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Effects of Plant Density and Growth Retardants on Yield and Quality of Machine Sown Cotton

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Abstract Field investigations were carried out during winter irrigated seasons of 2017 and 2018. The experiments were laid out in split plot design and replicated thrice. Treatments comprised of three crop geometries viz., 75 cm × 10 cm (M_1), 75 cm × 20 cm (M_2) and 75 cm × 30 cm (M_3) and seven sub plots with foliar application of different growth retardants along with one control viz., Cycocel 400 ppm(S_1), Cycocel 500 ppm (S_2), Mepiquat Chloride 100 ppm (S_3), Mepiquat Chloride 200 ppm (S_4), Maleic Hydrazide 400 ppm (S_5), Maleic Hydrazide 500 ppm (S_6) and Control (No Spray) (S_7). Crop was sown in raised bed with inclined plate planter and the major cultivation practices were carried out with machines. The machines used for cotton cultivation were, inclined plate planter for sowing, power weeder for weeding, drip irrigation system for irrigation and fertigation and harvesting was done manually. Cotton cultivated under 75 cm × 10 cm spacing in conjunction with foliar application of mepiquat chloride 200 ppm at 45 and 60 Days After Sowing (DAS) significantly influenced the yield attributes like number of sympodia, number of bolls per plant, boll weight and seed cotton yield. Better quality parameters of cotton were observed with wider spacing in combination with foliar application of 200 ppm mepiquat chloride.

Keywords High density planting system, Growth retardants, Mepiquat chloride, Machine sown cotton, Quality parameters.

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Introduction

Cotton (*Gossypium hirsutum* L.) known as the king of fibers, is one among the important commercial crops grown in India having largest number of processing industries, contributing nearly 65% of total raw material requirements of textile industry in the country. Cotton is being grown in 80 countries besides 123 countries are involved in the cotton related activities. Among them, 38 countries are the major producers and consumers, 30 countries are major raw cotton exporters and 25 countries exclusively import cotton (AICCIP 2017). The global cotton production is 96.5 million bales. India ranks first in the world in cotton production with 26.4 million bales followed by China, United States of America, Pakistan. India is the second largest consumer and exporter representing 5.3 and 5.8 million bales, respectively in 2016-17. Tamil Nadu requires 100 lakh bales per annum, but production is only 5 lakh bales. Hence, it is essential to produce more cotton to meet its demand (USDA 2017). Inspite of non-availability of labors, mechanization could play a major role in cotton production as major operations may be carried out with machines (Majumdar 2012).

Among the various cultural practices, plant population is one of the most critical factors those influence the growth, fruiting and yield of cotton. Increased or reduced population will have an adverse effect on economic yield of cotton. Hence, it is essential to find out a suitable plant density for new cotton genotype TCH 1819 to realize the maximum yield potential. As cotton is having indeterminate growth habit, vegetative and reproductive growth occurs simultaneously during major part of its life cycle. Nevertheless, sufficient vegetative growth is necessary to support reproductive growth. Under excessive vegetative growth, fruit abortion may increase and simultaneously crop maturity and harvest may also be delayed. Most of the cotton varieties are characterized by their tendency for aggressive vegetative growth under more availability of nutrients, timely and high rainfall or irrigation. Excessive vegetative growth in cotton may lead to severe production problems such as fruit abortion, delayed maturity, boll rot and harvest difficulties ultimately results in reduced yield. Regulation of plant canopy growth with the application of any potential growth retardants may provide an opportunity to modify the plant geometry and density per unit area which affects the economic yield of cotton. Plant growth retardants are substances when added in small amounts, have the capability of modifying plant growth and they are considered as new generation of agro-chemicals after fertilizers, pesticides and herbicides.

