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Influence of Cultivation Methods and Crop Geometry on Yield Attributes of Cotton (*Gossypium hirsutum* L.)

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ABSTRACT

Background: The cost of labour in India is constantly rising, so mechanization in cotton production will be critical in keeping costs under control. There will also be an increase in production as a result of high density. Thus, an attempt has been made through this study to compare the impact of mechanization in cotton with high-density planting to conventional farming methods with high-density planting.

Methods: The experiment was laid out in a split-plot design and replicated thrice. The treatments comprised of two cultivation methods *viz.*, mechanized cultivation (M_1) and conventional cultivation (M_2), assigned in main plot and four spacings *viz.*, 45 cm × 15 cm (1,48,148 plants/ha) (S_1), 60 cm × 15 cm (1,11,111 plants/ha) (S_2), 75 cm × 15 cm (88,888 plants/ha) (S_3) and 75 cm × 30 cm (44,444 plants/ha) (S_4) in the subplot.

Result: The results of this study revealed that cotton under mechanized cultivation with the closer spacing of 45 cm × 15 cm (M_1S_1) recorded fewer yield-attributing parameters, but because of their high plant population per unit area, it recorded a higher seed cotton yield than the other treatment combinations.

Key words: Cotton, Crop geometry, Cultivation method, Mechanized cultivation, Yield attributes.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.), white gold is one of the most important crop throughout the history of India and it also plays an important social and economic role in Indian society in the present age. The world cotton production is 96.5 million bales of 480 lb, in which India has emerged as the world's first producer of cotton accounting for 26.4 million 480 lb. bales, followed by China, the United States and Pakistan. India is also the second largest consumer and exporter representing 5.3 and 5.8 million 480 lb. bales in 2015-16 (USDA, 2016). Although, India is the largest producer of cotton, the second-largest exporter and the second-largest consumer of cotton, demand for cotton is expected to remain robust in India.

The major driven factor for low productivity in India is rainfed cultivation, small farm size, increasing pest and disease, inadequate inputs, lack of awareness about modern cultivation practices among Indian farmers, lack of irrigation facilities, lack of proper timing of field operations and too much dependence on labour to cultivate cotton (Majumdar, 2012). In most of the developing countries, especially in India cost of labour hiring is swiftly escalating. Mechanization in cotton production will definitely play a key role by keeping the expenditure under control.

The labour requirement for planting cotton is higher, which is next to harvesting operation; usually, cotton sown manually consumes more seed rate and labour cost. Therefore machine sowing is needed to avoid labour dependence (Vaiyapuri, 2004). Sowing cotton with an inclined plate planter saves 46.2 and 97.1 per cent saves in labour cost and time, respectively (Chandel *et al.,* 2010). Weeding is another important laborious practice; by adopting power weeder could cover an area of one hectare in a day of 8 hr. It comes only one-third of weeding cost incurrred by manual laboures (Tajuddin, 2006). Drip irrigation and fertigation in cotton help to the farmers to reduce the cost of cultivation, especially in labour-intensive operations such as weeding and irrigation, which reduces the cost of irrigation by 50 per cent (Narayanamoorthy, 2008).

Among all operations, cotton picking is the most difficult, tiresome and tedious. The average labour requirement in the conventional practice of hand-picking of cotton in India was reported to be about 517 man-hr/ha (Prasad *et al.*, 2004). It was not only a tedious job, but also ten times costlier than irrigation and twice costlier than the weeding operation (Prasad and Majumdar, 1999). A person can pick about 15 to 20 kg/day of seed cotton, compared to an average picking of 870 to 2180 kg/day by a single row spindle type cotton picker (Sandhar, 1999). Farmers in India still use traditional methods of cultivation of cotton crop,

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which leads to considerably low productivity. Along with the above reasons, the shortage of labour in some areas of India, which are rapidly industrializing, impacts the profitability of cotton crops. Within this context, a better understanding of the Indian cotton sector and the impact of mechanization on cotton cultivation need to be assessed.

