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SG Pawar
M.Sc. (Agri) Student, College of Agriculture, Department of Agronomy, VNMKV, Parbhani, Maharashtra, India

AD Pandagale
Associate Professor, Department of Agronomy, Cotton Research Station, VNMKV, Parbhani, Maharashtra, India

SG Ghule
M.Sc. (Agri) Student, College of Agriculture, Department of Agronomy, VNMKV, Parbhani, Maharashtra, India

NG Chopkar
M.Sc. (Agri) Student, College of Agriculture, Department of Agronomy, VNMKV, Parbhani, Maharashtra, India

NV Sawane
M.Sc. (Agri) Student, College of Agriculture, Department of Agronomy, VNMKV, Parbhani, Maharashtra, India

MP Gadekar
M.Sc. (Agri) Student, College of Agriculture, Department of Agronomy, VNMKV, Parbhani, Maharashtra, India

SK Bagal
M.Sc. (Agri) Student, College of Agriculture, Department of Agronomy, VNMKV, Parbhani, Maharashtra, India

Corresponding Author:
SG Pawar
M.Sc. (Agri) Student, College of Agriculture, Department of Agronomy, VNMKV, Parbhani, Maharashtra, India

Effect of canopy management on yield and yield indices of *Bt* cotton under high-density planting system

SG Pawar, AD Pandagale, SG Ghule, NG Chopkar, NV Sawane, MP Gadekar and SK Bagal

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Abstract
A field experiment was conducted at Cotton Research Station in Nanded (Maharashtra, India) during the *Kharif* season of 2023 to evaluate the impacts of various canopy management treatments on yield of *Bt* cotton under HDPS. The study was carried out on medium black cotton soil in randomized block design with three replications and seven treatments. The treatments were, T_1 - Cotton in HDPS - 90 x 30 cm (37037 plants ha^{-1}); T_2 - HDPS + de-topping at 90 DAS; T_3 - HDPS + de-topping at 75 DAS; T_4 - HDPS + pruning of monopodia at square formation stage; T_5 - HDPS + pruning of monopodia at square formation stage and de-topping at 75 DAS; T_6 - HDPS + two sprays of Mepiquat chloride @ 25 g *a.i.* at square formation followed by 15 days and T_7 - HDPS + poly mulch + pruning of monopodia at square formation stage and de-topping at 75 DAS.
Highest number of picked bolls plant^{-1}, boll weight (g), yield plant^{-1} (g), Seed cotton yield (kg ha^{-1}), lint yield (kg ha^{-1}), stalk weight (kg ha^{-1}) were found to be increased with T_7 treatment (HDPS + poly mulch + Pruning of monopodia at square formation stage and de-topping at 75 DAS. Crop earliness, harvest index (%), rain water use efficiency and soil moisture were also improved with same treatment (T_7). The seed and lint parameters *viz.*, Seed index (g), Lint index, ginning out turn were not affected due canopy management. Lower weed density and weed dry weight were recorded in treatment with poly mulch (T_7).

Keywords: *Bt* cotton, HDPS, canopy management, monopodia pruning, de-topping, poly mulch, mepiquat chloride

Introduction
Cotton (*Gossypium* spp.) is also known as 'white gold' or 'king of fiber'. It is a crucial crop for the survival of Indian farming community and the country's rural economy. The cotton fibres are used for textile purpose, seed is source of oil used for consumption and soap industry and leftover seed cake is source of concentrated organic manure. The cotton crop provides raw material for textile industry accounting for 26% of the total fiber production worldwide (Anonymous 2023) [1].
India ranks as the second-largest cotton producer globally, with a production of 323.11 lakh bales in the 2023-24 season and country with highest area under cotton. Gujarat state alone contributes about 29% of national production (Anonymous, 2024) [2]. However, regions like Marathwada and Vidarbha in Maharashtra face persistent challenges such as erratic rainfall and soil moisture deficit which significantly hinder productivity. It is necessary to optimize agronomic practices including plant density, moisture conservation and nutrition to increase seed cotton yield and enhance the financial condition of farmers.
Implementing high-density planting system and closer spacing has been shown to significantly enhance yield compared to conventional spacing (Rossi *et al.* 2004) [3]. Khetre *et al.* (2018) [4] optimized optimum spacing (90 x 30 cm) of High density planting for Marathwada region of Maharashtra with predominant black cotton soil and density 37037 plants ha^{-1} was recommended for the region as HDPS of cotton. Plant growth retardants (PGRs) such as Mepiquat chloride have been shown to reduce excessive vegetative growth, improve light interception and enhance boll size and retention (Murtza *et al.*, 2022) [5]. Detopping and pruning monopodial branches further optimize plant architecture, redirecting energy towards