Plant growth retardants play a key role in internal control mechanism of plant systems by interacting with basic metabolic processes such as nucleic acid and protein synthesis. They can reduce the vegetative growth of plants by modifying plant hormones production i.e. gibberellins, auxins and cytokinins. Therefore, the high density planting system (HDPS) coupled with foliar application of growth retardants is now being conceived as an alternate production technology having a potential for improving the productivity and profitability, increasing input use efficiency, reducing input costs and minimizing the risks associated with the current cotton production system in India. Thus an attempt has been made through this study to investigate the influence of different growth retardants on yield and quality of machine sown cotton under high density planting system.

Materials and Methods

Field experiments were carried out at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore during Winter irrigated seasons of 2017 and 2018. The soil of the experimental site was sandy clay loam in texture, which comes under *Typic Ustropept* series. The nutrient status of soil at the beginning of experiment was low in available nitrogen (223 kg ha^{-1}), medium in available phosphorus (12.4 kg ha^{-1}) and high in available potassium (438 kg ha^{-1}). Cotton genotype TCH 1819 was taken as test crop. The experiment was laid out in split plot design, replicated thrice and the same design was maintained during both the years of study. Main plot treatments were three different spacings viz., 75 cm × 10 cm (M_1), 75 cm × 20 cm (M_2) and 75 cm × 30 cm (M_3). Sub plot treatments consisted of foliar application of various growth retardants along with one control viz., Cycocel 400 ppm (S_1), Cycocel 500 ppm (S_2), Mepiquat Chloride 100 ppm (S_3), Mepiquat Chloride 200 ppm (S_4), Maleic Hydrazide 400 ppm (S_5), Maleic Hydrazide 500 ppm (S_6) and Control (No Spray) (S_7). Cotton crop was raised in raised beds and the major cultivation practices were carried out with machines and the cultivation practices from sowing to harvest were done as per the TNAU Crop Production Guide, 2012. The machine which used for cotton cultivation were inclined plate planter for sowing, power weeder for weeding, boom sprayer for pre-emergence herbicide application and drip system for irrigation and fertigation. Foliar application of growth retardants were given on 45 and 60 Days After Sowing (DAS). Harvesting was done manually. Cotton genotype TCH 1819 was used as test crop. The observations on yield attributes like number of sympodia, number of bolls per plant, boll weight and seed cotton yield were taken at the time of harvest of crop and quality parameters such as ginning out turn, lint index, seed index, fiber span length (mm), fiber fineness (µg / inch), fiber strength (g/tex), uniformity ratio were analyzed. The detailed procedures for fiber quality analyses are given below.

Sample preparation

Seed cotton was randomly selected and picked from each treatment during the first harvest. The collected

Table 1. Effect of growth retardants and plant densities on number of sympodia /plant, number of bolls / plant and boll weight of machine sown cotton during 2017 and 2018. Main plot: M_1–75 cm × 10 cm, M_2–75 cm × 20 cm, M_3–75 cm × 30 cm. Sub plot: S_1–Cycocel 400 ppm, S_2–Cycocel 500 ppm, S_3–Mepiquat chloride 100 ppm, S_4–Mepiquat chloride 200 ppm, S_5–Maleic Hydrazide 400 ppm, S_6–Maleic Hydrazide 500 ppm, S_7–Control.

Treatments	Number of sympodia/plant		Number of bolls / plant		Boll weight (g)	
Spacing	2017	2018	2017	2018	2017	2018
M_1	11.55	11.89	10.9	11.8	4.44	4.50
M_2	12.43	13.09	16.5	17.9	4.58	4.62
M_3	13.38	13.5	22.7	24.6	4.78	4.82
SEd	0.16	0.16	0.2	0.2	0.06	0.06
CD (p=0.05)	0.44	0.45	0.5	0.5	0.18	0.18
Growth retardants						
S_1	12.5	12.86	16.3	17.6	4.57	4.61
S_2	11.52	11.79	17.7	19.2	4.89	4.92
S_3	11.43	11.68	18	19.6	4.93	5.01
S_4	10.94	11.13	19.1	20.8	5.08	5.18
S_5	13.66	14.17	15.5	16.8	4.27	4.3
S_6	12.98	13.41	16.2	17.6	4.5	4.52
S_7	14.15	14.72	14	15.2	3.96	3.98
SEd	0.2	0.2	0.3	0.3	0.07	0.07
CD (p = 0.05)	0.4	0.41	0.6	0.7	0.15	0.15
Interaction	S	S	S	S	S	S

seed cotton was hand cleaned from contaminants like trash and dried leaves, insects damaged bolls and subjected for ginning. Cleaned and ginned lint samples of about 100 g were packed and labeled for quality testing.