The manipulation of row spacing, plant density and the spatial arrangements of cotton plants, to obtain higher yield has 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) resulting in a population of 50000 to 150000 plants/ha. The concept of high-density cotton planting, more popularly called Ultra Narrow Row (UNR) cotton was initiated by Briggs *et al.* (1967). An obvious advantage of this system is its earliness (Rossi *et al.,* 2004). The UNR cotton plants produce fewer bolls/plant than conventional cotton but retained a higher percentage of the total number of well-opened bolls per unit area in the first sympodial position and a lower percentage in the second position (Vories and Glover, 2006).

The high-density planting system (HDPS) is now being conceived as an alternative production system with the potential to improve productivity and profitability, increasing input use efficiency, reducing input costs and minimizing the risks associated with the current cotton production system in India. It unites with mechanization by boosting the production owing to synchronized maturity, which enables mechanized picking. Thus, an attempt has been made in this study to check the influence of mechanization in cotton with high-density planting compared with conventional cultivation method with high-density planting.

MATERIALS AND METHODS

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during summer 2015 and 2016. 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 the experiment was low in available nitrogen (210 kg/ha), medium in available phosphorus (12.6 kg/ha) and high in available potassium (429 kg/ha). The experiment was laid out in split plot design, replicated thrice and the same layout was maintained during both years of the study. Cultivation methods were assigned to the main plot and crop geometries were assigned to subplots. Main plot treatments were two cultivation methods *viz.,* mechanized cultivation (M_1) and conventional cultivation (M_2). The subplot treatments had four spacings *viz.,* 45 cm × 15 cm (S_1), 60 cm × 15 cm (S_2), 75 cm × 15 cm (S_3) and 75 cm × 30 cm (S_4). For the mechanized cultivation method, crops were raised on flatbed and the major cultivation practices from sowing to harvest were done with machines, whereas in the conventional cultivation method, crops were raised by ridges and furrow systems and the cultivation practices from sowing to harvest were done according to the crop production guide of TNAU (CPG, 2012). The machines used for mechanized cultivation system were, sowing with inclined plate planter, weeding with a power weeder, irrigation and fertigation with a micro-irrigation system and harvesting with the portable battery-operated cotton picker. Cotton variety Surabhi was used as a test crop. The observation on yield attributes and yield were recorded.

RESULTS AND DISCUSSION

Yield attributes of cotton

The yield attributing characters including the number of sympodial branches/plant, number of fruiting points/plant, number of bolls/plant, boll setting percentage and boll weight ultimately determine the seed cotton yield and were significantly influenced by cultivation methods and plant geometries (Table 1).

Number of sympodial branches/plant

Cotton under mechanized cultivation (M_1) recorded more sympodial branches (12.5 and 11.9/plant in 2015 and 2016, respectively) compared to conventional cultivation (M_2) (Table 1). This increase in sympodial branches might be due to timely field operations with machinery, including weeding with a power weeder, which reduced weed competition and allowed the crop to utilize growth factors more effectively. This resulted in more sympodial branches and a higher yield (Nithya and Chinnusamy, 2013). Similar findings were reported by Bhalerao *et al.* (2008). Additionally, drip fertigation under mechanized cotton cultivation likely improved nutrient uptake, boosting photosynthesis and the translocation of nutrients to reproductive parts compared to conventional soil-applied nutrients (Grieesha, 2003; Raskar, 2004). Kalaichelvi *et al.* (2017) and Suresh Kumar *et al*. (2016) also found that mechanized system improved growth and yield due to better nutrient and water management.

