



Role of agronomic manipulations in modification of wheat microclimate under central Punjab

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Abstract: Wheat crop is influenced by different microclimatic parameters like solar radiation, canopy temperature etc. Agronomic manipulation like change in row spacing and row direction can be used as a strategy to modify the microclimate of crop. Keeping these facts in view, field trials were conducted during *rabi* 2012-13 and 2013-14 under two experiments in first experiment wheat varieties HD 2967, PBW 550 and PBW 343 were sown under three row spacing viz. 15 cm, 22.5 cm and 30 cm. In second experiment, wheat varieties HD 2967, PBW 550 and PBW 343 were sown under two row direction viz. North-South (N-S) and East-West (E-W). Short wave radiation interception and canopy temperature was recorded under different treatments at 15 days interval. Among different row spacing, short wave radiation interception and canopy temperature was maximum at 30 cm row spacing (77.7% and 25.1°C) followed by 22.5 cm (75.7% and 24.2°C) and 15 cm row spacing (73.9% and 23.2°C), whereas under row directions short wave radiation interception and canopy temperature was more (76.5% and 23.9°C) in E-W row direction as compared to N-S row direction (75% and 23.2°C). Relationships were developed between dry matter accumulation and canopy temperature. Polynomial relationships gave significant R^2 value (0.66 & 0.69) under different treatments. This two year study indicated that agronomic manipulations play an important role in microclimate modification and canopy temperature significantly influence dry matter accumulation under different crop geometry.

Keywords: Canopy temperature, Microclimate, Short wave radiation, Wheat

INTRODUCTION

Wheat (*Triticum aestivum* L. Emend Feori and Paul) is the second most important *rabi* cereal crop in India after rice. It provides 21 per cent of the food calories and 20 per cent of the protein to more than 4.5 billion people in developing countries (Braun *et al.*, 2010). Wheat is the staple food of more than 40 per cent of the human population. In India it is second most important food crop, cultivated extensively in North-Western and Central zones. It contributes substantially to the national food security by providing more than 50 per cent of the calories to the people who mainly depend on it. In India, during 2013-14, wheat was grown on 31.30 million hectares with production of 95.80 million tones and per hectare yield of 30.59 quintals. In Punjab, during 2013-2014, it was grown on 35.12 lac hectares with production of 176.20 lac tonnes and per hectare yield of 50.17 quintals (Anonymous, 2014).

Wheat is a photo-insensitive and thermo-sensitive long day plant. Both the start and end of wheat crop season are limited by the onset and end of favourable temperature regimes. Wheat requires cool climate during the early part of its growth. Wheat grain yield and quality are also influenced by temperature regimes during different phases of crop growth. Within the

growing season itself, warmer temperature shortens the total crop duration. Higher temperature during early vegetative phase results in sparse tillering, poor vegetative growth and early heading; and during grain filling phase leads to forced maturity (Reddy, 2006). A mean daily temperature of 15-20 °C is optimum for crop growth, development and flowering of wheat crop. An increase of temperature by 2°C in wheat resulted in 15-17 per cent reduction in grain yield (Hundal, 2004). Current estimates indicates that in India alone around 13.5 million hectares of wheat is under heat stress (Joshi *et al.*, 2007).

Climate and weather variability especially temperature significantly affect potential wheat yield under irrigated conditions in Punjab. A better understanding of weather resources can help to increase crop productivity. It will enhance the benefits by minimizing losses due to adverse weather conditions (Virmani, 1994). Temperature, radiation and moisture are basic meteorological parameters of significance to agriculture. Under potential conditions, with adequate moisture and fertility, radiation plays the role of a decisive factor for crop growth and development. Thus, manipulation of radiant energy within a crop field by an appropriate adoption of crop stand geometry, like row orientation and row spacing can provide a means to create

light saturated conditions for crop canopy for the purpose of efficient harvest of solar energy for agricultural production. Row spacing can provide a physical barrier between the soil and atmosphere and consequently improve heat conditions at the soil surface.

