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Influence of crop geometry and nutrient levels on growth and seed cotton yield of compact cotton cv. co 17

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Abstract
Field experiments were conducted during summer season of 2019 and *rabi* season of 2019-20. The experiments were laid out in split plot design and replicated thrice with four plant spacing in main plot *viz.*, S_1- 100 x 10 cm, S_2 -75 x15 cm, S_3 -60 x15 cm and S_4 -45 x15 cm and four levels of nutrients in sub plot *viz.*, Control (without fertilizers), F_1 - 100% RDF (80:40:40 kg of NPK ha^{-1}), F_2 -125% RDF (100:50:50 kg of NPK ha^{-1}) and F_3 -150% RDF (120:60:60 kg of NPK ha^{-1}). The observations on crop growth components, yield components, seed cotton yield and harvest index were observed in both seasons, pooled and statistically analysed. The results revealed that among the different treatment combination, 60 x 15 cm with 125% RDF - 100:50:50 kg of NPK ha^{-1} (S_3F_2) registered the highest seed cotton yield (2745 kg ha^{-1}) which was on par with plant spacing of 100 x 10 cm along with 125% RDF (S_1F_2) recorded 2395 kg ha^{-1}. Hence, these treatment combinations can be recommended for high density planting system (HDPS) in compact cotton cv. CO 17.

Keywords: Compact cotton, crop geometry, nutrient levels, growth attributes and seed cotton yield

Introduction
Cotton the "White gold" enjoys a predominant position amongst all commercial crops in India (Deekshitha *et al.*, 2016) and it plays an important role in Indian economy by contributing 1/3 earning to the country. In India, cotton is cultivated in an area of 122 lakh hectare with a production of 377 lakh bales and the productivity of 524 kg lint ha^{-1}. High density planting system (HDPS) is generally referred as planting of cotton plants at close spacing than the recommended spacing with a sole objective of maximizing the yield per unit area. In Brazil, higher productivity is achieved through development of compact cotton genotypes suited for high density planting which enables to accommodate a plant population of 1.5 to 2.5 lakh plants/ha with 8-14 bolls per plant at a single boll weight of 4.0 g, thereby achieved higher seed cotton yield (44 to 55 q ha^{-1}). Adaptation of developed suitable compact cotton genotypes to accommodate higher plant densities ranging from 1-2.5 lakh plants ha^{-1} through narrow row spacing. (Kumar and Ramachandra, 2019) [12]. Application of optimum dose of NPK nutrients is essential to maximize the compact cotton yield. India's cotton production suffers not only from drought but also from non-scientific use of fertilizers. Under such the circumstances, present study was undertaken to find out the effect of different plant spacing and nutrients levels on the growth and yield of compact cotton cv. co 17.

Materials and Methods
Field experiments were conducted at Central farm, Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University (TNAU), Madurai during summer season of 2019 and *rabi* season of 2019-20. The experiments were laid out in split plot design replicated thrice with four plant densities *viz.*, S_1 - 100 x 10 cm (1,00,000 plants ha^{-1}), S_2 -75 x15 cm (88,888 plants ha^{-1}), S_3 -60 x15 cm (1,11,111 plants ha^{-1}) and S_4 - 45 x15 cm (1,48,148 plants ha^{-1}) in the main plot and four levels of NPK *viz.*, Control (without fertilizers), F_1 - 100% RDF (80:40:40 kg of NPK ha^{-1}), F_2 -125% RDF (100:50:50 kg of NPK ha^{-1}) and F_3 -150% RDF (120:60:60 kg of NPK ha^{-1}) in sub plot.

The compact cotton cv. CO 17 was used for experiment. The recommended package of practices was followed during the course of investigation. The growth characters such as plant height and DMP at harvest stage, LAI at 90 DAS (Ashley *et al.*, 1963) [2] and SPAD values (SPAD meter) at 90 DAS were recorded. The yield attributes *viz.*, number of bolls plant^{-1}, boll setting percentage and individual boll weight were observed at the time of harvest. The seed cotton yield (kg ha^{-1}) was recorded and harvest index (HI) also worked out. The collected data (both season pooled) were statistically analysed as per the statistical method suggested by Gomez and Gomez (2010) [9].

