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Prediction of water requirement of garden pea (*Pisum sativum*) under hilly agro-ecosystem of Meghalaya

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ABSTRACT

The aim of the present study was to evaluate various empirical methods of estimating evapotranspiration to predict water requirement of garden pea *(Pisum sativum*. L.) under mid hill altitudinal conditions of hilly agro-ecosystem of Meghalaya. Field experiments were conducted during 2007 and 2008 at ICAR farm located at Umiam, Meghalaya. Various empirical equations were evaluated based on the meteorological data. Study revealed that water requirement of garden pea estimated by Hargreaves method was in close agreement (4.4% deviation) with the actual water requirement (489.1 mm), followed by Blaney-Criddle method and FAO Pan method with deviations of –90.0 (–22.6%) and –175.0 mm (–55.7%), respectively. The other empirical methods predicted high water requirement than the actual value. Hence, Hargreaves method could be considered the most suitable among evaluated methods for predicting water requirement of pea in hill agro-ecosystem of Meghalaya.

Key words: Crop co-efficient, Evapotranspiration, Garden Pea, Hilly ecosystem, Water requirement

Agriculture in India has been and is likely to remain the major user of water but the share of water undergoes a decline (10–15%) in 2025. There is a speculation of an increase in water use from nearly 5–7% to 11% in industry in 2025 thus reducing the availability of irrigation water (Singh 2002). The most plausible means of mitigating the scarcity of water in different regions is through increasing the productivity of existing water resources and produce more crops with less water. Increase in water productivity provides a means both to ease water scarcity and to leave more water for other human and ecosystem uses.

The north-eastern region (NER), comprising eight states, is endowed with bountiful water resources accounting for about 46% of the total water resources in the country (ICAR Research Complex in NEH Region). Availability of abundant water supplies in this region does not necessarily mean that water is an 'unlimited' resource or a free commodity. Though the region receives high rainfall (average 2 000 mm), lack of appropriate rainwater management conditions coupled with lack of suitable soil and water conservation measures lead to severe water scarcity, particularly during post-monsoon season. Therefore, crop production through efficient water management is needed for agricultural development as well as enhancing rural economy and quality of life. The water requirement of crops varies during growing period mainly due to variation in crop canopy (Gerson *et al.* 2001). Knowledge of water requirement of different crops is needed for irrigation scheduling and planning farm irrigation systems. Information is needed on the crop environment (climate and soil) and physiological behaviour of the crops for reliable estimates of water requirements. The water requirement is the sum of crop evapotranspiration and losses of water. There are numerous approaches used to estimate evapotranspiration (Sikka *et al.* 2001). As the determination of water requirement of crops using lysimeter is laborious and quite expensive, efforts have been made to correlate the actual water requirements in the field with the agro-meteorological data using different equations/methods for estimation of crop water requirement (Doorenbos and Pruitt 1977, Sharda and Bhushan 1984, Allen 1993).

Garden pea *(Pisum sativum* L.) is one of the popular and important high value crops grown in this region. The farmers obtain good remuneration from this crop where included in high value sequences due to their heavy demands in local and regional markets (Singh 2005). The success of production of garden pea would largely depend upon well-proven agronomic production and water management practices. Therefore, the present study had been undertaken to estimate the evapotranspiration for predicting water requirement of commercially grown garden pea in humid zones of eastern Himalayas.

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MATERIALS AND METHODS

The study was conducted at ICAR Research Complex for NEH Region, Umiam (25° 41´N, 91° 63´E, 980 m above mean sea level) situated at East *Khasi* Hills of Meghalaya receiving an annual average rainfall of 2 439 mm with high degree of temporal and spatial variations. The maximum temperature does not exceed 35°C in summer and minimum recorded is as low as 2.5°C in January. The basic information about the climatic parameters during the study periods (September to February) for last 20 years (1988–2007) were presented in Figs 1, 2. The concept of potential evapotranspiration (PET) is an attempt to characterize the climatic environment in terms of its evaporative power, i e the maximal evaporation rate that the atmosphere is capable of extracting from well-watered field under given conditions. The PET is thus said to represent the climatically imposed