Kumar *et al.*, (2002) observed that the canopy temperature depression (CTD) showed strong positive correlations with organ temperature depression and grain yield of wheat. Organ temperature depression and CTD were positively correlated with LAI and CTD was probably little affected by leaf rolling. They also reported that spike temperature was generally higher than leaf temperature but lower than ambient air temperature. Kingra *et al.*, (2010) reported that during the reproductive phase, all the canopy temperature based indices viz., canopy temperature (T_c), average canopy minus air temperature ($T_c - T_a$) and summation stress degree days (SDD) showed a negative and significant relationship explaining 71-87 per cent variation in grain yield. These findings signify an ample scope of mid day canopy temperature as a possible tool for monitoring plant water status and grain yield prediction. Keeping in view the importance of agronomic manipulations viz. Row spacing and row orientation in modification of crop microclimate this study was planned.

MATERIALS AND METHODS

The field experiments on wheat were conducted at the Research Farm, School of Climate Change and Agricultural Meteorology during *rabi* 2012-13 and 2013-14. In first experiment wheat varieties HD 2967, PBW 550 and PBW 343 were sown under three row spacing viz. 15 cm, 22.5 cm and 30 cm. In second experiment, wheat varieties HD 2967, PBW 550 and PBW 343 were sown under two row direction viz. North-South (N-S) and East-West (E-W) under irrigated conditions. The crop was raised as per recommendations of Punjab Agricultural University. Short wave radiation was measured with Pyranalbedometer (Model LOM-1084). The incoming and reflected radiation measurements were made 1 meter above the canopy while transmitted radiation was recorded at the base of canopy at 15 days interval. Short wave radiation interception was calculated by using following formulae:

$$\text{SWR interception} = \frac{\text{Incoming radiation} - (\text{Reflected radiation} + \text{Transmitted radiation})}{\text{Incoming radiation}} \times 100$$

Canopy temperature was measured at 1400 hours with the help of Infrared Thermometer (FLUKE-574) in first and second experiment. The Infrared thermometer was held at 45° to the horizontal above the canopy so as to look in a downward direction towards the crop surface. Relationships of dry matter accumulation were developed with canopy temperature.

RESULTS AND DISCUSSION

Short wave radiation interception in different row

spacing: Solar radiation is the ultimate source of all the energy for physical and biological processes occurring on earth. All five determinants of crop growth proposed by Charles-Edward (1981), namely light interception, utilization of intercepted light, dry matter loss due to respiration, partitioning of assimilates to economically harvestable parts and duration of crop growth are influenced by the prevailing environmental conditions of radiation and temperature. Grain yield is the product of radiation interception, conversion efficiency of intercepted radiation to dry matter and partitioning (Jarwal and Singh, 1990). Short wave radiation interception in the crop canopy is an important aspect affecting the crop growth and yield. Apart from soil moisture and temperature, radiation received by crop canopy during the crop season is of much concern as it is directly related to dry matter production. Radiation dynamics within the crop significantly contribute to crop yield. Response of crop varieties may or may not be similar in same or different radiation regimes. Carretero *et al.* (2010) reported that the leaf area together with the angular arrangement of individual leaves determines the amount of radiation that penetrates the canopy and strikes the ground.

