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Research Paper

Effect of different agro-techniques on yield of *Bt* cotton

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ABSTRACT

A field experiment was conducted during the 2 consecutive *kharif* seasons of 2019 and 2020 at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, to study the yield maximization of *Bt* cotton through agro-techniques in loamy sand. The experiment consisted of four factors *viz*; spacing, detopping, intercropping and sowing time with two levels in each treatment. The results of pooled data of 2 years indicated that *Bt* cotton sown at spacing of 60 cm × 45 cm recorded significantly higher plant height, crop growth rate as well as seed cotton (3077 kg/ha) and stalk yields (5930 kg/ha), seed cotton equivalent yield (3512 kg/ha) and oil yield (335 kg/ha). However, wider spacing of 120 cm × 60 cm produced remarkably higher number of sympodial branches per plant, relative growth rate, number of open bolls per plant, weight of seed cotton per boll and seed cotton yield per plant. Topping carried out at 75 DAS remarkably improved growth and yield attributes, seed cotton and stalk yields, seed cotton equivalent yield, oil yield. All growth and yield attributes as well as seed cotton yield were recorded significantly higher without intercrop in *Bt* cotton. Though intercropping of greengram (additive series) in *Bt* cotton produced significantly higher seed cotton equivalent yield than no intercropping in pooled mean. Advance sowing of *Bt* cotton in last week of May produced significantly higher seed cotton yield and seed cotton equivalent $S_1T_2I_2D_1$ [Advance sowing (Last week of May)] at plant spacing of 60 cm × 45 cm along with detopping at 75 DAS and intercropping with greengram] gave significantly higher seed cotton equivalent yield as well as net returns and B: C ratio of *Bt* cotton.

India ranks second in area and production of cotton in the world. It plays a vital role in the national economy by contributing 29.8% India's agricultural gross domestic production. Among the different cotton growing countries in the world, India ranks second next to china with regards to production. In India, cotton is cultivated in an area of 132.9 lakh hectares with a production of 352.5 lakh bales of seed cotton (170 kg/bale) with a productivity of 451 kg/ha (Agricultural Statistics at a Glance, GoI, 2022).

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 factors 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 number of plants per unit area and closer spacing reduces yield due to competition within the plants (Patel *et al*., 2021). Growth modification practice such as detopping (removal of apex bud) becomes important by converting the vegetative phase of cotton crop to reproductive phase. Removing top terminal portion by detopping in cotton after prominent vegetative growth stage was found promising for encouraging growth of already formed sympodia as well as more formation and development of sympodia. Intercrops having different growth habit, canopy adoption, short duration pulse crop and root systems can easily be accommodated with the least competition in cotton. Introduction of short duration pulse as intercrop generate additional income besides improving soil fertility. Suitable sowing time is a non-monetary important agronomic practice to increase the yield of any crop. Sowing time provide favourable climate conditions to crop at different growth stages of crop that resulted in production of higher crop yield.

Keeping these points in view, an investigation was undertaken to identify optimum spacing, detopping, intercropping and sowing time to enhance the productivity of *Bt* cotton hybrid with existing plant architecture.

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MATERIALS AND METHODS

The experiment was carried out during *kharif* seasons of 2019 and 2020 at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, District Banaskantha in North Gujarat. The soil of the experimental field was loamy sand with low pH, organic carbon (0.22%) and available nitrogen (164 kg/ha), medium in phosphorus (33 kg/ha) and high in potassium (290 kg/ha). Spacing [60 cm × 45 cm (S_1) and 120 cm × 60 cm (S_2)], detopping [no detopping (T_1) and detopping at 75 DAS (T_2)], intercropping [no intercropping (I_1) and intercropping with greengram (I_2)] and sowing time [advance sowing (last week of May) (D_1) and normal sowing (3rd week of June) (D_2)]. The allotment of treatments to various plots in each replication was done by referring random number. *Bt* cotton hybrid GTHH 49 (BG II) was used as a main crop and greengram variety GM 4 was taken as an intercrop. Sowing of main crop (*Bt* cotton) and intercrop (greengram) was done on the same day as per treatments during both the years. Nitrogen fertilizer was applied (320 kg N/ha) in 5 equal splits (at basal, 30, 60, 75 and 90 DAS) in the form of urea. Potassium, in the form of muriate of potash, was applied basally (120 kg K_2O/ha). Greengram crop was fertilized with 20 kg N and 17.5 kg P/ha as basal dose. The yield of intercrop greengram was converted into seed cotton equivalent yield by using formula:

$$\text{SCEY (kg/ha)} = \frac{(Y_{sc} \times P_{sc}) + (Y_{cs} \times P_{cs}) + (Y_{gs} \times P_{gs}) + (Y_s \times P_s)}{P_{sc}}$$