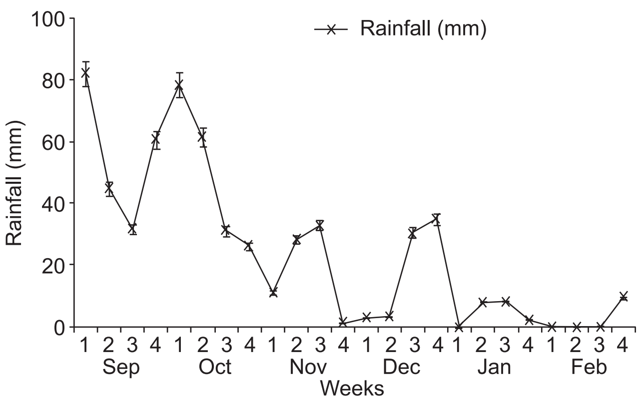

Fig 1 Weekly rainfall distribution pattern at Umiam, Meghalaya (1988–2007)

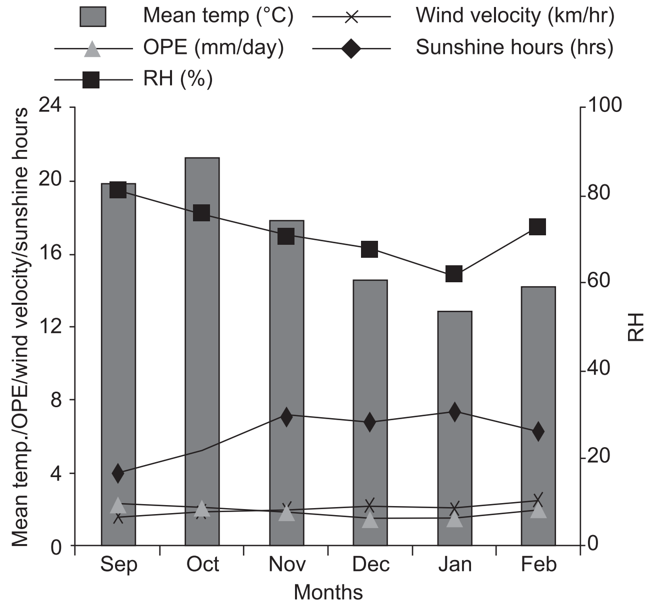

Fig 2 Monthly variation in climatic parameters at Umiam, Meghalaya (1988–2007)

'evaporative demand'. The potential evapotranspiration (PET) requirements of garden pea for the region have been calculated using different empirical equations (Table 1) based on the meteorological data for subsequent two crop growing seasons.

The water requirement of garden pea has been determined by conducting field experiments at the research farm (net plot size 3 m × 3 m with five replications) during 2007 and 2008. Actual water requirement of pea has been determined based on the actual evapotranspiration considering the effects

Table 1 Different empirical equation for measurement of ET

Method	Equation	Constant/abbreviation
Blaney-Criddle Method	$ET_{BC} = A + B\,(0.46T_m + 8.13)\,P$	*ET_{FAOBC}, PET (mm/d); A, Constant dependent on relative humidity and sunshine hours; B, constant dependent on relative humidity, sunshine hours and day time wind speed; T_m, mean monthly air temperature (°C) and P, monthly percentage of annual sunshine hours in the year*
Preistley-Taylor Method	$ET_{PT} = 1.26\,(\Delta/\Delta + \gamma)\,(R_{no} - G)$	*ET_{PT} , PET (mm/d), γ, net radiation (mm/d),G, soil air flus (mm/d),R_{no}, $R_{ns} + R_L$, where, R_{ns}, short wave net radiation (mm/d), R_L , net terrestrial radiation (mm/d)*
Hargreaves Method	$ET_{HARG} = 0.0023/\lambda\,[R_a \sqrt{T_d}\,(T_m + 17.8)\,]$	*ET_{HARG} ,PET (mm/d); λ ,latent heat of evaporation 2.45 mm per, MJ/m^2/d; R_a, extra terrestrial radiation, MJ/m^2/d; T_d , mean temperature range by month; T_m , mean air temperature (°C); T_d, $T_x - T_{n,}$ where T_x, max. air temperature (°C); T_n, min. air temperature (°C) T_m, $(T_x + T_n)/2$*
Evaporation Pan Method	$ET_{CPAN} = E_P\,P_C$	*ET_{CPAN} , PET (mmd); E_P , measured evaporation from pan (mm/d); P_C , pan evaporation correction factor*
Penmann- Monteith Method	$ET_{PENM} = R_{dp} + A_{dp}$	*ET_{PENM}, PET (mm/d); R_{dp}, radiation term (mm/d); A_{dp}, aerodynamic term (mm/d) R_{dp} , $(\Delta/\Delta + \gamma)\,(R_{np} - G)$, where R_{np}, net radiation (mm/d) and G, soil heat flux (mm/d), γ, psychrometric constant*

