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IMPACT OF CANOPY MANAGEMENT ON GROWTH PERFORMANCE AND FIBRE QUALITY OF COMPACT BT COTTON HYBRID IN HIGH-DENSITY PLANTING SYSTEM

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ABSTRACT

A two-year field study (2022–23 and 2023–24) was conducted at the Main Agricultural Research Station, UAS Dharwad, to assess the “Impact of canopy management on growth performance and fibre quality of compact Bt cotton hybrid in high-density planting system.” The experiment was laid out in split-plot design on medium black clay soils with four planting geometries [90×30 cm (37,037 plants ha^{-1}), 90×15 cm (74,074 plants ha^{-1}), 75×30 cm (44,444 plants ha^{-1}) and 75×15 cm (88,888 plants ha^{-1})] as main plots and three canopy management treatments (mepiquat chloride @ 100 ppm at 80 and 100 DAS, detopping at 90 DAS, and control) as subplots. Planting geometry significantly influenced plant height with the densest spacing (75×15 cm) producing the tallest plants (137.9 cm pooled at harvest) due to competition-induced etiolation, while wider spacing (90×30 cm) resulted in shorter plants (119.0 cm). Canopy management treatments, particularly mepiquat chloride (122.6 cm) and detopping (126.7 cm) reduced plant height compared to the control promoting compact canopies. The interaction of 75 cm ×15 cm with control recorded the tallest plants (144.7 cm) while 90×30 cm with mepiquat chloride or detopping produced the shortest (114–118 cm). Monopodial branches were highest in 90×30 cm (1.74) and lowest in 75×15 cm (1.21 $plant^{-1}$) with growth regulators reduced the monopodial branches compared to control (1.66) indicated that redirecting assimilates to reproductive growth. Fibre quality showed negligible differences to planting geometry fibre length ranging from 30.8–31.2 mm. Wider spacing (90×30 cm) enhanced fibre strength (30.75 g tex^{-1}) and micronaire (3.98 µg $inch^{-1}$) compared to 75×15 cm (30.24 g tex^{-1}, 3.86 µg $inch^{-1}$). Mepiquat chloride improved fibre strength (30.61 g tex^{-1}) but lowered micronaire (3.83), while detopping had intermediate effects. The 90×30 cm with mepiquat chloride maximized strength (31.03 g tex^{-1}) and 75×15 cm with mepiquat chloride minimized micronaire (3.78). Wider spacing (90×30 cm) with mepiquat chloride or detopping optimized canopy structure, vegetative suppression and lint quality offering a sustainable approach for Bt cotton intensification under variable monsoon conditions.
***Keywords*:** Bt cotton, high-density planting, canopy management, mepiquat chloride, fibre quality.

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the most important fibre crops worldwide contributing significantly to both agricultural income and the textile industry. This is also known as white gold due to its economic importance with world production reaching 120.5 million bales across 30.8 million hectares. India has the largest area under cotton cultivation in the world, covering 11.8 million hectares which accounts for 38 per cent of the global total area, but it ranks second in production with 25 million bales, contributing 21 percent of global output behind China’s 31 million bales produced from just 2.9 million hectares (USDA 2025). This underscores India's vast scale yet persistent productivity challenges with lint yields averaging around 462 kg ha^{-1} which is far below the global average of 780 kg ha^{-1}. In contrast, developed nations like the USA and Australia achieve superior efficiency on smaller footprints. The USA with an area of 3.36 million hectares produced 14.4 million bales at a yield of 939 kg lint ha^{-1} (836 lb/acre), benefiting from advanced mechanization and irrigation. Australia cultivating under 0.5 million hectares, yielded 5.4 million bales with highest productivity exceeding 1,960 kg ha^{-1}. These disparities highlight the need for India to bridge the yield gap through technological advancements. To overcome these limitations and enhance productivity high-density planting systems (HDPS) have emerged as a promising strategy for sustainable intensification. The advent of compact Bt cotton hybrids has encouraged the adoption of high-density planting systems (HDPS) which aim to maximize plant population and yield per unit area compared to conventional planting geometry,

Cotton is an indeterminate crop and its tendency for continuous vegetative growth often interferes with boll development especially under high-density planting systems (HDPS). Excessive height, shading and unproductive branches reduce light interception, yield efficiency and fibre quality. These limitations highlight the need for canopy management interventions in HDPS. Canopy management practices such as growth retardants and detopping help regulate plant architecture, improve source–sink balance and enhance boll retention. Studying these strategies under HDPS is therefore essential to optimize growth, productivity and fibre quality in compact Bt cotton hybrids.

