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Estimation of crop coefficient values of soybean (*Glycine max* (L.) Merril) cv. MAUS-71 by using lysimeter

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Abstract
A ratio of crop evapotranspiration (ETc) to reference evapotranspiration (ETO) determines a crop coefficient (Kc) value, which is related to specific crop phenological development to improve transferability of the Kc values. Development of Kc can assist in predicting crop irrigation needs using meteorological data from weather stations. The objective of the research was conducted to determine crop coefficient values of the soybean crop at research farm of Department of Agricultural Meteorology, College of Agriculture, and Parbhani during the *Kharif* season 2020-21. The research field was laid out in split-plot design with three replications and two factors *viz*. dates of sowing D_1 (25^{th} MW), D_2 (26^{th} MW), D_3 (27^{th} MW), and D_4 (28^{th} MW) and varieties V_1 (MAUS-158), V_2 (MAUS-71), and V_3 (JS-335). The total water requirement of the crop (ETc) was estimated during the life cycle of the crop was 546.4 mm. The Kc values were estimated to be 0.84, 1.33, and 1.60 for the initial, mid and final stage respectively.

Keywords: Crop coefficient, lysimeter, soybean, thermal indices, potential evapotranspiration

1. Introduction
Soybean was introduced in India from China in the tenth century. At present, India ranks fifth within the area and production within the world after the USA, Brazil, Argentina, and China.
Soybean is the most important annual legume crop that belongs to the family Leguminosae native to East Asia. Soybean is also known as 'Wonder Crop' and 'Gold of Century'. It is an important source of human dietary protein with an average of 40% content, 30% carbohydrate and oil content of 20%, 9% of water, and 5% ash (Anonymous 2005) [2].
The crop coefficient (Kc) is the ratio of the crop ETc to the reference ETO. The crop coefficient is estimated by using a weighing type field lysimeter and quantifying the actual reference crop evapotranspiration during different crop growth stages. The determination of daily crop evapotranspiration and computation of crop coefficients at different crop growth stages assist in proper irrigation scheduling and judicious water management in agriculture (Martins *et al*., 2013) [8].
In India, limited lysimeter studies on the measurement of ET for soybean crops were carried out by many researchers in different regions. Maniyar *et al.* (2010) [7] established the measured value of ET by lysimeter and estimate potential ET by different empirical formulae for soybean under the Marathwada region at Parbhani (Maharashtra).
With the above consideration, a field trial for "Estimation of crop coefficient of soybean (*Glycine max*) cv. MAUS-71 by using lysimeter" is proposed during *Kharif* season of 2020 at experimental farm, Department of Agricultural Meteorology, VNMKV, Parbhani (M.S.), India with the following objective:
To find out the crop co-efficient values of soybean cv. MAUS-71.

2. Materials and Methods
The datasets for this study were obtained from field research conducted during Kharif season 2020-21. The experimental field is located at Department of Agricultural Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (76° 46' E longitude; 19° 16' N latitude and 409 m altitude above MSL). The climate at center is described as semiarid with cold dry winter, hot and dry summer, and wet humidity with average temperature ranged.

between 19.9 ℃ to 34.0 ℃. The total rainfall with 48 rainy days was 1005.0 mm received during the growing period. The maximum and minimum relative humidity, and maximum and average wind speed were 96%, 79%, 5.6 Km hr-1 and 3.6 Km hr-1 respectively. The highest and lowest evaporation was 5.3 mm and 1.4 mm respectively.

The experimental field was laid out in a split-plot design with three replication and twelve treatment combinations consisting of four dates of sowing D1 (25th MW), D2 (26th MW), D3 (27th MW), and D4 (28th MW) and three varieties V1 (MAUS-158), V2 (MAUS-71), and V3 (JS-335). The total area of layout size was 5.4 × 4.5 m2 with a net plot size of one treatment was 4.5 × 3.6 m2. These 12 treatments were randomly distributed in blocks in each replication.

A variety MAUS-71 was selected for lysimeter experiment. Seeds were sown in weighing type lysimeter at a spacing of 45×5 cm2. The same crop was grown surrounding the lysimeter tanks with a view to create a similar cropping environment as in the lysimeter. Recommended doses of fertilizer were applied and necessary intercultural operations were done as and when required.

