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Effect of Sowing Time and Plant Spacing on Microclimate Profile, iPAR and Yield in *Bt* Cotton

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ABSTRACT

Plants' microclimate has a crucial role to play in regulating and affecting their physiological reactions as well as their energy exchange activities. In this context, field experiment was laid out at Research Farm, Department of Agricultural Meteorology, CCS HAU, Hisar, during the *kharif* season 2020 with *Bt* cotton hybrid RCH 773 BGII and sown at three times and three plant spacing's in split plot design and replicated by three times. The results revealed that the at 0800 hrs in morning an inverse trend (i.e. increase in temperature with height inside the crop canopy) of temperature profiles was observed while during 1800 hrs in evening temperature profiles were found to be lapse in nature (i.e. temperature decrement with height in the crop canopy). Temperature profiles during noon hrs (1400 hrs) remained to be isothermal (i.e. almost same temperature with height in the crop canopy). Late sown crop on 28th May (D_3) and wider spacing 100 × 60 cm resulted in high diurnal range of temperature as compared to early sown (19th April and 8th May) and narrow spaced cotton crop (100 × 45 cm and 67.5 × 60 cm) which reduced the crop growing period and resulted the seed cotton yield to be declined with delayed sowing and opposite trend was found in case of relative humidity. Accumulated intercepted photosynthetically active radiation (IPAR) increased with crop growth with its peak value at 135 DAS in all the treatments during the entire growing period and found maximum in early sown 19th April and narrow spaced 67.5 x 60 cm *Bt* cotton crop.

Keywords Temperature and relative humidity profiles, PAR interception, *Bt* cotton hybrid, Microclimate modifications.

INTRODUCTION

India's main cash crop and source of fiber is cotton

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(*Gossypium hirsutum* L.), which is crucial to the country's agricultural economy's modernization. Indian farmers focused heavily on cotton, and they successfully adapted to it. However, as cotton became the primary raw material for cotton textiles during the first half of the Industrial Revolution, several agronomic changes had an impact on the ecology and economics of cotton production in India. Cotton is grown in India in three distinct agro-ecological zones viz., north zone (Punjab, Haryana, Rajasthan and Western Uttar Pradesh), central zone (Gujarat, Madhya Pradesh, Maharashtra and Orissa) and south zone (Karnataka, Andhra Pradesh and Tamil Nadu). The northern zone is totally irrigated, while the percentage of irrigated area in the central and southern zones is much lower, the lowest being in the central zone which has nearly 60% of cotton area. It is also grown in small area in the eastern region in Sundarbans of West Bengal and in north-eastern states (Anonymous 2011). Cotton is a major cash crop of Haryana State in *kharif* season. The cotton production in Haryana increased from 4 lakh bales to 5 lakh bales (2018-19) compared to last year (Anonymous 2019).

The meteorological parameters i.e. temperature, precipitation, solar radiation, relative humidity, wind speed and soil temperature play an important role in the development and growth of the cotton crop. The solar radiation accounts important factor for photosynthesis processes, influencing carbohydrate distribution and biomass growth in individual plant parts. Crop growth and development are influenced by the quantitative effect of temperature or thermal time. The amount of solar energy absorbed by plant canopies affects the temperature, which controls the rate of biochemical and physiological processes in the plant. Favorable input resource conditions are necessary for efficient utilization of photosynthetically active radiation absorption, which influences crop yield. The amount of dry matter accumulated by a crop is proportional to the amount of radiation intercepted by the plant canopy. Light attenuation is an important aspect that influences the overall photosynthetic rate and the accumulation of biomass of plants, particularly cotton (*Gossypium hirsutum* L.). Light quality and light duration play an important role in the productivity of cotton (Chapepa *et al*. 2020). Sankaranarayanan *et al*. (2020) reported that at higher temperature cotton plants lose their reproductive capacity to a greater extent than their ability to produce biomass and face problems of cotton sterility and boll retention. Plant density is an important crop management practice that can optimize canopy light distribution and increase canopy photosynthetic capacity in cotton (Yao *et al*. 2016). Brar *et al*. (2015) reported that the higher plant density was observed in 67.5 cm x 45 cm gave higher yield in cotton. The number of bolls in upper nodes and distal fruiting positions, the number of seeds per boll, seed area and seed vigour index increased with decreasing plant density (Zhi *et al*. 2016). The important factor influencing crop yield are planting density, geometry and light interception through change in time and extent of crop canopy, thus influencing rate of crop growth (Chapepa *et al*. 2020). Variation in planting density alters the micro and macroclimate in which plants thrive, so it is important to investigate the effects of planting density on yield and growth. Consequently, favorable weather conditions are crucial for Agriculture, but the agricultural production is now risky and challenging due to weather event variations. In this situation, it's important to control the negative effects of bad weather on crop output to preserve food security without compromising resources in nature.

