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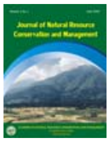

Microclimatic factors in crop growth and yield of pea in mid hills of Himachal Himalayas

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ABSTRACT

Field experiment was conducted during the *Rabi* season of 2017/2018 and 2018/2019 in randomized block design with three pea cultivars (Azad-P1, PB-89 and ESP-111) and two dates of sowing. The biological yield, pod yield, seed yield, dry matter accumulation, plant height, harvest index and leaf area index was observed higher in variety PB-89 under first date of sowing. A linear inverse relation was observed between the temperature in crop stand and pod yield which explained the 87.7 per cent variability in pod yield. The linear positive relation explained 67.9 per cent variation in pod yield by relative humidity in crop stand. The average PAR interception was observed highest at pod formation for both dates of sowing and afterwards, PAR interception decreased as the crop reached the maturity. The positive and linear relationship was observed between Leaf Area Index and IPAR in pea which explained 82.3 per cent variation in IPAR by LAI under different sowing environments, cultivars and irrigation levels. The findings of present study will help to understand that how microclimatic factors such as temperature, humidity, vapour pressure, soil temperature, soil moisture and net radiations etc. also could make dramatic changes in the final yield in spite of macroclimatic factors. The study suggests that the selection of improved varieties and date of sowing is imperative to enhance the total production and productivity of the pea crop. It is recommended that sowing of pea may be done on or before 1st December for higher yield and PB-89 variety for Rabi season in mid hills of south west Himalayas. To increase pea yields, new studies regarding the microclimatic conditions of the crop canopy should be developed to improve the maximum potential yield.

Keywords: Microclimate, phenophases, IPAR, crop stand, pea, mid-hills of Himachal Pradesh.

INTRODUCTION

The crop growth does not depend only on prevailing weather, but also on the microclimate or microenvironment within the crop canopy. Crop systems are complex and they depend in very complex ways on equally complex independent variables of weather and climate (Bunting, 1975). As a result of the process of substance and energy exchange between the active surface and the lowest layers of atmosphere a change of air temperature and humidity inside a canopy and immediately above it occurs. This way, every plant community creates its own microclimate and the climatic status of a canopy can be significantly influenced (Geiger, 1965). Each component of the microclimatic environment exhibits unique spatial and temporal responses to changes in riparian structural elements even the relationships between microclimate and biological processes are complex andoften nonlinear (Chen *et al.,* 1999).

Changes in crop microclimate can impact crop growth and development at several levels which, in turn, directly influence crop productivity (Mohan Singh *et al.,* 2018). Despite its economic importance, the microclimate in pea canopies has not yet been studied in detail. Such a study can yield valuable information regarding the interaction of a crop with its environment. In this context, the aim of this study was to evaluate some microclimatic parameters dynamic for threepea cultivars in mid hills of north western Himalayas.

MATERIALS AND METHODS

Field experiment was conducted during the *Rabi* season of 2017-2018 and 2018-2019 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. Pea is one of the most versatile crops that has unique attributes and can fit most cropping systems with ability to give profitable yield under rainfed area. Crops following pea have increased yields with reduced production costs because of increased moisture retention, nodulation characters and better soil tilth. Inspite of these characters still there are gaps in production and productivity so, present experiment was designed to study the agro-climatic parameters which according to local farmers may be the possible reason of yield gaps.

The experiment 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. These varieties selected for the study as they are widely adopted by a sizable growers in the state and major commercial *rabi* vegetables earning source of livelihood in the mid hill region especially. The sowing was done manually in rows at 45 x 20 cm spacing with 4-6 cm depth @ two seeds per hill. The excess plants were thinned/ gap filling was done at 20 days after sowing (DAS) keeping within row and plant distance maintaining uniform plant stand. The gross and net plot size was 3.0x2.0 m and 2.70 x 1.8 m, respectively. Two irrigation levels I_1 and I_2 were selected. In I_1 irrigation was applied at 3 days interval but, in I_2 at 6 days of intervals. Recommended packages of practices for pea crop were followed (Anonymous, 2017). 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 averages of two years meteorological condition during the crop growth period was given in Table 1. Following agro-climatic observations were recorded in the experiment.