Among the crop geometries, wider spacing with a low population produced more number of sympodial branches/plant than closer spacing with a high population. Crop geometry of 75 cm × 30 cm (S_4) produced a significantly greater number of sympodial branches (15.3 and 14.5/plant in 2015 and 2016, respectively) due to lability of space for lateral expansion of branches and the chance to enhance auxiliary buds of the plant compared to closer plant and row spacing recorded more competition for space, light and nutrient. These observations were consistent with the findings of Bhalerao *et al.* (2008). The reduced number of sympodial branches (8.8 and 8.3/plant in 2015 and 2016, respectively) was registered with spacing 45 cm × 15 cm (S_1), followed by spacing 60 cm × 15 cm (M_2). The decrease in sympodia with increasing plant density in cotton due to competition for light, moisture, nutrients, space and congestion induced more vertical growth through nodal elongation. As a result, the majority of the photosynthates consumed in vertical growth limit lateral branching. These results are in accordance with those reported by Narayana *et al.* (2008); Sowmiya and Sakthivel (2018).

A significant interaction between cultivation method and crop geometry was observed in the sympodial branches/ plant. A greater number of sympodial branches/plant was registered with the mechanized cultivation method at the spacing of 75 cm × 30 cm (M_1S_4), whereas the minimum number of sympodial branches/plant was registered with conventional cultivation method with a spacing of 45 cm × 15 cm (M_2S_1). This might be due to reduced competition for resources like nutrients, light and spacing *etc*. (Kalaichelvi, 2008; Baskar, 2014).

Number of fruiting points/plant

Fruiting points are crucial for assessing the cotton yield efficiency. Cultivation methods had significantly influenced number of fruiting points/plant in both the years of study (Table 1). Mechanized cultivation (M_1) recorded higher fruiting points (35.2 and 33.3 per plant in 2015 and 2016, respectively) compared to conventional cultivation. This increase was due to better nutrient absorption, efficient light interception and reduced weed competition (Narayan *et al*., 2008). With fewer weeds, the crop had better access to nutrients, enhancing growth factors like leaf area index (LAI) and dry matter production (DMP), ultimately leading to more fruiting points. These results align with the findings of Sureshkumar (2014).

Considering the crop geometry, wider spacing of 75 cm × 30 cm (S_4) and 75 cm × 15 cm (S_3) resulted in more fruiting points/plant (49.4 and 47.4; 30.9 and 29.2, respectively) compared to closer spacings. This supports the findings of Krishnaswamy and Iruthayaraja (1983), who observed that higher plant densities tend to increase fruiting points.

In the interaction effect, the mechanized cultivation with wider spacing of 75 cm × 30 cm (M_1S_4) recorded higher number of fruiting points/plant, than the other treatment combinations. The minimum number of fruiting points/plant was registered in conventional cultivation method with spacing 45 cm × 15 cm (M_2S_1). Similar observations were made by Ramesh *et al.* (2018), who reported that mechanized systems enhance nutrient uptake and light interception, leading to higher fruiting efficiency. Likewise, Kumar and Prasad (2017) found that wider plant spacing reduces intra-plant competition and promotes better reproductive development.

Number of bolls/plant

The number of bolls/plant was significantly influenced by cultivation methods and crop geometry and their interaction effect during both the years of study (Table 1). Among the cultivation methods, mechanized cultivation method (M_1) registered a significantly higher number of bolls (14.3 and 13.2/plant, respectively during summer 2015 and 2016) compared to the conventional cultivation method (M_2). It might be due to enhanced availability and uptake of nutrients under drip fertigation leading to enhanced photosynthesis, expansion of leaves and translocation of nutrients to reproductive parts compared to the conventional method of soil application of nutrients. Similar findings were also recorded by Grieesha (2003).

In crop geometry, wider spacing of 75 cm × 30 cm (S_4) recorded more number of bolls (22.4 and 20.6/plant) during summer 2015 and 2016. A minimum number of bolls was registered under spacing of 45 cm × 15 cm (S_1). This might be due to better light interception and lesser competition among the intra rows which leads to statistically improved mature bolls/plant in case of wider spacing. A similar result was agreed with Narayana *et al.* (2007).

