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Microclimatic conditions and seed cotton yield as affected by sowing time, row orientation and plant spacing under *Bt* cotton hybrid

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सार – कपास पर मौसम के प्रतिकूल प्रभाव को कम करने के लिए सूक्ष्म जलवायवी संशोधन एक प्रभावी और उपयुक्त अनुकूलन उपाय है। इस संदर्भ में, पंजाब के भटिंडा और फरीदकोट में 2018 में खरीफ के दौरान Bt-कॉटन हाइब्रिड RHC 773 BGII के साथ कई स्थानों पर खेतों में प्रयोग किए गए और तीन बार यानी 30 अप्रैल, 15 मई और 30 मई को दो पंक्ति अभिविन्यासों (उत्तर-दक्षिण: NS और पूरब-पश्चिम: EW) में बीज बोए गए और फैक्टॉरियल स्प्लिट प्लॉट डिजाइन में तीन पौधे (67.5 सेमी × 45.0 सेमी, 67.5 सेमी × 60.0 सेमी और 67.5 सेमी × 75.0 सेमी) की दूरी पर लगाए गए और इसकी तीन बार पुनरावृत्ति की गई। प्राप्त परिणामों से पता चला है कि सुबह (0730 भा.मा.स.) और दोपहर के समय (1430 भा.मा.स) मिट्टी और वितान के अंदर का तापमान देर से बुआई के कारण आरंभ में और विकास के बीच के समय अधिक पाया गया, जिससे फसल वृद्धि की अवधि कम हो गई परिणामस्वरूप कपास के बीज की उपज कम हुई। दूसरी ओर, वितान के भीतर सुबह और दोपहर की सापेक्षिक आर्द्रता फसल के संवेदनशील चरणों के दौरान देरी से बुवाई के साथ दर्ज की गई थी, जो कपास कीट और बीमारी के उच्च संक्रमण के लिए अनुकूल मौसम प्रदान करती थी और दोनों स्थानों के अध्ययनों में कपास के बीज के उत्पादन में कमी आई। मृदा तापमान और वितान का तापमान पूर्व-पश्चिम दिशा की पंक्ति में अधिक दर्ज किया गया था, जबकि वितान की सापेक्षिक आर्द्रता दोनों अध्ययन क्षेत्रों में उत्तर-दक्षिण दिशा की पंक्ति अभिविन्यास में अधिक था। मिट्टी के तापमान और सुबह एवं दोपहर के दौरान दर्ज तापमान में कपास के पूरे विकास काल के दौरान, पौधों की दूरी में वृद्धि के साथ वृद्धि पाई गई, जबकि दोनों स्थानों पर सुबह एवं दोपहर के समय के दौरान वितान की सापेक्षिक आर्द्रता को पौधे में वृद्धि के साथ कम पाया गया। सूक्ष्म जलवायवी मापदंडों में बुवाई की तारीखों के बीच उच्च भिन्नता देखी गई, जबकि पंक्ति अभिविन्यासों और पौधे के फैलाव के बीच कम भिन्नता दर्ज की गई।

ABSTRACT. Microclimatic modifications are the effective and suitable adaptation strategy to minimize the adverse affect of weather on cotton. In this context, multi-location field experiments were laid out at Bathinda and Faridkot, districts of Punjab during *Kharif* 2018 with *Bt*-cotton hybrid RCH 773 BGII and sown at three times *i.e*., April 30, May 15 and May 30 with two row orientations (North-South: N-S and East-West : E-W) and three plant spacing's (67.5 cm × 45.0 cm, 67.5 cm × 60.0 cm and 67.5 cm × 75.0 cm) in factorial split plot design and replicated by three times. The results revealed that during the morning (0730 IST) and afternoon time (1430 IST), soil and within-canopy temperature were found higher during emergence and mid growth stages with delayed sowing which reduced the crop growing period and resulted the seed cotton yield to be declined with delayed sowing. On the other hand, morning and afternoon within-canopy relative humidity was recorded higher with delayed sowing during sensitive stages of the crop which provided favorable weather for higher infestation of cotton insect-pest and disease and caused reduction in seed cotton yield at both the study locations. Soil temperature and within-canopy temperature were recorded higher in East-West row oriented, while within-canopy RH was higher under North-South row orientation at both the study regions. During entire growth period of cotton, soil temperature and within-canopy temperature recorded during morning and afternoon hours were found to be increased with increase in plant spacing whereas within-canopy relative humidity during morning and afternoon hours was found to be decreased with increase in plant spacing at both the locations. Among microclimatic parameters, higher variation was observed between sowing dates, while lesser variation was recorded among row orientations and plant spacings.

Key words – Microclimatic modifications, *Bt*-cotton hybrid, Soil temperature, Within-canopy temperature, Within-canopy relative humidity.

1. Introduction

Cotton, being one of the most valuable source of fibre, plays a vital role in agricultural and industrial economy of the country. It is a major cash crop of Punjab and widely known as the 'White Gold' or 'king of fibres. To maintain sustainability of cotton production system, more precise water, nutrition and plant growth management are required. Globally, cotton production was 121.37 million bales of 480 lb from 33.38 million ha having productivity of 792 kg ha^{-1} during 2017-18 (Anonymous, 2017). Similarly, in India, during 2017-18, cotton production was expected to be 377 lakh bales of 170 kg from 122 lakh hectares with a productivity of 524 kg lint ha^{-1} (Anonymous, 2017). Cotton, being considered as a predominant cash crop of the South-Western (S-W) region of Punjab, occupied 3.85 lakh ha area with 12 lakh bales production and 529 kg ha^{-1} productivity during 2017-18 (Anonymous, 2017).

