International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 3412-3419, 2023; Article no.IJECC.109089
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Agro-Climatic Indices, Plant Growth and Yield of *Bt* Cotton as Influenced by Planting Time and Spacing

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113515

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/109089

Original Research Article

Received: 12/09/2023
Accepted: 16/11/2023
Published: 20/11/2023

ABSTRACT

A field experiment was conducted in *kharif* season 2020 to study the effect of sowing time and row spacing on growth, yield and agro-climatic indices of Cotton at Research Farm, Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar. The experiment was performed in split-plot design and replicated thrice. The experiment included nine treatment combinations with three sowing dates and row spacings. Among different sowing times, cotton sown on 19th April had significantly higher plant height (176.3 cm), dry matter accumulation (453.39 g plant^{-1}), LAI (1.92), GDD (Growing Degree Days), HTU (Heliothermal Units), PTU (Photothermal Units) and seed cotton yield (3057 kg ha^{-1}) in comparison to sowing in May *i.e.* May 8th and May 28th. Among various row spacings, cotton planted with a row spacing of 67.5 cm x 60 cm produced significantly higher seed cotton (2657 kg ha^{-1}) and plant height (156.40 cm), although growth parameters *i.e.* LAI (2.26) and dry matter accumulation (397.92 g plant^{-1}) alongwith Agro-climatic indices (GDD, HTU, PTU) were observed to be greater with a row spacing of 100 x 60 cm.

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Keywords: Sowing time and spacing; leaf area index; seed cotton yield; agro-climatic indices; GDD; HTU; PTU.

1. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is an important cash crop and fibre crop in India. It is also an important part of the country's agricultural economy. Cotton, which is also called "White Gold," is the most important cash crop in India. It gives 65% of the cotton fibre that India's cotton textile companies need as their main raw material. Cotton occupies a preeminent position among cash crops, as it determines the fate of a sizable portion of the agricultural community as well as thriving textile industries, thanks to a favourable climate for cotton cultivation across the nation and improved technologies from the public and private sectors. At the time of a nation's independence, cotton was the primary basic material on which textile mills relied heavily on imports. Cotton is grown in about 60 countries around the world, but about 85% of the world's cotton comes from just 10 countries: Russia, the United States, China, India, Brazil, Pakistan, Turkey, Egypt, Mexico, and Sudan. It is grown on an area of about 32.9 million hectares, and 41.1 million tonnes of seed cotton are made from it. India is one of the world's biggest cotton producers. It has the most cotton fields and is also the second largest cotton user. Before the Government of India started the "Technology Mission on Cotton" in February 2000, the productivity of cotton was very low. However, significant progress has been made in increasing productivity and yield through the development of high-yielding varieties, better farm management, good weather, and an increase in the area where Bt cotton is grown. Haryana's cotton production might benefit greatly by adopting cutting-edge technology and putting it into timely operation, as it has in neighbouring states Punjab and Gujarat.

The management of planting dates has a significant impact not only on crop growth, development, and yield, but also on insect nuisance control. In recent years, reduced season management, in which early planting plays a key role, has become increasingly significant.

With increased late-season insect pressures, the ability to plant and establish a crop early, carry it through the primary fruiting cycle in a timely and efficient fashion, and then terminate it early has become increasingly important. This approach to earliness management has also been crucial in avoiding the adverse weather conditions typically associated with the summer monsoon season, which creates higher humidity (higher dew point temperatures) and higher night temperatures, resulting in accelerated rates of fruit loss and abortion [1]. According to Bozbek et al. [2], the optimal sowing date for a cultivar in a region is the most essential manageable factor in cotton crop. Drought conditions during the flowering and boll development stages (August to September) have a negative impact on the development and subsequent shedding of reproductive organs, resulting in a low crop yield. Early sowing appears to have a greater yield potential, whereas late planting of cotton crop appears to be very vegetative and difficult to manage, resulting in a lower seed cotton yield [3]. Due to numerous biotic and abiotic stresses, such as weed infestation, insect pests and diseases, sowing too early or too late, nutrient stress, and improper use of genotypes in different agro-ecological zones, it was previously impossible to obtain a high cotton yield [4,5]. The optimal fertilisation date plays a crucial role in yield potential; similarly, the optimal row spacing for a given region is necessary for optimal growth and development.

Deho et al. [6] noted that sowing date and row spacing management are significant factors that can have a substantial effect on the yield and qualitative characteristics of a cotton crop.