Adaptation measures must be developed in order to reduce the negative effects of weather on cotton. Microclimatic changes can be a useful adaptation method in this case. Microclimate manipulation involves artificially maintaining the ideal conditions for optimal crop growth, development, and production. Changes in sowing practies, including as timing, spacing as well as the use of suitable cropping systems, can modify the microclimate. 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 (Sharma *et al*. 2018). This research was done to determine how varying sowing conditions and plant spacings affected cotton's reaction to microclimate.

MATERIALS AND METHODS

Study locations and climatic conditions

The study was conducted at Research Farm, Department of Agricultural Meteorology, CCS HAU, Hisar, during the *kharif* season 2020, the experimental site situated in the sub-tropics at longitude 75º 46' E, latitude 29º 10' N with an altitude of 215.2 meters above mean sea level. Hisar region's arid subtropical monsoonal climate is due to its continental location on the outer margins of monsoon region, which is nearly 1600 km away from the ocean. In the summer, rain is brought by the south westerly monsoon current from the first week of July to the middle of September, Apart from few light showers caused by western disturbances, the weather remains extremely dry from October to the end of June. During the south-west monsoon season, approximately 80% of the annual precipitation is received. Summers are extremely hot (maximum temperatures of upto 45 ºC have been recorded, sometimes even higher), while winters are relatively cold (minimum temperatures of 1 to 2 ºC, or even less, have been recorded). In the months of December and January, the minimum temperature can occasionally fall below 0 degrees Celsius. The average annual rainfall is 460 mm.

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: 2nd fortnight of April (April 19), D_2: 1st fortnight of May (May 8) and D_3: 2nd fortnight of May (May 28) and three plant spacing's (S_1: 67.5 x 60 cm, S_2: 100 x 45cm and S_3: 100 x 60 cm) at Research Farm, Department of Agricultural Meteorology, CCS HAU, Hisar, during *kharif* 2020. 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 (Fig. 1).

Observation recorded

Agrometeorological observations

For recording micrometeorological observations, following methods were adopted: Temperature and relative humidity profiles were measured at 08:00 AM, 14:00 PM and 18:00 PM at three levels of crop canopy: Top, middle, and bottom using a Assmann Psychrometer at 30 days interval beginning 45 days after crop sowing.

Photosynthetically active radiation (PAR) was recorded with a line quantum sensor at 30 days intervals beginning 45 days after crop sowing.

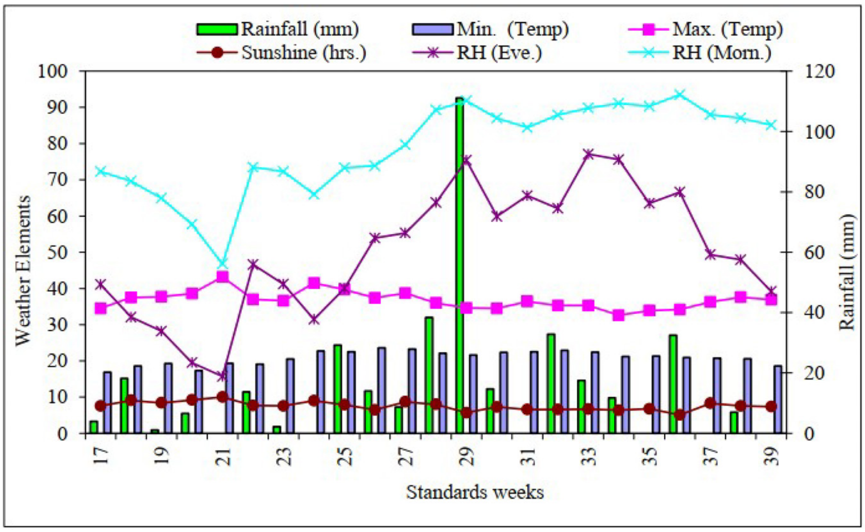


Fig.1. Mean weekly meteorological data during crop season (2020).

