E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 175-179
Received: 19-06-2025
Accepted: 21-07-2025

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Growth, yield and economics in high density planting system and canopy management practices in *Bt* cotton under drip irrigation

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9c.3742

Abstract
A field trial was conducted at Cotton Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *kharif* season of 2024-25 to evaluated the Growth, yield and economics in high density planting system and canopy management practices in *Bt* cotton under drip irrigation. The experiment was laid out Factorial Randomized Block Design with three replications and twelve treatment combinations. The field was equipped with an inline drip irrigation system with 16 mm laterals placed at 90 cm apart and drippers spaced 40 cm apart. The results showed that planting at 90 cm x 45 cm provided better crop growth, dry matter accumulation, leaf area, chlorophyll content, number of sympodial branches per plant, number of picked bolls per plant, and seed cotton yield per plant compared to plant spacing of 90 cm x 15 cm and 90 cm x 30 cm. However, the plant spacing of 90 cm x 15 cm gave the highest seed cotton yield at 4121 kg/ha and highest harvest index of 45.78, which was significantly better than the wider spacing. This also led to the highest gross monetary return (300761 Rs/ha), net monetary return (202209 Rs/ha) and a better benefit:cost ratio (3.05) compared to wider spacing. The study also found that canopy management practices, such as monopodia removal at 45-50 DAS and detopping at 100 cm plant height, helped to increase the number of sympodial branches per plant, number of picked bolls, seed cotton yield per plant, and overall seed cotton yield in kg/ha as compared to no canopy management. The treatment involving monopodia removal at 45-50 DAS and detopping at 100 cm plant height gave the highest seed cotton yield of 4119 kg/ha, along with the highest GMR (300484 Rs/ha), NMR (202050 Rs/ha), and B:C ratio (3.05) compared to the control. The second best treatment of seed cotton yield (3859 kg/ha) was recorded in the C4 treatment (two sprays of mepiquat chloride @25 g a.i. at 45-50 DAS and 60-65 DAS)

Keywords: Drip, plant geometry, canopy management, detopping, monopodia removal, PGR, economics

Introduction
Cotton is the most important crops in India and plays a significant role in agriculture and industry worldwide. As per data from the USDA, for the year 2024-25, the expected area under cotton cultivation is 31.1 million hectares and the production is 117.40 million bales, each weighing 217.72 kg. This is an increase of 4.4 lakh bales or 3.89% compared to the previous year estimate. The highest producing countries are China, India, Brazil, the United States, and Pakistan. China is largly produce 28.20 lakh bales, India 25 million bales, Brazil 16.90 million bales, the United States 14.30 million bales, and Pakistan 5.50 million bales. The area under cotton production in China was projected to be 2.85 million hectares in 2023-2024. The first advance estimates indicate that the cotton production is 299.26 lakh bales, which is less than the 325.22 lakh tonnes in 2023-2024.

Among the states, Maharashtra is the producer highest with 84.80 lakh bales followed by Gujarat (80.01 lakh bales), Telangana (48.95 lakh bales), Rajasthan (20.42 lakh bales), and Karnataka (18.56 lakh bales). As of 27 September 2024, the area under cotton for 2024-25 is 112.94 lakh hectares, which is less than the 123.70 lakh hectares covered in 2023-24. Maharashtra occupied in cotton area with 40.86 lakh hectares, followed by Gujarat (23.66 lakh hectares), Telangana (17.70 lakh hectares), Karnataka (6.84 lakh hectares), and Madhya Pradesh (6.14 lakh hectares).

This experiment was conducted to study the growth and development of *Bt* cotton hybrids by using detopping, pruning, and growth retardants to enhance productivity under drip irrigation. Cotton productivity largely depends on using high-yielding varieties and hybrids along with advanced farming methods. While *Bt* cotton has greatly increased yields, other factors can help improve cotton production. These factors include good soil fertility, use of chemical fertilizers, and proper irrigation, which can lead to more vegetative growth. This can cause the plant to grow too much foliage, which often results in lower yields. This type of growth can also lead to the early dropping of flowers and buds, cause delays in maturity, increase the chances of boll rot due to shading, and reduces overall yield. To prevent this problems, it is important to use growth regulation techniques that shift the plants focus from growing leaves to producing bolls and ensuring a good balance of nutrients between the plant parts.

