RESEARCH PAPER:

Phenophase and Metweekwise PET estimation and AET measurement in soybean [*Glycine max* (L.)]

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Asian Journal of Environmental Science, (December, 2010) Vol. 5 No. 2 : 107-112

SUMMARY

Soybean [*Glycine max* (L.)] is grown as rainfed crop, 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. It can be concluded from the field study that the modified penman method was found to be suitable and ideal for assessing the crop water requirements.The Blanney and criddle, Thornthwaite and pan evaporation methods do not give correct prediction of PET, due to estimated Kc values do 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 having found theoretical formulation and more accuracy in estimation as compared with the Blaney and criddle, Thornthwaite and pan evaporation methods.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 for this crop. This again necessities the application of protective irrigation to soybean during pod formation to grain formation stage by the modified penman method.

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Maniyar , V.G.., Kamble, P.S. and Jadhav, J.D. (2010). Phenophase and Metweekwise PET estimation and AET measurement in soybean [*Glycine max* (L.)]. *Asian J. Environ. Sci.*, **5**(2):107-112.

Key words : Phenophase, Metweek ,Water requirement

India has an agriculture base and the agricultural sector plays dominating role in Indian economy. However, it is erratic in nature and its distribution is inconsistent at any place during years. Average annual rainfall of the country is 119 cm; out of which about 400 M ha-m goes as surface runoff, whereas, only 215 M ha-m is infiltrated (Anonymous, 1998). Although, large irrigation potential has been created country since independence taking it from 22.6 M ha to 91 M (Sivanappan, 2000), however about 60 percent of the country's total cultivated area (145.6 M ha) is still rainfed.

Under the Marathwada region, the soybean [*Glycine max* (L.)] is grown as a rainfed crop,. 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 is an expensive procedure and beyond reach of individual farmer, therefore, it is essentinal 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 with the different approaches already published, with the following objectives: to Measure daily, weekly and phenophasewise Actual evapotranspiration of soybean crop under field conditions, using weighing type lysimeters, to estimate weather based, weekly and phenophase wise potential evapotranspiration in soybean crop, by using the approaches suggested by Blaney criddle, Thronthwaite, modified penman's and pan evaporation and to suggest proper timing for life saving irrigation during crop growing season.

MATERIALS AND METHODS

The present investigation was carried out by laying out experiment on soybean with objectives to study of the measurement of AET in soybean and estimation of PET by various

Received: *September, 2010*
Accepted : *October, 2010*

methods and its comparison with AET. The experiment was conducted during *Kharif* season 2007-08, on the experimental farm Department of Agricultural Meteorology, College of Agriculture, Parbhani. The details of the materials used and methods adopted during the present of investigations are narrated under following heads.

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., Blanny Criddle, Thornthwaite, Modified Penman and Pan evaporation. These methods comparison with AET in soybean. Similarly measured AET in soybean crop was various phenophases as well as meteorological week wise.

Potential Evapotranspiration by various methods:

The various researches have been developed different empirical formulae of estimation of PET. Using one or more than weather variables combined these are given as below :

– Blaney-criddle method (1950):

$$ET_0 = c\ [\ P\ (0.46\ T + 8)]\ mm/day$$

where,

ET_0 = reference crop ET in mm/day for the month considered.

T = Mean daily air temperature in ^{0}C over the month considered.

P = Mean daily percentage of total annual day time hours

c = Adjustment factor which depends upon relative humidity, sunshine hours and day time wind estimates

RH	n/N	Wind Velocity
Minimum < 20%	Low < 0.6	Light < 175 kmd^{-1}
Medium 20-50%	Medium 0.6-0.8	Moderate 175-425 kmd^{-1}
High > 50%	High > 0.8	High 425 – 700 kmd^{-1}
		Very strong > 700 kmd^{-1}

– Thornthwaite method (1948):

$$e = 1.6\ (\ 10\ t / I\ )^a$$

where,

e = Unadjusted PET (cm/month)

t = Mean air temperature ^{0}C

I = Annual or seasonal heat index (*i.e.*) summation of 12 values of monthly heat indices (i) when $i = (t/5)^{1.514}$

a = An empirical exponent computed by the equation

$a = 0.000000675\ I^3 - 0.0000771\ I^2 + 0.01792\ I + 0.49239$

The factor e is an adjusted value based on 12 hour day on 30 day month. It is corrected by actual day length in hours 'h' and days in a month M, to get the adjusted PET.

