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Influence of spacing and canopy management on growth parameters of *Bt. cotton* (*Gossypium hirsutum* L.)

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Abstract

A field experiment was conducted at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Dantiwada, Gujarat during the two consecutive *kharif* seasons of the year 2024-25 and 2025-26 on "Influence of spacing and canopy management on growth parameters of *Bt. cotton* (*Gossypium hirsutum* L.)". The soil of the experimental plot was loamy sand in texture, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash status. There were twenty treatment combinations comprising of four spacing treatments viz; S₁: 60 cm × 45 cm, S₂: 90 cm × 45 cm, S₃: 120 cm × 30 cm and S₄: 120 cm × 45 cm and five canopy management practices viz; C₁: Control, C₂: Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS, C₃: Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS, C₄: Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + removal of monopodial branches and C₅: Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + removal of monopodial branches were tested in a split plot design with three replications. Pooled analysis revealed that closer spacing of 60 cm × 45 cm produced higher plant height at 60, 90 DAS as well as at harvest and crop growth rate between 0-30 DAS, 30-60 DAS and 60-90 DAS, whereas 120 cm × 45 cm recorded higher dry matter accumulation at 60 and 90 DAS and relative growth rate between 0-30 DAS and 30-60 DAS. Among the canopy management treatments, control (no spray) recorded significantly higher plant height at 90 DAS and at harvest, dry matter accumulation at 90 DAS, crop growth rate between 60-90 DAS and relative growth rate between 60-90 DAS.

Keywords: *Bt. cotton*, spacing, canopy management, growth parameters, CGR and RGR

Introduction

Cotton is an important cash crop that belongs to the Malvaceae family and originated in Mexico. Cotton (*Gossypium spp.* L.) is one of the predominant fibre crops playing a pivotal role in agriculture, industrial development, employment generation and economy of India. It plays a prominent role in the national economy in terms of both employment generation and foreign exchange earnings. Indian textile industry is the second largest manufacturer and exporter in the world after China. Cotton is called as "King of fiber crops" due to higher economical value among all cash crops in India and also called as "White Gold". It is one of the most momentous and important cash crop exercising profound influences on economic and social affairs of the world as well as India. India ranks first in area and second in production of cotton in the world. All India cotton sowing area for the year 2024-25 has reached to 112.947 lakh hectares against last year's 123.709 lakh hectares which is 8.70% lower than last year. Production and productivity of *Bt. cotton* in India during 2024-25 was 312.40 lakh bales and 464 kg/ha, respectively. Gujarat, Maharashtra and Telangana are the major cotton growing states in the country. Area, production and productivity of cotton in Gujarat during 2024-25 was 23.72 lakh hectares, 71.57 lakh bales (69.58 lakh pressed bales + 1.99 lakh bales loose cotton) and 484.46 kg/ha, respectively (Anonymous, 2025)^[2]. Cotton is a sub-tropical, perennial plant with indeterminate growth habit. Vegetative and reproductive growth occurs simultaneously where vegetative growth is necessary to support reproductive growth. Cotton supplies products such as lint, oil, seed meal, hulls and linter, out of which lint and oil are the most important products. Among various production factors, geometry play very significant role as low monetary input. A spatial arrangement of plant governs the shape and size of the leaf area per plant, which in turn influences efficient interception of radiant energy and proliferation and growth of root and their activity. Maximum yield can be

