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Study of PAR interception, energy balance studies and microclimatic profiles in potato (*Solanum tuberosum*) cultivars under varying planting dates

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Abstract

The crop experiments were carried out during *Rabi* season 2016-17 & 2017-18. The experiment conducted at Research farm adjacent to agromet observatory (Latitude: 29° 10' N; Longitude: 75° 46' E & Altitude: 215 m), Department of Agricultural Meteorology, CCS HAU, Hisar, Haryana. The main aim and objectives of this work were to be accesses the microclimatic condition of potato under varying planting dates and varieties. Results revealed that micrometeorological parameters observed more favourable in 3rd week of October (D2) planted crop as compared to other planting dates. The absorbed PAR was recorded higher in 3rd week of October (D2) sown crop and Kufri Pushkar then other treatments at phenophases, respectively higher in during both seasons. PAR transmitted (watt/m^2) at bottom, Soil heat flux pattern was observed in decreasing trend from advanced vegetative stage to tuber bulking stage may be due to more cover of ground and absorption percentage of PAR. The consumption of PAR, bright sun shine and assimilation rate were more in second planting dates. Among planting dates, the net radiation (Rn) was higher at early vegetative stage in 3rd week of October (D2) and 1st week of November (D3) during both crop seasons. The major portion of Rn (Net radiation) was utilized by latent heat of vaporization (LE). The 2nd week of October (D1) was received higher values of soil heat flux (G) during both the crop seasons. The minimum value of G was observed at tuber bulking stage in 1st week of November (D3) during both crop seasons. LE was higher at all phenophases in 3rd week of October (D2) at early vegetative stage during both the crop seasons. G was highest at initiation of tuber and early vegetative stage in 3rd week of November (D4) respectively, during both season. Temperature profiles were inverse throughout the day within the canopy at all phenophases. Over the top of the crop canopy the temperature profile was lapse. The relative humidity profiles were lapse inside the crop canopy throughout the day at 9:00 hours where it was iso-humic. Further concluded that the microclimate profile condition pattern was optimum in second sown crops and produced higher tuber yield.

Keywords: Energy balance, canopy temperature, PAR, potato, vertical micrometeorological profile

Introduction

The potato (*Solanum tuberosum* L.) is the third most important food crop in the world after rice and wheat and consumed by more than a billion people worldwide. Globally potato has an annual production of around 388 million tons (Statista, 2019) [19]. The potato is a crop which has always been the 'poor man's food'. It belongs to the *Solanaceae* family of flowering plants. In India it is cultivated over an area of approximately 21.42 lakh ha with a production of 513.10 lakh metric ton and productivity 23.3 metric ton per ha (Anonymous, 2018) [3, 4]. In Haryana, potato is cultivated over an area of approximately 0.363 lakh ha with a production of 8.97 lakh metric ton and productivity 26.58 metric ton per ha (Anonymous, 2017) [3, 4].

Potato is regarded as a high potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (mostly<120 days) than major cereal crops (Adane *et al*., 2010) [1]. One hectare of potato can yield two to four times the food quantity of grain crops. It is a fundamental element in the food security for millions of people across South America, Africa, and Central Asia. Potato tubers give an exceptionally high yield per acre and are consumed as different recipies (Feustel, 1987; Talburt, 1987) [7, 20].

A different meteorological element governs growth, development, production and quality of potato crop. Potato is grown in many different environments, but it is best adapted to temperate climates (Haverkort, 1990) [12]. Tuber growth is sharply inhibited in temperatures below 10 °C and above 30 °C, while optimum yields are obtained where mean daily temperatures ranges between 18 to 20 °C range (Haris *et al*., 2015) [9]. Potato is also frost sensitive and severe damage may occur when temperature drops below 0 °C (Hijmans *et al*., 2003) [10, 11].

The first step to optimise tuber yield and quality is to understand crop responses to environmental and management factors. For a crop free of pests and diseases, weather is the primary determinant of crop yield. When crops are grown in non-limiting moisture, temperature and nutrient conditions, yield responds linearly to the amount of solar radiation intercepted (Monteith, 1977; Allen and Scott, 1980) [2, 13]. The effects of climate change on crop production can be complex. Depending on the temperature regime and the crop, high temperatures can lead to low yields due to increased development rates and higher respiration. Although in some regions changes in yield are strongly influenced by changes in temperature, radiation, sometimes induced by changes in cloudiness which influence potential yield of potato (Hijmans, 2003) [10, 11].

The microclimate of plant communities varied with energy balance, turbulent exchange and thermal status of the soil surface. Available net radiation is the balance between incoming and outgoing radiation. The balance of energy at the earth's surface is closely associated with the overlying atmospheric boundary layer (Roxy *et al*., 2014) [16]. The partitioning of net radiation into latent heat flux of a vegetated system, as well as into other components of energy balance is closely linked to changes in land use and system water availability. Apart from its intrinsic importance in energy balance studies, net radiation is a key input variable in climatologically models to assess evapotranspiration, and its precise estimate is essential for water resource management on regional scale (Villa Nova *et al*., 2006; Ryu *et al*., 2008; Pereira *et al*., 2011) [15, 17, 21], for frost prediction studies, and air pollution monitoring (Fritschen and Fritschen, 2007) [8]. Canopy leaf area is used to estimate the interception of PAR. Increases in plant mass (g/plant) are computed by multiplying light interception by a constant value for radiation use efficiency (grams of biomass per mega joule of intercepted PAR). (Kooman and Haverkort, 1995; Shaykewich *et al*., 1998) [12, 18].

The radiation transfer within the crop canopy play's crucial role in energy balance and turbulent transfer processes. Vertical profile of PAR, air temperature and humidity in case of horizontally uniform crop canopy the radiation transfer within the crop canopies plays a crucial role in many aspects of crop growth and development. Firstly the shortwave radiation is the governing component of canopy energy balance influencing leaf, soil, and within canopy air temperature. Second, together with friction, it is a driving force of turbulent transfer within the canopy. Finally, intensity of PAR, as a part of shortwave radiation spectrum, rates intensity of photosynthesis which directly influences the exchange of CO_2 between the crop canopy and the atmosphere (Wolfe and Thornton, 2011) [22]. Measurement of canopy temperature with infrared thermometers has been an efficient tool for irrigation scheduling in semi-arid and arid conditions (Evett *et al*., 2000) [6] and hence moisture status of soil as well as plant can also be indicated by canopy temperature of the crop.

Keeping in view the above facts, detailed micrometeorological studies are necessary to understand the crop-weather interaction under various planting dates. While scanning the literature one fails to find much relevant information on micrometeorological studies on potato particularly in Haryana conditions and therefore the study has been planned to generate relevant information on those aspects which play crucial role in development of both source and sink and thereby decides the quantum of final production. The study and use of micrometeorological processes to problems of agrometeorological importance has greatly increased the application of the physical processes regulating the natural environment of crop plants.

Material and Methods

An experiment was conducted in *Rabi* season, 2016-17 and 2017-18 at research farm, Department of Agricultural Meteorology, CCSHAU Hisar, Haryana. The field area was adjacent to Agrometeorological observatory at 29° 10' N latitude, 75° 46' E longitude and altitude of 215.2 m. The main plots treatments consisted of four planting dates *viz*. 2nd week of October (D_1), 3rd week of October (D_2), 1st week of November (D_3) and 3rd week of November (D_4) and the sub-plots consisted of three varieties: V_1 - Kufri Bahar, V_2 - Kufri Pushkar and V_3 - Kufri Surya. The forty eight treatment combinations were tested in split plot design with four replications. Each plot was 5.0 meters wide and 3.6 m long. There were 6 rows in all potato plots. After field preparation and pre sowing irrigation, potato crop was sown from seed potatoes; - small tubers. All seed tubers were presprouted. Tubers were kept for 25-30 days before planting in sufficiently humid and lighted room in a wooden box. The distance between tubers was 20 cm, and the distance between rows 60 cm apart at a depth of 5 to 10 cm manually. All inter-cultivation practices were kept uniform in the entire plots. The recommended dose of nitrogen (150kg N ha^{-1}), phosphorus (50 kg P_2O_5 ha^{-1}) and potassium (100 kg ha^{-1}) were applied. Full dose of DAP (245 g/plot), MOP (375 g/plot) and half dose of nitrogen were applied before sowing and remaining ½ N was top dressed after 25-30 days after sowing at earthing up. All the necessary cultural practices and plant protection measures were followed uniformly for all the treatments during the entire period of experimentation.

Micrometeorological observations

The following micro-meteorological observations were recorded in the experimental field during early vegetative, initiation of tuber and tuber bulking phases with clear sky at hourly interval from 0800 to 1700 hours.

a. PAR observations
b. Diurnal energy balance components
c. Temperature and humidity profile studies

A. PAR observations

Photosynthetically Active Radiation (PAR) was taken after 30 days of planting at 30 days interval. PAR was measured during noon hours at top, middle and bottom of canopy with the help of Line Quantum sensor. The reflected radiation was obtained by keeping the sensor inverted above the crop canopy and the transmitted radiation at the ground was obtained by keeping the sensor on ground across the rows diagonally at random sites. The vertical PAR observations were taken hourly basis interval on clear weather condition or in clear sky days from 0900 to 1700 hour. The day time vertical canopy PAR pattern was observed on occurrences of different phenophases.

- Transmitted radiation (%): It is the ratio of transmitted PAR to the total incidence on the crop surface and multiplied by 100.

- Reflected radiation (%): It is the ratio of reflected radiation by crop with the total incidence PAR over crop surface and multiplied by 100.
- Absorbed PAR: It is calculated by the formula as below:

APAR = 100 – transmitted - reflected

The IPAR (expressed as the percentage of the incidence PAR) was obtained by keeping the sensor above the canopy and absorbed radiation (A) was determined using the following established relationship.

Absorbed radiation (A) = Incidence radiation on the canopy (IPAR) – Reflected radiation by the canopy – Transmitted radiation

B. Diurnal energy balance components

Diurnal net radiation was measured at top of the canopy at early vegetative phase, initiation of tuber and tuber bulking stages.

- Solar radiation: The amount of solar radiation received by crop was measured with the help of pyranometer (Medoes and Co., Australia) connected to a digital multivoltmeter. The measurements were made at one meter height above crop. While making measurements the pyranometer was kept horizontally so as to follows the cosine law.
- Net radiation: Net radiation was measured at one meter height above crop canopy with net radiometer (Medoes and Co., Australia) connected to a digital multivoltmeter.
- Soil heat flux: Soil heat flux was measured with the help of three soil heat flux plate (Medoes and Co., Australia) which were kept at 5 cm soil depth in cropped field and connected to a digital multivoltmeter.

Computation of energy balance

The energy balance of a crop was computed by the following equation:

$$Rn = G + A + LE + Mi$$

Where,
Rn = Net radiation, mW cm^{-2}
G = Soil heat flux, mW cm^{-2}
A = Sensible heat, mW cm^{-2}
LE = Latent heat of vapour flux, mW cm^{-2}
Mi = Miscellaneous energy used in physiological processes of plant, mW cm^{-2}
(This parameter is generally neglected because of its low value of less than 2%)

The latent heat flux was calculated using the following formula:

$$LE = (Rn - G)/(1 + \beta)$$

Where, β is Bowen ratio and is inferred from the measurements of dry and wet bulb temperature at two heights and is represented as below:

$$\beta = 0.66 \text{ x } dt/de$$ (Denmead and Mclory, 1970) [5]

Where,
dt = Temperature gradient between two heights
de = Vapour pressure gradient between two heights

The sensible heat flux (A) was calculated from the energy balance equation using measured Rn and G and calculated LE values and is given as:

$$A = Rn - G - LE$$

The net radiation was also quantified daily and weekly basis, and pattern was evaluated.

C. Temperature and humidity profile studies

For recording various micrometeorological observations, following methods were adopted:

- Dry and wet bulb temperatures were measured at 8:00 AM, 2:00 PM and 6:00 PM at three levels of crop canopy: top, middle and bottom with the help of Assmann Psychrometer at different phenophases of pigeonpea. Psychrometric tables are used to find out relative humidity in the crop by using these values.
- Air and canopy temperature (°C) were measured through Infrared (IR) thermometer and Relative humidity (percentage) measured by digital psychrometer. The profile of air temperature, wind speed, humidity and canopy temperature pattern were measured at different phenophases and further quantified the pooled bases vertical pattern of these parameters.

Results and Discussion

Photosynthetically active radiation (PAR) of solar radiation *viz*., reflected (R), absorbed (A) and transmitted (T) of potato recorded at different phenophases are presented in table 1 for the year 2016-17 and 2017-18. Among planting dates, D_2 had more absorption *i.e.*89.56% and 94.83% at early vegetative stage and minimum absorption occurred in D_4 (84.80% and 88.30%) at early vegetative stage during crop season 2016-17 and 2017-18, respectively. Among varieties, Kufri Pushkar had highest absorption *i.e.*88.20 and 93.03% at early vegetative stage during crop season 2016-17 and 2017-18, respectively. The minimum absorptions were found in Kufri Surya (84.77%) at tuber bulking stage in 2016-17, whereas in 2017-18 lower in Kufri Surya (88.78) at tuber initiation stage. The absorption of radiation was more in 2017-18 than 2016-17.