The number of days from planting to physiological maturity varies because of fluctuations in daily minimum and maximum temperatures from year to year and between sites. GDD, PTU, and HTU meteorological indicators based on air temperature are employed to explain changes in phenological behavior and growth characteristics [7]. According to the heat unit idea, a direct and linear link between growth and temperature is advantageous for predicting a crop's output potential under diverse weather circumstances [8]. Sowing date changes have a direct impact on crop growth and development [9]. Temperature-based agrometeorological indicators provide an excellent forecast for crop development and yield. Using an accumulated heat unit approach, the effect of temperature on crop phenology and yield may be investigated in the field [10]. As a result, the current study was carried out on the heat unit requirements, plant growth and yield of

Bt cotton hybrid (RCH 773) as influenced by sowing time and spacing.

2. MATERIALS AND METHODS

During the *kharif* season of 2020, the experiment was conducted at Research Farm, Department of Agricultural Meteorology, CCS HAU, Hisar, located in the subtropics at $75^0 46'$ E, $29^0 10'$ N, and 215.2 metres above mean sea level. The experiment was designed with a split-plot layout and replicated thrice. The experiment comprised nine treatment combinations consisting of three sowing dates under three different row spacing. Three replications of the nine treatment combinations were arranged in a split plot design. The cotton crop was planted on the 2nd fortnight of April, 1st fortnight of May and 2nd fortnight of May under 67.5 X 60 cm, 100 X 45 cm and 100 X 67.5 cm row spacings.

The agro-meteorological observatory that is located close to the research area at the Department of Agricultural Meteorology provided the source for the collection of the mean weekly meteorological data from the 17th to the 40th (standard meteorological weeks) during the *kharif* season of 2020 (April to October) (Fig. 1). The minimum weekly temperature ranged from 9.8℃ to 28.3℃, and the maximum weekly temperature range was from 29.7℃ to 43.2℃. The weekly morning and evening relative humidity ranges varied from 46.8% to 93.5% and 15.7% to 77.1%, respectively. The total amount of rainfall that was received was 363.4 mm.

After seed treatment with imidachloprid, clean cotton seed of the hybrid variety RCH 773 was utilised for manual dibbling at a depth of 4-5 cm as per the treatments. The crop was raised according to the standard package and practices of CCS HAU, Hisar.

To calculate plant height (cm) three plants were selected randomly from each plot and average was taken as plant height at different intervals. Three plants selected randomly from each plot were cut at soil surface and dried in shade for 2-3 days. After sun drying these were transferred to oven and dried at 65 ℃ until a constant weight was achieved. Average was presented as dry matter accumulation per plant. Leaves were separated from plants collected for dry matter accumulation and leave area was measured using a leaf area metre (LI-3000C Area metre, LI-COR Biosciences, Nebraska, USA. Three plants were selected randomly from each plot and tagged for yield attributes and average was taken. The seed cotton was picked from net plot area of 1 X 1 m^2 and presented as kg ha^{-1}.

The leaf area measured with the help of leaf area meter was used to compute the leaf area index by the following formula:

LAI = Leaf area (cm^2) / Land area covered by plant (cm^2)

The cumulative growing degree days were computed by adding the daily mean temperature above the basal temperature and are denoted in ^{0}C day. This was computed using the formula shown below:

$$\text{GDD } (^oC \text{ day}) = \sum \frac{\text{Tmax-Tmin}}{2} - T_b$$

Where,

T_{max}. = Daily maximum temperature (°C)
T_{min}. = Daily minimum temperature (°C)
T_b = Base temperature (10°C, WMO, 1996)

Photothermal units were computed by multiplying the cumulative value of GDD by the altmost possible sunshine hours and are expressed in ^{0}C day hours:

$$\text{PTU } (^\circ C \text{ day hours}) = \sum (\text{GDD} \times \text{N})$$

Where,

N = Maximum possible sunshine hours or day length

Heliothermal units for a day are the product of GDD and actual bright sunshine hours and are expressed in ^{0}C day hours:

$$\text{HTU } (^\circ C \text{ day hours}) = \sum (\text{GDD} \times \text{BSS})$$

Where,

BSS = Bright sunshine hours

The analysis of variance (ANOVA) for the split plot design was calculated using OPSTAT software. At a significance level of 5%, the F-test was used to ascertain the significance of the treatment effects.