Results and Discussion

Growth characters

Plant height is an important morphological character in cotton crop which provides seat for nodes and internodes from where morphological and sympodial branches emerge (Eaton, 1955) [7] and plays an important role in determining morphological architecture which decides the productivity. In the present study, the plant height at harvest stage was significantly influenced by crop geometry and nutrients (Table 1). Among the crop geometry, 45 x 15 cm (S_4) spacing recorded the highest plant height (101.3 cm). The lowest plant height of 93.16 cm was recorded in spacing of 100 x 10 cm (S_1). The highest plant height achieved in 45 x 15 cm could be attributed to the fact that due to its closer spacing with compact and erect type of the variety (CO 17), no sympodial growth was possible and only vertical growth occurred which resulted in the higher plant height. This is in concordance with the findings of Parihar *et al.* (2018) [13]. With regarded to nutrient levels at harvest stage, application of 150% RDF with 120:60:60 kg NPK ha^{-1} significantly enhanced the plant growth and recorded the highest plant height (114.8 cm) as against control which recorded 78.3 cm at harvest stage. The higher availability of N, P and K at 150% RDF to the cotton plants might have accelerated the plant height. Similar results was also observed by Bharathi *et al.* (2018) [4]. The interaction effect between spacing and nutrient was found to be significant. The highest plant height (123.61 cm) was registered in 45 x 15 cm with 150% RDF (S_2F_3), whereas the lowest plant height was registered in 100 x 10 cm with control (S_1C).

The leaf area index, as a measure of canopy growth which was significantly influenced by different spacing and levels of nutrients. At 90 DAS, the highest LAI (3.39) was recorded in 60 x 15 cm (S_3) and the lowest LAI (3.32) was registered with spacing of 75 x 15 cm (S_3). The plant population with optimum spacing of 60 x 15 cm might have provided enough space to allow sufficient light interception and air in to the plant canopy which could have ultimately resulted in higher LAI. The present findings are in conformity with the findings of Raut *et al.* (2005) [16] and Reddy and Gopinath (2008) [17]. Data pertaining to the various levels of nutrients, the maximum LAI of 3.55 was registered in the plot which received 150% RDF and the minimum LAI (3.14) was observed in control plot (without fertilizer). It is a general phenomenon that higher nutrient application usually increased the number of leaves and leaf size which might have resulted in higher LAI. The present finding was akin to the report of Brar *et al.* (2013) [5].

The interaction effect was found to be significant. Among the different crop geometries and nutrient levels, the treatment combination of 60 x 15 cm with application of 150% RDF (S_3F_3) significantly recorded the highest LAI (3.59) and it was followed by S_1F_3 (3.5) and S_1F_2 (3.45). These treatment combinations were found to be on par with each other. The lowest LAI (3.16) was observed in 100 x 10 cm with fertilization (S_1C). The synergic effect of optimum plant population as well as higher available nutrients might have been the probable reason for higher LAI. This was in close conformity with the findings of Basha *et al.* (2017) [3].

SPAD value, is an indirect measurement of chlorophyll content which was significantly influenced by crop geometry and nutrient levels. Comparing the different spacing, 60 x 10 cm (S_1) registered the highest SPAD value of 41.70 as against S_4 which recorded the lowest SPAD value (40.99). Similarly, application of 150% RDF (F_3) registered the higher chlorophyll content (44.62); whereas the control plot (without fertilization) recorded the lowest SPAD value (36.41). With regarded to the interaction effect, similar to the LAI, S_3F_3 significantly registered the highest SPAD value of 45.26 as against 100 x 10 cm, without fertilization (S_1C) recorded the lowest SPAD value (36.53). The higher performance of 60 x 15 cm with 150% RDF (S_3F_3) in terms of enhanced SPAD value might be due to its higher nitrogen level (120 kg ha^{-1}) along with optimum plant spacing (60 x 15 cm). The application of 120 kg ha^{-1} increased the N availability the plant growth and it could have resulted in higher chlorophyll content in terms of SPAD value. Similar findings were reported by Devraj *et al.* (2011) [6] and (Singh *et al.*, 2017a) [18].

