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Yield maximization of *Bt.* cotton by integrated crop management techniques

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Abstract
A field experiment entitled, "Yield maximization of *Bt*. cotton by integrated crop management techniques" was caried out during *kharif*, 2023 at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (India). The experiment was laid out in Randomized Block Design (RBD) with three replications and nine treatments. The results of present investigation revealed that, yield and yield contributing characters of *Bt*. cotton were significantly influenced by different treatments. Treatment T_1 *i.e.*, wider spacing (90 cm × 90 cm) recorded significantly maximum lint weight boll^{-1} (1.36 g), seed weight boll^{-1} (2.64 g), boll weight (4.00 g), number of green (unopened) bolls plant^{-1} (2.60), number of picked bolls plant^{-1} (45.09) and seed cotton yield plant^{-1} (180.36 g). The highest seed cotton yield (4162 kg ha^{-1}) and stalk yield (6202 kg ha^{-1}) were recorded with treatment T_9 (Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS). The quality parameters *viz.*, ginning percentage (%), lint index (%), micronaire value (µg inch^{-1}), tensile strength (g tex^{-1}), 2.5% span length (mm) and uniformity ratio (%) were not influenced significantly due to different treatments. Treatment T_9 (Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS) recorded highest cost of cultivation (₹ 1,27,328), gross monetary returns (₹ 2,81,780), net monetary returns (₹ 1,54,452) and B:C ratio (2.21) than rest of all treatments.

Keywords: *Bt*. cotton, closer spacing, mepiquat chloride, detopping, pruning of monopodia

Introduction
Cotton is one of the predominant fiber crop and plays a pivotal role in agriculture, industrial development, employment generation and economic development of India. It is called as "King of fibers" and "White gold " due to higher economical values among all cash crops in India. Nearly one third of India's export earnings are from the textile sectors. Apart from its fiber, it contributes considerably to the non-edible oil pool of our country and likely to play pivotal role in paper, particle board and card board industries, etc. in coming decades (Elamathy *et al.*, 2022) [5].

Cotton is a sub-tropical plant having indeterminate growth habit. Among various agronomic practices to boost up crop productivity, plant population is one of the most important factor for efficient utilization of available resources. The manipulation of plant density and crop geometry is a time-tested agronomic technique for achieving higher crop yield. In wider spacing, yield reduces due to less plant per unit area and closer spacing reduces yield due to competition within the plants (Gohil *et al.*, 2023) [6].

Managing the equilibrium between vegetative and reproductive growth is an important part in cotton production. This can be achieved by detopping and pruning or removal of monopodial branches. Detopping is the removal of top terminal portion after prominent vegetative growth stage. This may encourage growth of already formed sympodia as well as formation and development of fruiting bodies. Detopping may also help to reduce sucking pests and bollworm infestation, as it avoids fresh growth emergence which is unwanted at particular stage (Kakde *et al.*, 2023) [7].

In India, cotton is grown under diverse agro-climatic conditions. With the better understanding of plant growth habits, new agricultural practices are developed for higher productivity of the crops. Production and productivity of cotton crop increased with the introduction of genetically modified *Bt.* cotton in the country. For fully exploitation of the crop yield, there is a need to develop new crop management practices.

Materials and Methods

The field experiment entitled, "Yield maximization of *Bt.* cotton by integrated crop management techniques" was conducted at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri during *kharif* season, 2023-2024. The soil of the experimental plot was clayey in texture, low in available nitrogen (177.20 kg ha^{-1}), medium in available phosphorus (26.50 kg ha^{-1}), very high in available potassium (680 kg ha^{-1}) and slightly alkaline in reaction (pH 7.7). The EC and organic carbon content was 0.38 dSm^{-1} and 0.57% respectively. The experiment was laid out in Randomized Block Design (RBD) with three replications and nine treatments *viz.*, T_1: Farmer's practice (90 cm × 90 cm spacing), T_2: Cotton in closer spacing (90 cm × 30 cm spacing), T_3: Cotton in closer spacing + Detopping at 100 cm height, T_4: Cotton in closer spacing + Pruning of monopodia at 45 DAS, T_5: Cotton in closer spacing + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS, T_6: Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS, T_7: Cotton in closer spacing + Detopping at 100 cm height + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS, T_8: Cotton in closer spacing + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS, T_9: Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS. Seeds of cotton variety Ajeet-155 were sown in line by dibbling method and two hand weedings were given to keep the plots weed free. The recommended fertilizer dose (125:65:65 N:P_2O_5:K_2O kg ha^{-1}) was applied through urea, SSP and MOP along with FYM.