Climatic factors such as temperature, rainfall and relative humidity are the important factors that have an adverse affect on flower and boll production of cotton in case the plant does not get optimum climatic requirements from those parameters at different growth stages. Adverse air temperature is the major factor which affects the plant reproductive processes such as pollen tube growth, pollen germination and fruit setting. For germination cotton requires a minimum daily temperature of 15 °C, for vegetative period, it requires daily air temperature of 21-27 °C and for fruiting period relatively low temperature *i.e.*, 27-32 °C is required (Santosh *et al.*, 2017). During flowering, heavy rainfall leads to fall of flower buds and young boll. Flowering and boll development are the most moisture sensitive stages of cotton. Optimum rainfall during these phenological stages can increase the cotton yields (Cetin and Bilgel, 2001). The optimum soil temperature at seed depth should be above 18 °C. To ensure proper seed germination and crop emergence cotton needs adequate soil temperature and moisture conditions (FitzSimons, 2016). Therefore, favourable weather conditions play a major role in agriculture but fluctuations in existing weather events have created the crop production risky as well as difficult. Under these conditions, there is a need to manage the impacts of adverse weather conditions on crop production to maintain sustainability of food without disturbing the natural resources.

To minimize the adverse affect of weather on cotton, there is a need to develop suitable adaptation strategies. For that, microclimatic modifications can be effective adaptation strategy. Microclimate is the climatic conditions of a small area. Area can be few meters above or below the earth surface or within the crop canopy. Microclimate modification is an artificial control of field environment to keep the optimum condition for better crop growth, development and yield. Microclimatic modifications can be done by alteration in sowing time, spacing and row orientation, by adopting appropriate cropping systems etc. (Munir *et al.*, 2015; Sharma *et al*., 2018). This study has been carried out to quantify the microclimatic effect on cotton in response to different sowing environment, row orientation and plant spacings.

2. Materials and method

2.1. *Study locations and climatic conditions*

The field experiment was conducted at the two locations, *viz*., Punjab Agricultural University (PAU) Regional Research Station, Bathinda (30° 58' N, 74° 18' E) and PAU Regional Research Station Faridkot (30° 40' N, 74° 44' E) during the *Kharif* season of the year 2018. Bathinda region falls under south western part of the state in 4th Agro Climatic zone (ACZ), while, Faridkot is on 5th ACZ of Punjab and their climate are classified as semi-arid. The average annual rainfall of Bathinda and Faridkot are 436 mm and 433 mm, respectively. Frosty night associated with chilled winds are common when night temperature touches 0 °C during January-December and dust storms occur in May-June when the mercury touches over 47 °C.

2.2. *Soil characteristics of the experimental sites*

The soil of the both the experimental sites of Bathinda and Faridkot is mostly loamy sandy to sandy loam in texture. There was wide variation in soil fertility status of soils developed on various land forms. The soil is moderately dark coloured and well drained. The soils have developed from calcareous medium to moderately coarse textured material under the predominant influence of tall grasses in moderately well drained conditions and important physicochemical properties of experimental soil (Table 1). The N, P and K contents in the soil of both the districts are low, low to medium and medium to high respectively. The soils have sufficient contents of Fe, Cu, Zn and Mn for supply to crops (Yadav *et al.*, 2018).

2.3. *Microclimatic modifications*

The selection of sowing date and plant spacing are the important management options for optimizing seed cotton yield in the study region. In this regards, the field experiments were laid out with cultivar - RCH 773 BGII and sown at three dates *i.e.*, D_1 : April 30, D_2 : May 15 and D_3 : May 30 with two row directions (R_1 : North-South and R_2 : East-West) and three plant spacing's (P_1 : 67.5 cm × 45.0 cm, P_2 : 67.5 cm × 60.0 cm

TABLE 1

Physio-chemical characteristics of soil of the experimental sites

S. No.	Particulars	Values				Method used
		Bathinda		Faridkot		
		0-15 cm	15-30 cm	0-15 cm	15-30 cms	
1.	Organic carbon (%)	0.34	0.29	0.44	0.25	Walkley and Black's method (Jackson, 1973)
2.	Available nitrogen (kg ha^{-1})	198	188	210	248	Alakaline $KMnO_4$ (Subbiah and Asija, 1956)
3.	**Soil texture (%)**					
	Sand (%)	76	73	74	71	Hydrometer method (Bouyoucos, 1927)
	Silt (%)	15	16	14	12	
	Clay (%)	09	11	12	17	
4.	Textural class	Sandy loam		Sandy loam		Triangular method
5.	Field capacity (%)	27	30	29	32	Field method (Piper, 1950)
6.	Wilting point (%)	9.50	10.20	9.87	10.60	Pressure plate apparatus (Richards, 1954)
7.	Bulk density, moist (g/cm^3)	1.35	1.38	1.55	1.54	Core method (Richards, 1954)

and P_3 : 67.5 cm × 75.0 cm) at Bathinda and Faridkot during *Kharif* 2018. Weather data of T_{min}, T_{max}, RH_m, RH_e and Rainfall were taken from the agro-meteorological observatories of the respective study locations.