The data of short wave radiation (SWR) interception was recorded on 45, 60, 75, 90, 105, 120 and 135 days after sowing in varieties HD 2967, PBW 550 and PBW 343 in different row spacing. SWR interception is presented in Figs. 1 (a-f). Short wave radiation interception varied with leaf area index (LAI). SWR interception was highest during the heading stage almost about 90 days after sowing in all the varieties under different row spacing. SWR interception was highest (77.5 and 77.7 per cent) in 30 cm row spacing followed by 22.5 cm row spacing (75.4 and 75.7 per cent) and 15 cm row spacing (73.7 and 73.9 per cent). Among different varieties, HD 2967 intercepted maximum SWR (73.7 and 73.9) in 15 cm row spacing followed by PBW 343 (73.4 and 72.0 per cent) and PBW 550 (72.8 and 73.0 per cent) during 2012-13 and 2013-14. Under 30 cm row spacing, HD 2967 intercepted maximum SWR (77.5 and 77.7 per cent) followed by PBW 343 (76.8 and 77.0 per cent) and was minimum in PBW 550 (74.6 and 75.0 per cent) during 2012-13 and 2013-14 at heading stage. SWR interception decreased gradually 90 days afterwards due to decrease in leaf area of crop. Tompkins *et al.* (1993) observed that row spacing had a significant influence on the level of solar radiation that penetrated to the base of the crop canopy. The mean daily solar radiation was 1100 $\mu\text{mol}/\text{m}^2/\text{s}$ within the 36 cm row spacing canopy, compared with 845 $\mu\text{mol}/\text{m}^2/\text{s}$ within the 9 cm row spacing canopy. About 30 per cent more light penetrated to the base of the 36 cm row spacing canopy.

Short wave radiation interception in different row direction: Solar radiation is one of the important parameter of the climate which provides essential energy

