Journal of Agrometeorology **1(1)** : 85-88 (June 1999)

On the empirical estimation of evapotranspiration in pigeonpea

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ABSTRACT

Irrigation scheduling needs precise information on crop water requirements. Crop coefficient (K_c) values aid in the estimation of regional crop water requirements. Three empirical methods namely Blaney-Criddle, Pan evaporation and modified Penman were used in estimating potential evapotranspiration. Evapotranspiration values estimated by these relations using k_c values of Doorenbos and Pruitt (1979) were compared with those measured from a pigeonpea crop. Of the three, Pan evaporation method showed least deviation. Calibration coefficients were evolved that narrowed down the errors in prediction.

Key words : Pigeonpea, Evapotranspiration, Empirical methods

Timing, intensity and depth of irrigation water application are the important criteria for judicious use of this scanty resource. Estimates on regional crop water requirements are helpful in planning the irrigation systems. This could be accomplished by the use of empirical K_c value, a ratio of actual evapotranspiration (AET) under non-stressed conditions to reference evapotranspiration (PET). Stage-specific K_c values for different crops that respond to varying weather conditions have been proposed by Doorenbos and Pruitt (1979). They also gave four PET estimating methods employing weather data as input to varying degrees.

Pigeonpea (*Cajanus cajan L.*) is mainly grown as *kharif* crop in Andhra Pradesh, but in the recent past this has been subjected to severe *Heliothis* damage. Shifting its cultivation to *rabi*, in a skip/escape mechanism, was found advantageous. As the crop has to rely on stored soil moisture during *rabi*, irrigating the crop at sensitive stages may alleviate the moisture stress effects as also noticed elsewhere (Chauhan, 1990). The K_c values can be made use of in scheduling irrigation but the availability of weather data for the computation of PET is a major limitation. Thus, an attempt has been made here to find a suitable method of estimating PET empirically, a pre-requisite for employing K_c values in irrigation scheduling and the applicability of K_c values suggested for pulse crops by Doorenbos and Pruitt (1979) to a pigeonpea crop.

MATERIALS AND METHODS

The data on AET used in the present analysis were collected from a field experiment conducted at Agricultural College Farm, Bapatla during rabi 1996-97. The soil of the test site is clayey having an average field capacity of 47.6 per cent, permanent wilting point of 25.7 per cent on volume basis and a

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bulk density of 1.32 g cc^{-1} in the 0-30 cm soil layer. The crop (Cv. LRG-30) was adequately fertilized (20-50-0 kg N-P-K ha^{-1}) and protected from pest and diseases. The treatments consisted of three dates of sowing (5th November, 20th November and 5th December) and three levels of irrigation (IW/CPE ratios of 0.25,0.50 and 0.75), all these treatments were laid out in a randomized block design with factorial concept and replicated thrice. A polythene sheet embedded vertically to a depth of 50 cm separated each plot to avert seepage effects. A measured quantity of 50 mm depth of water was given at each irrigation. AET was determined by monitoring changes in soil moisture content thermo-gravimetrically, 15cm layer-wise, from the 0-60 cm depth at 10-day interval and again before each irrigation.

Crop evapotranspiration (ET_e) was estimated using K_c values suggested for pulses by Doorenbos and Pruitt (1979). PET values required for estimating ET_e were estimated using three methods namely Blanney-Criddle, Pan evaporation and modified Penman method used by Doorenbos and Pruitt (1979). More details of these methods are described by Doorenbos and Pruitt (1979). The data required for computation of PET were collected from Meteorological Observatory located on the College Farm. On some days, hours of bright sunshine data were not available and these were taken from the Regional Agricultural Research Station, Lam. The accuracy of these methods in predicting the AET from pigeonpea was determined by comparing phenophase-wise ET_e values with the measured AET of a non-stressed treatment (0.75 IW/CPE) with three sowing dates. The data were analyzed statistically using RMSE, MBE and MPE values as follows

$$\text{RMSE} = \{ \sum_{i=1}^{n} (ET_e - AET)^2/n \}^{0.5}$$

$$\text{MBE} = [\sum_{i=1}^{n} (ET_e - AET)]/n$$

$$\text{MPE} = [\sum_{i=1}^{n} \{(AET-ET_e)/AET\} 100]/n$$

where,

n = no. of observations.

While determining the MPE values, the signs of the error were ignored and the percentage errors were added to calculate the mean.

RESULTS AND DISCUSSION

The values of AET and ET_e estimated by using PET values as determined by different empirical methods for different stages of crop growth are presented in Table1.

