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M Uma Maheswari
PhD Scholar, Department of Agronomy, Tamil Nadu Agricultural University, Tamil Nadu, India

S Murali Krishnasamy
Professor (Agronomy), Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Correspondence
S Murali Krishnasamy
Professor (Agronomy), Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Effect of crop geometries and plant growth retardants on physiological growth parameters in machine sown cotton

M Uma Maheswari and S Murali Krishnasamy

Abstract

Field experiments were conducted at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore during Winter irrigated seasons of 2017 and 2018 to study the effect of plant growth retardants on physiological growth parameters of machine sown cotton under high density planting system with varying crop geometries. The experiments were laid out in split plot design and replicated thrice. Treatments comprised of three crop geometries *viz.*,75 cm x 10 cm (1,33,333 plants ha^{-1}) (M_1), 75 cm x 20 cm (66,666 plants ha^{-1}) (M_2) and 75 cm x 30 cm (44,444 plants ha^{-1}) (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). The results of the present study revealed that machine sown cotton with closer spacing of 75 cm x 10 cm in conjunction with foliar application of 200 ppm mepiquat chloride (M_1S_4) significantly influenced the physiological growth parameters like leaf area index, leaf area duration, crop growth rate, chlorophyll index and light interception and increased the seed cotton yield.

Keywords: cotton, crop geometries, growth retardants, physiological parameters, seed cotton yield

Introduction

Cotton (*Gossypium hirsutum* L.) is a commercial crop of global importance has retained its unique name and fame as “King of fibres” and “White gold” because of its higher economic value among all the cultivable crops for a long period. It contributes a huge share to Indian agriculture in terms of industrial development, employment generation and national economy. It plays a potential role in socio-economic and political affairs of the World. Cotton provides employment to 70 million people and contributes nearly 75 per cent of total raw material to the textile industry in India (Kairon *et al.*, 2004) [13]. 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) [1]. 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 etc. India is the second largest consumer and exporter representing 5.4 and 5.9 million bales, respectively in 2017-18. 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 the demand (USDA, 2017) [27].

Nowadays, cotton cultivation has become highly labourious particularly for picking. In developing countries, like India, cost on labour hiring is swiftly escalating where mechanization in cotton production will play a key role by keeping the expenditures under control. Altering crop geometries in cotton *i.e* shifting towards high density planting system unites with mechanization by boosting the production due to synchronized maturity of the crop which can enable mechanized picking in future.

Cotton producers and researchers have used plant growth retardants as tools to manage the balance between vegetative and reproductive growth for efficient cotton production. But research on application of growth retardants in conjunction with high density planting would pave way for synchronized maturity of the crop with uniform plant height that might help in harvesting of seed cotton mechanically at large scale level. Therefore, the high density planting system (HDPS) coupled with foliar application of growth retardant 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 check the effect of growth retardants on physiological parameters in machine sown cotton under high density planting system.

Materials and Methods

Field experiment was conducted during winter irrigated seasons of 2017 and 2018 at Department of Cotton in Tamil Nadu Agricultural University, Coimbatore. The experimental site is geographically located in the Western Agro Climatic Zone of Tamil Nadu at 11 °N latitude, 77 °E longitude with an altitude of 426.7 m above mean sea level. The soil of the experimental site was sandy clay loam in texture, belonging to *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}).

The experiment was laid out in split plot design, replicated thrice. Various crop geometries were assigned to main plots and foliar application of growth retardants were assigned to sub plots. Main plot treatments comprised of 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). Crop was sown in raised beds and the major cultivation practices were done with machines and the cultivation practices from sowing to harvest were done as per the crop production guide of TNAU (CPG, 2012). Foliar application of growth retardants were given on 45 and 60 Days after Sowing (DAS). Various machines were used for cultivation of cotton namely; inclined plate planter for sowing, boom sprayer for herbicide application, power weeder for weeding, irrigation and fertigation with drip irrigation system. Harvesting was done manually. Cotton genotype TCH 1819 was used for the experiment. Observations on physiological growth parameters like leaf area index, crop growth rate, leaf area duration, light interception and chlorophyll index were made during maturity stage of the crop during both the years of the study. Seed cotton yield was also recorded at the time of harvest. The growth indices were calculated using established formulae.