3. RESULTS AND DISCUSSION

3.1 Agroclimatic Indices

During the *kharif* season 2020, agrometeorological indices such as GDD, HTU, and PTU were measured in *Bt* cotton grown in various environments. Early sown *i.e.* 19th April, cotton had the maximum number of growing degree days, heliothermal units and photothermal units at maturity followed by crop sown on 8th May and 28th May (Fig. 2). Among different row spacing, GDD, HTU and PTU were highest under row spacing of 100 × 60 cm followed by 100 × 45 cm and 67.5 × 60 cm (Figs. 2, 3 and 4). The reason may be that the previous date of sowing and spacing required a greater number of days to achieve distinct phenophases. Kular and Hundal [11] also discovered that the heat units accumulated by various cotton cultivars were greater in early sown crops than in medium and late sown crops.

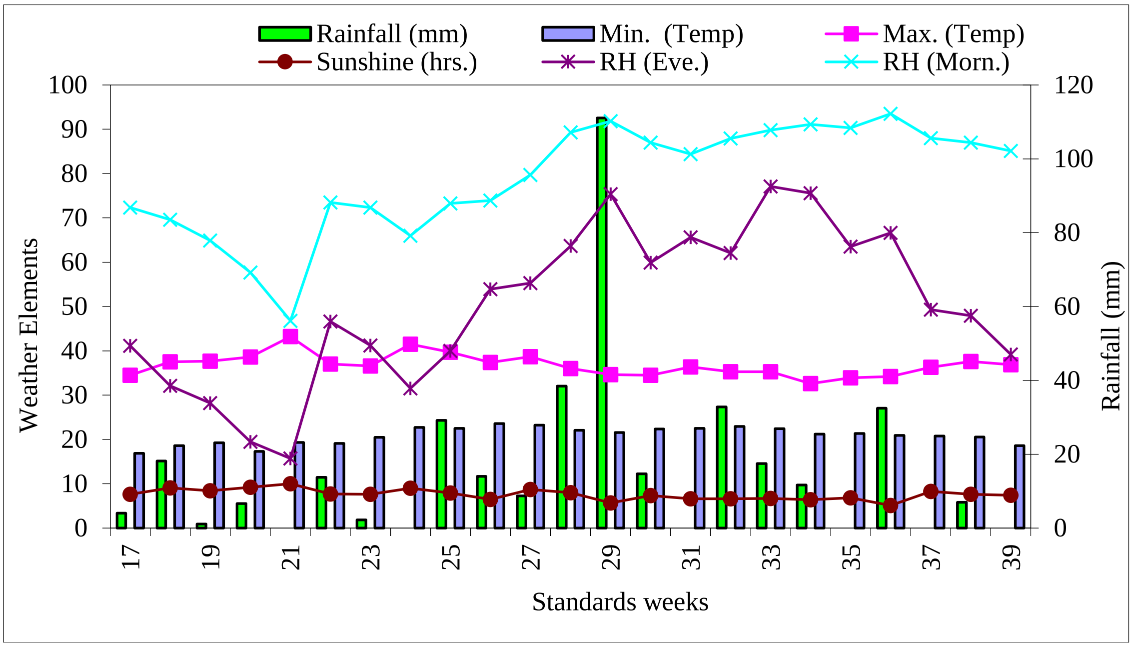

Fig. 1. Mean weekly meteorological data during crop season (2020)

