Yield Maximization of *Bt* cotton through agro-techniques

Abstract

A field experiment was conducted during the two 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, topping, intercropping and sowing time with two levels in each treatment. The results of pooled data of 2 years revealed that *Bt* cotton sown at spacing of 60 cm × 45 cm recorded significantly higher plant height, crop growth rate as well as seed cotton and stalk yields, seed cotton equivalent yield, oil yield while significantly higher number of sympodial branches per plant, relative growth rate, number of brusted bolls per plant, weight of seed cotton per boll and seed cotton yield per plant with wider spacing of 120 cm × 60 cm. 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 on last week of May significantly 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 topping 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.

Key words: Bt cotton, cotton production, Yield Maximization

Introduction

India ranks first 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 129.7 lakh hectares with a production of

371.0 lakh bales of seed cotton (170 kg/bale) with a productivity of 487 kg per hectare (Anonymous, 2021).

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 (Khetre *et al*., 2018). Growth modification practice such as topping (removal of apex bud) becomes important by converting the vegetative phase of cotton crop to reproductive phase. Removing top terminal portion by topping in cotton after prominent vegetative growth stage which found promising for encouraging growth of already formed sympodia as well as more formation and development of sympodia. Intercrop 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, topping, intercropping and sowing time to enhance the productivity of *Bt* cotton hybrid with existing plant architecture.

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) status. Spacing [60 cm × 45 cm (S_1) and 120 cm × 60 cm (S_2)], topping [no topping (T_1) and topping 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

(3^{rd} 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 a intercrop. Sowing of main crop (*Bt* cotton) and intercrop (greengram) was done on the same day as per treatments during both the years. *Bt* cotton was fertilized 320 kg N/ha in 5 equal splits (64 kg N/ha each at basal, 30, 60, 75 and 90 DAS) in the form of urea and 120 kg K_2O/ha as a basal in the form of muriate of potash. Greengram crop was fertilized with 20:40:00 kg N: P_2O_5: K_2O/ha as basal dose. The yield of intercrop greengram was converted into seed cotton equivalent yield by using formula.

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 between 30-60 DAS, 60-90 and 90-120 DAS (Table 1) were significantly improved with different 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 (Mahil and Loandhan, 2018). 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 get even space from all sides which increase the availability of moisture and nutrients besides maximum intercropping of incoming solar radiation enhanced production and translocation of photosynthesis towards the reproductive organs.

An examination of data presented in Table 2 showed that significant increase in number of brusted 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 plant spacing. Significant more number of bolls per plant at different stages under lower 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 feeding 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 obtained significantly higher under higher plant density of *Bt* cotton *i.e*. 60 cm × 45 cm spacing over wider spacing of 120 cm × 60 cm as it could not compensate the loss in 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 Mahil and Loandhan (2018). Patel *et al*. (2021) reported higher seed cotton yield of *Bt* cotton with plant spacing of 45 cm × 30 cm than other plant spacing.

Effect of toping

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, weight of seed cotton per boll and seed yield per plant were significantly influenced due to topping treatments. The plant height was found significantly higher under no topping as compared to topping at 75 DAS at 90 DAS and at harvest. Topping of terminal bud arrest the growth of main stem as terminal bus is responsible for plant elongation led to 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 (21.24 and 24.53, respectively), CGR of 6.35 and 4.55 g/m^2/day and RGR 19.92 and 10.03 mg/g/day between 60-90 and 90-120 DAS, respectively; number of bolls per plant of 36.54, 46.48 and 50.78 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 topping treatment as compared to no topping 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 on higher yield of *Bt* cotton. Swetha *et al.* (2009) observed under topping at 80 DAS than no topping. Topping at 75 DAS resulted in significant increase in oil yield (314 kg/ha) than no topping. This might be due to significantly higher seed cotton yield observed under topping treatment. The research findings of Chaudhri *et al*. (2021) and they reported higher seed cotton yield per plant with topping at 100 DAS during their three year of study.

