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Effect of Plant Density and Branching Pattern on Cotton Seed Yield Components and Quality

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ABSTRACT: Cotton is one of the most vital fiber and cash crop of India. The production and productivity of cotton remained low until recent years. Further improvements in cotton yields are possible only through changes in agronomic management and cropping systems. Keeping these in view, current investigations were made to find out the influence of plant spacing and branching pattern on crop growth, flowering, boll production, seed filling, seed yield and quality characteristics of cotton *cv.* MCU 12. Three different plant spacing *viz.*, narrow spacing (45 × 15 cm), medium spacing (60 × 30 cm) and wider spacing (90 × 45 cm) and three different branching patterns *viz.*, Branching pattern I (3 monopodia and 11 sympodia), Branching pattern II (2 monopodia and 12 sympodia) and Branching pattern III (1 monopodia and 15 sympodia) were studied in this research. Study on the influence of plant spacing on crop growth and seed yield of cotton revealed that a closer spacing of 45 × 15 cm produced more number of plants plot^{-1} (177) whereas medium (60 × 30 cm) and wider spacing (90 × 45 cm) recorded lower plant population of 66 and 29 plants plot^{-1}, respectively. More number of flowers plant^{-1}, bolls plant^{-1}, highest kapas and seed yield plant^{-1} were recorded in wider spacing of 90 × 45 cm (68, 18.8, 39.24, 64.78 g and 45.77 g, respectively) than the other two spacing's. However, higher kapas and seed yield ha^{-1} (5709.1 kg and 3741.6 kg, respectively) was recorded in closer spacing (45 × 15 cm) because of more number of plants due to closer spacing. The results on the effect of branching pattern on seed yield and quality characteristics revealed that the number of flowers and bolls branch^{-1} was also found to be the highest in the B_1 (sympodia I) of branching pattern I (7.6 and 1.5, respectively), followed by B_1 of branching pattern II (7.4 and 1.4, respectively) and B_1 of branching pattern III (6.3 and 1.7, respectively). The number of seeds and filled seeds kapas^{-1} was also the highest in first branch (B_1) of branching pattern I (38.71 and 26.3), followed by B_1 of branching pattern II (38.29 and 24.0) and branching pattern III (37.14 and 21.6, respectively). The kapas yield branch^{-1} was drastically reduced from 5.29 g (B_1) to 1.09 g (B_{14}) in branching pattern I, whereas it was 5.05 g (B_1) to 2.16 g (B_{14}) and 5.39 g (B_1) to 1.07 g (B_{16}) in branching pattern II and III, respectively. The seed yield plant^{-1} was directly proportional to the kapas yield branch^{-1}. Mean seed yield branch^{-1} was found to be highest in branching pattern 1 (3.23 g) followed by branching pattern 2 (2.60 g) while it was the lowest in branching pattern 3 (1.91 g). The 100 seed weight, seed germination and vigour index was higher in first branch of branching pattern 1 (7.88 g, 82 % and 2706), when compared to other branches. As the hierarchy of branching order increased significant reduction in cotton seed quality. Hence, maximum seed yield in cotton can be achieved by increasing the plant population per unit area by decreasing plant spacing.

Key words: Branching pattern, Cotton, Seed yield, Spacing, Quality.

INTRODUCTION

Cotton (*Gossypium* sp.) is an important fibre crop cultivated in tropical and sub-tropical regions of more than seventy countries (Ali *et al.*, 2009). Cotton has a unique name and fame as "King of Fibres" and "White Gold" because of its high economic value among cultivable annual crops. It provides employment opportunities to about 70 million people and contributes nearly 75 per cent of total raw material to the textile industry in India. It is the backbone of the flourishing textile industry in India (O'Brien *et al.*, 2005). The production and productivity of cotton remained low until recent years. Further improvements in cotton yields are possible only through changes in agronomic management and cropping systems. Due to mobilization of nutrients to the developing bolls the vegetative growth is restricted and the canopy size reduced, offering scope for planting cotton at higher planting densities in India (Balkcom *et al.*, 2010). The manipulation of row spacing, plant density and the spatial arrangements of cotton plants for obtaining higher yield have been attempted by scientists for several decades in many countries. The concept of high density cotton planting, more popularly called as Ultra Narrow Row (UNR) cotton was developed by Briggs et al.

