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Assessment of crop water requirement of field pea (*Pisum sativum* L.) in foothills valley areas of Manipur, North East India

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ABSTRACT

The purpose of this study was to assess the evapotranspiration in field pea (*Pisum sativum* L.) in foothills valley areas of Manipur using the Hargreaves-Samani equation to predict the plant water demand. The crop coefficient (K_c) values ranged between 0.45 and 1.28 during the crop growth stages of field pea for the five crop seasons (2013-18). The average five-year effective rainfall was estimated to be 59.0 mm, with standard deviation (SD±) ranging between 4.4 to 35.1 mm. The average crop water requirement for field pea was estimated to be 221.0 mm and the average water demand for different crop growth stages of field pea was estimated to be 20.0 mm (initial stage), 52.0 mm (development stage), 100.0 mm (mid-season) and 49.0 mm (late season). Thus, the information generated may help in effective management of crop water requirements for sustainable crop production including field pea in the region.

Key words: Crop coefficient, reference evapotranspiration, crop evapotranspiration, effective rainfall

The demand for water is growing day by day due to the fast-growing of the human population, agricultural and industrial growth, and per capita availability of water decreases year by year. This imbalance declines the natural resources on the earth thus threaten to all living beings. Water is an essential component of all living beings on the earth. Water being critical component of all living beings; is essential for food security, life support, industrial production, and ecological sustainability as well as socio-development of a country. An additional 5,600 km^3/year of consumptive water will be required to meet potential food demands by the year 2050 (Falkenmark 2007). Water consumption in the agricultural sector is about 75% of the worldwide water utilized (Falkenmark and Rockström, 2004). Nearly one-third of the world's populations are living in different countries, are experiencing moderate to severe water stress (WMO, 1997). With the ever-increasing demand for water due to modern in agricultural practices and rapid urbanization it is essential to focus on efficient consumption and management of accessible water resources. Increasing water demand due to increase in crop production is a new challenge for water resources planners and managers. To cope up with the increasing population, agricultural production needs to be increased along with the irrigation application at the proper time (Khare *et al.,* 2007). Climatic conditions, soil and crop cover patterns are the most significant factors for understanding agricultural water requirements. In India, irrigation is the main water consumption, which occupies more than 80 per cent of total water use (MoWR, 1999). The agricultural segment is the major consumer of water resources around the world and increasing population requires more food production, which enhances more pressure on water consumption. Hence, the assessment of crop water demand will provide valuable information to improve agricultural water management practices for sustainable crop production (Pandey *et al.,* 2008; Mehta and Pandey, 2016; Singh *et al.,* 2019).

The North East Region (NER) in India has abundant water resources, which account for about 46% of the country's total water resources (Saha, 2011). Although high rainfall is occurring in the region, the lack of adequate rainwater management conditions and adequate soil and water conservation measures lead to severe water scarcity, especially in the post-monsoon period. Therefore, efficient water management requires efficient crop production for agricultural development and for improving the rural economy and quality of life. There are many challenges in sustaining agricultural production with the increased scarcity of water resources and increasing costs of production. However, these restrictions, agricultural production needs to rise drastically over the next decade to meet the food requirements and particularly those of the developing nations. Hence, producing more crops with less input resources is a difficult assignment to ensure various securities such as foods, economic, and water in this region. Field pea (*Pisum sativum* L.) is one of the significantly high-value crops grown in Manipur. The performance of field pea production depends largely on good agronomic practices and effective water management. The present study was, therefore, planned and taken up with specific objectives to assess crop coefficient, to estimate reference and crop evapotranspiration, to evaluate effective rainfall and to estimate water requirement in field pea using the Hargreaves-Samani equation for effective water resources management.

MATERIALS AND METHODS

Description of the study area and datasets used

The study was conducted in the Imphal West District of Manipur, North East India. The agrometeorological data *viz.*, maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, bright sunshine hours, wind speed and also relevant crop data were collected from ICAR Research Complex for NEH Region, Manipur Centre. For the purpose of this study, five crop seasons (2013-18) data were considered and utilized to achieve the above objectives. The agrometeorological observatory is located geographically at 24.45° N latitude and 93.54° E longitude and 774 m amsl altitude at the experimental farm, ICAR Research Complex of the NEH Region, Manipur Center, Imphal, Lamphelpat. The average annual rainfall in the study area is 1450 mm in 152 rainy days; the rainy/monsoon season lasts from the beginning of May to October.

Estimation of crop water requirement

The depth of crop water demand (CWD) for field pea was estimated by multiplying Evapotranspiration (ET_o) and crop coefficient (K_c). Then, crop water requirement (CWR) was computed by subtracting effective rainfall from crop water demand (Smith, 1992).