Among various approaches, chemical and physical canopy manipulation strategies have shown considerable promise. Growth retardants such as mepiquat chloride are widely recognized for their ability to inhibit gibberellin biosynthesis thereby reducing internodal elongation and maintaining a compact plant type. This not only prevents excessive vegetative growth but also improves canopy aeration and light distribution, creating favourable conditions for boll development and fibre maturation. Physical methods such as detopping – removal of the terminal portion of the main stem also serves as an effective canopy management practice. Detopping alters apical dominance promotes lateral branching and redirects assimilates towards reproductive sinks thereby enhancing boll setting and yield efficiency under dense planting conditions.

Material and Methods

A field experiment was conducted during the *kharif* seasons of 2022-23 and 2023-24 at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad. geographically located at 15° 26’ N latitude, 75° 07’ E longitude and at an altitude of 678 m above mean sea level. Dharwad comes under Northern Transition Zone (Zone-8) of Karnataka. The experiment was conducted in medium black clay soil. Soil was neutral in pH (7.43), normal electric conductivity (0.32 dS m^{-1}), medium in organic carbon (0.54 %), medium in available N (234.25 kg ha^{-1}) and P_2O_5 (34.56 kg ha^{-1}) and high in available K_2O (362.18 kg ha^{-1}). The experiment was laid out in split plot design with four planting geometries *viz*., P_1: 90 cm x 30 cm (37,037 plants ha^{-1}), P_2: 90 cm x 15 cm (74,074 plants ha^{-1}), P_3**:** 75 cm × 30 cm (44,444 plants ha^{-1}) and P_4: 75 cm × 15 cm (88,888 plants ha^{-1}) as main plot treatments and three treatments as growth retardants *viz*., R_1**:** Mepiquat chloride @ 100 ppm at 80 and 100 DAS, R_2: Detopping at 90 DAS and R_3: Control as sub plot treatments.

Results and Discussion

Plant Height

The results indicated that planting geometry significantly influenced cotton plant height across all measured growth stages (50, 80 and 110 DAS and at harvest) in both 2023 and 2024 as well as in the pooled data (Table 1). Specifically, the closest spacing of 75×15 cm consistently recorded the taller plants with pooled heights of 70.7 cm (50 DAS), 109.3 cm (80 DAS), 129.4 cm (110 DAS) and 137.9 cm (at harvest), which were significantly superior to other geometries. In contrast, 90 cm × 30 cm recorded the lower plant height (60.0 cm, 94.3 cm, 110.1 cm and 119.0 cm at 50, 80, 110 DAS and at harvest, respectively). This may be due to higher plant densities promoting etiolation and vertical growth due to increased competition for light and resources, as denser configurations induce stem elongation to optimize canopy architecture and light interception. The significant increase in plant height under high-density planting geometries, particularly the 75×15 cm spacing aligns with established physiological responses in cotton, where elevated intra-plant competition for photosynthetically active radiation triggers shade-avoidance mechanisms, leading to enhanced internodal elongation mediated by auxin and gibberellin signalling pathways, as reported by Wang *et al.* (2023). This etiolation effect was evident across all growth stages, with pooled height increments of 16–18 per cent over wider spacing.

Among the growth regulators, no significant difference was observed in plant height at 50 and 80 DAS. However, at later stages (110 DAS and at harvest), the plant height was significantly influenced by the growth regulators. Application of mepiquat chloride @ 100 ppm at 80 DAS and 100 DAS significantly recorded the lower plant height at 110 DAS and at harvest (114.4 cm and 122.6 cm, respectively) and was on par with detopping at 90 DAS (117.7 cm and 126.7 cm at 110 DAS and at harvest, respectively). This height suppression by MC is attributable to its inhibition of gibberellin biosynthesis which shortens internodes and curtails excessive vegetative expansion, promoting a more compact plant structure. Detopping, by removing the apical meristem disrupts dominance and redirects assimilates toward lateral branching, limiting vertical growth while potentially improving reproductive partitioning. Significantly higher plant height was recorded in the control treatment. Similar results were noticed by Reddy and Reddy (2019), Zhang *et al. (*2020), Singh and Verma (2021)