Maintaining a balance between vegetative and reproductive growth is a important part of successful cotton production. This can be achieved by canopy management practices like detopping and pruning of vegetative branches. Detopping involves cutting the top of the plant once it has grown enough, which encourages the growth of more branches and helps develop more bolls per plant. This practice is especially effective when done after the plant has reached a good stage of vegetative growth. Monopodial branches that come from the base can block the growth of other branches, so removing them is important for increasing the number of bolls per plant and improving overall yield. Clearing these branches also allows more light to reach the plants and reduces shading, which helps the plants grow better. Using growth retardants like mepiquat chloride can also be very beneficial. These help shorten the length between leaves, reduce plant height, and direct the plant's resources toward bolls, which increases yield. Mepiquat chloride is the most commonly used plant growth regulator in cotton. It helps control excessive growth, increases yield and fibre quality, and is also effective in improving seed cotton yield. It is important to monitor crops, manage nutrients, and control the plant canopy to improve the harvest index. This experiment was conducted to study the growth and development of *Bt* cotton hybrids by using detopping, pruning, and growth retardants to enhance productivity under drip irrigation.

Materials and Methods

The field experiment entitled "Growth, yield and economics in high density planting system and canopy management practices in *Bt* cotton under drip irrigation" was conducted at the Cotton Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *kharif* season of 2024 25. The main goal was to study how detopping, pruning of the vegetative branches and using plant growth retardants can help improve the productivity of *Bt* cotton under drip irrigation. The experiment was laid out at Factorial Randomized Block Design with three replications and twelve treatment combinations. These treatments included three different plant geometry *viz*., 90 cm x 15 cm (S1), 90 cm x 30 cm (S2), and 90 cm x 45 cm (S3). For canopy management, there were four treatments: Control (C1), monopodial removal at 45-50 DAS and detopping at 100 cm plant height (C2), monopodial removal at 45-50 DAS and one spray of mepiquat chloride @ 25 g a.i. at 60-65 DAS (C3), and two sprays of mepiquat chloride @ 25 g a.i. at 45-50 DAS and 60-65 DAS (C4). The field had a fairly flat and uniform topography. The soil was black and clayey, belonging to vertisols, and had a slightly alkaline reaction (pH 8.10). It had available nitrogen of 214 kg/ha, medium levels of phosphorus at 16.80 kg/ha, fairly high levels of available potassium at 308 kg/ha and organic carbon at 4.16 g kg^{-1}. The farm used an inline drip irrigation system with 16 mm lateral lines placed at 90 cm intervals and 40 cm dripper spacing. Cotton planting was done on 6th July 2024 at the three different spacing, using an RDF of 120:60:60 NPK kg/ha. Water was applied through drip irrigation every alternate day based on cumulative pan evaporation. The quantity of water required per plant was calculated using a formula by Michael (2008) [16]. nutrient was supplied using urea (46% N), single super phosphate (16% P2O5), and murate of potash (60% K2O) respectively.

Results and Discussion

The results and discussion of the present study have been summarized under following heads:

Effect of plant geometry

The data in table 1 showed that among different plant geometry, the highest plant height (129.50 cm) was found in the high density planting with plant spacing of 90 cm x 15 cm. This was followed by lower plant densities with plant spacing of 90 cm x 30 cm (120.73 cm) and 90 cm x 45 cm (115.17 cm). The highest plant height in high density planting was due to more competition between plants. Similar results have been reported by Paslawar *et al*. (2015) [18], Parihar *et al*. (2018) [17], and Gouthami *et al.*

Table 1: Growth characters and yield attributes of *Bt* cotton as influenced by different plant geometry and canopy management under drip irrigation.

Treatment	Plant height (cm)	Leaf area (dm^2)	Chlorophyll content Index	Total dry matter plant^{-1} (g)	No. of sympodia plant^{-1}	No. of picked bolls plant^{-1}	Seed cotton yield plant^{-1} (g)
I. Plant geometry							
S1: 90 x 15 cm	129.50	25.33	32.24	299.60	17.02	19.60	91.08
S2: 90 x 30 cm	120.73	28.67	36.47	365.23	20.84	28.77	142.43
S3: 90 x 45 cm	115.17	31.43	37.41	395.03	24.98	35.28	171.41
SE (m) ±	1.80	1.24	0.59	5.54	0.91	0.98	3.68
CD at 5%	5.28	3.62	1.72	16.24	2.66	2.89	10.80
II. Canopy management practice							
C1: Control	138.76	34.27	33.69	321.95	14.99	23.94	115.41
C2: Monopodia removal at 45-50 DAS detopping at 100 cm plant height	104.89	24.90	36.93	386.20	26.72	30.98	153.51
C3: Monopodia removal at 45-50 DAS and one spray of mepiquat chloride @ 25 g a.i. at 60-65 DAS	132.99	28.93	34.27	354.46	18.66	28.01	133.37
C4: Two spray of mepiquat chloride @ 25 g a.i. at 45-50 DAS and 60-65 DAS	110.56	25.79	36.61	350.54	23.43	28.60	137.59
SE (m) ±	2.08	1.43	0.68	6.39	1.05	1.14	4.25