(1967). High Density Planting Systems (HDPS) are commonly followed to obtain high yields with straight varieties across the world especially in the major cotton growing countries (Anjum *et al*., 2010). Generally wider row-to-row spacing is followed in deep soils and irrigated farms and ultra-narrow row spacing in rainfed conditions. The early maturity in soils that do not support excessive vegetative growth (Jost and Cothern, 2001) can make this system ideal for shallow to medium soils. Hence, the performance of cotton crop with reference to different spacing needs to be studied well in order to understand the effect of seed yield and quality (Basanagouda and Patil, 2007). In cotton two types of branches are produced. Monopodial branches are the vegetative branches and structurally similar to the main stem. Sympodial branches are the fruiting branches produced by the main stem and monopodial branches and grow at an acute angle to the main stem (Bednarz *et al.,* 2000). Every sympodial branch has a main stem leaf associated with the branch for new fruiting node has an extending leaf and a fruiting structure or square at each node. The development of this branch terminates in a square, but a second leaf and square develop in the axil of the first leaf and similarly extend away from the first leaf and square by internode elongation (Bhalerao and Godavari, 2010). Repetition of this process produces several squares and leaves resulting in the typical zigzag appearance of the fruiting branch. The flowers are opposite to the leaves on the sympodial branches and develop more rapidly than monopodial branches (Bharathi et al., 2012). High Density Planting System (HDPS) is now being conceived as an alternate production system 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 (Brodrick *et al.*, 2012). Keeping the above facts in the view the present study was carried out to determine the influence of plant spacing and branching pattern on flowering, seed filling, seed yield and resultant seed quality characteristics of cotton *cv.* MCU 12.

MATERIALS AND METHODS

Field experiments were conducted in the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore to study the effect of plant spacing on crop growth, flowering, boll production, seed filling, seed yield and quality in cotton. The cotton *cv.* MCU 12 was raised at different plant spacing of wider 90 × 30 cm, medium with 60 × 30 cm and closer spacing (45 × 15 cm) with seven replications in a randomized complete block design (RBD) having a net plot area of 4 × 3 m. All the required cultural operations were adopted throughout the growing period uniformly in all the treatments. For recording biometric observations five plants were selected randomly from each treatment for recording number of flowers and bolls plant^{-1}, kapas and seed yield plant^{-1}ha^{-1}. Cotton crop raised in the spacing's of 90 × 45 cm (wider spacing), 60 × 30 cm (medium spacing) and 45 × 15 cm (closer spacing) exhibited varied branching pattern with respect to the number of monopodia and sympodia. Based on the branching pattern observed in the selected 20 plants from different spacing, following three branching patterns were formed.

Branching Pattern	No. of monopodial branches	+	No. of sympodial branches	No. of plants observed
Pattern I	3		11	20
Pattern II	2		12	20
Pattern III	1		15	20

For recording biometric observations 20 plants were selected randomly from each treatment, observations on number of flowers, no. of bolls, no. of filled seeds kapas^{-1}, No. of ill filled seed kapas^{-1} (1st to nth branch), kapas yield (g branch^{-1}), seed yield (g branch^{-1}), Resultant seed quality characteristics *viz.,* 100 seed weight (g), seed germination (%) and vigour Index in the 1st to nth branch of each selected plants**.** The data was collected from various experiments were analyzed statistically adopting the procedure described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

