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Impact of global warming on future ET_0 and ET_C for pea in Himachal Himalayas

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Abstract: *Pea is one of the most important Rabi crops of Himachal and northern gangetic plain and thousands of farmers depends upon its cultivation to earn their livelihood. Reference crop evapotranspiration (ET_0) and crop evapotranspiration (ET_c) of pea during Rabi 2017-18 for mid hill region of Himachal Pradesh was computed using FAO CROPWAT model. Seasonal mean reference crop evapotranspiration (ET_0) was relatively higher in D_2 (1.79 mm/day) as compared to D_1 (1.59 mm/day) and similar trend was also observed in radiation use efficiency viz. 14.77 MJ/m^2/day and 14.19 MJ/m^2/day, respectively. A direct relation was observed between $ET_0$and RUE. It was also found that an increase in the existing temperature by 0.5, 1.0, 1.5 and 2.0 ^oC will increase the ET_0 by 0.63, 1.26, 1.89 and 2.52 % and irrigation water requirement by 1.10, 2.21, 3.31and 4.35 % , respectively. A higher positive linear relation was observed between predicted and observed ET for first date of sowing which indicated that pea must be sown on or before 1st December in the mid hills of HP. The study concluded that global warming scenarios are likely to increase crop water requirements, suggesting thereby the need for effective planning and sustainable use of water resources in the region.*

Keywords: *Pea, Climate change, water requirements, Reference crop evapotranspiration.*

INTRODUCTION

Pea (*Pisumsativum*L.) an important pulse crop, a native of fertile crescent, was among the first crops cultivated by primitive man for food, forage and vegetable(Zohary and Hopf, 2002). In India, it occupies an area of approximately 530 ('000) ha with an average productivity of 10.08 MT/ha (NHB, 2017). In Himachal Pradesh, the total area under pea cultivation is around 23.65 ('000) ha, annual production is 277.20 ('000) MT with an average productivity of 11.72 MT/ha (DOA, 2017). Like other crops, pea is influenced by the complexity of weather and climate as it does not thrive in summer heat or lowland tropical climates, but grow well in cooler and high altitude tropical areas (Oelke*et al.*, 1991). Pea is one of the important *Rabi*pulsewith high water requirements and could be grown under assessed irrigation facilities. One of the best and effective methods to cope up with the situation of severe water scarcity is to increase the productivity of the water resources and accurate estimation of evapotranspiration. Thomas (2008) claimed that evapotranspiration and water use efficiency of crops will be altered by climate change in future. For attaining proper irrigation scheduling, it is imperative to determine the actual crop evapotranspiration (ET_c) during the growing season (Hunsaker*et al.*, 1996).Besides this, proper usage and management of water resource systems require knowledge of the actual evapotranspiration (AET) and irrigation water requirement (IWR) of the crops (Droogers*et al.,* 2010).

Simulation models and decision support systems can play effective role in enabling farmers to select water use options including irrigation systems and to implement appropriate irrigation scheduling. The CROPWAT model is a windows-based decision support system that estimates the reference evapotranspiration, crop evapotranspiration, crop water requirements and irrigation scheduling and based on data *viz.,* monthly rainfall, evapotranspiration, temperature, sunshine, humidity, wind speed and radiation as input to run the model (FAO, 2010). Many studies are available in different cereal and vegetable crops but hitherto very less work is available in pea crop, a very important and widely used pulse.Therefore, an experiment was planned to calculate the two very important agrometeorological parameters, reference evapotranspiration (ET_0) and crop evapotranspiration (ET_C) of peainmid hills of Himachal Himalayasusing FAO CROPWAT model.

MATERIALS AND METHODS

A field experiment was conducted during the *Rabi* season of 2017-18 in the experimental farm of the Department of Environmental Science, Dr. YS Parmar University of Horticulture & Forestry Nauni (30°86'N, 77°16'E and 1275 m amsl) with three pea cultivars under different crop growing environments. The climate of the area is sub-tropical to sub-temperate and semi-humid characterized by cold winters and having distinguished four major seasons in the year. The Climatograph of crop growing period was given in Figure 1. The treatments comprised of two dates of sowing *viz.*, D_1 (1st December) and D_2 (15th December) as main plot and three pea varieties (Azad-P1, PB-89 and ESP-111) as subplot were replicated thrice in a randomized block design. The sowing was done manually in rows at 45 x 20 cm spacing with 4-6 cm depth @ two seeds per hill. Irrigation was scheduled as and when required.