There are several methods for determining reference evapotranspiration, ETO. Among them, Penman-Monteith method has been recommended for empirical determination of ETO using climatic data *viz*., relative humidity, temperature, sunshine hours and wind velocity (Allen *et al*., 1998; Michael, 2014) [10, 9]. According to Smith *et al*. (1992) [10], FAO Penman-Monteith method gives more consistent ETO estimates and has been shown to perform better than other methods. In this study, reference evapotranspiration, ETO, was estimated by using different reference evapotranspiration models.

The crop coefficient, Kc, was estimated by using the following formula:

$$ETc = Kc \times ETO$$

At 120 days after sowing, the data on plant height and number of branches per plant were recorded from 05 observational plants from each net plot. Pods were counted at 15-day intervals from 60 DAS and the average worked was out. The yield and yield contributing data were collected during and after harvesting of the crop.

3. Result and Discussion

3.1 Crop coefficient (Kc)

The crop growth stages *viz*. initial, development, mid-season and late season stages are internationally recognized for the calculation of crop coefficients (Allen *et al*., 1998) [10]. The length of growing season of a particular crop and climate determine the duration of each stage (Doorenbos and Pruitt, 1975; Smith *et al*., 1992) [4, 10]. Evapotranspiration and crop coefficients vary with the crop growth stages.

At the initial stage, the average ETc was 40.16 mm, which fluctuated throughout the growth period. It reached at 37.62 mm during the period of 85 days after sowing (mid stage), and again increased to 39.57 mm at 120 days after sowing (final stage). Similarly, ETO being 38.89 mm at the primary stage. The mid-season ETO was interestingly lower than the primary stage but it increased again to reach 28.94 mm prior to harvest (Figure 4). During harvest, the cumulative ETc was 546.4 mm.

The crop coefficient values were found to be 0.84, 1.33 and 1.60 at the initial, mid and final stages (Table 5). By taking average (Biswas *et al*., 2014) [3] for the consecutive growth stages the Kc values of three growth stages are illustrated in Figure 6. The estimated crop-coefficient values of soybean cv. MAUS-71 during different growth stages *viz*. sowing to emergence (P1), emergence to seedling (P2), seedling to branching (P3), branching to flowering (P4), flowering to pod formation (P5), pod formation to grain formation (P6), grain formation to pod development (P7), pod development to pod containing full-size grain (P8), pod containing full size to dough stage (P9), dough stage to maturity (P10) were found 0.7, 0.9, 0.9, 0.7 1.2, 1.4, 0.8, 1.3, 2.4, and 1.7 respectively (Table 4 and Figure 1).

3.2 Estimation of crop coefficient of Soybean cv. MAUS-71 by using different reference evapotranspiration models.

The crop coefficient values of soybean cv. MAUS-71 (Table 4) by using Hargreaves models are 0.70, 1.04, 1.28 and by using Penman-monteith model are 0.84, 1.33, 1.60 for initial, mid and final stages respectively. Whereas by using FAO modified Penman model are 4.44, 3.90, 3.92 by Turc model is 2.00, 3.30, 3.07, and by using Hargreaves and Samani method are 0.28, 0.42, 0.52 for initial, mid and final stages respectively. (Sarma and Bharadwaj, 2020).

The findings of several investigators conform to the findings of the current study. For instance, Karam *et al*. (2005) [6] found that Kc values of soybean were 0.62, 1.0 and 0.81 at the initial, pod formation and mature pod stage at Tal Amara Research Station, Lebanon. Allen *et al*. (1998) [10] found the Kc values of 0.40, 1.15 and 0.50 for the initial, mid-season and late-season stage, respectively. Doorenbos and Kassam (1975) [4] reported Kc values of 0.3-0.4, 0.7-0.8, 1.0-1.15 and 0.7-0.8 for initial, crop development, mid-season and late season stages, respectively. The Kc values obtained in our experiment were much higher than the FAO recommended values. Such variations are common and are expected because of the fact that different varieties perform differently in terms of their growth and development.