Where,

SCEY = Seed cotton equivalent yield (kg/ha)
Y_{sc} = Seed cotton yield of cotton (kg/ha)
P_{sc} = Price of seed cotton (₹/kg)
Y_{cs} = Yield of cotton stalk (kg/ha)
P_{cs} = Price of cotton stalk (₹/kg)
Y_{gs} = Yield of greengram seed (kg/ha)
P_{gs} = Price of greengram seed (₹/kg)
Y_s = Yield of greengram stover (kg/ha)
P_s = Price of greengram stover (₹/kg)

All the data recorded in individual year as well as in pooled analysis were statistically analyzed for their test of significant using the F-test (Cochran and Cox, 1967). The significance of difference between treatment means was compared with critical difference at 5% level of probability.

RESULTS AND DISCUSSION

Effect of spacing

All growth attributes viz. periodical plant height, number of sympodial branches per plant at 60, 90 and 120 DAS, CGR and RGR for the 30-60 DAS, 60-90 and 90-120 DAS (Table 1) were significantly affected by plant spacing. *Bt* cotton sown at narrow spacing (60 cm × 45 cm) produced taller plants and higher crop growth rate in pooled results as compared to wider spacing (120 cm × 60 cm). The congestion of plants per unit area induced more vertical growth, produced taller plants under closer spacing (Ajaykumar *et al*., 2017). The closer inter and intra row spacing accommodate more plants per unit area as compared to wider spacing which produced more dry matter per ground area per unit time ultimately reflected in higher CGR value over different time span.

On the contrary, wider spacing of 120 cm × 60 cm registered remarkably higher sympodial branches per plant as well as RGR at different period over closer spacing because each plant got sufficient space from all sides and possibly increased the availability of moisture and nutrients besides maximum incoming solar radiation enhanced production and translocation of photosynthesis towards the reproductive organs.

An examination of the data presented in Table 2 showed that significant increase in number of open bolls per plant at 90, 120, 150 and 180 DAS, weight of seed cotton per boll and seed cotton yield per plant of *Bt* cotton due to different plant spacing. Significantly more number of bolls per plant at different stages with less plant density (60 cm × 45 cm) might be due to less number of plants per unit area set more bolls per plant on second and third position of sympodial branches. Bolls tends to be larger in low density stands because of better penetration of light to the leaves that increased number of bolls. Higher number of bolls per plant and seed cotton weight per boll ultimately gave higher seed cotton yield per plant. This might be attributed to relatively less inter plant competition because of more availability of space to individual plant. Similar observations were reported by Pandagale *et al*. (2015).

Seed cotton yield and stalk yield (kg/ha) were significantly higher under higher plant density (60 cm × 45 cm spacing) over less plant population (120 cm × 60 cm) as it could not compensate the number of plants per hectare as well as remarkably higher number of bolls per unit area. Similar observations of higher seed cotton and stalk yields at closer spacing compared to wider spacing was reported by Patel *et al*. (2021).

Effect of detopping

A perusal of data exhibited in Table 1 and 2 indicated that various growth attributes viz. plant height at 90 DAS and at harvest, sympodial branches per plant at 90 and 120 DAS, CGR and RGR between 60-90, 90-120 DAS as well as yield attributes *viz.* number of bolls per plant at 120, 150 and 180 DAS, boll weight and seed yield per plant were significantly influenced by de-topping treatments. The plant height was significantly higher under no topping as

Table 1. Effect of spacing, detopping, intercropping and sowing time on plant height, sympodial branches/plant, CGR and RGR of *Bt* cotton (pooled data of 2 years)