CWD and CWR were computed using following equations:

$$CWD = ET_O \ x \ K_C$$

$$CWR = CWD - P_e$$

where, CWD = crop water demand (mm day^{-1}), ET_o = reference evapotranspiration (mm day^{-1}), K_c = crop coefficient, CWR = crop water requirement (mm day^{-1}), and P_e = effective rainfall (mm day^{-1}).

Estimation of reference evapotranspiration

In the present study, reference evapotranspiration (ET_o) was computed using Hargreaves-Samani (HS) equation for the period 2013-18. MS-Excel software was used for the calculation of ET_o. The Hargreaves-Samani (HS) equation (Hargreaves and Samani, 1985) is empirical in nature and described as:

$$ET_0 = 0.408 \ x \ 0.0023 \ x \ R_a \ (T_{mean} + 17.8) \ (\Delta T)^{0.5}$$

where, ET_o = reference evapotranspiration (mm/day), R_a = extraterrestrial radiation (MJ m^{-2} day^{-1}), T_{mean} = mean air temperature (°C) estimated as the average of minimum (T_{min}) and maximum (T_{max}) daily air temperatures, ΔT = difference between T_{max} and T_{min} (°C), 0.0023 = an empirical constant of the H-S equation and 0.408 = conversion factor, which converts MJ m^{-2} day^{-1} to mm/day.

Determination of crop coefficient (K_c)

Values of crop coefficient (K_c) of field pea were obtained using the guidelines of FAO Irrigation and Drainage Paper No. 56 (Allen *et al.*, 1998) and values of $K_{c\ mid}$ and $K_{c\ end}$ were adjusted at the local condition using local meteorological data of wind speed, minimum relative humidity and mean plant height (Allen *et al.*, 1998).

Determination of Kc mid

$$K_{c\ mid} = K_{c\ mid\ (Tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0.3}$$

Determination of Kc end

$$K_{c\ end} = K_{c\ end\ (Tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0.3}$$

value for $K_{c\ end}$ taken from FAO Irrigation and Drainage Paper No. 56 (Allen *et al*., 1998), u_2 = mean value for daily wind speed at 2 m height over grass during the late season growth stage [m s^{-1}], for 1 m s^{-1} $\leq u_2 \leq$ 6 m s^{-1}, RH_{min} = mean value for daily minimum relative humidity during the late season stage [%], for 20% $\leq RH_{min} \leq$ 80%, h = mean plant height during the late season stage [m], for 0.1 m $\leq$ h $\leq$ 10 m.

Estimation of effective rainfall

The effective rainfall is that part of the total rainfall, which potentially lowers the plants' net quantity of required irrigation water. Effective rainfall (P_e) is

Table 1: The mean, standard deviation (SD) and coefficient of variation (CV) of effective rainfall, ETc, and crop water requirement during 2013-18 period

Growth Stage	Growth duration (Days)	Effective rainfall			Crop water demand/ET_c			Crop water requirement		
		Mean (mm)	SD (mm)	CV (%)	Mean (mm)	SD (mm)	CV (%)	Mean (mm)	SD (mm)	CV (%)
Initial stage	20	14.0	17.3	121.8	30.0	2.8	9.3	20.0	12.3	62.9
Development stage	30	21.0	35.1	167.2	69.0	5.8	8.4	52.0	31.2	59.8
Mid-season stage	35	15.0	12.8	87.7	115.0	4.1	3.5	100.0	16.1	16.1
Late season stage	15	9.0	4.4	48.4	58.0	2.1	3.6	49.0	6.2	12.8
Total	100	59.0	---	---	272.0	---	---	221.0	---	---

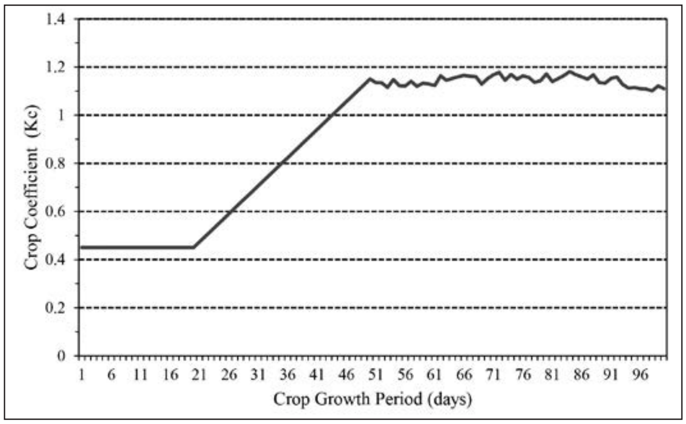

Fig. 1: Mean crop coefficient (K_c) of field pea for crop growth period during 2013-18.