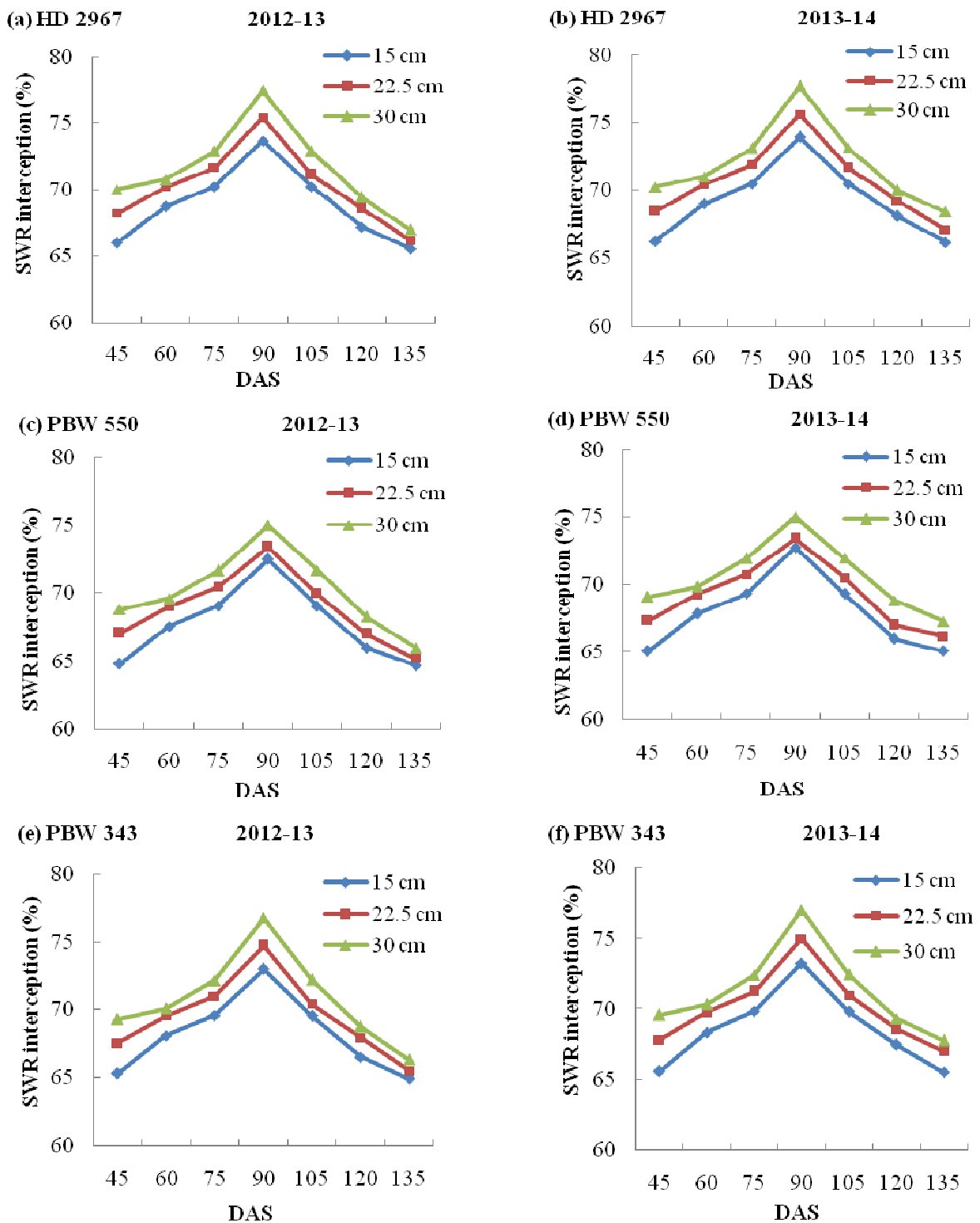


Fig. 1 (a-f). Comparison of mean SWR interception in different row spacing during 2012-13 and 2013-14.

to the crop plants for their growth and development. All the important phenological stages of the crops are generally influenced by quality and quantity of the solar radiation. Solar radiation is very important for plants as it is indispensable to photosynthesis. Short wave radiation plays an important role in biomass production. Thus apart from biomass production,

photosynthates production and its translocation solely depends on radiation regime experienced by the crop at its different phenological stages. Different management practices influence solar radiation interception so knowledge of effects of management practices on solar radiation interception and utilization is necessary to know the physiological basis of improved management