Treatment	Plant height (cm)				Sympodial branches plant			Crop growth rate ($g/m^2/day$)			Relative growth rate (mg/g/day)		
	30 DAS	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	120 DAS	30–60 DAS	60–90 DAS	90–120 DAS	30–60 DAS	60–90 DAS	90–120 DAS
Spacing (S)													
S_1, 60 cm × 45 cm	30.1	77.1	101.2	119.0	12.0	18.7	22.8	5.7	6.9	5.1	31.8	17.9	8.9
S_2, 120 cm × 60 cm	29.7	72.3	93.2	112.8	14.4	22.2	24.7	4.1	5.3	3.6	47.0	20.0	10.2
S.Em.±	0.3	1.0	1.2	1.2	0.2	0.3	0.3	0.1	0.1	0.2	1.4	0.4	0.3
CD (P=0.05)	NS	2.7	3.3	3.4	0.6	0.7	0.8	0.3	0.2	0.4	3.8	1.1	0.9
Topping (T)													
T_1, No topping	30.2	75.7	106.8	138.4	13.0	19.7	23.0	5.3	5.9	3.9	40.8	17.1	9.0
T_2, Topping at 75 DAS	29.5	73.6	87.5	93.4	13.4	21.2	24.5	4.6	6.4	4.6	44.7	19.9	10.0
S.Em.±	0.3	1.0	1.2	1.2	0.2	0.3	0.3	0.1	0.1	0.2	1.4	0.4	0.3
CD (P=0.05)	NS	NS	3.3	3.4	NS	0.7	0.8	NS	0.2	0.4	NS	1.1	0.9
Intercropping (I)													
I_1, No intercropping	30.1	77.8	100.9	118.1	13.6	21.4	24.1	5.1	6.2	4.7	43.8	19.6	10.1
I_2, Intercropping with greengram	29.6	71.6	93.4	113.7	12.8	19.6	23.4	4.7	6.0	4.0	34.9	18.0	9.0
SEm±	0.3	1.0	1.2	1.2	0.2	0.3	0.3	0.1	0.1	0.2	1.4	0.4	0.3
CD (P=0.05)	NS	2.7	3.3	3.4	0.6	0.7	NS	0.3	0.2	0.4	3.8	1.1	0.9
Sowing time (D)													
D_1, Last week of May (Advance sowing)	30.2	75.7	98.5	117.0	13.1	20.6	24.0	5.1	6.2	4.6	42.7	19.5	9.9
D_2, 3rd week of June (Normal sowing)	29.6	73.7	95.8	114.8	13.3	20.4	23.6	4.8	5.9	4.1	36.0	18.3	9.2
SEm±	0.3	1.0	1.2	1.2	0.2	0.3	0.3	0.1	0.1	0.2	1.4	0.4	0.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions	NS	NS	NS	117.0	NS	NS	NS	NS	NS	NS	NS	NS	NS

compared to detopping at 75 DAS at 90 DAS and at harvest. Topping of terminal bud arrests the growth of main stem, as terminal bud is responsible for plant elongation, resulting in a decrease in plant height. On the other hand, topping of buds carried out at 75 DAS in *Bt* cotton proved superior with respect to number of sympodial branches per plant at 90 and 120 DAS (21.2 and 24.5, respectively), CGR of 6.3 and 4.5 $g/m^2/day$ and RGR of 19.9 and 10.0 mg/g/day between 60-90 and 90-120 DAS, respectively; number of bolls per plant of 36.5, 46.5 and 50.8 at 120, 150 and 180 DAS, respectively; weight of seed cotton per boll (3.366 g) and seed cotton yield per plant (151.48 g) over without topping of terminal bud. The remarkable improvement under topping treatment might be because of improved source-sink relationship and better translocation of metabolites towards growing and reproductive sink due to retardation of excessive vegetative growth. These results are corroborated by Hallikeri *et al.* (2010).

