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Impact of high density planting system and growth retardants on root growth and yield attributes in machine sown cotton

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Abstract
Field experiments were carried out during winter irrigated seasons of 2017 and 2018 at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore. The experiments were laid out in split plot design with three replications. Treatments comprised of three crop geometries *viz.*, 75 cm x 10 cm (M_1), 75 cm x 20 cm (M_2) and 75 cm x 30 cm (M_3) and seven sub plots with foliar application of different doses of 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, boom sprayer for pre emergence herbicide application, power weeder for weeding, drip irrigation system for irrigation and fertigation and harvesting was done manually. Cotton cultivated under 75 cm x 10 cm spacing in conjunction with foliar application of mepiquat chloride 200 ppm at 45 and 60 Days After Sowing (DAS) significantly influenced the root parameters like root length, root volume, root dry weight and yield attributes like number of sympodia, number of bolls per plant, boll weight and seed cotton yield.

Keywords: High density planting system, Growth retardants, Mepiquat chloride, Root parameters, yield attributes

1. Introduction
Cotton (*Gossypium hirsutum* L.) is the major fibre and cash crop, not only in India but for the entire world. It is cultivated in tropical as well as sub - tropical regions of more than seventy countries of the world. Cotton is a crop of global significance playing a significant role in the agricultural and industrial economy. Around 60% of fibre to Indian textiles is from cotton. Cotton is commonly known as “White gold” and “King of natural fibre” owing to its higher economical value amid the cash crops. In India, Cotton is grown in three different agro - ecological zones *viz.*, Northern, Central and Southern zone. Nearly 70 percent of the crop is cultivated under rainfed conditions in the Central and Southern regions of the country. Among the cotton producing states, Maharashtra is the largest producer with an area of 38.06 lakh ha followed by Gujarat (24 lakh ha) and Telangana (17.78 lakh ha). The production is highest in Gujarat with 95 lakh bales followed by Maharashtra (89 lakh bales) and Telangana (59.50 lakh bales). Karnataka stands first in productivity of 769 kg ha^{-1} followed by Andhra Pradesh (719 kg ha^{-1}) and Rajasthan (692 kg/ha). The cotton productivity of India during 2017 - 18 was 568 kg ha^{-1} with area coverage of 105 lakh ha and production of 351 lakh bales (CCI, 2018) [8].
The manipulation of row spacing, plant density and the spatial arrangements of cotton plants, for obtaining higher yield have been attempted by agronomists for several decades in many countries. The most commonly tested plant densities range from 5 to 15 plants m^{-2} (Kerby *et al.*, 1990) [24] resulting in a population of 50000 to 150000 plants ha^{-1}. The concept on high density cotton planting, more popularly called Ultra Narrow Row (UNR) cotton was initiated by Briggs *et al.* (1967) [6]. The obvious advantage of this system is earliness (Rossi *et al.*, 2004) [39]. The UNR cotton plants produce less number of bolls $plant^{-1}$ than conventional cotton but retain a higher percentage of the total number of good opened bolls per unit area in the first sympodial position and a lower percentage in the second position (Vories and Glover, 2006) [50]. The other advantages include better light interception, efficient leaf area development and early canopy closure which will shade out the weeds and reduce their competitiveness (Wright *et al.*, 2011) [51]. The early maturity in soils that do not support excessive vegetative growth (Jost and Cothren, 2001) [20] can make this system ideal for

shallow to medium soils under rainfed condition, where conventional late maturity hybrids experience terminal drought.

The cotton plant is a perennial with an indeterminate growth habit, and reputed to have the most complex growth habit of all major row crops. Furthermore, it is very responsive to management and changes in the environments and responds to any perturbations in its environment with a dynamic growth response that is often unpredictable. Plant growth retardants are natural or synthetic organic compounds that control or modify one or more physiological events in plants. These synthetic compounds are widely used in cotton, for reducing plant height. The plant growth retardants affect many physiological functions in plants. They are essentially responsible for controlling cell elongation and shoot and stem growth (Spitzer *et al.*, 2011) [45]. When plant growth retardants are applied to plants, internodes become shorter and leaves become thicker and greener, alters plant morphology and can alter assimilate partitioning in favor of plant growth by increasing radiation utilization efficiency and also increases net photosynthesis. The response of plants to PGR applications can differ with plant growth stage, rates of application, and environmental conditions during the applications (Kim *et al.,* 2003) [27]. Cotton producers and researchers have, therefore, used plant growth retardants as a means to manage the balance between vegetative and reproductive growth for efficient cotton production. But research on application of growth retardants in conjunction high density planting will pave way for synchronized maturity of the crop with uniform plant height that may help in harvesting of seed cotton mechanically at large scale level. Therefore, the present investigation was designed and conducted to find out optimum crop geometry and to know the yield potential of cotton genotype TCH 1819 along with root growth pattern 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 x 10 cm (M_1), 75 cm x 20 cm (M_2) and 75 cm x 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. Root parameters like root length, root volume and root dry weight were taken at maturity stage of the 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. Statistical analysis were carried out as per the procedure given by Gomez and Gomez, 1984 [13]. Wherever the treatmental differences were found significant
(`F` test), critical difference was worked out at 0.05 probability level. Treatmental differences that were non significant were denoted by “NS”.