Leaf area index (LAI)

From the selected plants in each treatment plots, leaf length and maximum width of the third leaf from the top was measured from five representative samples. Total number of leaves in each plant was counted. From these observations made on squaring, flowering, boll development and maturity stages, the LAI was calculated using the following formula suggested by Ashley *et al.*, (1963) [4].

$$LAI = \frac{L \times W \times N \times K}{\text{Land area } (cm^2) \text{ occupied by one plant}}$$

Where,
L = Length of the leaf in cm
W = Width of the leaf in cm
N = Number of the leaves per plant and
K = Constant factor (0.775 for cotton)

Leaf area duration (LAD)

The mean LAD was calculated using the formula suggested by Power *et al.*, (1967) [23], which was further modified by Kvet *et al.*, (1971) [16].

$$LAD = \frac{L1 + L2}{2} \times (t_2 - t_1)$$

Where,
L1 and L2 are the LAI at time t_1 and t_2.

Crop growth rate (CGR)

Crop Growth Rate (CGR) is defined as the rate of increase in dry weight per unit land area per unit time. The crop growth rate was estimated by adopting the formula given by Watson (1958) [28] and expressed in g $m^{-2}day^{-1}$.

$$CGR = \frac{W_2 - W_1}{(t_2 - t_1)}$$

Where,
W_1 and W_2 - dry weight of plants in g at times t_1 and t_2 respectively.
$t_2 - t_1$ - time intervals in days between stages

Estimation of light interception

Light interception measurements were taken at squaring, flowering, boll development and maturity stages using a Lux meter. Readings were recorded at the top, middle and ground level of the crop. Keeping the light intensity in the open as 100, light interception in per cent was calculated by using the following formula (Chellaiah, 1996) [7].

$$\text{Light interception (\%)} = \frac{\text{Light intensity in open (Lux)} - \text{Average intensity in crop (Lux)}}{\text{Light intensity in open (Lux)}}$$

Chlorophyll index

SPAD meter was used to measure chlorophyll content in leaves. Measurements were taken from upper most fully expanded leaf (4^{th} leaf from the apex) (Wood *et al.*, 1992) [29]. SPAD 502 readings were recorded on squaring, flowering, boll development and maturity stages from five plants $plot^{-1}$. Five chlorophyll meter readings were taken around the midpoint of each blade of the leaf in a plant. Thus, fifty SPAD readings were taken from five plants to represent the mean SPAD 502 values of each plot (treatment).

Results and Discussions

Leaf Area Index

Within various crop geometries, the increased leaf area index of 3.44 and 3.61 was recorded with closer spacing 75 cm x 10 cm (M_1) during 2017 and 2018, respectively (Table 1and 2). This may be due to higher plant density,utilized all natural resources such as solar radiation, moisture, nutrients and space leading to increased LAI (Mohapatra and Nanda, 2011) [19]. This was followed by 75 cm x 20 cm spacing (M_2). The leaf area was reduced with wider spacing of 75 cm x 30 cm (M_3). This is in consonance with the findings of Brodrick *et al.* (2013) [6].

Among the subplot treatments, control (S_7) had increased leaf area index of 3.71 and 3.89 at prior to harvest during 2017 and 2018 respectively, compared to foliar application of growth retardants (Table 1). Reduced leaf area index was recorded with foliar application of 200 ppm mepiquat chloride (S_4). This variation in leaf area index could be attributed to differential dose and mode of growth retardants. The reduction in leaf area by application of mepiquat chloride may be due to inhibition of leaf expansion. Mepiquat chloride inhibits the key enzyme in the production of gibberlic acid (Rademacher, 2000) [24]. Reduction in LAI by growth retardants might also be due to increased juvenility.