expected only when plant population allows individual plant to achieve their maximum inherent potential. Thus, there is a need to work out an optimum population density by adjusting inter and intra row spacing in relation to other agronomic factors. However, numerically lower monopodial with closer plant geometry and lower sympodial with wider plant geometry were observed indicating more period under vegetative growth with wider spacing. Closer plant geometry also recorded higher seed cotton yield/ha (Sankaranarayanan *et al.*, 2004; Buttar and Singh, 2006 and Singh *et al.*, 2007) [21, 4, 25]. Plant growth regulators are substances when added in small amount to modify the growth of plant and they are considered as new generation of agro-chemicals after fertilizers, pesticides and herbicides. Mepiquat chloride is an anti-gibberellin that inhibits cell expansion but not cell division. Mepiquat chloride can restrict vegetative growth, inducing the plant to direct more carbohydrates into reproductive organs. Cycocel is an anti-gibberellin dwarfing agent, and foliar spray of this may induce deficiency of gibberellin in the plant and reduce the growth by blocking and conversion of geranyl pyrophosphate to coponyl pyrophosphate. Monopodial branches are always formed at the base of cotton plant. Induction of high number of sympodial branches and thereby increase in number of square and bolls are essential for yield maximization of seed cotton (Dhillon *et al.*, 2006) [5]. Therefore, there is need to manipulate the growth of cotton to get good architecture by monopodia removal, so that the plant can get required sunlight with minimal mutual shading. (Shwetha *et al.*, 2009) [24].

Material and Methods

A field experiment entitled “Influence of spacing and canopy management on growth parameters of *Bt.* cotton (*Gossypium hirsutum* L.)” was conducted at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, on plot No. C-5 and A-7 during *kharif* 2024- 25 and 2025-26, respectively. The experiment was conducted on *Bt.* cotton variety GTHH-49 with 20 treatment combinations comprising of four spacing treatments viz; S₁: 60 cm × 45 cm, S₂: 90 cm × 45 cm, S₃: 120 cm × 30 cm and S₄: 120 cm × 45 cm and five canopy management practices viz; C₁: Control, C₂: Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS, C₃: Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS, C₄: Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + removal of monopodial branches and C₅: Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + removal of monopodial branches were tested in a split plot design with three replications. The soil of the experimental plot was loamy sand in texture, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash status. Geographically, Sardarkrushinagar is located at 24° 19' North latitude and 72° 19' East longitude with an elevation of 154.52 metre above the mean sea level and situated in the North Gujarat Agro-climatic Zone. The climate of this region is sub-tropical monsoon type and falls under the semi-arid region having extreme cold winter and hot and dry windy summer. During 2024-25 and 2025-26, mean maximum temperature ranged from 24.6-40.6 and 24.5-38.8 °C, respectively, while mean minimum temperature ranged from 6.3-26.9 and 9.7-26.7 °C. Morning relative humidity ranged from 70–98 and 73-94 per cent, and evening relative humidity from 22-89 and 22-87 per cent, respectively. Mean bright sunshine hours ranged from 0.5- 9.4 and 0.2-9.1 hours/day, while mean evaporation ranged from 2.0-11.2 and 1.2-7.6 mm during the respective years. A common application of 10 t FYM /ha was made before sowing. The crop received the recommended

fertilizer dose of 320-00-120 kg N-P₂O₅-K₂O /ha. At sowing, one-fifth of nitrogen (64 kg/ha) as urea and the entire potassium (120 kg/ha) as muriate of potash were applied in furrows. The remaining nitrogen was top-dressed in four equal splits at 30, 60, 75 and 90 DAS through urea, depending on soil moisture. Foliar sprays were imposed twice at 60 and 75 days after sowing (DAS) in the respective treatment plots, while monopodial branches were removed by pruning non-fruitlet vegetative branches from the basal portion. For dry matter accumulation, five plants were uprooted from the sampling area of each plot at 30, 60 and 90 DAS. Plants were destructively sampled by cutting at the base, shade-dried for 24 hours, cut into pieces, placed in labelled brown paper bags and oven-dried at 65 °C for 72 hours. Oven-dried weight was recorded using an electronic balance and expressed as dry matter accumulation (g/plant). Crop growth rate (CGR) and relative growth rate (RGR) were calculated using the methods of Radford (1967) [20] and Hunt (1990) [8], respectively:

$$\text{CGR} = (W_2 - W_1) / (t_2 - t_1) \times 1/P$$

where CGR = crop growth rate (g/m²/day), W₁ and W₂ = dry weight of plant (g) at times t₁ and t₂, respectively, t₂ – t₁ = time interval between consecutive stages (days), and P = ground area (m²) per plant.

$$\text{RGR} = [\ln W_2 - \ln W_1] / (t_2 - t_1)$$

where RGR = mean relative growth rate (mg/g/day), W₁ and W₂ = dry weight of plant (g) at times t₁ and t₂, respectively, t₂ – t₁ = time interval between consecutive stages, and LN = natural logarithm.