Results and Discussion

Root parameters

Crop geometries had significant influence on root characters *viz.* root length, root volume and root dry weight. Root length was higher under closer spacing (75 cm x 10 cm and 75 cm x 20 cm), whereas root volume and dry weight were higher under wider plant spacing (75 cm x 30 cm) Table 1. Higher root length at closer spacing might be credited to the higher competition laterally by the nearest plant which pushed them vertically down, while in the wide spaced crop rows, the spread was more owing to the fact that the plants had sufficient proliferating area laterally leading to higher dry weight and volume compared to closer spaced crop. This finding is in agreement with the findings of Arunvenkatesh (2013) [1] and Baskar (2014) [2] also reported similar results. No significant differences were observed among growth retardants spray for root parameters during 2017 and 2018. Interaction between crop geometries and growth retardants spray did not show any significant effect on root characters during both years.

Yield Attributes

The yield attributing characters *viz.*, number of sympodial branches/plant, number of bolls/plant and boll weight which ultimately decide the seed cotton yield, were significantly influenced by plant geometries and growth retardants and is depicted in Table 2 and Table 3.

Number of sympodial plant^{-1}

Sympodial branches form the principal segment of super structures of cotton plants on which the fruiting bodies develop. Higher number of sympodia indicates the formation of more fruiting points (Khargade and Ekbote, 1980) [26].

The sympodia plant^{-1} was higher under 75 cm x 30 cm plant spacing and it was significantly superior over rest of the plant spacings during both the years of study. The increase in number of sympodia plant^{-1} under wider spacing of 75 cm x 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 sympodia plant^{-1}. 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) [4] and Kalaichelvi (2009) [22]. The dense plant population of 1,33,333 plants/ha at 75 cm x 10 cm depressed the horizontal growth resulting in lower number of sympodia plant^{-1} compared to lower densities of 66,666 plants/ha at 75 cm x 20 cm. Similar result was observed by Reddy and Gopinath (2008) [38] and Narayana *et al*. (2008) [32].

The number of sympodia plant^{-1} 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 sympodia arise. Similar results were also observed by Gadakh *et al.* (1992) [11] and More *et al.* (1993) [29]. The application of 100 ppm mepiquat chloride also significantly reduced the number of sympodia as compared to control in cotton (Reddy and Gopinath, 2008) [38].

In addition, drip fertigation might have enhanced the availability and uptake of nutrients which lead to enhanced photosynthesis and translocation of nutrients to reproductive parts compared to conventional method of soil applied nutrients. Similar findings were also recorded by Grieesha (2003) [14]. Raskar (2004) [37] and Veeraputhiran and Chinnusamy (2009) [47] further substantiated that maintenance of optimum moisture at root zone through drip fertigation helped in maintaining optimum pressure in plant.

The interaction effect of crop geometries and growth retardants spray significantly influenced the number of sympodia plant^{-1} during both the years. Higher sympodia plant^{-1} was recorded under control with wider spacing of 75 cm x 30 cm followed by 75 cm x 20 cm. It might be due to reduced competition for resources like nutrients, light and spacing etc. this is in confirmation with the earlier findings of Kalaichelvi (2008) [21] and Baskar (2014) [2]. Reduced number of sympodia plant^{-1} was recorded in cotton under 200 ppm mepiquat chloride with closer spacing of 75 cm x 10 cm due to decreased plant height, main stem nodes and restricted horizontal space for production of more number of sympodia plant^{-1}. These results are line with the findings of Bhalerao *et al*. (2010) [3].

Number of bolls plant^{-1}

The total number of bolls that a cotton plant produces is an important yield component having the greatest influence on yield. This character was greatly influenced by both physiological and environmental factors.