CD at 5%	6.09	4.19	1.98	18.75	3.08	3.33	12.47
Interaction (S X C)							
SE(m) ±	3.60	2.47	1.17	11.07	1.82	1.97	7.36
CD at 5%	NS	NS	NS	NS	NS	NS	NS

Table 2: Seed cotton yield (kg ha^{-1}), harvest index and economics of *Bt* cotton influenced by different plant geometry and canopy management practices under drip irrigation.

Treatment	Seed cotton yield (kg ha^{-1})	Harvest index (%)	GMR (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C Ratio
I. Plant geometry					
S1- 90 x 15 cm	4121	45.78	300761	202209	3.05
S2- 90 x 30 cm	3589	45.44	262069	170790	2.87
S3- 90 x 45 cm	3139	42.85	229817	144058	2.68
SE (m) ±	80	-	5796	5240	-
CD at 5%	235	-	16999	15369	-
II. Canopy management practice					
C1- Control	3037	42.97	222279	139120	2.67
C2- Monopodia removal at 45-50 DAS detopping at 100 cm plant height	4119	46.23	300484	202050	3.05
C3- Monopodia removal at 45-50 DAS and one spray of mepiquat chloride @ 25 g a.i. at 60-65 DAS	3452	44.27	252322	158890	2.70
C4- Two spray of mepiquat chloride @ 25 g a.i. at 45-50 DAS and 60-65 DAS	3859	45.26	281779	189350	3.04
SE (m) ±	92	-	6693	6051	-
CD at 5%	271	-	19629	17747	-
Interaction (S X C)					
SE(m) ±	160	-	11592	10480	
CD at 5%	NS	-	NS	NS	

(2023) [5]. The maximum leaf area (31.43 dm²), highest chlorophyll content (37.41) and the highest dry matter accumulation per plant (395.03 g) were recorded in the wider plant spacing of 90 cm x 45 cm compared to the narrower plant spacing of 90 cm x 15 cm (299.60 g) and 90 cm x 30 cm (365.23 g). The best accumulation of dry matter and proper distribution of nutrients to the growing parts helped the crop reach its maximum yield potential. Similar results were found by Jagtap and Bhale (2011) [9] and Paslawar *et al*. (2015) [18].

The yield attributes characters, such as number of picked bolls per plant (35.28) and seed cotton yield per plant (171.41), were found highest in the wider spacing of 90 cm x 45 cm compared to the closer spacing. This was reported by Gouthami *et al*. (2023) [5]. However, the lowest number of bolls per plant in closer spacing was made up for by having more plants per hectare, which led to a significantly higher total seed cotton yield (4121 kg/ha) in the closer plant spacing of 90 cm x 15 cm compared to wider spacing of 90 cm x 30 cm (3689 kg/ha) and 90 cm x 45 cm (3139 kg/ha). Similar results were found by Solanki *et al*. (2020) [22] and Gouthami *et al*. (2023) [5].

Canopy management practices

Different canopy management practices like removing monopodia, detopping and using plant growth retardant showed significant changes in plant growth, yield attributes and seed cotton yield in kg/ha. All the growth parameters significantly influenced to different canopy management practices. The control (C1) treatment recorded highest plant height (138.76 cm) and greatest leaf area (34.27 cm). Lower plant height and leaf area observed in other canopy treatments (C2, C3 and C4) was noticed because of detopping practices and mepiquat chloride spray as a growth retardant. The treatment where monopodia removal at 45-50 DAS and detopping at 100 cm plant height had showed the highest chlorophyll content (36.93) and greater number of sympodial branches per plant (26.72). The next best treatment was two spray of mepiquat chloride @ 25 g a.i. at 45-50 DAS and 60-65 DAS (C4). Removing monopodia and detopping practices helps to create more numbers of sympodial branches per plant, which improves the movement of nutrients to the plant parts that make proper seed growth and leading to more branches per plant. This results reported by Hallikeri *et al*. (2010) [6], Kataria and Valu (2018) [12], Dodiya *et al*. (2018) [2], and Chaudhari *et al*. (2021) [1].

