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Effect of low-cost management practices on yield, quality and economics of Bt cotton (*Gossypium hirsutum* L.) under middle Gujarat conditions

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Abstract
A field experiment to assess the effect of low-cost management practices *viz*; crop geometry, detopping and plant growth regulator on yield, quality and economics of Bt cotton (*Gossypium hirsutum* L.) under middle Gujarat conditions was carried out during *kharif* season of 2016-17 and 2017-18 at the College Agronomy Farm, Department of Agronomy, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) in loamy sand soils. The treatment combinations comprising three crop geometry treatments *i.e.*, 90 cm x 45 cm (C_1), 120 cm x 45 cm (C_2) and 90 cm x 60 cm (C_3) and five different detopping and plant growth regulator treatments *i.e.*, Control (no detopping and no spray of NAA) (D_1), Detopping at 60 DAS (D_2), Detopping at 60 DAS + spray of NAA @ 30 ppm at 60 DAS (D_3), Detopping at 80 DAS (D_4) and Detopping at 80 DAS + spray of NAA @ 30 ppm at 60 DAS (D_5) laid in a split plot design with four replications.
The results indicated that sowing of Bt cotton at 90 cm x 45 cm crop geometry recorded significantly higher plant population at 30 DAS and at harvest. Plant height at 40, 80 and 120 DAS and number of monopodial branches before first plucking, boll weight at every plucking, average boll weight and seed index were remained unaffected due to crop geometry. However, number of sympodial branches before first plucking, number of plucked bolls per plant, seed and stalk yields per ha as well as harvest index were significantly higher under crop geometry of 90 cm x 60 cm. Higher gross realization (₹ 1,86,520 ha^{-1}), net realization (₹ 1,23,879 ha^{-1}) and B:C ratio (2.98) were obtained when *Bt* cotton was sown at 90 cm x 60 cm crop geometry. The quality parameters *viz.*, ginning percentage, fiber length, fiber strength and oil content were found unaffected due to different crop geometry treatments. Significantly higher oil yield recorded under the crop geometry 90 cm x 60 cm.
Plant population at 30 DAS and at harvest, number of monopodial branches before first plucking per plant, boll weight at every plucking, number of plucked bolls per plant, seed index, ginning percentage and oil content remained unaffected due to different detopping and plant growth regulator treatments. The control treatment (no detopping and no spray of NAA) recorded significantly higher plant height at 80 and 120 DAS.
Yield attributes *viz.*, number of sympodial branches before first plucking and average boll wt, quality parameters *viz.*, fiber length, fiber strength and oil yield as well as seed cotton yield and harvest index were found significantly higher when crop was detopped at 80 DAS + spray of NAA @ 30 ppm at 60 DAS than rest of treatments, whereas, significantly higher stalk yield was produced under detopping at 60 DAS + spray of NAA @ 30 ppm at 60 DAS. Maximum gross realization (₹ 1,85,816 ha^{-1}), net realization (₹ 1,28,722 ha^{-1}) and B:C ratio (3.25) were observed under detopping at 80 DAS + spray of NAA @ 30 ppm at 60 DAS.

Keywords: Bt. cotton, crop geometry, detopping, growth regulator, NAA

Introduction
From time immemorial, India was the only country known for its cotton fabrics since the Indus valley civilization which flourished in the Indian sub-continent some 5000 years ago. Practically, till the end of 18th Century**,** no source of supply of cotton other than India was known to the world (DCD, 2017) [5]. Cotton, also known as the "king of fiber" and "White Gold", is one of the most momentous and important cash crops exercising profound influences on economic and social affairs of the world as well as of India. Cotton is grown in 75 countries in the world, of which United States, China and India contribute about 80% of total yield in the world. India ranks first in area and second in production of cotton in the world. It plays a vital role in the national economy by contributing 29.8% of India's agricultural gross domestic production. Cotton crop covered 10.50 million hectares area with a production of 5.9 million tonnes with productivity of 568 kg ha^{-1} in India during the year 2016-17 (CAB, 2017) [4].