Results and Discussion

Yield Contributing Characters Studies

Table 1: Number of picked bolls $plant^{-1}$ and boll weight as influenced by integrated crop management techniques

	Treatment details	Number of picked bolls $plant^{-1}$	Boll weight (g)
T_1	Farmer's practice (90 cm × 90 cm spacing)	45.09	4.00
T_2	Cotton in closer spacing (90 cm × 30 cm spacing)	24.58	3.11
T_3	Cotton in closer spacing + Detopping at 100 cm height	27.01	3.38
T_4	Cotton in closer spacing + Pruning of monopodia at 45 DAS	27.15	3.43
T_5	Cotton in closer spacing + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	27.41	3.54
T_6	Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS	29.21	3.70
T_7	Cotton in closer spacing + Detopping at 100 cm height + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	27.76	3.64
T_8	Cotton in closer spacing + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	28.16	3.66
T_9	Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	29.23	3.86
	S.E m ±	5.05	0.10
	C.D. at 0.05	16.63	0.32
	General mean	29.51	3.59

The statistically analysed data revealed that yield and yield contributing characters of ***Bt.*** cotton at harvest was significantly influenced due to various treatments. Farmer's practice (90 cm × 90 cm spacing) recorded significantly higher number of picked bolls $plant^{-1}$ at harvest, however, it was at par with treatment T_9 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS) and treatment T_6 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS). Lower number of picked bolls $plant^{-1}$ was recorded at treatment T_2 *i.e.*, Cotton in closer spacing (90 cm × 30 cm). More number of picked bolls $plant^{-1}$ in farmer's practice is might be due to the substantial space available for growth, more photosynthetic efficiency, frequent availability of water and nutrients, which resulted in increase in fruiting points, fruiting period, fruit retention and ultimately greater picked bolls $plant^{-1}$. Similar results were obtained by Munir *et al.* (2015) [10] and Uma Maheswari *et al.* (2019) [16].

Table 2: Seed cotton yield $plant^{-1}$, seed cotton yield and stalk yield as influenced by integrated crop management techniques

	Treatment details	Seed cotton yield $plant^{-1}$ (g)	Seed cotton yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
T_1	Farmer's practice (90 cm × 90 cm spacing)	180.36	2227	4231
T_2	Cotton in closer spacing (90 cm × 30 cm spacing)	76.43	2621	4980
T_3	Cotton in closer spacing + Detopping at 100 cm height	91.30	3157	5367
T_4	Cotton in closer spacing + Pruning of monopodia at 45 DAS	93.13	3258	5539
T_5	Cotton in closer spacing + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	97.01	3432	5835
T_6	Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS	108.08	4012	6178
T_7	Cotton in closer spacing + Detopping at 100 cm height + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	101.02	3589	5922
T_8	Cotton in closer spacing + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g	103.05	3703	6036

	a.i. at 45 and 60 DAS			
T_9	Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	112.80	4162	6202
	S.E m ±	24.40	74.49	44.13
	C.D. at 0.05	73.20	223.32	132.39
	General mean	107.02	3351.28	5587.73

Farmer's practice (90 cm × 90 cm spacing) recorded significantly higher boll weight at harvest, however, it was at par with treatment T_9 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS) and treatment T_6 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS). Lower boll weight was recorded at treatment T_2 *i.e.,* closer spacing (90 cm × 30 cm). Maximum boll weight in wider spacing is might be due to improved source-sink relationship and better partitioning of photoassimilates into reproductive structures as reported by Kaul *et al.* (2016) [8] and Uma Maheswari *et al.* (2019) [16].

Farmer's practice (90 cm × 90 cm spacing) recorded significantly higher seed cotton yield plant^{-1} at harvest, however, it was at par with treatment T_9 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS) and treatment T_6 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS). Lower seed cotton yield plant^{-1} was recorded at treatment T_2 *i.e.,* closer spacing (90 cm × 30 cm). Under wider spacing availability of photosynthates to individual plant was more to produce maximum seed cotton yield plant^{-1} as compared to closer plant spacing. This might be due to overall improvement in growth attributes and its positive effect on number of bolls plant^{-1} and seed cotton weight boll^{-1} under wider plant spacing. The above results are in conformity with the findings of Khetre *et al.* (2018) [9] and Gohil *et al.* (2023) [6].

Treatment T_9 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS) recorded significantly higher seed cotton yield at harvest, however, it was at par with treatment T_6 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS). Lower seed cotton yield was recorded at farmer's practice (90 cm × 90 cm). The remarkable improvement in seed cotton yield in treatment combination of integrated crop management techniques could be due better partitioning of photo assimilates towards reproductive structures, improved source-sink relationship and better translocation of metabolites towards growing and reproductive sink due to retardation of excessive vegetative growth. The results are in conformity with those obtained earlier by Bhalerao and Gaikwad (2010) [1], Shekar *et al.* (2015) [13], Parihar *et al.* (2018) [11] and Uma Maheswari *et al.* (2019) [16].

Treatment T_9 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS) recorded significantly higher stalk yield at harvest, however, it was at par with treatment T_6 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS). Lower stalk yield was recorded at farmer's practice (90 cm × 90 cm). The higher cotton stalk yield under closer spacing is mainly due to higher plant population as compared to the wider spacing. These findings are in line with those supported by Bhalerao and Gaikwad (2010) [1], Shekar *et al.* (2015) [13] and Khetre *et al.* (2018) [9].