Meteorological data was recorded from the Agrometeorological Observatory, situated near the experimental farm and Potential Evapotranspiration (PET) was estimated using Thornthwaite method and Reference Evapotranspiration (ET_0) using CROPWAT model and this model was calibrated and validated for the mid hill region.

Estimation of PET using Thornthwaite method

Computation of PET for a given climate is essentially required to arrive at a meaningful and scientific conclusion before taking any agricultural decision. The Thornthwaite method (1948) is the best among different empirical approaches as used by many workers for estimation of PET over several locations of India (Kumar *et al.,* 1986)as it requires only monthly mean temperature data which was actually available at all the meteorological stations also used in the present study:

$$\mathbf{PET = 1.6\,(10T/I)^{a}\,(D/12)\,(N/30)}$$

For a month consisting 30 days and 12 hours a day, the above equation can be written as:

$$\mathbf{E = 1.6(10T/I)^{a}}$$

Where,

E = Unadjusted PET, cm/month

T = Mean air temp, °C

I = Annual heat index. It is the summation of 12 values of monthly heat indices i.

$$\mathbf{i = (T/5)^{1.514}}$$

a = an empirical exponent computed by an expression given as,

$$a = 6.75\times10^{-7} I^3 - 7.71\times10^{-5} I^2 + 1.79\times10^{-2} I + 0.49239$$

For daily computation the equation is modified as:

PET = (KxEx10)/30 (mm/day)

Where, K = Adjustment factor

Estimation of ET_0 using CROPWAT model

In the present investigation, CROPWAT (Version 8.0) model developed by FAO was used to calculate the evapotranspiration and irrigation water requirement of pea. The necessary crop data required to run the model successfully was presented in Table 1.

RESULTS AND DISCUSSION

PET estimated by Thornthwaite method

The maximum value of monthly heat index (i) was obtained in June (10.9) and minimum in January (3.1) while, the annual heat index (I) was 88.2for the mid hill region of HP. The monthly maximum PET was in the month of June (102.16mm/month) and minimum in January (20.5mm/month) and the annual PET was 756.97 mm for the mid hill region of HP (Table 2).

Reference Evapotranspiration(ET_0) using CROPWAT model

The meteorological parameters were collected and used in the CROPWAT model and got the seasonal evapotranspiration rate and radiation use efficiency of peaas output (Table 3). The higher ET_0 rate(1.79 mm/day)was observed in D_2 as compared to D_1 (1.59 mm/day) and similar trend was observed in radiation use efficiency *viz.*14.77 MJ/m²/day and 14.19 MJ/m²/day, respectively.

Effect of elevated temperature on water requirement of pea

The effect of increasing temperature on water requirement of pea was assessed by simulation. With the existing temperature, the model predicted an average seasonal ET of 1.59 mm day^{-1} along with a seasonal irrigation water requirement of 144.8 mm for mid hill region of HP (Table 4). When the temperature increased from existing to +2 °C, the model projected water requirement of pea from 144.8 mm to 151.4 mm, also a significant increase in average ET rate from 1.59 mm day^{-1} to 1.63 mm day^{-1}. Per cent departure of seasonal ET and water requirement from the existing conditions with the increase in temperature was also calculated using CROPWAT. It was observed that with increase in temperature up to 0.5 ° C from the present state, + 0.63 per cent increase occurred in seasonal ET along with + 1.10 per cent increase in seasonal IWR value from the present state. If we increase the temperature up to +2 ° C, the model gave + 2.52 per cent increase in seasonal ET requirement along with the + 4.35 per cent increase in water requirement. Shahid (2011) evaluated the impact of climate change on crop water requirement and reported that the irrigation requirement will increase by 0.8 mm day^{-1} by the end of this century. Banerjee *et al.* (2016) reported that with increase in temperature by 2 and3°C over normal, the mean ET of potato would increase by0.06 and 0.16 mm day^{-1} and average water requirement by6.0 mm and 16.6 mm per season, respectively.

Validation of CROPWAT model

The CROPWAT model was validated under different environments for pea crop. The Predicted ET was found higher than observed ET for both the dates of sowing. The predicted as well as observed ET showed a positive correlation with the increasing LAI and was highest at maturity. A linear and positive relation was observed between predicted and observed ET (Fig.2 and 3). There was good higher correlation (R^2= 94.6) for D_1 as compared to D_2 (R^2= 89.2) which indicated that pea must be sown on or before 1st December in the mid hills of HP.

