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RESEARCH ARTICLE

Estimation of PET measurement and actual AET in groundnut by various methods

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SUMMARY : A field experiment was conducted at dry farming research unit, Solapur. The experiment was conducted with groundnut crop in a field where two weighing types of lysimeter 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 were recorded at nearby observatory and were tabulated. The PET were 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 and Criddle and Pan evaporation estimation methods underestimated 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 was not included which also played a significant role in affecting ET. The results obtained through these methods are not comparable.

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Key Words :
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Evapotranspiration (ET) is frequently estimated for determining crop water requirements and thereby, scheduling irrigation, design and management of irrigation systems, planning suitable cropping pattern, management of available soil water in rainfed agriculture and hydrological water balance. Most of the current hydrologic, water management and crop growth models require accurate estimates of potential evapotranspiration (PET) for reliable applications (Choisnel *et al*., 1992). Every farmer at the commencement of season needs to have a water management programme for his cropping pattern, which in turn maximizes his economic returns. Similarly, a better understanding of water balance is essential for exploring good returns. Furthermore, a better understanding of water balance is essential for exploring water-saving measures. Water use efficiency can be improved by proper irrigation scheduling, which is essentially governed by crop evapotranspiration (ET_c). Crop ET is a function of reference crop ET (ET_o), because of variation in crop canopy and climatic conditions, ET_c differs with crop and also with its growth stage.

Crop evapotranspiration can be estimated by direct measurements of the water loss from a soil (using lysimeter) and vegetation samples or can be estimated by the reference crop evapotranspiration (ET_o) (Doorenbos and Pruitt, 1977; Kang, 1986; 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 lysimeter 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. Although the measurement methods are not simple for routine measurements, the other approaches proposed by earlier researchers can be an ideal tool for assessing the crop water requirements in the life cycle of a given crop. However, these approaches need to be tested for application in given location.

These methods for computing the potential evapotranspiration from climatologically data include Blaney Criddle approach, Thornthwaite approach, Penman method and Pan Evaporation etc. Out of these, Blaney Criddle, Thornthwaite, Pan Evaporation methods require minimum weather parameters. Under such circumstances the modified Penman method requires maximum data for estimation of the PET under the ideal conditions (Allen *et al.*, 1998). Therefore, comparison of all these methods with actual evapotranspiration of groundnut crop is necessary for its use as a tool in scheduling irrigation.

EXPERIMENTAL METHODOLOGY

The present investigation was carried out by laying out experiment on groundnut with objectives to study of the measurement of AET in groundnut and estimation of PET by various methods and its comparison with AET. The experiment was conducted during *Kharif* season 2010 at dry farming research unit, Solapur. 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, dry farming research unit, Solapur. 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 Criddle, Thornthwaite, Modified Penman and Pan evaporation. These methods are compared with AET in groundnut. Similarly measured AET in groundnut crop was studied on phenophases as well as on meteorological week. The actual evapotranspiration was measured by the two weighing type of lysimeter and estimated PET by various methods.

Actual crop evapotranspiration :

The daily actual crop (ET_c) for each phenophases was obtained using lysimeter data with respect to groundnut 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.

Potential evapotranspiration by various methods :

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

Blaney - criddle method (1950) :

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

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 as 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

Rn = Net Radiation = Rns – Rnl

Rns = The net incoming short wave solar radiation

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

where,

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 = Net long wave radiation

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

l-W = 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

$$= ea ò \frac{RH\ \%\ Mean}{100}$$

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

Pan evaporation method :

Reference crop evapotranspiration was calculated from pan evaporation using standard pan coefficient of 0.70 for this region (for RH_{mean} 40 to 70 per cent from Table 18, FAO 24, (Doorenbos and Pruitt, 1977) using the following equation:

$$ET_0 = K_p * E_{pan}$$

where, K_p is the pan coefficient and E_{pan} is the pan evaporation (mm d^{-1}).

Lysimeters :

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

EXPERIMENTAL FINDINGS AND DISCUSSION

A field experiment was conducted at dry farming research unit, Solapur. The experiment was conducted with groundnut crop 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 were compared with estimated PET using Blaney and Criddle approach. The data revealed that the AET values measured through lysimeter in different phenophases as presented in Table 1, 2 and Fig. 1, 2 ranged from 34.36 mm to 95.23 mm, while the PET values estimated through this method ranged between 27.12 mm to 76.12 mm. The comparison between AET measured in lysimeters and estimated PET. 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 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 26, 28 and 33 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 are closely in conformity with the results of Kadam *et al.* (1978) for Marathwada region.

Thornthwaite approach :

The recorded data on AET were compared with estimated PET using Thornthwaite approach. The data revealed that the

Table 1: Measured actual evapotranspiration (AET) and estimated potential evapotranspiration (PET) values according to different phenophases of the groundnut crop by various crop

Phenophases	Actual evapotran-spiration (AET in mm)	Potential evapotranspiration (PET in mm)			
		Blaney and Criddle	Modified Penman	Thornthwaite	Pan evaporation
Sowing to emergene (P1)	35.12	33.39	59.21	44.25	28.42
Emergence to vegetative (P2)	40.56	37.98	72.18	53.83	31.08
Vegetative to flowering(P3)	63.78	57.32	97.33	79.39	44.03
Flowering to peg formation(P4)	58.96	51.89	95.24	77.92	41.16
Peg formation to pod formation (P5)	73.23	67.01	103.68	87.7	38.01
Pod formation to kernel development (P6)	95.23	76.12	93.95	95.23	42.7
Maturity (P7)	34.36	27.12	58.098	44.04	20.09

AET values measured through lysimeters in different phenophases as well as meteorological week wise are presented in Tables 1, 2 and Fig. 1, 2 which ranged from 34.36 mm to 85.12 mm. While the PET values estimated through this method ranged between 44.04 mm to 95.23 mm. 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.