Among the crop geometries, the number of bolls plant^{-1} decreased as the plant population increased. Higher number of bolls plant^{-1} was recorded under wider spacing

(75 cm x 30 cm) than closer spacing (75 cm x 10 cm and 75 cm x 20 cm). More number of bolls plant^{-1} in wider spacings, 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 in fruiting points, fruiting period, fruit retention and ultimately greater bolls plant^{-1} (Munir *et al*., 2015) [31]. Similar result reported by Narayana *et al.* (2007) [33] and Reddy and Gopinath (2008) [38] are in agreement with the present result. However, reduced number of bolls plant^{-1} was recorded under closer spacing of 45 75 cm x 10 cm and 75 cm x 20 cm, due to greater interplant competition. Similar result reported by Brar *et al.* (1996) [5] is concomitant to the present finding. Venugopalan *et al.* (2011) [48] also reported that number of bolls decreased with closer spacing due to interplant competition. However, the number of bolls plant^{-1} was significantly lower with 75 cm x 10 cm followed by 75 cm x 20 cm spacing, but the reduction in number of bolls plant^{-1} at closer spacing was compensated by higher plant population per hectare there by resulting in higher seed cotton yield. The other reason behind it is the production of more vegetative biomass, more flowers and their conversion into better bolls and more retention in plants under drip irrigation compared to conventional method of irrigation as reported by Jayakumar *et al.* (2014) [17].

Within growth retardants spray, mepiquat chloride 200 ppm recorded higher number of bolls. This might be due to reduction in the abscission of buds 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) [25] observed that the application of mepiquat chloride at 49 g ha^{-1} increased the number of bolls.The present result corroborate with the findings of Keith (2000) [23] and Joseph and Johnson (2006) [19].

Further, the interaction between crop geometry and growth retardants spray also had significant influence on number of bolls plant^{-1} during both the years of study. Cotton under the treatment combination of wider spacing of 75 cm x 30 cm with 200 ppm mepiquat chloride recorded higher number of bolls plant^{-1} than closer spacing while decreased number of bolls plant^{-1} was recorded under control with closer spacing 75 cm x 10 cm and 75 cm x 20 cm. Similar findings were reported by Gwathmey and Clement (2010) [15] and Muhammad Iqbal *et al*. (2007) [30].

Boll weight

Average boll weight was influenced significantly by the plant geometries during both 2017 and 2018. Plant geometry of 75 cm x 30 cm recorded larger bolls compared to other plant geometries during both the years. A significant increase in boll weight with increasing row spacing was reported by Devraj *et al.* (2011) [9]. 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) [41]. Reductions in plant to plant spacing decreased boll weight due to intense competition for nutrients, water and light at higher plant density (Ogola *et al*., 2006) [36]. Though the boll weight was higher in plots with wider spacing, the beneficial effect was offset due to less number of plants per unit area. Similar results were noticed by Kalaiselvi (2009) [22]. The present results are in conformity with results of Dong *et al.* (2010) [10], who reported that higher plant density reduced the boll weight relative to low plant density. Smaller boll size found in these experiments suggests that carbohydrate supply was not sufficient to meet the demand of the individual plants under high density planting compared to the conventionally spaced plants as indicated by Jost and Cothren (2001) [20].

The boll weight varied significantly due to different growth retardants application. 200 ppm mepiquat chloride spray found to have more boll weight than other treatments. This might be due to better partitioning of photoassimilates into reproductive structures. The investigation of Hunnur (2007) [16] showed similar results with the application of growth regulators. Gwathmey and Clement (2010) [15] and Muhammad Iqbal *et al*. (2007) [30] also found similar results with application of growth retardants.

The interaction effect of crop geometries and growth retardants spray 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 x 30 cm was found to have more boll weight than other treatments. This is in correlation with findings of Livingston *et al. (*1992) [28] 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 x 60 cm.

Influence of cultivation methods and crop geometries on seed cotton yield

Yield is the manifestation of various morphological, physiological, biophysical, biochemical and yield parameters. Seed cotton yield is the reflection of yield attributing characters like number of sympodial branches plant^{-1}, number of bolls plant^{-1} and boll weight.