CONCLUSIONS

It can be inferred from the present study that the date of sowing play a very important role in determining the water consumption and ET rate in pea cultivars. Seasonal mean reference crop evapotranspiration (ET_0) was relatively higher in D_2 (1.79 mm/day) as compared to D_1 (1.59 mm/day) and similar trend was also observed in radiation use efficiency (RUE) *viz.* 14.77 MJ/m^2/day and 14.19 MJ/m^2/day, respectively. It has also been observed that ET_0 is directly related to the RUE. A direct relation was observed between ET_0 and RUE. It was also found that an increase in the existing temperature by 0.5, 1.0, 1.5 and 2.0 °C will increase the ET_0 by 0.63, 1.26, 1.89 and 2.52 % and irrigation water requirement by 1.10, 2.21, 3.31and 4.35 % , respectively. A higher positive linear relation was observed between predicted and observed ET for first date of sowing which indicated that pea must be sown on or before 1st December in the mid hills of HP. A linear and positive higher relation was observed between predicted and observed ET under D_1which indicated that pea must be sown on or before 1st December in the mid hills of HP. The study concluded that global warming scenarios are likely to increase crop water requirements, suggesting thereby the need for effective planning and sustainable use of water resources in the region.

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IMAGES AND TABLES

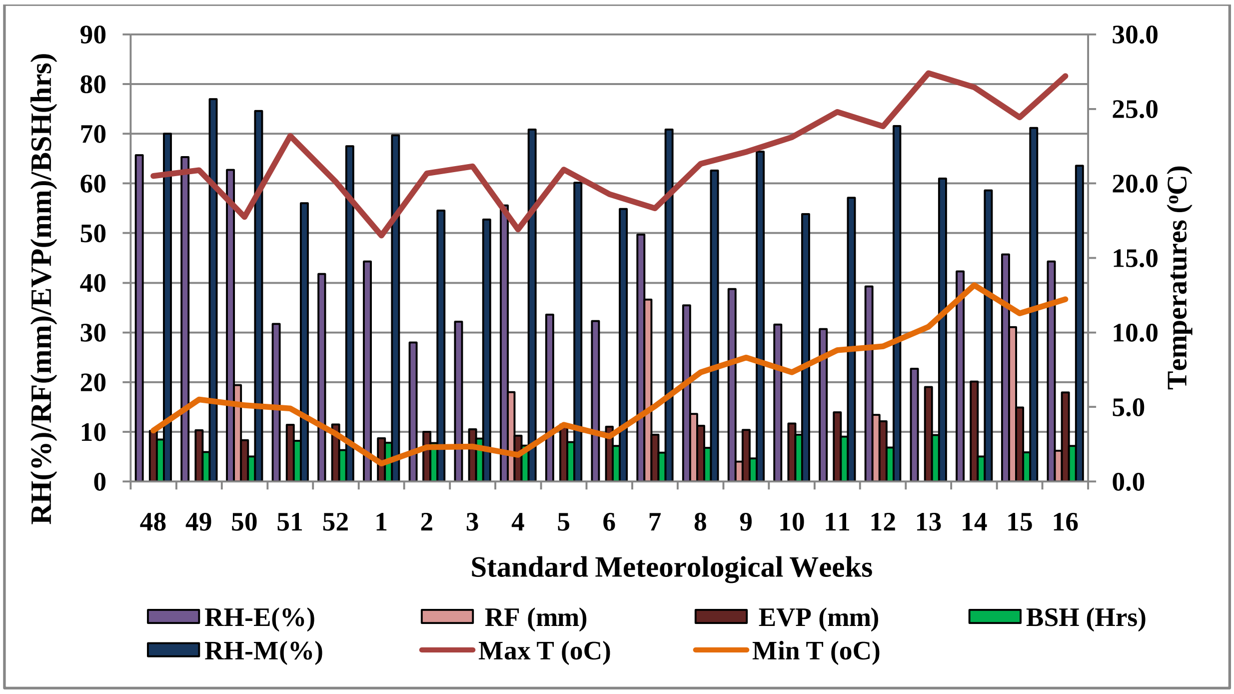

Fig.1: Climatograph of the study area for crop growing period

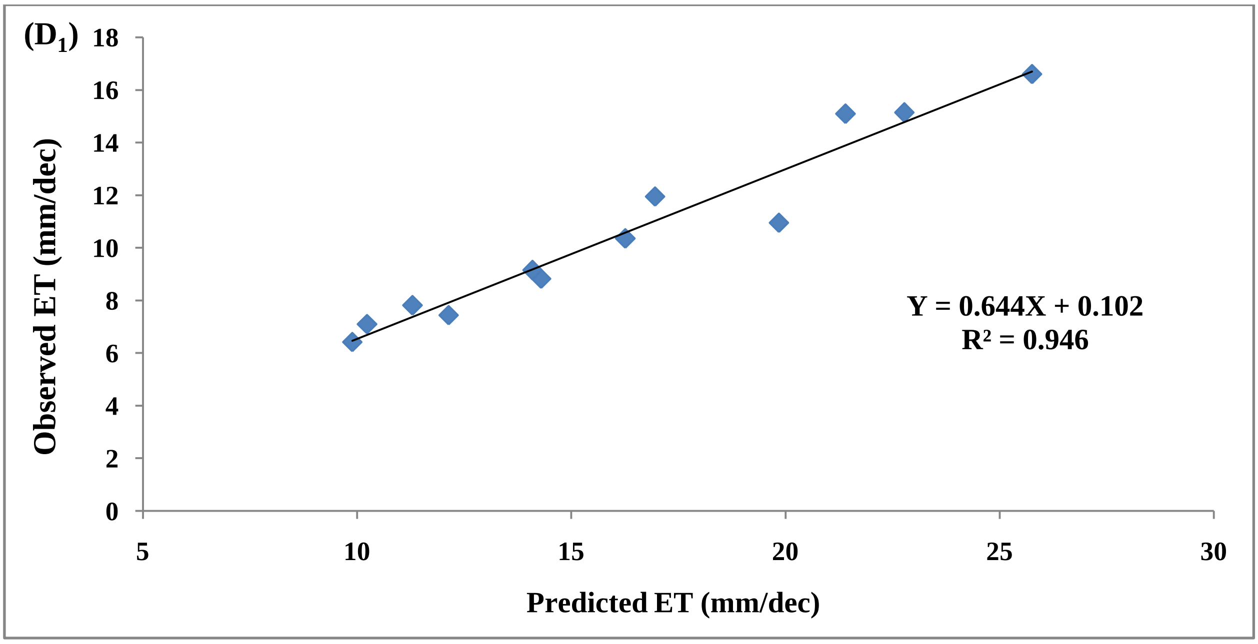

Fig.2: Relation between Observed and Predicted ET under D_1

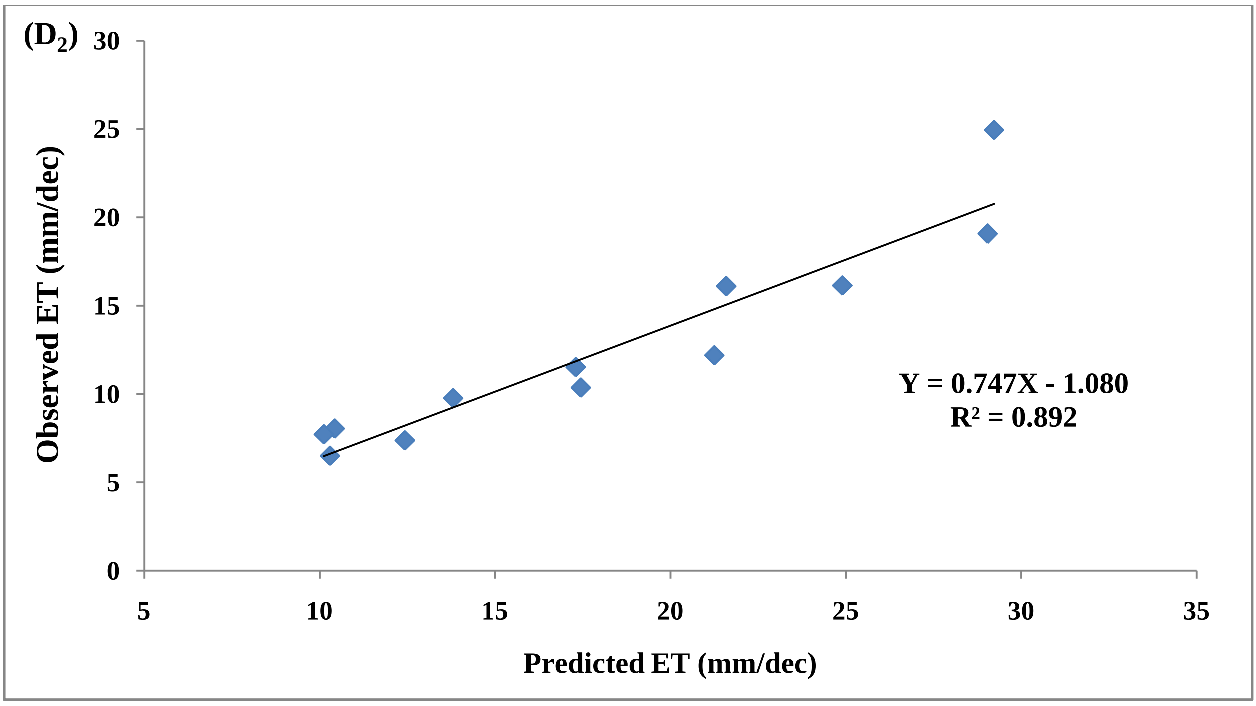

Fig.3: Relation between Observed and Predicted ET under D_2

Table 1: Input data required to run the CROPWAT model

Crop Name- Pea	**Planting Date: 01/12/2017**			**Harvesting date: 31/03/2018**	
Stage	**Initial**	**Development**	**Mid - season**	**Late season**	**Total**
Stage days	10	27	38	46	121
K_C values	0.52	---	1.38	1.20	
Rooting depth (m)	0.10	---	0.12	0.12	
Critical depletion (fraction)	0.42	---	0.46	0.48	
Yield response (fraction)	0.52	0.49	0.46	0.44	0.42
Crop height (m)			0.35		

Table 2: Calculated PET using Thornthwaite method

Month	T-mean	i	A	E	K	PET/day (mm)	PET/M (mm)
Jan-18	10.6	3.1	1.93474	2.28292	0.9	0.6678	20.5
Feb-18	12.8	4.1	1.93474	3.26335	0.9	1.04894	29.3
Mar-18	16.6	6.1	1.93474	5.40563	0.9	1.56938	48.6
Apr-18	19.9	8.1	1.93474	7.68454	0.9	2.30536	69.1
May-18	23.4	10.3	1.93474	10.5818	0.9	3.07214	95.2
Jun-18	24.3	10.9	1.93474	11.3516	0.9	3.40548	102.1
Jul-18	23.5	10.3	1.93474	10.634	0.9	3.0873	95.7
Aug-18	23.8	10.6	1.93474	10.9328	0.9	3.17405	98.4
Sep-18	21.7	9.2	1.93474	9.12499	0.9	2.7375	82.1