The seed cotton yield

The seed cotton was picked from 1 × 1 m^2 area from each plot and the yield was calculated on a net plot area basis.

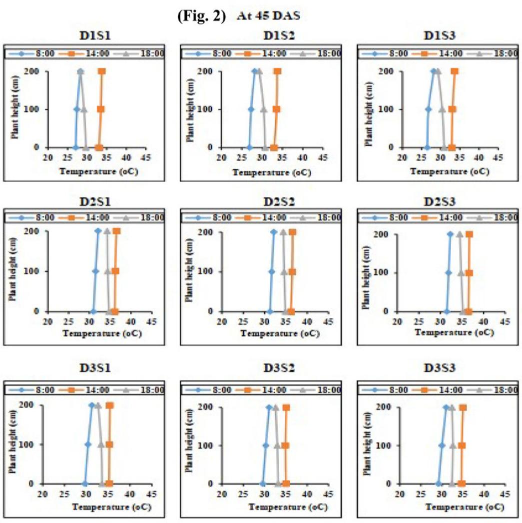
RESULTS AND DISCUSSION

Temperature profiles

Air temperature with diurnal profiles at 30 days interval after 45 days of sowing of *Bt* cotton under different growing environments have been presented in Figs. 2 - 5. Minimum temperature was recorded during 0800 hrs while maximum temperature was recorded at 1400 hrs under all growing environments throughout the crop season 2020. Temperature profiles at 0800 hrs were inverse in nature while at 1800 hrs temperature profiles were lapse in nature while during noon i.e. at 1400 hrs the profiles were nearly isothermal. Diurnal ranges of temperature were higher in crop sown on 28th May (D_3) as compared to crops grown on 8th May (D_2) and 19th April (D_1). In case of spacing the diurnal range of temperature profile was maximum in 100 cm × 60 cm as compared to spacing 100 cm × 45 cm and 67.5 cm × 60 cm. This might be due more and deeper radiation penetration inside the crop canopy in late sown and wider spaced cotton crop. The results are in tune with the work by kalia (2019).

Relative humidity profile

Relative humidity profiles were observed at 30 days interval after 45 days of sowing of *Bt* cotton under different environments during the kharif season 2020 have been presented in Figs. 6 - 9. The humidity profiles were lapse in nature inside the crop canopy among all treatments. The humidity decrease rate with height was less at 0800 hrs in comparison to other recorded hours of the day. The humidity diurnal profiles range were maximum in 28th (D_3) May sown crop as compared to 19th April (D_1) and 8th May (D_2). In case of spacing, the diurnal profiles range of humidity were maximum in (100 cm × 60 cm) as compared to (67.5 cm × 60 cm) and (100 cm × 45 cm). This might be due to late sown and wider spaced crop don‟t have uniform humidity condition in the crop canopy due