reproductive parts of the plant (Kakade *et al.*, 2023) [6]. Additionally, the use of plastic mulch improves microclimatic conditions, leading to increased yields (Nalayini *et al.*, 2004) [7]. Thus, cotton in high density planting system coupled with crop canopy management by monopodia pruning, de-topping, mulch and use of PGR can harvest better crop with sustainable seed cotton yield. These integrated agronomic practices are essential for improving cotton productivity and ensuring the economic viability of farmers in India.

Materials and Methods

A field trial was carried out during *Kharif* 2023-24 in randomized block design with three replications under rainfed condition at Cotton Research Station, Nanded, VNMKV, Parbhani (M.S.). The soil of experimental field was clayey in texture, low in available nitrogen (138.30 kg ha^{-1}), phosphorous (11.96 kg ha^{-1}) and high in available potash (442.45 kg ha^{-1}) and was slightly alkaline in reaction (pH 8.08). Nanded is situated at latitude, longitude and altitude of 19.13 ^{0}N, 77.34 ^{0}E and 984 feet above mean sea level, respectively. Nanded has sub-tropical climate, with an average annual precipitation of 935.3 mm. The monsoon arrived during second week of June and cotton crop was sown manually by dibbling method on 7th July, 2023. *Bt* cotton hybrid 'Moksh (KCH15K39/ BGII)' was used for conduct of the field trial and sowing was done at 90 x 30 cm spacing. All the recommended practices for *Bt* cotton under High Density Planting System (HDPS) were followed. The experiment comprised of seven treatments: T_1 - Cotton in HDPS - 90 x 30 cm (37,037 plants ha^{-1}), T_2 - HDPS + de-topping at 90 DAS, T_3 - HDPS + de-topping at 75 DAS, T_4 - HDPS + prunning of monopodia at square formation stage, T_5 - HDPS + prunning of monopodia at square formation stage and de-topping at 75 DAS, T_6 - HDPS + two sprays of Mepiquat chloride @ 25 g *a.i.* at square formation followed by 15 days, T_7 - HDPS + poly mulch + prunning of monopodia at square formation stage and de-topping at 75 DAS.

The Bartlett's earliness index indicates the maturity timing of a crop. A higher value of the index reflects an earlier harvest for the crop. The Bartlett's earliness index was calculated by adopting formula given by Bartlett (1973) [8] as below:

$$\text{Bartlett's index} = \frac{P_1 + (P_1 + P_2) + (P_1 + P_2 + \ldots\ldots + Pn)}{n\,(P_1 + P_2 + \ldots\ldots + Pn)}$$

Where P_1 = seed cotton yield in first picking; P_2 = seed cotton yield in second picking; Pn = seed cotton yield in nth picking and n = number of pickings.

Results and Discussion

Weed dynamics: The original values of weed density are subjected to square root transformation and transformed values are presented in parenthesis (Table 1). HDPS + polymulch + prunning of monopodia and de-topping (T_7) treatment recorded lower number of weeds m^{-2} and weed dry weight at all the stages of observations (35.67, 22.00, 4.67 m^2 and 6.80, 8.41, 3.49 g m^2, respectively). Polythene mulch had covered nearly about 2/3rd of the ground area in this treatment which doesn't allow the emerged weeds beneath the polymulch to survive leading to significantly lower weed count. Similarly lower number of weeds m^{-2} has resulted in lower weed dry weight. Lower weed population in polymulch than control was also documented by Varsha *et al.* (2019) [9]. All other treatments were on par with each other denoting no effect on weed growth.

Soil moisture study: Mean soil moisture in 0-45 cm soil depth was highest at 30 DAS (32.90 percent) and was found to be reduced gradually with increase in duration of crop and Lowest soil moisture (14.27 percent) was measured at harvest (Table 2). The highest soil moisture (%) was measured in HDPS + polymulch + pruning of monopodia and de-topping (T_7) treatment at all the stages and was significantly superior over all other treatments except HDPS + two spray of mepiquat chloride (T_6) at 90 DAS (19.18 percent). Improvement in soil moisture content in poly mulch was due to reduced evaporation by poly mulch and increased moisture conservation in broad bed and furrow beneath poly mulch. Nalayini *et al.* (2009) [10] and Isal *et al.* (2019) [11] also documented improvement in percent soil moisture due to poly mulch.