Table 1: Effect of cultivation methods with varying crop geometries on yield attributes of cotton.

Treatments	Summer 2015				Summer 2016			
	Number of sympodial branches /plant	Plant of bolls /plant	Number of fruiting points /plant	Boll setting percentage	Number of sympodial branches /plant	Number of bolls /plant	Number of fruiting points /plant	Boll setting percentage
Cultivation method								
M_1- Mechanized cultivation	12.5	14.3	35.2	38.8	11.9	13.2	33.3	38.5
M_2 - Conventional cultivation	10.6	12.2	32.6	35.5	10.1	11.5	30.9	34.6
SEd	0.2	0.2	0.6	0.6	0.2	0.2	0.5	0.6
CD (P = 0.05)	0.9	0.9	2.4	2.7	0.9	0.9	2.3	2.7
Crop geometry								
S_1 - 45 cm × 15 cm	8.8	8.2	26.8	28.9	8.3	7.3	24.7	29.8
S_2- 60 cm × 15 cm	10.5	10.2	28.6	53.6	9.8	10.1	26.9	36.1
S_3- 75 cm × 15 cm	11.7	12.0	30.9	38.8	11.4	11.1	29.2	38.0
S_4- 75 cm × 30 cm	15.3	22.4	49.4	45.4	14.5	20.6	47.4	42.6
SEd	0.2	0.2	0.6	0.6	0.2	0.2	0.6	0.6
CD (P = 0.05)	0.4	0.7	1.3	1.3	0.4	0.5	1.2	1.3
Interaction	S	S	S	S	S	S	S	S

In interaction effect, mechanized cultivation method with wider spacing of 75 cm × 30 cm (M_1S_4) recorded a higher number of bolls/plant than the other treatment combinations, whereas a minimum number of bolls/plant registered was with conventional cultivation method with spacing 45 cm × 15 cm (M_2S_1). This result supports earlier research indicating that mechanized systems combined with optimal plant spacing maximize boll development (Kumar *et al.,* 2019; Sharma *et al.,* 2017).

Boll setting percentage

A significantly higher boll setting percentage (38.8 and 38.5) was observed under mechanized cultivation (M1) than the conventional during 2015 and 2016, respectively. This improvement can be attributed to better resource availability and reduced plant stress under mechanized systems, as reported by Sendouka *et al.* (1980). Mechanized cultivation, particularly with drip irrigation, has been shown to enhance boll retention by minimizing stress factors such as nutrient deficiencies and water scarcity (Kumar *et al.,* 2016).

Reduction in boll setting percentage was recorded with high density planting under closer spacing (45 cm × 15 cm and 60 cm × 15 cm) than the low density planting under wider spacing (75 cm × 15 cm and 75 cm × 30 cm) due to less number of fruiting points and number of bolls. Greater interplant competition under closer spacing might have been led to the shedding of fruiting bodies (Sendouka *et al.,* 1980).

In interaction effect, mechanized cultivation method with wider spacing of 75 cm × 30 cm (M_1S_4) recorded higher boll setting percentage than the other treatment combinations. Minimum boll setting percentage was registered with conventional cultivation method with spacing 45 cm × 15 cm (M_2S_1). This confirms that optimal plant spacing combined with efficient cultivation methods significantly improves boll retention and overall yield potential.

Boll weight

Cultivation methods did not significantly influence boll weight during both years of study (Table 2). This aligns with the findings of Kalaichelvi (2009), who also reported no significant difference in boll weight between mechanized and conventional methods. Similarly, the interaction between cultivation methods and crop geometry showed no notable effect on boll weight.

Crop geometry, however, showed a clear impact on boll size. Wider spacing 75 cm × 30 cm (S_4) produced larger bolls (4.6 g and 4.5 g in 2015 and 2016, respectively) compared to closer spacing 45 cm × 15 cm (S_1), which resulted in smaller bolls (4.3 g and 4.2 g). This difference can be attributed to increased competition for essential resources such as nutrients, water, and light in higher plant densities, as noted by Ogola *et al.* (2006). Although wider spacing produced larger bolls, the lower plant population per unit area offset this advantage in terms of overall yield. Similar findings were reported by Sharma *et al.* (2019), who observed that increased plant density leads to smaller boll sizes due to heightened competition for resources.

