the local K_c values are greater than FAO K_c values which indicated higher water requirement of Fodder Bajra considering local conditions.

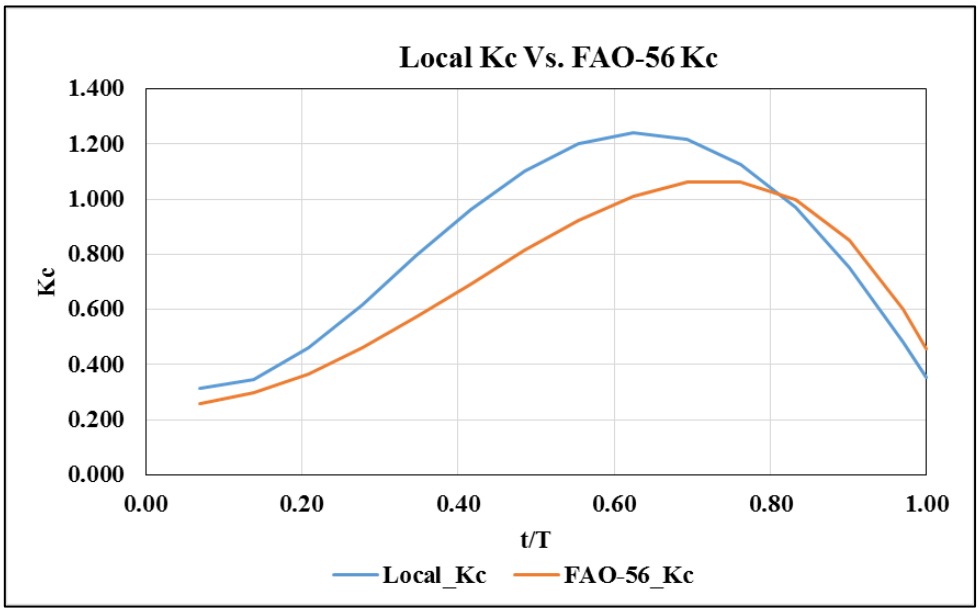

Figure 5. Comparison between polynomial curve obtained from local and FAO derived K_c values

5. Irrigation Water Requirement using locally derived Kc values for Fodder Bajra for Western Maharashtra Region

To calculate crop and irrigation water requirement using weekly K_c values for western Maharashtra, observed meteorological data from 22 Agricultural Research Stations (listed below in table 5) under jurisdiction of MPKV, Rahuri was obtained from Head, Department of Agricultural Meteorology, College of Agriculture, Pune.

The data obtained from these stations were checked for uniformity in data in terms of all weather parameters required for calculation of Reference Evapotranspiration by Penman-Monteith method. However, six weather parameters required for determination of Reference evapotranspiration by Penman-Monteith method were not available for all meteorological stations. As the data of minimum and maximum temperature were available for all these stations, Hergreaves-Samani method was chosen for calculating reference evapotranspiration for these stations. Reference evapotranspiration was calculated using Phule Jal using minimum and maximum temperature and latitude of these stations. The detail methodology for calculation of reference evapotranspiration in FAO Irrigation and Drainage Paper No. 56

After the calculations of reference evapotranspiration, 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 Fodder Bajra is close growing row crop, the suitable shading factor is considered as 1.

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

Table 5: List of Agricultural Research Station from 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

6. **Photographs taken during experimental period from 12th April, 2022 to 23rd July, 2022.**

Fodder Bajra Crop at development stage

View of Fodder Bajra in Field around Lysimeter

General View of Fodder Bajra Field

Fodder Bajra Crop at harvesting stage in and around lysimeter

7. Yield Data of Fodder Bajra

The data on yield of fodder bajra from lysimeter and surrounding area are tabulated in table 6. The seed was provided by Grass and Forage Scheme, MPKV, Rahuri on gratis. The fodder bajra produced in the experiment was supplied as a feed to dairy animals of Department of Animal Husbandry and Dairy Science on gratis.

Table 6: Yield of Fodder Bajra in Lysimeter and surrounding field

Particular	Production	Area	Yield per unit area
Lysimeter Yield	16.71 kg	2.25 m^2	740.67 q/ha
Yield from Surrounding Field	6800 kg	5000 m^2	136 q/ha

8. Expenditure statement till 28th February, 2023

Table 7: Expenditure statement till 28th February, 2023

Sr. No.	Head wise Expenditure	Amount, Rs.
1.	**Human Resources**	
a)	SRF	223960.00
b)	Field Assistant	110323.00
	Subtotal	**334283.00**
2.	**Recurrent Expenditure**	
a)	Farm input	16581.00
b)	Travelling	0.00
c)	Stationery and other contingencies	12415.00
d)	Contractual labours	103009.00
	Subtotal	**132005.00**
	Total expenditure till February, 2023	**466288.00**
	Released Grant	**855399.00**
	Balance	**389111.00**

Appendix – A

Daily K_c Values for Summer Fodder Bajra

DAS	Kc	DAS	Kc	DAS	Kc
1	0.339	36	0.898	71	1.170
2	0.328	37	0.922	72	1.155
3	0.319	38	0.946	73	1.139
4	0.314	39	0.969	74	1.122
5	0.311	40	0.992	75	1.104
6	0.310	41	1.013	76	1.084
7	0.312	42	1.035	77	1.063
8	0.316	43	1.055	78	1.041
9	0.322	44	1.075	79	1.017
10	0.330	45	1.093	80	0.993
11	0.340	46	1.111	81	0.967
12	0.352	47	1.128	82	0.941
13	0.365	48	1.143	83	0.913
14	0.380	49	1.158	84	0.884
15	0.396	50	1.172	85	0.855
16	0.414	51	1.184	86	0.824
17	0.433	52	1.196	87	0.792
18	0.453	53	1.206	88	0.760
19	0.474	54	1.215	89	0.727
20	0.496	55	1.223	90	0.693
21	0.519	56	1.229	91	0.659
22	0.542	57	1.235	92	0.623
23	0.566	58	1.239	93	0.588
24	0.591	59	1.241	94	0.551
25	0.616	60	1.243	95	0.515
26	0.641	61	1.243	96	0.477
27	0.667	62	1.242	97	0.440
28	0.693	63	1.239	98	0.402
29	0.719	64	1.235	99	0.364
30	0.745	65	1.230	100	0.326
31	0.771	66	1.223	101	0.288
32	0.797	67	1.215		
33	0.822	68	1.206		
34	0.848	69	1.195		
35	0.873	70	1.183		