Results and discussion

1. Plant height (cm)

The result of experiments on plant height at 60, 90 DAS and at harvest of *Bt.* cotton is summarized in Table 1 and graphically depicted in Figure 1. An examination of data revealed that *Bt.* cotton planted at a spacing of 60 cm × 45 cm (S₁) recorded significantly tallest plants at 60 DAS (76.84, 93.33 and 85.08 cm), 90 DAS (101.79, 105.4 and 103.6 cm) and at harvest (131.21, 136.57 and 133.89 cm) than 120 cm × 30 cm (S₃), 90 cm × 45 cm (S₂) and 120 cm × 45 cm (S₄) during both the years and in pooled analysis, respectively. While, treatment S₄: spacing of 120 cm × 45 cm recorded significantly lower plant height at 60 DAS (67.76, 82.98 and 75.37 cm), 90 DAS (90.97, 92.50 and 91.73 cm) and at harvest (112.29, 115.90 and 114.09 cm) as compared to rest of the treatments during 2024-25, 2025-26 and in pooled analysis, respectively. Plant height was increase with decrease in plant spacing and shorter in plant height under wider spacing might be due to suppression of apical dominance as against higher plant density which induced more vertical growth due to congestion of plant per unit area. These results are supported by Khetre *et al.* (2018) [11], Mahil and Lokanadhan (2018) [12], Patel *et al.* (2021) [17], Gohil *et al.* (2024) [6], Sankat *et al.* (2024) [22] and Karnavat *et al.* (2025) [9]. For different canopy management treatments, the plant height (cm) at 60 DAS of *Bt.* cotton was not influence significantly due to canopy management treatments. This is because mepiquat chloride and cycocel treatments were imposed from 60th day after sowing and its effect was seen from 65th DAS onwards. Among different canopy management treatments, spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + removal of monopodial branches (C₄) recorded significantly lower plant height of *Bt.* cotton at 90 DAS (87.61, 91.1 and 89.36 cm) and at harvest (115.55, 121.89 and 118.72 cm) during 2024-

25, 2025-26 and in pooled results, respectively. On the contrary, control treatment (no spray) (C_1) registered significantly higher plant height at 90 DAS (105.6, 109.3 and 107.5 cm) and at harvest (124.91, 131.58 and 128.24 cm) during both the years and in pooled mean, respectively. which was found statistically at par with spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS (C_2) and spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS (C_3) during 2024-25; treatment C_2 (spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS) during 2025-26 and treatment C_3 (spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS) in pooled mean. The decrease in plant height of cotton plants sprayed with mepiquat chloride could be due to the interference of these chemicals as growth regulator in gibberellic acid biosynthetic pathway. The reduced amount of gibberellins in the plant system affects the growth and decrease plant height. The present results corroborated with the findings of Prakash and Korekar (2017)^[18], Malakannavar *et al.* (2018)^[13], Borge and Dattatraya (2019)^[3], Veeraputhiran and Gunasekaran (2020)^[26] and Patel *et al.* (2021)^[17].