Interaction between crop geometries and foliar application of growth retardants significantly influenced the leaf area index of cotton during both the years of study. Cotton with closer spacings (75 cm x 10 cm) coupled with control recorded higher leaf area index. Increased LAI in closer spacing might be due to higher plant population per unit area, more number of leaves per ground area and optimum plant stature and diversion of more photo assimilates towards vegetative growth of the plant (Arunvenkatesh, 2013) [3].

Leaf Area Duration

Leaf area duration is directly proportional to leaf area index. Leaf area duration also increased as leaf area index in closer spacing (75 cm x 10 cm) than under wider spacing due to increased plant density (Table 1 and 2). The result is in agreement with the findings of Ma *et al*. (2007) [17]. The LAD reduced significantly in all the growth retardants applied plots especially with mepiquat chloride 200 ppm due to reduced leaf area and leaf area index. This is in consonance with the results of Kholer (2008) [15].

Interaction between crop geometries and foliar application of growth retardants significantly influenced the leaf area duration of cotton during both the years of the study. Cotton under closer spacings (75 cm x 10 cm) coupled with control recorded increased leaf area duration than other treatment combinations. This might be due to diversion of more photo assimilates towards vegetative growth of the plant which resulted higher leaf area index and leaf area duration (Munir, 2014) [21]. This is in correlation with the results of Anbarasi and Rajendran (2017) [2].

Crop Growth Rate

Crop growth rate is described as the gain in dry biomass of plant per unit area per unit of time. The CGR was found to be lesser at early stages due to slow growth of the crop and increased at later stages and subsequently, it declined at harvest stage due to cessation of growth at maturity and abscission of leaves which reduced the photosynthates accumulation.

Among the different crop geometries, increased crop growth rate was recorded with closer spacing of 75 cm x 10 cm compared to other spacings due to high LAI and LAD during both the years of study (Table 1 and 2). Reduced crop growth rate was recorded under wider spacing of 75 cm x 30 cm. A similar observation of higher CGR at higher plant density was reported by Manjunatha *et al.* (2010) [18] and Chukka (2012) [8]. Combination of 75 cm x 10 cm with mepiquat chloride 200 ppm recorded increased crop growth rate compared to other treatment combinations due to increased dry matter production. During the both the years of experimentation, increased crop growth rate was found with closer spacing (M_1) than the recommended spacing (M_3) due to corresponding increase in their plant growth and dry matter production. This result is in line with findings of Kalaiselvi (2008) [14]. The improvement in growth attributing characters under wider spacing might be due to better availability of solar radiation that helped in synthesis and partitioning of assimilates to individual plant which ultimately translocated assimilates from source to sink and caused partitioning in dry matter that lead to significant increment in growth attributes (Bhalerao *et al.*, 2010) [5].

Chlorophyll index

Chlorophyll index determines the photosynthetic capacity of the cotton which directly influences the rate of photosynthesis, dry matter production and yield. The variation in chlorophyll content due to growth retardants application may be attributed to decreased chlorophyll degradation and increased chlorophyll synthesis.

Chlorophylls are the pigments responsible for harvesting solar energy and converting into chemical energy and exhibited differential pattern in their accumulation within plants. Chlorophyll index was significantly influenced by different plant geometries. However, increased chlorophyll index was recorded with wider spacing (75 cm x 30 cm) compared to closer spacing (75 cm x 10 cm) (Table 1 and 2). Increased chlorophyll index under wider row spacing might be because of increased concentration of leaf pigments. These results are in line with findings of Jahedi *et al.* (2013) [11].

In the present study, foliar application of mepiquat chloride 200 ppm and mepiquat chloride 100 ppm as well as cycocel 500 ppm recorded increased total chlorophyll content. Kholer (2008) [15] inferred that the application of growth retardants produced thicker leaf blades, whereas the application of CCC resulted in significantly increased total chlorophyll content. This is in corroboration with the results of Gowtham and Korekar (2017) [10] and also with the findings of Gobi and Karthikraja (2019) [9].