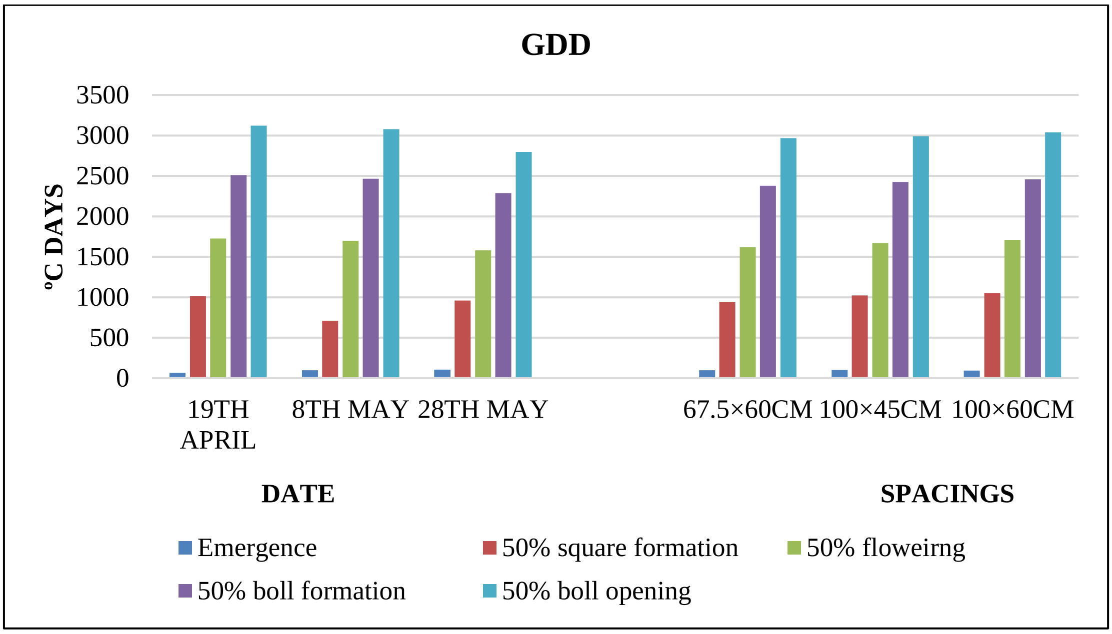

Fig. 2. Effect of treatments on GDD (Growing Degree Days) in *Bt* cotton at various phenophases under different growing environments

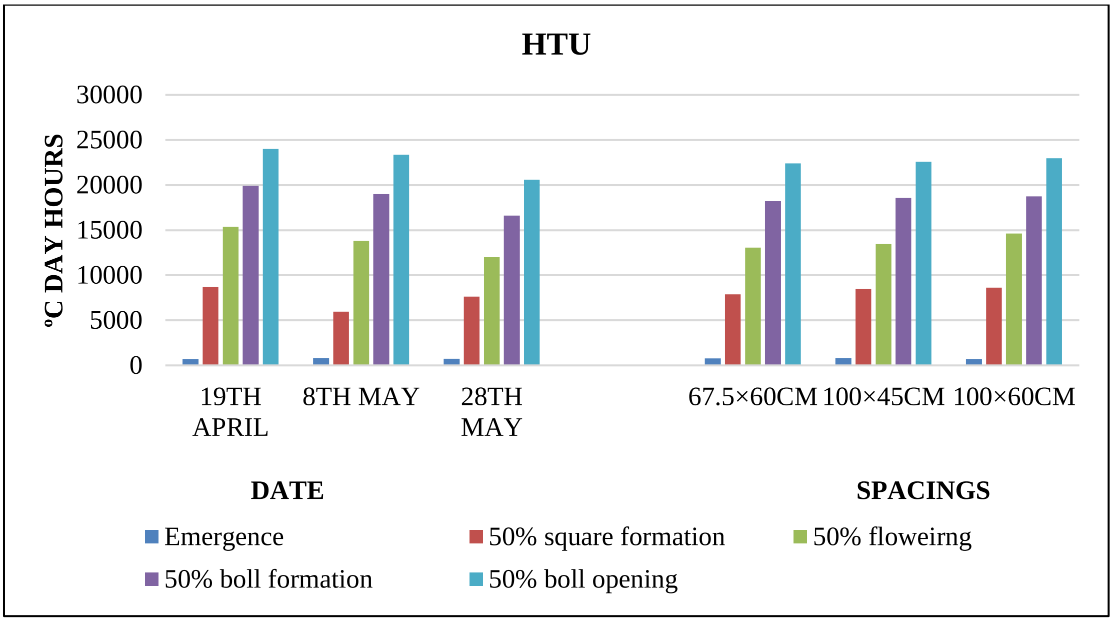

Fig. 3. Effect of treatments on HTU (Heliothermal Units) in *Bt* cotton at various phenophases under different growing environments