Maharashtra, Gujarat, Haryana, Punjab, Rajasthan, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu are the major cotton growing states in India. As far as area is concerned Maharashtra ranked first (3.80 million ha), followed by Gujarat (2.40 million ha), Karnataka ranked first for productivity (769 kg ha^{-1}) during the year 2016-17. In Gujarat, cotton has been cultivated in all most all the districts except Dang and Kutch. Cotton occupies 2.40 million hectares under cultivation with total production of 1.61 million tonnes, with the productivity of 673 kg ha^{-1} during 2016-17 (CAB, 2017) [4]. Genetically Modified (GM) cotton, popularly known as '*Bt* cotton' has emerged as an effective alternative to traditional cotton varieties by inhibiting bollworm attack, thereby improving yield and income. The production of cotton has accelerated more than 4 times and reached a peak of 359.02 lakh bales during 2013-14 compared to 86.24 lakh bales in 2002-03 (DCD, 2017) [5].

To make the cotton cultivation economically more viable, cost of cultivation for cotton can be curtailed by adopting certain low-cost production practices. Among various low-cost production practices, crop geometry, detopping and use of growth regulator play very significant role. Maximum yield can be expected only when plant population allows individual plant to achieve their maximum inherent potential (Ghule *et al*., 2013) [7]. The plant geometry shows significant effect on various growth characters, yield attributes and yield of *Bt* cotton through its influence on light interception, rooting pattern and moisture extraction pattern. (Waghmare *et al*., 2018) [22].

In cotton, as with other dicotyledonous plants, the stem apex is a terminal bud. This bud normally produces auxin, mainly from the young developing leaves, but also to some extent from the stem apex itself. Hall *et al*., 1957 [8] reported that as long as the terminal bud is present and actively growing, it prevents the development of the lateral or axillary buds below it. Hallikeri *et al.*, 2010 [9] observed that growth modification practices become more important by converting its phase of vegetative to reproductive growth. Removing top terminal portion by detopping of cotton at prominent vegetative growth stage may be promising for encouraging growth of already formed sympodia as well as more formation and development of fruiting bodies. The seed cotton yield was observed increase by detopping over no detopping (Shwetha *et al*., 2009) [19]. Several synthetic PGRs such as NAA, have also been developed, which is classified as a reproductive development-oriented PGR. It is one of the synthetic auxin compounds. The application of these substances at the correct concentration and at a specific time during plant development may improve the fruit set (Sawan *et al.*, 1998) [17]. However, there is a dearth of information about the impact of crop geometry, detopping and use of growth regulator on productivity, quality and economics of Bt. Cotton under middle Gujarat conditions, hence, this experiment was conducted.

Materials and Methods

A field experiment was conducted during the *kharif* seasons of the year 2016-17 and 2017-18 at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, (Gujarat) in loamy sand soil having slightly alkaline pH, found low in organic carbon, medium in available nitrogen and phosphorus and high in available potassium. The experiment was carried out on Bt. Cotton variety GTHH-49 (BG-II), with treatment combinations comprising three crop geometry treatments *i.e.*, 90 cm x 45 cm (C_1), 120 cm x 45 cm (C_2) and 90 cm x 60 cm (C_3) and five different detopping and plant growth regulator treatments *i.e.*, Control (no detopping and no spray of NAA) (D_1), Detopping at 60 DAS (D_2), Detopping at 60 DAS + spray of NAA @ 30 ppm at 60 DAS (D_3), Detopping at 80 DAS (D_4) and Detopping at 80 DAS + spray of NAA @ 30 ppm at 60 DAS (D_5) laid in a split plot design with four replications.

Nitrogen was applied in four equal splits in the form of urea as per recommendation (240 kg Nha^{-1}). First dose of the nitrogen was applied as basal, and remaining three doses of nitrogen were applied at 30, 60 and 90 DAS, respectively. Detopping treatment was applied to plants at 60 and 80 DAS by pinching the apical bud. Solutions for plant growth regulator (PGR), used in this experiment were prepared as stock solution of NAA with 30 ppm concentration, prepared by dissolving 1 g of NAA in small amount of NaOH and made the total volume up to 10 ml as stock solution for PGR's. Then taken 3 ml of stock solution per pump of 10 lit water and sprayed at 60 DAS in respective gross plot of each replication. At each plucking seed cotton was harvested separately from net plot and recorded the weight in kg and converted on hectare basis. The total seed cotton was harvested in three plucking. The seed cotton of each plucking from net plot was weighed separately. The sum of seed cotton per plot picked at different plucking was used for working out total seed cotton yield per hectare.