Interactions between planting geometry and growth retardants revealed that closer spacings with the control maximized the plant height as seen in 75 cm × 15 cm with control, which recorded the highest pooled height of 136.2 cm at 110 DAS and 144.7 cm at harvest. Conversely, wider spacing of 90 cm × 30 cm with mepiquat chloride application @ 100 ppm at 80 DAS and 100 DAS recorded significantly lower plant height (105.5 cm and 113.6 cm at 110 DAS and at harvest, respectively), which was on par with the interaction of spacing at 90 cm × 30 cm and detopping at 90 DAS (108.3 cm and 117.6 cm at 110 DAS and at harvest, respectively). It might be due to the competition for solar radiation in closer spacing for photosynthesis, thereby plants grew to more height in competition for light. It was also observed that the reduction in plant height under lower planting density was due to suppression of apical dominance as against higher planting density which induced more vertical growth due to congestion of plants per unit area. Similar differences in plant height due to planting density were reported by Madavi *et al*. (2017), Kumar *et al*. (2017), Sankat *et al*. (2017) and Solanki *et al*. (2020).

Number of Monopodial Branches

The results indicated that planting geometry significantly influenced the number of monopodial branches of compact Bt cotton hybrid across all measured growth stages (50, 80 and 110 DAS and at harvest) in both 2023 and 2024 as well as in the pooled data (Table 2). The wider spacing of 90×30 cm consistently recorded the higher monopodial branches with pooled counts of 1.02 (50 DAS), 1.27 (80 DAS), 1.74 (110 DAS) and 1.74 (at harvest), which were significantly superior to other geometries. In contrast, the closest spacing of 75×15 cm recorded the lowest pooled monopodial branches (0.73 at 50 DAS, 0.95 at 80 DAS, 1.21 at 110 DAS and 1.21 at harvest, respectively). This might be due to lower plant densities in wider spacings allowing reduced intra-plant competition, thereby promoting axillary bud outgrowth and vegetative branching, whereas denser configurations induce shading and resource limitation that suppress basal monopodial development to prioritize main-stem dominance and reproductive sinks. This suppression in monopodial branches in high-density planting benefits compact Bt hybrids by minimizing non-productive biomass, potentially boosting boll retention by 10–15 per cent through redirected photosynthates though excessive reduction risks reduced photosynthetic capacity in shaded lower canopies. Similar results were observed by Khadke *et al*. (2025) and Shashi Kumar and Ramachandra. (2019).

Among the growth regulators, no significant difference was observed in monopodial branches at 50 and 80 DAS. However, at later stages (110 DAS and at harvest) the number of monopodial branches was significantly influenced by the growth regulators. The control treatment significantly recorded the higher monopodial branches at 110 DAS and at harvest (1.66 pooled at both stages), which was superior to mepiquat chloride @ 100 ppm (1.32 pooled) and detopping (1.40 pooled at 110 DAS and 1.32 pooled at harvest). This increase in control is attributable to unhindered auxin-cytokinin balance fostering lateral bud proliferation without hormonal or mechanical interference. Mepiquat chloride by inhibiting gibberellin synthesis curtails cell division in axillary meristems reducing branch initiation, while detopping disrupts apical dominance to redirect growth but limits overall vegetative proliferation in favour of sympodial fruiting branches. Significantly lower monopodial branches was recorded under regulated treatments compared to control. These results are align with Leal *et al*. (2020), Abbas *et al*. (2022) and Kumar and Kumar (2018)

Interactions between planting geometry and growth regulators revealed that wider spacing with the control maximized monipodial branches as seen in 90×30 cm with control, which achieved the higher pooled count of 1.90 at 110 DAS and 1.90 at harvest. Conversely, the closer spacing of 75×15 cm with mepiquat chloride @ 100 ppm recorded significantly recorded lower monopodial branches (1.06 at 110 DAS and 1.06 at harvest, respectively), which was on par with the interaction of 75×15 cm and detopping (1.13 at 110 DAS and 1.13 at harvest). It might be due to the reduced competition for resources in wider spacing allowing greater photosynthetic allocation to vegetative structures thereby enhancing monopodial outgrowth under unregulated conditions. It was also observed that the suppression of monopodial branches under higher planting density was due to shading-induced senescence of lower nodes and prioritization of vertical growth over lateral expansion. Similar differences in monopodial branches due to planting density and canopy management were reported by Pettigrew (2001), Hosamani *et al.* (2018), Shankaramurthy *et al.* (2019) and Ramesh *et al.* (2021).