Effect of intercropping

The mean plant height at 60, 90 DAS and at harvest, number of sympodial branches per plant at 60 and 90 DAS, CGR and RGR at 30-60 DAS, 60-90 and 90-120 DAS, number of bolls per plant at 90 DAS, weight of seed cotton per boll and seed cotton yield per plant were significantly affected due to intercropping treatments in pooled analysis. It is inferred from the data (Table 1 and 2) 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 (13.60 and 21.36 at 60 and 90 DAS, respectively), CGR (5.13, 6.24 and 4.66 g/m^2/day at 30-60, 60-90 and 90-120 DAS, RGR (43.79, 19.59 and 10.06 mg/g/day at 30-60, 60-90 and 90-120 DAS, respectively), number of bolls per plant at 90 DAS (22.68), weight of seed cotton per boll (3.356 g) and seed cotton yield per plant (151.15 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 led 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. Kumar *et al*. (2017) reported higher seed cotton equivalent yield in intercropping as compared to sole crop.

Effect of sowing time

Sowing time treatments failed to excert their 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 provide 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 from $S_1T_2I_2D_1$ 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.

Economics

Looking to the data on gross and net realization as well as BCR (Table 4) showed that the highest gross and net realization of ₹ 2,13,208/ha and ₹ 1,28,784/ha, respectively with the BCR of 2.53 was secured under treatment combination $S_1T_2I_2D_1$ (advance sowing of *Bt* cotton 60 cm × 45 cm with topping at 75 DAS and intercropping with greengram) closely followed by treatment combination $S_1T_1I_2D_2$ (*Bt* cotton sown on 3rd week of June at 60 cm × 45 cm without topping and intercropping with greengram).

Conclusion

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

Table 1: Effect of spacing, topping, intercropping and sowing time on periodical plant height, sympodial branches per plant, CGR and RGR of *Bt* cotton (pooled data of two years)

Treatments	Plant height (cm)				Sympodial branches per 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	12.02	18.72	22.81	5.74	6.93	5.08	31.75	17.91	8.90
S_2: 120 cm × 60 cm	29.7	72.3	93.2	112.8	14.37	22.19	24.73	4.12	5.30	3.60	46.97	20.00	10.16
S.Em.±	0.3	1.0	1.2	1.2	0.20	0.25	0.27	0.11	0.07	0.16	1.36	0.39	0.31
C.D. (P=0.05)	NS	2.7	3.3	3.4	0.57	0.70	0.76	0.31	0.19	0.44	3.83	1.09	0.87
Topping (T)													
T_1: No topping	30.2	75.7	106.8	138.4	13.04	19.67	23.01	5.27	5.88	3.91	40.84	17.07	9.03
T_2: Topping at 75 DAS	29.5	73.6	87.5	93.4	13.36	21.24	24.53	4.59	6.35	4.55	44.67	19.92	10.03
S.Em.±	0.3	1.0	1.2	1.2	0.20	0.25	0.27	0.11	0.07	0.16	1.36	0.39	0.31
C.D. (P=0.05)	NS	NS	3.3	3.4	NS	0.70	0.76	NS	0.19	0.44	NS	1.09	0.87
Intercropping (I)													
I_1: No intercropping	30.1	77.8	100.9	118.1	13.60	21.36	24.14	5.13	6.24	4.66	43.79	19.59	10.06
I_2: Intercropping with greengram	29.6	71.6	93.4	113.7	12.79	19.55	23.40	4.73	5.99	4.00	34.93	17.99	9.00
S.Em.±	0.3	1.0	1.2	1.2	0.20	0.25	0.27	0.11	0.07	0.16	1.36	0.39	0.31
C.D. (P=0.05)	NS	2.7	3.3	3.4	0.57	0.70	NS	0.31	0.19	0.44	3.83	1.09	0.87
Sowing time (D)													
D_1: Last week of May (Advance sowing)	30.2	75.7	98.5	117.0	13.14	20.55	23.96	5.09	6.23	4.57	42.73	19.48	9.87
D_2: 3rd week of June (Normal sowing)	29.6	73.7	95.8	114.8	13.26	20.36	23.57	4.77	5.93	4.14	35.99	18.25	9.19
S.Em.±	0.3	1.0	1.2	1.2	0.20	0.25	0.27	0.11	0.07	0.16	1.36	0.39	0.31
C.D. (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
C.V. %	8.57	10.33	9.66	8.35	12.29	9.70	9.14	13.37	8.70	13.80	9.41	16.45	13.20

Table 2: Effect of spacing, topping, intercropping and sowing time on number of brusted bolls per plant, weight of seed cotton per boll, seed cotton yield per plant, seed cotton yield, , stalk yield, seed cotton equivalent yield and oil yield of *Bt* cotton (pooled data of two years)