High volume instrument system (HVI)

Various conventional instruments were integrated into a single compact operating system by using a state of art technology in optics, machines and electronics. The high volume instrument system provides the measurement of fiber span length (mm), fiber fineness (µg/ inch), fiber strength (g/tex) and uniformity ratio. Cotton samples were tested for fibers quality parameters at the Department of Cotton, Tamil Nadu Agricultural University, Coimbatore with HVI instrument (in ICC mode) by the method adopted from ASTM D-5867 given by Sundaram (1979).

Ginning out turn

The ratio of weight of lint to that of seed cotton was worked out and expressed in percentage using the formula given by Santhanam (1976).

$$\text{Ginning out turn} = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

Lint index

The quantity of lint obtained from 100 seeds after ginning was expressed as lint index (Santhanam 1976).

Seed index

Hundred seeds selected at random after ginning was weighed and expressed as seed index (Santhanam 1976).

2.5% span length

It is the distance spanned by specific percent of the fiber in the test board. The 2.5% span length is distance from the clamp of fiber board to a point up to which only 2.5% of the fiber extends and expressed in mm (Sundaram 1979).

Micronaire

It is the measure of fiber weight in microgram per inch length of fiber (µg / inch). The fiber fineness was

Table 2. Effect of growth retardants and plant densities on seed cotton yield (kg ha^{-1}) of machine sown cotton during 2017 and 2018.

Treatments	2017 75 cm × 10 cm	2017 75 cm × 20 cm	2017 75 cm × 30 cm	2017 Mean	2018 75 cm× 10 cm	2018 75 cm× 20 cm	2018 75 cm × 30 cm	2018 Mean
Cycocel 400 ppm	2389	2179	2004	2191	2587	2482	2172	2414
Cycocel 500 ppm	2819	2609	2087	2505	3058	2691	2265	2671
Mepiquat chloride 100 ppm	2865	2655	2075	2532	3111	2783	2254	2716
Mepiquat chloride 200 ppm	3109	2899	2172	2726	3378	3062	2362	2934
Maleic hydrazide 400 ppm	2043	1833	1900	1926	2211	2077	2058	2115
Maleic hydrazide 500 ppm	2316	2106	1970	2131	2507	2414	2135	2352
Control	1990	1780	1707	1826	2151	1936	1848	1978
Mean	2505	2295	1988		2715	2492	2156	
	M	S	M×S	S×M	M	S	M×S	S×M
SEd	37	34	65	58	40	37	71	64
CD (p = 0.05)	103	68	149	118	112	75	162	129

another important quality character, which plays a prominent role in determining spinning performance of cotton. The fiber fineness denoted the size of the cross sectional dimension of fiber (Sundaram 1979).

Fiber strength

It denotes the maximum tension at which the fiber is able to sustain before it breaks. It could be defined as the ratio of breaking strength of a bundle of fibers to its weight and expressed in gram / tex (Sundaram 1979).

Results and Discussion

Number of sympodia per plant

Sympodial branches form the Principal segments of super structures of cotton crops on which the fruiting bodies develop. Increased number of sympodia per plant indicates the formation of more fruiting points.