Dry matter production (DMP) is a true index of measuring crop productivity. In the present study, the DMP was significantly increased by both spacing and levels of nutrients. With regard to spacing, adaptation of 60 x 15 cm (S_3) recorded the maximum DMP (4904 kg ha^{-1}), followed by S_1 (4804 kg ha^{-1}) and both S_3 and S_1 were found to be on par. S_2 (75 x 15 cm) recorded the lowest DMP (4471 kg ha^{-1}). Production of DMP was significantly increased with increasing levels of nutrients. The treatment F_3 (150% RDF) registered the highest DMP (5705 kg ha^{-1}); whereas the lowest DMP (3709 kg ha^{-1}) was recorded in control (without fertilizers). The interaction effect between levels of crop geometry and nutrient levels was found to be significant. The highest DMP of 5943 kg ha^{-1} was observed in the treatment combination which received 150% RDF with 60 x 15 cm spacing and it was followed by (5832 kg ha^{-1}) in S_1F_3 and both were found to be on par with each other. The lowest DMP of 3767 kg ha^{-1}was observed in plot which received no fertilizer in 100 x 10 cm (S_1C). Hence, it was very well evident from the present study that the combination of 60 x 15 cm (S_3) along with 150% RDF (F_3) performed better in terms of overall growth expressed in terms of DMP. Adequate availability of nutrients with optimum plant populations (S_3 and S_1) which provides the best opportunity to utilize the physical and bio-resources available to cotton plants may be the probable reason for the higher performance in terms of DMP in S_3F_3 and S_1F_3. The results are in line with the findings of Sisodia and Khamparia (2007) [20] and Parihar *et al.* (2018) [13].

Yield attributes

Data on yield attributes *viz.*, boll setting (per cent), number of bolls plant^{-1} and individual boll weight were recorded at harvest stage. The results of the study revealed that these yield attributes were significantly altered by both crop geometry and levels of nutrients (Table 2). In respect of boll setting per cent, comparing the spacing, the highest boll setting per cent (25.70 per cent) was registered in spacing of

75 x 15 cm (S_2) and it was followed by 25.30 per cent 100 x 10 cm (S_1). However, S_2 and S_1 were on par with each other. The lowest boll setting (17.62 per cent) was observed in spacing of 45 x 15 cm (S_4). Analysing the data on nutrient levels, it was inferred that application of 125% RDF; 100:40:40 kg NPK ha^{-1} (F_2) recorded the maximum boll setting (27.36 per cent); whereas the control (without fertilizers) recorded the minimum boll sett (15.54 per cent)

The interaction effect between spacing and nutrients was found to be significant. The combination of 75 x 15 cm with 125% RDF-100:50:50 kg NPK ha^{-1} (S_2F_2) registered the highest boll setting percentage of 31.79 and it was followed by crop geometry of 100 x 10 cm with 150% RDF (S_1F_2) which recorded 13.50 per cent, while S_1C (100 x 10 cm with no fertilizer application) registered lower boll setting (16.07 per cent). The higher boll setting percentage is one of the pre-requisite for obtaining maximum yield in seed cotton and it has been achieved by the optimum plant population (S_3) with 125% RDF (F_2) and S_1 with F_2. The spacing of 75 x 15 cm with 100% RDF could probably allow more sunlight and air which could lead to production of auxin and hence, resulting in more boll retention than the other treatments. These results are in accordance with the findings of Parlawar *et al.* (2017) [14] and Bharathi *et al.* (2018) [4].