Among planting dates, reflected radiation were highest in D_4 (7.24%) and least in D_2 (5.17%) at early vegetative stage during 2016-17. However in 2017-18, reflected radiation were highest in D_4 (5.52%) and it was least in D_2 (1.77%) at tuber bulking stage. In case of varieties, reflected radiation was more in Kufri Surya (7.32%) and minimum in Kufri Pushkar (4.92%) during 2016-17, however, in 2017-18, reflected radiation were more in Kufri Surya (4.92) at tuber bulking stage and it was least in Kufri Pushkar (2.58). The reflection of radiation was increased at early vegetative stage and initiation of tuber afterwards it starts declining at tuber bulking stage except tuber bulking stage in 2016-17, it increased abruptly, while, reflection and transmission of radiation was minimum in D_2 and maximum in D_4during both the crop seasons except D_1 in tuber bulking stage at 2016-17.

Transmitted radiation of PAR was highest in D_4 (8.53%) at tuber bulking stage and least in D_1 (4.52%) at early vegetative stage during 2016-17. However, in 2017-18, transmitted radiation was highest in D_4 (7.77%) at tuber bulking stage and it was least in D_2 (3.46%) at early vegetative stage. In case of varieties, transmitted radiation was maximum in Kufri Surya (7.13%) at tuber bulking stage and minimum in Kufri Pushkar (4.40%) at early vegetative stage.

Over the bare field, the absorption was between 85.40 to 90.30% in 2016-17 and 94.50 to 95.35% in 2017-18. The reflected radiation varied between 5.74 to 9.60% and 2.54 to 3.54% during crop season 2016-17 and 2017-18, respectively.

Energy balance components (Wm^{-2})

The energy balance components namely, net radiation (Rn), soil heat flux (G), latent heat of vaporization (LE) and sensible heat flux (A) were studied at different phenophases for two crop seasons (Figure 1 and 2). The values of energy fluxes at different phenophases of potato were calculated from the integration of diurnal hourly observations. All the energy fluxes vary considerably during crop growth stages and within the seasons.

Net radiation (Rn)

The net radiation was maximum in D_2 (465.55 W m^{-2} and 462.35 W m^{-2}) and minimum in D_4 (345.04 W m^{-2} and 389.45 W m^{-2}) at early vegetative phase during crop season 2016-17 and 2017-18, respectively. Among varieties, highest net radiation was observed in Kufri Pushkar (468.16 W m^{-2} and 473.69 W m^{-2}) and minimum net radiation observed in Kufri Surya (333.20 W m^{-2} and 466.52 W m^{-2}) at early vegetative stage during crop season 2016-17 and 2017-18, respectively.

On bare soil, the maximum net radiation (492.22 W m^{-2} and 489.94 W m^{-2}) was observed at initiation of tuber and minimum (436.25 W m^{-2}and 458.94 W m^{-2}) was at tuber bulking stage during crop season 2016-17 and 2017-18, respectively.

Soil heat flux (G)

The soil heat flux was highest at initiation of tuber in D_1 (38.14 W m^{-2} and 37.44 W m^{-2}) during crop season 2016-17 and 2017-18. However, the minimum soil heat flux was recorded at tuber bulking stage in D_3 (23.40 W m^{-2} and 27.59 W m^{-2}) during crop season 2016-17 and 2017-18. The contribution of soil heat flux in net energy were higher in D_1 (8.70% and 8.41%) and lower in D_2 (6.02% and 6.67%) at initiation of tuber during 2016-17 and 2017-18.

At initiation of tuber, the highest soil heat flux was observed in Kufri Pushkar (37.38 W m^{-2}) and Kufri Bahar (37.07 W m^{-2}) during crop season 2016-17 and 2017-18, respectively. Minimum soil heat flux was observed in Kufri Bahar: 24.88 W m^{-2} and Kufri Pushkar (28.82 Wm^{-2}) at early vegetative stage during crop season 2016-17 and 2017-18, respectively among varieties. The proportion of soil heat flux in net energy balance were more in Kufri Bahar (9.05% and 9.05%) at initiation of tuber during 2016-17 and 2017-18 and lower in Kufri Pushkar (5.34%) in 2016-17 and Kufri Surya (6.18%) in 2017-18 at early vegetative stage.

On bare soil, the higher soil heat flux (31.13 W m^{-2}) was observed at tuber bulking stage and lower (24.04 W m^{-2}) was at initiation of tuber during crop season 2016-17 whereas, the highest soil heat flux (32.76 W m^{-2}) was recorded at initiation of tuber and lowest (29.68 W m^{-2}) was at early vegetative stage during next crop season.

Latent heat of vapour flux (LE)

The latent heat of vaporization was higher at early vegetative stage in D_2 (320.11 W m^{-2}) and D_2 (354.22 W m^{-2}) at initiation of tuber during crop season 2016-17 and 2017-18, respectively. The lower latent heat of vaporization was recorded at tuber bulking stage in D_4 (212.33 W m^{-2}) and D_4 (236.76 Wm^{-2}at early vegetative stage) during crop season 2016-17and 2017-18, respectively among planting time. The proportion of LE in net energy were higher in D_2 (68.98% and 76.98% at initiation of tuber during 2016-17 and 2017-18) whereas lower proportion were found in D_4 (57.70%) at tuber bulking stage in 2016-17 and D_4 (60.79%) at early vegetative stage in 2017-18.

At initiation of tuber, higher latent heat of vaporization was observed in Kufri Bahar (344.64 W m^{-2}and 369.62 W m^{-2}) during crop season 2016-17 and 2017-18, respectively. The minimum latent heat of vaporization was observed in Kufri Pushkar (244.56 Wm^{-2}) and Kufri Surya (275.16 Wm^{-2}) at tuber bulking stage during crop season 2016-17 and 2017-18, respectively among varieties. The contribution of LE in net radiation was higher in Kufri Pushkar (69.97% and 78.03%) at early vegetative stage during 2016-17 and 2017-18. The contribution of LE in net radiation was lower in Kufri Surya (59.22% and 66.57%) at initiation of tuber during 2016-17 and 2017-18.

On bare soil, the maximum latent heat of vaporization (301.22 W m^{-2}) was observed at early vegetative stage and minimum (277.80 W m^{-2}) was at initiation of tuber in the first year experiment, whereas, the highest latent heat of vaporization (295.64 W m^{-2}) was observed at initiation of tuber and lowest (269.10 W m^{-2}) was at tuber bulking stage in the second year experiment.

Sensible heat flux (A)

The sensible heat flux was highest at initiation of tuber and tuber bulking stage in D_4 (137.28 W m^{-2} and121.43 W m^{-2}) during crop season 2016-17 and 2017-18, respectively. However, the minimum sensible heat flux was recorded at initiation of tuber and early vegetative stage in D_2 (101.52 W m^{-2}) and D_4 (76.40 W m^{-2}) during both crop season. The proportion of sensible heat in net energy were higher in D_4 (34.77% and 30.40%) at tuber bulking stage during 2016-17 and 2017-18. whereas lower proportion were found in D_2 (22.81%) at initiation of tuber in 2016-17 and D_4 (19.62%) at early vegetative stage in 2017-18.

At tuber bulking stage, highest sensible heat flux was observed in Kufri Bahar (32.22%) and Kufri Surya (24.82%) during crop season 2016-17 and 2017-18, respectively and minimum sensible heat flux was observed in Kufri Pushkar (24.59%and 15.45%) at early vegetative stage during crop season 2016-17 and 2017-18, respectively among varieties.

Temperature profile

The temperature profiles shown in Fig 5 to 8 indicated that the temperature inside the canopy was lower than that recorded at top of the canopy in all the treatments *i.e.* temperature profiles were inverse throughout the day within the canopy. Over the top of the crop canopy the temperature profile was lapse. The temperature varied from bottom to top of canopy among the treatments. The maximum temperature was observed at 1400 hours and the minimum was at morning which was mostly Iso-thermic with height at all growth stages during both crop seasons. The maximum temperature at noon hour was 34.5 °C in D_1, 28.4 °C in $D_2$and 28.3 °C in D_2 during crop season 2016-17, whereas 28.6 °C in D_2, 27.6 °C in D_2, 28.4 °C in D_2 during crop season 2017-18 at early vegetative stage, initiation of tuber and tuber bulking stage, respectively. Among different growing environments, the maximum temperature was observed in the temperature profile at early vegetative stage during 2016-17 and maximum temperature was observed in initiation of tuber during crop season 2017-18. Higher temperature was observed in 2016-17 as compared to crop season 2017-18 at most of the growth stages.

Among varieties, The maximum temperature at 1400 hour was 30 °C in Kufri Bahar, 27 °C in Kufri Pushkar and 27.2 °C in Kufri Surya during crop season 2016-17 whereas 27.4°C in Kufri Surya, 26.8 °C in Kufri Surya and 29.1 °C in Kufri Bahar during crop season 2017-18 at early vegetative stage, initiation of tuber and tuber bulking stage. The maximum temperature was observed at early vegetative phase and tuber bulking phase in temperature profile during 2016-17 and 2017-18, respectively.

Relative humidity profile

The humidity profiles shown in Fig 9 to 13 indicated that the relative humidity was higher inside the crop canopy than above the canopy in all the treatments *i.e.* the relative humidity profiles were lapse inside the crop canopy throughout the day but profiles were near iso-humic at 9:00 hours at different phenophases during both crop seasons. The maximum relative humidity of the day was observed at 9:00 hours. The relative humidity was lowest at noon time. The relative humidity varied from bottom to top of canopy as well as phenophase to phenophase under different planting dates and varieties during both the year. The maximum humidity at morning were 86.7% in D_4, 87.8% in D_1, 86.8% in D_1 respectively during crop season 2016-17, whereas, the maximum humidity at morning were recorded 68.2% in D_3, 82.6% in D_3, 78.2% in D_3 at early vegetative stage, initiation of tuber and tuber bulking phase, respectively during crop season 2017-18. The highest humidity was measured at tuber bulking phase during both seasons.

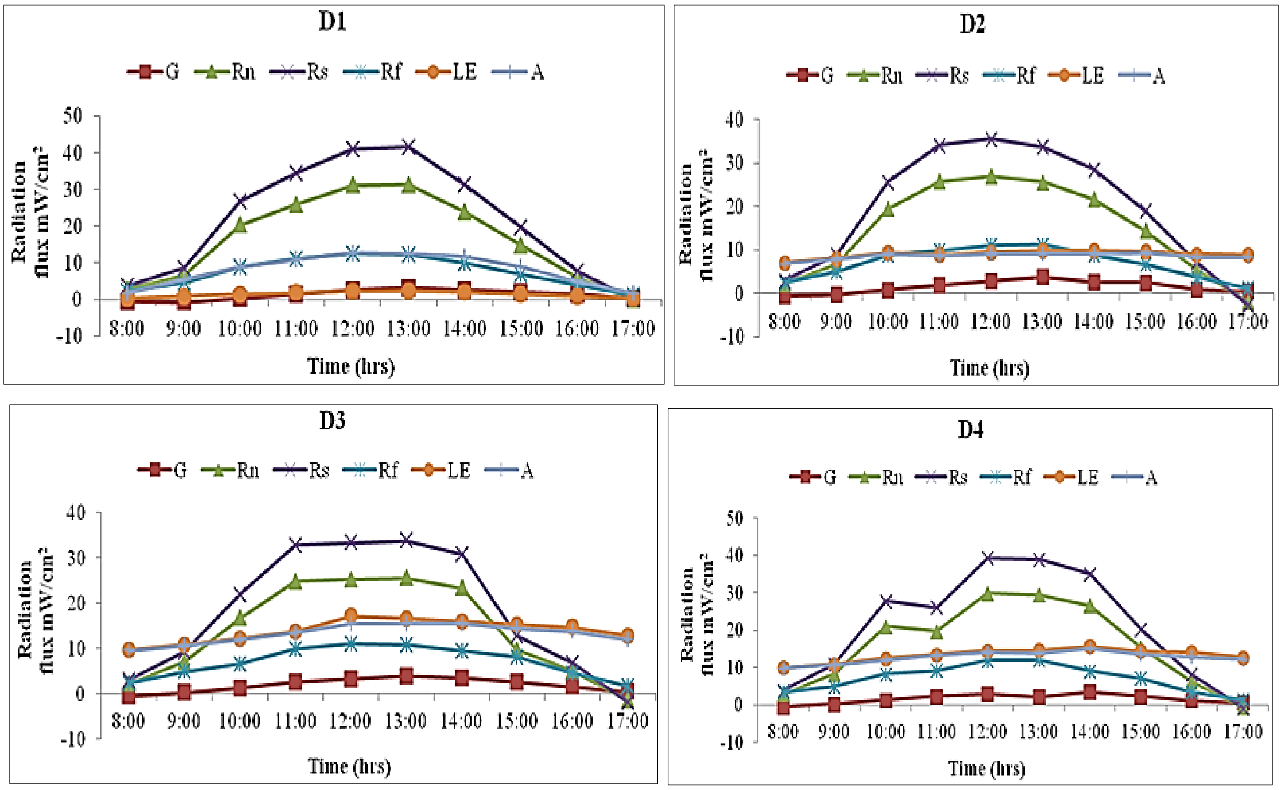
Among varieties, The maximum humidity at morning was 79.3% in Kufri Bahar, 80.1% in Kufri Pushkar and 85.1% in Kufri Bahar at early vegetative stage, initiation of tuber and physiological maturity in 2016-17 at early vegetative stage, initiation of tuber and tuber bulking phase, respectively, whereas, the maximum humidity at morning was recorded and 54.5% in Kufri Surya, 80.5% in Kufri Bahar and 77.1% in Kufri Pushkar at early vegetative stage, initiation of tuber and tuber bulking phase, respectively, during crop season 2017-18. The highest humidity was measured at tuber bulking stage in 2016-17 and initiation of tuber during crop season 2017-18.