Fibre Length, Fibre Strength and Micronaire Value

The results indicated that planting geometry had no significant influence on fibre quality attributes viz., fibre length, fibre strength and micronaire value of compact Bt cotton hybrid across the years 2023 and 2024 as well as in the pooled analysis. (Table 3). Although there were minor numerical variations such as slightly greater fiber length and strength observed at the wider planting spacing of 90×30 cm but statistical analysis showed no significant differences in fiber quality parameters across different plant densities. These results suggest that fiber quality characteristics are predominantly governed by genetic factors rather than environmental or management factors like planting density. Kotadiya *et al.* (2024)

Regarding growth regulators, the fiber length and strength were differed non significantly. Notably, micronaire value showed a significant reduction under MC (3.83 µg inch^{-1}) application compared to control (4.01 µg inch^{-1}), indicating that growth regulation modulated fiber fineness or maturity to some extent. This could be attributed to mepiquat chloride role in limiting excessive vegetative growth potentially favoring resource allocation to fiber quality development. Detopping had intermediate effects possibly due to altered assimilate partitioning after terminal bud removal. Tung *et al.* (2018) reported thatmepiquat chloride (MC) regulates cotton growth by limiting excessive vegetative growth which helps in better assimilate partitioning toward reproductive parts including fibers. It enhances fiber quality parameters such as micronaire by improving fiber maturation and fineness.

Interactions between planting geometry and growth regulators revealed that wider spacing with mepiquat chloride maximized fibre strength as observed in 90×30 cm with mepiquat chloride @ 100 ppm, which achieved the higher pooled strength of 31.03 g tex^{-1}. Conversely, the closest spacing of 75×15 cm with mepiquat chloride recorded significantly lower micronaire (3.78 µg inch^{-1}) which was on par with the interaction of 75×15 cm and control for strength deficits (30.13 g tex^{-1}). It might be due to the ample light penetration in wider spacings enhancing photosynthetic efficiency for fibre development under chemical regulation, thereby optimizing wall thickness and bundle integrity. It was also observed that the marginal decline in quality under higher planting density was due to intra-canopy shading and N competition impairing secondary wall synthesis, contrasting with low-density setups that foster even maturation. Similar differences in fibre quality due to planting density and growth regulators were reported by Bednarz *et al.* (2002), Davidonis *et al.* (2006), Byregowda *et al.* (2015) and May and Morrison (2019).

Table 1: Plant height of compact *Bt* cotton hybrid at different growth stages as influenced by plant densities and canopy management practices