The number of bolls per plant was significantly influenced by both spacing and levels of nutrients. Among the various spacing S_2 (75 x 15 cm) recorded highest number of bolls (10.23 per plant), followed by S_1 (100 x 10 cm) which recorded 9.99 bolls per plant and S_2 and S_1 were on par with each other. The treatment with highest population with spacing of 45 x 15 cm (S_4) registered lowest number of bolls (5.74). Comparing the nutrients, fertilization of 125% RDF-100:50:50 kg NPK ha^{-1} (F_2) retained more number of bolls per plant (14.11) than the other treatments. The interaction effect was found to be significant. The maximum number of bolls per plant were obtained from S_2F_2 (14.11 per plant), followed by S_1F_2 (13.50 per plant) and these two treatment combinations were on par with each other. The lowest bolls per plant of 4.66 was registered by S_1C. This may be due to fact that optimum plant population could have utilized resources effectively and hence more bolls are retained (Paslawar *et al.*, 2015) [15]. The present study was in consonance with the report of Ajayakumar *et al.* (2017) [1].

Data related to individual boll weight revealed that crop geometry of 75 x 15 cm (S_2) recorded the maximum individual boll weight (3.89 g/boll) and it was followed by S_1 (3.87 g/boll). However, these treatments S_2 and S_1 were on par. The lowest boll weight (3.49 g/boll) was registered in higher population 45 x 15 cm (S_4). In respect of fertilizer level, F_2 (125% RDF; 100:50:50 kg NPK ha^{-1}) recorded highest boll weight (4.02 g/ boll) and the lowest boll weight of 3.31 g/boll was obtained in control (without fertilizer).

The interaction effect was found to be significant. Among the treatment combinations, S_2F_2 (75 x 15 cm with 125% RDF) recorded the highest boll weight (4.33 g/boll) and it was followed by S_1S_2 which registered the boll weight of 4.23 g/boll. The treatment combinations S_2F_2 and S_1F_2 were found to be on par with each other. The treatment combination of 100 x 10 cm with no fertilizer (S_1C) recorded the lowest boll weight (3.36 g/boll). Under optimum plant population, over all plant growth and development resulted in better source-sink relation, which resulted in higher boll weight (Jahedi *et al.*, 2013) [10]. The current study are in line with the report of Bharathi *et al.* (2018) [4]

Yield

Data on seed cotton yield (kg ha^{-1}) revealed that it was significantly influenced by different levels of plant spacing and nutrients (Table.3). Among the spacing, S_3 (60 x 15 cm-1,11,111 plants /ha) recorded the maximum seed cotton yield of 1816 kg ha^{-1} which was on par with S_1 (100 x 10 cm-1,00,000 plants /ha) with a seed yield of 1739 kg ha^{-1}. The minimum seed cotton yield (1292 kg ha^{-1}) was recorded in plant spacing of 45 x 15 cm (S_4 - 1,48,148 plants ha^{1}). The reason could be due to the better utilization of available resources by optimum plant population could be probable reason for higher seed cotton yield in both S_3 and S_1. The lowest seed cotton yield in S_4 (densely populated treatments) may be due to the inter and intra competition for resource *viz.*, light, water and nutrients. Similar results were observed by Srinivasan (2006) [22] and Giri *et al.* (2008) [8].

Different levels of nutrients significantly influenced the seed cotton yield of compact cotton. The highest seed cotton yield was obtained in 125% RDF-100:50:50 kg NPK ha^{-1} (F_2); whereas the lowest seed cotton yield (824 kg ha^{-1}) was recorded in control (without fertilizer). It is a well known fact that nutrient application at optimum level increased the yield attributes which could have resulted in higher seed cotton yield. These findings are corroborate with the results of Kote *et al.* (2005) [11] and Singh *et al.* (2017b) [19].

The interaction effect on seed cotton yield was found to be significant. The highest seed cotton yield (2475 kg ha^{-1}) was obtained in adopting spacing of 60 x 15 cm (S_3) along with 125% RDF (F_2) which was on par with 100 x 10 cm with 125% RDF (S_1F_2) which recorded the seed cotton yield of 2395 kg ha^{-1}. The lowest yield of 796 kg ha^{-1} was obtained in treatment combination of 100 x 10 cm and without nutrient (S_1 C). The higher seed cotton yield in S3F2 and S_1F_2 could be due to the more penetration of light with optimum plant population coupled with sufficient availability of nutrients (F_2) which resulted in overall improvement in growth attributes and its positive effect on number of boll per plant along with higher boll weight. The above result is in close conformity with the findings of Solanke *et al.* (2001) [21] and Singh *et al.* (2017b) [19].