In crop geometries, higher seed cotton yield per hectare was recorded under closer spacing of 75 cm x 10 cm and 75 cm x 20 cm as compared to wider spacing due to more number of picked bolls per unit area (Table 4 & Fig 1). This might be due to higher values of yield attributes and ultimately produce more seed cotton yield. These findings were corroborate the results of Sarkar and Malik (2004) [40], Nehra *et al.* (2004) [34], Buttar and Singh (2006) [7], Singh *et al.* (2007) [43] and Giri *et al.* (2008) [12]. Several research workers (Srinivasan, 2006; Sisodia and Khamparia, 2007; Vishwanath, 2007 and Shwetha, 2008) [46, 44, 49, 42] have obtained higher seed cotton yield with closer spacing due to their higher plant population. Further, the angle and orientation of leaves were found adjusted at higher population, thereby minimizing overlapping and mutual shading, responsible for greater leaf development at high population resulting in increased growth and yield.

Among the growth retardants spray, foliar application of 200 ppm mepiquat chloride found to have higher yield which was followed by 100 ppm mepiquat chloride. Under the circumstances of high soil fertility, excessive rainfall as well as under high input management situations cotton, being an indeterminate crop, puts forth excessive vegetative growth at cost of economic yield. Limiting and regulating the excessive vegetative growth of cotton due to several factors as well as at high density planting through application of mepiquat chloride was also found encouraging in the current study. 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) [35], Joel (2005) [18] and Zakaria *et al.* (2006) [52] reported a complimentary effect of growth regulators in increasing the yield of cotton.

There was a significant effect of interaction on the seed cotton yield with crop geometries and growth retardants spray during both the year of study. Two sprays of 200 ppm mepiquat chloride at 45 and 60 DAS under 75 cm x 10 cm spacing recorded significantly higher seed cotton yield over all other treatment combinations. Same trend was observed by Muhammad Iqbal *et al.* (2007) [30] 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.

Table 1: Effect of crop geometries and growth retardants on root parameters of machine sown cotton (2017& 2018)

Treatment	Root length (cm)		Root volume (cc)		Root dry weight (g)	
Spacing	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
M_1	29.75	30.32	28.61	31.30	19.73	21.41
M_2	27.54	28.89	31.27	33.99	21.43	23.25
M_3	24.60	26.60	33.20	35.68	22.49	24.40
SEd	0.43	0.44	0.42	0.45	0.29	0.31
CD (P=0.05)	1.19	1.21	1.15	1.25	0.80	0.87
Growth retardants						
S_1	27.11	28.37	30.97	33.57	21.41	23.21
S_2	27.98	29.36	32.12	34.87	22.97	24.94
S_3	28.31	29.75	32.47	35.29	23.05	25.05
S_4	29.40	30.96	33.53	36.47	24.23	26.35
S_5	26.13	27.29	29.23	31.66	18.58	20.12
S_6	26.97	28.21	30.80	33.37	21.08	22.84
S_7	25.19	26.25	28.07	30.37	17.22	18.64
SEd	27.11	0.43	0.50	0.53	0.34	0.37
CD (P=0.05)	NS	NS	NS	NS	NS	NS

*Interaction absent

Table 2: Effect of crop geometries and growth retardants on yield attributes of machine sown cotton (2017)

Treatments	No. of Sympodia plant^{-1}				No. of bolls plant^{-1}				Boll weight (g)			
	M_1	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**
S_1	11.47	12.65	13.38	12.50	10.4	15.6	22.8	16.3	4.41	4.50	4.80	4.57
S_2	10.86	11.04	12.67	11.52	11.6	17.7	23.8	17.7	4.64	4.92	5.10	4.89
S_3	10.35	11.89	12.04	11.43	11.8	17.9	24.5	18.0	4.68	4.97	5.13	4.93
S_4	10.27	11.34	11.21	10.94	12.8	18.9	25.6	19.1	4.92	5.12	5.19	5.08
S_5	12.56	13.54	14.88	13.66	10.2	15.4	20.9	15.5	4.30	4.10	4.40	4.27
S_6	12.02	12.88	14.04	12.98	10.4	16.4	21.9	16.2	4.36	4.45	4.70	4.50
S_7	13.31	13.67	15.47	14.15	9.2	13.3	19.6	14.0	3.79	3.99	4.11	3.96
Mean	11.55	12.43	13.38		10.9	16.5	22.7		4.44	4.58	4.78	
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.16	0.20	0.35	0.34	0.2	0.3	0.5	0.5	0.06	0.07	0.13	0.12
CD (P = 0.05)	0.44	0.40	0.76	0.69	0.5	0.6	1.1	1.1	0.18	0.15	0.29	0.25