2.4. *Micrometeorological observations*

In order to study the microclimatic effect in response to sowing time, row orientation and plant spacing on *Bt* cotton hybrid, soil temperatures (at 10 cm depth), within-canopy temperature and within-canopy relative humidity were recorded at a specific interval of 15 days starting from sowing to maturation of the crop. Among these micrometeorological observations, soil temperature was taken by inserting mercury-in-glass soil thermometers in each plot of experimental field at 10 cm depth. Within-canopy temperature and relative humidity were recorded using Kestrel 4500 NV pocket weather meter. These micrometeorological observations were recorded at 07:30 and 14:30 Indian Standard Time (IST) hours.

3. Results and discussion

3.1. *Soil temperature*

Results indicated that, among the sowing environment, row orientation and plant spacing used for the study, the value of morning (0730 IST) and afternoon (1430 IST) soil temperatures ranged between 21.5-35.5 and 26.0-39.5 °C at Bathinda (Fig. 1) and between 20.5-35.5 and 25.5-39.5 °C at Faridkot (Fig. 2), respectively. At both the study locations, significant variations were observed in morning and afternoon soil temperature among different sowing dates at all the phenophases and lower value of soil temperature was recorded during early stages of the crop with timely sown crop followed by late sowing, while, at later stages of the crop, reverse trend was observed, in which higher value of soil temperature was recorded with timely sown crop than late sowing crop (Figs. 1&2).

Moreover, higher value of morning as well as afternoon soil temperature was recorded with delayed sowing during first fortnight from sowing and at flowering stage after 75 DAS which caused reduction in crop growing period and resulted seed cotton yield to be declined. On the other hand, morning and afternoon soil temperature was observed to be increased during emergence to vegetative stages of the crop with delayed sowing. However, during later stages a reverse trend in soil temperature was recorded up to maturation of the crop (Figs. 1&2). Awal and Ikeda, (2002) found that soil temperature was highest during emergence stage than other stages of groundnut crop.

Among row orientation and plant spacing, there was no significance difference in morning and afternoon soil temperature because of non development of canopy cover in early stages of the crop starting from sowing to 45 DAS at both the study locations. Among the study locations, soil temperature recorded during morning and afternoon hours was found to be more under E-W direction than N-S direction due to proper distribution of sun light under E-W sown crop (Figs. 1&2).

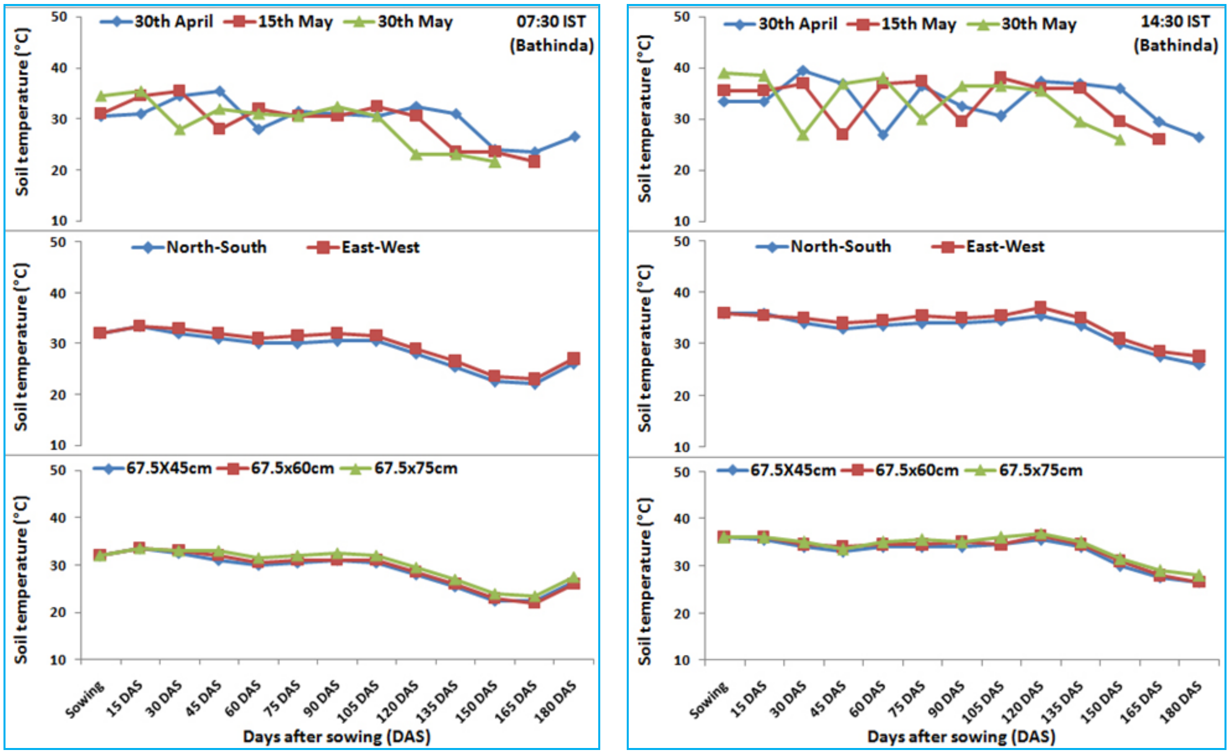

Fig. 1. Soil temperatures recorded at 0730 and 1430 IST during different stages of Bt cotton hybrid as influenced by sowing time, row orientation and plant spacings (*Kharif* 2018 at Bathinda)