2. Dry matter accumulation (g/plant) at 30, 60 and 90 DAS

Table 2 indicated that different plant spacing showed significant effect on dry matter accumulation (g/plant) of *Bt.* cotton at 60 and 90 DAS except at 30 DAS during both the years and in pooled results. It was increased with broader spacing. Spacing of 120 cm $\times$ 45 cm (S_4) recorded significantly the highest dry matter per plant at 60 DAS (90.56, 95.90 and 93.23 g) as compared to 60 cm $\times$ 45 cm (S_1) and 120 cm $\times$ 30 cm (S_3) during both years and in pooled analysis, respectively, but it was found at par with treatment S_2 (90 cm $\times$ 45 cm) at 60 DAS during 2024-25 and treatment S_2 (90 cm $\times$ 45 cm) at 90 DAS during 2024-25, 2025-26 and in pooled results. On the contrary, significantly lower dry matter accumulation per plant was at 60 DAS 72.61, 77.03 and 74.82 g and at 90 DAS was 121.68, 128.61 and 125.15 g during 2024-25, The increase in dry matter accumulation per plant at wider spacing (lower plant density) might be mainly due to the larger ground area, maximum moisture and more interception of light by more number of leaves and leaf area resulting in more photosynthetic activity and more biomass accumulation through the process of plant metabolism. Similar observations of higher dry matter accumulation per plant at lower plant densities as compared to higher plant densities was also reported by Nagender *et al.* (2017)^[15], Parlawar *et al.* (2017)^[16], Khetre *et al.* (2018)^[11], Patel *et al.* (2021)^[17] and Anbarasan *et al.* (2022)^[1]. Differences in dry matter accumulation per plant (g) due to canopy management treatments not reach the level of significance during initial growth period at 30 and 60 DAS. At 30 and 60 DAS, no such differences were noticed since the mepiquat chloride and cycocel first foliar application was started at 60 DAS. The distribution of dry matter in different plant parts showed that at early stages, leaves contributed to a greater proportion of total dry matter, but at later stages stem and reproductive parts contributed more. Foliar application of cycocel 0.004% (40 ppm) at 60 and 75 DAS + removal of monopodial branches (C_5) noted significantly the lowest dry matter accumulation per plant at 90 DAS (121.76, 132.57 and 127.17 g) during individual year as well as in pooled analysis, respectively. The results further indicated that significantly the highest dry matter accumulation per plant at 90 DAS (150.31, 156.41 and 153.36 g) was registered under control (no spray) (C_1) treatment during 2024-25, 2025-26 and in pooled analysis, respectively. Minimum dry matter production due to canopy management is due to the fact that cycocel and mepiquat chloride restricts the vegetative growth of plants and increases the partitioning of assimilates towards fruiting bodies. These results

are in conformity with the results reported by Kaul *et al.* (2016)^[10], Malakannavar *et al.* (2018)^[13], Borge and Dattatraya (2019)^[3], Patel *et al.* (2021)^[17] and Priyadarshini *et al.* (2023)^[19].

3. Crop growth rate at 30-0, 60-30 and 90-60 DAS (g/m²/day)

Dry matter production per ground area i.e. CGR increased significantly with increase in age and crop growth period up to 60-90 DAS. It was increased with dense spacing. Scrutiny of crop growth rate data revealed that spacing of 60 cm $\times$ 45 cm (S_1) recorded significantly highest crop growth rate of 3.77, 3.89 and 3.83 g/m²/day between 0-30 DAS; 5.19, 5.62 and 5.41 g/m²/day between 30-60 DAS and 6.06, 6.37 and 6.21 g/m²/day between 60-90 DAS during 2024-25, 2025-26 and in pooled results, respectively. Significantly the lowest crop growth rate of 2.08, 2.21 and 2.14 g/m²/day between 0-30 DAS; 3.51, 3.71 and 3.61 g/m²/day between 30-60 DAS and 3.49, 3.92 and 3.71 g/m²/day between 60-90 DAS were noted with spacing of 120 cm $\times$ 45cm (S_4) during both the individual year and in pooled results, respectively. Crop growth rate (CGR) are derived with biomass over time unit. In present study, improvement in dry matter accumulation per plant was observed with increasing plant density. These results are in conformity with the results reported by Manjunatha *et al.* (2010)^[14], Mahil and Lokanadhan (2018)^[12], Patel *et al.* (2021)^[17] and Gohil *et al.* (2024)^[6]. Canopy management treatments does not significantly influenced on crop growth rate (g/m²/day) between 0-30 and 30-60 DAS during both the years and in pooled analysis, but it was significantly influenced by various canopy management treatments between 60-90 DAS during both the years and in pooled analysis. Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + removal of monopodial branches (C_5) recorded significantly lower crop growth rate of 3.84, 4.31 and 4.07 g/m²/day and maximum crop growth rate of 5.93, 6.12 and 6.02 g/m²/day between 60-90 DAS during 2024-25, 2025-26 and in pooled analysis, respectively was registered under control treatment (no spray) (C_1). The crop growth rate in cotton was more closely associated with vegetative growth than seed cotton yield. A similar trend was reported by Hunnur (2007)^[7]. Crop growth rate (g/m²/day) was not reach the level of significance due to various canopy management treatments during initial growth period i.e. upto 60 DAS since the mepiquat chloride and cycocel were imposed from 60th day after sowing and onward.