Yield contributing characters: Yield contributing characters and seed cotton yield of *Bt* cotton is presented Table 3. Higher boll weight was obtained in HDPS + poly mulch + pruning of monopodia and de-topping (T_7 - 5.57 g) because of favourable conditions due to poly mulch, pruning of monopodia and de-topping and was at par with HDPS + two spray of Mepiquat chloride (T_6 - 5.44 g). Increase in boll weight in Mepiquat chloride might be due to reduction of energy flow from its utilization on vegetative growth and its diversion towards fruiting bodies Kumar *et al.* (2005) [12]. Increase in boll weight due to application of Mepiquat chloride was also noted by Singh *et al.* (2017) [13] and Maheswari *et al.* (2019) [14]. Number of picked bolls plant^{-1} were not influenced due to canopy management treatments. Greater number of reproductive parts and open bolls plant^{-1} in this treatment has resulted in numerical increase in boll numbers plant^{-1}. Highest number of bolls in poly mulch was also found by Jadhav and Jadhav (2024) [15]. Due to effect of poly mulch resulted in increased soil moisture status. Similarly, increased number of bolls plant^{-1} and boll weight might have resulted due to monopodia pruning, increased number sympodial branches and de-topping. Combined effect of all these parameters has resulted significant increase in yield plant^{-1} HDPS + Poly mulch + monopodia pruning + de-topping (T_7 - 76.33 g) and was increased by 43.66 percent over HDPS only (T_1). These results are in conformity with Isal *et al.* (2019) [11] and Choudhary *et al.* (2021) [16].

Seed cotton yield (kg ha^{-1}): HDPS + poly mulch + pruning of monopodia and de-topping (T_7) treatment has outyielded with 48.66 percent increase highest seed cotton yield (T_7 - 2734 kg ha^{-1}) and was significantly superior over all other treatments (Table 3). All other treatments were on par with each other. Early retention of bolls in HDPS + poly mulch + pruning of monopodia and de-topping (T_7) treatment might have got the full advantage of available soil moisture and slow mineralization of nutrients making them available during boll development stage which in turn reflected in higher seed cotton yield (kg ha^{-1}). The higher yield advantage with HDPS + poly mulch + pruning of monopodia and de-topping at 75 DAS was also observed by Kakade *et al.* (2023) [6].

Lint yield (kg ha^{-1}): Sowing of cotton in HDPS + poly mulch + monopodia pruning + de-topping (T_7) recorded significantly highest lint yield (991 kg ha^{-1}) and was increased by 47.03 percent over sowing in HDPS alone (Table 4). Lint yield in all other treatments was statistically similar. Increase in seed cotton yield in this treatment has resulted in increased lint yield. Similar result was also observed by Jadhav and Jadhav (2024) [15].

Stalk yield (kg ha^{-1}): The treatment HDPS + polymulch + pruning of monopodia and de-topping (T_7 – 2959 kg ha^{-1}) recorded significantly highest stalk weight. Increased cotton stalk yield with poly mulch practice due to better moisture supply to the crop throughout its growing period, which helped in translocation of photosynthates to enhance the physiological growth of crop by maintaining the water balance. Increased moisture might have resulted to increased production of photosynthates and allocation of dry matter to vegetative as well as reproductive parts might have resulted to significantly higher stalk yield in treatment with poly mulch (T_7). Similar findings were also reported by Isal *et al.* (2019) [11].

Harvest index: The data indicates that mean harvest index of *Bt* cotton hybrid during present field trial was 45.23 percent (Table 4). The canopy management treatments did not meet the level of significance for harvest index. The HDPS + poly mulch + pruning of monopodia and de-topping (T_7) recorded highest values of harvest index (48.22 percent) and had 11.00 percent additional harvest index of *Bt* cotton over cotton in HDPS - 90 x 30 cm (37,037 plants ha^{-1}) (T_1). Increased seed cotton yield in poly mulch practice in comparison with comparatively low increase in stalk yield was resulted to numerical increase in harvest index in this treatment.