The sympodial branches per plant was increased under plant spacing of 75 cm × 30 cm and it was significantly superior over rest of the plant spacings during both the years of study (Table 1). The increase in number of sympodial branches per plant under wider spacing 75 cm × 30 cm was mainly due to availability of adequate amount of nutrients, moisture and higher light interception which resulted in optimum growth and development leading to production of more number of sympodial branches per plant. Availability of more space for lateral expansion of branches and chance to enhance auxiliary buds of plant as compared to closer planted crops resulted in more branches under wider spaced plants. These observations are in conformity with Bhalerao et al. (2008), Kalaiselvi (2009). The dense plant population of 1,33,333 plants / ha at 75 cm × 10 cm depressed the horizontal growth resulting in lower number of sympodial branches per plant compared to lower densities of 66,666 plants / ha at 75 cm × 20 cm. Similar result was observed by Reddy and Gopinath (2008), Narayana et al. (2008).

The number of sympodial branches per plant was found to be less under mepiquat chloride 200 ppm and mepiquat chloride 100 ppm than other treatments. It may be due to the reduction in plant height and main stem nodes, as main stem nodes are the points where sympodial branch arise. Similar results were also observed by Kholer (2008). The results of present study was also in conformity with Shekar (2011) who reported that the application of 100 ppm mepiquat chloride also significantly reduced the number of sympodial branches as compared to control in cotton.

Number of bolls / plant

The total number of bolls that are produced is an

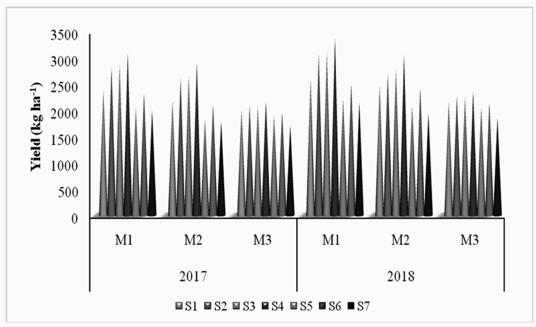

Fig. 1. Effect of growth retardants and plant densities on seed cotton yield (kg ha^{-1}) of machine sown cotton during 2017 and 2018.

important component that influences on seed cotton yield. This character was greatly influenced by both physiological and environmental factors.

Among the crop geometries,the number of bolls/ plant decreased as the plant population increased. Higher number of bolls / plant was recorded under wider spacing (75 cm × 30 cm) than closer spacing (75 cm × 10 cm and 75 cm × 20 cm) (Table 1). More number of bolls / plant in wider spacings was observed because of substantial space available for growth, more photosynthetic efficiency, frequent availability of water and nutrients, less humidity for efficient control of insect pest attack and boll saving from rottening, which resulted in increase of fruiting points, fruiting period, fruit retention and ultimately increased bolls/plant (Munir et al. 2015). Similar result reported by Narayana et al. (2007), Reddy and Gopinath (2008) are also in agreement with the current result. However, reduced number of bolls/ plant was recorded under closer spacing of 75 cm × 10 cm and 75 cm × 20 cm, due to greater interplant competition. Similar result reported by Brar et al. (1996) is concomitant to the present finding. Venugopalan et al. (2011) also reported that number of bolls decreased with closer spacing due to interplant competition. However, the number of bolls / plant was significantly lower with 75 cm × 10 cm followed by 75 cm × 20 cm spacing, but the reduction in number of bolls / plant at closer spacing was compensated by higher plant population per hectare there by resulting in higher seed cotton yield.

Within growth retardants applied plots, foliar application of 200 ppm mepiquat chloride recorded increased number of bolls. This might be due to reduction in the abscission of squares and bolls. In addition mepiquat chloride might have completely counteracted the effect of abscissic acid and thus reduced the shedding of reproductive structures over control. Kerby et al. (1986) observed that the application of mepiquat chloride increased the number of bolls/plant. The present result corroborate with the find ings of Keith (2000), Joseph and Johnson (2006).