Table 1: Monthly weather parameter values of study area during crop period

Months	Rainfall	Rainy days	Temperature oC		Humidity (%)		EVP (mm)	BSS (Hrs.)	WS (Kmph)
			Max	Min	RH1	RH2			
July	238.8	10	31.76	23.05	84.03	67.03	3.98	5.56	3.71
August	132.7	12	30.16	22.13	89.16	70.52	2.78	3.63	3.71
September	318.4	13	31.72	22.11	90.43	64.57	3.70	5.41	3.09
October	17	1	33.10	21.48	87.44	45.67	4.63	6.49	3.57

Table 2: Crop coefficient values of MAUS-71 soybean

Stages of crop	DAS	Etc (mm)	ETO (mm)	Kc values	Kc values by FAO-56
Initial stage	1 to 30	40.16	38.89	0.84	0.50
Mid stage	31 to 85	37.62	25.84	1.33	1.15
End stage	86 to 120	39.57	28.94	1.60	0.5-1.0

Table 3: Phenological stage wise calculated crop-coefficient of soybean cv. MAUS-71

Phenological stages of soybean	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
Kc Values	0.7	0.9	0.9	0.7	1.2	1.4	0.8	1.3	2.4	1.7

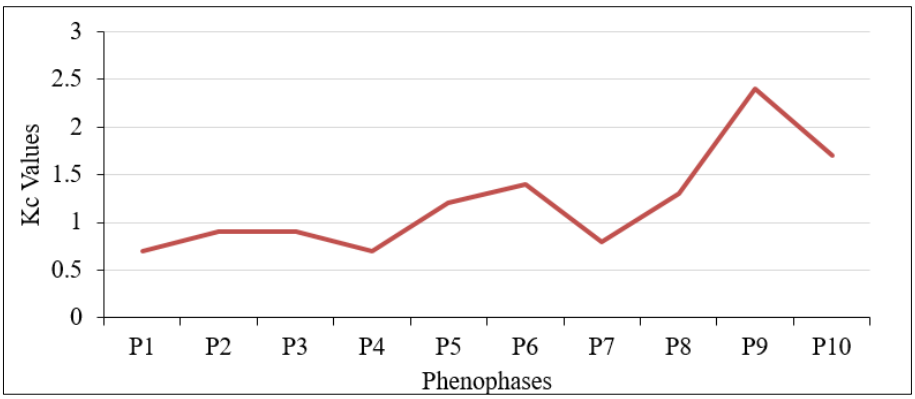

Fig 1: Phenological stage wise crop-coefficient of soybean cv. MAUS-71

Table 4: Estimation of crop coefficient of Soybean cv. MAUS-71 by using different reference evapotranspiration model.

DAS	1 to 30	31 to 85	86 to 120
crop coefficient	**Kc ini**	**Kc mid**	**Kc end**
Kc (P-M method)	0.84	1.33	1.60
Kc (Fao modified penman)	4.44	3.90	3.92
Kc (Hargreaves)	0.70	1.04	1.28
Kc (Turc)	2.00	3.30	3.07
Kc (Hargreaves-Samani)	0.28	0.42	0.52