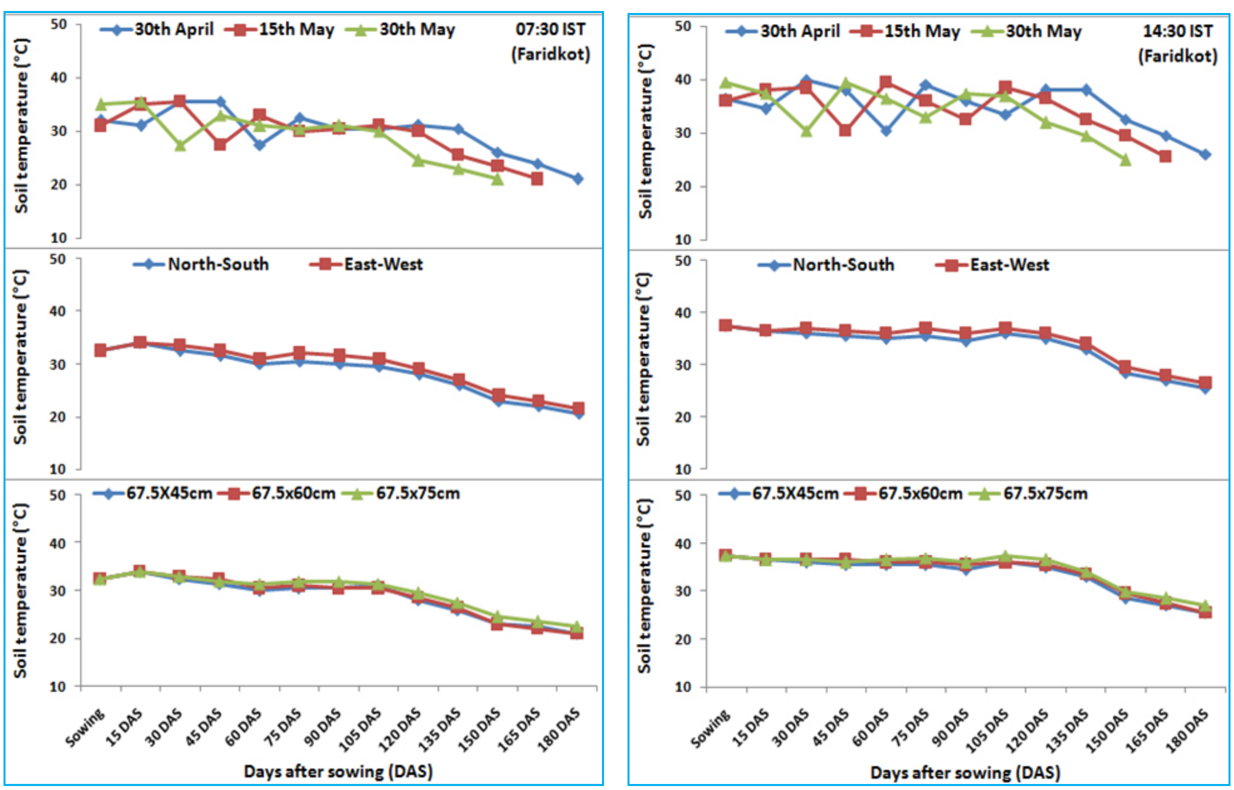

Fig. 2. Soil temperatures recorded at 0730 and 1430 IST during different stages of Bt cotton hybrid as influenced by sowing time, row orientation and plant spacings (*Kharif* 2018 at Faridkot)