Crop observation

Phenology: In the present investigation five major phenophases *viz.*, emergence, first node, flowering, pod formation and maturity and days taken to attain the same were recorded in three pea cultivars (Azad P-1, PB-89 and ESP-111) and two dates of sowing (1st December & 15th December). The number of days taken to attain these phenophases and the physiological maturity decreases significantly with delayed sowing of pea.

LAI: The leaf area index (LAI) was calculated at every phenophases from each treatment.

Dry matter partitioning: The accumulation of dry matter in different plant parts viz. root, stem, leaves and pods were calculated at 15 day interval by uprooting the plants from each treatment and taking fresh & oven dried weights. The plant height also observed after uprooting the plants.

Yield and yield attributes: The yield and yield attributed like number of plants per plot, number of pods per plant, number of seeds per pod, weight per pod and 100 seeds test weight etc. were also recorded from each treatment.

Microclimatic observations

The meteorological parameters like temperature, relative humidity and vapour pressure were measured in crop stand at middle of the crop height

Table 1. Normal climatic parameters of crop duration on month basis.

Months	Temperature (°C)			Relative Humidity (%)			Wind Speed	Sunshine
	Max.	Min.	Mean	M	E	Mean	(*kmph*)	(*hrs*)
December	20.4	4.5	12.5	69	51	60	0.6	6.4
January	19.1	2.1	10.6	61	39	50	0.3	7.7
February	20.2	5.3	12.8	63	38	50.5	0.1	6.8
March	24.3	8.8	16.6	62	32	47	0.1	8
April	27.1	12.6	19.9	61	40	50.5	0.1	7.1
Mean	22.22	6.66	14.4	63.2	40	51.6	0.24	7.2

in each treatment with the help of dry and wet bulb thermometers. The soil temperature was measured by installing soil thermometer at 5cm depth. The soil moisture was measured in percentage by gravimetric method taking soil sample from next day of irrigation application from all the irrigation treatments.

Intercepted photosynthetically active radiation IPAR): Daily solar radiation was calculated by using the formula:

Rs = RA (1-r) (a+b n/N)

Where,

Rs = Solar radiation

RA = Solar constant

r = Albedo

a, b = Constants (a = 0.32, b = 0.46)

n = Actual bright sunshine hours

N = Maximum possible sunshine hours

The incoming PAR was then calculated by multiplying RS by 0.45 (Rosenthal and Gerik, 1991). Daily PAR intercepted by the canopy was then determined from the computed extinction coefficient, incoming and reflected PAR and interpolated leaf area index estimated between two radiation measurements as:

IPAR = (l – e-KF) PAR

Where, PAR = Incoming photo-synthetically active radiation, K = Crop coefficient

Data representation

The results are presented in Table 1 (climatic normals of the crop growing period) and Table 2 (correlation parameters average of two years and different treatments. Similarly the data represented in Figure 1 to 5 is of average of two years and treatments.

RESULTS AND DISCUSSION

Temperature in crop stand and yield

The variation of temperature within canopy of pea under different environments and cultivars observed weekly from 65 DAS to maturity. Among the different cultivars, V_2 recorded highest temperature within canopy followed by V_1 and V_3. However, significant increase in temperature within canopy was observed during later stage environment which may be due to the increase in the environmental temperature and moisture stress. A linear inverse relation was observed between the temperature in crop stand and pod yield (Fig 1a) and this temperature explained the 87.7 per cent variability in pod yield of pea (Table 2). A linear and positive relation was observed between temperature in crop stand and soil temperature in pea crop. The relation explained 51.0 per cent variation in temperature within canopy by soil temperature. Hence it can be concluded that increase in temperature within crop may decrease the pod yield to some extent.

Relative humidity in crop stand and yield

The variation of relative humidity in middle of the crop stand under different environments was observed weekly from 65 DAS to maturity. The highest relative humidity (89%) was recorded in V_2 followed by V_1 (85%) and V_3 (82%) under first date of sowing (D_1). Similarly, in second date of sowing (D_2), V_2 recorded highest relative humidity (91%) followed by V_1 (86%) and V_3 (83%). Among the different cultivars, V_2 recorded highest relative humidity within canopy followed by V_1 and V_3 which may be due to the increase in air temperature from March onwards. A positive linear regression relationship (Fig 1b) was observed between relative humidity and pod yield and the humidity explained 67.9 per cent variation in pod yield (Table 2). Sankar and Swamy, (1988) obtained similar results in pea, and Khichar and Ram Niwas (2006) in wheat.

