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Total dry matter accumulation, dry matter partitioning and uptake of nitrogen, phosphorus and potassium in high density planting system and canopy management operations in *Bt* cotton under rainfed situation

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Abstract
The field investigation titled "Total dry matter accumulation, dry matter partitioning and uptake of nitrogen, phosphorus and potassium in high density planting system and canopy management operations in *Bt* cotton under rainfed situation." was accomplished at the Cotton Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola throughout the *Kharif* season 2024-2025. Three separate trials were set up using a Randomized Block Design to set up the experiment. Eight different treatments were applied, each involving different methods of managing the plant canopy and varying level of HDPS. Experimental results revealed that, mepiquat chloride @45ppm at square initiation and 15 days after first spray had highest total dry matter accumulation at harvest (199.17 g/plant) and dry matter distribution to different plant components of cotton. At harvest, significantly higher dry matter accumulation of leaves (23.79), stem (55.07) and fruting bodies (120.31) was recorded in treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray). The total nutrient uptake of nitrogen (76.83 kg ha^{-1}), phosphorus (24.40 kg ha^{-1}) and potassium (56.84 kg ha^{-1}) was seen highest with the application of the mepiquat chloride @45ppm at square initiation and 15 days after first spray.

Keywords: *Bt* cotton, HDPS, Detopping, Mepiquat chloride, canopy management practices, Dry matter accumulation, uptake of nutrients

Introduction
Cotton comes from the Arabic word "Quntun." it is part of the Malvaceae family, often called "White Gold" or "King of Fibre." It plays a important role in the economy of rural regions, the country, and all around the world. Cotton belongs to the group Malvales, the family Malvaceae, and the genus Gossypium. The cotton species recognized in the world are about 50, of which four are commercially grown species of cotton. *Gossypium hirsutum* (tetraploid) - known as upland cotton, native to Central America, Mexico, the Caribbean and southern Florida (90% of world production) (Beckert, 2014) [3]. *Gossypium barbadense* (tetraploid) - known as extra-long staple cotton, native to tropical South America (8% of world production). *Gossypium arboreum* (diploid) - known as tree cotton, native to India and Pakistan (less than 2%) and *Gossypium herbaceum* (diploid) - known as Levant cotton, native to southern Africa and the Arabian Peninsula (less than 2%). Hybrid varieties are also cultivated (Singh, 2023) [14]. While cotton fibers found naturally in colors of white, brown, pink and green, fears of contaminating the genetics of white cotton have led many cotton-growing locations to ban the growing of colored cotton varieties.
Cotton farming in India supports the livelihoods of nearly 6 million farmers. Additionally, about 40 to 50 million people are involved in jobs related to cotton, such as trading, processing, and making clothes. Cotton makes up two-thirds of the total fiber used in India's textile industry. According to the first advance estimates for 2024-25, the cotton crop is expected to be about 299.26 lakh bales, which is less than the 325.22 lakh tonnes produced in 2023-24. Among the states, Maharashtra is the top producer 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 September 27, 2024, the area used for growing cotton in the 2024-25 season is 112.94 lakh hectares. This is lower than the 123.70 lakh hectares used in the previous season, 2023-24. Among the states, Maharashtra has the highest cotton area with 40.86 lakh hectares. Gujarat comes next with 23.66 lakh hectares, followed by Telangana at 17.70 lakh hectares, Karnataka with 6.84 lakh hectares, and Madhya Pradesh with 6.14 lakh hectares.