Main plot	**Sub plot**
M_1 – 75 cm X 10 cm	S_1- Cycocel 400 ppm
M_2 - 75 cm X 20 cm	S_2- Cycocel 500 ppm
M_3 - 75 cm X 30 cm	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

Table 3: Effect of crop geometries and growth retardants on yield attributes of machine sown cotton (2018)

Treatments	No. of Sympodia plant^{-1}				No. of bolls plant^{-1}				Boll weight (g)			
	M_1	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**
S_1	11.93	13.13	13.53	12.86	11.3	16.9	24.7	17.6	4.44	4.52	4.86	4.61
S_2	10.94	12.08	12.36	11.79	12.6	19.2	25.9	19.2	4.68	4.96	5.13	4.92
S_3	10.84	11.97	12.24	11.68	12.8	19.4	26.6	19.6	4.76	5.11	5.15	5.01
S_4	10.34	11.43	11.63	11.13	14.0	20.6	27.8	20.8	5.09	5.19	5.26	5.18
S_5	13.13	14.41	14.98	14.17	11.1	16.7	22.6	16.8	4.32	4.12	4.46	4.30
S_6	12.43	13.67	14.14	13.41	11.2	17.8	23.7	17.6	4.36	4.48	4.73	4.52
S_7	13.62	14.93	15.61	14.72	9.9	14.4	21.3	15.2	3.85	3.96	4.14	3.98
Mean	11.89	13.09	13.50		11.8	17.9	24.6		4.50	4.62	4.82	
	M	S	M x S	S x M	M	S	M x S	S x M	M	S	M x S	S x M
SEd	0.16	0.20	0.36	0.35	0.2	0.3	0.6	0.6	0.06	0.07	0.13	0.13
CD (P = 0.05)	0.45	0.41	0.79	0.71	0.5	0.7	1.2	1.1	0.18	0.15	0.29	0.25

Main plot	Sub plot
M_1 – 75 cm X 10 cm	S_1- Cycocel 400 ppm
M_2 - 75 cm X 20 cm	S_2- Cycocel 500 ppm
M_3 - 75 cm X 30 cm	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

Table 4: Effect of crop geometries and growth retardants on seed cotton yield of machine sown cotton (2017 & 2018)

Treatment	Seed cotton yield (kg ha^{-1})	
Spacing	2017	2018
M_1	2505	2715
M_2	2295	2492
M_3	1988	2156
SEd	37	40
CD (P=0.05)	103	112
S_1	2191	2414
S_2	2505	2671
S_3	2532	2716
S_4	2726	2934
S_5	1926	2115
S_6	2131	2352
S_7	1826	1978
SEd	34	37
CD (P=0.05)	68	75
Interaction	S	S

Main plot	Sub plot
M_1 – 75 cm X 10 cm	S_1- Cycocel 400 ppm
M_2 - 75 cm X 20 cm	S_2- Cycocel 500 ppm
M_3 - 75 cm X 30 cm	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