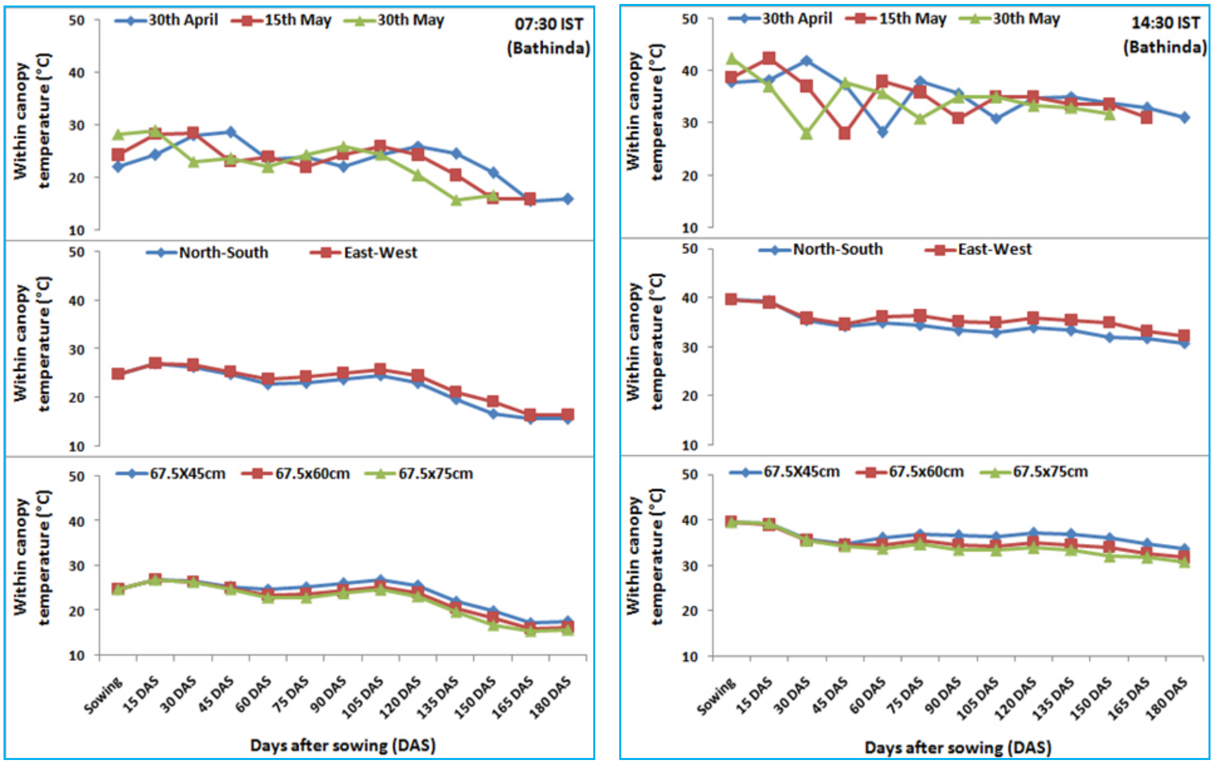

Fig. 3. Within-canopy temperatures recorded at 0730 and 1430 IST during different stages of Bt cotton hybrid as influenced by sowing time, row orientation and plant spacings (*Kharif* 2018 at Bathinda)

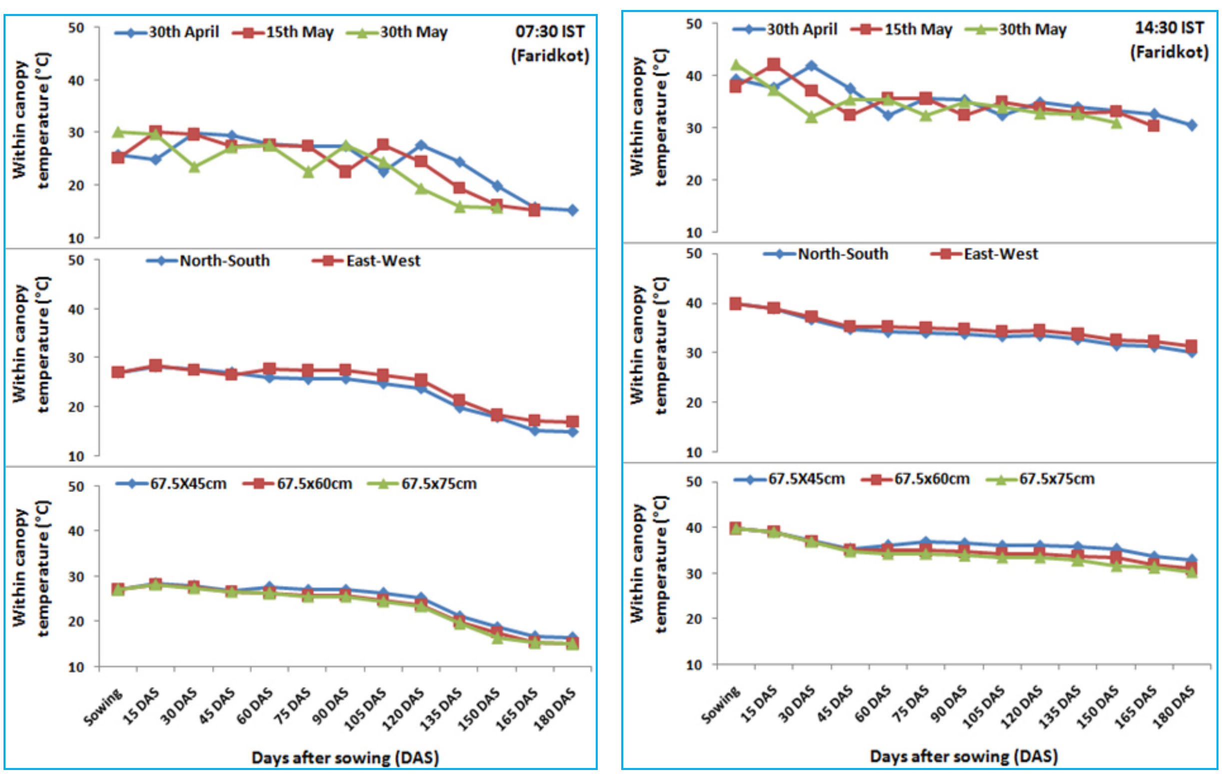

Fig. 4. Within-canopy temperatures recorded at 0730 and 1430 IST during different stages of Bt cotton hybrid as influenced by sowing time, row orientation and plant spacings (*Kharif* 2018 at Faridkot)

TABLE 2

Seed cotton yield as affected by sowing time, row orientations and plant spacings during *Kharif* 2018 at study locations of Bathinda and Faridkot