Vapor Pressure in crop stand and yield

The highest vapor pressure (16.2 mb) was recorded in V_2 followed by V_1 (14.7 mb) and V_3 (13.7 mb) under first date of sowing (D_1), that was calculated on weekly basis starting from 65 DAS to maturity by measuring dry and wet bulb temperature in the middle of crop canopy. Similarly, in second date of sowing (D_2), V_2 recorded highest vapor pressure (16.7 mb) followed by V_1 (15.7 mb) and V_3 (15.0 mb). Among the different cultivars, V_2 recorded highest vapor pressure within crop canopy as compared to V_1 and V_3. A positive linear regression relationship was observed between vapour pressure and pod yield (Table 2).

Intercepted photosynthetically active radiation (IPAR)

It is very crucial to measure the photo-synthetically active radiation (PAR) interception,

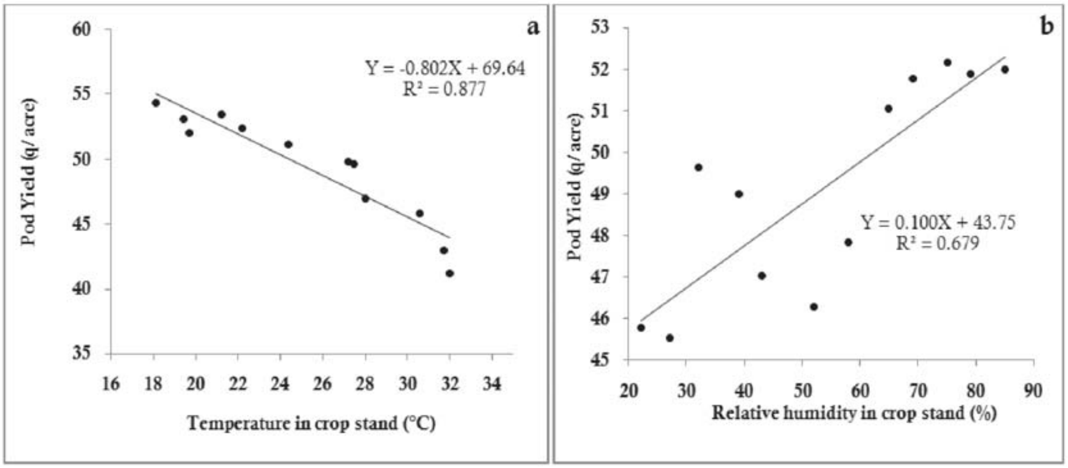

Figure 1. Relationship of pod yield with temperature (a) and relative humidity (b) in crop stand (*polled data of all the treatments*)

Table 2. Correlation parameters of temperature, relative humidity and vapour pressure with days after sowing in pea crop under different treatments

Treatments		Temperature			Relative humidity			Vapour pressure		
DOS	Variety	R^2	Slope (Rate)	Constant	R^2	Slope	Constant	R^2	Slope	Constant
D_1	V_1	0.378	0.128	21.5	0.0752	-0.281	45.9	0.059	0.025	8.4
	V_2	0.487	0.126	23.1	0.0973	-0.212	49.7	0.068	0.023	9.8
	V_3	0.368	0.123	20.6	0.0721	-0.201	42.8	0.056	0.024	7.3
D_2	V_1	0.197	0.091	23.3	0.0072	-0.075	44.4	0.098	0.041	9.2
	V_2	0.231	0.088	24.7	0.0121	-0.074	49.3	0.198	0.039	10.1
	V_3	0.171	0.086	22.3	0.0068	-0.077	14.4	0.083	0.038	8.4

transmission and distribution within crop canopy which ultimately decides the crop production and yield. Five major phenophases *viz.*, emergence, first node, flowering, pod formation and maturity and days taken to attain the same were recorded in three pea cultivars (Azad P-1, PB-89 and ESP-111) and two dates of sowing(1st December & 15th December). The number of days taken to attain these phenophases and the physiological maturity decreases significantly with delayed sowing of pea. The IPAR was calculated for different phenophases under different environments, cultivars and irrigation levels (Fig. 2a & 2b). Among different sowing environments, D_1 recorded higher PAR interception than D_2 at every phenophases except the first node which may be due to longer duration and higher good crop growth in D_1 (Fig 2a). Similar results were obtained by Ghosh *et al.* (2018) and Kumar *et al.,* (2010).

