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Micrometeorological dynamics within mustard (*Brassica juncea*) crop canopy under semi-arid conditions of northern India

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ABSTRACT

Field experiments were conducted for two years (2005-06 and 2006-07) at IARI, New Delhi, India research farm to assess the variations of micrometeorological parameters under differential hydrothermal regimes in mustard crop. Changes in sowing time and branch removal/defoliation treatments were imposed in order to create variations in hydrothermal regimes under phenology based irrigation scheduling. It was inferred that near-ground surfaces in the debranched plot where microenvironment was modified, air temperatures were higher (2 to 3 ^{0}C) as compared to control plots, decreased at 35 cm and remained almost similar with further increase in height at 1130 hrs while at 1430 hrs the magnitude of temperature variations was relatively higher. In contrast to air temperature, the relative humidity in debranched plot was less than that of the control plot. At near-ground, even at higher canopy height about 10% higher RH variations were observed in control plot as compared to debranched plot both in morning and afternoon hours. Furthermore, leaf area index could explain variations in temperature and RH to the tune of 40-50%. Radiation penetration and soil moisture depletion pattern also indicated significant impact of microclimatic variations near the ground.

Key Words: Brassica juncea; micrometeorology; soil temperature; radiation penetration

Within-season weather variability is considered to be one of the major factors of climatic variability impacting on crop growth and developments in all environments. In arid and semiarid environments, besides rainfall and sunshine hours, within-canopy air temperature and relative humidity variations may also have bearing on crop phenophases. Understanding within-canopy microclimatic variations can assist in better understanding of plant microclimate characteristics and its effect on plant processes (Schween *et al.,* 1997; Jaya *et al.,* 2001).

Energy exchange between a plant community and its environment is a complex physical phenomenon. The soil surface temperature plays a crucial role in hydrological modeling and land-atmosphere energy balance by controlling the amount of evaporation and thermal heat exchange between the land surface and overlying atmosphere. Understanding the relationships between the soil temperature distribution in the profile with properties such as surface moisture, radiation balance, and evaporation as well as within-canopy microenvironments is important in better explanation of the yield and yield attributes (Xiao *et al.,* 2005).

The crop may experience moisture or temperature stress at its various phenological stages or under field conditions and may undergo within-canopy microenvironment change that may or may not be helpful for the crop. The objective of the present study was to evaluate the microenvironment existed near-ground under differential hydrothermal regimes owing to changes in sowing time coupled with branch removal. This branch removal helps in penetration of higher amounts of radiation and thus inevitably influences the soil temperature, within-canopy temperature, relative humidity and soil moisture in a way of energy exchange processes.

MATERIALS AND METHODS

Field experiments were laid out at the experimental farm of IARI. The area is represented by its semi-aridity in nature, with dry hot summer and cold winter. The texture of the soil was sandy clay loam. Two cultivars of *Brassica juncea* viz., Pusa Jaikisan and BIO169-96 (developed at NRCPB, IARI, New Delhi) were grown during two *rabi* seasons of 2005-06 and 2006-07, following the recommended agronomic practices under irrigated conditions. To maintain optimum moisture regime, apart from one pre-sowing irrigations, two irrigations of 60 mm each was applied at two critical stages, namely flowering and pod developmental stages. Both the varieties were sown on 15th and 30th October keeping in view farmer's practice that prevailed in north and north-western parts of the country; normal, advanced / delayed by a fortnight or so due to delay in harvesting of previous crop. The microenvironment modification was further created by removing 3 to 4 lower branches at 40 days after sowing (DAS) (D1) and 50 DAS (D2) in both the cultivars of 15th October sown plots, while in 30th October sown plots, debranching was done at 50 DAS and 60 DAS due to less plant growth. For comparison one control plot (D0) was also maintained without removing branches. The experiment was laid out in a randomized block design with three replications in a 5 m x 5 m plot. Fertilizers were applied as per recommended doze. Thinning was done manually to maintain plant-to-plant distance of 15 cm. Weeding was done manually in each plot as and when needed.