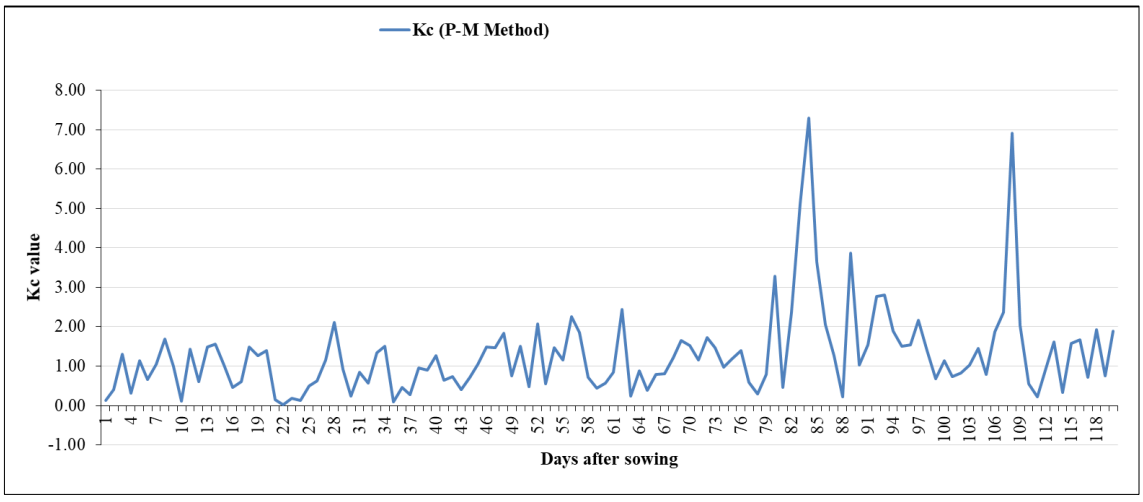

Fig 2: Kc (P-M Method)

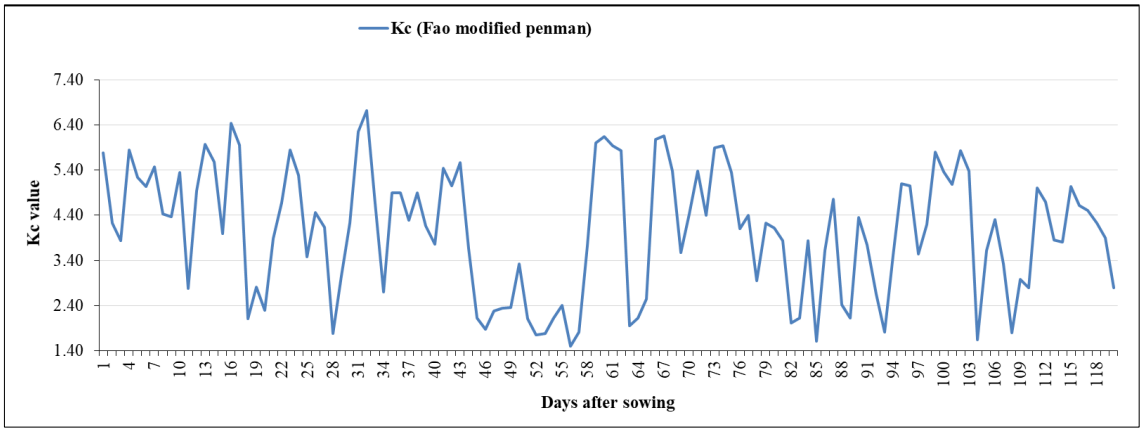

Fig 3: Kc (Fao modified penman)

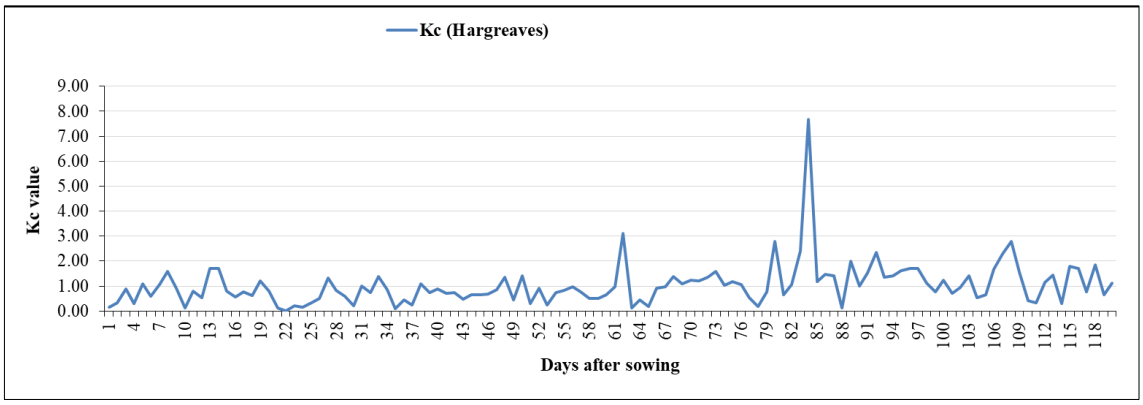

Fig 4: Kc (Hargreaves)