4. Relative growth rate at 30-0, 60-30 and 90-60 DAS (mg/g/day)

The data presented in Table 4 highlighted that different spacing exhibited their non-significant effect on relative growth rate (mg/g/day) between 0-30, 30-60 and 60-90 DAS during both the years as well as in pooled analysis except pooled mean between 0-30 and 30-60 DAS. The data on relative growth rate indicated that spacing treatments was significantly increased relative growth rate (mg/g/day) at 0-30 and 30-60 DAS in pooled analysis. Relative growth rate (mg/g/day) was increased with increase in plant spacing. At lower plant density of 18,518 plants/ha (120 cm $\times$ 45 cm) (S_4) recorded significantly highest relative growth rate of 118.15. mg/g/day at 0-30 DAS, but it was at par with 90 cm $\times$ 45 cm (S_2) and 120 cm $\times$ 30 cm (S_3) spacing with corresponding value of 117.00 and 116.42 mg/g/day, respectively in pooled analysis. Relative growth rate was declined at later stages of crop growth which might be due to partitioning of extra photosynthates towards the developing sink during reproductive development. At higher planting densities, growth rate was significantly lower as compared to minimum plant densities. These results are in

conformity with the results reported by Shukla *et al.* (2013)^[23], Mahil and Lokanadhan (2018)^[12], Patel *et al.* (2021)^[17] and Gohil *et al.* (2024)^[6]. Differences due to various canopy management treatments significantly influenced the relative growth rate (mg/g/day) at 60-90 DAS during both the years and in pooled analysis, but it was found non-significant at 0-30 and 30-60 DAS. At 60-90 DAS, spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + removal of monopodial branches (C₅) recorded significantly lower relative growth rate of 14.31, 14.95 and 14.63 mg/g/day during both 2024-25, 2025-26 and in pooled results, respectively, but it was stood at par with spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + removal of monopodial branches (C₄) during both the individual years of experiment with relative growth rate value of 16.25 and 16.50 mg/g/day, respectively. The significantly maximum relative growth rate (19.76, 19.70 and 19.73 mg/g/day) was obtained under control (no spray) (C₁) treatment between 60-90 DAS during 2024-25, 2025-26 and in pooled analysis, respectively. However, it was found at par with treatment C₂ (spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS) during 2024-25 and 2025-

26 which registered relative growth rate value of 18.07 and 18.36 mg/g/day, respectively. Relative growth rate of cotton was more closely associated with vegetative growth and dry matter accumulation than seed cotton yield. A similar trend was reported by Hunnur (2007)^[7] and Patel *et al.* (2021)^[17].

5. Interaction effect

Interaction effect between different spacings and canopy management practices was found significant with respect to plant height at 90 DAS in pooled results, but it failed to exhibit significant response during 2024-25 and 2025-26 at 60, 90 DAS and at harvest and at 60 DAS and at harvest in pooled data and it is presented in Table 5. Results indicated that treatment combination of 60 cm × 45 cm along with control registered significantly higher plant height at 90 DAS (109.3 cm) in pooled results. Whereas, treatment combination of 120 cm × 45 cm along with spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + removal of monopodial branches recorded remarkably lower plant height of 80.99 cm.