Daily weather data of maximum and minimum temperatures, morning and evening relative humidity, rainfall, wind speed, bright sunshine hours and evaporation rates for both the seasons were obtained from the meteorological observatory of the division of Agricultural Physics, located adjacent to the experimental site. Digital thermo-hygroclocks were installed within the debranched and non-debranched plots at 5, 35, 85 and 135 cm canopy height. These instruments were continuously and simultaneously recording within-canopy air temperature and relative humidity. Pooled data were analyzed and reported on weekly basis. However, due to paucity of instruments, pooled data of D2 and D0 were presented and discussed. For measuring soil temperature variations, platinum resistance soil thermometers were installed in the soil at 5 and 15 cm soil depths. Observations were recorded at the morning and afternoon hours and weekly average soil temperatures were reported. Solar radiation transmissions within plant canopy were recorded. Both incoming and outgoing Photosynthetically Active Radiation (PAR) was measured at three heights viz., top, middle (50 per cent canopy height) and bottom of the crop throughout the growing season using line quantum sensor (LICOR-3000). To get reflected radiation from top, middle and bottom ground, the sensor was held in inverted position and the radiation penetration was calculated as radiation penetration from top to bottom = {(Incoming – outgoing) PAR at bottom *100}/ (Incoming PAR at top) and radiation penetration from mid to bottom = {(Incoming – outgoing) PAR at bottom*100}/ (Incoming PAR at mid). All these measurements were made on cloud free days between 1100 to 1300 hours IST at solar zenith angles ranging between 40 and 50^0 in order to get minimum disturbances from the atmosphere, changes in solar angle and elevation, leaf shading and leaf curling.

Biophysical parameters like leaf area index (LAI) and dry biomass production were recorded and reported on weekly basis. For this purpose, three randomly selected plant samples (above ground) were taken and the leaf area was measured using leaf area meter (model LICOR- 3100). The same plant samples were oven dried at 80^{0}C for 48 hours to obtain dry biomass production of stems and leaves. Statistical analysis of all measurements pertaining to statistical significant, Pearson's correlation coefficients and best fit polynomial regression analysis were done using SPSS version 12.0 and statistically significant graphs were drawn using Microsoft Excel software.

RESULTS AND DISCUSSION

Variations in air temperature and ralative humidity

The within-canopy air temperature at different heights at morning and afternoon hours (1130 hrs and 1430 hrs) during crop season in control and debranching plots revealed that the temperature variation was relatively more in debranching plots as compared to control plot. Initially 2 to 2.5^{0}C higher temperatures were observed in debranched treatment than in control plot at 46 to 50 days after sowing (DAS) near the ground (at 5 cm canopy height). The higher temperature in debranched plots were mainly attributed to removal of lower 3 to 4 branches coinciding with better radiation penetration as compared to non-debranched plot which could probably be responsible for differences in temperature particularly at 5 cm height. With the rapid development of leaf area, the radiation penetration decreased within the canopy which further justifies lower temperature difference at the higher canopy height.

In contrast to air temperature variations, the RH in debranched plot was less as compared to the control plot. Interestingly, it was observed that the variation decreased from 5 cm to 135 cm height within the crop canopy. At 5 cm canopy height, in control plots the RH was higher by about 10 per cent as compared to debranched plot at1130 hrs in both the seasons. While at 1430 hrs, the magnitude of variation was more or less during the same in first season.

During the second season, initially up to 87 DAS, 10 to 30 per cent higher RH was found in control plot as compared to debranched plot but thereafter the differences were less than 10 per cent. Likewise, at 35 cm canopy height in control plot RH was higher by about 10 per cent than in debranched plots in both the seasons. Furthermore at 85 and 135 cm the variations during 1130 and 1430 hrs were negligible. This kind of study is particularly important from view point of disease infection (White rust etc.) and its spreading behaviour wherein high air or soil temperature coupled with lower RH decreases the intensity and spread of white rust in mustard (Chakravarty *et al.*, 2008).