Treatments	Number of brusted bolls per plant				Weight of seed cotton per boll (g)	Seed cotton yield per 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	19.08	27.99	36.70	39.90	3.208	95.66	3077	5930	3512	335
S_2: 120 cm × 60 cm	24.89	42.32	53.94	59.44	3.342	201.71	2434	4838	2673	269
S.Em.±	0.34	0.41	0.48	0.48	0.033	1.19	42	88	42	7
C.D. (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	21.53	33.78	44.17	48.56	3.184	145.90	2658	5182	2989	291
T_2: Topping at 75 DAS	22.43	36.54	46.48	50.78	3.366	151.48	2854	5586	3195	314
S.Em.±	0.34	0.41	0.48	0.48	0.033	1.19	42	88	42	7
C.D. (P=0.05)	NS	1.15	1.36	1.34	0.092	3.35	118	248	118	19
Intercropping (I)										
I_1: No intercropping	22.68	35.73	45.99	50.11	3.356	151.15	2877	5636	2929	317
I_2: Intercropping with greengram	21.28	34.59	44.65	49.23	3.194	146.22	2634	5131	3256	288
S.Em.±	0.34	0.41	0.48	0.48	0.033	1.19	42	88	42	7
C.D. (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)	22.14	35.48	45.86	50.07	3.305	149.25	2840	5447	3173	311
D_2: 3rd week of June (Normal sowing)	21.83	34.83	44.78	49.27	3.244	148.12	2672	5320	3012	294
S.Em.±	0.34	0.41	0.48	0.48	0.033	1.19	42	88	42	7
C.D. (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
S.Em.±	NS	NS	NS	NS	NS	NS	118	NS	118	NS
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	334	NS	332	NS
C.V. %	12.29	9.29	8.54	7.67	7.97	6.42	12.21	13.12	10.82	17.91

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

Treatments	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
$T_1I_1D_1$	3714	2402	3245	2201	3480	2302	3770	2446	3300	2201	3535	2324
$T_1I_1D_2$	2996	2490	2826	2231	2911	2360	3050	2533	2877	2272	2964	2402
$T_1I_2D_1$	2957	2516	2778	2365	2867	2440	3819	2957	3492	2758	3656	2857
$T_1I_2D_2$	3006	2176	2842	1779	2924	1977	3894	2637	3573	2245	3734	2441
$T_2I_1D_1$	3566	2985	3119	2525	3343	2755	3628	3039	3175	2569	3402	2804
$T_2I_1D_2$	3391	2782	3084	2479	3238	2631	3453	2834	3141	2525	3297	2680
$T_2I_2D_1$	3111	2579	2992	2380	3052	2479	4003	3031	3750	2778	3877	2905
$T_2I_2D_2$	2898	2621	2710	2437	2804	2529	3802	3081	3459	2857	3630	2969
S.Em.±	183		152		118		183		150		118	
C.D. (P=0.05)	522		432		334		521		427		332	
C.V. %	12.70		11.56		12.21		11.26		10.22		10.82	

Table 4: Economics of different treatment combinations

Treatment Combinations	Seed cotton equivalent yield (kg/ha)	Gross realization (₹ /ha)	Total cost (₹ /ha)	Net realization (₹ /ha)	B:C ratio
$S_1T_1I_1D_1$	3535	194424	71594	122830	2.72
$S_1T_1I_1D_2$	2964	162993	71594	91399	2.28
$S_1T_1I_2D_1$	3656	201056	82115	118941	2.45
$S_1T_1I_2D_2$	3734	205344	82115	123229	2.50
$S_1T_2I_1D_1$	3402	187084	73902	113182	2.53
$S_1T_2I_1D_2$	3297	181327	73902	107425	2.45
$S_1T_2I_2D_1$	3877	213208	84424	128784	2.53
$S_1T_2I_2D_2$	3630	199661	84424	115237	2.36
$S_2T_1I_1D_1$	2345	128994	61625	67369	2.09
$S_2T_1I_1D_2$	2402	132124	61625	70499	2.14
$S_2T_1I_2D_1$	2857	157153	67601	89552	2.32
$S_2T_1I_2D_2$	2419	133029	67601	65428	1.97
$S_2T_2I_1D_1$	2804	154227	62779	91448	2.46
$S_2T_2I_1D_2$	2680	147376	62779	84597	2.35
$S_2T_2I_2D_1$	2905	159765	68755	91010	2.32
$S_2T_2I_2D_2$	2969	163284	68755	94529	2.37

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