Materials and Method

The experiment on the plot was done at the Cotton Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the Kharif season of 2024-2025. The field had a flat and even surface. The soil was medium black cotton soil, which is a type of vertisols. It had low levels of available nitrogen (214.64 kg per hectare), medium levels of available phosphorus (19.60 kg per hectare), very high levels of available potassium (310.70 kg per hectare), and was slightly alkaline (pH 8.1). The electrical conductivity was 0.30 dSm-1, and the organic carbon content was 4.20 grams per kilogram. The experiment followed a Randomised Block Design with three replications. There were eight treatments, each having HDPS with different canopy management techniques. The treatments were: T_1 (Control), T_2 (Detopping at the 20th node), T_3 (Mepiquat chloride @45ppm at square initiation), T_4 (Mepiquat chloride @45ppm at square initiation + Detopping at the 20th node), T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after the first spray), T_6 (Mepiquat chloride @45ppm at square initiation and 15 days after the first spray + Detopping at the 20th node), T_7 (Mepiquat chloride @45ppm at square initiation and 15 days after the first spray and 15 days after the second spray (as needed)), T_8 (Mepiquat chloride @45ppm at square initiation and 15 days after the first spray and 15 days after the second spray (as needed) + Detopping). The Bt cotton variety Rasi Swift RCH 971 seeds were planted in rows using the dibbling method, with each plant spaced 90 cm apart in the row and 15 cm between the rows. The recommended dose of fertilizer was 90:45:45 N:P2O5:K2O kg per hectare. The study aimed to understand how crop management practices affect the growth, yield, and economic performance of Bt cotton. Observations were recorded at different stages of the crop's growth.

Results and Discussion

Effect on total dry matter accumulation

Total dry matter production shows the total amount of plant growth during the whole growing season, and it affects how much seed cotton is produced through the harvest index. The data on total dry matter per plant measured at 30, 60, 90, 120 days after sowing and at harvest are shown in Table 1.

Total dry matter buildup went up as the crop grew older until 120 days after sowing (DAS), and then started to go down by the time of harvest. The highest amount of dry matter was found at 120 DAS.

The total dry matter buildup in Bt cotton at 30 DAS wasn't much affected by the different canopy management practices. This is because all those practices like detopping and plant growth regulators were started after 45 DAS.

At 60 DAS, treatment T_1 (Control) had the highest total dry matter per plant, which was 39.69. Treatment T_2 (Detopping at the 20th node) had 37.20, which was found at par with treatment T_1. The lowest dry matter was seen in treatment T_5 (Mepiquat chloride @45ppm applied at square initiation and 15 days after the first spray), which had 30.45

At 90 DAS, treatment T_2 (Detopping at the 20th node) had the highest total dry matter per plant, which was 142.42. Treatments T_3, T_4, T_5, T_6, T_7, and T_8 were statistically comparable with treatment T_2. The lowest dry matter was in treatment T_1 (Control), which had 109.87.

At 120 DAS, significantly higher total dry matter accumulation per plant was recorded in treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray) (278.81) due to progressive accretion of photosynthates in leaves, stem and reproductive parts due to increase in the uptake of nutrients, hence increase in the growth of components and it lead to the more dry matter production plant^{-1}. However, treatment T_2, T_4, T_6 were statistically comparable with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray). Lowest total dry matter accumulation was recorded in treatment T_1 (Control) (190.21).

Table 1: Total dry matter accumulation plant^{-1} of cotton as influenced by HDPS planting and different canopy management practices

Treatments	Total dry matter accumulation (g plant^{-1})				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1: Control	9.82	39.69	109.87	190.21	149.97
T_2: Detopping (20th node)	9.65	37.20	142.42	255.55	185.24
T_3: Mepiquat chloride @45ppm at square initiation	8.80	33.51	132.55	236.46	178.31
T_4: Mepiquat chloride @45ppm at square initiation + Detopping (20th node)	9.41	33.63	140.14	261.92	194.85
T_5: Mepiquat chloride @45ppm at square initiation and 15 days after first spray	8.23	30.45	137.42	278.81	199.17
T_6. Mepiquat chloride @45ppm at square initiation and 15 days after first spray + Detopping (20th node)	8.35	31.31	138.77	258.03	191.67
T_7: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)	9.40	34.91	131.64	249.32	183.20
T_8: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)+ Detopping	8.72	33.54	132.44	237.61	180.52
SE(m)±	0.40	0.83	5.02	9.55	4.47
CD at 5%	NS	2.56	15.35	29.30	13.72
GM	9.05	34.28	133.16	245.99	182.87

At harvest, significantly higher total dry matter accumulation per plant was recorded in treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray) (199.17). However treatment T_4, T_6 were statistically comparable with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray). Lowest total dry matter accumulation was recorded in treatment T_1 (Control) (149.97).