Treatments	Bathinda		Faridkot	
	Seed cotton yield (kg ha^{-1})	Ginning (%)	Seed cotton yield (kg ha^{-1})	Ginning (%)
Dates of sowing				
April 30	3,203	33.0	3370	38.1
May 15	3,010	32.8	2929	37.8
May 30	2,487	32.1	2673	37.1
CD (5%)	84.01	0.64	109.17	0.49
Row orientations				
North-South	2,762	32.3	2896	37.1
East-West	3,038	33.0	3085	37.6
CD (5%)	71.85	NS	89.14	NS
Plant spacing (cm)				
67.5 × 45	2,807	32.5	2926	37.0
67.5 × 60	2,891	32.3	2985	37.5
67.5 × 75	3,004	33.1	3061	37.5
CD (5%)	81.55	NS	78.34	NS

N- north, S- south, E- east and W- west, NS- non significant

Similarly, morning as well as afternoon soil temperature within all the plant placings was found to be decreased from early growth stages to late reproductive stages, among the study regions (Figs. 1&2). Also, it was noticed that soil temperature increased with increase in plant spacing during different phenological stages of crop due to proper interception of solar radiations on earth surface with widely spaced crop followed by high density plantation which led to high soil temperature. Siddiqui *et al*. (2007) found that seed cotton yield was significantly affected by plant spacing and varieties. Better aeration as well as proper light distribution under widely spaced crop (67.5 cm × 75.0 cm) resulted higher seed cotton yield along-with higher value of ginning per cent at both the study regions (Table 2 and Figs. 1&2). Saleem *et al*. (2009) also reported that the cultivars as well as row spacing significantly affected almost all the characters of cotton and found highest seed cotton yield (2603 kg ha^{-1}) with 75 cm row spacing.

3.2. *Within-canopy temperature*

Among sowing environments, row orientations as well as plant spacings, the range of morning (0730 IST) and afternoon hours (1430 IST) within-canopy temperature was observed in the range between 15.5-28.8 and 28.0-42.3 °C at Bathinda (Fig. 3) and between 15.0-30.2 °C and 30.2-42.2 °C at Faridkot (Fig. 4), respectively. The study revealed that morning and afternoon within-canopy temperature differed significantly under different sowing dates during all the phenophases of crop, but among row orientation as well plant spacing it was found non-significant upto 30 DAS at both the research farms.

Similarly, like soil temperature, higher value of within-canopy temperature was also recorded from sowing to 15 DAS and also at flowering stage of the crop and thus reduced the growing phase and seed cotton yield with delayed sowing at both the experimental sites. Due to lesser crop canopy acreage in early period of the crop, negligible variations were found in within-canopy temperature between row orientations and plant placings at both the study regions (Figs. 3&4).

Within-canopy temperature recorded during morning and afternoon hours was found to be more under E-W direction than N-S direction in almost all the phenological