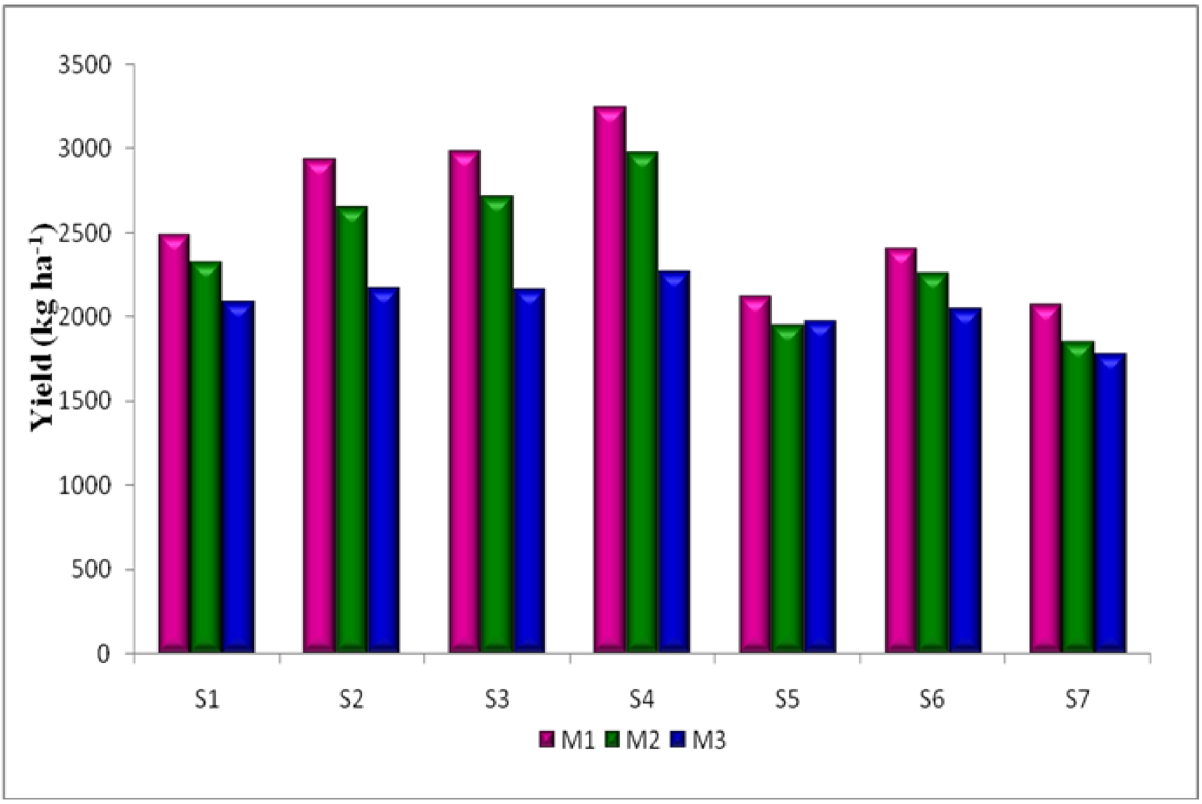

Fig 1: Effect of crop geometries and growth retardants on seed cotton yield (kg ha^{-1}) of machine sown cotton (pooled data for 2017 and 2018)

Conclusion

Modification of plant compactness due to foliar application of mepiquat chloride and plant density treatments showed an effect on yield attributes and seed cotton yield whereas. The root parameters are influenced by crop geometries but not by the foliar application of growth retardants. 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 x 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 foliar application of growth retardants on root parameters with Cotton genotype TCH 1819. Hence, machine sown cotton under 75 cm x 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.

References

1. Arunvenkatesh S. Influence of high density planting system in cotton genotypes. Ph.D., Thesis, Tamil Nadu Agricultural University, Coimbatore, India, 2013.
2. Baskar P. Influence of crop geometry and drip fertigation on growth and yield of Bt cotton. Ph.D., Thesis, Tamil Nadu Agricultural University, Coimbatore, India, 2014
3. Bhalerao PD, Patil BR, Ghatol PU, Gawande PP. Effect of spacing and fertilizer levels on seed cotton yield under rainfed condition. Indian J Agric. Res. 2010; 44(1):74-76.
4. Bhalerao PD, Gawande PP, Ghatol PU, Patil BR. Performance of Bt cotton hybrids for various spacing under rainfed condition. Agric. Sci. Digest. 2008; 28(1):54-56.
5. Brar AS, Thind RJS, Kular JS, Singh TH. Effect of sowing time, spacing and nitrogen levels on upland cotton cultivars in Punjab. J Indian Soc. Cotton Improv. 1996; 21(1&2):41-44.
6. Briggs RE, Patterson LL, Massey GD. Within and between row spacing of cotton. Arizona Annual Report. Univ. of Arizona Agric. Ext. Service, Arizona, 1967, 6-7.
7. Buttar GS, Singh P. Performance of *Bt* cotton hybrids at different plant populations in south western region of Punjab. J Cotton Res. Dev. 2006; 20(1):99-101.
8. CCI, Cotton Advisory Board (CAB), 2017 (http://cotcorp.gov.in/statistics.aspx#area).
9. Devraj MS, Bhattoo BS, Duhan P, Kumari, Jain PP. Effect of geometry and fertilizer levels on seed cotton yield and nutrient uptake of Bt cotton under irrigated conditions. J Cotton Res. Dev. 2011; 25(2):176-180.
10. Dong H, Kong X, Li W, Tang W, Zhang D. Effects of plant density and nitrogen and potassium fertilization on cotton yield and uptake of major nutrients in two fields with varying fertility. Field Crops Res. 2010; 119(1):106-113.
11. Gadakh SR, Pol KM, Patil VA. Effect of growth retardants on hybrid cotton (Varalaxmi). Journal of Maharashtra Agricultural Universities. 1992; 17:137.
12. Giri AN, Anudhekar RL, Kapse PS, Suryavanshi SB. Response of *Bt* cotton hybrids to plant densities and fertilizers levels. J Cotton Res. Dev. 2008; 22(1):45-47.
13. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research 2nd Edn. John Wiley and Sons, New York, U.S.A., 1984.
14. Grieesha G. Crop establishment studies to increase yield in irrigated cotton (cv. MCU 12). M.Sc. Thesis, Tamil Nadu Agricultural University, Coimbatore, India, 2003.
15. Gwathmey CO, Clement JD. Alteration of cotton source-sink relations with plant population density and mepiquat chloride. Field Crops Research. 2010; 116:101-107.
16. Hunnur R. Studies on bioefficacy of plant growth regulators in Bt cotton. M.Sc. (Agri.) Thesis. University