A. Effect of planting pattern on seed cotton yield and yield components

In the present study, the data representing number of plants per plot, number of flowers and bolls per plant indicated that all the spacing treatments had produced significantly different number of plants per plot, flowers and bolls plant^{-1} (Table 1). A closer spacing of 45 × 15 cm produced more number of plants plot^{-1} (177) whereas medium (60 × 30 cm) and wider spacing (90 × 45 cm) recorded lower plant population of 66 and 29 plants plot^{-1}, respectively. The plant spacing of 90 × 45 cm had more number of flowers and bolls (68 and 18.8, respectively) than 60 × 30 cm (66 and 16.3, respectively) and 45 × 15 cm spacing (64 and 11.9, respectively). This might be to the better assimilation of nutrients and optimum plant density without any population pressure. The enhanced availability of nutrients to the crop at optimum density helped in improved growth and expression in terms of yield (Buttar and Sudeep Singh, 2007). This is in confirmation with the earlier reports of Krishnaswamy and Iruthiayaraj (1983) who reported that higher number of fruiting points with plant density of 33,333 plants ha^{-1} as compared to 66,666 plants ha^{-1}.

The final yield is the function of combined effect of all the yield components**.** Comparing the plant spacings, wider spacing with 90 × 45 cm recorded higher kapas and seed yield plant^{-1} as compared to medium and closer spacing of 60 × 30 and 45 × 15 cm, respectively. The highest kapas yield of 64.78 g was recorded in wider plant spacing (90 × 45 cm) and the lowest kapas yield (38.71 g) was recorded in closer spacing of 45 × 15 cm.

Table 1: Effect of plant spacing on plant height, seed yield and yield attributes of cotton cv. MCU 12.

Treatments	No. of plants/plot	No. of flowers plant^{-1}	No. of bolls plant^{-1}	Kapas yield plant^{-1} (g)	Seed yield plant^{-1} (g)	kapas yield ha^{-1} (kg)	seed yield ha^{-1} (kg)
T_1 (90 × 45 cm)	29	68	18.8	64.78	45.77	1565.8	1105.8
T_2 (60 × 30 cm)	66	66	16.3	54.05	38.90	2972.5	2139.1
T_3 (45 × 15 cm)	177	64	11.9	38.71	25.37	5709.1	3741.6
Mean	**90.7**	**66**	**15.7**	**52.51**	**36.68**	**3415.8**	**2328.8**
SEd	0.436	**0.74**	0.47	0.46	0.28	1.02	0.68
CD (P=0.05)	0.950**	**1.62****	1.04**	1.00**	0.61**	2.23**	1.48**

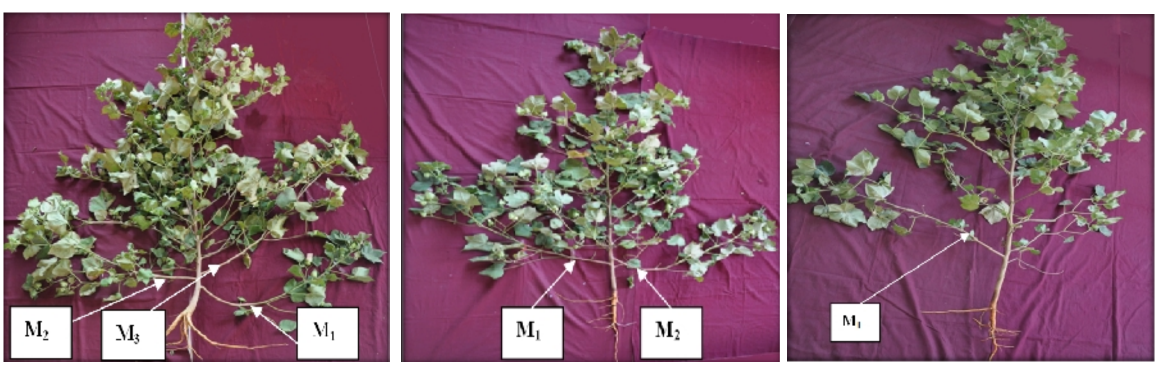
From the generated data, it is clearly understood that in optimum plant density, the competition between the plants are also found to be lesser (Clawson *et al*., 2006). Another factor is that wider spacing (medium high density planting) paved a way for enhanced availability of nutrients to the crop and increased the nutrient uptake which helped in improved crop growth, which in turn was expressed in terms of yield. This is in line with the earlier findings of Bhalerao *et al.* (2008) and Saleem *et al.* (2009) who reported similar findings.