The results show that ET_e values estimated by modified Penman evaporation were closest to the measured AET at some phenological stages and those of pan evaporation at other. The ET_e values of Blaney-Criddle resulted in over-estimation at all the stages. The ET_e values of the entire crop season were then subjected to statistical scrutiny. The results (Table 2) indicate that Blaney-Criddle and Penman methods exibit more deviations based on their RMSE and MPE values, over-estimated based on their MBE values compared to Pan evaporation method. Of the three, Blaney-Criddle over-estimated by as much as 50 per cent and thus does not hold a suitable relation for the region of study as it utilizes only temperature to estimate PET. It is thus interesting to note here that Penman method, though considered to be realistic in predicting PET by several authors (Kumar *et al.*,1988; Rao *et al.*, 1983) probably because

Table 1: Phenophase-wise evapotranspiration (mm) –measured and estimated by different empirical methods

Phenophase	Measured			Blaney-Criddle			Pan evaporation			Modified Penman		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
P_1	84.9	72.6	71.7	117.6	113.9	109.8	60.3	62.5	60.7	78.4	72.9	69.5
P_2	46.5	40.8	37.3	95.0	93.0	86.3	56.1	54.5	54.5	59.5	62.8	66.2
P_3	53.1	45.0	48.2	60.9	68.9	75.7	38.7	45.8	54.1	45.1	52.9	63.0
P_4	22.7	14.3	20.6	34.3	25.2	22.0	24.2	16.0	16.3	25.3	18.0	19.5
P_5	20.3	12.0	14.7	19.1	14.9	15.6	14.2	11.5	10.0	15.9	13.1	13.0
P_6	12.2	14.9	14.0	20.7	23.1	24.7	12.8	17.3	16.6	17.1	19.9	18.7
P_7	24.2	23.9	14.9	4.5	32.6	27.0	35.7	21.0	15.1	37.6	25.0	20..7

D_1, D_2 and D_3 – Dates of sowing; P_1 - Branch formation to flower initiation
P_2 - Flower initiation to 50% flowering; P_3 - 50% flowering to 100% flowering
P_4 - 100% flowering to pod initiation; P_5 - Pod initiation to 50% podding
P_6 - 50% podding to 100% podding; P_7 - 100% podding to maturity

Table 2: Performance of empirical methods (seasonal data)

Parameter	Blaney-Criddle	Pan evaporation	Modified Penman
RMSE	26.04	9.47	10.26
MBE	+19.83	-0.5	+5.07
MPE	57.09	1.81	19.00

Table 3: Calibration coefficients for empirical methods

Method	a	b	R^2	r	Standard error
Blaney-Criddle	2.9571	0.5749	0.87	0.94	8.05
Pan evaporation	0.064	1.0135	0.81	0.90	9.94
Modified Penman	-0.3946	0.8796	0.85	0.92	8.93

Table 4: Post-calibration performance of empirical methods

Parameter	Blaney-Criddle	Pan evaporation	Modified Penman
RMSE	7.66	9.46	8.49
MBE	-0.01	0.00	-0.02
MPE	3.10	3.45	2.95

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of the involvement all variables that are known to influence PET, resulted in more errors in the present investigation. Pan evaporation method resulted in better estimates of AET. Khade *et al.* (1990) also noticed the advantage of pan evaporation over modified Penman, Blanney-Criddle and radiation methods.

Keeping in view the errors of prediction, an attempt has been made to evolve calibration coefficients for the three relations by regressing the predicted values on the observed ones. The coefficients obtained from the regression analysis are presented in Table 3.

Utilizing the calibration coefficients of each relation in Table 3, AET values were again predicted and the resultant estimates were subjected to further statistical analysis (Table 4).

The errors in estimating AET narrowed down with the employment of calibration coefficients and all the three methods resulted in about 3 per cent error only. Thus, a calibration procedure helps in reducing the errors and this may be applicable in climatically analogous stations.

REFERENCES

Chauhan, Y.S. 1990. Pigeonpea: Optimum agronomic management.p257-278. (In) Nene,Y.L; Hall,S.D and Sheila, V.K. (Eds.). The Pigeonpea, CAB International, Wallingford, UK.

Doorenbos, J. and Pruitt, W.O. 1979. Guidelines for predicting crop water requirements. FAO Drainage and Irrigation paper no.24, 2nd Ed., FAO, Rome, Italy.

Khade, V.N.; Patil, B.P; Dongale, J.H. and Khanvilkar,. 1990. A note on evapotranspiration studies on rabi hot weather groundnut as computed by different methods in warm humid climate of Konkan. Journal of Indian Society of Coastal Agricultural Research, 8 : 43-46.

Kumar, K.K., Rupa Kumar,K. and Rakecha, P.R. 1987. Comparison of Penman and Thornthwaite methods of estimating potential evapotranspiration for Indian conditions. Theoretical and Applied Climatology, 38: 140-146.

Rao, M.S., Reddy,Y.M. and Reddy,S.R. 1983. Reliability of empirical formulae for the determination of crop water requirements. Andhra Agricultural Journal, 30: 160-165.