of Agricultural Sciences, Dharwad, India, 2007.
17. Jayakumar M, Surendranb U, Manickasundaram P. Drip fertigation effects on yield, nutrient uptake and soil fertility of Bt Cotton in semi arid tropics. Int. J Plant Prod. 2014; 8(3):375-390.
18. Joel F. Plant growth regulator use. Virginia Cotton Production Report, 2005.
19. Joseph TJ, Johnson TP. Effect of mepiquat pentaborate on cotton cultivars with different maturities. The Journal of Cotton Science. 2006; 10:128-135.
20. Jost PH, Cothren JT. Phenotypic alterations and crop maturity differences in ultra-narrow row and conventionally spaced cotton. Crop Sci. 2001; 41(4):1150-1159.
21. Kalaichelvi K. Effect of plant spacing and fertilizer levels on insect pests in Bt cotton hybrid. Indian J. Ent., 2008; 70(4):356-359.
22. Kalaichelvi K. Bt cotton response to plant geometry and fertilizer levels J. Cotton Res. Dev. 2009; 23(1):96-99.
23. Keith LE. Suggestion for growth regulator use. Crop Science Extension, 2000.
24. Kerby TA, Cassman KG, Keekey M. Genotypes and plant densities for narrow-row cotton system. I. Height, nodes, earliness and location of yield. Crop Sci. 1990; 30(3):645-649.
25. Kerby TA, Kater H, Markley K. Cotton modification with mepiquat chloride. Agronomy Journal. 1986; 98:907-912.
26. Khargade PW, Ekbote AP. Path coefficient analysis in upland cotton. Indian J Agric. Sci. 1980; 50(1):6-8.
27. Kim SK, Lee SC, Lee BH, Choi HJ, Kim KU, Lee IJ. Bulbil formation and yield responses of Chinese yam to application of gibberellic acid, mepiquat chloride and trinexapac-ethyl. J Agron Crop Sci. 2003; 189:255-260.
28. Livingston SD, Anderson DJ, Wide LB, Hickey JA. Use of foliar application of pix, PGR-IV and PCHA in low rate multiple applications for cotton improvement under irrigated and dry land conditions. Proceedings of the Beltwide Cotton Conference. 1992, 3:1055-1066.
29. More PR, Waykar SK, Coulwar SB. Effect of Cycocel (CCC) on morphological and yield contributing characters of cotton. Journal of Maharashtra Agricultural Universities. 1993; 18:294-295.
30. Muhammad Iqbal, Khezir and Hayat Noor-ul-islam. Cotton response to mepiquat chloride and nitrogen under ultra narrow plant spacing. Asian Journal of Plant Sciences. 2007; 6(1):87-92.
31. Munir MK, Tahir M, Saleem MF, Yaseen M. Growth, yield and earliness response of cotton to row spacing and nitrogen management. J Anim. Plant Sci., 2015; 25(3):729-738.
32. Narayana E, Hema K, Srinivasulu K, Prasad NVVSD, Rao NHP. Performance of Bt cotton hybrid (NCS-145 Bt) to varied spacing and fertilizer levels in vertisols under rainfed conditions. J Indian Soc. Cotton Improv., 2008; 33:33-36.
33. Narayana E, Hema K, Srinivasulu K, Prasad NV, Rao NP. Agronomic evaluation of *Gossypium hirsutum* hybrids for varied spacings and nitrogen levels in vertisols under rainfed conditions. J Cotton Res. Dev., 2007; 21(2):197-200.
34. Nehra PL, Nehara KC, Kumawat PD. Response of *hirsutum* cotton to wider row spacing and potassium in north-western plain zone of Rajasthan.
35. Wankhade ST, Turkhede AB, Katkar RN, Sakhare BA, Solanke VM. Effect of spacing and nitrogen on growth and yield of the deshi hybrid cotton AKDH 7. J. Cotton Res. Dev. 2004; 2005; 19(1):77-79.
36. Norton LJ, Clark H, Borrego, Bryan Ellsworth. Evaluation of two plant growth regulators from LT. Biosyn Arizona Cot. Rep, 2005, 142.