Harvest index (HI) is the ratio of economic yield to the biological yield. It was calculated by using the formula given by Donald and Hamblin (1962) [6].

$$\text{Harvest Index} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

Quality parameters

Ginning percentage (%)

Treatment wise composite samples were taken to assess the ginning percentage (GP). This is the ratio of lint to seed cotton expressed as percentage and can be calculated by the following formula:

$$\text{Ginning percentage (\%)} = \frac{\text{Lint weight (g)}}{\text{Seed cotton weight (g)}} \times 100$$

Fiber length (mm)

It is the distance spanned by a specified percent of the fibers in the test bread. 2.5% span length is the distance from the clamp on fiber bread to a point up to which only 2.5% of the fiber extend. It is expressed as 2.5% span length in mm.

Fiber strength (g tex^{-1})

It denotes the maximum tension at which the fiber is able to sustain before it breaks. It can be defined as the ratio of the breaking strength of bundle of fiber to its weight and expressed in grams per Tex.

Oil content (%)

Random seed sample from each net plot produce was drawn to estimate the oil content. The oil content was determined by IBM DC/20 series, NMR (Nuclear Magnetic Resonance) analyzer and oil percent was recorded (Tiwari *et al.* 1974) [20].

Oil yield (kg ha^{-1}): The amount of oil yield per hectare for various treatments was calculated by using following formula.

$$\text{Oil yield (kg ha}^{-1}) = \frac{\text{Oil content in seed (\%)} \times \text{Seed yield (kg ha}^{-1})}{100}$$

Benefit cost ratio: Benefit cost ratio was worked out from the total income accrued from sum of total seed cotton yield and stalk yield obtained over total expenditure incurred considering the prevailing market rates for produce and each input required for different treatments.

$$\text{B:C ratio} = \frac{\text{Gross realization (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

Results and Discussion

Effect on growth parameters

Effect of different low-cost management practices on growth parameters like periodical plant population net plot^{-1}, plant height (cm), number of monopodial and sympodial branches plant^{-1} and their interaction effects are presented in Table 1(a) and 1(b).

Table 1a: Periodical plant population and different growth parameters as influenced by different treatments (Pooled)

Treatments	Plant population net plot^{-1}		Plant height (cm)			No. of monopodial branches plant^{-1}	No. sympodial branches plant^{-1}
	30 DAS	At harvest	40 DAS	80 DAS	120 DAS	Before 1st plucking	Before 1st plucking
Crop geometry (C)							
C_1: 90 cm x 45 cm	46.68	45.85	75.38	127.75	135.12	3.27	25.31
C_2: 120 cm x 45 cm	31.30	30.73	76.29	129.72	135.80	3.35	27.57
C_3: 90 cm x 60 cm	29.48	29.10	74.59	127.70	135.06	3.33	30.90
S. Em. ±	0.28	0.31	1.18	1.77	1.57	0.06	0.52
C. D. (P = 0.05)	0.85	0.97	NS	NS	NS	NS	1.60
C. V.%	4.85	5.63	9.93	8.70	7.32	11.63	11.77
Detopping and plant growth regulator (D)							
D_1: Control (No detopping and no spray of NAA)	35.71	35.21	77.00	158.99	178.71	3.20	25.19
D_2: Detopping at 60 DAS	35.75	35.29	72.64	94.40	96.23	3.32	27.32
D_3: Detopping at 60 DAS + Spray of NAA @ 30 ppm at 60 DAS	35.96	35.29	75.08	96.72	100.78	3.46	28.37
D_4: Detopping at 80 DAS	35.54	35.00	77.46	149.02	152.84	3.35	27.87
D_5: Detopping at 80 DAS + Spray of NAA @ 30 ppm at 60 DAS	36.13	35.33	74.91	142.83	148.07	3.25	30.87
S. Em. ±	0.22	0.22	1.22	7.03	1.90	0.08	0.52
C. D. (P = 0.05)	NS	NS	NS	27.61	5.37	NS	1.46
Interaction (C x D)							
S. Em. ±	0.39	0.56	2.12	3.50	3.29	0.13	0.89
C. D. (P = 0.05)	NS	NS	NS	NS	9.30	NS	NS
C. V.%	3.04	3.05	7.94	7.70	6.87	11.39	9.03