Table 1: Effect of planting dates and varieties on photosynthetically active radiation (PAR,%) in potato during 2016-17 & 2017-18

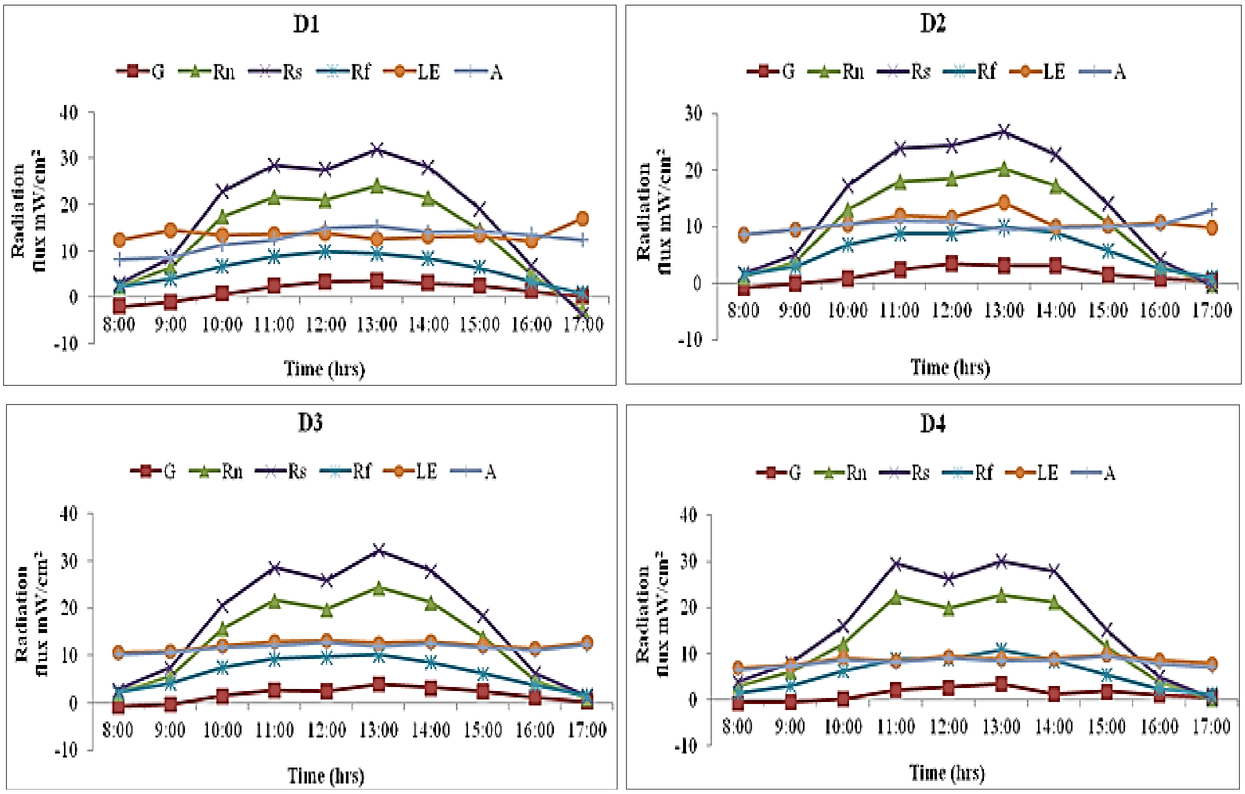
Treatments	Early vegetative phase			Initiation of tuber			Tuber bulking phase		
	R	A	T	R	A	T	R	A	T
D_1- 8th Oct.	6.80	88.67	4.53	6.52	86.24	7.24	5.92	86.63	7.45
D_2- 22th Oct.	5.17	89.56	5.27	5.17	87.60	7.23	5.53	88.47	6.00
D_3- 4th Nov.	6.90	86.57	6.53	6.66	85.61	7.73	6.84	85.00	8.16
D_4- 23th Nov.	7.24	84.80	7.98	6.89	85.26	7.89	6.03	85.43	8.53
SEm	0.03	0.70	0.06	0.04	0.03	0.05	0.04	0.06	0.06
CD at 5%	0.11	2.29	0.19	0.13	0.10	0.18	0.13	0.20	0.21
V_1- K. Bahar	5.20	87.00	7.80	5.30	87.05	7.65	5.40	86.48	8.13
V_2- K. Pushkar	4.92	88.20	6.88	5.23	87.60	7.18	5.09	87.90	7.01
V_3- K. Surya	7.32	86.29	6.39	6.01	85.88	8.13	6.82	84.77	8.41
SEm	0.06	1.22	0.10	0.07	1.21	0.10	0.07	0.10	0.09
CD at 5%	0.19	NS	0.30	0.22	NS	0.30	0.22	0.32	0.31
Bare Soil	7.48	89.60		5.74	90.30		9.60	85.40	

Where, R- Reflected PAR, A- Absorbed PAR, T-Transmitted PAR, NS = Treatment difference not significant

Early vegetative phase



Initiation of Tuber



Tuber bulking phase

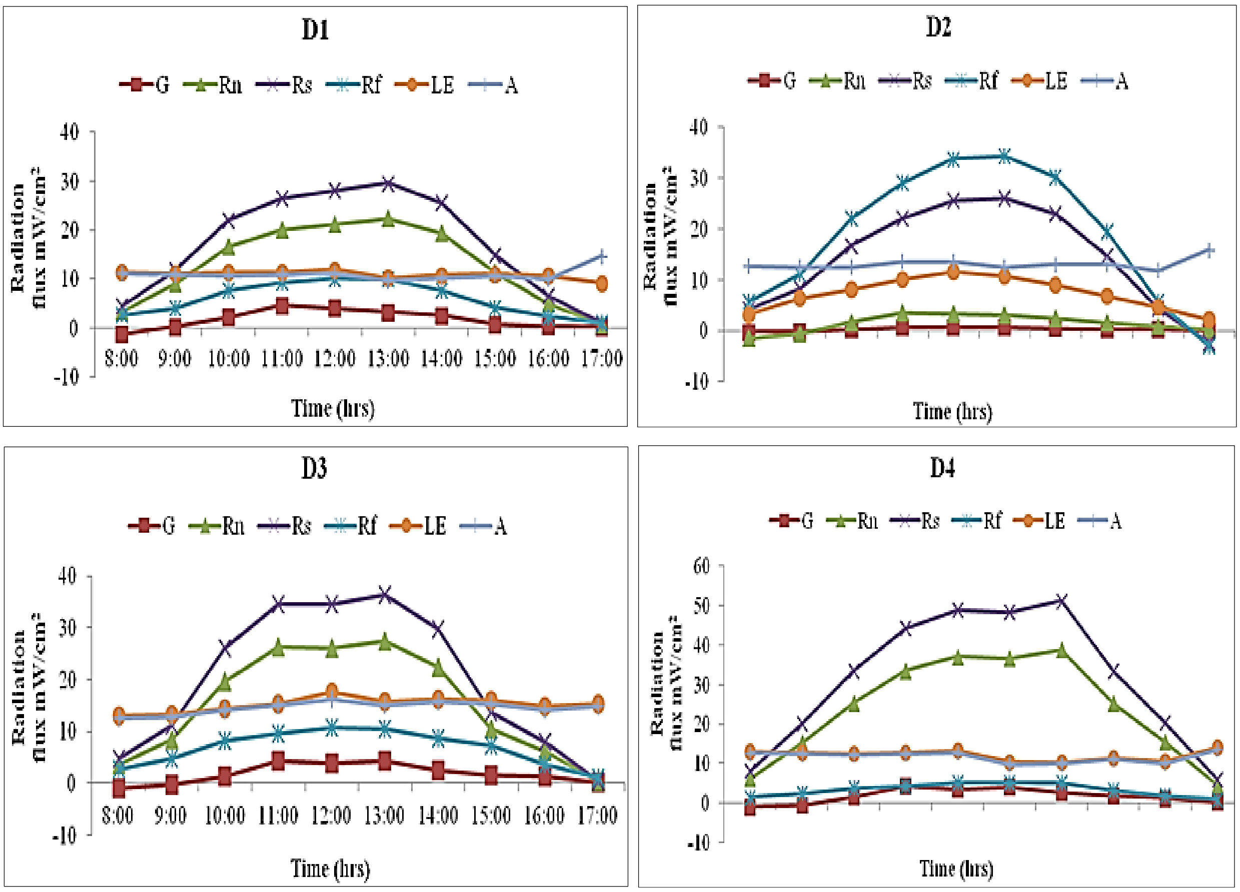
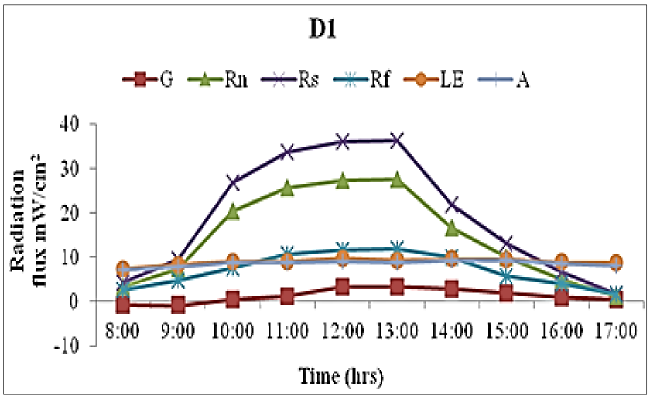
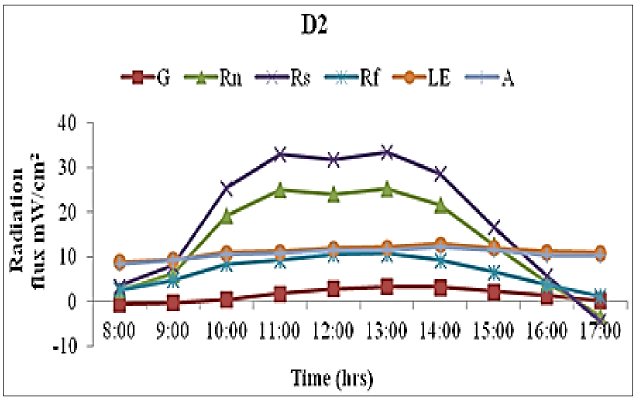
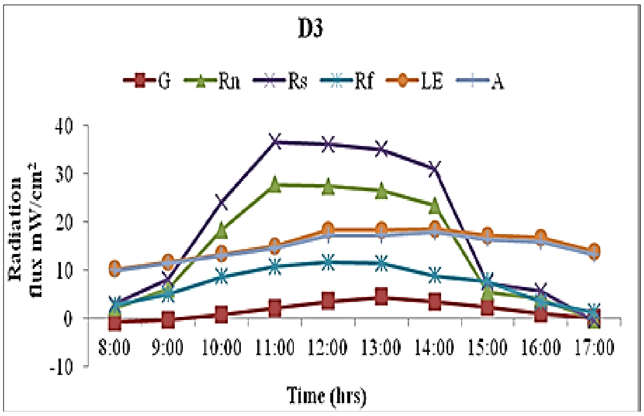