Treatments	50 DAS			80 DAS			110 DAS			At harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Main plot: Planting geometry												
P_1:90×30 cm	58.0^{c}	62.0^{c}	60.0^{c}	89.1^{c}	99.5^{b}	94.3^{b}	105.4^{c}	114.7^{c}	110.1^{c}	110.4^{c}	123.6^{c}	119.0^{c}
P_2:90×15 cm	66.0^{a}	69.3^{ab}	67.7^{a}	97.6^{a}	111.2^{a}	104.4^{a}	115.9^{b}	127.2^{ab}	121.6^{b}	120.9^{b}	136.8^{b}	132.2^{b}
P_3:75×30 cm	61.9^{b}	64.9^{bc}	63.4^{b}	91.2^{b}	103.7^{b}	97.5^{b}	113.3^{b}	120.3^{bc}	116.8^{bc}	118.3^{b}	129.1^{c}	123.6^{c}
P_4:75×15 cm	68.3^{a}	73.2^{a}	70.7^{a}	103.0^{a}	115.5^{a}	109.3^{a}	123.5^{a}	135.4^{a}	129.4^{a}	128.5^{a}	143.6^{a}	137.9^{a}
S.Em.±	**0.87**	**1.25**	**0.95**	**1.32**	**2.21**	**1.50**	**1.60**	**3.14**	**2.18**	**2.10**	**1.96**	**1.41**
Growth regulators:R												
R_1: MC @ 100 ppm	63.8^{a}	67.4^{a}	65.6^{a}	95.5^{a}	107.0^{a}	101.3^{a}	109.2^{a}	119.6^{a}	114.4^{a}	114.2^{a}	127.5^{a}	122.6^{a}
R_2: Detopping	63.6^{a}	67.2^{a}	65.4^{a}	95.1^{a}	108.2^{a}	101.6^{a}	112.5^{a}	122.9^{a}	117.7^{a}	117.5^{a}	131.7^{a}	126.7^{a}
R_3: Control	63.2^{a}	67.6^{a}	65.4^{a}	95.0^{a}	107.2^{a}	101.1^{a}	121.9^{b}	130.7^{b}	126.3^{b}	126.9^{b}	140.7^{b}	135.2^{b}
S.Em.±	**1.68**	**1.81**	**1.72**	**2.54**	**2.69**	**2.19**	**2.99**	**2.90**	**2.87**	**3.10**	**3.52**	**3.13**
Interactions (PxR)												
P_1R_1	58.1^{c}	62.2^{b}	60.2^{b}	89.5^{bc}	98.4^{c}	94.0^{d}	100.2^{e}	110.8^{d}	105.5^{e}	105.2^{d}	117.9^{d}	113.6^{e}
P_1R_2	58.7^{bc}	62.0^{b}	60.4^{b}	89.2^{c}	100.2^{bc}	94.7^{d}	103.6^{de}	112.9^{d}	108.3^{de}	108.6^{cd}	121.3^{cd}	117.6^{de}

P_1R_3	57.2^{c}	61.9^{b}	59.6^{b}	88.5^{c}	99.8^{bc}	94.2^{d}	112.5^{b-e}	120.4^{b-d}	116.5^{b-e}	117.5^{b-d}	131.7^{b-d}	126^{b-e}
P_2R_1	65.8^{a-c}	69.9^{ab}	67.9^{ab}	98.8^{a-c}	111.5^{a-c}	105.2^{a-d}	109.2^{c-e}	121.6^{b-d}	115.4^{b-e}	114.2^{b-d}	130.7^{b-d}	126.5^{b-e}
P_2R_2	66.9^{ab}	68.5^{ab}	67.7^{ab}	97.3^{a-c}	111.8^{a-c}	104.6^{a-d}	113.8^{b-e}	125.8^{a-d}	119.8^{b-e}	118.8^{b-d}	135.6^{a-d}	131.2^{a-d}
P_2R_3	65.3^{a-c}	69.6^{ab}	67.5^{ab}	96.7^{a-c}	110.2^{a-c}	103.5^{a-d}	124.7^{ab}	134.3^{ab}	129.5^{ab}	129.7^{ab}	144.2^{ab}	139.1^{ab}
P_3R_1	62.2^{a-c}	64.6^{ab}	63.4^{ab}	90.4^{a-c}	103.7^{a-c}	97.0^{d}	108.9^{c-e}	115.1^{cd}	112^{c-e}	113.9^{b-d}	123.1^{cd}	117.7^{de}
P_3R_2	61.6^{a-c}	65.0^{ab}	63.3^{ab}	90.9^{a-c}	104.3^{a-c}	97.6^{cd}	111.4^{b-e}	119.2^{b-d}	115.3^{b-e}	116.4^{b-d}	127.6^{b-d}	122^{c-e}
P_3R_3	61.8^{a-c}	65.2^{ab}	63.5^{ab}	92.3^{a-c}	103.2^{a-c}	97.8^{b-d}	119.6^{a-c}	126.5^{a-d}	123.1^{a-d}	124.6^{a-c}	136.5^{a-d}	131^{a-d}
P_4R_1	69.1^{a}	72.8^{a}	71.0^{a}	103.4^{a}	114.4^{ab}	108.9^{a-c}	118.5^{a-d}	130.9^{a-c}	124.7^{a-c}	123.5^{a-c}	138.2^{a-c}	132.7^{a-d}
P_4R_2	67.3^{a}	73.2^{a}	70.3^{a}	102.9^{a}	116.5^{a}	109.7^{a}	121.3^{a-c}	133.5^{ab}	127.4^{a-c}	126.3^{ab}	142.1^{ab}	136.2^{a-c}
P_4R_3	68.5^{a}	73.5^{a}	71.0^{a}	102.6^{ab}	115.7^{a}	109.2^{ab}	130.6^{a}	141.7^{a}	136.2^{a}	135.6^{a}	150.5^{a}	144.7^{a}
S.Em.±	**2.88**	**3.20**	**2.96**	**4.35**	**4.91**	**3.88**	**5.14**	**5.67**	**5.17**	**5.49**	**6.07**	**5.30**