Table 1b: Interaction effect of crop geometry, detopping and plant growth regulator on plant height (cm) as influenced by different treatments at 120 DAS (Pooled)

Plant height (cm)			
Crop geometry / Detopping and plant growth regulator	C_1: 90 cm x 45 cm	C_2: 120 cm x 45 cm	C_3: 90 cm x 60 cm
D_1: Control (No detopping and no spray of NAA)	180.72	185.63	169.78
D_2: Detopping at 60 DAS	99.82	92.90	95.98
D_3: Detopping at 60 DAS + Spray of NAA @ 30 ppm at 60 DAS	101.20	100.40	100.75
D_4: Detopping at 80 DAS	146.37	153.98	158.17
D_5: Detopping at 80 DAS + Spray of NAA @ 30 ppm at 60 DAS	147.48	146.10	150.63
S. Em. ±	3.29		
C. D. (P = 0.05)	9.30		
C. V.%	6.87		

Effect of crop geometry

Plant population at 30 DAS and at harvest net plot^{-1} was influenced due to different crop geometry. The 90 cm X 45 cm geometry recorded significantly higher plant population (46.68) as compared to rest of the treatments on pooled mean of experimentation. Shukla *et al*. (2012) [18] observed that an increase or a decrease in plant population per unit area is a direct impact of the adopted plant geometry *i.e.*, spacing between two rows and within the row. Thus, plant population per unit area was higher in closer inter and intra row spacing over wider spacing. Plant height at 40, 80 and 120 DAS as well as number of monopodial branches plant^{-1} before first plucking were found unaffected due to various crop geometry treatments on pooled basis. These results are in conformity with the results reported by Buttar and Singh (2006) [3] and Pendharkar *et al*. (2010) [14]. The number of sympodial branches plant^{-1} before first plucking in *Bt* cotton were influenced significantly due to the different crop geometry on pooled mean. The crop geometry 90 cm x 60 cm recorded significantly higher number of sympodial branches plant^{-1} (30.90) than rest of crop geometries on pooled analysis. Under 90 cm x 60 cm crop geometry treatment,

photosynthetic and stomatal activities might increase and that enhanced the translocation of photosynthates towards the reproductive organs *i.e.* yield attributes due to equal spatial distribution for each plant which might increase the availability of moisture, nutrients as well as induce higher interception of solar radiation to each plant. These results are in conformity with the results reported by Kalaichelvi (2012) [10].

Effect of Detopping and plant growth regulator

Plant populations at 30 DAS and at harvest from net plot were not significantly influenced due to different Detopping and plant growth regulator treatments, indicating nearly uniform plant population in all the treatments. Though different treatments failed to exert any significant impact on plant height at 40 DAS and on number of monopodial branches plant^{-1} before 1st plucking, they had significant influence on plant height at 80 and 120 DAS and on number of sympodial branches plant^{-1} before 1st plucking on pooled basis. This is because all Detopping and plant growth regulator treatments were given after 60 DAS of *Bt* cotton. The control treatment (no detopping and no spray of NAA) registered significantly higher plant height at 80 DAS (158.99 cm) and at 120 DAS (178.71 cm) on pooled mean. Detopping at 60 DAS observed significantly lowest plant height at 80 DAS (94.40 cm) and 120 DAS (96.23 cm) on pooled mean. Decrease in plant height was due to termination of apical dominance by detopping over control. In the case of spray of NAA increase in plant height was due to biological activities of auxin *viz.*, stimulation of cell elongation and promotion of cell division. These results are in conformity with the results reported by Pothiraj *et al*. (1995) [15] and Brar *et al*. (2000) [20].

Interaction effect

All the interaction effects (Table 1 (a)) between crop geometry and detopping coupled with plant growth regulator were found non-significant except plant height at 120 DAS on pooled basis; wherein, cotton grown at 120 cm x 45 cm without detopping and spray of regulator (control) recorded significantly higher plant height (163.85 cm), followed by cotton sown at 90 cm x 45 cm with control (180.72 cm) over rest of the treatment combinations.