37. Ogola AH, Opondo RM, Omuga G, Malaya H. The effect of plant density and soil fertility regimes on seed cotton (*Gossypium hirstum*) yield. p.4. In: Proc. 10th KARI Biennial Scientific Conf., Nairobi.12-17 Nov. KARI Headquarters, Kaptagat Road, Loresho, Nairobi, Kenya, 2006. Online available at www.kari.org.
38. Raskar BS. Effect of irrigation methods, fertilizer levels and green manuring on yield and nutrient balance in summer cotton. J Cotton Res. Dev. 2004; 18(2):180-183.
39. Reddy PRR, Gopinath M. Influence of fertilizers and plant geometry on the performance of Bt cotton hybrid. J Cotton Res. Dev. 2008; 22(1):78-80.
40. Rossi J, Novick G, Murray J, Landivar J, Zhang S, Baxevanos D *et al*. Ultra narrow row cotton: Global Perspective and Reduce Pesticide use Proceedings of the Technical Seminar of the 3rd Plenary Meeting of the ICAC: How to improve yields. Mumbai, India. Nov, 2004, 7-11.
41. Sarkar RK, Malik GC. Effect of method of planting and crop geometry on productivity of rainfed upland cotton (*Gossypium hirsutum* L.) grown in low land rice (O*ryza sativa*) fallows. Indian J of Agron. 2004; 49(4):278-281.
42. Sharma SK, Dungarwal HS. Nutrients uptake in cotton as affected by growth regulators, sulphur application and crop geometry. J Cotton Res. Dev. 2003; 19(1):53-56.
43. Shwetha NS. Studies on the manipulation of growth as a means of increasing productivity of Bt cotton (*Gossypium hirsutum* L.). M.Sc. Thesis, University of Agricultural Sciences, Dharwad, India, 2008.
44. Singh K, Jindal V, Singh V, Rathore P. Performance of Bt cotton hybrids under different geometrical arrangements. J Cotton Res. Dev. 2007; 21(1):45-48.
45. Sisodia RI, Khamparia SK. American cotton varieties as influenced by plant densities and fertility levels under rainfed conditions. J Cotton Res. Dev. 2007; 21(1):35
46. Spitzer T, Matusinsky P, Klemova Z, Kazda J. Management of sunflower stand height using growth regulators. Plant Soil Environ. 2011; 57:357-363.
47. Srinivasan G. Agronomic evaluation of Bt cotton hybrids in summer irrigated tract of southern Tamil Nadu. J Cotton Res. Dev. 2006; 20(2):224-225.
48. Veeraputhiran R, Chinnusamy C. Soil moisture and water use studies under drip and furrow irrigation methods in hybrid cotton. J Cotton Res. Dev. 2009; 23(1):74-79.
49. Venugopalan MV, Prakash AH, Kranthi KR, Deshmukh R, Yadav MS, Tandulkar NR. Evaluation of cotton genotypes for high density planting systems on rainfed vertisols of central India. In: Proc. of World Cotton - Wheat System, Indian J Weed Sci. 2011; 34:243-246.
50. Vishwanath. Response of late sown Bt cotton (*Gossypium hirsutum* L.) to plant spacings, fertilizer levels and NAA applications under irrigation. M.Sc. Thesis, University of Agricultural Sciences, Dharwad, India, 2007.
51. Vories ED, Glover RE. Comparison of growth and yield components of conventional and ultra- narrow row cotton. J Cotton Sci. 2006; 10(3):235-243.

52. Wright DL, Marois JJ, Sprenkel RK, Rich JR. Production of ultra narrow row cotton. University of Florida (UF), IFAS Extension. SS-AGR- 8, 2011.
53. Zakaria M, Sawan, Mohmoud, Amal HE. Response of yield, yield component and fibre properties of Egyptian cotton (*Gssypium barbadense* L.) to nitrogen fertilization and foliar applied potassium and mepiquat chloride. The J Cot. Sci. 2006; 10:224-234.