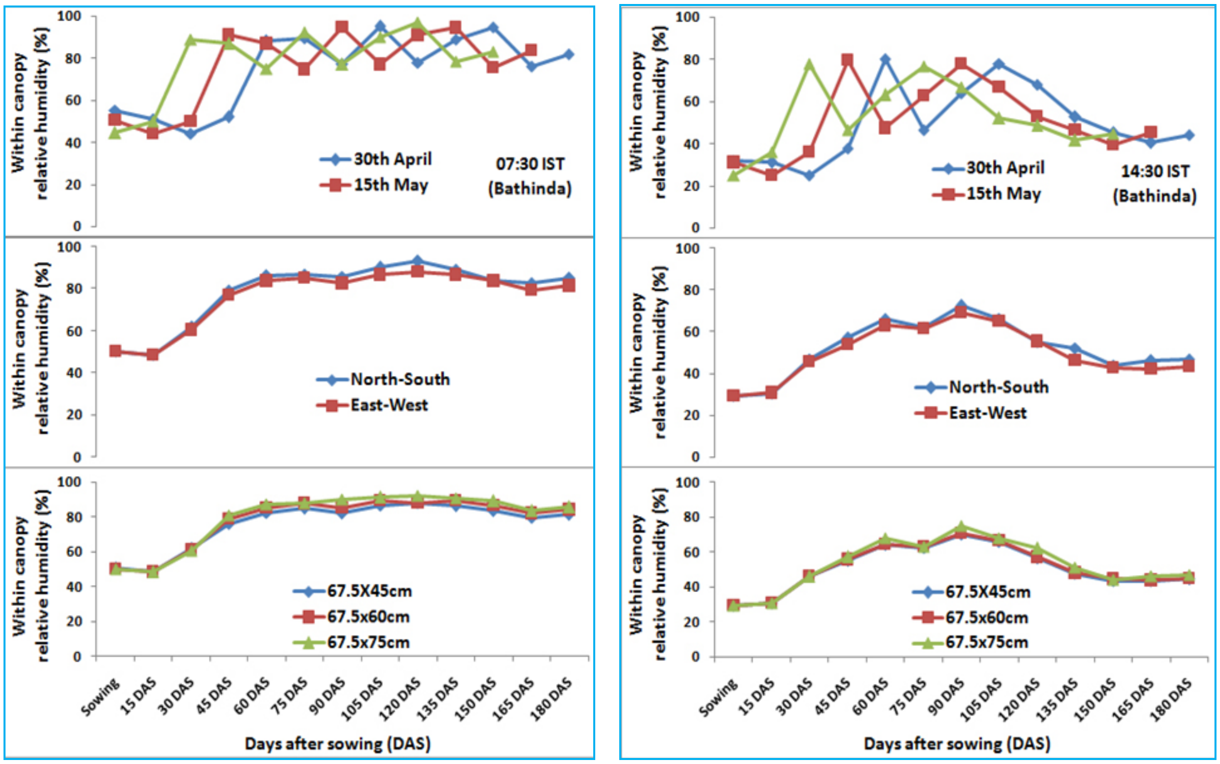

Fig. 5. Within-canopy relative humidity recorded at 0730 and 1430 IST during different stages of Bt cotton hybrid as influenced by sowing time, row orientation and plant spacings (*Kharif* 2018 at Bathinda)

stages and study locations (Figs. 3&4). Also, within-canopy temperatures recorded during morning (0730 IST) and afternoon hours (1430 IST) were found to be decreased with increase in plant spacing. Moreover, decreasing trend in within-canopy temperature was observed from 105 DAS to maturation stage. Almost in all the treatments, highest within-canopy temperature were recorded during 15 DAS and lowest was recorded during 165 DAS because of more canopy coverage; less penetration of sun rays during late growth stages took place (Figs. 3&4).

At the study location of Faridkot, higher value of within-canopy temperature recorded at 1430 IST hours along with minimum value of within-canopy relative humidity almost throughout the crop season provided good microclimatic conditions for the crop. These conditions protected the crop for lesser infestation of disease and insect-pest and resulted higher seed cotton yield (Table 2 and Fig. 4). The similar trend was observed at the location of Bathinda (Table 2 and Fig. 3). The results are in line with results on temperature profiles by Singh (2005) in cotton crop. Throughout the crop season, higher value of within-canopy temperature was possessed at 1430 IST hours followed by 0730 IST hours in both the experiments.

3.3. *Within-canopy relative humidity*

The effect of dates of sowing, row orientations and plant spacings on within-canopy relative humidity (RH) recorded throughout the crop season is depicted in Figs. 5&6. Among all dates of sowing, row orientation and plant spacing, the range of morning (0730 IST) and afternoon (1430 IST) within-canopy RH was observed in the range between 44-93 and 25-80% at Bathinda (Fig. 5) and between 43-95 and 24-81% at Faridkot (Fig. 6), respectively. It is also observed that the sowing dates had significant effect on morning and afternoon within-canopy RH whereas row orientation as well as plant spacing had non-significant effect during whole crop lifecycle.

Higher the value of within-canopy RH with delayed sowing specially during square formation to boll formation stage, higher is the incidence of insect-pest and disease of cotton which resulted lesser seed cotton yield along-with lower value of ginning per cent with delayed sowing at both the locations (Table 2 and Figs. 5&6). Kataria and Pal, 2014; Babuta *et al.*, 2016 also reported that higher humidity during maximum vegetative period especially during flowering supports higher infestation of cotton insect-pest. Within-canopy relative humidity was