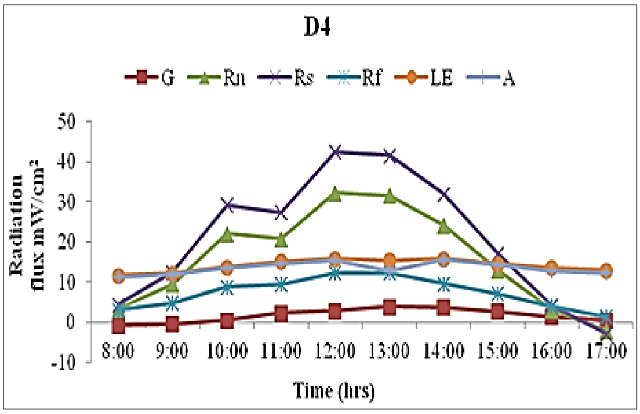
Fig 1: Effect of different growing environments on energy balance component from early vegetative stage to tuber bulking stage over potato crop during 2016-17

Early vegetative phase

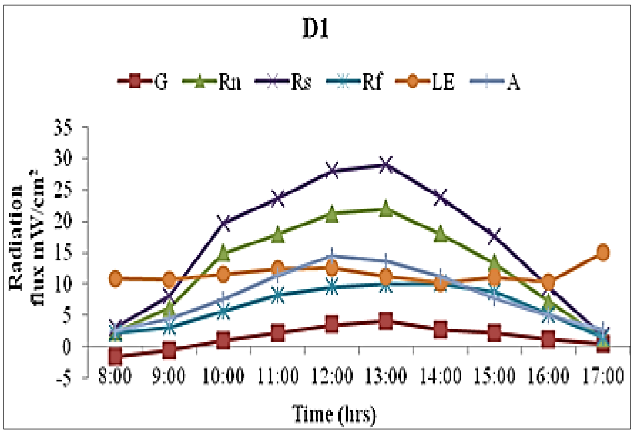


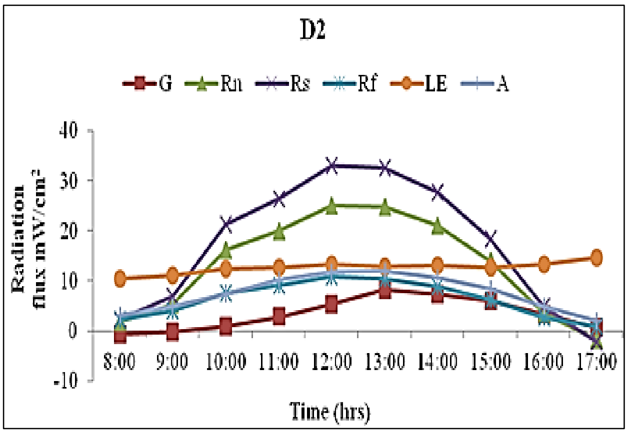


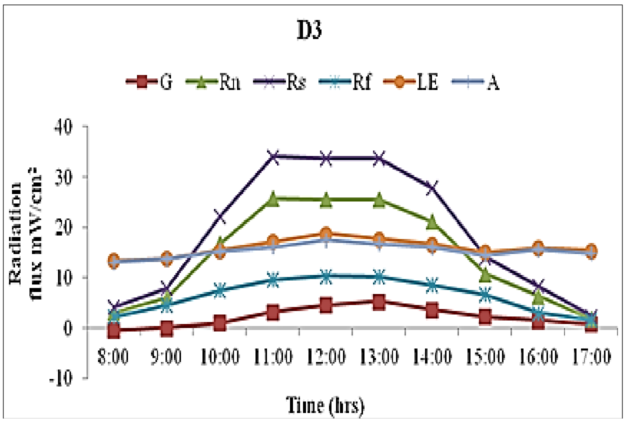


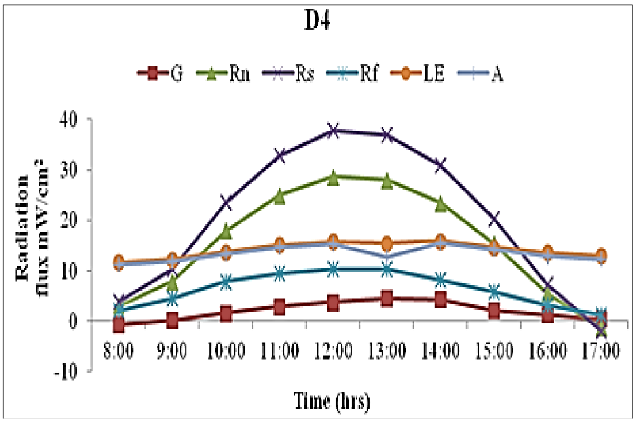


Initiation of Tuber









Tuber bulking phase

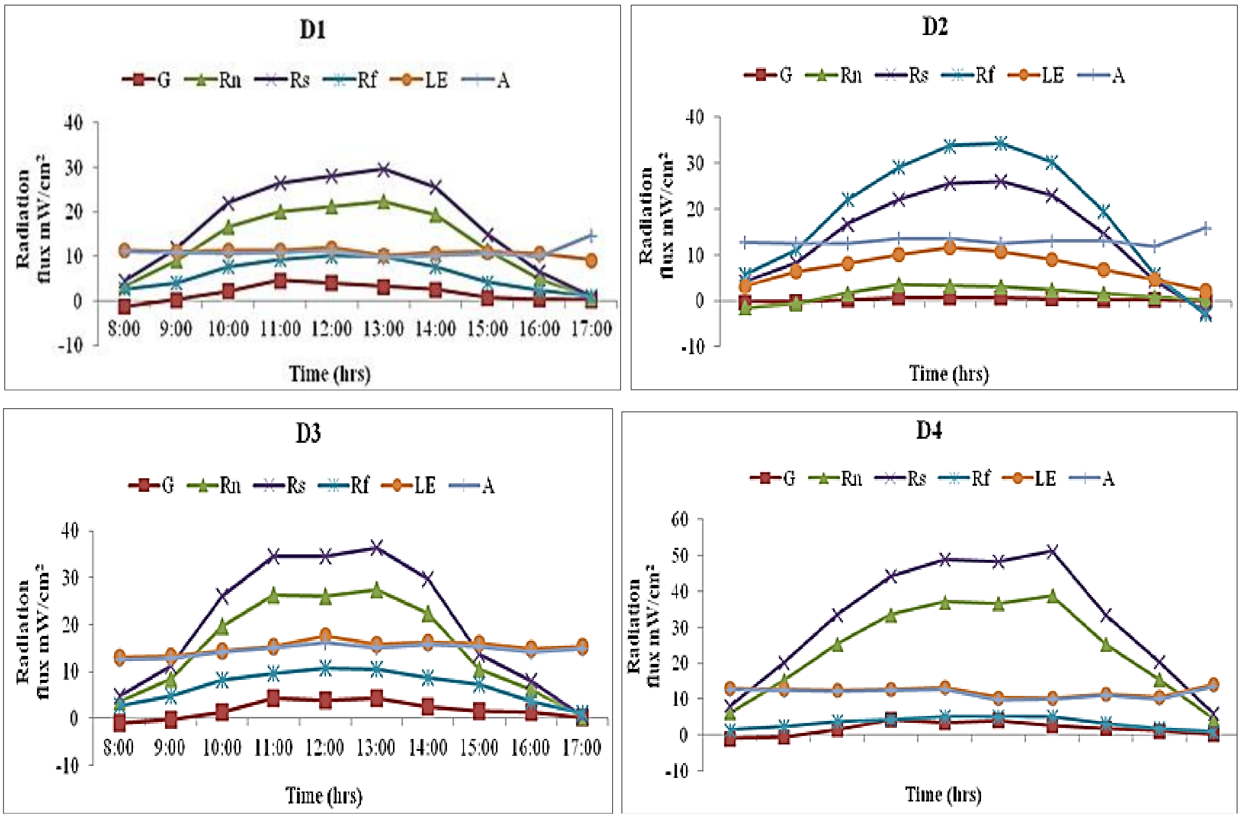


Fig 2: Effect of different growing environments on energy balance component from early vegetative stage, tuber initiation and tuber bulking stage over potato crop during 2017-18

Bare Soil (2016-17)

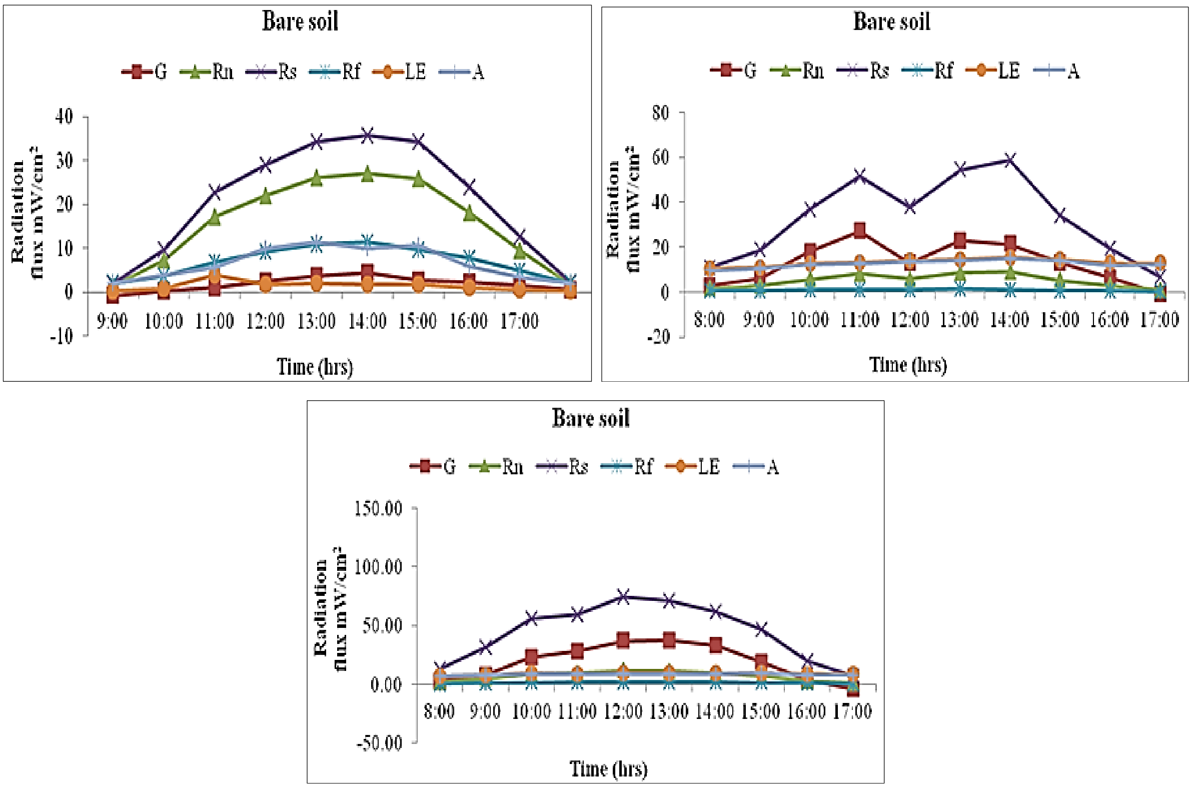


Fig 3: Effect of planting dates and varieties on photosynthetically active radiation (PAR,%) in potato during 2016-17

Bare Soil (2017-18)