The distribution of total 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. Similar results have been reported by Prakash and Prasad (2000) [9], Zhao and Oosterhuis (2000) [17], Wankhade *et al.* (2001) [16], Siddique *et al.* (2002) [13], Shwetha *et al.* (2009), Hallikeri *et al.* (2010) [5], Rajini (2010) [10], Paslawar *et al.* (2015) [8], Rajni and Deol (2015) [11], Kataria and Valu (2018) [6], Chaudhari *et al.* (2021) [4].

Effect on dry matter partitioning

Dry matter partitioning per plant of cotton as influenced by HDPS planting and different canopy management practices.

The buildup and partitioning of dry matter in different parts of a plant are closely connected to how well it can do photosynthesis. Because leaves are key in this process, the amount of dry matter they have directly influences the plant's overall ability to perform photosynthesis. The following data shows how dry matter is distributed among different plant parts at various stages of crop growth, as presented in Table 2 (a & b)

The dry matter partitioning per plant of *Bt* cotton at 30 DAS was not significantly affected by the various canopy management practices. This is because all the canopy management practices such as detopping, plant growth regulator were implemented only after 45 DAS stage.

At 60 DAS, treatment T_1 (Control) recorded significantly higher dry matter accumulation of leaves (16.18), stem (14.25) and fruting bodies (9.26) over all the other treatment. However, treatment T_2 (Detopping 20th node) were statistically comparable with treatment T_1 (Control). Lowest dry matter of leaves (11.67), stem (10.23) and fruting bodies (7.43) was recorded in treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray).

At 90 DAS, significantly higher dry matter accumulation of leaves (35.99), stem (46.01) and fruting bodies (61.13) was recorded in treatment T_2 (Detopping 20th node). However, treatment T_3, T_4, T_5, T_6, T_7, T_8 were statistically comparable with treatment T_2 (Detopping 20th node). Lowest dry matter of leaves (24.32), stem (35.62) and fruting bodies (49.93) was recorded in treatment T_1 (Control).

At 120 DAS, significantly higher dry matter accumulation of leaves (61.03), stem (70.02) and fruting bodies (147.76) was recorded in treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray). However, treatment T_2, T_4, T_6 were statistically comparable with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray). Lowest dry matter accumulation of leaves (40.92), stem (45.18) and fruting bodies (104.11) was recorded in treatment T_1 (Control).

At harvest, significantly higher dry matter accumulation of leaves (23.79), stem (55.07) and fruting bodies (120.31) was recorded in treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray). However treatment T_4, T_6 were statistically comparable with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray). Lowest dry matter accumulation of leaves (17.13), stem (36.11) and fruting bodies (96.73) was recorded in treatment T_1 (Control).

The highest accumulation of dry matter in the fruiting parts of the plant may be linked to better use of photosynthates resulting from the spraying of growth retardant and detopping. These practices likely provided a resource advantage over other treatments. This improvement could be due to more efficient use of moisture, nutrients, and sunlight by the cotton crop, along with better aeration in the root zone. The absence of vegetative (monopodial) branches and the practice of detopping likely enhanced nutrient availability and uptake, which in turn boosted photosynthesis and the movement of nutrients to the fruiting parts, leading to greater dry matter accumulation per plant. Similar results were recorded by Prakash and Prasad (2000) [9], Zhao and Oosterhuis (2000) [17], Wankhade *et al.* (2001) [16], Siddique *et al.* (2002) [13], Shwetha *et al.* (2009) [12], Hallikeri *et al.* (2010) [5], Rajini (2010) [10], Paslawar *et al.* (2015) [8], Rajni and Deol (2015) [11] Kataria and Valu (2018) [6], Chaudhari *et al.* (2021) [4].

Table 2 (a): Dry matter distribution to different plant components of cotton and total dry matter (g plant^{-1}) as influenced by HDPS planting and different canopy manageme practices