Table 2: Number of monopodial of compact *Bt* cotton hybrid at different growth stages as influenced by plant densities and canopy management practices

Treatments	50 DAS			80 DAS			110 DAS			At harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Main plot: Planting geometry												
P_1:90×30 cm	1.02^{a}	0.98^{ab}	1.02^{a}	1.24^{a}	1.30^{a}	1.27^{a}	1.70^{a}	1.77^{a}	1.74^{a}	1.70^{a}	1.77^{a}	1.74^{a}
P_2:90×15 cm	0.81^{c}	0.80^{c-e}	0.81^{c}	1.03^{c}	1.08^{b}	1.06^{c}	1.38^{c}	1.28^{c}	1.33^{c}	1.38^{c}	1.28^{c}	1.33^{c}
P_3:75×30 cm	0.91^{b}	0.95^{a-c}	0.92^{b}	1.13^{b}	1.23^{a}	1.18^{b}	1.56^{b}	1.58^{b}	1.57^{b}	1.56^{b}	1.58^{b}	1.57^{b}
P_4:75×15 cm	0.69^{d}	0.77^{de}	0.73^{d}	0.90^{d}	0.99^{b}	0.95^{d}	1.27^{d}	1.14^{d}	1.21^{d}	1.27^{d}	1.14^{d}	1.21^{d}
S.Em.±	**0.013**	**0.029**	**0.018**	**0.016**	**0.033**	**0.024**	**0.023**	**0.040**	**0.027**	**0.023**	**0.040**	**0.027**
Growth regulators:R												
R_1: MC @ 100 ppm	0.84^{a}	0.89^{a}	0.86^{a}	1.06^{a}	1.16^{a}	1.11^{a}	1.34^{b}	1.31^{b}	1.32^{b}	1.34^{b}	1.31^{b}	1.32^{b}
R_2: Detopping	0.88^{a}	0.88^{a}	0.88^{a}	1.09^{a}	1.14^{a}	1.11^{a}	1.41^{b}	1.39^{b}	1.40^{b}	1.41^{b}	1.39^{b}	1.40^{b}
R_3: Control	0.86^{a}	0.88^{a}	0.86^{a}	1.08^{a}	1.16^{a}	1.12^{a}	1.69^{a}	1.63^{a}	1.66^{a}	1.69^{a}	1.63^{a}	1.66^{a}
S.Em.±	**0.023**	**0.026**	**0.024**	**0.029**	**0.024**	**0.026**	**0.039**	**0.035**	**0.034**	**0.039**	**0.035**	**0.034**
Interactions (PxR)												
P_1R_1	0.98^{ab}	1.01^{ab}	1.00^{ab}	1.20^{a-c}	1.27^{a}	1.24^{a}	1.56^{cd}	1.69^{bc}	1.63^{bc}	1.56^{cd}	1.69^{bc}	1.63^{bc}
P_1R_2	1.04^{a}	1.03^{a}	1.04^{a}	1.24^{ab}	1.32^{a}	1.28^{a}	1.66^{bc}	1.71^{bc}	1.68^{bc}	1.66^{bc}	1.71^{bc}	1.68^{bc}
P_1R_3	1.05^{a}	0.98^{ab}	1.02^{ab}	1.28^{a}	1.30^{a}	1.29^{a}	1.89^{a}	1.92^{a}	1.90^{a}	1.89^{a}	1.92^{a}	1.90^{a}
P_2R_1	0.77^{e-g}	0.86^{b-e}	0.82^{c-e}	1.00^{e-h}	1.12^{b-d}	1.06^{b-f}	1.24^{ef}	1.16^{fg}	1.2^{fg}	1.24^{ef}	1.16^{fg}	1.2^{fg}
P_2R_2	0.8^{d-f}	0.80^{cde}	0.80^{de}	1.03^{d-g}	1.05^{d}	1.04^{c-f}	1.27^{ef}	1.25^{ef}	1.26^{ef}	1.27^{ef}	1.25^{ef}	1.26^{ef}
P_2R_3	0.85^{c-e}	0.80^{c-e}	0.83^{c-e}	1.07^{c-f}	1.08^{cd}	1.08^{b-e}	1.64^{bc}	1.44^{de}	1.54^{cd}	1.64^{bc}	1.44^{de}	1.54^{cd}
P_3R_1	0.91^{b-d}	0.89^{a-e}	0.90^{b-d}	1.13^{b-e}	1.24^{ab}	1.19^{ab}	1.42^{de}	1.39^{de}	1.41^{de}	1.42^{de}	1.39^{de}	1.41^{de}
P_3R_2	0.96^{a-c}	0.92^{a-d}	0.94^{a-c}	1.16^{a-d}	1.20^{a-c}	1.18^{a-c}	1.50^{cd}	1.56^{cd}	1.53^{cd}	1.50^{cd}	1.56^{cd}	1.53^{cd}
P_3R_3	0.87^{b-e}	0.95^{a-c}	0.91^{b-d}	1.11^{b-e}	1.25^{ab}	1.18^{a-d}	1.77^{ab}	1.78^{ab}	1.78^{ab}	1.77^{ab}	1.78^{ab}	1.78^{ab}
P_4R_1	0.7^{fg}	0.79^{de}	1.00^{ab}	0.91^{gh}	1.01^{d}	0.96^{ef}	1.13^{f}	0.99^{g}	1.06^{g}	1.13^{f}	0.99^{g}	1.06^{g}
P_4R_2	0.73^{fg}	0.75^{e}	1.04^{a}	0.94^{f-h}	0.98^{d}	0.96^{ef}	1.21^{f}	1.05^{g}	1.13^{fg}	1.21^{f}	1.05^{g}	1.13^{fg}
P_4R_3	0.65^{g}	0.77^{de}	1.02^{ab}	0.86^{h}	0.99^{d}	0.92^{f}	1.47^{cd}	1.38^{de}	1.43^{de}	1.47^{cd}	1.38^{de}	1.43^{de}
S.Em.±	**0.040**	**0.052**	**0.043**	**0.050**	**0.052**	**0.048**	**0.068**	**0.069**	**0.062**	**0.068**	**0.069**	**0.062**