Table 1: Effect of spacing and canopy management on periodical plant height of *Bt.* Cotton

Treatments	60 DAS (cm)			90 DAS (cm)			At harvest (cm)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Main plot treatment: Spacing (S)									
S ₁ : 60 cm × 45 cm	76.84	93.33	85.08	101.79	105.40	103.60	131.21	136.57	133.89
S ₂ : 90 cm × 45 cm	69.81	83.64	76.73	92.91	94.82	93.87	114.31	126.66	120.49
S ₃ : 120 cm × 30 cm	70.86	85.18	78.02	96.50	97.90	97.20	125.55	127.45	125.50
S ₄ : 120 cm × 45 cm	67.76	82.98	75.37	90.97	92.50	91.73	112.29	115.90	114.09
S.E.m.±	1.67	2.17	1.37	2.10	2.23	1.53	2.73	2.70	1.92
C.D. at 5%	5.77	7.51	4.22	7.26	7.71	4.72	9.45	9.34	5.92
C. V.%	9.06	9.74	9.51	8.51	8.84	8.68	8.79	8.25	8.51
Sub- plot treatment: Canopy management (C)									
C ₁ : Control	72.40	88.06	80.23	105.56	109.30	107.50	124.91	131.58	128.24
C ₂ : Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS	72.15	86.51	79.33	93.23	96.70	95.00	120.27	126.43	123.35
C ₃ : Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS	71.98	86.28	79.13	99.23	99.39	99.31	122.67	127.09	124.88
C ₄ : Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + Removal of monopodial branches	69.97	84.84	77.40	87.61	91.10	89.36	115.55	121.89	118.72
C ₅ : Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + Removal of monopodial branches	70.07	85.73	77.90	92.10	91.80	92.00	118.30	126.25	122.27
S.E.m.±	1.73	2.04	1.34	2.04	2.11	1.47	1.77	2.70	1.61
C.D. at 5%	NS	NS	NS	5.88	6.08	4.15	5.09	5.20	4.55
Interaction									
S × C	NS	NS	NS	NS	NS	S	NS	NS	NS
Y × S	-	-	NS	-	-	NS	-	-	NS
Y × C	-	-	NS	-	-	NS	-	-	NS
Y × S × C	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	8.40	8.19	8.32	7.40	7.49	7.45	5.08	7.38	6.40

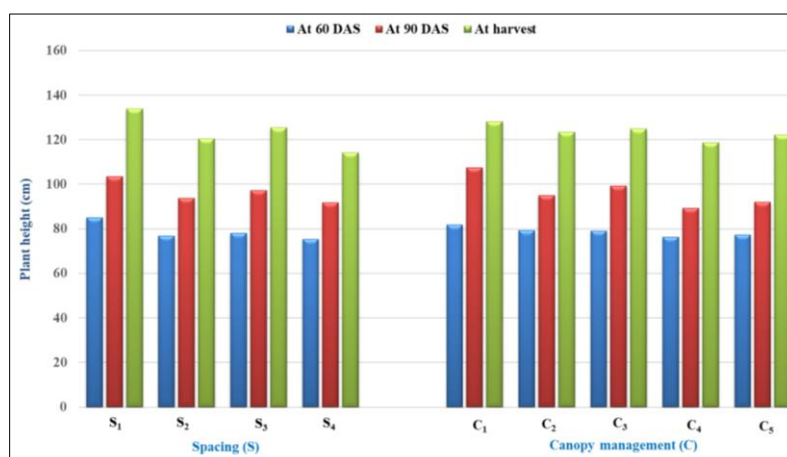


Fig 1: Effect of spacing and canopy management on periodical plant height of *Bt.* cotton (pooled)

Table 2: Effect of spacing and canopy management on periodical dry matter accumulation of *Bt.* cotton