Further, the interaction between crop geometry and growth retardants spray also had significant influence on number of bolls/plant during both the years of study. Cotton under the treatment combination of wider spacing of 75 cm × 30 cm with 200 ppm mepiquat chloride recorded higher number of bolls/ plant than closer spacing while decreased number of bolls/plant was recorded under control with closer spacing 75 cm × 10 cm and 75 cm × 20 cm. Similar findings were reported by Gwathmey and Clement (2010), Muhammad and Hayat (2007).

Boll weight

Among the crop geometries, wider spacing recorded increased boll weight than the closer spacings during both the years of study (Table 1). Crop geometry of 75 cm × 30 cm (M_3) recorded higher boll weight of 4.78 g and 4.82 g during 2017 and 2018 respectively, followed by crop geometry of 75 cm × 20 cm (M_2). The least boll weight was registered under the spacing of 75 cm × 10 cm (M_1) during both the years of study. A significant increase in boll weight with increasing row spacing was reported by Devraj et al. (2011). This might be due to the higher interception of solar radiation, better utilization of available nutrients, lesser competition for moisture which resulted in higher photosynthetic activity as reported by Sharma and Dungarwal (2003).

The boll weight varied significantly due to application of different growth retardants. Foliar application of 200 ppm mepiquat chloride found to have more boll weight than other treatments. This might

Table 3. Effect of growth retardants and plant densities on quality parameters in machine sown cotton during 2017 and 2018. *Interaction absent. Main plot: M_1–75 cm × 10 cm, M_2–75 cm × 20 cm, M_3–75 cm × 30 cm, Sub plot: S_1–Cycocel 400 ppm, S_2–Cycocel 500 ppm, S_3–Mepiquat chloride 100 ppm, S_4–Mepiquat chloride 200 ppm, S_5–Maleic Hydrazide 400 ppm, S_6–Maleic Hydrazide 500 ppm, S_7–Control.

Treatments	Ginning out turn (%)	Lint index (g)	Seed index (g)	2017 2.5% Span length (mm)	Fiber strength (g/tex)	Micro-naire (10^{-6} g/inch)	Unifor-mity ratio
Spacing							
M_1	36.36	6.44	10.83	27.12	19.01	4.49	43.23
M_2	37.80	6.69	11.26	27.48	19.77	4.66	44.94
M_3	38.13	6.75	11.35	27.73	19.94	4.70	45.32
SEd	0.51	0.09	0.15	0.38	0.27	0.06	0.61
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS
Growth retardants							
S_1	37.43	6.62	11.10	27.46	19.56	4.61	44.50
S_2	37.48	6.67	11.22	27.44	19.62	4.66	44.53
S_3	37.51	6.72	11.28	27.50	19.65	4.72	44.57
S_4	37.56	6.79	11.36	27.58	19.73	4.78	44.62
S_5	37.35	6.53	11.03	27.37	19.48	4.53	44.44
S_6	37.39	6.57	11.08	27.41	19.51	4.57	44.46
S_7	37.29	6.49	10.97	27.35	19.46	4.46	44.36
SEd	0.58	0.10	0.17	0.42	0.30	0.07	0.69
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS

Table 3. Continued.

Treatments	Ginning out turn (%)	Lint index (g)	Seed index (g)	2018 2.5% Span length (mm)	Fiber strength (g/tex)	Micro-naire (10^{-6} g/inch)	Unifor-mity ratio
Spacing							
M_1	36.40	6.47	10.86	27.35	19.07	4.51	43.32
M_2	37.84	6.74	11.31	27.55	19.82	4.69	45.04
M_3	38.16	6.80	11.42	27.76	19.99	4.73	45.42
SEd	0.51	0.09	0.15	0.39	0.27	0.06	0.61
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS
Growth retardants							
S_1	37.47	6.66	11.17	27.55	19.62	4.64	44.59
S_2	37.53	6.70	11.23	27.54	19.69	4.69	44.61
S_3	37.57	6.75	11.29	27.61	19.71	4.74	44.63
S_4	37.59	6.80	11.38	27.72	19.76	4.79	44.67
S_5	37.38	6.58	11.13	27.48	19.52	4.55	44.56
S_6	37.43	6.63	11.15	27.52	19.59	4.59	44.57
S_7	37.31	6.56	11.01	27.46	19.49	4.49	44.49
SEd	0.58	0.10	0.17	0.42	0.30	0.07	0.69
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS

be due to better partitioning of photo assimilates into reproductive structures. The investigation of Hunnur (2007) showed similar results with the application of growth regulators. Gwathmey and Clement (2010), Muhammad and Hayat (2007) also found similar results with application of growth retardants.

