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Effect of mepiquat chloride on yield attributes, yield and economics of *Bt* cotton under high density planting system

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Abstract
A field experiment was conducted during the two consecutive *kharif* seasons of the year 2018 and 2019 at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, to study the "Enhancing productivity of *Bt* cotton grown under high density planting system using mepiquat chloride." Significantly higher number of bolls/plant, average boll weight and seed cotton yield/plant were recorded with plant density of 37,037 plants/ha (60 cm × 45 cm). Seed cotton and stalk yield (kg/ha) as well as harvest index was found significantly higher with narrow plant density of 74,074 plants/ha (45 cm × 30 cm). The magnitude of increase in seed cotton and stalk yield (kg/ha) due to plant density of 74,074 plants/ha (45 cm × 30 cm) over plant density of 37,037 plants/ha (60 cm × 45 cm) was 68.53 and 35.17 per cent, respectively on pooled analysis basis. Among plant density treatments, narrow plant density of 74,074 plants/ha (45 cm × 30 cm spacing) ranked at top in terms of net realization and B: C ratio. Three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing recorded significantly highest values of yield attributes, seed cotton yield and harvest index. Three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing produced 28.83 per cent higher seed cotton yield than control treatment in pooled mean. The highest net realization and B: C ratio were obtained with treatment of three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing.

Keywords: Yield, economics, mepiquat chloride, high density planting system and *Bt* cotton

Introduction
Cotton (*Gossypium hirsutum* L.) is one of the most important commercial cash crop, important fibre crop of global significance and cultivated in more than seventy countries. It is an important raw material of economy in terms of both employment generation and foreign exchange and hence it is known as: 'White gold' or 'king of fibre'. The cotton plant belongs to the genus Gossypium of the family Malvaceae. Cotton is one of the principle crop of India and plays a vital role in the country's economic growth by providing substantial employment and making significant contributions to export earnings. In India, cotton is cultivated in an area of 12.58 million hectares with a production of 370 lakh bales of cotton lint (170 kg per bale) during 2017 - 18 (Anonymous, 2020) [2].

The *Bt* cotton was introduced in India during 2002 and it is being extensively grown in Andhra Pradesh with an area coverage of 90 per cent. The superiority of Bt Cotton over conventional varieties and hybrids was well established. Among the various cultural practices, plant population is one of the most critical factors that influence the growth, fruiting and yield of cotton. Higher or lower than the optimum population had an adverse effect on economic yield of cotton. Hence it is essential to find out a suitable plant density for recently released *Bt* cotton hybrids to realize the maximum yield potential.

As the cotton is having indeterminate growth habit, vegetative and reproductive growth occurs simultaneously during major part of its life cycle. Never the less, sufficient vegetative growth is necessary to support reproductive growth. Under excessive vegetative growth, fruit abortion may increase, crop maturity and harvest may be delayed. Most of the cotton hybrids are characterized by their tendency for aggressive vegetative growth under high availability of nutrients, timely and high rainfall or irrigation. Excessive vegetative growth leads to severe production problems such as fruit abortion, delayed maturity, boll rot and harvest difficulties ultimately reducing the yield.

Regulation of plant growth and canopy with the application of any promising growth regulator may provide an opportunity to modify the plant geometry and density per unit area which affects the economic yield of the crop. Plant growth regulators are substances when added in small amounts modify the growth of plant and they are considered as new generation of agro-chemicals after fertilizers, pesticides and herbicides.

Plant growth regulators like promoters, inhibitors or retardants play a key role in internal control mechanism of plant system by interacting with key metabolic processes such as nucleic acid and protein synthesis. They reduce the vegetative growth of a plant by modifying the production of plant hormones such as gibberellins, auxins and cytokinins. The most commonly used growth regulator in cotton is mepiquat chloride, which decreases vegetative growth by reducing gibberellic acid formation and increases yield. Mepiquat chloride is an anti gibberellin that inhibits cell expansion but not cell division.

Keeping this in view, the present study was planned to assess the response of *Bt* cotton to growth regulator mepiquat chloride and high density planting.