For daily computation, the formula is modified under

PET = K x e x 10 / number of days in month expressed in mm/ day

where, K is adjustment factor for which table values are given by Michael (1978)

(adopted from Mavi and Chaurasia 1980)

– Modified Penman Method (1977):

Based on intensive studies of the climatic and measured gross ET data from various research stations in the world and the available literature on prediction of ET or ET_0. Doorenbos and Pruitt (1977) proposed the modified penman method, as below for estimation fairly accurately the reference crop ET.

$$ET_0 = c\ [W.\ Rn + (1 - W)\ f\ (u)\ (ea - ed)]$$

where,

ET_0 = Reference crop ET in mm/day

W = Temperature related weighting factor for the effect of radiation on ET^0 (Annexure VIII)

Rn = Net Radiation = Rns – Rnl

Rns = The net incoming short wave solar radiation

Rns = Ra (1-W) (0.25 + 0.50 n/N)

Ra = Extraterrestrial radiation expressed in equivalent evaporation in mm/day.

n/N is the ratio between n = actual duration of bright sunshine hours and

N = Maximum possible duration of bright sunshine hours

α = Reflection coefficient

Rnl = The net long wave radiation

= f (t) f (ed) f (n/N)

1 - Wz = A temperature and elevation weighing factor for the effect of wind and humidity on ET^0

f (U) = A wind related function

ea = Saturation vapour pressure in m bar at the mean air temperature in ^0C

ed = Mean actual vapour pressure of the air in m bar

$$= ea \times \frac{RH\% \text{ Mean}}{100}$$

c = adjustment factor to compensate for the day and night weather effects.

Lysimeters:

Weighing type of lysimeters are the most effective devices for direct measurement of evapotranspiration. Two weighing balance type gravimetric lysimeters, consisting of a weighing platform with 2 tones capacity.

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.

Blaney and criddle approach:

The recorded data on AET was compared with estimated PET using Blanney and Criddle approach. The data revealed that the AET values measured through lysimeters in different phenophases as presented in table (1, 2) and Fig. (1, 2) ranged from 10.74mm to 70.56mm, while the PET values estimated through this method ranged between 10.3mm to 62.2mm. The comparison between AET measured in lysimeters and estimated PET through this approach showed that the estimated PET was underestimated. This is not true in practical ; The under estimation of PET over AET may be attributed to only air temperature has been considered as an limiting factor, whereas, the other important parameters such as aerodynamic characteristics were ignored.

The results on meteorological week basis also showed similar trend in respect of this approach, however, during later stage of crop *i.e.* MW 27, 37, 39 and 40 had shown comparably higher values of PET over measured lysimeteric data. But during this period there were continuous showers, which should have equal AET values and PET values. These results were closely confirmity with the results of Kadam *et al.* (1978) for Marathwada region.

Thornthwaite approach:

The recorded data on AET was compared with estimated PET using Thornthwaite approach. The data revealed that the AET values measured through lysimeters in different phenophases as well as meteorological week wise presented in Table (1, 2) and Fig. (1, 2) ranged from 10.42mm to 70.56mm. While the PET values

Table 1 : Measured Actual evapotranspiration (AET) and etimated potential evapotranspiration (PET) values according to different phenophases of the soybean crop by various methods