Harvest index

Harvest index (HI) is a measure of partitioning efficiency between biological yield and economic yield which was significantly altered by the treatments (Table.3). With regard to crop geometry 60 x 15 cm (S_3) recorded the higher of 0.37 HI and it was followed by S_1 with the harvest index of 0.35. The main plot treatments S_3 and S_1 were on par with each other. The lowest HI (0.28) was recorded in densely populated 45 x 15 cm (S_4) treatment. With regards to nutrients, similar to the seed cotton yield, application of 125% RDF (F_2) recorded the highest HI (0.43). However, the lowest HI of 0.22 was recorded by control (nil nutrients). The interaction effect was found to be significant. The highest HI (0.48) was increased in S_2F_3 and it was followed by S_1F_2 which recorded 0.47 and were found to in on par with each other. The minimum HI (0.21) was recorded in 100 x 10 cm with control no fertilizer (S_1C). It indicates that optimum population with 125% RDF could provide conducive environment to translocate more source to sink. So that higher HI was achieved. Similar increases in HI was also reported by Bharathi *et al.* (2018) [4] and Kumar and Ramachandra (2019) [12].

Based on the above findings, it could be concluded that for compact cotton variety, spacing of 60 x 10 cm (S_3) with fertilizer application of 125% RDF - 100:50:50 kg NPK ha^{-1} (F_2) can be recommended for getting maximum seed cotton yield (2475 kg ha^{-1}) and was followed by crop geometry of 100 x 10 cm along with 125% RDF-100:50:50 kg NPK ha^{-1} (S_1F_2) recorded significant higher seed cotton yield 2395 kg ha^{-1}. These two treatement combination were found to be on par with each other. These two treatment combinations, 60 x 10 cm (S_3) with fertilizer application of 125% RDF - 100:50:50 kg NPK ha^{-1} (F_2) and 100 x 10 cm (S_1) along with 125% RDF 100:50:50 kg NPK ha^{-1} (F_2) can be explored for mechanised harvesting.

Table 1: Influence of crop geometry and nutrient levels on growth components in compact cotton cv. co 17 (pooled data of summer 2019 and *rabi* 2019-20)

Treatments	**Growth parameters**			
Crop geometry	**Plant height at harvest (cm)**	**LAI on 90 DAS**	**SPAD value on 90 DAS**	**DMP at harvest (kg ha^{-1})**
S_1 (100 x10 cm)	93.16	3.38	41.49	4802
S_2 (75 x15 cm)	98.31	3.32	40.55	4482
S_3 (60 x15 cm)	94.9	3.39	41.70	4905
S_4 (45 x15 cm)	101.3	3.35	40.99	4642
S.Ed	0.6	0.02	0.36	62
CD (p=0.05)	1.6	0.07	0.90	151
Nutrient levels				
C (nil nutrient)	78.3	3.14	36.41	3709
F_1 (100% RDF)	92.9	3.33	40.90	4422
F_2 (125% RDF)	101.6	3.43	42.74	4994
F_3 (150% RDF)	114.8	3.55	44.62	5706
S.Ed	0.76	0.03	0.40	45
CD (p=0.05)	1.53	0.07	0.80	96
Interaction				
S_1C	76.3	3.16	36.53	3767
$S_1 F_1$	89.4	3.36	41.29	4494
$S_1 F_2$	98.8	3.45	43.03	5113
$S_1 F_3$	107.9	3.57	44.91	5832
$S_2 C$	79.0	3.13	36.13	3530
$S_2 F_1$	94.1	3.29	40.06	4265
$S_2 F_2$	102.5	3.39	42.08	4721
$S_2 F_3$	117.4	3.51	43.94	5411
$S_3 C$	77.6	3.16	36.68	3883
$S_3 F_1$	91.8	3.37	41.59	4560
$S_3 F_2$	100.2	3.47	43.29	5235
$S_3 F_3$	110.2	3.59	45.26	5943
S_4C	80.37	3.14	36.31	3658
$S_4 F_1$	96.5	3.32	40.70	4368
$S_4 F_2$	104.9	3.42	42.58	4904
$S_4 F_3$	123.6	3.54	44.38	5636
S.Ed	2.16	0.10	1.14	134
CD (p=0.05)	4.33	0.25	2.42	278