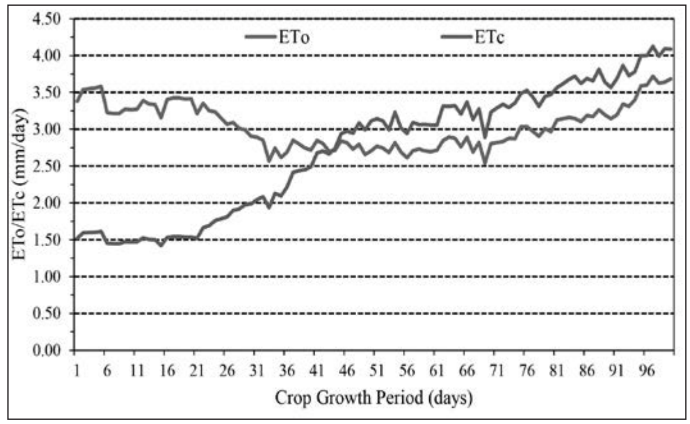

Fig. 2: Comparison between mean ET_o and ET_c of field pea for crop growth period during 2013-18.

simply the amount of rainfall that is valuable for plant growth. Effective rainfall was computed according to the method developed by the USDA Soil Conservation Service (Dastane, 1974), described as:

$$P_e = P(125 - 0.2P)/125 \quad \text{for } P \leq 250 \text{ mm}$$
$$P_e = 125 + 0.1P \quad \text{for } P > 250 \text{ mm}$$

where, P_e is the effective rainfall (mm/month); P the total precipitation (mm/month).

RESULTS AND DISCUSSION

Variation of crop coefficient

The variation of mean crop coefficient (K_c) of field pea for crop growth period of different years during 2013-18 period has been given in Fig. 1. During the crop development stage of field pea, minimum and maximum value of crop coefficient (K_c) was obtained as 0.47 and 1.15, respectively during all the five seasons of 2013-18 period owing the vibrant and luxurious leaves with higher rate of photosynthesis and transpiration. The standard deviation (SD) during mid-season stage of field pea varied from 0.02 to 0.06, whereas SD during late season stage for field pea varied from 0.02 to 0.07.

Reference evapotranspiration (ET_o) and crop evapotranspiration (ET_c)

The comparison between mean ET_o and ET_c of field pea for crop growth period of five years 2013-18 period has been given in Fig. 2. The standard deviation (SD) of daily reference evapotranspiration during the growth period of crop varied between 0.04 to 0.85 mm day^{-1}. The standard deviation (SD) of daily crop evapotranspiration during the growth period of field pea varied between 0.05 to 0.89 mm day^{-1} because of change in leaf area covering the soil surface beneath over the growing period.

Effective rainfall and crop water requirement

The variations in mean effective rainfall for different crop growth stages for the period 2013-18 has been given in Table 1. The average five seasons effective rainfall was estimated as 59.0 mm with standard deviation (SD) varying between from 4.4 to 35.1 mm. The average crop water demand for field pea crop evaluated was 272.0 mm/season and average crop water demand at various crop growth stages estimated were 30.0 mm (at initial stage), 69.0 mm (at crop development stage), 115.0 mm (at mid-season stage) and 58.0 mm (at late season stage). The SD for various crop growth stages varied between 30 to 115 mm and the coefficient of variation (CV) varied between 3.5 to 9.3 per cent.

The variations in mean crop water requirement of field pea for different crop growth stages during the period 2013-18 has been given in Table 1. The average crop water requirement for field pea was assessed to be 221.0 mm and further at different growth stages, the average crop water requirement has been estimated 20.0 mm (at initial stage), 52.0 mm (at crop development stage), 100.0 mm (at mid-season stage) and 49.0 mm (at late season stage). The SD of crop water requirement at different crop growth stages varied between 6.2 to 31.2 mm and the coefficient of variation (CV) varied between 12.8 to 62.9 per cent.

CONCLUSION

It has been concluded with the results obtained using the Hargreaves-Samani equation/method for average crop water requirement in field pea was maximum at peak growth stage than the initial and later stages of crop growth. Therefore, the method can be suitably used to estimate the water demand of field pea at various growth stages and may further assist in effective management of crop water requirements and adaptive strategies for sustainable crop production.

Conflict of Interest Statement : The author(s) declare (s) that there is no conflict of interest.

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