Effect on yield attributes and yield

Effect of crop geometry

Different crop geometry did not exert any significant impact on average boll weight at 1st, 2nd and 3rd plucking, seed cotton yield at 2nd and 3rd plucking as well as on seed index, however, it manifested significant impact on number of plucked bolls plant^{-1}, seed cotton yield at 1st plucking and total seed cotton yield as well as on stalk yield and harvest index (Table 2 & 3(a)). Cotton sown at 90 cm x 60 cm produced significantly highest number of plucked bolls plant^{-1} (51.04), seed cotton yield at 1st plucking (2149 kg ha^{-1}), Total seed cotton yield (3654 kg ha^{-1}) and harvest index (36.05). However, significantly higher stalk yield (7858 kg ha^{-1}) was recorded with 90 cm x 45 cm sowing, which was found at par with 120 cm x 45 cm sowing. The increase in yield might be because of higher values of growth and yield attributing characters *viz.*, sympodial branches per plant, average boll wt. and number of bolls plant^{-1} resulted in higher seed cotton. In case of 90 cm x 60 cm crop geometry each plant obtained more even space from all sides which helps to increase the availability of moisture and nutrients as well as interception of maximum solar radiation as a result of this photosynthetic and stomatal activities were increased and that enhanced the translocation of photosynthates towards the reproductive organs *i.e.* yield attributes. These results are in conformity with the results reported by Pendharkar *et al*. (2010) [14] Biradar *et al.* (2012) [1] and Kalaichelvi (2012) [10].

Effect of detopping and plant growth regulator

Though various treatments of detopping and growth regulators failed to exert any significant influence on average boll weight at 1st, 2nd and 3rd plucking, number of plucked bolls plant^{-1}, seed cotton yield at 2nd and 3rd plucking and seed index, they had significant effect on average boll weight, seed cotton yield at 1st plucking, total seed cotton yield, stalk yield and harvest index on pooled basis (Table 2 & 3(a)). Detopping at 80 DAS coupled with spray of NAA @ 30 ppm at 60 DAS recorded significantly higher average boll weight (4.05 g), which remained at par with detopping at 60 DAS coupled with spray of NAA @ 30 ppm at 60 DAS and detopping at 80 DAS. Detopping at 80 DAS coupled with spray of NAA @ 30 ppm at 60 DAS, being at par with detopping at 60 DAS coupled with spray of NAA @ 30 ppm at 60 DAS and detopping at 60 DAS produced significantly higher seed cotton yield (2062 kg ha^{-1}) at 1st plucking, while the same treatment out yielded all the treatment and produced significantly the highest total seed cotton yield (3624 kg ha^{-1}). As far as stalk yield was concerned, detopping at 60 DAS coupled with spray of NAA @ 30 ppm at 60 DAS being at par with all the treatments barring detopping at 60 DAS reported significantly higher stalk yield (7505 kg ha^{-1}), whereas, treatment with detopping at 80 DAS coupled with spray of NAA @ 30 ppm at 60 DAS revealed significantly higher harvest index (33.39), which was found at par with all the treatments except control on pooled basis. The increase in yield might be because of detopping and spray of NAA and cumulative effect of a greater number of sympodial branches per plant, number of bolls per plant and average boll weight as compared to rest of the treatments. Detopping resulted in better architectural plant which may increase penetration of sunlight in canopy because of reduced foliage and lodging resulted in higher photosynthetic activity, as well as more spread of plant which also harvest more sunlight and more photosynthesis. Kiran Kumar *et al.* (2005) [12] noticed that growth modification practices become more important by converting its phase of vegetative to reproductive growth. Removing terminal portion by detopping of cotton after prominent vegetative growth stage may be promising for encouraging growth of already formed sympodia as well as more formation and development of fruiting bodies. NAA have been shown to increase the rate of photosynthesis by increasing size of mesophyll cells and chlorophyll content in leaves of cotton thereby leading to more rapid exchange of CO_2 into mesophyll cell by virtue of their large surface area. NAA also increased the source sink ratio and sympodial branches. Spray of NAA favorably affected on the development and retention of fruiting bodies, so increased seed cotton yield. Similar results were observed by Virdia (2011) [21], Sarlach and Sharma (2012) [16], Shwetha *et al.* (2009) [19] and Kaul *et al.* (2013) [11].