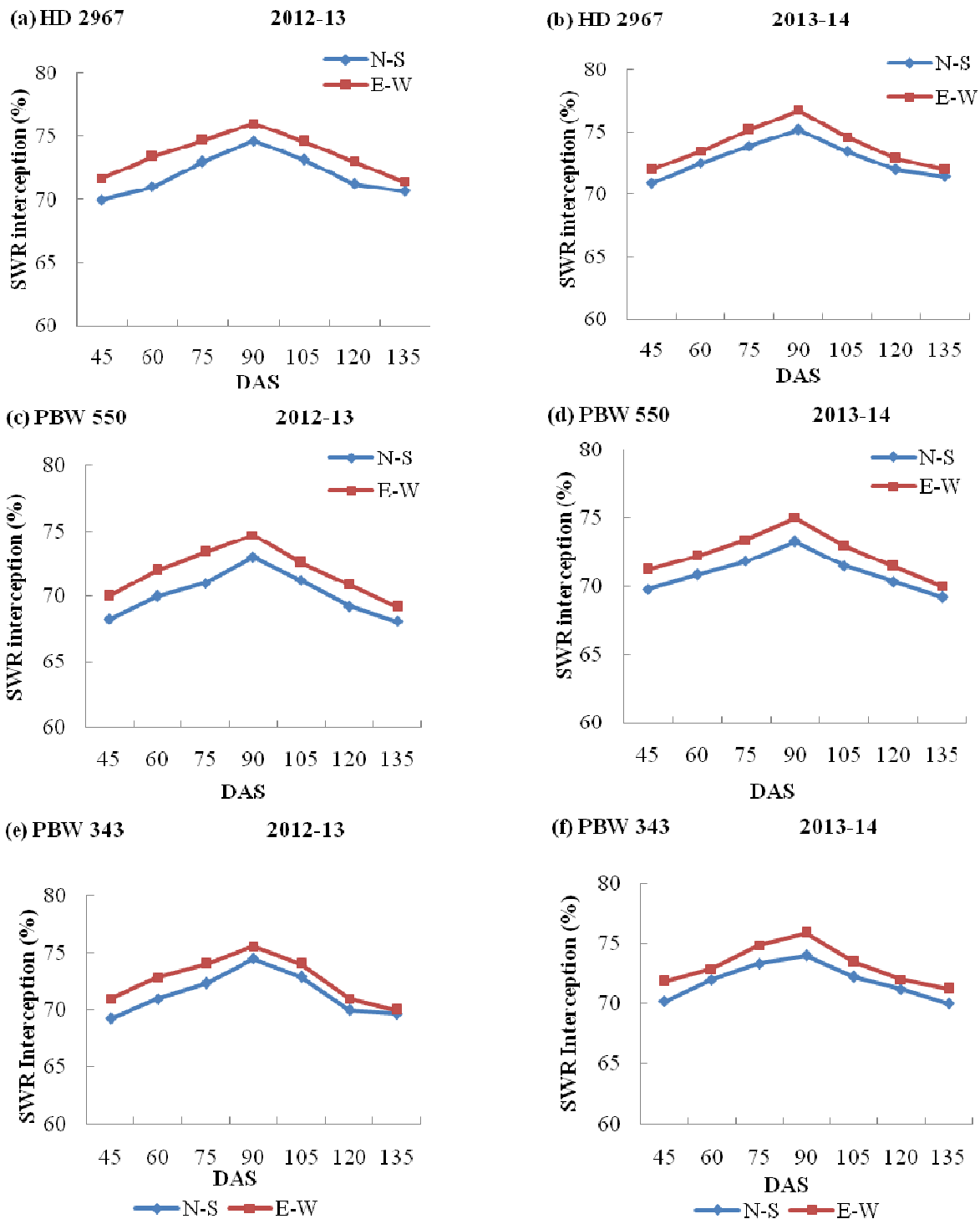


Fig. 2 (a-f): Comparison of mean SWR interception in different row direction during 2012-13 and 2013-14

practices. Short wave radiation interception in the crop canopy is an important aspect affecting the crop growth and yield. So increase in grain yield under E-W row direction can be associated with higher rate of radiation interception. Response of different cultivars to radiation regime may not be similar. The canopy architecture strongly influences the radiation dynamics at any instant in time at any location within crop canopy.

The data of short wave radiation (SWR) interception was recorded on 45, 60, 75, 90, 105, 120 and 135 days after sowing in varieties HD 2967, PBW 550 and PBW 343 in different row direction is presented in Figs. 2 (a-f). Short wave radiation interception varied with leaf area index (LAI). SWR interception was highest during the heading stage almost about 90 days after sowing. Mean SWR interception was higher (76.0 and 76.5

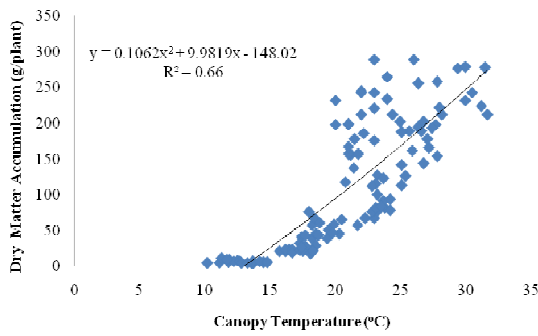


Fig. 3. Relationship between canopy temperature and dry matter accumulation in wheat sown under different row spacing.

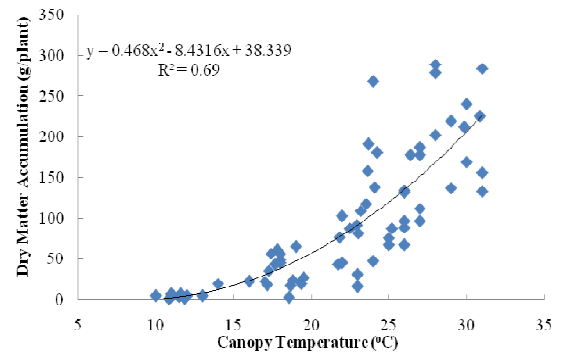


Fig. 4. Relationship between canopy temperature and dry matter accumulation in wheat sown under different row direction.