Material and Methods

The experiment was conducted at the Agronomy Instruction Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, District: Banaskantha, Gujarat during the *kharif* season of two consecutive years 2018 and 2019. Sardarkrushinagar (Gujarat) lies on the geographical coordinates of 24° 19' N, 72° 19'. The soils of experimental site was loamy sand, low in organic carbon and available nitrogen, medium in phosphorus and high potassium status. Walkley and Black's method (Jackson, 1973) [8], Alkaline permanganate method (Subbiah and Asija, 1956) [17], Olsen's method (Olsen *et al.*, 1954) [12], Flame photometer Method (Jackson, 1973) [8] for the determination of organic carbon, available nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O).

The experiment was conducted with twenty treatment combination consists of four plant density treatments *i.e.* S_1: 60 cm × 30 cm (55,556 plants/ha), S_2: 60 cm × 45 cm (37,037 plants/ha), S_3: 45 cm × 30 cm (74,074 plants/ha) and S_4: 45 cm × 45 cm (49,383 plants/ha) as main plot and five mepiquat chloride treatments *i.e.* M_1: Mepiquat chloride:@ 0.2 ml/lit (3 spray at 45, 60 and 75 days after sowing), M_2: Mepiquat chloride @ 0.2 ml/lit (2 spray at 45 and 60 days after sowing), M_3: Mepiquat chloride @ 0.4 ml/lit (3 spray at 45, 60 and 75 days after sowing), M_4: Mepiquat chloride @ 0.4 ml/lit (2 spray at 45 and 60 days after sowing) and M_5: Control (no spray) as sub plot. These treatments were evaluated under Split Plot Design with three replications. Size of the gross plot was 6.3 m x 5.4 m.

The sowing of experiments was completed in the 3rd week of June during both the years. Agronomic practices like weeding, inter-culturing, fertilizer application and plant protection measures were taken as and when required. Yield and yield attributes *viz.*, number of bolls/plant, average boll weight, seed cotton yield/plant, seed cotton and stalk yield as well as harvest index were measured at harvest. The data recorded were tabulated and analyzed statistically using Fisher's analysis of variance (ANOVA) technique and the treatment were compared at 5% level of significance. Statistical analysis was done by Cochran and Cox (1967) [4].

Result and Discussion

Effect of plant density on yield attributes and yield of *Bt* cotton

Examination of data presented in Table 1 revealed significant differences on the number of bolls/plant, average boll weight and seed cotton yield/plant in *Bt* cotton due to different plant densities during course of investigation. Significantly, more number of bolls/plant (40.20, 44.86 and 42.53), average boll weight (3.32 g, 3.77 g and 3.45 g) and:seed cotton yield/plant (70.05, 81.06 and 75.56 g/plant) were counted under lower plant density of 37,037 plants/ha (60 cm × 45 cm) (S_2) during both the years 2018 and 2019 as well as in pooled analysis, respectively than plant densities of 74,074 plants/ha (45 cm × 30 cm) (S_3), 55,556 plants/ha (60 cm × 30 cm) (S_1) and 49,383 plants/ha (45 cm × 45 cm) (S_4). The increase in seed cotton yield/plant under S_2 over S_1, S_3 and S_4 was to the tune of 17.88, 36.39 and 14.99 per cent, respectively in pooled data. This was might be due to less competition exerted for light, moisture and nutrients. Sufficient interception of sunlight promotes efficient photosynthesis activities and ultimately greater accumulation of photosynthesis under wider spacing with lower plant density. These results are in conformity with the results reported by Gohil *et al.* (2016) [7], Ajayakumar *et al.* (2017) [1] and Mahil and Lokanadhan (2018) [9].