Light interception

Light interception was influenced neither by crop geometries nor by growth retardants application during both the years of experimentation (Table 1 and 2). Among the different crop geometries, light interception was higher with closer spacing of 75 cm x 10 cm due to earlier canopy development than the wide spacing plots. This is consonance with the findings of Roche *et al*. (2003) [25] who reported that the closely spaced crop reached maximum light interception earlier than the wider spaced crop. Within different growth retardants application, mepiquat chloride 200 ppm found to have higher light interception than other treatments. This may be due to reduction in plant height and compactness of the crop compared to control.

Seed cotton yield

Crop geometry of 75 cm x 10 cm (M_1) recorded increased seed cotton yield (2505 and 2715 kg ha^{-1} during 2017 and 2018) than other spacings (Table 3 and Fig. 1). It was followed by crop geometry of 75 cm x 20 cm (M_2). It might be due to more number of picked bolls per unit area. This is in confirmation with the findings Srinivasan (2006) [26] have observed increased seed cotton yield with increased plant population. Among the foliar application of growth retardants, 200 ppm mepiquat chloride found to have increased seed cotton 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) [22], Joel (2005) [12] and Zakaria *et al.* (2006) [30] 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. Application 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) [20] who reported that increased 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 growth retardants on physiological growth parameters in cotton at maturity stage under high density planting system during 2017

	LAI				LAD (days)				Chlorophyll index				CGR (g m^{-2}day^{-1})				Light Interception Percentage			
Treatments	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	3.31	3.17	2.76	3.08	78.14	75.89	67.16	73.73	36.40	38.78	43.53	39.57	5.56	3.63	1.45	3.54	78.14	75.89	67.16	73.73
S_2	3.29	3.14	2.74	3.06	80.41	76.54	68.54	75.16	37.00	39.42	44.24	40.22	4.11	3.02	2.01	3.05	80.41	76.54	68.54	75.16
S_3	3.17	3.12	2.70	3.00	81.47	78.99	70.85	77.10	37.94	40.42	45.36	41.24	4.23	2.99	1.84	3.02	81.47	78.99	70.85	77.10
S_4	2.62	3.08	2.61	2.77	82.01	80.37	71.65	78.01	39.48	42.05	47.20	42.91	4.78	3.62	2.14	3.51	82.01	80.37	71.65	78.01
S_5	3.59	3.43	2.86	3.29	75.23	72.52	64.21	70.65	33.96	36.17	40.60	36.91	4.99	3.53	2.18	3.57	75.23	72.52	64.21	70.65
S_6	3.68	3.52	2.81	3.34	76.28	73.87	65.99	72.05	35.09	37.38	41.95	38.14	4.72	3.51	2.10	3.45	76.28	73.87	65.99	72.05
S_7	4.42	3.73	2.99	3.71	73.29	70.27	61.27	68.28	32.42	34.54	38.76	35.24	3.98	2.81	1.73	2.84	73.29	70.27	61.27	68.28
Mean	3.44	3.31	2.78		78.12	75.49	67.10		36.04	38.39	43.09		4.62	3.30	1.92		78.12	75.49	67.10	
	M	S	M x S	S x M	M	S	M x S	S x M	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	0.05	0.05	0.09	0.08	1.12	1.11	2.10	1.92	0.51	0.63	1.13	1.08	0.07	0.05	0.10	0.08	1.12	1.11	2.10	1.92
CD (P = 0.05)	0.14	0.10	0.21	0.17	3.12	2.24	4.71	3.88	1.42	1.27	2.46	2.20	0.19	0.09	0.24	0.16	3.12	2.24	4.71	3.88

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 2: Effect of growth retardants on physiological growth parameters in cotton at maturity stage under high density planting system during 2018