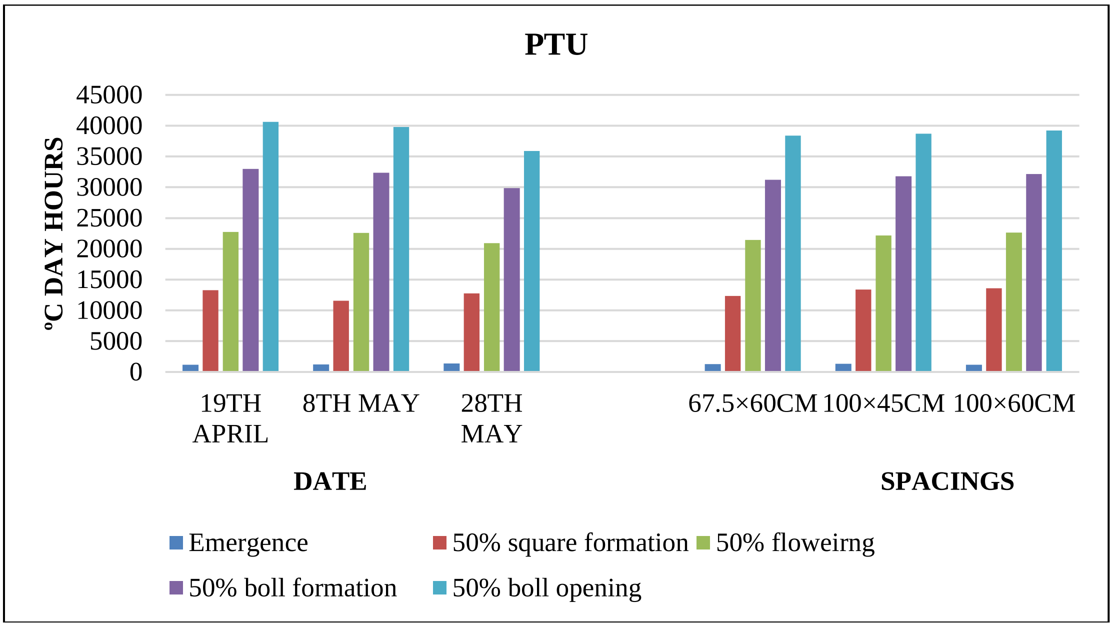

Fig. 4. Effect of treatments on PTU (Photothermal Units) in *Bt* cotton at various phenophases under different growing environments

3.2 Growth Parameters

Among different date of sowing, the crop planted on 19th April had significantly higher plant height, dry matter accumulation and leaf area index as compared to sowing on 8th and 28th May. Among different row spacing, cotton grown under 100 cm x 60 cm spacing had maximum dry matter accumulation and leaf area index while plant height was maximum under 67.5 x 60 cm. It was significantly superior over rest of the row spacing at different intervals (Table 1, Table 2 and Table 3). Early sown cotton had better growth as compared to sowing in May. With delay in sowing significant effect on growth was observed. In early sown cotton, maximum number of days are available for proper growth and development. Wider spacing resulted in maximal plant height, dry matter accumulation per plant and leaf area index as a result of efficient growth, ground area available to each plant and increased light interception by leaves which led to increased photosynthetic activity and better growth of cotton. The highest level of photosynthetically active radiation (PAR) intercepted by the early-sown crop may have contributed to its maximum growth. These findings are in line with Bhalerao et al*.,* [12], Singh et al*.,* [13], Triphati [14], Khamparia and Sisodia [15] and Pouresia and Nabipour [16].

3.3 Yield and its Attributes

Early planting of cotton in 2nd fortnight of April *i.e.* 19th April resulted in significantly greater number of sympodial per plant, number of bolls per plant, boll weight (g) per plant and seed cotton yield in comparison to sowing in May. Row spacing had significantly affected the yield and yield attributes of cotton. Significantly higher yield attributes of cotton were reported under 100 cm x 60 cm row spacing when compared to 100 x 45 cm and 67.5 x 60 cm. However, number of monopodia per plant and seed cotton was higher under 67.5 x 60 cm spacing (Table 4). In comparison to other sowing dates, crops planted on April 19 absorb more radiation and are more energy efficient. Similarly, Swami et al. [17] found that late-planted crops have very weak growth. In comparison to wider spacing, 67.5 cm x 60 cm spacing resulted in a greater crop yield than wider spacing. It may be a result of greater LAI and PAR absorption per unit area. While yield attributes values per plant, number of bolls per plant and number of sympodial branches per plant) were found to be greater in wider spacing (100 X 60 cm) as a result of greater energy efficiency by each plant. These results are in line with Kaur et al*.,* [18], Bhalerao et al., [12] and Singh et al*.,* [13].