Among different varieties, V_2 recorded maximum PAR interception (97.6%) at pod formation followed by V_1 and V_3 (Fig 2b). Thus, more PARs will be intercepted by the crop if it develops leaf area rapidly. PAR interception is directly proportional to the leaf area index (LAI) of the crop (Fig. 4). The average PAR interception was observed highest at pod formation for both dates of sowing & all the cultivars and afterwards, PAR interception decreased as the crop reached the maturity. The positive and linear relationship was observed between Leaf Area Index and IPAR in pea crop under different treatments (Fig. 4). The 82.3 per cent variation in IPAR was being explained by LAI under different sowing environments, cultivars and irrigation levels.

Soil moisture variations

Soil moisture is a key component of micro-climate that directly affects water availability to plants and indirectly influences the temperature and humidity within canopy (Bramer *et al.*, 2018). Per cent soil moisture was measured under different dates of sowing and irrigation levels to assess the

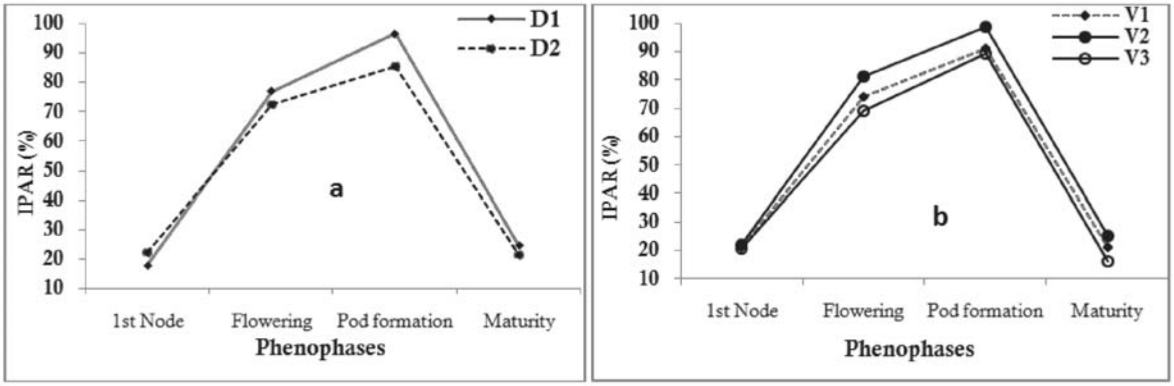

Figure 2. IPAR at different phenophases of pea *w.r.t.* dates of sowing (a) and cultivars (b)

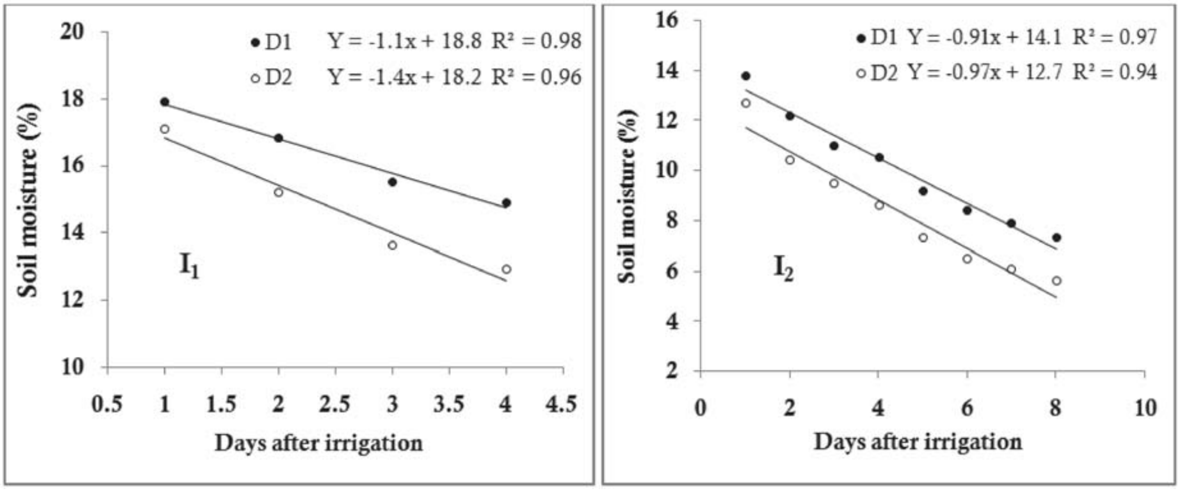

Figure 3. Variation of soil moisture with days after irrigation under two irrigation levels in each date of sowing of pea crop (*average of three varieties*)