The interaction effect of crop geometries and growth retardants application was found to be significant with the boll weight of cotton. The treatment combination of 200 ppm mepiquat chloride under wider spacing of 75 cm × 30 cm was found to have more boll weight than other treatments. This is in correlation with findings of Livingston et al. (1992) who found higher number of bolls per plant, boll size and opened bolls per plant, when cotton plants were sprayed with pix (mepiquat chloride) under wider spacing of 90 cm × 60 cm.

Seed cotton yield

Crop geometry of 75 cm × 10 cm (M_1) recorded increased seed cotton yield (2505 and 2715 kg ha^{-1} during 2017 and 2018) than other spacings (Table 2 and Fig. 1). It was followed by crop geometry of 75 cm × 20 cm (M_2). It might be due to more number of picked bolls per unit area. This is in confirmation with the findings Srinivasam (2006) have observed increased seed cotton yield with increased plant population. Among the foliar application of growth retardants, 200 ppm mepiquat chloride application found to have higher yield which was followed by the foliar application of 100 ppm mepiquat chloride. The seed cotton yield depends on the accumulation and partitioning of photo assimilates in reproductive parts of the plant. Higher seed cotton yield could be due to relatively higher biomass, better partitioning of photo assimilates towards reproductive structures, higher values of yield components. Norton et al. (2005), Joel (2005), Zakaria et al. (2006) reported a complimentary effect of growth regulators in increasing the yield of cotton.

There existed a significant interaction on the seed cotton yield with crop geometries and foliar application of growth retardants during both the years of study. Two sprays of 200 ppm mepiquat chloride at 45 and 60 DAS under 75 cm × 10 cm spacing recorded significantly higher seed cotton yield over all other treatment combinations. Same trend was observed by Muhammad and Hayat (2007) who reported that high seed cotton yield can be achieved at closer plant spacing with the use of mepiquat chloride to manage the excessive plant growth.

Quality parameters

The quality parameters like ginning percent, seed index, lint index were not significantly influenced by varying crop geometries and foliar application of growth retardants during the both the year of study (Table 3). Similar results were reported by Dhillon et al. (2006). Several researchers have reported a similar lack on the effect of spacing on fiber quality parameters (Hawkins and Peacock 1973, Smith et al. 1979, Jost and Cothren 2000, Nichols et al. 2004). In our study, though there was no significance between the treatments, mepiquat chloride application improved fiber length and strength, micronaire and therefore cotton fiber quality as a whole. Cotton fiber length across mepiquat chloride treated plots at reduced plant density was more than that at increased plant density during both the years of study. This is in correlation with the research findings of Jones and Wells (1998). However, other factors such as genotype and agronomic management may also affect the fiber quality (Bednarz et al. 2005).

Conclusion

Modification of plant compactness due to foliar application of mepiquat chloride and plant density treatments showed an effect on cotton yield and quality. In general, applying mepiquat chloride decreases cotton height and the length of fruit branches, resulting in compact plant architecture suitable for mechanical harvesting. From the results, it could be concluded that machine sown cotton with crop geometry of 75 cm × 10 cm coupled with foliar application of 200 ppm mepiquat chloride recorded increased seed cotton yield. However, no significant variations were observed in light of quality parameters with Cotton genotype TCH 1819. Therefore, machine sown cotton under 75 cm × 10 cm spacing in conjunction with foliar application of 200 ppm mepiquat chloride will be a promising technology for the farmers to get desirable yield.

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