Table 1. Effect of treatments on Plant height of *Bt* cotton at various growth intervals under different growing environments

	Plant height (cm)				
Treatments	**45 DAS**	**75 DAS**	**105 DAS**	**135 DAS**	**Harvest**
Dates of sowing					
D_1- 19th April	43.11	91.67	162.11	167.78	173.33
D_2- 8th May	40.28	85.06	151.28	153.28	155.95
D_3- 28nd May	36.54	73.10	126.75	128.43	129.54
SEm ±	**0.74**	**0.45**	**0.59**	**0.67**	**0.66**
CD (P=0.05)	**3.00**	**1.82**	**2.38**	**2.70**	**2.67**
Spacing					
S_1- 67.5cm x 60cm	41.64	84.29	151.61	153.07	156.40
S_2- 100cm x 45cm	39.85	83.98	146.08	149.09	152.31
S_3- 100cm x 60cm	38.44	81.55	143.77	147.33	150.11
SEm ±	**0.61**	**0.47**	**0.55**	**0.82**	**0.63**
CD (P=0.05)	**1.90**	**1.4**	**1.71**	**2.56**	**1.97**

Table 2. Effect of treatments on dry matter (g/plant) of *Bt* cotton at various growth intervals under different growing environments

	Dry matter (g/plant)				
Treatments	**45 DAS**	**75 DAS**	**105 DAS**	**135 DAS**	**Harvest**
Dates of sowing					
D_1- 19th April	16.70	87.66	334.62	433.39	453.39
D_2- 8th May	13.20	66.24	244.25	306.23	317.34
D_3- 28nd May	11.33	56.74	205.92	253.03	260.48
SEm ±	**0.24**	**0.70**	**4.05**	**8.33**	**2.48**
CD (P=0.05)	**0.97**	**2.83**	**16.35**	**33.60**	**10.00**
Spacing					
S_1- 67.5cm x 60cm	12.91	63.94	234.88	293.43	305.09
S_2- 100cm x 45cm	13.75	67.55	252.66	316.20	328.20
S_3- 100cm x 60cm	14.75	79.15	297.26	383.03	397.92
SEm ±	**0.35**	**0.50**	**3.62**	**6.01**	**5.61**
CD (P=0.05)	**1.09**	**1.55**	**11.27**	**18.74**	**17.50**

Table 3. Effect of treatments on Leaf area index of *Bt* cotton at various growth intervals under different growing environments

	Leaf area index				
Treatments	**45 DAS**	**75 DAS**	**105 DAS**	**135 DAS**	**Harvest**
Dates of sowing					
D_1- 19th April	0.42	1.77	3.52	4.68	1.92
D_2- 8th May	0.38	1.66	3.31	4.21	1.75
D_3- 28nd May	0.31	1.28	2.77	3.84	1.51
SEm ±	**0.017**	**0.03**	**0.07**	**0.05**	**0.06**
CD (P=0.05)	**0.06**	**0.12**	**0.30**	**0.20**	**0.24**
Spacing					
S_1- 67.5cm x 60cm	0.30	1.20	2.25	3.17	1.01
S_2- 100cm x 45cm	0.38	1.66	3.54	4.57	1.90
S_3- 100cm x 60cm	0.41	1.85	3.82	5.00	2.26
SEm ±	**0.009**	**0.04**	**0.05**	**0.07**	**0.04**
CD (P=0.05)	**0.02**	**0.12**	**0.18**	**0.21**	**0.13**

Table 4. Effect of treatments on Yield attributes and yield of *Bt* cotton under different growing environments

	Yield attributes and yield				
Treatments	**Number of sympodia per plant**	**Number of monopodia per plant**	**Number of bolls per plant**	**Boll weight (g)**	**Seed cotton yield (kg/ha)**
Dates of sowing					
D_1- 19th April	31.28	2.72	52.78	4.83	3057
D_2- 8th May	29.90	1.76	50.31	4.61	2268
D_3- 28nd May	27.14	1.58	46.39	4.33	1853
SEm ±	**0.55**	**0.05**	**0.74**	**0.15**	**39.53**
CD (P=0.05)	**2.24**	**0.20**	**3.01**	**NS**	**159.37**
Spacing					
S_1- 67.5 cm x 60 cm	27.37	2.47	47.26	4.22	2657
S_2- 100 cm x 45 cm	29.73	2.14	49.52	4.70	2432
S_3- 100 cm x 60 cm	31.21	1.45	52.63	4.84	2089
SEm ±	**0.17**	**0.10**	**0.64**	**0.11**	**15.95**
CD (P=0.05)	**0.55**	**0.32**	**2.01**	**0.35**	**49.71**

4. CONCLUSION

Based on the experiment, it can be concluded that early planting of cotton on 19th April resulted in better growth and yield of cotton in comparison to late planting in May. Cotton grown under row spacing of 67.5 cm x 60 cm had higher seed cotton yield however growth was better under 100 x 45 cm.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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