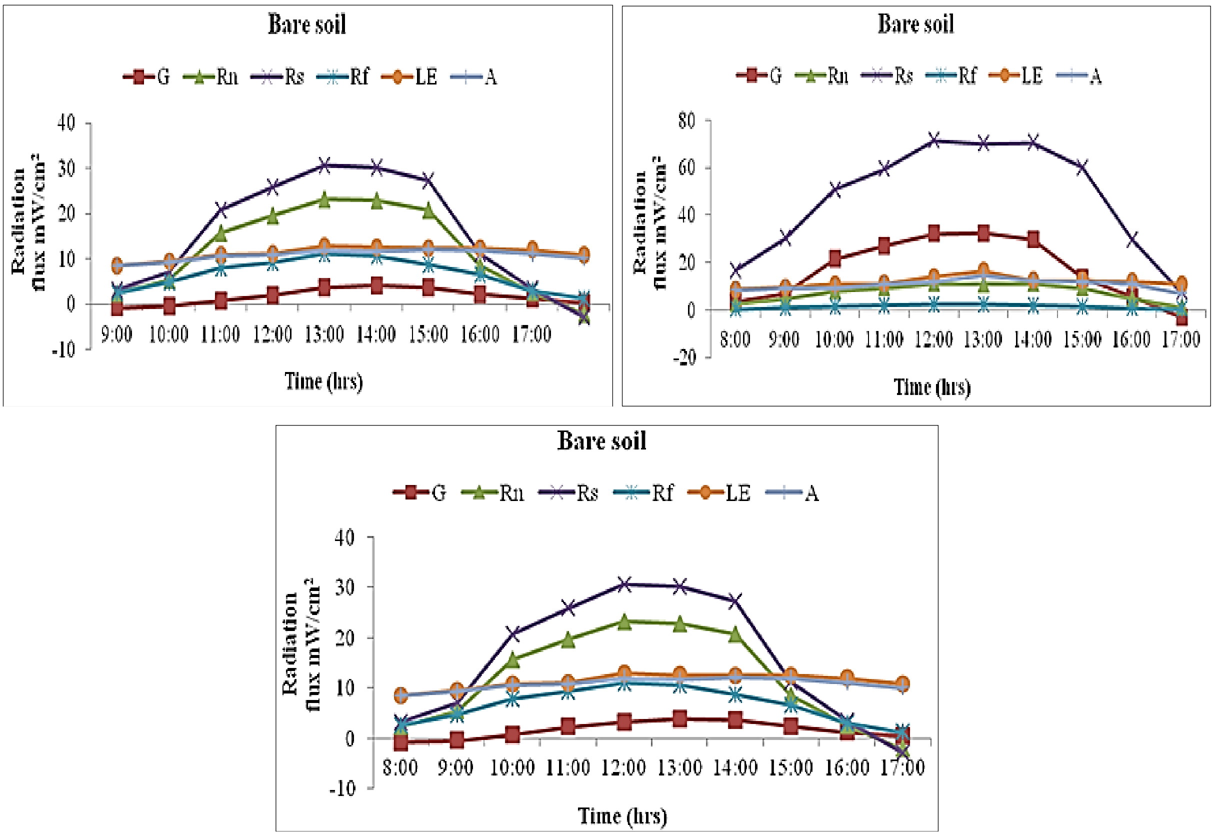
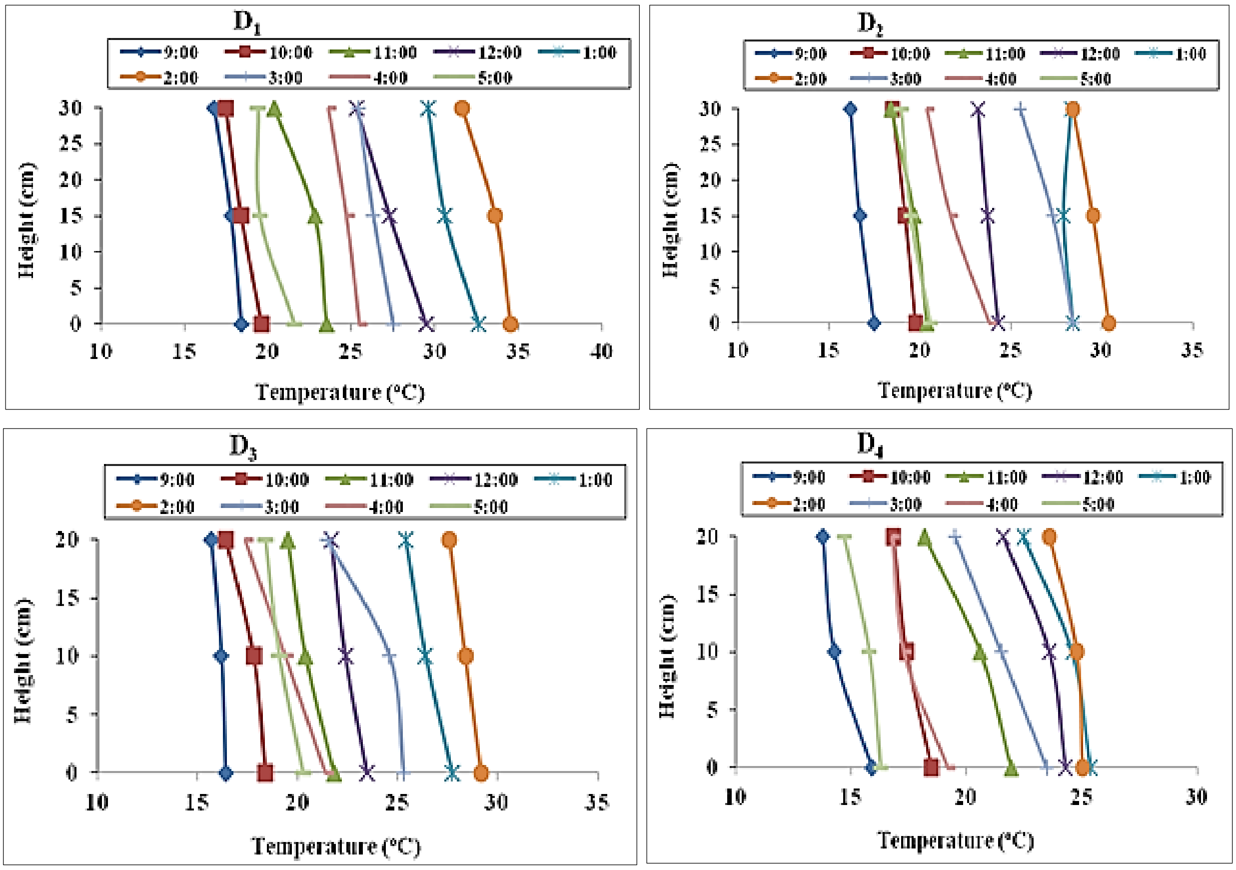
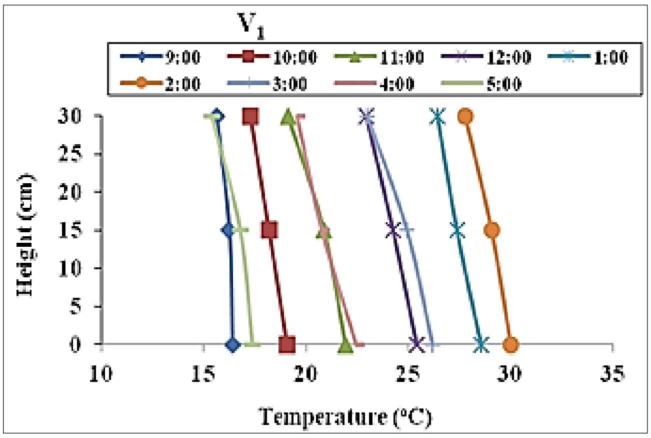


Fig 4: Effect of planting dates and varieties on photosynthetically active radiation (PAR,%) in potato during 2016-17

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Height (cm)
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25
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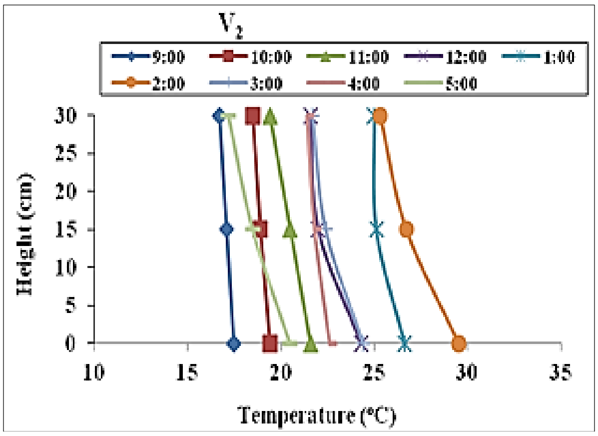
35
Temperature (°C)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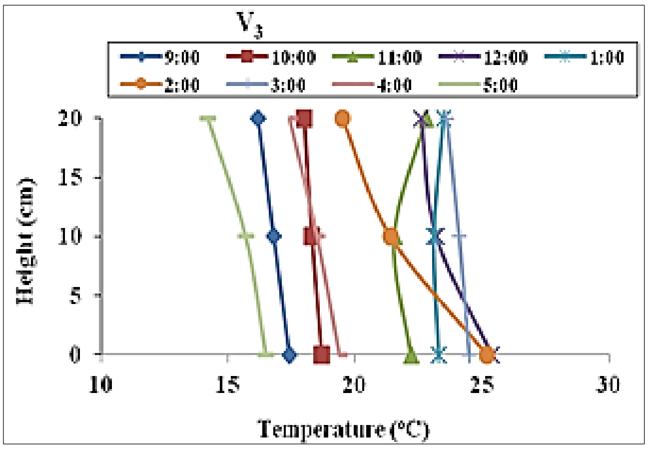
Temperature (°C)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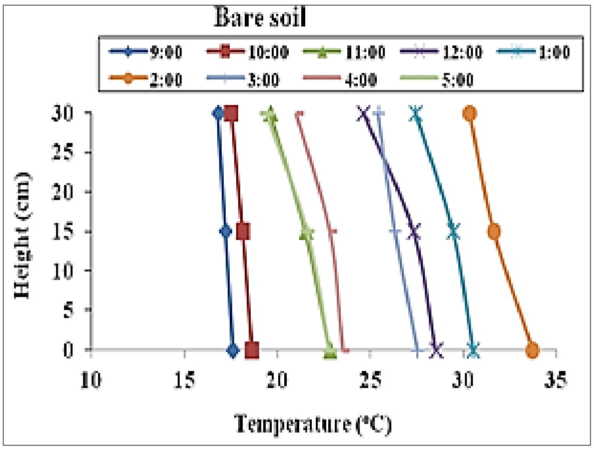
Temperature (°C)


Bare soil
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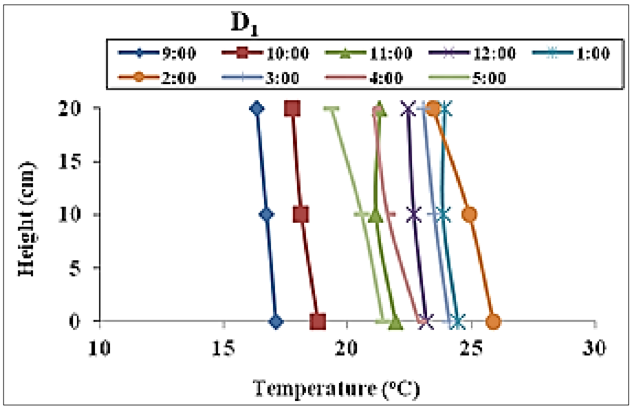
Temperature (°C)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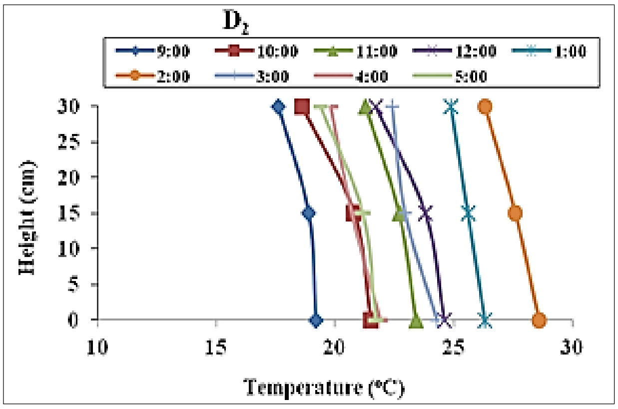
Temperature (°C)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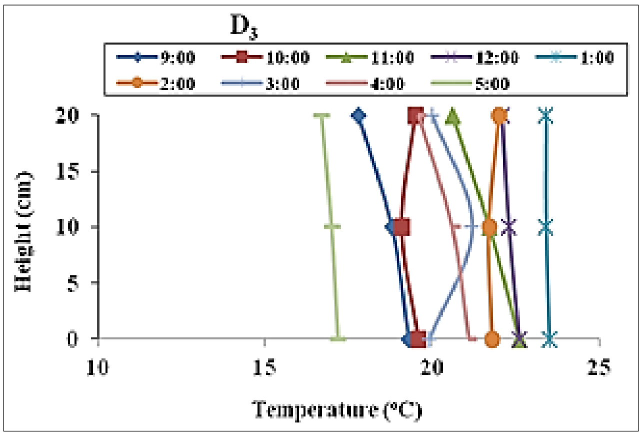
Temperature (°C)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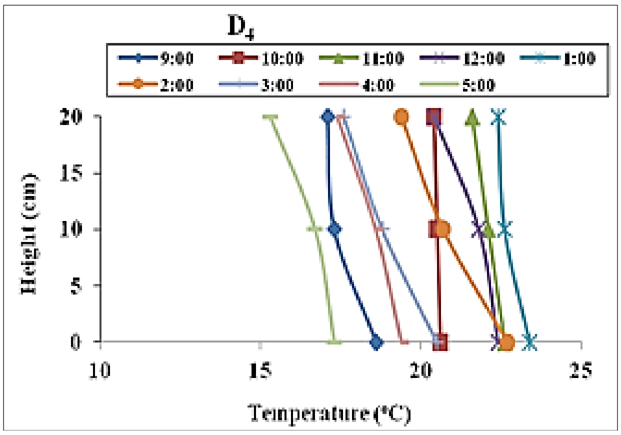
Temperature (°C)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Temperature (°C)