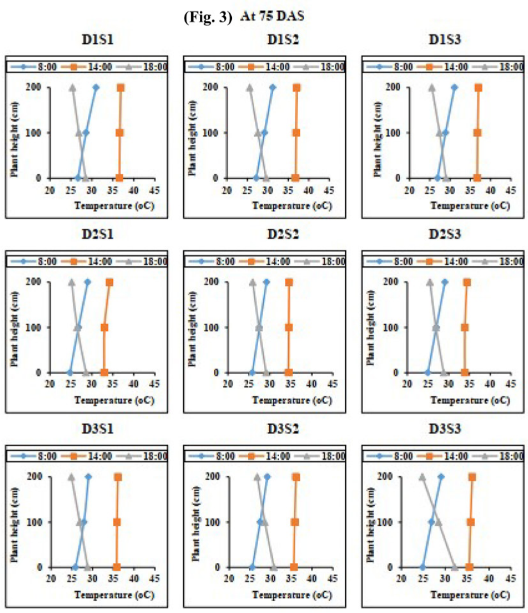
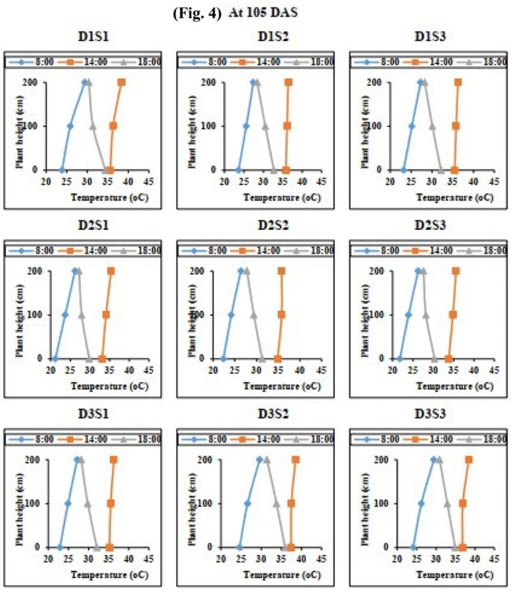


Fig. 2. Diurnal profiles of temperature in *Bt* cotton at 45 days after sowing under different growing environments. **Fig. 3.** Diurnal profiles of temperature in *Bt* cotton at 75 days after sowing under different growing environments.



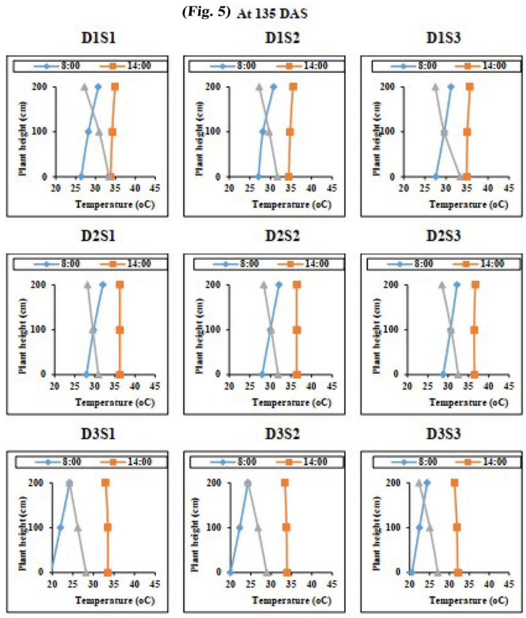
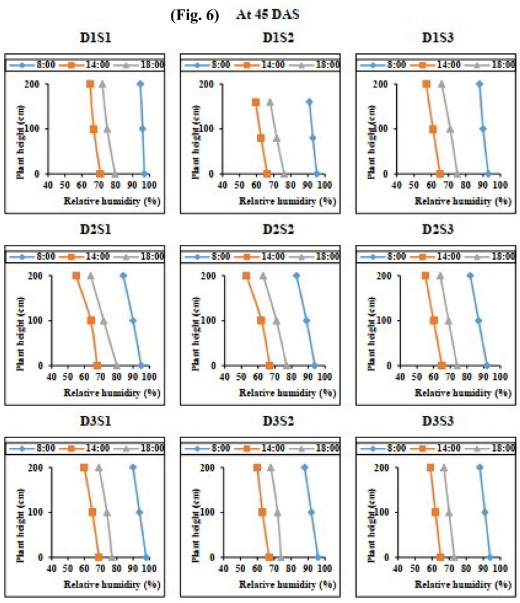


Fig. 4. Diurnal profiles of temperature in *Bt* cotton at 105 days after sowing under different growing environments. **Fig. 5.** Diurnal profiles of temperature in *Bt* cotton at 135 days after sowing under different growing environments.

to less leaf area index and moisture escapes easily. The results are in tune with the work by Kalia (2019).