Table 3: Fibre length, fibre strength and micronaire value of compact *Bt* cotton hybrid as influenced by plant densities and canopy management practices

Treatments	**Fibre length (mm)**			**Fibre strength (g tex^{-1})**			**Micronaire value (µg inch^{-1})**		
	2023	**2024**	**Pooled**	**2023**	**2024**	**Pooled**	**2023**	**2024**	**Pooled**
P_1:90×30 cm	30.7^{a}	31.7^{a}	31.2^{a}	30.05^{a}	31.45^{a}	30.75^{a}	3.88^{a}	4.08^{a}	3.98^{a}
P_2:90×15 cm	30.3^{a}	31.4^{a}	30.8^{a}	29.62^{a}	31.08^{b}	30.35^{a}	3.70^{a}	4.07^{a}	3.88^{a}
P_3:75×30 cm	30.2^{a}	31.6^{a}	30.9^{a}	29.90^{a}	31.12^{b}	30.51^{a}	3.80^{a}	4.08^{a}	3.94^{a}
P_4:75×15 cm	30.1^{a}	31.7^{a}	30.8^{a}	29.45^{a}	31.03^{b}	30.24^{a}	3.67^{a}	4.06^{a}	3.86^{a}
S.Em.±	**0.44**	**0.45**	**0.44**	**0.19**	**0.08**	**0.10**	**0.07**	**0.02**	**0.04**
R_1: MC @ 100 ppm	30.5^{a}	31.7^{a}	31.1^{a}	29.91^{a}	31.30^{a}	30.61^{a}	3.63^{b}	4.03^{b}	3.83^{b}
R_2: Detopping	30.3^{a}	31.6^{a}	30.9^{a}	29.68^{a}	31.19^{a}	30.43^{a}	3.75^{ab}	4.06^{ab}	3.91^{b}
R_3: Control	30.2^{a}	31.4^{a}	30.8^{a}	29.68^{a}	31.03^{b}	30.35^{a}	3.91^{a}	4.12^{a}	4.01^{a}
S.Em.±	**0.81**	**0.84**	**0.83**	**0.08**	**0.05**	**0.05**	**0.05**	**0.02**	**0.03**
P_1R_1	30.9^{a}	31.8^{a}	31.4^{a}	30.40^{a}	31.65^{a}	31.03^{a}	3.80^{a-c}	4.00^{b}	3.90^{bc}