Table 2: Influence of crop geometry and nutrient levels on yield components in compact cotton cv. co 17 (pooled data of summer 2019 and *rabi* 2019-20)

Treatments	**yield parameters**		
Crop geometry	**Boll setting per cent**	**Number of bolls plant^{-1}**	**Individual boll weight**
S_1 (100 x10 cm)	25.30	9.99	3.87
S_2 (75 x15 cm)	25.71	10.24	3.91
S_3 (60 x15 cm)	24.47	9.51	3.79
S_4 (45 x15 cm)	17.63	5.75	3.49
S.Ed	0.22	0.11	0.02
CD (p=0.05)	0.54	0.28	0.05
Nutrient levels			
C (nil nutrient)	15.55	4.49	3.32
F_1 (100% RDF)	25.72	10.41	3.89
F_2 (125% RDF)	27.99	11.48	4.06
F_3 (150% RDF)	23.86	9.12	3.76
S.Ed	0.27	0.10	0.04
CD (p=0.05)	0.54	0.20	0.08
Interaction			
S_1C	16.07	4.66	3.36
$S_1 F_1$	28.31	11.59	4.02
$S_1 F_2$	31.06	13.50	4.23
$S_1 F_3$	25.78	10.23	3.84

S_2 C	17.39	5.16	3.42
S_2 F_1	29.28	13.17	4.12
S_2 F_2	31.79	14.11	4.33
S_2 F_3	24.38	9.43	3.75
S_3 C	14.96	4.27	3.29
S_3 F_1	27.31	10.93	3.93
S_3 F_2	30.19	12.85	4.11
S_3 F_3	25.43	9.98	3.81
S_4C	13.76	3.86	3.21
S_4 F_1	17.98	5.93	3.51
S_4 F_2	18.93	6.37	3.58
S_4 F_3	19.84	6.81	3.65
S.Ed	0.63	0.29	0.11
CD (p=0.05)	1.76	0.58	0.23

Table 3: Influence of crop geometry and nutrient levels on seed cotton yield and harvest index in compact cotton cv. co 17 (pooled data of summer 2019 and *rabi* 2019-20)

Treatments	**Yield and Harvest index**	
Crop geometry	**Seed cotton yield (kg ha^{-1})**	**Harvest index**
S_1 (100 x10 cm)	1739	0.35
S_2 (75 x15 cm)	1520	0.34
S_3 (60 x15 cm)	1816	0.36
S_4 (45 x15 cm)	1292	0.27
S.Ed	28	0.002
CD (p=0.05)	70	0.006
Nutrient levels		
C (nil nutrient)	825	0.22
F_1 (100% RDF)	1842	0.44
F_2 (125% RDF)	2135	0.40
F_3 (150% RDF)	1565	0.27
S.Ed	19	0.003
CD (p=0.05)	29	0.007
Interaction		
S_1C	796	0.21
S_1 F_1	2062	0.46
S_1 F_2	2395	0.47
S_1 F_3	1702	0.29
S_2 C	705	0.20
S_2 F_1	1902	0.54
S_2 F_2	2254	0.41
S_2 F_3	1219	0.23
S_3 C	869	0.22
S_3 F_1	2118	0.47
S_3 F_2	2475	0.47
S_3 F_3	1800	0.30
S_4C	929	0.25
S_4 F_1	1287	0.30
S_4 F_2	1413	0.29
S_4 F_3	1537	0.27
S.Ed	42	0.010
CD (p=0.05)	85	0.020

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