This same treatment also led to the highest dry matter accumulation per plant. The highest total dry matter (386.20 g) was showed in C2 treatment (monopodia removal at 45-50 DAS and detopping at 100 cm plant height), followed by dry matter (354.46 g) in C3 treatment (monopodia removal at 45-50 DAS and one spray of mepiquat chloride @ 25 g a.i. at 60-65 DAS). The control treatment had recorded least dry matter (321.95 g). Similar results were found by Turkhade *et al*. (2003) [23].

In terms of yield, C2 treatment (monopodia removal at 45-50 DAS and detopping at 100 cm plant height) were found significantly superior in number of bolls per plant (30.98) and the highest seed cotton yield per plant (153.51 g). All the growth and yield attributes in canopy management practices resulted in increased seed cotton yield was 4119 kg/ha in C2 treatment (monopodia removal at 45-50 DAS and detopping at 100 cm plant height), which was followed by seed cotton yield of 3859 kg/ha in C4 treatment (two spray of mepiquat chloride @ 25 g a.i. at 45-50 DAS and 60-65 DAS). However, C2 and C4 were found significantly at par with each other in respect of seed cotton yield. Similar result found by Jadhav *et al*. (2019) [8] and Chaudhari *et al*. (2021) [1]. Kaul *et al*. (2016) [13] also showed that mepiquat chloride sprays helps to grow better cotton plants and increase yield. C2 treatment (monopodia removal at 45-50 DAS and detopping at 100 cm plant height) gave a 26.27% higher yield than the control.

Since cotton grows continuously, detopping after plant reaches 100 cm plant height helps better growth of existing branches and increases the number and size of bolls. This C2 treatment (monopodia removal at 45-50 DAS and detopping at 100 cm

plant height) worked best in this experiment and observed highest harvest index of 46.23%. Similar results have been reported by Kataria and Valu (2018) [12], Singh *et al*. (2014) [21], Veeraputhiran *et al*. (2020) [24], Jadhav *et al*. (2019) [8], Chaudhari *et al*. (2021) [1], and Kakade *et al*. (2023) [10]

Interaction

Interaction effects of different plant geometry and different canopy management practices in cotton didn't show significant difference in all growth factors like plant height, leaf area, chlorophyll content, dry weight per plant, no. of sympodial branches and no. of bolls per plant. Also, other yield attributes such as number of picked bolls per plant, seed cotton per plant, and total seed cotton yield in kg/ha didn't show significant different in plant geometry and canopy management practices.

Economics

The 90 cm x 15 cm plant spacing gave higher GMR (300761 Rs/ha), NMR (202209 Rs/ha), and B:C ratio (3.05) as compared to 90 cm x 30 cm and 90 cm x 45 cm plant spacing (Table 2). These results were reported by Ghule *et al*. (2013) [3] and Karle *et al*. (2015) [11]. Among the canopy management practices, C2 treatment (monopodia removal at 45-50 DAS and detopping at 100 cm plant height) gave highest GMR (300484 Rs/ha), NMR (202050 Rs/ha) and B:C ratio (3.05) compared to other canopy management practices. The next best treatment followed by C4 (two spay of mepiquat chloride @ 25 g a.i. at 45-50 DAS and 60-65 DAS) and C3 (monopodia removal at 45-50 DAS and one spay of mepiquat chloride @ 25 g a.i. at 60-65 DAS) in respect of GMR, NMR and B:C ratio. The lowest GMR (222279 Rs/ha), NMR (139120 Rs/ha), and B:C ratio (2.67) were recorded in the control treatment (C1), which had no canopy management practices was adopted. Canopy management with monopodia removal at 45-50 DAS and detopping at 100 cm plant height obtained 26.03% increased in NMR compared to the control treatment, which showing the importance of canopy management in *Bt* cotton under irrigation. Similar results found with GMR, NMR and B:C ratio was also reported earlier by Shwetha *et al*. (2009) [20], Gohil *et al*. (2023) [4] and Kakade *et al*. (2023) [10].

Conclusion

The study found that 90 cm x 45 cm plant spacing gave better growth and yield attributes characters and higher seed cotton yield per plant. However, 90 cm x 15 cm plant spacing gave the highest seed cotton yield in kg/ha, better harvest index, GMR, NMR and B:C ratio under drip irrigation. The study also showed that canopy management practices like removing monopodial branches and detopping help in getting more seed cotton yield than no canopy management practices. Using mepiquat chloride sprays also helped increase seed cotton yield compared to the control. Overall, canopy management practices produces higher GMR, NMR, and B:C ratio as compared to the farmer practices (control).

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