Interaction Effect

All the yield attributes and yields barring test weight and

harvest index remained statistically at par due to interaction effect between crop geometry and detopping and spraying of plant growth regulator in pool analysis. Sowing of cotton at 90 cm x 60 cm along with detopping at 60 DAS coupled with spray of NAA @ 30 ppm at 60 DAS being at par with sowing of cotton at 120 cm x 60 cm along with detopping at 80 DAS reported significantly higher seed index (8.90) over all the treatment combinations (Table 3(b)), while the same treatment combination reported statistically higher harvest index (39.03) over rest of the treatment combinations barring sowing at 90 cm x 60 cm along with detopping at 60 DAS and detopping at 80 DAS coupled with spray of NAA @ 30 ppm at 60 DAS (Table 3 (c)).

Table 2: Yield attributes as influenced by different treatments (Pooled)

Treatments	Average boll wt. (g)			Average boll wt. (g))	No. of plucked bolls plant^{-1}
	At Ist plucking	At 2nd plucking	At 3rd plucking		
Crop geometry (C)					
C_1: 90 cm x 45 cm	4.53	3.82	3.37	3.91	33.49
C_2: 120 cm x 45 cm	4.63	3.83	3.46	3.99	46.23
C_3: 90 cm x 60 cm	4.67	3.83	3.50	4.01	51.04
S. Em. ±	0.08	0.08	0.06	0.03	1.06
C. D. (P = 0.05)	NS	NS	NS	NS	3.27
C. V.%	10.62	12.67	11.78	5.42	15.41
Detopping and plant growth regulator (D)					
D_1: Control (No detopping and no spray of NAA)	4.49	3.37	3.34	3.87	41.70
D_2: Detopping at 60 DAS	4.61	3.75	3.37	3.92	43.16
D_3: Detopping at 60 DAS + Spray of NAA @ 30 ppm at 60 DAS	4.66	3.91	3.51	4.03	43.77
D_4: Detopping at 80 DAS	4.63	3.78	3.48	3.97	43.16
D_5: Detopping at 80 DAS + Spray of NAA @ 30 ppm at 60 DAS	4.67	3.96	3.51	4.05	46.16
S. Em. ±	0.07	0.09	0.08	0.04	1.13
C. D. (P = 0.05)	NS	NS	NS	0.12	NS
Interaction (C x D)					
S. Em. ±	0.12	0.15	0.14	0.07	1.96
C. D. (P = 0.05)	NS	NS	NS	NS	NS
C. V.%	7.26	11.16	11.12	5.29	12.74

Table 3a: Seed cotton and stalk yield as influenced by different treatments (Pooled)

Treatments	Seed cotton yield (kg ha^{-1})			Total Seed cotton Yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Seed index (g)	Harvest index
	At 1st plucking	At 2nd plucking	At 3rd plucking				
Crop geometry (C)							
C_1: 90 cm x 45 cm	1759	807	518	3081	7858	8.49	28.42
C_2: 120 cm x 45 cm	1929	811	528	3265	6942	8.63	31.93
C_3: 90 cm x 60 cm	2149	975	528	3654	6560	8.71	36.05
S. Em. ±	41.03	40.52	12.78	80.74	151.91	0.09	0.74
C. D. (P = 0.05)	126	NS	NS	249	468	NS	2.27
C. V.%	13.34	13.00	15.41	15.32	13.49	6.85	14.50
Detopping and plant growth regulator (D)							
D_1: Control (No detopping and no spray of NAA)	1862	808	438	3102	7050	8.43	30.64
D_2: Detopping at 60 DAS	1954	831	470	3249	6537	8.55	33.20
D_3: Detopping at 60 DAS + Spray of NAA @ 30 ppm at 60 DAS	2012	895	505	3411	7505	8.69	31.89
D_4: Detopping at 80 DAS	1840	874	560	3281	7174	8.61	31.55
D_5: Detopping at 80 DAS + Spray of NAA @ 30 ppm at 60 DAS	2062	913	650	3624	7334	8.78	33.39
S. Em. ±	40.03	44.62	36.43	74.27	173.10	0.10	0.70
C. D. (P = 0.05)	113	NS	NS	210	490	NS	1.98
Interaction (C x D)							
S. Em. ±	69.33	71.21	67.52	128.64	678.36	0.17	1.21
C. D. (P = 0.05)	NS	NS	NS	NS	NS	0.49	3.43
C. V.%	10.08	11.35	11.15	10.92	11.91	5.64	10.67