Treatments	Dry matter partitioning at 30 DAS			Dry matter partitioning at 60 DAS				Dry matter partitioning at 90 DAS			
	Leaves	Stem	Total	Leaves	Stem	Fruting bodies	Total	Leaves	Stem	Fruting bodies	Total
T1: Control	6.92	2.90	9.82	16.18	14.25	9.26	39.69	24.32	35.62	49.93	109.87
T2: Detopping (20th node)	6.33	3.32	9.65	15.40	12.91	8.89	37.20	35.99	46.01	61.13	142.42
T3: Mepiquat chloride @45ppm at square initiation	5.81	2.99	8.80	14.49	11.24	7.79	33.52	33.36	43.24	55.95	132.55
T4: Mepiquat chloride @45ppm at square initiation + Detopping (20th node)	6.38	3.03	9.41	14.21	11.32	8.10	33.63	35.28	45.04	59.11	140.14
T5: Mepiquat chloride @45ppm at square initiation and 15 days after first spray	5.70	2.53	8.23	11.67	10.23	7.43	30.45	34.53	43.98	58.91	137.42
T6: Mepiquat chloride @45ppm at square initiation and 15 days after first spray + Detopping (20th node)	5.75	2.61	8.36	13.30	11.35	7.78	31.31	34.94	43.91	59.92	138.77
T7: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)	6.07	3.33	9.40	14.62	11.83	8.46	34.91	32.54	40.49	58.61	131.64
T8: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)+ Detopping	5.88	2.84	8.72	14.41	11.18	7.95	33.54	31.28	41.61	59.55	132.44
SE(m)±	0.42	0.18	0.40	0.73	0.60	0.37	0.83	1.17	1.31	1.82	5.02
CD at 5%	NS	NS	NS	2.23	1.85	1.13	2.56	3.6	4.01	5.59	15.35
GM	6.11	2.94	9.05	14.29	11.79	8.21	34.28	32.78	42.49	57.89	133.16

Table 2 (b): Dry matter distribution to different plant components of cotton and total dry matter (g plant^{-1}) as influenced by HDPS planting and different canopy management practice

Treatments	Dry matter partitioning at 120 DAS				Dry matter partitioning at harvest			
	Leaves	Stem	Fruting bodies	Total	Leaves	Stem	Fruting bodies	Total
T1: Control	40.92	45.18	104.11	190.21	17.13	36.11	96.73	149.97
T2: Detopping (20th node)	58.66	65.71	131.18	255.55	22.70	51.92	110.62	185.24
T3: Mepiquat chloride @45ppm at square initiation	52.54	59.96	123.96	236.46	21.21	48.09	109.01	178.31
T4: Mepiquat chloride @45ppm at square initiation + Detopping (20th node)	60.50	67.93	133.49	261.92	21.52	53.32	120.01	194.85
T5: Mepiquat chloride @45ppm at square initiation and 15 days after first spray	61.03	70.02	147.76	278.81	23.79	55.07	120.31	199.17
T6: Mepiquat chloride @45ppm at square initiation and 15 days after first spray + Detopping (20th node)	59.97	66.48	131.58	258.03	20.68	51.51	119.48	191.67
T7: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)	58.24	64.99	126.09	249.32	20.69	50.87	111.64	183.20
T8: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)+ Detopping	52.78	60.38	124.45	237.61	22.40	47.27	110.85	180.52
SE(m)±	3.66	4.71	7.33	9.55	1.01	2.15	2.91	4.47
CD at 5%	11.24	14.45	22.50	29.30	3.11	6.59	8.92	13.72
GM	55.58	62.58	127.83	245.99	21.27	49.27	112.33	182.87

Effect on Nutrient uptake

Data pertaining to uptake of nitrogen, phosphorus and potassium by cotton as influenced by different treatments are presented in Table 3 (a, b, c) respectively.

Nitrogen uptake

The maximum uptake of nitrogen by Bt. cotton was found with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray) (76.83 kg ha^{-1}). However, treatment T_2, T_4, T_6, T_7 were significantly comparable with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray) where biological yield was maximum. Minimum uptake of nitrogen by crop was recorded with treatment T_1 (Control) (61.38 kg ha^{-1}).

Kuchenberg and Sung (1988) [7], reported that the activity of nitrate reductase increased significantly with the application of growth regulators which resulted in the enhanced nitrate uptake by plants.

Phosphorous uptake

The phosphorus uptake by seed, straw as well as total phosphorus uptake by plant was significantly higher under treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray) (24.40 kg ha^{-1}). However, treatment T_2, T_4, T_6, T_7 were significantly comparable with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray) than rest of treatments. Lowest was recorded under T_1(Control) (18.31 kg ha^{-1}). These results are corrugated with the findings of Kuchenberg and Sung (1988) [7] and Veeraputhiran *et al*. (2004) [15].