Data outlined in Table 2 revealed significantly differences in seed cotton and stalk yield (kg/ha) in *Bt* cotton due to the different plant densities during both the years and on pooled mean. Seed cotton yield was progressively increased with increase in planting density. Higher plant density of 74,074 plants/ha (45 cm × 30 cm) (S_3) produced significantly highest seed cotton yield (3544, 3740 and 3642 kg/ha), stalk yield (6727, 7064 and 6895 kg/ha) and harvest index (34.42, 34.71 and 34.57%) of *Bt* cotton than plant densities during both the years and in pooled analysis, respectively, harvest index was remained at par with S_1 during first year. In case of second year, harvest index was at par with S_1 and S_4. The magnitude of increase in seed cotton and stalk yield due to plant density of S_3 over S_2 was 68.53 and 35.17 per cent in pooled mean, respectively. The ultimate seed cotton yield is the manifestation of yield contributing characters. These yield attributing characters were significantly affected by different plant populations. Even though the per plant yields were higher at wider spacing, the total seed cotton yield was less compared to that of closer plant populations as it could not compensate the loss in number of plants per hectare. Higher yields at closer spacing might be due to more number of bolls per unit area. Similar observations of higher yield at higher plant density compared to lower plant densities were also reported by Shekar *et al.* (2013) [16], Ghule *et al.* (2013) [6] and Nagender *et al.* (2017b) [11].

Effect of mepiquat chloride yield attributes and yield of *Bt* cotton

The number of bolls/plant, average boll weight and seed cotton yield/plant in *Bt* cotton was considerably affected due to the different mepiquat chloride treatments during both the years and on pooled analysis. Significantly the more number of bolls/plant *i.e.* 36.63, 42.97 and 39.80 was noted with treatment M_3 (three spray of mepiquat chloride @ 0.4 mi/lit at 45, 60 and 75 days after sowing) during 2018, 2019 and in pooled data, respectively over rest of the treatments except treatment M_1 during the 2018. The present result corroborate

with the findings of Malakannavar *et al.* (2018) [10] and Deol *et al.* (2018) [5].

Three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing (M_3) produced significantly highest average boll weight (3.32, 3.78 and 3.55 g) and seed cotton yield/plant (70.94, 76.51 and 73.73 g/plant) over rest of the mepiquat chloride treatments during both the years as well as in pooled analysis, respectively. The seed cotton yield/plant noted with M_3 was 10.97, 19.85, 7.65 and 32.18 per cent higher than M_1, M_2, M_4 and M_5, respectively in pooled mean. This was due to better partitioning of photoassimilates into reproductive structures. These results are in conformity with the results reported by Shekar *et al.* (2015) [15], Malakannavar *et al.* (2018) [10] and Deol *et al.* (2018) [5] were also agreed that yield attributes of *Bt* cotton was increased positively with increased spray of mepiquat chloride treatments.

A critical scanning of the data in Table 3 shows that marked effect of mepiquat chloride treatments on the seed cotton and stalk yield (kg/ha) in individual years and in pooled mean. Three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing (M_3) registered significantly higher seed cotton yield (3083, 3288 and 3186 kg/ha) than rest of the treatments and control during both the years and on pooled mean, respectively, which was remained at par with M_4 during both the year. Three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing recorded 31.14, 26.66 and 28.83 per cent higher seed cotton yield over control (no spray) treatment during 2018, 2019 and on pooled mean, respectively. Three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing (M_3) produced the lowest stalk yield (5314, 5675 and 5495 kg/ha during both the years and in pooled mean, respectively) which was 14.92, 17.96 and 16.51 per cent lower than control (no spray) during both the years and in pooled mean, respectively. On opposite side, significantly highest stalk yield was registered under control (no spray) (M_5) treatment during both the years and on pooled mean, respectively. This might be due to the restricted vegetative growth and thus enhance reproductive organs by allowing plants to direct more energy towards the reproductive structure. These results are in conformity with the results reported by Shekar (2011) [14], Shekar *et al.* (2015) [15] and Prakash and Korekar (2017) [13].

It was observed from the data given in Table 2 revealed that harvest index of *Bt* cotton was influenced significantly due to the different mepiquat chloride treatments during both the individual years and in pooled analysis. The treatment three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing (M_3) recorded significantly highest harvest index (36.37, 36.35 and 36.36%) during the both the years and in pooled analysis, respectively. These results are in conformity with the results reported by Malakannavar *et al.* (2018) [10].