With respect to seed yield per plant, the highest seed yield of 45.77 g was recorded in wider spacing of 90 × 45 cm followed by 60 × 30 cm (38.90 g) and the lowest seed yield (25.37 g) was recorded in closer spacing of 45 × 15 cm. In the present study, even though the all yield attributing characters very maximum due to wider spacing but the kapas yield and seed yield per hectare (5709.1kg and 3741.6 kg, respectively) were higher at closer spacing of 45 × 15 cm since number of plants were higher at closer spacing. This is in conformity with the findings of Anjum *et al.* (2010) who found that maximum seed cotton yield was recorded with 75 cm row spacing followed by 60 cm row spacing. Pradeep Kumar *et al.*, 2014 reported that planting of cotton at 45 × 15 cm^2 registered higher seed cotton yield and quality. Maximum yield in cotton can be achieved by decreasing the row spacing to 60 × 15 cm and increasing the plant population per unit area (1,11,111 plants ha^{-1}) (Sowmiya and Sakthivel, 2021). Gunasekaran *et al,* 2020 and Kumar *et al,* 2017 reported that under High Density Planting System in cotton seed yield was increased in closer spacing than in wider spacing.

B. Influence of branching pattern on flowering, seed filling, seed yield and quality of cotton

The cotton is a slow growing, long duration crop, which produces monopodial and sympodial branches. In this experiment, efforts were taken to study the different branching behavior of cotton as influenced by the wider, medium and closer spacing of plants. The three types of branching patterns were recorded. i) Three monopodia and eleven sympodia (Branching pattern 1), ii) Two monopodia and twelve sympodia (Branching pattern 2) and iii) One monopodia and fifteen sympodia (Branching pattern 3) (Plate 1). In these three types of branching patterns, branch wise observation was taken on total number of flowers branch^{-1}, number of bolls branch^{-1}, number of seeds kapas^{-1}, number of filled seeds kapas^{-1}, number of ill filled seeds kapas^{-1}, kapas yield branch^{-1}, seed yield kapas^{-1}, 100 seed weight, seed germination (%) and vigour index of seeds collected from each branch were also recorded.

The number of flowers branch^{-1} was found to be highest in the B_1 of branching pattern I (7.6), followed by B_1 of branching pattern II (7.4) and B_1 of branching pattern III (6.3). The total number of bolls branch^{-1} in a single branch was highest in branching pattern I and II, while it was lowest in branching pattern III; on average it was 1.3, 1.1 and 0.8 bolls branch^{-1}, respectively. The number of seeds kapas^{-1} was highest in B_1 of branching pattern I (38.71), followed by B_1 of branching pattern II (38.29) and branching pattern III (37.14).



Branching pattern I **Branching pattern II** **Branching pattern III**

Plate 1. Branching pattern I (90 × 45 cm), branching pattern II (60 × 30 cm) and branching pattern III (45 × 15 cm) in cotton *cv.* MCU 12.

As the branch number progressed further the no. of seeds kapas^{-1}, reduced progressively as 23.86 in B_{14} of branching pattern I, 23.43 in B_{14} of branching pattern II and 24.00 in B_{16} of branching pattern III. As the days to 50 % flowering is delayed, it is bound to have a negative effect on seed filling itself since the duration for seed filling is reduced. Thereby, the number of filled seeds kapas^{-1}, was highest in the B_1 of branching pattern I (26.3), while it was relatively lower in B_1 of branching pattern II (24.0) and III (21.6), respectively. The corresponding number of ill filled seeds kapas^{-1}, was 12.43, 14.29 and 15.57, respectively. In the final branch *i.e.*, B_{14} of branching pattern I and II the no. of ill filled seeds kapas^{-1} produced was 4.86 and 5.10, respectively; while in the final branch of B_{16} of branching pattern III, 7.14 ill filled seeds were produced. The kapas yield branch^{-1}, was drastically reduced from 5.29 g (B_1) to 1.09 g (B_{14}) in branching pattern I. Whereas, it was 5.05 g (B_1) to 2.16 g (B_{14}) and 5.39 g to 1.07 g (B_{16}) in branching pattern II and III, respectively (Table 2).