Potassium uptake

The maximum uptake of potassium by *Bt.* cotton was found with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray) (56.84 kg ha^{-1}). However, treatment T_2, T_4, T_6, T_7 were significantly comparable with treatment T_5 (Mepiquat chloride @45ppm at square initiation and 15 days after first spray) over all the other treatments. Minimum uptake of potassium by crop was recorded with treatment T_1 (Control) (45.71 kg ha^{-1}) where no canopy management practices were done. These results are corrugated with the findings of Kuchenberg and Sung (1988) [7] and Veeraputhiran *et al*. (2004) [15].

Table 3 (a): Uptake of Nitrogen (Kg ha^{-1}) by crop as influenced by HDPS planting and different canopy management practices in cotton

Treatments	N Uptake		Total N uptake
	Seed	Stalk	
T_1: Control	45.40	15.98	61.38
T_2: Detopping (20th node)	53.12	19.16	72.29
T_3: Mepiquat chloride @45ppm at square initiation	48.15	17.41	65.56
T_4: Mepiquat chloride @45ppm at square initiation + Detopping (20th node)	54.52	19.89	74.41
T_5: Mepiquat chloride @45ppm at square initiation and 15 days after first spray	55.74	20.63	76.38
T_6: Mepiquat chloride @45ppm at square initiation and 15 days after first spray + Detopping (20th node)	53.58	19.80	73.38
T_7: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)	52.65	19.09	71.74
T_8: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)+ Detopping	49.53	17.74	67.28
SE(m)±	1.62	0.60	2.18
CD at 5%	4.98	1.85	6.69
GM	51.59	18.71	70.30

Table 3 (b): Uptake of Phosphorus (Kg ha^{-1}) by crop as influenced by HDPS planting and different canopy management practices in cotton.

Treatments	P uptake (Seed)	P uptake (Stalk)	Total P uptake
T1: Control	12.10	6.21	18.31
T2: Detopping (20th node)	14.42	7.97	22.40
T3: Mepiquat chloride @ 45 ppm at square initiation	12.96	6.60	19.56
T4: Mepiquat chloride @ 45 ppm at square initiation + Detopping (20th node)	15.17	8.25	23.42
T5: Mepiquat chloride @ 45 ppm at square initiation and 15 days after first spray	15.50	8.91	24.40
T6: Mepiquat chloride @ 45 ppm at square initiation and 15 days after first spray + Detopping (20th node)	14.65	8.22	22.87
T7: Mepiquat chloride @ 45 ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)	14.19	7.49	21.68
T8: Mepiquat chloride @ 45 ppm at square initiation and 15 days after first spray and 15 days after second spray (need based) + Detopping	13.37	6.98	20.36
SE(m) ±	0.58	0.34	0.86
CD at 5%	1.79	1.04	2.64
GM	14.05	7.58	21.62

Table 3 (c): Uptake of potassium (Kg ha^{-1}) by crop as influenced by HDPS planting and different canopy management practices.

Treatments	K Uptake		Total K uptake
	Seed	Stalk	
T_1: Control	18.62	27.08	45.71
T_2: Detopping (20th node)	21.95	31.62	53.57
T_3: Mepiquat chloride @45ppm at square initiation	19.78	28.77	48.55
T_4: Mepiquat chloride @45ppm at square initiation + Detopping (20th node)	22.82	32.52	55.34
T_5: Mepiquat chloride @45ppm at square initiation and 15 days after first spray	23.37	33.47	56.84
T_6: Mepiquat chloride @45ppm at square initiation and 15 days after first spray + Detopping (20th node)	22.32	32.34	54.66
T_7: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)	21.78	31.58	53.36
T_8: Mepiquat chloride @45ppm at square initiation and 15 days after first spray and 15 days after second spray (need based)+ Detopping	20.43	29.60	50.03
SE(m)±	0.77	1.00	1.75
CD at 5%	2.37	3.07	5.38
GM	21.38	30.87	52.26

Conclusion

Based on the current investigation, it can be said that application of Mepiquat chloride @45ppm at square initiation and 15 days after first spray showed highest total dry matter accumulation and dry matter partitioning in leaves, stem and fruiting bodies. It also had improved uptake of nitrogen, phosphorus and potassium in cotton.

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