Fiber Quality Studies

The statistically analysed data revealed that the quality parameters of *Bt.* cotton *viz.,* ginning percentage (%), lint index (%), micronaire value (µg inch^{-1}), tensile strength (g tex^{-1}), 2.5% span length (mm) and uniformity ratio (%) were not influenced significantly due to different treatments. Similar results were observed by Dhillon *et al.* (2006) [4], Pendharkar *et al.* (2010) [12], Dadgale *et al.* (2012) [3], Kaul *et al.* (2016) [8] and Chetana *et al.* (2023) [2].

Table 3: Quality parameters as influenced by integrated crop management techniques

	Treatment details	Ginning percent (%)	Lint index (%)	Micronaire value (µg inch^{-1})	Tensile strength (g tex^{-1})	2.5% span length (mm)	Uniformity ratio (%)
T_1	Farmer's practice (90 cm × 90 cm spacing)	34.01	4.02	3.62	27.93	26.90	83.67
T_2	Cotton in closer spacing (90 cm × 30 cm spacing)	34.08	4.07	3.61	28.07	26.80	85.67
T_3	Cotton in closer spacing + Detopping at 100 cm height	34.23	4.05	3.50	27.90	27.07	84.00
T_4	Cotton in closer spacing + Pruning of monopodia at 45 DAS	34.17	4.12	3.73	29.20	27.17	85.00
T_5	Cotton in closer spacing + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	33.55	4.16	3.61	28.70	27.57	84.00
T_6	Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS	34.57	4.26	3.63	27.40	26.00	83.00
T_7	Cotton in closer spacing + Detopping at 100 cm height + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	34.67	4.16	3.69	29.00	27.60	84.00
T_8	Cotton in closer spacing + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	34.73	4.23	3.50	27.93	27.30	85.00
T_9	Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	34.80	4.39	3.70	29.60	27.20	83.00
	S.E m ±	0.26	0.11	0.11	0.47	0.32	1.67
	C.D. at 0.05	NS	NS	NS	NS	NS	NS
	General mean	34.31	4.16	3.62	28.41	27.07	84.15

Economic Studies

Table 4: Economic studies of *Bt.* cotton as influenced by integrated crop management techniques

	Treatment details	**Cost of cultivation (₹ ha^{-1})**	**Gross monetary returns (₹ ha^{-1})**	**Net monetary returns (₹ ha^{-1})**	**B:C ratio**
T_1	Farmer's practice (90 cm × 90 cm spacing)	90567	150748	60181	1.66
T_2	Cotton in closer spacing (90 cm × 30 cm spacing)	100143	177463	77319	1.77
T_3	Cotton in closer spacing + Detopping at 100 cm height	109060	213741	104681	1.96
T_4	Cotton in closer spacing + Pruning of monopodia at 45 DAS	111699	220577	108878	1.97
T_5	Cotton in closer spacing + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	111837	232365	120528	2.07
T_6	Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS	122993	271593	148601	2.20
T_7	Cotton in closer spacing + Detopping at 100 cm height + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	116895	242970	126074	2.08
T_8	Cotton in closer spacing + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	119535	250699	131164	2.10
T_9	Cotton in closer spacing + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS	127328	281780	154452	2.21
	S.E m ±	-	3800	3800	-
	C.D. at 0.05	-	11394	11394	-
	General mean	112228	226881	114653	2.00

In economic studies, treatment T_9 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS + Two sprays of Mepiquat chloride @ 25 g a.i. at 45 and 60 DAS) recorded significantly higher cost of cultivation, gross monetary returns, net monetary returns and B:C ratio. However, it was at par with treatment T_6 (Cotton in closer spacing (90 cm × 30 cm) + Detopping at 100 cm height + Pruning of monopodia at 45 DAS) in case of GMR, NMR and B:C ratio. Lower economic values were recorded at farmer's practice (90 cm × 90 cm). This was mainly due to yield obtained in closer spacing was higher than that of wider spacing. Similar results were observed by Shwetha *et al*. (2009) [14], Bhalerao and Gaikwad (2010) [1], Dadgale *et al.* (2012) [3], Singh *et al*. (2017) [15], Khetre *et al.* (2018) [9] and Chetana *et al.* (2023) [2].

Conclusion
On the basis of present investigation, it can be concluded that the *Kharif* season *Bt.* Cotton shall be sown at 90 cm x 30 cm spacing along with complete package of integrated crop management techniques including detopping at 100 cm height, pruning of monopodia at 45 DAS and application of mepiquat chloride @ 25 g a.i. at 45 and 60 DAS for getting maximum yields, gross monetary returns, net monetary returns and benefit cost ratio in medium black soil of Maharashtra.

By keeping in view the hazardous effects of application of chemicals such as mepiquat chloride on soil and environment, it is recommended to practice closer spacing at 90 cm x 30 cm along with integrated crop management techniques including detopping at 100 cm height and pruning of monopodia at 45 DAS for sustainable production and productivity in *Bt.* cotton.

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Conflict of Interest
The authors declare there are no conflict of interest relevant to this article.

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