Economics

Effect of planting density

It is apparent from Table 3 revealed that plant density of 74,074 plants/ha (45 cm × 30 cm) (S_3) registered maximum gross realization (₹ 1,58,415/ha) and net realization (₹ 79,134/ha), respectively with the benefit: cost ratio (BCR) 2.00, respectively on two year mean basis. This increase in profitability was mainly due to higher seed cotton yield. These results are in conformity with the results reported by Ghule *et al.* (2013) [6] and Aruna (2016) [3].

Effect of mepiquat chloride

A close look at Table 3 showed that three spray of mepiquat chloride @ 0.4 ml/lit at 45, 60 and 75 days after sowing (M_3) secured maximum gross realization ₹1,38,312/ha, net realization ₹ 66,831/ha and benefit: cost ratio (BCR) 1.93. This might be attributed due to higher seed cotton yield under this treatment. Similar result was also found by Shekar *et al.* (2013) [16].

Table 1: Effect of plant density and mepiquat chloride on number of bolls/plant, average boll weight (g) and seed cotton yield/plant (g) of *Bt* cotton

Treatments				Number of bolls/plant			Average boll weight (g)			Seed cotton yield/plant (g)		
				2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
[A]	**Main plot treatments: Plant density (S)**											
	S_1	:	60 cm × 30 cm (55,556 plants/ha)	32.19	38.03	35.11	3.01	3.29	3.15	61.05	67.15	64.10
	S_2	:	60 cm × 45 cm (37,037 plants/ha)	40.20	44.86	42.53	3.32	3.77	3.54	70.05	81.06	75.56
	S_3	:	45 cm × 30 cm (74,074 plants/ha)	28.79	34.65	31.72	2.50	3.13	2.81	52.70	58.09	55.40
	S_4	:	45 cm × 45 cm (49,383 plants/ha)	37.00	41.67	39.34	3.09	3.53	3.31	62.89	68.53	65.71
	S.Em.±			0.71	0.89	0.57	0.08	0.09	0.06	1.56	1.65	1.14
	C.D. at 5%			2.45	3.07	1.75	0.28	0.32	0.19	5.38	5.72	3.50
	C.V.(%)			7.93	8.62	8.35	10.53	10.29	10.42	9.77	9.32	9.54
[B]	**Sub-plot treatments: Mepiquat chloride (M)**											
	M_1	:	Mepiquat chloride @ 0.2 ml/lit (3 spray at 45, 60 and 75 days after sowing)	35.52	40.51	38.01	2.99	3.38	3.18	62.33	70.54	66.44
	M_2	:	Mepiquat chloride @ 0.2 ml/lit (2 spray at 45 and 60 days after sowing)	33.30	38.32	35.81	2.93	3.30	3.12	58.21	64.83	61.52
	M_3	:	Mepiquat chloride @ 0.4 ml/lit (3 spray at 45, 60 and 75 days after sowing)	36.63	42.97	39.80	3.32	3.78	3.55	70.94	76.51	73.73
	M_4	:	Mepiquat chloride @ 0.4 ml/lit (2 spray at 45 and 60 days after sowing)	35.27	41.17	38.22	3.08	3.49	3.29	64.71	72.27	68.49
	M_5	:	Control (no spray)	32.00	36.06	34.03	2.58	3.19	2.88	52.17	59.39	55.78
	S.Em.±			0.47	0.51	0.35	0.08	0.08	0.06	1.03	1.24	0.81
	C.D. at 5%			1.35	1.48	0.98	0.22	0.24	0.16	2.96	3.57	2.28
C.V.(%)				4.69	4.48	4.58	8.90	8.33	8.60	5.78	6.25	6.05

Table 2: Effect of plant density and mepiquat chloride on seed cotton and stalk yield (kg/ha) as well as harvest index (%) of *Bt* cotton