Ginning out turn (%), seed index (g) and lint index: Different canopy management treatments might have statistically similar effect on development of seeds and fibers (Table 4). Cotton in HDPS - 90 x 30 cm (T_1) had highest numerical values of ginning out turn (36.67 percent), where as HDPS + two spray of Mepiquat chloride @ 25 g *a.i.* at square formation followed by 15 days (T_6) had lowest (36.12 percent). Highest values of ginning out turn under high density planting were also reported by Madavi *et al.* (2017) [17] and Parihar *et al.* (2018) [18]. HDPS + two sprays of mepiquat chloride @ 25 g *a.i.* (T_6) treatment recorded the highest values of seed index (10.15 g) and lint index (5.75). Improvement in seed size as compared lint percentage due to foliar application of Mepiquat chloride was also found by Kadiyam *et al.* (2022) [19]. Non-significant differences in harvest index and seed index might be due to increase in seed and fiber development in various treatments which therefore could not meet level of significance.

Earliness: The HDPS + poly mulch + pruning of monopodia and de-topping (T_7) treatment showed higher value of Bartlett's index (0.87) suggesting the earliness of crop with respect to seed cotton yield in proportion to number pickings (Table 4). Similarly, this (T_7) treatment also recorded highest earliness percentage (74.98 percent) whereas lowest value of earliness percentage was recorded in cotton in HDPS - 90 x 30 cm (T_1 – 59.98%). It indicates that poly mulch results greater share of seed cotton in first picking.

Rainwater use efficiency (kg ha^{-1} mm^{-1}): Increase in seed cotton yield due to Poly mulch, monpodia pruning and de-topping (T_7) has resulted to significant increase rain water use efficiency (4.39 kg ha^{-1} mm^{-1}). Nalayani *et al.* (2009) [10], Hargilas (2018) [20] and Isal *et al*. (2020) [21] also reported improved water use efficiency by use of poly mulch in cotton.

Table 1: Weed dynamics as influenced by canopy management treatments

Treatments	Weed density m^{-2}			Weed dry weight (g m^{-2})		
	3 WAS	9 WAS	At harvest	3 WAS	9 WAS	At harvest
T_1 - Cotton in HDPS - 90 x 30 cm (37037 plants ha^{-1})	66.67 (8.21)	36.67 (6.12)	7.33 (2.88)	11.00 (3.46)	16.53 (4.18)	5.83 (2.61)
T_2 - HDPS + De-topping at 90 DAS	67.00 (8.23)	32.33 (5.76)	6.33 (2.70)	10.80 (3.43)	15.05 (4.00)	6.42 (2.72)
T_3 - HDPS + De-topping at 75 DAS	67.67 (8.27)	39.33 (6.33)	6.00 (2.64)	10.60 (3.40)	16.60 (4.18)	6.55 (2.74)
T_4 - HDPS + Pruning of monopodia at square formation stage	68.67 (8.33)	37.00 (6.15)	6.67 (2.76)	10.80 (3.43)	17.27 (4.27)	6.05 (2.65)
T_5 - HDPS + Pruning of monopodia at square formation stage and de-topping at 75 DAS	68.33 (8.32)	39.67 (6.37)	7.33 (2.88)	10.50 (3.39)	15.16 (4.01)	6.24 (2.69)
T_6 - HDPS + Two spray of mepiquat chloride @ 25 g *a.i.* at square formation followed by 15 days	69.33 (8.37)	37.33 (6.18)	6.33 (2.70)	10.70 (3.41)	14.02 (3.87)	6.74 (2.77)
T_7 - HDPS + Polymulch + Pruning of monopodia at square formation stage and de-topping at 75 DAS	35.67 (6.05)	22.00 (4.79)	4.67 (2.38)	6.80 (2.79)	8.41 (3.06)	3.49 (2.11)
SE+	0.26	0.19	0.07	0.10	0.12	0.07
CD at 5%	0.83	0.61	0.24	0.32	0.39	0.23
CV (%)	5.79	5.69	4.98	5.33	5.50	5.04
GM	63.33 (7.97)_	34.90 (5.96)	6.38 (2.71)	10.17 (3.33)	14.72 (3.94)	5.90 (2.61)

(Figures in parenthesis are square root transformed values)

Table 2: Soil moisture content (%) in 0-45 cm depth of *Bt* cotton as influenced by different treatments