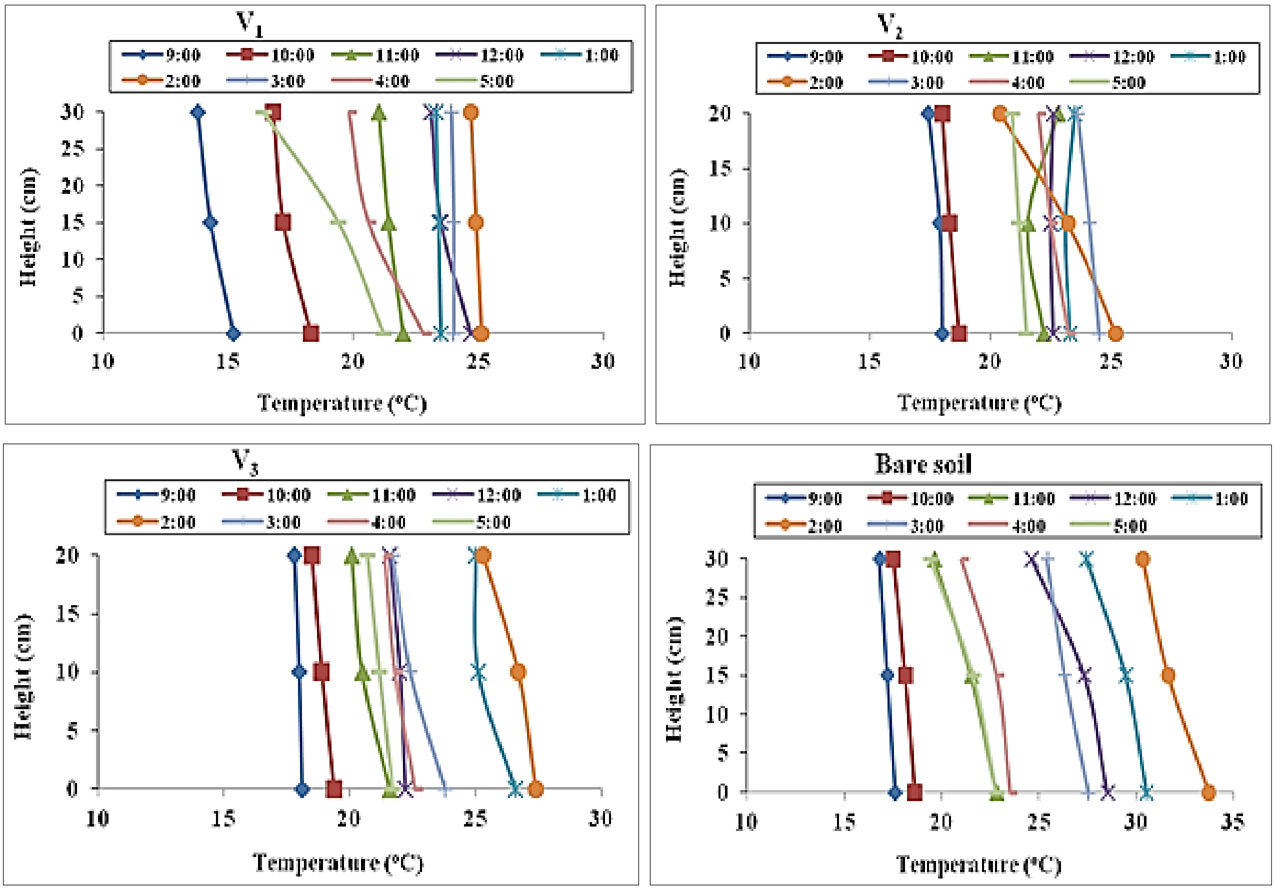
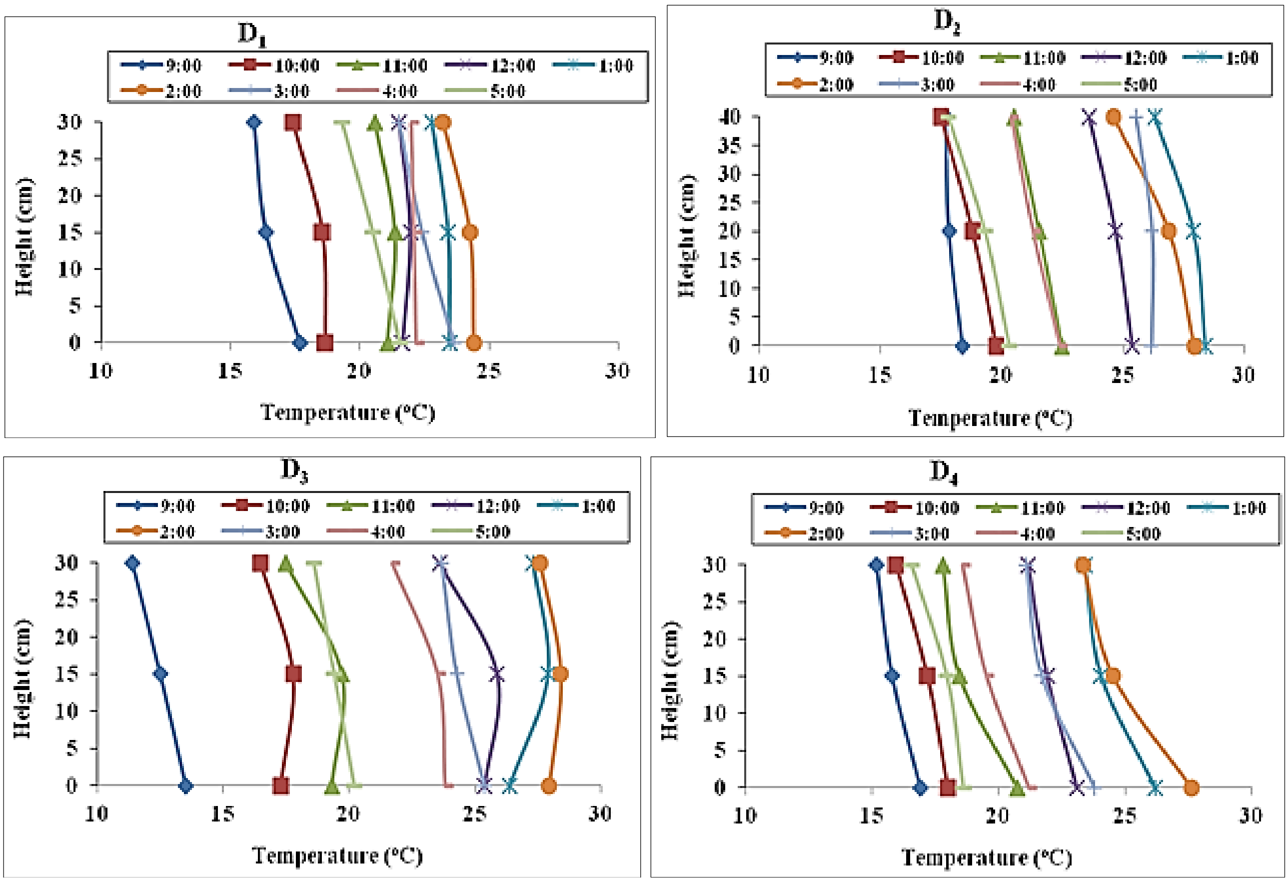
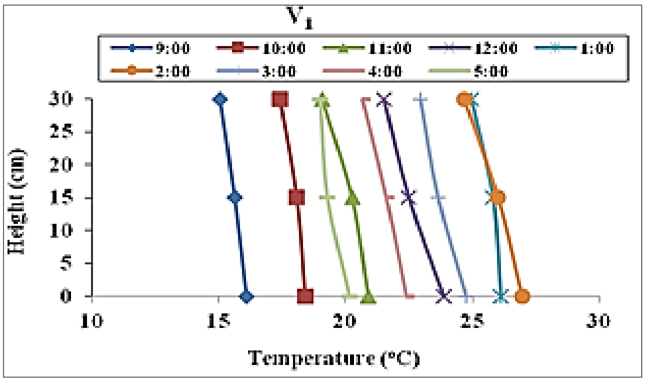


Fig 5: Temperature profile at early vegetative phase under different planting dates and varieties of potato crop and bare soil during 2016-17 and 2017-18

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Height (cm)
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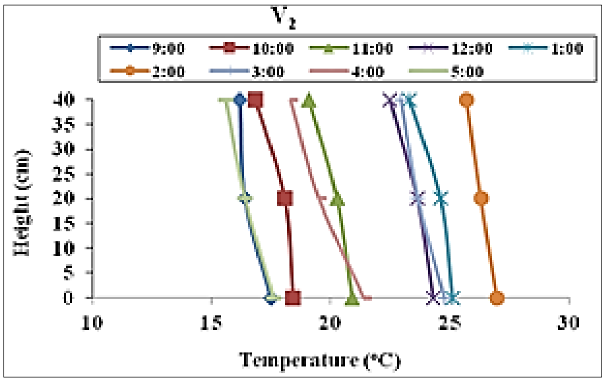
10 15 20 25 30
Temperature (°C)


V₂
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Height (cm)
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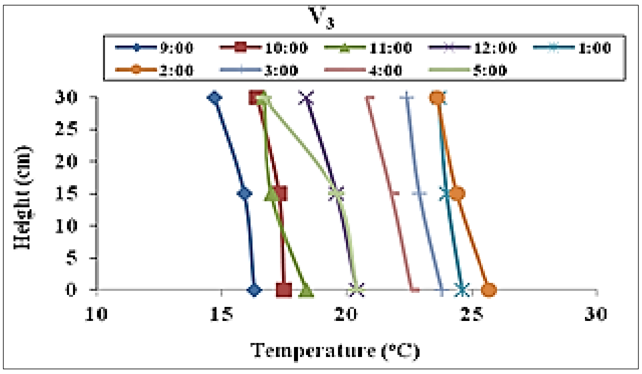
10 15 20 25 30
Temperature (°C)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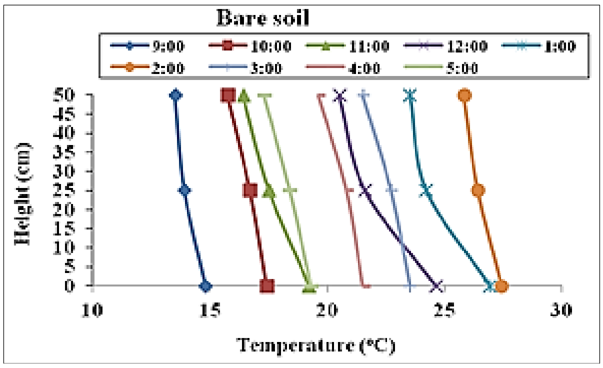
10 15 20 25 30
Temperature (°C)


Bare soil
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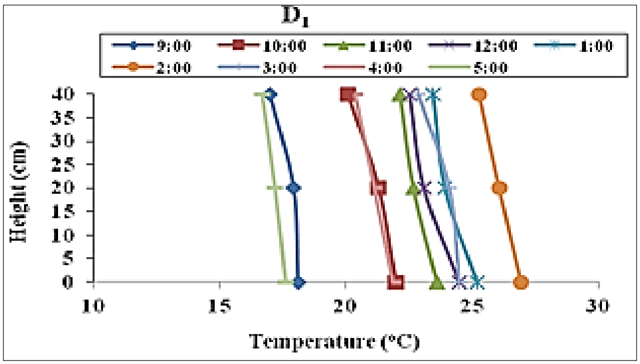
10 15 20 25 30
Temperature (°C)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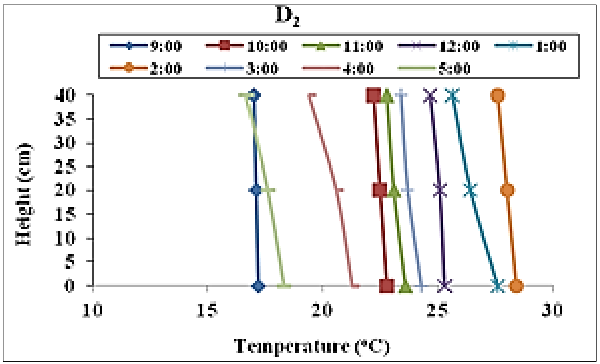
Temperature (°C)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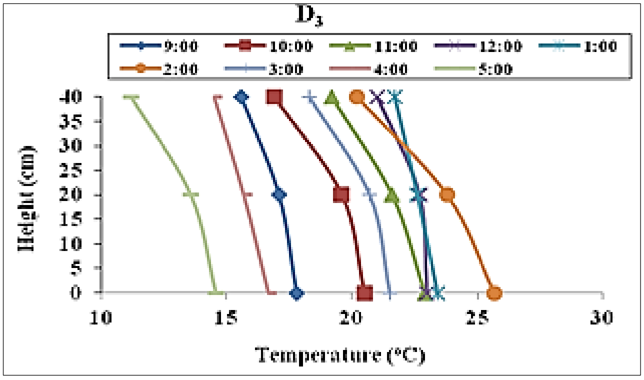
Temperature (°C)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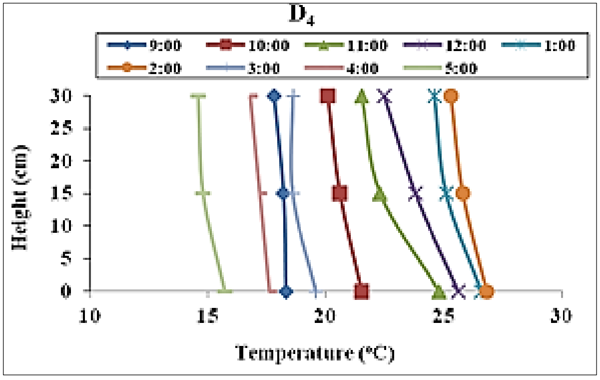
Temperature (°C)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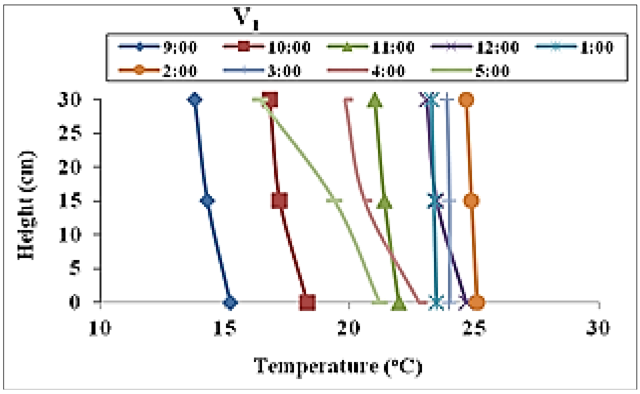
Temperature (°C)