The data of the present study stands proof that, in the final two branches of the branching pattern I, seed filling efficiency was drastically reduced. In the branching pattern II, the kapas yield branch^{-1}, was 6.14 g in the B_3, there after it progressively reduced to 3.61 in B_8 and further reduced to 2.16 in B_{14}. Similarly, in branching pattern III, the kapas yield branch^{-1}, was 5.39 in B_1 and it reduced drastically from B_6 (2.51) onwards to reach 1.07 in B_{16}. Thus, the data reveals that more number of branches leads to more number of bolls plant^{-1}, leading to decrease in supply of source materials to the increased number of sink (seeds) leading to lower kapas yield branch^{-1}. The seed yield plant^{-1} was directly proportional to the kapas yield branch^{-1} (Table 3). Padmaja Rao (1991) and Kush waha (2000) also confirmed the same in rice with respected to tillers of late formed. Mean seed yield (g branch^{-1}) was found to be highest in branching pattern 1 (3.23 g) followed by branching pattern 2 (2.60 g) while it was lowest in branching pattern 3 (1.91 g). As the branching order increased, the seed yield branch^{-1} was found to decrease. In the first branches, the seed yield branch^{-1} was highest in first monopodial branch of branching pattern 3 plants (3.90 g) followed by first monopodial branch of branching pattern 1 (3.81 g) and branching pattern 2 (3.37 g). Among the last branches, the higher seed yield of 1.44 g was recorded in branching pattern 2 plants (14th branch), followed by branching pattern 1 (0.76 g) while it was less in branching pattern 3 (0.69 g).

Table 2. Effect of branching pattern on kapas yield branch^{-1} (g) in cotton *cv.* MCU 12.

Treatments (T)	Kapas yield branch^{-1} (g)																
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	Mean
Branching Pattern 1	5.29	5.08	4.72	6.17	4.72	5.08	3.99	3.99	4.76	5.08	5.81	6.17	2.54	1.09	0	0	**4.61**
Branching Pattern 2	5.05	3.97	6.14	5.78	5.78	5.05	4.69	3.61	3.61	3.61	2.16	2.52	1.08	2.16	0	0	**3.94**
Branching Pattern 3	5.39	5.75	5.75	3.23	3.23	2.51	3.59	3.23	5.75	2.55	1.07	2.15	1.43	1.43	2.15	1.07	**3.14**
Mean	**5.24**	**4.93**	**5.54**	**5.06**	**4.58**	**4.21**	**4.09**	**3.61**	**4.71**	**3.75**	**3.01**	**3.61**	**1.68**	**1.56**	**2.15**	**1.07**	**3.90**

	T	B	T x B
SEd	0.006	0.016	0.029
C D (P=0.05)	0.013**	0.033**	0.057**

Table 3: Effect of branching pattern on seed yield branch^{-1} (g) in cotton *cv.* MCU 12

Treatments (T)	Seed yield branch^{-1} (g)																
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	Mean
Branching Pattern 1	3.81	3.56	3.30	4.32	3.30	3.56	2.79	2.79	3.30	3.56	4.06	4.32	1.78	0.76	0	0	**3.23**
Branching Pattern 2	3.37	3.03	4.10	3.86	3.86	3.37	3.13	2.41	2.41	2.41	1.44	1.68	0.72	1.44	0	0	**2.66**
Branching Pattern 3	3.90	3.71	3.71	2.08	2.08	1.62	2.32	2.08	1.39	1.62	0.69	1.39	0.92	0.92	1.39	0.69	**1.91**
Mean	**3.69**	**3.43**	**3.70**	**3.42**	**3.08**	**2.85**	**2.75**	**2.43**	**2.37**	**2.53**	**2.06**	**2.46**	**1.14**	**1.04**	**1.39**	**0.69**	**2.60**