Treatments	Soil moisture content (%) in 0-45 cm depth				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1 : Cotton in HDPS - 90 x 30 cm (37037 plants ha^{-1})	33.39	20.26	18.22	18.22	13.74
T_2 : HDPS + De-topping at 90 DAS	32.23	20.48	18.30	18.30	13.80
T_3 : HDPS + De-topping at 75 DAS	33.01	20.28	18.89	18.89	13.98
T_4 : HDPS + Pruning of monopodia at square formation stage	33.05	20.48	17.82	17.82	13.83
T_5 : HDPS + Pruning of monopodia at square formation stage and de-topping at 75 DAS	31.89	20.52	17.72	17.72	13.67
T_6 : HDPS + Two spray of mepiquat chloride @ 25 g *a.i.* at square formation followed by 15 days	32.31	20.53	19.18	19.18	13.57
T_7: HDPS + Polymulch + Pruning of monopodia at square formation stage and de-topping at 75 DAS	34.43	23.37	20.76	22.76	17.34
SE±	1.33	0.63	0.57	0.94	0.7
CD at 5%	N.S.	1.94	1.77	2.91	2.17
CV (%)	7.04	5.26	5.33	8.62	8.56
GM	32.90	20.69	18.70	18.98	14.27

Table 3: Yield and yield attributing characters as influenced by different canopy management treatments

Treatments	Number of picked bolls $plant^{-1}$	Boll weight (g)	Yield $plant^{-1}$ (g)	Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Stalk weight (kg ha^{-1})
T_1 - Cotton in HDPS - 90 x 30 cm (37037 plants ha^{-1})	12.67	4.56	53.13	1839	674	2393
T_2 - HDPS + De-topping at 90 DAS	12.93	4.62	54.60	1890	690	2311
T_3 - HDPS + De-topping at 75 DAS	12.27	4.55	52.87	1835	662	2242
T_4 - HDPS + Pruning of monopodia at square formation stage	12.47	4.66	54.60	1913	696	2347
T_5 - HDPS + Pruning of monopodia at square formation stage and de-topping at 75 DAS	13.13	4.71	55.13	1939	705	2216
T_6 - HDPS + Two spray of mepiquat chloride @ 25 g *a.i.* at square formation followed by 15 days	11.33	5.44	54.67	1907	688	2180
T_7 - HDPS + Polymulch + Pruning of monopodia at square formation stage and de-topping at 75 DAS	14.07	5.57	76.33	2734	991	2959
SE±	0.72	0.17	4.15	122.48	48.32	116.04
CD at 5%	N.S.	0.52	12.80	377.40	148.90	357.56
CV (%)	9.78	6.09	12.55	10.56	11.47	8.45
GM	12.70	4.87	57.33	2008	730	2378

Table 4: Post harvest studies, earliness and rain water use efficiency of *Bt* cotton as influenced by canopy management treatments

Treatments	Harvest index (%)	Ginning Out turn (%)	Seed index (g)	Lint index	Earliness		RWUE (kg ha^{-1} mm^{-1})
					Bartlett's index	Percent Earliness (%)	
T_1 - Cotton in HDPS - 90 x 30 cm (37037 plants ha^{-1})	43.44	36.67	9.79	5.67	0.80	59.98	2.95
T_2 - HDPS + De-topping at 90 DAS	44.95	36.49	9.80	5.63	0.81	62.03	3.03
T_3 - HDPS + De-topping at 75 DAS	44.99	36.11	9.85	5.57	0.81	62.02	2.95
T_4 - HDPS + Pruning of monopodia at square formation stage	44.92	36.29	9.88	5.62	0.81	61.99	3.07
T_5 - HDPS + Pruning of monopodia at square formation stage and de-topping at 75 DAS	46.75	36.37	9.92	5.67	0.81	62.99	3.11
T_6 - HDPS + Two spray of mepiquat chloride @ 25 g *a.i.* at square formation followed by 15 days	46.63	36.12	10.15	5.75	0.83	66.02	3.06
T_7 - HDPS + Polymulch + Pruning of monopodia at square formation stage and de-topping at 75 DAS	48.22	36.22	9.99	5.67	0.87	74.98	4.39
SE±	2.00	0.61	0.35	0.20	-	-	0.19
CD at 5%	N.S.	N.S.	N.S.	N.S.	-	-	0.6
CV (%)	7.62	2.95	6.12	6.29	-	-	10.56
GM	45.70	36.32	9.91	5.65	0.82	64.29	3.22

Conclusion

Planting of cotton crop with HDPS + poly mulch + pruning of monopodia at square formation stage and de-topping at 75 DAS is found to be beneficial for improving soil moisture content; reduction in weed density and biomass; getting higher yield attributes, seed cotton yield and rain water use efficiency.

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