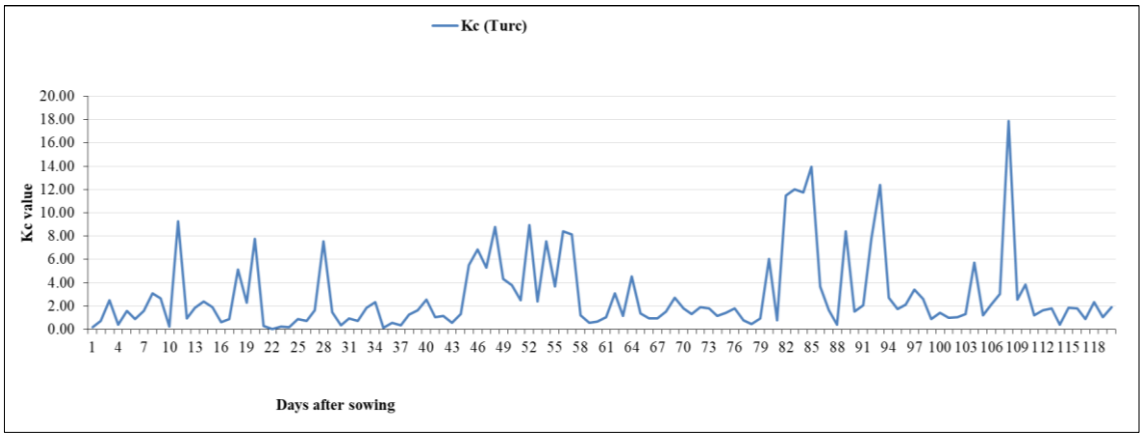

Fig 5: Kc (True)

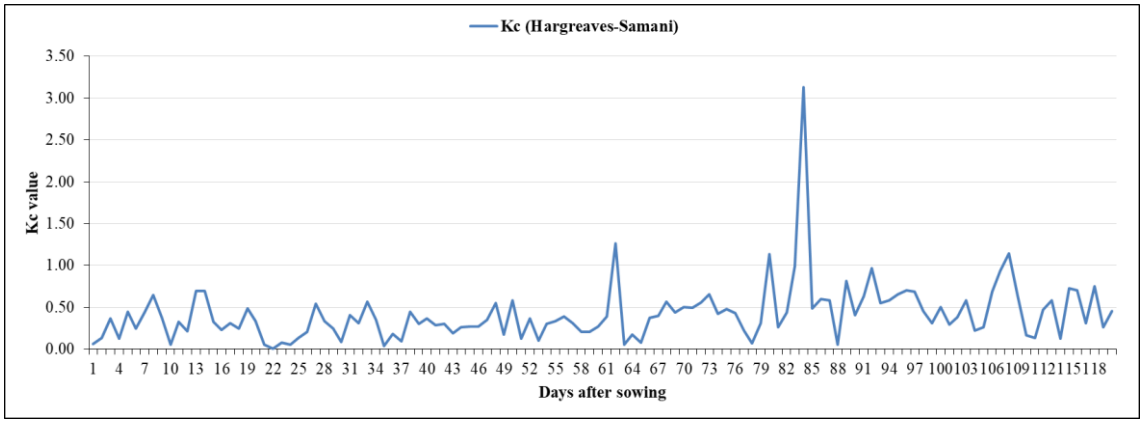

Fig 6: Kc Hargreaves-Samani)

4. Conclusion

The field experiment was conducted during Kharif season 2020-21 at the experimental farm of Department of Agricultural Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Results showed that sowing of soybean during 25th MW with variety V1 (MAUS-158) is better to obtain a higher seed yield. Seasonal crop evapotranspiration of soybean was 483.6 mm. The crop coefficient values of MAUS-71 soybean variety at the initial, development, mid-season and late season stages were, 0.84, 1.33 and 1.60 respectively. The estimated values of crop coefficient for soybean variety considerably over the growth stages from those recommended by FAO. Nevertheless, the locally calibrated values of the crop co-efficient can be used for more reliable planning and distribution of regional water resources for irrigation.

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