Cumulative intercepted photosynthetically active radiation (PAR)



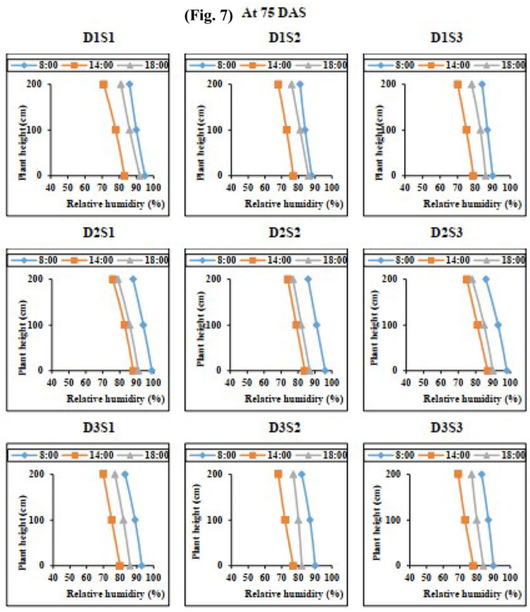
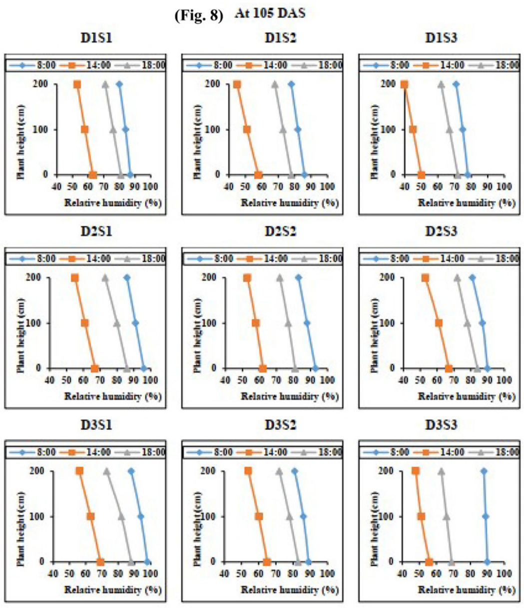


Fig. 6. Diurnal profiles of relative humidity in *Bt* cotton at 45 days after sowing under different growing environments. **Fig. 7.** Diurnal profiles of relative humidity in *Bt* cotton at 75 days after sowing under different growing environments.



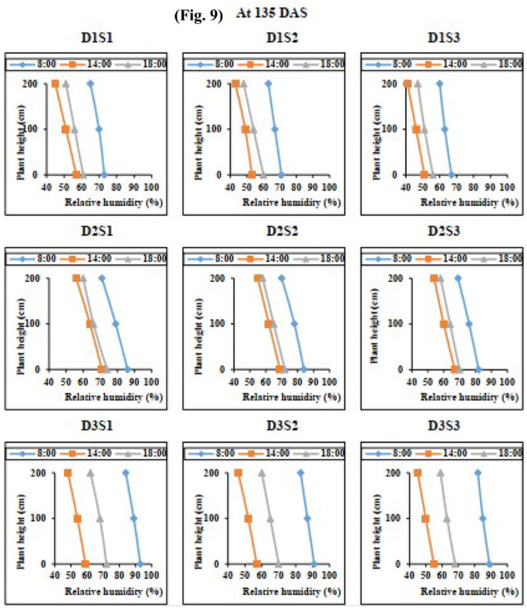


Fig. 8. Diurnal profiles of relative humidity in *Bt* cotton at 105 days after sowing under different growing environments. **Fig. 9**. Diurnal profiles of relative humidity in *Bt* cotton at 135 days after sowing under different growing environments.

The value of cumulative IPAR was found to be maximum in first date of sowing 19th April (D_1) followed by 8th May (D_2) and 28th May (D_3) and their values at 135 DAS were 893.9 MJ/m^2, 794.9 MJ/m^2, and 673.7 MJ/m^2 respectively. While in case of spacing, iPAR was observed to be maximum in 67.5 cm × 60 cm, followed by 100 cm × 45 cm and 100 cm × 60 cm, whose values were 841.3 MJ/m^2, 774.9 MJ/m^2 and 746.3 MJ/m^2, respectively (Fig. 10). Similar results have been reported by Singh (2016), Kaur *et al*. (2014) due to more leaf area index more interception of PAR.