Phenophases	Actual evapotranspiration (AET in mm)	Potential evapotranspiration (PET in mm)			
		Blaney criddle	Modified Penman	Thornthwaite	Pan evaporation
Sowing to emergence (P_1)	11.74	15	34.88	25.08	11.06
Emergence to seedling (P_2)	70.56	62.2	184.79	107.23	69.65
Seedling to branching (P_3)	28.79	25.6	49.92	39.84	23.24
Branching to flowering (P_4)	15.57	10.3	28.08	19.46	13.51
Flowering to pod formation (P_5)	22.15	19.1	46.42	28.66	18.83
Pod formation to grain formation (P_6)	21.44	17.9	22.13	28.68	17.57
Grain formation to pod development (P_7)	42.09	35.8	80.44	53.76	36.26
Pod development to grain development in full size (P_8)	55.9	50.5	87.97	69.74	47.46
Dough stage (P_9)	54.13	50.7	99.06	73.98	43.96
Maturity (P_{10})	10.42	23.14	32.78	25.64	17.99

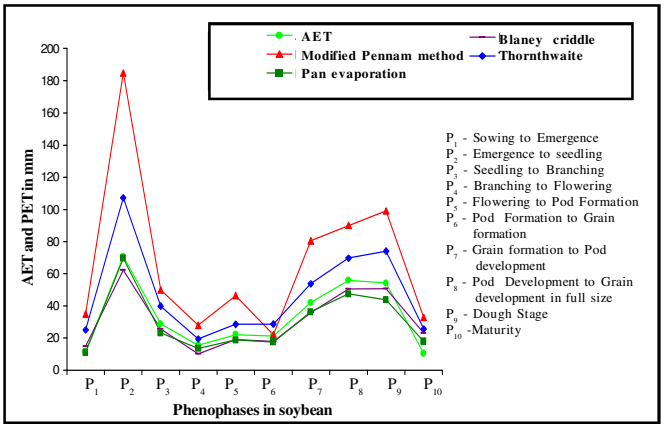

Fig. 1 : Phenophases, AET and PET by the different methods during soybean crop growing season 2007

estimated through this method ranged between 19.46mm to 107.23mm. The comparison between AET measured in lysimeters and estimated PET through this approach showed that the estimated PET were higher than measured AET of the crop in various phenophases. However when there were rains in a week spread over more rainy days, the evapotranspirative demand of the atmosphere should have met and the AET values should have been equal to PET, but this was not observed. The reason of higher PET values, is also attributed to the fact that in this approach only air temperature is considered to be limiting factor. However the other parameters such as radiation, atmospheric humidity, wind speed, and vapour pressure was not taken care of, However, this method seems to be useful where data on these parameters are not available and hence being used widely for estimation of crop water requirements.

Modified Penman Method:

The recorded data on AET was compared with estimated PET using modified Penman approach. The data revealed that the AET values measuered through lysimetres in different phenophase as well as meteorological week wise presented in Table (1, 2) and Fig. (1, 2). The measured AET ranged from 10.42 (P_{10}) MW to 70.56mm (P_2), where as the PET values estimated through this method ranged between 28.08 (P_4).to 184.79mm (P_2) . the comparison between AET measured in lysimeters and estimated PET through this approach showed that the estimated PET values where higher than AET measured in phenophases of the crop. Similar trend was also noticed when it was treated under meteorological week bans. This attributed to aerodynamic and radiation terms which has been considered. The turbulant eddies that are mainly responsible for the transport of water vapour. The complete earth surface maintains wet conditions due to south west monsoon rains and the vapour pressure gradients will be directed into the atmosphere, hence the eddies transport more vapour through turbulence and contributed to high values of PET as compared with AET values. At the same time the resistance offered by plant body under field conditions, the AET values are relatively lower than PET. The highest

Table 2 : Measured actual evapotranspiration (AET) and estimated potential evapotranspiration (PET) values according to Meteorological week (MW) of the soybean crop by various methods