V₁
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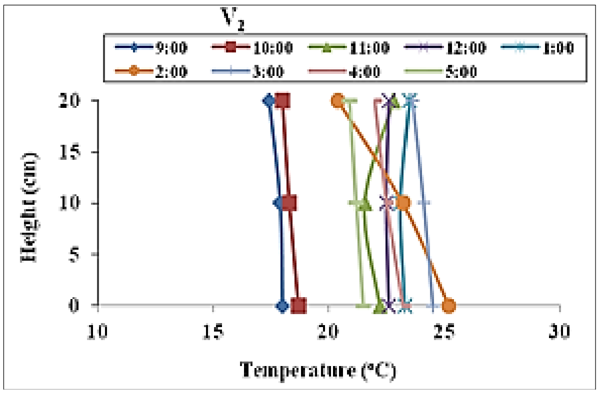
Temperature (°C)


V₂
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Temperature (°C)

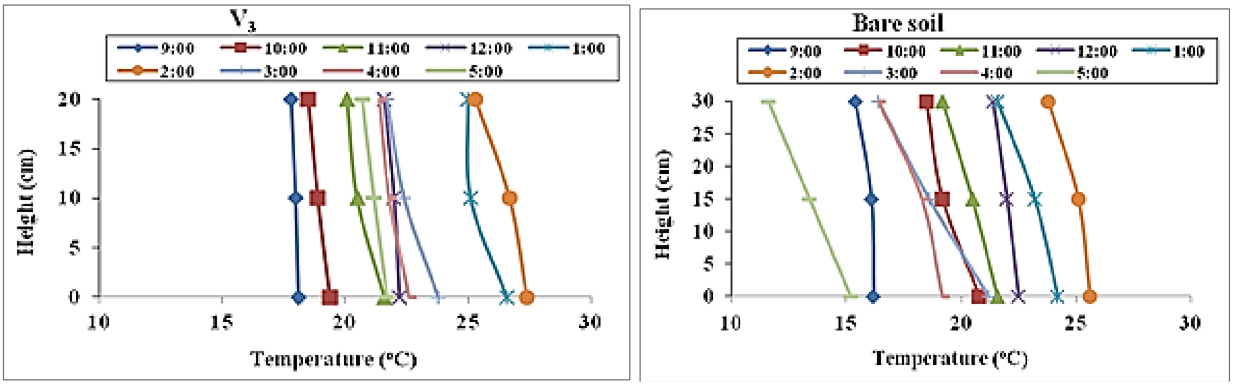
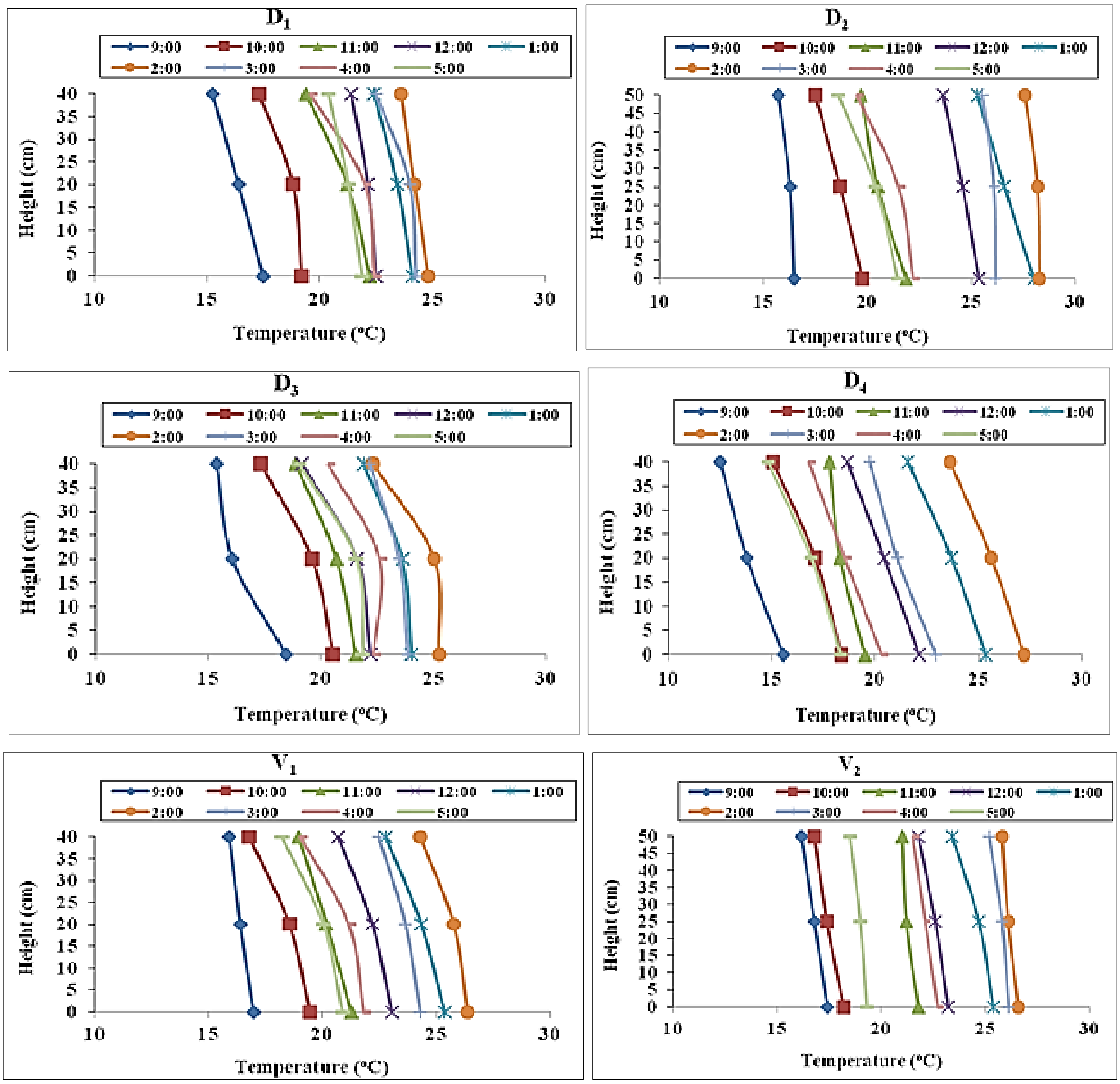
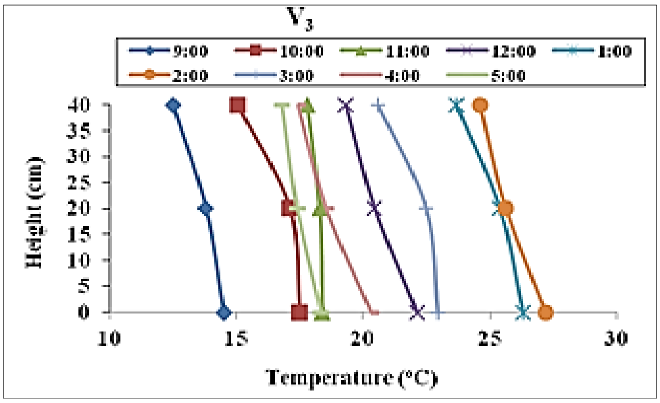


Fig 6: Temperature profile at initiation of tuber under different planting dates and varieties of potato crop and bare soil during 2016-17 and 2017-18.




V₃
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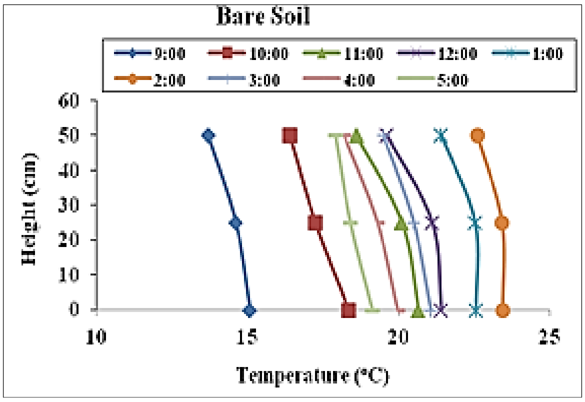
Temperature (°C)


Bare Soil
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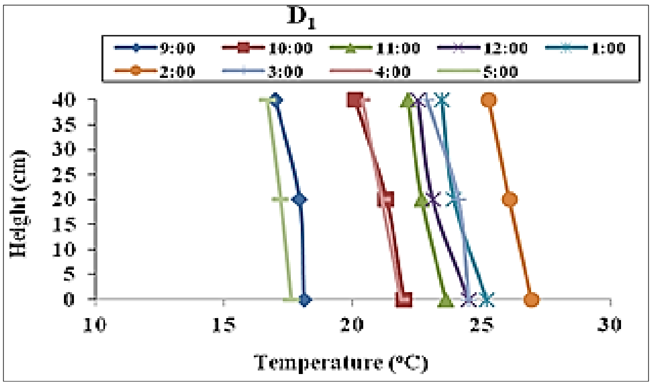
Temperature (°C)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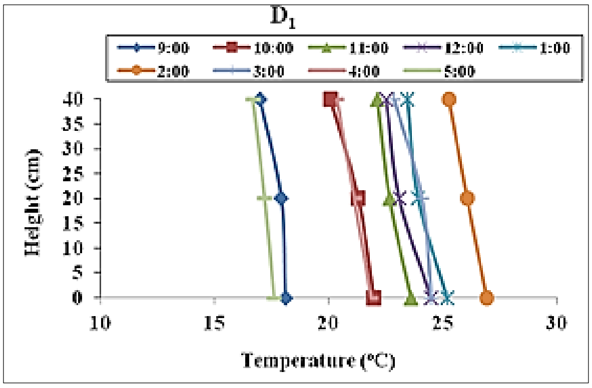
Temperature (°C)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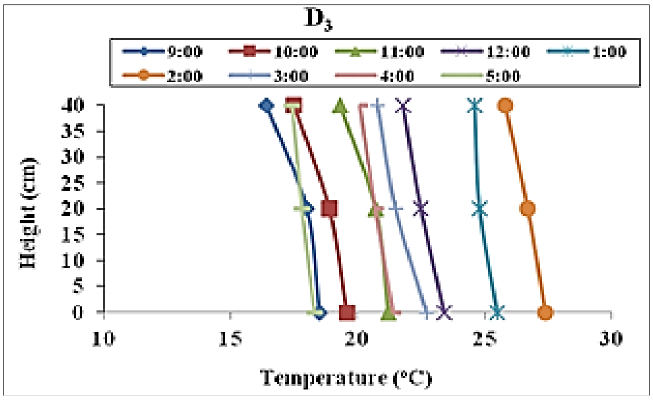
Temperature (°C)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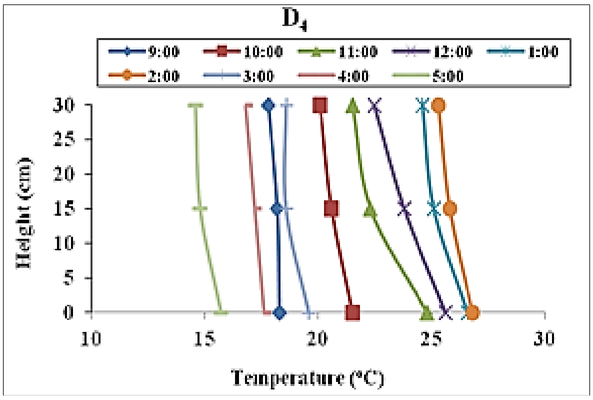
Temperature (°C)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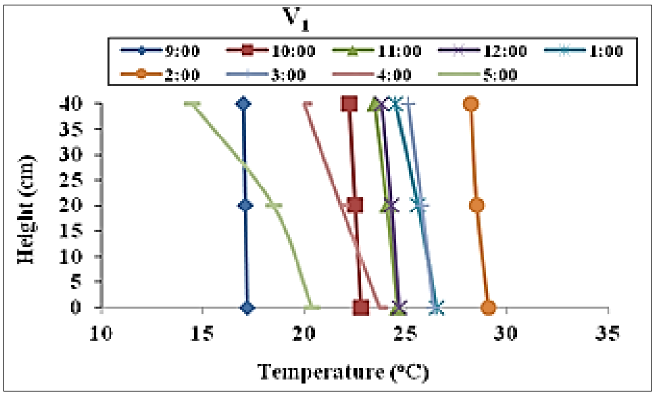
Temperature (°C)