Seed cotton yield (kg/ha) as influenced by microclimatic modifications

Data recorded for seed cotton yield (kg/ha) in *Bt* cotton under different treatments have been shown in Fig. 11. The data showed that *Bt* cotton sown on 19th April (D_1) achieved maximum seed cotton yield (3057 kg/ha) followed by 2268 kg/ha with 8th May (D_2) and 1853 kg/ha with 28th May (D_3) sown crops. *Bt* cotton with spacing 67.5 cm x 60 cm produced more seed cotton yield (2657 kg/ha) as compared to 100 cm x 45 cm (2432 kg/ha) and 100 cm x 60

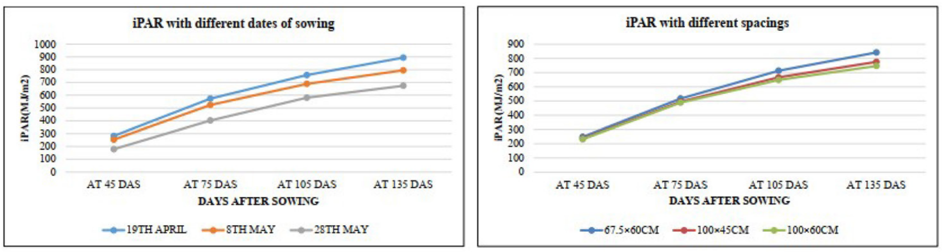


Fig. 10. Cumulative intercepted photosynthetically active radiation of *Bt* cotton at various crop growth intervals under different growing environments.

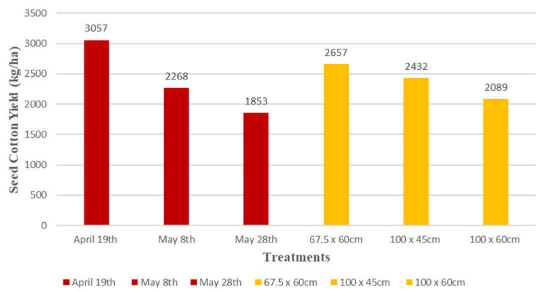


Fig. 11. Seed Cotton Yield under different growing environments.

cm (2089 kg/ha). The yield decreased with planting delay and were found to be higher in crop planted on April 19th (D_3), which could be due to crop planted on April 19th having higher radiation absorption and better energy efficiency than other planting dates. Swami *et al.* (2016) and Dhir *et al*. (2020) similarly discovered that late sown crops shows very poor growth. Among different spacing, yield was more in narrow spacing of 67.5 cm x 60 cm as compared to other wider spacing. It might be due to more LAI and PAR absorption per unit area.

CONCLUSION

The study reveals that the crop microclimate offers important insights about how a crop interacts with its surroundings. Within canopy temperature at 0800 hrs in morning an inverse trend (i.e. increase in temperature with height inside the crop canopy) of temperature profiles was observed while during 1800 hrs in evening temperature profiles were found to be lapse in nature (i.e. temperature decrement with height in the crop canopy). Temperature profiles during noon hours (1400 hrs) remained to be isothermal (i.e. almost same temperature with height in the crop canopy) and opposite trend was found in case of relative humidity. Late sown crop on 28th May (D_3) and wider spacing 100 × 60 cm resulted in high diurnal range of temperature as compared to early sown (19th April and 8th May) and narrow spaced cotton crop (100 × 45 cm and 67.5 × 60 cm) which reduced the crop growing period and resulted the seed cotton yield to be declined with delayed sowing. Accumulated intercepted photosynthetically active radiation (IPAR) increased with crop growth with its peak value at 135 DAS in all the treatments during the entire growing period and found maximum in early sown 19th April and narrow spaced 67.5 x 60 cm *Bt* cotton crop. Consequently, early crop planting before May 8th and wider plant spacing (100 × 60 cm) may be crucial agricultural practices to increase seed cotton yield while also enhancing microclimates.

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