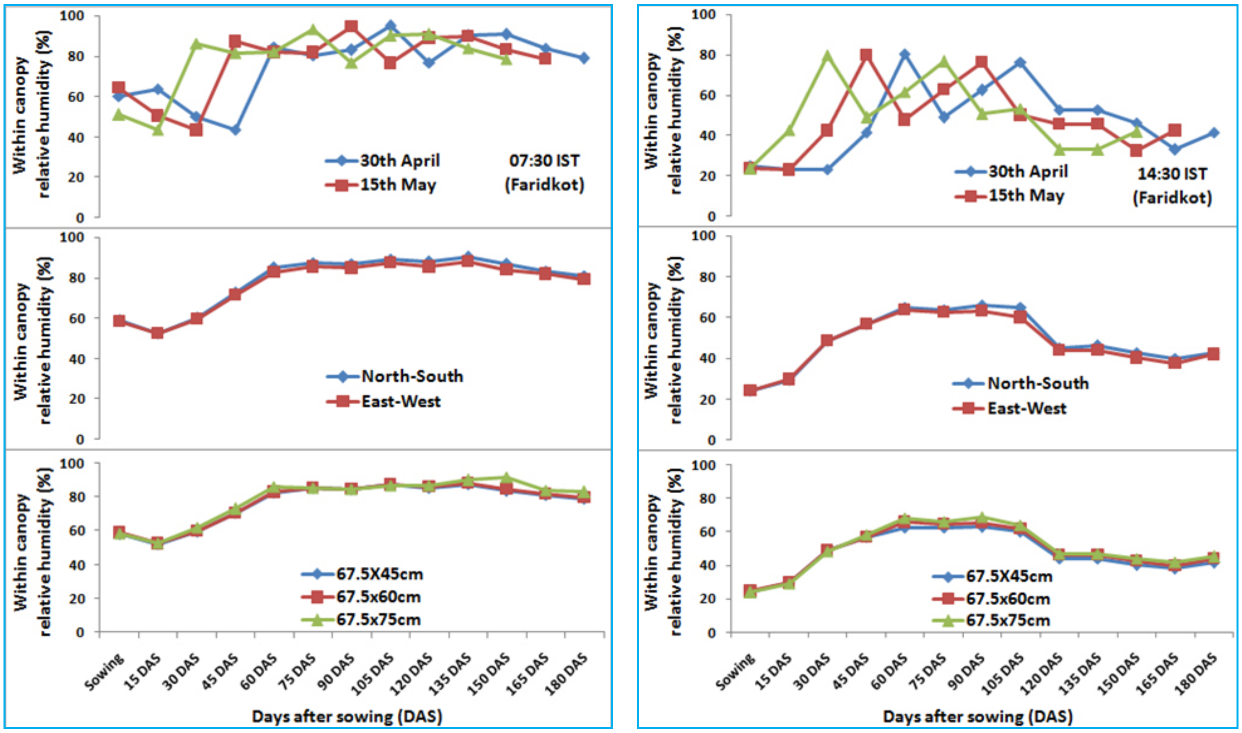

Fig. 6. Within-canopy relative humidity recorded at 0730 and 1430 IST during different stages of Bt cotton hybrid as influenced by sowing time, row orientation and plant spacings (Kharif 2018 at Faridkot)

found lesser during early growth stages upto 60 DAS and then humidity got increased and found to be higher between peak of vegetation to maturity stage at Bathinda and Faridkot (Figs. 5&6).

Within-canopy relative humidity recorded during morning and afternoon hours was found to be slightly less under E-W direction than that of under N-S direction in almost all the phenological stages at both the study locations. Among row orientations, the value of within-canopy RH was found to be decreased from sowing up to 15 DAS, while the value increased thereafter till 120 DAS of the crop at study location of Bathinda (Fig. 5), almost similar trends was also observed for Faridkot region (Fig. 6).

The value of morning and afternoon within-canopy RH was found to be decreased with increase in plant spacing at both the locations. Among all the treatments, highest within-canopy relative humidity were observed during mid growth stages (90 DAS-120 DAS) and lowest was observed during early growth stages (0 DAS-45 DAS). Within-canopy RH values during mid growth stages were high because crop attained almost its full growth and canopy cover which leads to pass less air and less sun rays within-canopy. Singh (2005) in cotton, Bose (2008) in pearl millet and Khichar and Niwas (2006) in wheat found similar results for within-canopy relative humidity. Very less variation was observed among row orientation and plant spacing at early stages of the crop from sowing to 30 DAS due to negligible canopy cover at both sites (Figs. 5&6).

3.4. *Seed cotton yield and ginning per cent as influenced by microclimatic modifications*

The effect of microclimatic conditions on *Bt* cotton hybrid and ginning per cent in response to different sowing environment, row orientation and plant spacing is shown in Table 2. Among the treatments, cotton yield was found in the range between 2487-3203 kg ha^{-1} for Bathinda and 2673-3370 kg ha^{-1} for Faridkot, respectively. Significantly higher seed cotton yield was recorded with crop sown on April 30th (3203 and 3370 kg ha^{-1}) along-with East-West row orientation (3038 and 3085 kg ha^{-1}) and 67.5 cm × 75 cm plant spacing (3004 and 3061 kg ha^{-1}) cotton crop for Bathinda and Faridkot respectively as explained in Table 2**.** Rajkumar and Gurumurthy (2008) also observed more seed cotton yield in wider rows than closer spacing due to optimum space available for growth and development of crop.

Results also revealed that, seed cotton yield was found reduced by 6.0% for Bathinda and 13.1% for

Faridkot due to delayed sowing by 15 days from April 30 to May 15. Similarly, seed cotton yield declined by 17.4% for Bathinda and 8.7% for Faridkot with further delayed sowing from May 15 to May 30. Moreover, delay in planting time of one month from April 30 to May 30, caused reduction in seed cotton yield by 22.36% and 20.37% at Bathinda and Faridkot, respectively (Table 2). Buttar *et al.* (2005) also observed higher yield in early sown crop (April 24) because of higher number of sympods/plant, boll size and number of bolls. Similarly, Kumar *et al.* (2014) also found the reduction in yield by 25.9% for June 6 sowing as compared to April 20 sown crop. Pal *et al.*, 2016; Pal and Yadav, 2018; Pal, 2018 also found similar result of reduction in seed cotton yield with delayed sowing.

Ginning outturn, being an important quality character which determines the price of cotton in the market, varied from 32-33.1% and 37-38.1% at Bathinda and Faridkot, respectively and found significantly higher value with early sowing (30th April) at both the locations. While, non-significantly higher value of ginning % was found with East-West row oriented and widely spaced (67.5 cm × 75 cm) cotton crop at both the study regions (Table 2).

4. Conclusions

The study showed that the crop microclimate provides valuable information about the interaction of the crop and its environment. Micrometeorological observations *i.e.*, soil temperature and within-canopy temperatures as well as within-canopy relative humidity recorded in morning (0730 IST) and afternoon hours (1430 IST) showed significance variations among different sowing dates at both the study locations. Moreover, not significant difference was observed among row orientations and plant spacings due to very less variation especially in early and later stages of the crop. On the other hand, among microclimatic parameters, higher variation was observed between sowing dates, while lesser variation was recorded among row orientations and plant spacings. Hence, early sowing of the crop before 15th May onwards with East-West row orientation and wider plant spacing (67.5 cm × 75 cm) could be an important agricultural practice to augment cotton productivity besides improving microclimatic conditions.

Disclaimer

The contents and views expressed in this research paper are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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