Table 3b: Interaction effect of crop geometry, detopping and plant growth regulator on seed index (g) as influenced by different treatments (Pooled)

Seed index (g)			
Crop geometry / Detopping and plant growth regulator	**C_1: 90 cm x 45 cm**	**C_2: 120 cm x 45 cm**	**C_3: 90 cm x 60 cm**
D_1: Control (No detopping and no spray of NAA)	8.45	8.48	8.35
D_2: Detopping at 60 DAS	8.48	8.63	8.54
D_3: Detopping at 60 DAS + Spray of NAA @ 30 ppm at 60 DAS	8.51	8.67	8.90
D_4: Detopping at 80 DAS	8.51	8.89	8.43
D_5: Detopping at 80 DAS + Spray of NAA @ 30 ppm at 60 DAS	8.52	8.47	9.34
S. Em. ±	0.17		
C. D. (P = 0.05)	0.49		
C. V.%	5.64		

Table 3c: Interaction effect of crop geometry, detopping and plant growth regulator on harvest index as influenced by different treatments (Pooled)

Harvest index			
Crop geometry / Detopping and plant growth regulator	**C_1: 90 cm x 45 cm**	**C_2: 120 cm x 45 cm**	**C_3: 90 cm x60 cm**
D_1: Control (No detopping and no spray of NAA)	26.05	31.86	34.03
D_2: Detopping at 60 DAS	29.75	32.68	37.15
D_3: Detopping at 60 DAS + Spray of NAA @ 30 ppm at 60 DAS	26.39	30.26	39.03
D_4: Detopping at 80 DAS	30.09	30.67	33.89
D_5: Detopping at 80 DAS + Spray of NAA @ 30 ppm at 60 DAS	29.83	34.19	36.15
S. Em. ±	1.21		
C. D. (P = 0.05)	3.43		
C. V.%	10.67		

Effect on quality

Impact of low-cost practices on quality *viz*; ginning percentage, fiber length, fiber strength, oil content and oil yield of Bt. Cotton are given in table 4.

Table 4: Quality parameters of cotton as influenced by different treatments

Treatments	Ginning percentage (%)	Fibre length (mm)	Fibre strength (g tex^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
Crop geometry (C)					
C_1: 90 cm x 45 cm	34.01	28.03	30.68	17.88	558
C_2: 120 cm x 45 cm	34.22	28.21	31.11	18.37	606
C_3: 90 cm x 60 cm	34.54	29.04	30.98	18.29	675
S. Em. ±	0.15	0.11	0.19	0.18	15.34
C. D. (P = 0.05)	NS	NS	NS	NS	47
C. V.%	2.70	2.57	3.94	6.28	15.83
Detopping and plant growth regulator (D)					
D_1: Control (No detopping and no spray of NAA)	34.04	28.36	30.19	18.06	566
D_2: Detopping at 60 DAS	34.17	27.71	30.66	18.13	599
D_3: Detopping at 60 DAS + Spray of NAA @ 30 ppm at 60 DAS	34.49	27.42	30.68	18.16	624
D_4: Detopping at 80 DAS	34.07	28.42	31.34	18.08	599
D_5: Detopping at 80 DAS + Spray of NAA @ 30 ppm at 60 DAS	34.51	28.09	31.75	18.45	675
S. Em. ±	0.17	0.14	0.23	0.20	14.76
C. D. (P = 0.05)	NS	0.39	0.65	NS	42
Interaction (C x D)					
S. Em. ±	0.53	0.24	0.40	0.34	25.57
C. D. (P = 0.05)	NS	NS	NS	NS	NS
C. V.%	2.43	2.37	3.63	5.31	11.80

Effect of crop geometry

Pursuance of results given in table 4 indicated that except oil yield, none of the quality parameter was affected significantly due to crop geometry. Sowing of cotton at 90 cm x 60 cm gave significantly highest oil yield (675 kg ha^{-1}), which might be the resultant effect of higher total seed cotton yield under the same treatment. These results are in conformity with the results reported by Pendharkar *et al.* (2010) [14] Biradar *et al.* (2012) [1] and Kalaichelvi (2012) [10].