change in soil water status in the crop. The consumptive use of water was more in I_1 followed by I_2 for all the treatments. There was a higher rate of soil moisture depletion in D_2 compared to D_1 for both the irrigation levels. A strong significant relation (R^2> 94) was observed between soil moisture depletion with days after irrigation under both the dates of sowing and irrigation levels (Fig. 3). Similar results were obtained by Kovac *et al*. (2005) for different dates of sowing and irrigation levels.

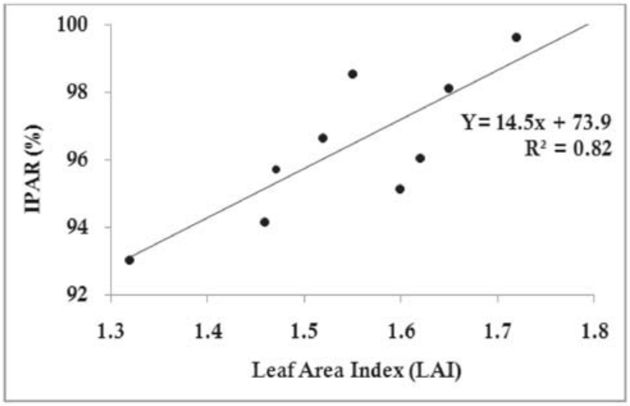

Figure 4. Variation of IPAR with LAI (average of all treatments)

Variation of soil temperature

Soil temperature is very important microclimatic parameters which affect the germination, moisture/ nutrients uptake and microbial activities of the soil. A linear but inverse relation was observed between relative humidity in crop stand and soil temperature of the cropped field. The soil temperature explained 34.6 per cent variation in relative humidity within the crop canopy (Fig 5). Thus, it can be perceived that as the soil temperature increases, relative humidity within canopy will be reduced.

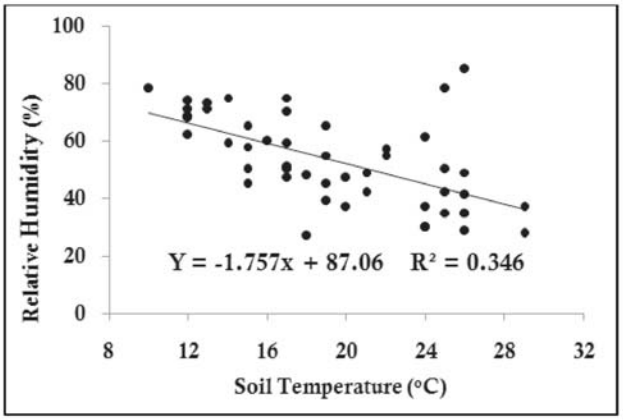

Figure 5. Variation of RH with soil temperature (average of all treatments)

CONCLUSION

In recent times all over the world pressure has been increasing on usable land in order to satisfy the overgrowing demand for food and fodder, to face this situation scientists are exploring both the waste land and best agricultural technology to harness agro climatic (micro and macro climate) parameters. Knowledge of the impact of these parameters would be a very vital in crop planning which is no doubt crucial for rainfed hill farming. Studies clearly showed that the crop microclimate provide valuable information regarding the interaction of the crop with its environment. The date of sowing, irrigation level and different varieties are most important variables for evaluation of optimum microclimate of the crop for maximum growth and yield. The results concluded that the diurnal temperatures were higher in two growing environments and three cultivars at 1300 hours as compared to other hours. It is also recommended that sowing of pea may be done on or before 1st December for higher yield and PB-89 variety for Rabi season in mid hills of south west Himalayas. The findings of present study will help to understand that how microclimatic factors such as temperature, humidity, vapour pressure, soil temperature, soil moisture and net radiations etc. also could make dramatic changes in the final yield in spite of macroclimatic factors. It can be concluded that cropping success in rainfed regions is outcome of both microclimatic and macroclimatic factors and both plays significant role to obtain optimum production and productivity.

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