of effective rainfall (R_E), depth of irrigation water applied (I), the contribution through capillary rise from groundwater-table (C_P), deep percolation loss (D_P), surface water runoff (R_P) and change in soil profile moisture (ΔS). Effective rainfall was computed based on the actual rainfall during crop growing season using balance sheet method. Soil samples were collected at 15 days interval throughout crop growing season for soil moisture analysis and to find out the change in soil profile moisture.

RESULTS AND DISCUSSIONS

Potential and reference evapotranspiration

The potential and reference evapotranspiration rates estimated by various methods are presented in Fig 3. The potential ET estimated by Preistley-Taylor and Penmann-Monteinth equations (mean 5.92 and 5.82 mm, respectively) were higher as compared to other methods (2.37 to 3.34 mm) throughout the crop growing season. Similar results were found in case of reference ET of pea. Preistley-Taylor and Penmann- Monteinth methods were based on sunshine hours, more precisely on the ratio of actual monthly mean sunshine hours and monthly mean maximum sunshine hours. The monthly mean maximum sunshine hours have been determined from the sunrise hour angle. However, the experimental farm as well as the meteorological station is surrounded by north-eastern hills of higher altitudes. So, the actual sunshine hours are much lower than those determined by using sunrise hour angle due to shading by hills. Therefore, the ET estimated by the above referred methods is bound to be higher than the actual and the latter is realistic for flat topographic situations. The ET estimated by Blaney-Criddle method was marginally on lower side under this study. In this method, the ratio of actual monthly mean sunshine hours and the monthly mean maximum sunshine hours is used as a natural logarithm and its effect is marginally on higher side in estimating ET values. However, in other methods, i e Hargreaves and FAO Pan methods, the solar radiation/ sunshine hours is not a prerequisite parameter; hence the ET rates estimated by this methods had the lower values (Fig 3).

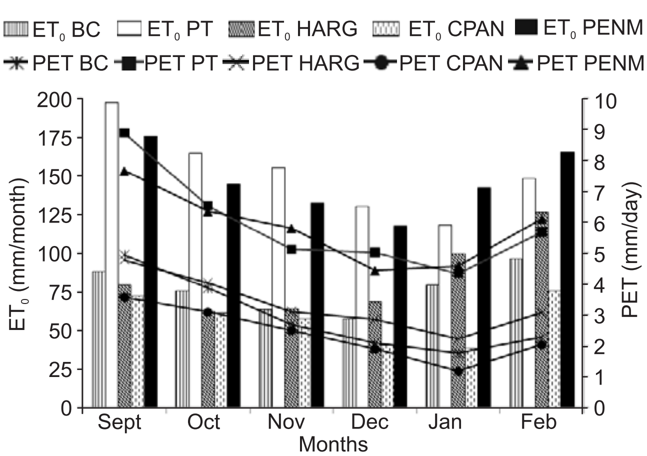

Fig 3 Potential evapotranspiration (PET) and reference evapotranspiration (ET_0) estimated by various empirical equations during the study period