Meteorological weeks	Actual evapotranspiration (AET in mm)	Potential evapotranspiration (PET in mm)			
		Blaney criddle	Modified Penman	Thornthwaite	Pan evaporation
26	22.93	19.1	38.62	35.64	17.71
27	19.6	22	70.43	35.48	23.66
28	23.64	19.2	58.83	35.5	23.31
29	24.85	22.5	58.56	36.2	22.54
30	25.32	21.7	46.82	35.08	20.3
31	26.1	19.6	45.51	34.32	21.63
32	26.43	21.6	53.89	33.45	21.91
33	24.45	22.1	49.94	33.72	22.91
34	28.06	23.9	53.24	34.2	24.08
35	25.95	20.8	37.98	33.58	20.02
36	24.56	21.9	43.1	31.69	22.26
37	26.06	28.4	47.26	32.76	21.49
38	21.68	17.2	35.51	32.02	17.43
39	23.74	25.9	48.39	32.54	19.11
40	10.22	26.63	42.42	28.91	26.95

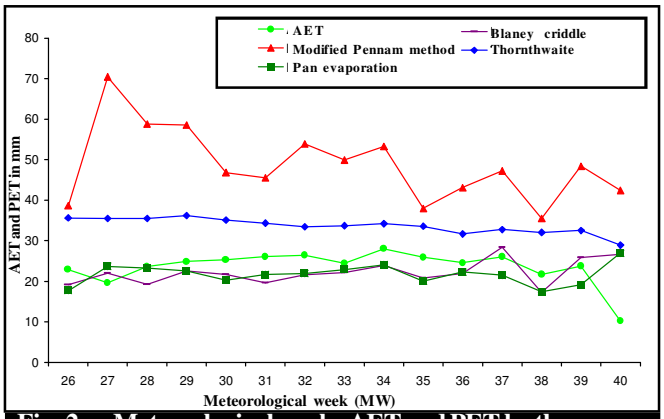

Fig. 2 : Meteorological week , AET and PET by the different methods during soybean crop growing

PET values as well as measured AET values were recorded in P_2 (Emergence to Seedling). It is evident that the duration for these phenophases was longer duration. Coupled with higher air temperature and relatively lower relative humidity of both the timings (morning and noon).

The actual evapotranspiration (AET) for soybean is lower than the estimated potential evapotranspiration (PET) by modified penman approach. The measured AET values and estimated PET values by this approach during pod formation to grain formation stage, where AET values matched with PET, since rainfall was more or less uniformly distributed resulting in the soil water availability. This shows that higher crop water requirements during pod formation to grain formation stage. Due to these season AET remained higher even after pod formation to grain formation stage. Due to availability of soil water resulting from rainfall events and high evaporative demand of atmosphere. It was also observed that the high rainfall restricted crop roots to uptake soil water resulting in lower values of AET. Result thus indicates that the PET is affected mostly due to availability of soil water, evaporative demand of atmosphere and the stage of soybean crop. This results were closely related with (Kadam *et al.*, 1978) for Marathwada and Jadhav *et al.* (1999) for western Maharashtra ,

Pan evaporation method:

The measured data on AET in different phenophases as well as meteorological week wise compared with estimated PET data estimated through Pan Evaporation method were compared and presented in Table (1) and Fig. (1). The comparison of the data showed that the PET estimated through this method was almost matching with the AET measured in different phenophases. This may be due to lustrous canopy development in its grand growth period which seems to have increased AET as compared to PET estimated through this method. However the AET values showed higher trend during P_8 (Pod development stage) and P_9 (dough stage) than PET estimated through this approach.

The data on AET measured through lysimetres and PET estimated through Pan evaporation method on meteorological week basis are presented in Table (2) and Fig. (2). The data revealed that the AET measured showed higher values in MW 26, onwards till MW 39 except MW 27. The higher PET values seems to be due to lustours canopy development in MW 40 the leaf resistence should have reduced AET, when compared with PET measured thourogh this approach. These results were agreement with Kadam *et al.* (1978) for Marathwada region. These results also confirms the findings of Subramanium and Rao (1985), Omar and mehanna (1986), Mao *et al.* (2002) and Mao and Gupta (2002)

Conclusion:

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

– 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

– 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.

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

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

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