RESEARCH PAPER:

Crop coefficients (K_C) of soybean [*Glycine max* (L.) Merrill]

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SUMMARY

In the Marathwada region, soybean [*Glycine max* (L.) Merrill] is grown as a rainfed crop, which is exposed to varying sets of weather conditions in general and rainfall distribution is particular. The acute need of water at critical growth stages, through lysimetric observations and its comparison with different approaches may provide information for decision making in irrigation scheduling the measurement of AET by means of lysimeter and it is essential to establish a relationship between the measured value of AET by in lysimeter and the estimated PET by different empirical formulae. Keeping these points in mind, a research project was planned on estimation of crop evapotranspiration in soybean crop through lysimeter. From the field study it was seen that the Blaney and Criddle, Thornthwaite and pan evaporation methods did not give correct prediction of PET, due to estimated K_C values and did not give correct estimation at various phenophases. For estimation of PET under Marathwada region at Parbhani condition, the modified Penman method is the most suitable. The total seasonal Actual evapotranspiration (AET) for soybean was found to be 353.59 mm. This again necessitied the application of protective irrigation to soybean during pod formation to grain formation stage by the modified Penman method.

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Crop evapotranspiration can be estimated by direct measurements of the water loss from a soil (using lysimeters) and vegetation samples or can be estimated by the reference crop evapotranspiration (ETo) and crop coefficient (K_C) by Doorenbos and Pruit, 1977; Kang, 1986 and Kerr *et al.*, 1993. Crop evapotranspiration is not easy to measure since specific devices and measurements of various physical parameters or the soil water balance in lysimeters are required. These methods are often expensive, demanding in terms of accuracy of measurement and can only be fully exploited by well-trained research personal.

The crop coefficient represents crop specific water need and is essential for accurate estimation of irrigation requirement of different crops in the command area (CSSRI, 2000). Crop co-efficient also serves as an aggregation of the physical and physiological differences between crops (Allen, 1994). Although crop coefficients, in general, are suggested by various researchers for a number of crops grown under different climatic conditions (Doorenbos and Pruitt, 1977), these values are general estimates and can only be used at locations where local data are not available. Crop coefficients need to be derived empirically for each crop based on lysimetric data and local climatic conditions (Allen *et al.*, 1998). Therefore, there is an acute need for local calibration of crop coefficient under given climatic conditions since such studies on crop coefficients are very limited and are not well documented for semi-arid region of Marathwada.

Keeping these points in mind, a research project was planned on estimation of crop evapotranspiration in soybean crop through lysimeter and its comparison with the different approaches.

MATERIALS AND METHODS

The present investigation was carried out by laying out experiment on soybean with objectives to study the measurement of AET in soybean and estimation of PET by various methods and its comparison with AET. The daily data of all weather parameters *viz.*, maximum and minimum air temperature, maximum and minimum relative humidity, wind speed, actual sunshine hours and rainfall for the crop growing season were collected from the weather station at meteorological observatory, Marathwada Agricultural University, Parbhani. The pan evaporation data measured from USWB Class-A pan was collected for this period. These meteorological parameters were used for estimation of potential evapotranspiration (PET) by different methods namely, Blaney and Criddle, Thornthwaite, Modified Penman and Pan evaporation. Similarly, measured AET in soybean crop were various phenophases as well as meteorological week wise. The actual evaportranspiration was measured by the two weighing type of lysimeters and estimated PET by various methods according to developed crop coefficient was estimated according to the phenophases of the crop as well as meteorological week wise.

The daily actual crop (ETc) for each phenophase was obtained using lysimeter data with respect to soybean crop grown in and outside the lysimeter. The AET values were derived from the difference of weight of the lysimeter in 24 hours, which was recorded daily at 8.30 am. The measured crop coefficients (K_C) for all the methods for soybean crops under study was calculated using the relation.

$$K_C = ETc / ET_0$$

In which, ETc is the actual crop evapotranspiration mm day^{-1} measured from lysimeter and PET estimated by the Blaney and Criddle, Thronthwaite, E Pan and modified Penman method.

RESULTS AND DISCUSSION

A field experiment was conducted at experimental farm, Department of Agricultural Meteorology, Marathwada Agricultural University, Parbhani. The experiment was conducted with soybean crop cv. MAUS – 71 in a field where two weighing type of lysimeters were installed. The experiment was non-replicated and estimation of reference crop evapotranspiration was measured on daily basis. At the same time, the daily weather data recorded at near by observatory were tabulated. The results of the present study are described and discussed in the following paragraphs.