Oct-18	17.1	6.4	1.93474	5.75438	0.9	1.67063	51.7
Nov-18	14.1	4.8	1.93474	3.97486	0.9	1.19246	35.7
Dec-17	12.5	3.9	1.93474	3.11643	0.9	0.90477	28.5
Sum		**88.2**					**756.9**

Table 3: Estimated Reference Evapotranspiration (ET_0) of pea using CROPWAT model under varying environments

Months	Temperatures		Relative Humidity (%)	Wind Speed (km/day)	Sunshine (Hours)	RUE (MJ/m²/day)	ET_0 (mm/day)
	Min Temp(°C)	Max Temp (°C)					
D_1 (1st December)							
December	4.50	20.40	51.00	14.20	6.40	11.05	1.11
January	2.10	19.10	39.00	6.80	7.70	13.10	1.16
February	5.30	20.20	38.00	2.20	6.80	14.20	1.59
March	8.80	24.30	32.00	3.00	8.00	18.40	2.48
Mean	**5.18**	**21.00**	**40.00**	**6.55**	**7.23**	**14.19**	**1.59**
D_2 (15th December)							
December	3.78	21.28	38.29	10.87	7.19	11.71	1.04
January	2.10	19.10	39.00	6.80	7.70	13.10	1.16
February	5.30	20.20	38.00	2.20	6.80	14.20	1.59
March	8.80	24.30	32.00	3.50	8.00	18.40	2.48
April	12.17	25.21	44.71	3.26	5.36	16.45	2.69
Mean	**6.43**	**22.02**	**38.40**	**5.33**	**7.01**	**14.77**	**1.79**

Table 4: Projected ET_C and irrigation requirement of pea under elevated temperatures

Temperature (°C)	Seasonal ET (mm/day)	Seasonal IWR (mm)
Existing	1.59	144.8
Existing + 0.5	1.60 (0.63%)	146.4 (1.10%)
Existing + 1.0	1.61 (1.26%)	148.0 (2.21%)
Existing + 1.5	1.62 (1.89%)	149.6 (3.31%)
Existing + 2.0	1.63 (2.52%)	151.1 (4.35%)