Skewness and kurtosis of micrometeorological parameters within crop canopy

Within canopy air temperature showed a positive skewness and negative kurtosis at the morning and afternoon hours (Table 1). The values were highly skewed at the second crop season as compared to the first crop season. However, at the higher crop canopy height, it seems a negative skewness during the first season. In contrast to air temperature, within canopy relative humidity variations showed mostly positive skewness and kurtosis across the canopy height (Table 1). The vertical relative humidity dynamics were highly skewed at upper canopy height (85 and 135 cm) at the morning hours while the magnitude was lower in the afternoon hours. Similar trends were also observed with the kurtosis values at higher canopy height. Jacobs *et al.* (2001) concluded form the study on daily course of skewness and kurtosis within and above a maize canopy that the daytime and night-time turbulent processes differ considerably due to differences in within-canopy as well as above-canopy stability conditions. During daytime it appears that the above and within-canopy characteristics are dominated by sweeps, which means a positive *u*-skewness and a negative *w*-skewness. During daytime the within-canopy kurtosis is extremely high due to strong turbulence events of sweeps as well as ejections. During night-time, hot plumes released from the soil surface dominate the extremes, which results in a positive skewness, above as well as within the canopy. The temperature skewness is mostly positive within as well as above the canopy. After mid-day on the clear day with low wind conditions, however, the within-canopy skewness for temperature is negative nearly throughout the whole canopy due to sweeps from a relatively high and cool level.

LAI Vs within-canopy air temperature and relative humidity

The correlation between LAI and canopy air

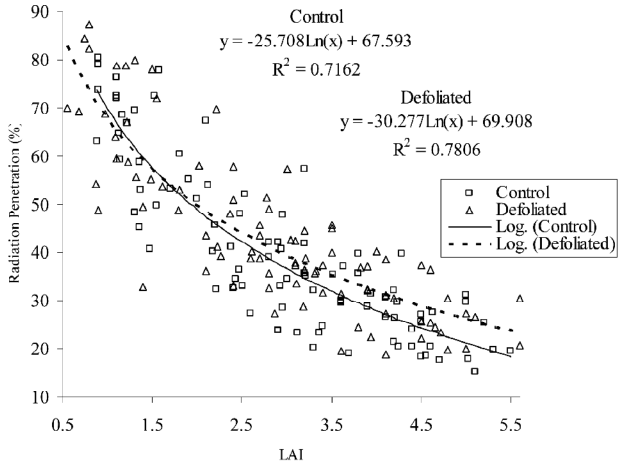

Fig. 1 : Relationship between radiation penetration and LAI under modified and non-modified microenvironment

temperature was significant and positive at 11.30 hrs under both control as well as debranched treatments, while it was negative with relative humidity. Both the micrometeorological parameters had non-significant correlation at 14.30 hrts. (Table 2).

Normally, rediation penetration through crop canopy is conceptialized as a series of absorbing layers of leaves, each of which atennuates a fraction of the incident radiation according to the Beer-Lombert law. Thus radiation penetration when correlated with LAI, it showed a logarithmic trend. Pooled data of radiation penetration revealed that around 78% variations at defociated plot were observed while in controlled condition, it was upto 71% (Fig. 1).