Table 1. Canopy temperature of wheat sown under different row spacing during 2012-13.

DAS	HD 2967			PBW 550			PBW 343		
	15 cm	22.5 cm	30 cm	15 cm	22.5 cm	30 cm	15 cm	22.5 cm	30 cm
45	11.1	11.9	12.5	10.2	11.6	12.2	11.3	11.7	12.35
60	16.2	16.5	17.7	15.7	16.2	17.5	16.7	16.7	17.2
75	18.2	19.0	20.3	17.4	17.7	18.2	18.5	18.7	19.3
90	22.3	23.2	23.9	21.7	22.9	23.3	22.8	23.8	23.5
105	21.5	22.2	22.8	21.2	21.8	22.3	20.8	21.4	22.2
120	26.6	26.7	27.2	25.4	26.2	26.5	26.2	26.5	27.1
135	27.8	28.4	29.5	26.4	26.9	27.2	27.0	27.3	27.9

Where, DAS: Days after sowing.

Table 2. Canopy temperature of wheat sown under different row spacing during 2013-14.

DAS	HD 2967			PBW 550			PBW 343		
	15 cm	22.5 cm	30 cm	15 cm	22.5 cm	30 cm	15 cm	22.5 cm	30 cm
45	13.6	13.75	14.5	12.7	13.7	14.2	12.7	13.3	14.8
60	17.3	17.8	18.5	17.3	17.5	18.3	17.4	18.1	18.3
75	19.5	19.9	20.5	18.4	18.7	19.5	18.8	19.4	19.8
90	23.2	24.2	25.1	23.1	23.7	24.2	22.8	23.1	23.5
105	25.1	25.7	26.4	24.4	25.1	25.9	25.1	25.4	26.8
120	27.8	27.7	28.2	26.4	27.1	27.7	26.8	27.4	27.8
135	30.4	30.8	31.5	29.4	30.0	30.5	30.0	31.2	31.7

Table 3. Canopy temperature of wheat sown under different row directions during 2012-13.

DAS	HD 2967		PBW 550		PBW 343	
	N-S	E-W	N-S	E-W	N-S	E-W
45	11.2	12.2	10.7	11.5	10.8	11.8
60	18.8	19.5	18.5	19.3	18.6	19.3
75	17.4	17.8	17.2	18.1	17.2	17.7
90	22.0	23.2	21.7	22.9	21.9	23.1
105	23.7	24.2	22.5	23.6	23.6	24.1
120	25.1	26.2	25.9	27.2	26.4	27.9
135	30.0	31.0	28.7	30.1	29.8	30.8

Where, DAS: Days after sowing N-S: North-South E-W: East-West

per cent) in case of HD 2967 in E-W row direction followed by PBW 343 (75.0 and 76.0 per cent) and was lower in PBW 550 (74.4 and 75.0 per cent) during 2012-13 and 2013-14 at heading stage. SWR interception was less in N-S row direction as compared to E-W row direction. In HD 2967 mean SWR interception in

N-S direction was 74.6 and 75.0 per cent followed by PBW 343 (74.5 and 74.0 per cent) and PBW 550 (73.0 and 73.3 per cent) during 2012-13 and 2013-14. In all the three varieties SWR interception decreased gradually 90 days afterwards as after heading stage as LAI decreased in both row directions. Similarly, Khan *et al.*

Table 4. Canopy temperature of wheat sown under different row directions during 2013-14.

DAS	HD 2967		PBW 550		PBW 343	
	N-S	E-W	N-S	E-W	N-S	E-W
45	12.7	14.1	11.6	13.3	12.1	13.8
60	21.0	22.5	20.7	22.2	20.8	22.1
75	18.7	19.6	17.7	19.1	18.2	19.1
90	23.2	23.9	24.5	24.9	25.1	25.8
105	26.1	27.3	24.2	24.0	24.8	24.6
120	28.2	28.9	26.4	27.1	26.8	27.8
135	31.0	31.7	30.6	31.0	31.0	31.4

Where, DAS: Days after sowing

N-S: North-South

E-W: East-West

(2010) observed that accumulated global radiation during vegetative phase of crop showed a positive correlation but during reproductive and grain filling phases they exhibited negative correlation with dry matter production in wheat. O'Connell *et al.*, (2004) also reported similar results. Similarly, Adak and Chakravarty (2012) concluded that radiation penetration at the early crop growth stage was highest and decreases within crop canopy as the leaf area develops.