	LAI				LAD (days)				Chlorophyll index				CGR (g m^{-2}day^{-1})				Light Interception Percentage			
Treatments	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	3.48	3.34	2.93	3.25	98.73	96.48	82.68	92.63	36.65	39.05	43.83	39.84	5.43	3.84	2.37	3.88	82.04	79.60	70.13	77.26
S_2	3.46	3.31	2.91	3.22	98.86	95.56	81.86	92.09	36.48	38.86	43.62	39.65	4.47	3.28	2.18	3.31	84.64	80.44	71.75	78.94
S_3	3.34	3.31	2.87	3.17	96.29	94.14	80.39	90.27	37.70	40.16	45.08	40.98	4.59	3.25	2.00	3.28	85.87	83.17	74.33	81.12
S_4	2.79	3.24	2.77	2.94	77.05	92.32	78.10	82.49	39.52	42.09	47.25	42.95	5.20	3.94	2.33	3.82	86.53	84.74	75.26	82.18
S_5	3.76	3.60	3.03	3.47	105.60	101.25	85.80	97.55	34.72	36.98	41.51	37.73	5.41	3.82	2.36	3.86	78.82	75.89	66.89	73.86
S_6	3.85	3.69	2.98	3.51	107.21	103.01	85.37	98.53	35.74	38.07	42.73	38.84	5.11	3.81	2.28	3.73	79.99	77.38	68.84	75.40
S_7	4.59	3.90	3.17	3.89	128.28	106.79	89.94	108.33	30.86	32.87	36.89	33.54	4.31	3.05	1.88	3.08	76.65	73.39	63.65	71.23
Mean	3.61	3.49	2.95		101.71	98.50	83.45		35.95	38.30	42.99		4.93	3.57	2.20		82.08	79.23	70.12	
	M	S	M x S	S x M	M	S	M x S	S x M	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	0.05	0.05	0.10	0.09	1.44	1.44	2.73	2.50	0.51	0.62	1.12	1.08	0.07	0.05	0.11	0.09	1.18	1.16	2.20	2.01
CD (P = 0.05)	0.14	0.10	0.22	0.18	4.00	2.93	6.10	5.07	1.42	1.26	2.45	2.19	0.20	0.10	0.25	0.17	3.28	2.35	4.94	4.07

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

Main plot	Sub plot
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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 growth retardants on seed cotton yield (kg ha^{-1}) under high density planting system during 2017 and 2018

	2017				2018			
Treatments	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	2389	2179	2004	2191	2587	2482	2172	2414
S_2	2819	2609	2087	2505	3058	2691	2265	2671
S_3	2865	2655	2075	2532	3111	2783	2254	2716
S_4	3109	2899	2172	2726	3378	3062	2362	2934
S_5	2043	1833	1900	1926	2211	2077	2058	2115
S_6	2316	2106	1970	2131	2507	2414	2135	2352
S_7	1990	1780	1707	1826	2151	1936	1848	1978
Mean	2505	2295	1988		2715	2492	2156	
	M	S	M x S	S x M	M	S	M x S	S x M
SEd	37	34	65	58	40	37	71	64
CD (P = 0.05)	103	68	149	118	112	75	162	129

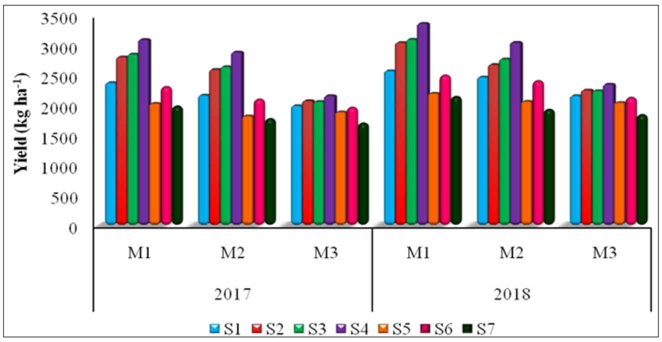

Fig 1: Effect of growth retardants on seed cotton yield (kg ha^{-1}) of machine sown cotton under high density planting system during 2017 and 2018

Conclusion
From the results of the experiments conducted during 2017 and 2018, it could be concluded that cotton with closer spacing of 75 cm x 10 cm in conjunction with foliar application of 200 ppm mepiquat chloride (M1S4) was found to be a promising technology for enhanced physiological growth and seed cotton yield in genotype TCH 1819.

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