Treatments				Seed cotton yield (kg/ha)			Stalk yield (kg/ha)			Harvest index (%)		
				2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
[A]	**Main plot treatments: Plant density (S):**											
	S_1	:	60 cm × 30 cm (55,556 plants/ha)	2889	3069	2979	5848	6499	6173	33.17	32.10	32.63
	S_2	:	60 cm × 45 cm (37,037 plants/ha)	2073	2249	2161	4845	5357	5101	30.03	29.77	29.90
	S_3	:	45 cm × 30 cm (74,074 plants/ha)	3544	3740	3642	6727	7064	6895	34.42	34.71	34.57
	S_4	:	45 cm × 45 cm (49,383 plants/ha)	2597	2933	2765	5768	6259	6013	31.03	31.93	31.48
	S.Em.±			98	95	69	155	179	118	0.69	0.91	0.57
	C.D. at 5%			340	330	211	535	618	364	2.39	3.14	1.76
	C.V.(%)			13.72	12.33	13.00	10.33	10.99	10.70	8.33	10.93	9.71
[B]	**Sub-plot treatments: Mepiquat chloride (M)**											
	M_1	:	Mepiquat chloride @ 0.2 ml/lit (3 spray at 45, 60 and 75 days after sowing)	2863	3035	2949	5766	6156	5961	32.73	32.89	32.81
	M_2	:	Mepiquat chloride @ 0.2 ml/lit (2 spray at 45 and 60 days after sowing)	2647	2948	2797	5914	6574	6244	30.83	30.73	30.78
	M_3	:	Mepiquat chloride @ 0.4 ml/lit (3 spray at 45, 60 and 75 days after sowing)	3083	3288	3186	5314	5675	5495	36.37	36.35	36.36
	M_4	:	Mepiquat chloride @ 0.4 ml/lit (2 spray at 45 and 60 days after sowing)	2937	3121	3029	5744	6151	5948	33.57	33.42	33.49
	M_5	:	Control (no spray)	2351	2596	2473	6246	6917	6582	27.30	27.25	27.27
	S.Em.±			63	58	43	133	96	82	0.67	0.53	0.43
	C.D. at 5%			180	167	120	384	276	232	1.94	1.53	1.21
C.V.(%)				7.81	6.71	7.24	7.96	5.27	6.65	7.26	5.72	6.53

Table 3: Economics of *Bt* cotton as influenced by different treatments

Treatments				Yield (kg/ha)		Gross realization (₹/ha)	Cost of cultivation (₹/ha)	Net realization (₹/ha)	Benefit: Cost: Ratio:(BCR)
				Seed cotton	Stalk				
[A]	**Main plot treatments: Plant density (S)**								
	S_1	:	60 cm × 30 cm (55,556 plants/ha)	2979	6173	129843	71022	58821	1.83
	S_2	:	60 cm × 45 cm (37,037 plants/ha)	2161	5101	94501	63051	31450	1.50
	S_3	:	45 cm × 30 cm (74,074 plants/ha)	3642	6895	158415	79281	79134	2.00
	S_4	:	45 cm × 45 cm (49,383 plants/ha)	2765	6013	120657	68948	51709	1.75
[B]	**Sub-plot treatments: Mepiquat chloride (M)**								
	M_1	:	Mepiquat chloride @ 0.2 ml/lit (3 spray at 45, 60 and 75 days after sowing)	2949	5961	128460	70922	57538	1.81
	M_2	:	Mepiquat chloride @ 0.2 ml/lit (2 spray at 45 and 60 days after sowing)	2797	6244	122134	70447	51687	1.73
	M_3	:	Mepiquat chloride @ 0.4 ml/lit (3 spray at 45, 60 and 75 days after sowing)	3186	5495	138312	71481	66831	1.93
	M_4	:	Mepiquat chloride @ 0.4 ml/lit (2 spray at 45 and 60 days after sowing)	3029	5948	131858	70820	61038	1.86
	M_5	:	Control (no spray)	2473	6582	108517	69208	39309	1.57

Conclusion

In light of the results obtained from the two years investigation, it is concluded that for obtaining higher seed cotton yield and net realization, *Bt* cotton (var. GTHH 49 (BG II) should be grown under high density planting system at 45 cm × 30 cm spacing (74,074 plants/ha) with two spray of mepiquat chloride @ 0.4 ml/lit at 45 and 60 days after sowing under loamy sand soil of North Gujarat conditions.

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