The field experiment was conducted to evaluate the performance of various approaches for estimation of PET in soybean crop. The methods used for estimation of PET were Blaney and Criddle (1950), Thornthwaite (1948), modified Penmann (1977) and Pan evaporation method. The estimation was done on phenophase basis as well as meteorological week basis. The results of each method are as below:

Crop coefficients estimated by various approaches:

The crop coefficient (K_C) is the ratio of AET to PET. It clearly means that crop coefficient is the value which represents the canopy development and radiation trapping, in the course of crop development. The estimated (K_C) values were obtained using different approaches. Tested in this study on phenophase basis as well as meteorological week basis are presented in Table (1) and (2) graphically in Fig. 1 and 2.

The data (Table 1) indicate that the K_C values obtained through Blaney and Criddle and Pan evaporation approach was higher than one throughout the crop life cycle as well as meteorological week basis. The comparison of different approaches revealed that the Kc values obtained through Thornthwaite method next to Blaney and Criddle and pan evaporation. The K_C values through modified Penman approach showed lower K_C values throughout the different phenophases as well as

Table 1: Estimated crop coefficient values (K_c) according to different phenophases of the soybean crop by various methods

Phenophases	Blaney and Criddle	Modified Penman	Thornthwaite	Pan evaporation
Sowing to emergence (P_1)	0.79	0.34	0.47	1.07
Emergence to seedling (P_2)	1.14	0.39	0.66	1.02
Seedling to branching (P_3)	1.13	0.58	0.73	1.24
Branching to flowering (P_4)	1.52	0.56	0.81	1.16
Flowering to pod formation (P_5)	1.16	0.48	0.78	1.18
Pod formation to grain formation (P_6)	1.2	0.97	0.75	1.23
Grain formation to pod development (P_7)	1.18	0.53	0.79	1.17
Pod development to grain development in full size (P_8)	1.11	0.63	0.81	1.18
Dough stage (P_9)	1.07	0.55	0.74	1.24
Maturity (P_{10})	0.46	0.32	0.41	0.58

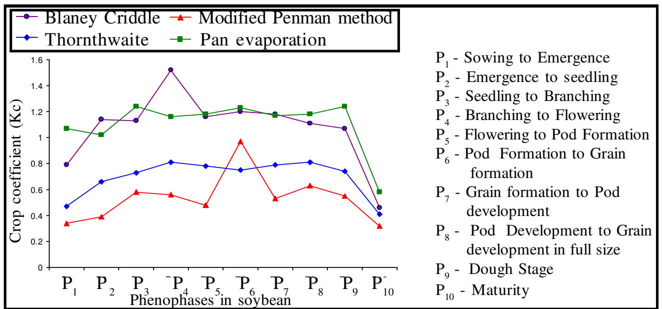

Fig. 1: Phenophases and crop coefficient (Kc) by the different methods during soybean crop growing season

through meteorological week wise. The higher K_C values were due to lower PET values estimated through Blanny and Criddle, Pan evaporation and Thornthwaite approaches. The K_C values in different phenophases obtained to various approaches ranged between 0.46 to 1.52, 0.58 to 1.24, 0.41 to 0.81 and 0.32 to 0.58 for Blaney and Criddle, pan evaporation, Thornthwaite and modified Penman approach, respectively. While these values when estimated on meteorological week basis ranged between 0.39 to 1.34, 0.38 to 1.29, 0.36 to 0.83 and 0.25 to 0.69 for Blaney and Criddle, Pan evaporation, Thornthwaite and modified Penman approach, respectively. The trend indicated that the K_C values increased uniformly and gradually through P_1 (Sowing to emergence) to P_9 (dough stage). The comparison between different approaches showed a similar trend in all the methods studied. The crop coefficient (K_C) graph reflects (Fig. 1) seedling stage with low values and then rising limb during increased growth and peak were the crop attains maximum cover and growth followed by the decreasing limb when leaves started shedding at the end of the growth cycle (Li *et al.*,2003).

The modified Penman was correct estimation of Kc suggested by FAO56 Allen *et al.* (1998) according to various phenophases of soybean. The K_C values for soybean increased in modified Penman method in pod formation to grain formation stage, due to the need of protective irrigation at this stage.

Temporal variation of crop coefficients (K_C) for soybean:

Temporal variation of K_C for soybean indicated a cyclic variation of K_C throughout the crop growth period. The variation in K_C may be due to occurrence of rainfall events resulting in increased values of Kc whereas when the soil is dry, the less availability of soil water reduces Kc values. The K_C values of soybean increased during pod formation to grain formation stage due to high evaporative demand. The PET values were affected due to the availability of soil water, method of estimation of PET due to variation in K_C occurred.