Similarly, significantly higher seed cotton yield (2854 kg/ha), stalk yield (5586 kg/ha) and oil yield (314 kg/ha) were recorded under detopping treatment as compared to no detopping in pooled data (Table 2). Topping resulted in better architectural plant which increase penetration of sun light in canopy resulted in better photosynthetic activity ultimately reflected in higher yield of *Bt* cotton. Swetha *et al.* (2009) observed topping at 80 DAS resulted in significant increase in oil yield (314 kg/ha) than no detopping. This might

Table 2. Effect of spacing, detopping, intercropping and sowing time on number of open bolls/plant, boll weight, seed cotton yield/plant, seed cotton yield, stalk yield, seed cotton equivalent yield and oil yield of *Bt* cotton (pooled data of 2 years)

Treatment	Number of open bolls /plant				Boll weight (g)	Seed cotton yield plant (g)	Seed cotton yield (kg/ha)	Stalk yield (kg/ha)	Seed cotton equivalent yield (kg/ha)	Oil yield (kg/ha)
	90 DAS	120 DAS	150 DAS	180 DAS						
Spacing (S)										
S_1, 60 cm × 45 cm	19.1	28.0	36.7	39.9	3.208	95.66	3,077	5,930	3,512	335
S_2, 120 cm × 60 cm	24.9	42.3	53.9	59.4	3.342	201.71	2,434	4,838	2,673	269
SEm±	0.34	0.41	0.48	0.48	0.033	1.19	42	88	42	7
CD (P=0.05)	0.95	1.15	1.36	1.34	0.092	3.35	118	248	118	19
Topping (T)										
T_1, No topping	21.5	33. 8	44.2	48. 6	3.184	145.90	2,658	5,182	2,989	291
T_2, Topping at 75 DAS	22.4	36.5	46.5	50. 8	3.366	151.48	2,854	5,586	3,195	314
SEm±	0.34	0.41	0.48	0.48	0.033	1.19	42	88	42	7
CD (P=0.05)	NS	1.15	1.36	1.34	0.092	3.35	118	248	118	19
Intercropping (I)										
I_1, No intercropping	22.7	35.7	46.0	50.1	3.356	151.15	2,877	5,636	2,929	317
I_2, Intercropping with greengram	21.3	34.6	44.7	49.2	3.194	146.22	2,634	5,131	3,256	288
SEm±	0.34	0.41	0.48	0.48	0.033	1.19	42	88	42	7
CD (P=0.05)	0.95	NS	NS	NS	0.092	3.35	118	248	118	19
Sowing time (D)										
D_1, Last week of May (Advance sowing)	22.1	35.5	45.9	50.1	3.305	149.25	2,840	5,447	3,173	311
D_2, 3rd week of June (Normal sowing)	21.8	34.8	44.8	49.3	3.244	148.12	2,672	5,320	3,012	294
SEm±	0.34	0.41	0.48	0.48	0.033	1.19	42	88	42	7
CD (P=0.05)	NS	NS	NS	NS	NS	NS	118	NS	118	NS
Interactions										
S × T × I × D	NS	NS	NS	NS	NS	NS	Sig.	NS	Sig.	NS
SEm±	NS	NS	NS	NS	NS	NS	118	NS	118	NS
CD (P=0.05)	NS	NS	NS	NS	NS	NS	334	NS	332	NS

be due to significantly higher seed cotton yield observed under detopping treatment.

Effect of intercropping

Intercropping had a significant effect on mean plant height, number of sympodial branches per plant, CGR and RGR, number of bolls per plant, boll weight and seed cotton yield per plant (Tables 1 and 2). From the data (Tables 1 and 2), it is inferred that no intercropping treatment produced taller plants (77.8, 100.9 and 118.1 cm at 60 DAS, 90 DAS and at harvest, respectively), sympodial branches per plant (13.6 and 21.4 at 60 and 90 DAS, respectively), CGR (5.1, 6.2 and 4.7 g/m^2/day at 30-60, 60-90 and 90-120 DAS, RGR (43.8, 19.6 and 10.1 mg/g/day at 30-60, 60-90 and 90-120 DAS, respectively), number of bolls per plant at 90 DAS (22.6), weight of seed cotton per boll (3.36 g) and seed cotton yield per plant (151.2 g) than intercropping with greengram. Similarly, significantly higher seed cotton yield (2877 kg/ha) and stalk yield (5636 kg/ha) were obtained under sole *Bt* cotton in pooled data.