Effect of detopping and plant growth regulator

Nevertheless, detopping and plant growth regulator had significant impact on quality parameters except ginning percentage and oil content. Detopping at 80 DAS recorded significantly higher fiber length (28.42 mm), which was found at par with detopping at 80 DAS coupled with spray of 30 ppm NAA at 60 DAS and control (No detopping and no spray). However, detopping at 80 DAS coupled with spray of 30 ppm NAA at 60 DAS observed significantly higher fiber

strength (31.75 mm) and oil yield (675 kg/ha^{-1}), it remained at par with detopping at 80 DAS for fiber strength. Detopping might have coincided with the active period of boll development. Increased dry matter accumulation into reproductive structures during this stage, might have encouraged the fibers to grow longer. These results are in accordance with those reported by Sawan and Sakr (1998) [17], Shwetha *et al*. (2009) [19], Biradar *et al*. (2010) [1] and Hallikeri *et al*. (2010) [9].

Interaction Effect

None of the interaction effect between crop geometry and detopping coupled with plant growth regulator exerted any significant influence on any of the quality parameters of Bt. Cotton.

Economics

The regional adaptability of any agronomic practices in the yield of any crop is completely based on the highest economic return of a treatment. On the basis of prevailing market prices of seed cotton and stalk yields of *Bt* cotton and different variable and non-variable inputs cost incurred during investigation, the total expenditure, gross and net realization as well as B: C ratio were worked out for individual treatments and presented in Table 5.

Table 5: Economics of *Bt* cotton crop as influenced by different treatments

Treatments	*Bt* cotton		Gross realization (₹ ha^{-1})	Total cost of cultivation (₹ ha^{-1})	Net realization (₹ ha^{-1})	B:C ratio
	Seed cotton yield (kg ha^{-1})	Stalk yield (kg ha^{-1})				
Crop geometry (C)						
C_1	3081	7858	159597	65015	94583	2.45
C_2	3265	6942	167743	62641	105103	2.68
C_3	3654	6560	186520	62641	123879	2.98
Detopping and plant growth regulator (D)						
D_1	3102	7050	159824	55446	104377	2.88
D_2	3249	6537	166550	56651	109899	2.94
D_3	3411	7505	175497	57094	118403	3.07
D_4	3281	7174	168763	56651	112112	2.98
D_5	3624	7334	185816	57094	128722	3.25

Sale price of seed cotton: ₹ 49.25 kg^{-1} Sale price of cotton stalk: ₹ 1.00 kg^{-1}

Effect of crop geometry

Among different crop geometry treatments, sowing the Bt cotton at 90 cm x 60 cm crop geometry (C_3) registered maximum gross (₹ 1,86,520 ha^{-1}) and net realization (₹ 1,23,879 ha^{-1}) with B:C ratio of 2.98. This increase in profitability was mainly due to higher seed cotton yield. These results are in conformity with the results reported by Biradar *et al.* (2012) [1] and Ghule *et al.* (2013) [7].

Effect of detopping and plant growth regulator

Results presented in Table 5 showed that detopping at 80 DAS + spray of NAA @ 30 ppm at 60 DAS (D_5) gave maximum gross and net realization as well as B:C ratio of *Bt* cotton ₹ 1,85,816 ha^{-1}, ₹ 1,28,722 ha^{-1} and 3.25, respectively which was mainly due to higher seed cotton yield. Similar result was also registered by Shwetha *et al.* (2009) [19] and Kulkarni *et al.* (2011) [13].

Conclusion

Thus, on the basis of two years field experimentation, it could be concluded that *Bt* cotton (GTHH-49) in *kharif* season should be sown at 90 cm x 60 cm geometry, spray of NAA @ 30 ppm at 60 DAS and detopped at 80 DAS for higher yield, improved quality and maximum net realization and B:C ratio under loamy sand soil of middle Gujarat conditions.

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