Also demonstrated that the measured crop coefficient for soybean were higher than the empirical K_C by Blaney and Criddle (1950) and the pan evaporation approaches. On the other hand, in the later crop growth stages namely, seedling, flowering, pod formation, grain formation and pod development stages. The measured in K_C were higher than those suggested by in FAO 56 Allen *et al.* (1998). Crop coefficients are found to vary with the percentage of the ground covered by crops, rate of crop development, time to achieve full ground cover and frequency of precipitation (Jagtap and Jones, 1989). The higher measured K_C values in the various crop stages by Blaney and Criddle and Pan evaporation indicated that the error in prediction of PET and crop canopy cover was the least and hence showed higher K_C than empirical one. On the contrary, the lower measured K_C P_1 (sowing to emergence) and P_{10} (maturity) growth stages may be attributed to the fact that the lower rainfall observed due to which limited availability of water for crops at these growth stages (Table 2 and Fig. 2).

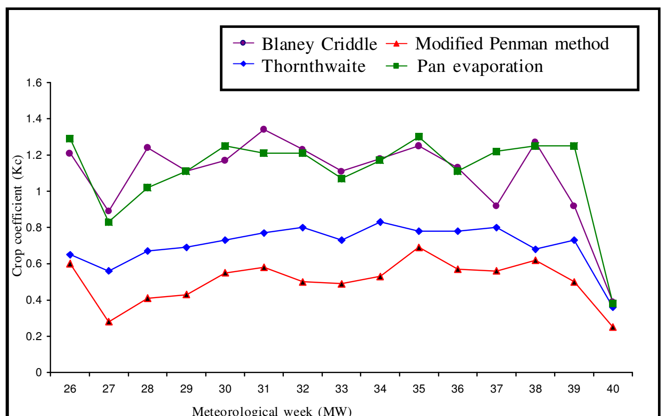

Fig. 2: Meteorological week and crop coefficient (Kc) by the different methods during soybean crop growing season

Conclusion:

Though irrigation facilities are created to a remarkable increase after independence, major area is still under rainfed cropping system. However, the erratic behaviour of monsoon stakes the agricultural enterprise at gamble. Judicious use of rainwater to meet the crop water requirement is a need of hour for a step towards stabilized agriculture. This input if taken care of, the productivity of the rainfed crops can be increased substantially. The accurate estimation of

Table 2: Estimated crop coefficient (K_c) values according to different meteorological weeks of the soybean crop by various methods

Meteorological weeks	Blaney criddle	Modified Penman	Thornthwaite	Pan evaporation
26	1.21	0.6	0.65	1.29
27	0.89	0.28	0.56	0.83
28	1.24	0.41	0.67	1.02
29	1.11	0.43	0.69	1.11
30	1.17	0.55	0.73	1.25
31	1.34	0.58	0.77	1.21
32	1.23	0.5	0.8	1.21
33	1.11	0.49	0.73	1.07
34	1.18	0.53	0.83	1.17
35	1.25	0.69	0.78	1.3
36	1.13	0.57	0.78	1.11
37	0.92	0.56	0.8	1.22
38	1.27	0.62	0.68	1.25
39	0.92	0.5	0.73	1.25
40	0.39	0.25	0.36	0.38

evapotranspiration can help in a better way to estimate the crop water requirements in the transe of crop phenophases.

Evaluating the actual crop water requirements and proper irrigation scheduling are the major points to be considered for agricultural planning. The accurate estimation of evapotranspiration can help to determine crop water requirements under existing cropping pattern and climatic conditions. Water use efficiency and proper irrigation scheduling basically are governed by crop evapotranspiration, which is a function of potential evapotranspiration (PET) and crop coefficient (K_C). On the other hand the crop ET (AET) and crop coefficient varied with the crop and also with its growth stages.

Reference crop ET was estimated and compared with lysimetric observations. The study revealed that among the methods tested, modified Penman method was found to be suitable for advocating the irrigation scheduling as it matched well throughout the crop season. The Blaney Criddle and Pan evaporation estimation methods under estimated the values when compared with lysimetric data. As these methods are based on only air temperature, pan evaporation and other parameters such as radiation, relative humidity, bright sunshine hours, wind factor were not included which also played significant role in affecting the ET. The results obtained through these methods are not comparable.

It can be concluded from the study that the modified Penman method was found suitable and ideal for assessing the crop water requirements.

Following conclusions could be drawn from the result of the study.

– The total seasonal Actual evapotranspiration (AET) for soybean is found to be 353.59 mm at Parbhani to be less than the seasonal water requirement of this crop for Marathwada region.

– The Blaney Criddle, Thronthwaite and Pan evaporation methods do not give correct prediction of PET, due to the estimated K_C values do not gives correct estimation at various phenophases.

– For estimation of potential evapotranspiration (PET) under Marathwada region at Parbhani condition the modified Penman method is the most suitable having sound theoretical formulations and more accuracy in estimation as compared with the Blanny Criddle, Thornthwaite and Pan evaporation methods.

– This again necessities the application of protective irrigation to soybean especially during pod formation to grain formation stage by the modified Penman method.

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