Seed cotton yield

Cotton under mechanized cultivation resulted in significantly higher seed cotton yields of 2323 and 2262 kg ha^{-1} in 2015 and 2016, respectively, compared to conventional cultivation (Table 2). This might be due to efficiency of mechanization, which enables faster, less labour-intensive and timely operations, enhancing overall productivity and land use efficiency (Yadav *et al*., 2014). Additionally, the precise application of water and nutrients through drip fertigation contributed to improved crop growth and yield attributes, leading to higher yields (Raskar, 2004). These findings are consistent with those of Singh *et al.* (2017), who reported that mechanization significantly improves yield through efficient resource management.

Among the crop geometries, closer spacing of 45 cm × 15 cm (S_1) recorded higher seed cotton yield (2512 and 2462 kg ha^{-1} on 2015 and 2016, respectively) compared to other spacings. It was comparable with the spacing of 60 cm × 15 cm (S_2), which recorded 2349 and 2299 kg ha^{-1}

Table 2: Effect of cultivation methods and crop geometries on boll weight and seed cotton yield of cotton.

Treatment	Bolls weight (g)		Seed cotton yield (kg ha^{-1})	
	Summer 2015	Summer 2016	Summer 2015	Summer 2016
Cultivation methods				
M_1- Mechanized cultivation	4.5	4.4	2323	2262
M_2- Conventional cultivation	4.3	4.3	2026	2011
SEd	0.1	0.1	40	39
CD (P = 0.05)	NS	NS	172	170
Crop geometry				
S_1 - 45 cm × 15 cm	4.3	4.2	2512	2462
S_2 - 60 cm × 15 cm	4.3	4.3	2349	2299
S_3 - 75 cm × 15 cm	4.4	4.3	1989	1973
S_4 - 75 cm × 30 cm	4.6	4.5	1850	1813
SEd	0.2	0.2	46	45
CD (P = 0.05)	0.2	0.3	102	100
Interaction	NS	NS	S	S

in the respective years. The higher plant population per unit area contributed to increased yield, compensating for the lower number of bolls per plant. In contrast, wider spacings, despite producing more bolls per plant, resulted in lower seed cotton yield due to the reduced plant population. These findings align with those of Shashi and Ramachandra (2019) and Srinivasa *et al.* (2020), who also observed that higher plant densities lead to greater overall yield despite reduced individual plant productivity.

The interaction between cultivation methods and crop geometry significantly influenced seed cotton yield. Mechanized cultivation combined with closer spacing of 45 × 15 cm (M_1S_1) registered higher seed cotton yield than the other treatment combinations and was comparable with mechanized cultivation with 60 cm × 15 cm spacing (M_1S_2) during both 2015 and 2016. Conversely, conventional cultivation under wider spacing of 75 × 30 cm (M_2S_4) resulted in lower seed cotton yield. These results align with the findings of Bhardwaj *et al.* (2020), who reported that increased plant population density positively impacted overall yield, even with fewer bolls per plant. Similar results were also documented by Verma *et al.* (2020), who emphasized that optimizing plant density enhances yield despite variations in boll retention.

CONCLUSION

Based on the experimental results, it can be concluded that cotton cultivation under mechanized conditions with crop geometry of 45 cm × 15 cm (M_1S_1) proves to be a promising method for achieving higher yields. This approach significantly enhances yield attributes, including the number of sympodial branches, fruiting points and bolls per plant. It holds considerable potential for improving cotton yield and profitability, especially in response to rising labor costs in India.

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Conflict of interest

The authors declare that there is no conflict of interest related to this research.

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