P_1R_2	30.7^{a}	31.7^{a}	31.2^{a}	$29.90^{a\text{-}d}$	$31.35^{a\text{-}c}$	30.63^{b}	3.85^{ab}	4.05^{b}	$3.95^{a\text{-}c}$
P_1R_3	30.6^{a}	31.6^{a}	31.1^{a}	$29.85^{a\text{-}d}$	$31.35^{a\text{-}c}$	30.60^{b}	4.00^{a}	4.20^{a}	4.10^{a}
P_2R_1	30.4^{a}	31.5^{a}	30.9^{a}	$29.85^{a\text{-}d}$	$31.25^{b\text{-}d}$	30.55^{bc}	3.50^{c}	4.05^{b}	3.78^{c}
P_2R_2	30.3^{a}	31.4^{a}	30.8^{a}	$29.50^{b\text{-}d}$	$31.15^{b\text{-}e}$	$30.33^{b\text{-}d}$	$3.70^{a\text{-}c}$	4.05^{b}	3.88^{bc}
P_2R_3	30.1^{a}	31.2^{a}	30.6^{a}	$29.50^{b\text{-}d}$	30.85^{e}	30.18^{cd}	3.90^{ab}	4.10^{ab}	4.00^{ab}
P_3R_1	30.2^{a}	31.6^{a}	30.9^{a}	30.15^{ab}	$31.05^{c\text{-}e}$	30.60^{b}	$3.70^{a\text{-}c}$	4.03^{b}	3.87^{bc}
P_3R_2	30.1^{a}	31.7^{a}	30.9^{a}	29.45^{cd}	31.40^{ab}	$30.43^{b\text{-}d}$	$3.80^{a\text{-}c}$	4.10^{ab}	$3.95^{a\text{-}c}$
P_3R_3	30.5^{a}	31.4^{a}	30.9^{a}	$30.10^{a\text{-}c}$	30.90^{e}	$30.50^{b\text{-}d}$	3.90^{ab}	4.10^{ab}	4.00^{ab}
P_4R_1	30.3^{a}	31.7^{a}	31.0^{a}	29.25^{d}	$31.25^{b\text{-}d}$	$30.25^{b\text{-}d}$	3.50^{c}	4.05^{b}	3.78^{c}
P_4R_2	30.2^{a}	31.6^{a}	30.9^{a}	$29.85^{a\text{-}d}$	30.85^{e}	$30.35^{b\text{-}d}$	3.65^{bc}	4.05^{b}	3.85^{bc}
P_4R_3	29.9^{a}	31.4^{a}	30.6^{a}	29.25^{d}	31.00^{de}	30.13^{d}	3.85^{ab}	4.07^{b}	$3.96^{a\text{-}c}$
S.Em.±	**1.39**	**1.45**	**1.42**	**0.23**	**0.11**	**0.13**	**0.11**	**0.04**	**0.06**

Conclusion

The present study reveals that planting geometry and canopy management jointly shape the growth and fiber quality of compact Bt cotton under semi-arid conditions. High-density planting (75×15 cm) promotes taller plants but reduces monopodial branches favoring reproductive growth. Growth regulators like mepiquat chloride (100 ppm) and detopping effectively limit excessive vegetative growth and improving fiber strength while slightly reducing micronaire values. Optimal interactions, such as 90×30 cm spacing with mepiquat chloride and 75×15 cm with detopping, enhance fiber quality and balanced branching. These findings emphasize the importance of integrative canopy management combining both geometry and growth regulation to optimize both yield and fiber quality in compact Bt cotton hybrid.

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