This might be due to absence of competition between *Bt* cotton and intercrop greengram that provide more plant nutrients, soil moisture, space and solar radiation which les to remarkable improvement of growth and yield attributed and ultimately reflected on seed cotton yield of *Bt* cotton.

While, seed cotton equivalent yield was recorded significantly higher when *Bt* cotton was sown with intercrop (3256 kg/ha) than no intercrop in pooled mean. Intercropping system brought significant improvement in seed cotton equivalent yield over sole *Bt* cotton on account of additional yield obtained from intercrop greengram in addition to sole crop yield contributed to higher seed cotton equivalent yield. Singh *et al*. (2015) reported higher seed cotton equivalent yield in intercropping as compared to sole crop.

Effect of sowing time

Sowing time treatments failed to exert significant influence on growth and yield attributes but seed cotton yield, stalk yield and seed cotton equivalent yield of *Bt* cotton was significantly influenced due to sowing time. Advance sowing of *Bt* cotton (last week of May) produced significantly higher seed cotton yield (3173 kg/ha) and stalk yield (5447 kg/ha) than *Bt* cotton sown on 3rd week of June in pooled results. The advance sowing provided congenial climatic condition to crop during the period of crop growth resulted in significant improvement in seed cotton yield in pooled data. These results are in conformity with the results reported by Bozbek *et al*. (2006).

Interaction (S×T×I×D)

Interaction effect of spacing, topping, intercropping and sowing time significantly influenced the seed cotton yield and seed cotton equivalent yield (Table 3). Advance sowing of *Bt* cotton (last week of May) at 60 cm × 45 cm without topping and intercropping ($S_1T_1I_1D_1$) registered significantly higher seed cotton yield (3480 kg/ha) than rest of treatment combinations in pooled analysis. However, it is remained on the same bar with treatment combinations $S_1T_2I_1D_1$ and $S_1T_2I_1D_2$. These results are in line of those reported by Shwetha *et al*. (2009) and Pandagale *et al.* (2015). Whereas, significantly higher seed cotton equivalent yield (3877 kg/ha) was obtained in $S_1T_2I_2D_1$ but did not differ significantly over $S_1T_1I_2D_2$, $S_1T_1I_2D_1$ and $S_1T_2I_2D_2$ in pooled results.

Thus, it may be concluded that *Bt* cotton should be sown during last week of May to third week of June at 60 cm × 45 cm spacing along with topping (removal of

Table 3. Interaction effect of spacing, detopping, intercropping and sowing time on seed cotton yield and seed cotton equivalent yield of *Bt* cotton

Treatment	Seed cotton yield (kg/ha)						Seed cotton equivalent yield (kg/ha)					
	2019		2020		Pooled		2019		2020		Pooled	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
$T_1I_1D_1$	3,714	2,402	3,245	2,201	3,480	2,302	3,770	2,446	3,300	2,201	3,535	2,324
$T_1I_1D_2$	2,996	2,490	2,826	2,231	2,911	2,360	3,050	2,533	2,877	2,272	2,964	2,402
$T_1I_2D_1$	2,957	2,516	2,778	2,365	2,867	2,440	3,819	2,957	3,492	2,758	3,656	2,857
$T_1I_2D_2$	3,006	2,176	2,842	1,779	2,924	1,977	3,894	2,637	3,573	2,245	3,734	2,441
$T_2I_1D_1$	3,566	2,985	3,119	2,525	3,343	2,755	3,628	3,039	3,175	2,569	3,402	2,804
$T_2I_1D_2$	3,391	2,782	3,084	2,479	3,238	2,631	3,453	2,834	3,141	2,525	3,297	2,680
$T_2I_2D_1$	3,111	2,579	2,992	2,380	3,052	2,479	4,003	3,031	3,750	2,778	3,877	2,905
$T_2I_2D_2$	2,898	2,621	2,710	2,437	2,804	2,529	3,802	3,081	3,459	2,857	3,630	2,969
SEm±	183		152		118		183		150		118	
CD (P=0.05)	522		432		334		521		427		332	
CV %	12.70		11.56		12.21		11.26		10.22		10.82	

terminal bud) at 75 DAS and intercropping with greengram (additive series in 1:1 row ratio) under loamy sand soils.

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