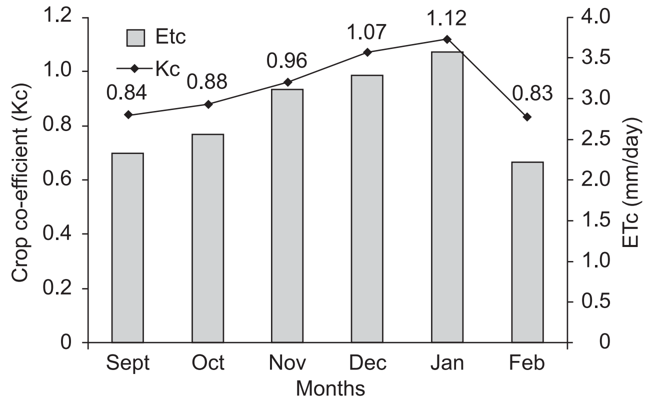

Fig 4 Month-wise crop co-efficient and evapotranspiration values for garden pea

Crop co-efficients and evapotranspiration (ET_c)

The average crop co-efficients (K_c) values obtained from crop evapotranspiration and reference evapotranspiration for different growth stages is presented in Fig 4. The crop co-efficient values increases with crop growing season, reaches its peak at January (1.12) and thereafter decreases with time. Based on the change in crop co-efficients, the entire cropping period is divided into three distinct stages. During the initial stage, K_c value goes on increasing from 0.84 to 1.07. In the mid stage for nearly two months in between initial and late stages, i e December and January, crop co-efficients attained nearly constant value with peak value (1.12) at January. During late stage, it again declined with an average value of 0.83. This type of variation in crop co-efficient is mainly due to plant water requirement patronized by trend in canopy development (Kashyap and Panda 2001).

The average daily crop evapotranspiration (ET_c) of garden pea was found to be minimum (2.32 mm/day) in September and maximum (3.58 mm/day) during January. In other months, it varied in between 2.22 and 3.11 mm/day (Fig 4). It was observed that the ET_c increased over time due to canopy development in the initial stage; attained nearly constant rate in the mid-stage season and declined in late stage. An increasing trend of ET_c in the mid-stages can be attributed to more crop water demand owing to full canopy development in addition to evaporative demand. However, in late stage, the rate of evapotranspiration decreases due to decrease in physiological activity.

Water requirement of garden pea

The predicted water requirement of garden pea estimated by different empirical methods using crop co-efficients (Doorenbos and Pruitt 1977) is given in Table 2. The predicted total water requirements of pea were: Preistley-

Table 2 Estimated water requirement (mm) for garden pea

Month	PET under various empirical equations				
	BC*	PT	HARG	CPAN	PENM
September	75.4	175.3	67.2	61.3	141.3
October	68.2	155.0	55.5	50.2	122.0
November	54.5	136.8	68.9	40.9	105.3
December	49.0	112.1	73.1	33.2	97.5
January	62.2	98.6	88.4	47.5	117.9
February	89.8	130.6	114.7	81.0	140.8
Total water requirement (estimated)	399.1	808.4	467.8	314.1	724.8
Deviations from actual water requirement (% deviations)	–90.0 (–22.6%)	319.3 (39.5%)	- 21.9 (–4.4%)	–175.0 (–55.7%)	235.7 (32.5%)

*BC, Blaney-Criddle Method; PT, Preistley-Taylor Method; HARG, Hargreaves Method; CPAN, Evaporation Pan Method PENM, Penmann- Monteith Method

Taylor Method; 808.4 mm, Penmann-Monteinth Method; 724.8 mm, Blaney-Criddle Method; 399.1 mm, Hargreaves Method; 467.8 mm and FAO Pan Methods; 294.1 mm. The actual water requirement of pea from the field experimentation was found to be 489.1 mm. The deviation of water requirement of pea estimated by Hargreaves Method from that of actual requirement was minimum (–21.9, 4.4% deviation). The suitability of other empirical Methods decreases in the order of Blaney-Criddle Method and FAO Pan Method with deviations of –90.0 (–22.6%) and –175.0 mm (–55.7%), respectively, which are highly significant.

It is concluded that the water requirement of pea as predicted by Hargreaves equation is in close agreement (4.4% deviation) with the actual water requirement. Therefore, the equation is the most suitable for predicting the water requirement of pea. All the other methods in which solar radiation parameter is involved show deviations towards the higher side, i e predicting high water requirement than the actual and hence, are not suitable for mid-hill agro-climatic conditions of Meghalaya.

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