Canopy temperature under different treatments:

Canopy temperature is referred as the average temperature of leaves of foliage of crop. Canopy temperature is a useful indicator of plant water status. Plant water status by regulating the vital physiological and morphological characteristics of plants proved to be a useful factor in determining the grain yield.

When there is abundant supply of water and ambient temperature is not very high, the plants would transpire freely without any restriction. As a result cooling of leaves would continue causing low temperature of leaves and thereby reducing the canopy temperature. The canopy temperature was minimum in 15 cm row spacing in all the three varieties (HD 2967, PBW 550 and PBW 343) followed by 22.5 cm row spacing and was maximum in 15 cm row spacing. As in wider spacing due to less plant population transpiration rate was less as compared to narrow (15 cm) row spacing. Chen *et al.* (2010) confirmed that with the increase in row spacing the rate of transpiration decreases. Among different varieties canopy temperature did not show much difference. Although canopy temperature was slightly higher in HD 2967 followed by PBW 343 and PBW 550 because plant stand and other characteristics were better under HD 2967.

Variation in canopy temperature at 15 days interval is presented in Tables 1 and 2 in different wheat varieties under different row spacing. During 2012-13, the canopy temperature was low during 75 DAS in all the three varieties under different row spacing because at 75 DAS there was 23.6 mm rainfall which decreased the mean temperature. Among 2012-13 and 2013-14 there was slight difference in canopy temperature. Any fall or rise in canopy temperature was due to prevailing

weather conditions of that particular period. Yang *et al.* (2008) reported that leaf area index decreased and canopy openness increased with increased row spacing. Moreover, relative humidity decreased and canopy temperature at each layer increased.

Canopy temperature was recorded at 15 days interval in different wheat varieties under different row direction viz. N-S and E-W during 2012-13 and 2013-14. Among different growth stages canopy temperature was lower during initial stages of crop and was higher at reproductive stage due to less transpiration rate at reproductive stage. Canopy temperature was slightly higher in E-W row direction as compared to N-S row direction as shown in Tables 3 and 4.

Relationship between canopy temperature and dry matter accumulation:

Regression analysis was conducted between canopy temperature and dry matter accumulation in wheat sown under different row spacing and row direction. Polynomial equations were found to be best fit in both cases as presented in figs. 3 and 4. Dry matter accumulation invariably showed a high degree of relationship with canopy temperature which indicated that dry matter accumulation is influenced by canopy temperature. Relationship between dry matter accumulation and canopy temperature of wheat sown under different row spacing gave significant R^2 value (0.66) which indicated that 66 per cent variability in dry matter accumulation was because of canopy temperature of wheat varieties sown under different row spacing. Similarly, dry matter accumulation and canopy temperature of wheat sown under different row direction gave significant R^2 value (0.69) which indicated that 69 per cent variability in dry matter accumulation was because of canopy temperature of crop. According to Kaur *et al.* (2002) canopy temperature has a significant effect on wheat dry matter accumulation and grain yield so there is ample scope that mid-day canopy temperature can be used as a possible tool for monitoring plant water status and grain yield prediction.

Conclusion

Agronomic manipulations viz. change in row spacing and sowing of wheat in different row direction

influenced microclimate of wheat. Solar radiation interception and canopy temperature were influenced by agronomic manipulations and further influenced dry matter accumulation of wheat. Dry matter accumulation is the important component of grain yield. Canopy temperature can be used as important tool to predict dry matter accumulation of wheat.

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