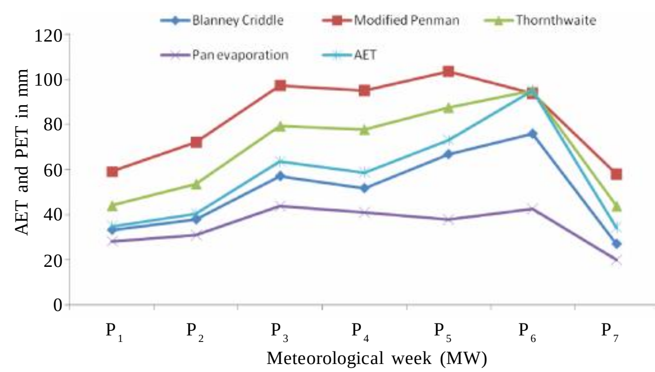

Fig. 1 : **Phenophases, AET and PET by different methods during groundnut crop growing season 2010**

where,
P_1 - Sowing to emergence
P_2 - Emergence to vegetative
P_3 - Vegetative to flowering
P_4 - Flowering to peg formation
P_5 - Peg formation to pod formation
P_6 - Pod formation to kernel development
P_7 - Maturity

Modified penman method :

The recorded data on AET were compared with estimated PET using modified Penman approach. The data revealed that the AET values measured through lysimetres in different phenophase as well as meteorological week wise are presented in Tables 1, 2 and Fig. 1, 2. The measured AET ranged from 34.36 (P_7) MW to 95.23 mm (P_6), where as the PET values estimated through this method ranged between 58.098 mm (P_7). to 103.63 mm (P_6). The comparison between AET measured in lysimeter 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 have been considered. The turbulent eddies 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

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

Meteorological weeks	Actual evapotranspiration (AET in mm)	Potential evapotranspiration (PET in mm)			
		Blaney criddle	Modified penman	Thornthwaite	Pan evaporation
26	30.45	29.16	51.28	36.27	27.18
27	29.78	27.85	45.06	38.32	21.7
28	32.85	28.41	47.76	39.022	20.58
29	33.45	29.41	43.72	38.64	23.38
30	30.65	28.01	41.36	39.05	16.94
31	28.98	27.68	43.26	38.64	20.16
32	34.12	28.12	48.69	39.6	21.84
33	29.37	27.53	46.25	38.76	17.57
34	30.45	27.41	47.083	38.23	14.91
35	29.86	27.23	49.6	37.9	11.27
36	25.69	23.92	45.36	36.74	11.76
37	25.78	24.15	46.01	36.11	15.75
38	28.75	26.3	46.01	38.51	15.68
39	32.12	27.62	48.07	38.63	19.95
40	31.64	25.85	45.71	36.44	18.83

plant body under field conditions, the AET values are relatively lower than PET. The highest PET values as well as measured AET values were recorded in P_6 (pod formation to kernel development). 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 groundnut was lower than the estimated potential evapotranspiration (PET) by modified Penman approach. The measured AET values and estimated PET values by this approach during peg formation to pod formation stage, where AET values matched with PET, since rainfall was more or less uniformly distributed resulting in the soil water availability. This showed the higher crop water requirements during pod formation to grain formation stage. Due to these season AET remained higher even after peg formation to pod 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 groundnut crop. These results are closely related with Kadam *et al.* (1978) for Marathwada and Jadhav *et al.* *(*1999) for Western Maharashtra.

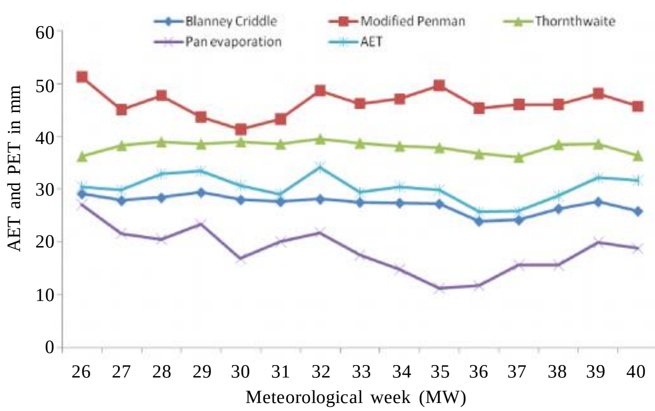

Fig. 2 : Meterological week, AET and PET by different methods during groundnut crop growing season 2010.

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_5 (peg formation to pod formation) and P_6 (pod formation to kernel development) than PET estimated through this approach.

The data on AET measured through lysimeter 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 40. The higher PET values seems to be due to lustours canopy development in MW 40. The leaf resistance should have reduced AET, when compared with PET measured thorough this approach. These results are agreement with Kadam *et al.* (1978) for Marathwada region. These results also confirm the findings of Subramanian and Rao (1985), Omar and Mehanna (1986), Mao *et al*. (2002) and Mall and Gupta (2002).

Conclusion :

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

– The total seasonal Actual Evapotranspiration (AET) for groundnut was found to be 401.24 mm at Solapur to be less than the seasonal water requirement of this crop for dryland region.

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

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