Interrelationship between soil temperature and canopy temperature

A strong interrelationship was found between the soil temperature and canopy air temperature particularly during morning hours whereas during afternoon hours the scatteredness of soil temperature was higher (Fig. 2). In general higher soil temperatures were found in debranched than in control plot. During the morning hours, the degree of soil temperature variations was found to be low. The study indicated rise in maximum and average soil temperatures but hardly changed minimum soil temperature. This is probably because solar radiation dominated in the summer season (i.e. higher percentage of radiation penetration) and increased soil temperature; on the other hand, net long-wave radiation, and releases of latent and sensible heat from the soil surface, were predominant in

Table 1: Skew ness and Kurtosis of micrometeorological parameter within the mustard crop canopy

		Skewness				Kurtosis			
		1130 Hrs		1430 Hrs		1130 Hrs		1430 Hrs	
Crop Season	Canopy Height	D_2	D_0	D_2	D_0	D_2	D_0	D_2	D_0
Within-canopy air temperature									
2005-06	5	0.26	0.32	0.38	0.56	-0.71	-1.01	-0.45	-0.68
	35	0.04	0.16	0.09	0.15	-0.43	-0.60	-0.60	-0.79
	85	0.18	0.31	-0.10	-0.04	-0.16	-0.28	0.16	0.11
	135	-0.10	-0.09	-0.13	-0.10	-0.93	-0.98	-0.07	-0.06
2006-07	5	0.19	0.40	0.54	0.57	-0.30	0.19	-0.11	0.03
	35	0.60	0.16	0.68	0.49	1.30	0.42	0.38	0.17
	85	0.66	0.40	0.50	0.36	1.57	1.33	-0.15	-0.18
	135	0.19	0.46	0.24	0.21	0.90	0.66	-0.74	-0.86
Within-canopy relative humidity									
2005-06	5	-0.06	-1.37	0.23	-0.65	1.06	1.38	-0.43	-0.44
	35	1.04	0.61	0.88	0.81	0.61	-0.40	0.61	0.56
	85	1.30	1.38	1.51	1.38	2.66	2.14	2.00	1.84
	135	0.99	1.19	1.64	1.79	1.97	2.42	3.58	3.78
2006-07	5	0.18	-0.45	0.30	-0.18	0.84	0.32	0.48	-0.01
	35	0.93	0.30	0.84	0.69	0.90	0.44	0.35	0.25
	85	1.36	1.27	0.99	0.97	2.23	1.25	0.95	0.66
	135	1.58	1.43	1.20	1.13	2.38	1.41	1.23	0.82

Table 2 : Correlation coefficients among within-canopy air temperature and relative humidity with LAI

Time	Debranched	Cantrol
	Air temperature	
1130 Hrs	0.63*	0.67*
1430 Hrs	NS	NS
	Relative Humidity	
1130 Hrs	-0.56*	-0.59**
1430 Hrs	NS	NS

*Correlation is significant at 0.05 level (2-tailed), ** Correlation is significant at 0.01 level (2-tailed) and NS-Non-significant.

the night/cool season (Ottosson-Lofvenius, 1993; Morecroft *et al*., 1998; Betts *et al.,* 2000; Langvall and Ottosson-Lofvenius, 2002; Hashimoto and Suzuki, 2004).

CONCLUSIONS

The present study was an attempt to find out the extent of variability of modified microenvironment parameters within a crop canopy. The microenvironment created at the near-ground soil surfaces experienced spontaneous exchange of energies. The micrometeorological observations revealed that the air temperature and RH variations were more near the ground (5 cm canopy height) and decreased with increase in height within the crop canopy (i.e., 35, 85 and 135 cm). In the debranched plots where microenvironment was modified, air temperatures were higher (2 to 3 ^{0}C) as compared to control plots within the canopy (at 5 cm canopy height), decreased at 35 cm and remained almost same with further increase in height at morning hours (1130 hrs) while during the afternoon hours (at 1430 hrs) the magnitude of temperature variations were relatively higher. In contrast to air temperature, the relative humidity in debranched plot was less than that in the non modified plot. At 5 cm height, the RH in control plot was more than 10 per cent higher as compared to debranched plot at 1130 hrs as well as at 1430 hrs in both the seasons. Likewise, at 35 cm about 10 per cent higher RH variation was observed in control plot as compared to debranched plot in both the seasons. Radiation penetration and soil moisture depletion pattern were also indicated significant impact of microclimatic variations near the ground.

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