Treatments	30 DAS (g/plant)			60 DAS (g/plant)			90 DAS (g/plant)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Main plot treatment: Spacing (S)									
S ₁ : 60 cm × 45 cm	30.55	31.48	31.09	72.61	77.03	74.82	121.68	128.61	125.15
S ₂ : 90 cm × 45 cm	33.20	33.87	33.54	83.28	85.33	84.30	141.26	146.66	143.96
S ₃ : 120 cm × 30 cm	32.20	33.08	33.00	78.77	82.95	80.86	132.82	139.32	136.07
S ₄ : 120 cm × 45 cm	33.64	35.84	34.74	90.56	95.90	93.23	147.15	159.49	153.32
S.Em.±	1.17	1.20	0.84	2.57	2.60	1.83	2.87	4.07	2.49
C.D. at 5%	NS	NS	NS	8.89	8.99	5.63	9.93	14.09	7.67
C. V. %	13.99	13.79	13.88	12.24	11.79	12.01	8.19	10.99	9.77
Sub- plot treatment: Canopy management (C)									
C ₁ : Control	33.03	33.88	33.45	83.19	86.60	84.90	150.31	156.41	153.36
C ₂ : Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS	32.68	33.84	33.26	81.69	85.92	83.81	140.14	148.74	144.44
C ₃ : Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS	32.53	33.74	33.13	81.33	84.58	82.95	135.26	140.61	137.93
C ₄ : Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + Removal of monopodial branches	32.22	33.70	33.05	80.90	84.85	82.88	131.17	139.27	135.22
C ₅ : Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + Removal of monopodial branches	31.49	33.52	32.51	79.42	84.56	81.99	121.76	132.57	127.17
S.Em.±	0.80	0.82	0.58	1.77	1.60	1.19	2.27	2.07	1.54
C.D. at 5%	NS	NS	NS	NS	NS	NS	6.54	5.95	4.33
Interaction									
S × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y × S	-	-	NS	-	-	NS	-	-	NS
Y × C	-	-	NS	-	-	NS	-	-	NS
Y × S × C	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	8.59	8.47	8.52	7.52	6.48	7.00	5.80	4.99	5.39

Table 3: Effect of spacing and canopy management on periodical crop growth rate of *Bt.* cotton

Treatments	0-30 DAS (g/m ² /day)			30-60 DAS (g/m ² /day)			60-90 DAS (g/m ² /day)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Main plot treatment: Spacing (S)									
S ₁ : 60 cm × 45 cm	3.77	3.89	3.83	5.19	5.62	5.41	6.06	6.37	6.21
S ₂ : 90 cm × 45 cm	2.73	2.79	2.76	4.12	4.24	4.18	4.77	5.05	4.91
S ₃ : 120 cm × 30 cm	2.98	3.13	3.05	4.35	4.56	4.45	5.00	5.22	5.11
S ₄ : 120 cm × 45 cm	2.08	2.21	2.14	3.51	3.71	3.61	3.49	3.92	3.71
S.Em.±	0.12	0.14	0.09	0.17	0.16	0.12	0.19	0.18	0.13
C.D. at 5%	0.40	0.48	0.28	0.60	0.56	0.37	0.66	0.63	0.41
C. V. %	15.48	17.91	16.79	15.56	13.90	14.72	15.37	13.67	14.50
Sub- plot treatment: Canopy management (C)									
C ₁ : Control	2.92	3.02	2.97	4.41	4.62	4.52	5.93	6.12	6.02
C ₂ : Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS	2.93	3.03	2.98	4.30	4.54	4.42	5.16	5.53	5.34
C ₃ : Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS	2.92	3.00	2.96	4.29	4.44	4.37	4.74	4.98	4.86
C ₄ : Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + Removal of monopodial branches	2.87	2.97	2.92	4.27	4.54	4.41	4.50	4.76	4.63
C ₅ : Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + Removal of monopodial branches	2.81	2.99	2.90	4.21	4.50	4.36	3.84	4.31	4.07
S.Em.±	0.08	0.08	0.06	0.17	0.15	0.11	0.22	0.19	0.15
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.64	0.54	0.41
Interaction									
S × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y × S	-	-	NS	-	-	NS	-	-	NS
Y × C	-	-	NS	-	-	NS	-	-	NS
Y × S × C	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	9.57	9.25	9.41	13.78	11.41	12.59	15.91	12.63	14.27

Table 4: Effect of spacing and canopy management on periodical relative growth rate of *Bt.* cotton