V₁
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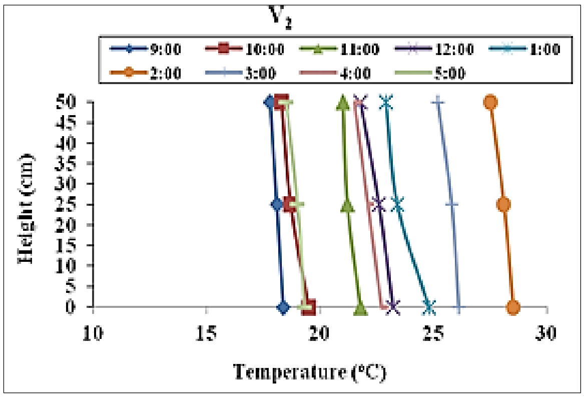
Temperature (°C)


V₂
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Temperature (°C)

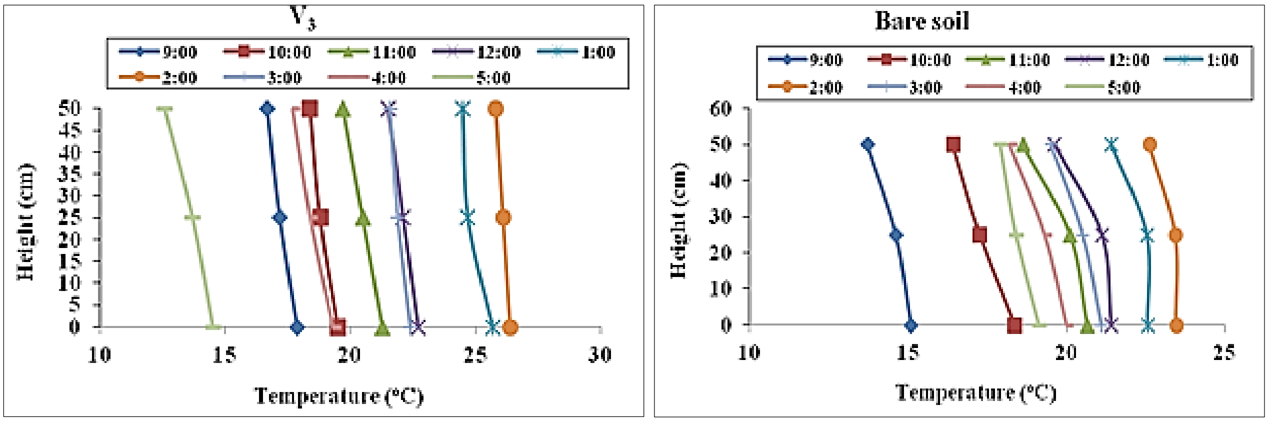
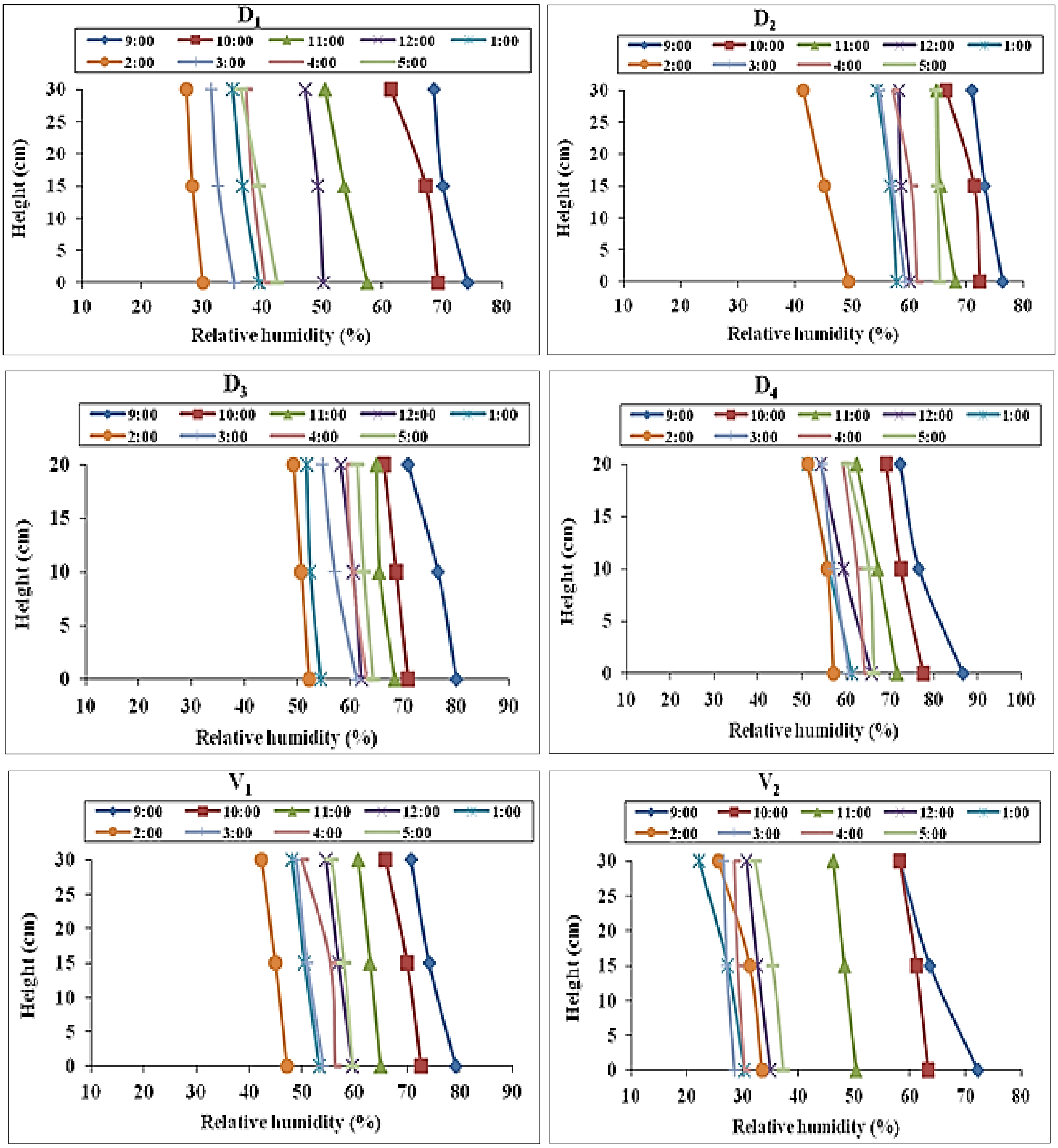


Fig 7: Temperature profile at tuber bulking stage under different planting dates and varieties of potato crop and bare soil during 2016-17 and 2017-18



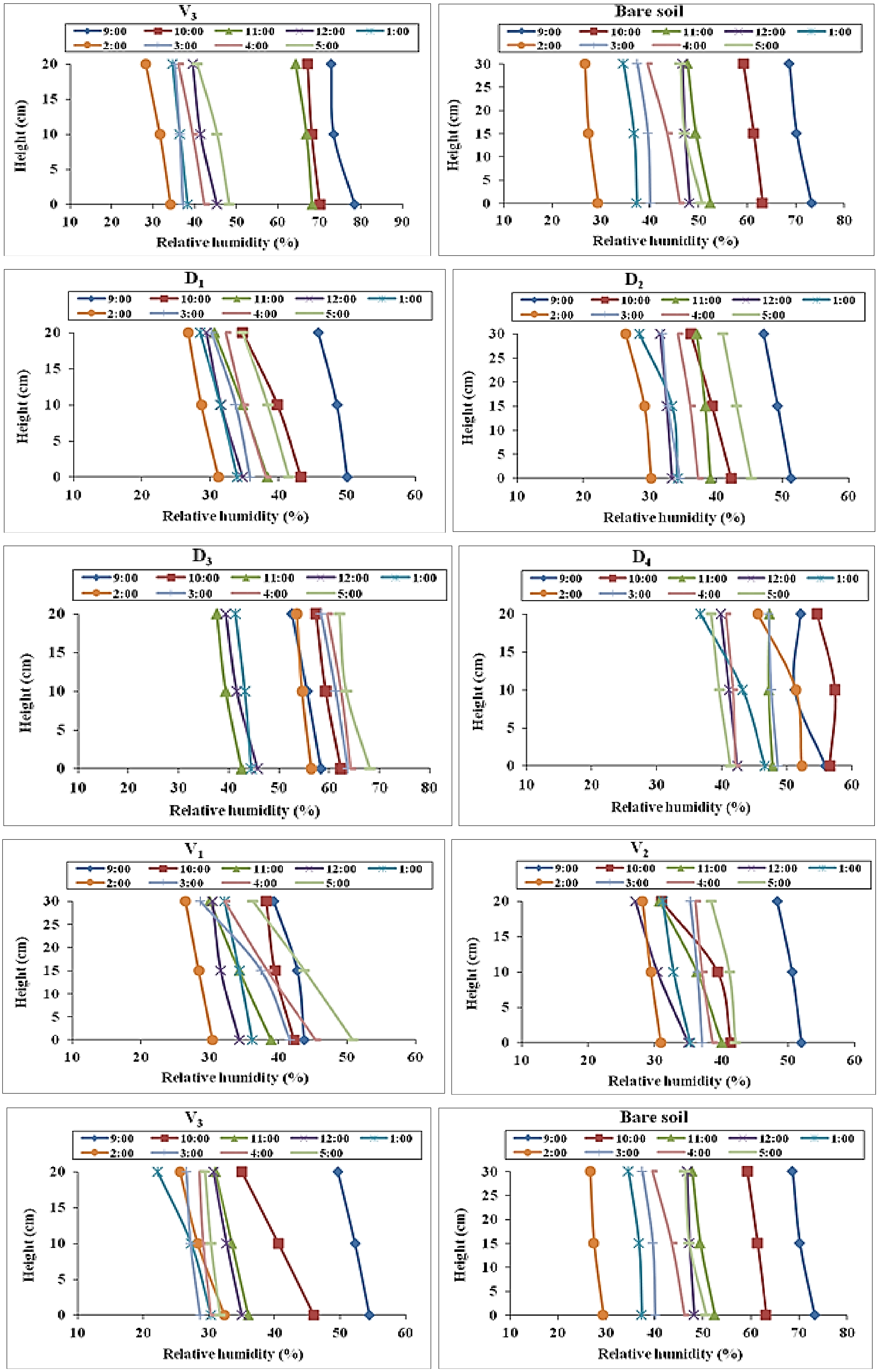


Fig 8: Relative humidity profile at early vegetative phase under different planting dates and varieties of potato crop and bare soil during 2017-18

Conclusion

It may be concluded that the micrometeorological parameters observed more favourable in 3rd week of October (D_2) planted crop. The absorbed PAR was recorded higher in 3rd week of October (D_2) sown crop and Kufri Pushkar then other treatments at all phenophases higher in during both crop seasons. The reflected and transmitted radiation was highest in 3rd week of November (D_4) at all phenophases during both the years. Among different planting dates, the net radiation was higher at early vegetative stage in 3rd week of October (D_2) and 1st week of November (D_3) during both crop seasons. Among all treatments, the major portion of net radiation was utilized by latent heat of vaporization. The 2nd week of October (D_1) was received higher values of soil heat flux during both the crop seasons. Temperature profiles were inverse throughout the day within the canopy at all phenophases. Over the top of the crop canopy the temperature profile was lapse. The relative humidity profiles were lapse inside the crop canopy throughout the day at 9:00 AM hours where it was iso-humic.

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4. Anonymous 2018. https://www.indiastat.com.
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