	T	B	T x B
SEd	0.007	0.017	0.030
C D (P=0.05)	0.014**	0.035**	0.060**

The 100 seed weight of the B_1 of branching pattern I, II and III was 7.88, 7.54 and 7.27, respectively. The values recorded for the final branches were 7.83, 7.46 and 7.18, respectively. The lower 100 seed weight is also a direct contributor for the lower seed yield branch^{-1}. Similar result was reported by Kawano and Tanaka (1968) in rice. The poor quality of seeds in the branching pattern III and in the final branches of all the branching patterns had resulted in proportional reduction in all the seed quality parameters *viz.*, seed germination (%) and vigour index . The seed germination in B_1 and B_2 of branching pattern I and B_1 of branching pattern II was the highest (82 per cent). Thereafter, the seed germination progressively decreased and reached 66 per cent in B_{13} and B_{14}, of branching pattern I. However, in the branching pattern III, even in B_1 only 80 per cent germination was recorded. In branching pattern II, the lowest value of 64 per cent was recorded in B_{12}, B_{13} as well as B_{14}. Similarly, in branching pattern III, in the last six branches i.e., B_{11} to B_{13} (66 per cent) and B_{14} to B_{16} (64 per cent) lower seed germination was observed. The data is in corroboration with the lower 100 seed weight and more ill filled seeds observed in these branches.

Thus, the study reveals that more number of branches plant^{-1}, is negatively correlated with the seed quality although seed yield interms of plant^{-1} may not be decreased. Concomitant with the higher 100 seed weight, higher filled seed (%) and higher seed germination per cent, and vigour index were also higher in first formed branches of all branching patterns. Among the branching patterns, branching pattern I was superior to II and III. This is in accordance with the findings of Vergara *et al.* (1990); Awan *et al.* (2007) and Wang *et al.* (2007) in rice.

The significant finding of the present study is that the first formed branches are most efficient in terms of source - sink efficiency as they recorded the highest values for number of seeds kapas^{-1}, number of filled seeds kapas^{-1}, filled seeds (%) kapas^{-1}, kapas yield branch^{-1} and seed yield branch$^{-1.}$ The 100 seed weight of seeds borne in those branches was also higher when compared to later formed branches. The higher number of ill filled seeds percentage and lower 100 seed weight in the later formed branches, underscore that in order to obtain seed lot of higher quality, later formed branches should be avoided. To reduce the number of branches plant^{-1} , wider crop spacing should be adopted for seed production purpose since high density planting can be detrimental to seed quality. Further, the study also put forth that lower number of branches (branching pattern I) is superior to higher number of branches (branching pattern II and III). Therefore, it is proposed that even in a wider spaced crop (branching pattern I), there is immense scope to further increase the seed quality by arresting late formed branches, and managing the source-sink potential.

CONCLUSION

Cotton sown at wider spacing of 90 × 45 cm recorded more number of flowers, bolls, higher percentage of filled seeds, more kapas and seed yield plant^{-1} over medium (60 × 30 cm) and closer spacing (45 × 15 cm). On the contrary, closer spacing of 45 × 15 cm (high density planting) has helped to maintaining more number of plants per unit area that enable to increase the kapas and seed seed yield per ha over wider spacing in the experiment. Within the branches of the different branching pattern, the first formed branches are most efficient in terms of source - sink efficiency as they recorded the highest values for number of bolls branch^{-1}, number of seeds kapas^{-1}, kapas yield branch^{-1}, seed yield branch^{-1} and 100 seed weight than the later formed branches. As the hierarchy of branching order increased, significant reduction in seed quality parameters were noted.

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