Treatments	0-30 DAS (mg/g/day)			30-60 DAS (mg/g/day)			60-90 DAS (mg/g/day)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Main plot treatment: Spacing (S)									
S ₁ : 60 cm × 45 cm	113.72	114.75	114.23	28.96	30.01	29.48	17.26	17.05	17.15
S ₂ : 90 cm × 45 cm	116.71	117.30	117.00	30.59	30.88	30.73	17.61	18.02	17.82
S ₃ : 120 cm × 30 cm	115.59	117.26	116.42	29.90	29.98	29.94	17.38	17.23	17.30
S ₄ : 120 cm × 45 cm	117.06	119.25	118.15	33.07	32.75	32.91	16.03	16.91	16.47
S.E.m.±	1.30	1.23	0.88	1.20	1.05	0.80	0.72	0.57	0.46
C.D. at 5%	NS	NS	2.71	NS	NS	2.47	NS	NS	NS
C. V. %	4.2	4.07	4.13	15.28	13.17	14.25	16.31	12.68	14.59
Sub- plot treatment: Canopy management (C)									
C ₁ : Control	116.40	117.16	116.78	30.77	31.36	31.06	19.76	19.70	19.73
C ₂ : Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS	116.21	117.33	116.77	30.30	30.90	30.60	18.07	18.36	18.21
C ₃ : Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS	115.99	117.18	116.58	30.46	30.55	30.50	16.96	17.02	16.99
C ₄ : Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + Removal of monopodial branches	115.62	117.01	116.32	30.59	30.89	30.74	16.25	16.50	16.37
C ₅ : Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + Removal of monopodial branches	114.63	117.01	115.82	31.04	30.81	30.92	14.31	14.95	14.63
S.E.m.±	0.87	0.82	0.60	0.98	0.97	0.69	0.82	0.61	0.51
C.D. at 5%	NS	NS	NS	NS	NS	NS	2.37	1.76	1.45
Interaction									
S × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y × S	-	-	NS	-	-	NS	-	-	NS
Y × C	-	-	NS	-	-	NS	-	-	NS
Y × S × C	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	2.60	2.42	2.51	11.11	10.91	11.01	16.71	12.21	14.61

Table 5: Interaction effect of spacing and canopy management on plant height of *Bt.* cotton in pooled data

Canopy management (C)		Spacing (S)			
		S ₁	S ₂	S ₃	S ₄
		60 cm × 45 cm	90 cm × 45 cm	120 cm × 30 cm	120 cm × 45 cm
C ₁	Control	109.25	108.89	108.86	102.82
C ₂	Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS	99.08	92.22	97.59	90.93
C ₃	Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS	102.97	98.52	99.70	96.05
C ₄	Spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + Removal of monopodial branches	101.25	86.93	88.25	80.99
C ₅	Spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + Removal of monopodial branches	105.78	82.42	91.74	87.86
S.E.m.±		2.94			
C.D. at 5%		8.29			
C.V.(%)		7.45			

Conclusion

In light of results obtained from the two years investigation, it is concluded that sowing of *Bt.* cotton should be done at 60 cm × 45 cm produced significantly higher plant height at 60, 90 DAS and harvest and crop growth rate between 0-30 DAS, 30-60 DAS and 60-90 DAS. While, dry matter accumulation per plant at 60 DAS and 90 DAS and relative growth rate between 0-30 DAS and 30-60 DAS recorded significantly higher with spacing of 120 cm × 45 cm. Among canopy management treatments, plant height at 90 DAS and at harvest, dry matter accumulation per plant at 90 DAS, crop growth rate between 60-90 DAS and relative growth rate between 60-90 DAS recorded significantly higher under control treatment (no spray of growth retardant). In contrast significantly lower plant height was found with spray of mepiquat chloride 0.04% (0.4 ml/lit) at 60 and 75 DAS + removal of monopodial branches (C₄). Similarly, dry matter accumulation at 90 DAS, crop growth rate between 60-90 DAS and relative growth rate between 60-90 DAS were significantly lower with the spray of cycocel 0.004% (40 ppm) at 60 and 75 DAS + removal of monopodial branches.

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