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Effect of high density planting and nutrient management on growth and yield of compact cotton (*Gossypium hirsutum* l.) Genotypes

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Abstract
A Field experiment was conducted during the *Kharif* 2015 at Agricultural College farm, Raichur to study the effect of high density planting and nutrient management in compact cotton (*Gossypium hirsutum* L.) genotypes. The result of this experiment revealed that there was no significant difference in growth, yield contributing characters and seed cotton yield in between Rahc-1011 and Rahc-1012 of compact cotton genotypes. Among the genotypes, seed cotton yield of Rahc-1012 (1816 kg ha^{-1}) was statistically on par with Rahc-1011 (1754 kg ha^{-1}). Spacing of 60 cm x 30 cm recorded significantly higher (1922 kg ha^{-1}) seed cotton yield as compared to 60 cm x 45 cm (1566 kg ha^{-1}) and was on par with 60 cm x 15 cm spacing (1816 kg ha^{-1}). Application of 125 per cent RDF recorded significantly higher seed cotton yield (2012 kg ha^{-1}) when compared to 100 per cent RDF (1871 kg ha^{-1}) and 75 per cent RDF (1473 kg ha^{-1}).

Keywords: Compact genotypes, RDF, Spacing

Introduction
Cotton (*Gossypium hirsutum* L.) is considered as an important fibre crop of India and Karnataka. It is the backbone of textile industries mainly because of its lint. India contributes 85 per cent of raw material to textile industry and it earns about 33 per cent of total foreign exchange (Anon., 2014-15) [1]. In India, cotton has an area of 11.97 m ha with a production of 34.22 m bales and productivity of 486 kg lint ha^{-1} during 2012-13 as against an area of 5.88 m ha with a production of 3.04 m bales and productivity of 88 kg ha^{-1} in 1950-51 (Anon 2014-15) [1]. In Karnataka, cotton occupies an area of 5.40 lakh ha with a production of 14.0 lakh bales and with productivity of 434 kg lint per ha. The Northern dry zone of the state (Zone 2 and 3) covers partly the Tungabhadra and Upper Krishna Command areas (TBP & UKP). In these regions, Bt-cotton is intensively cultivated on black soil under irrigation. The area under this crop in these command areas has been increasing steadily over the past half decade and occupying more than 1.5 lakh ha during 2009-10. The average seed cotton yield is around 20 q ha^{-1} which is far less than actual potential yield.
The maximum yield potential of cotton is yet to be trapped under irrigated condition, but low production of cotton yield in rained condition is due to monocropping practice, planting density, decline in soil fertility status and delayed sowing (due to failure of rains or late release of canal water), imbalanced nutrition and lack of improved varieties are major constraints for low productivity. Among the different constraints maintenance of plant density is the major problem which results in 20-30 per cent seed cotton yield loss. High Density Planting Systems (HDPS) are commonly followed to obtain high yields with straight varieties across world, especially in the major cotton growing countries such as USA, Australia, China, Brazil and Uzbekistan. High Density Planting Systems (HDPS) is more relevant to India to establish sustainable production system. So, it was necessary to conduct experiment to know the effect of high density planting and nutrient management on growth and yield of compact cotton (*Gossypium hirsutum* L.) genotypes under rainfed conditions.

Material and methods
A field experiment was conducted during the *Kharif* 2015 at Agricultural College farm, Raichur, situated on the latitude of $16^{0}12^{1}$ N latitude, $77^{0}20^{1}$ E longitude with an elevation of 389 meters above mean sea level and is located in North Eastern Dry Zone of Karnataka. The experiment was laid out in factorial RCBD with 18 treatments replicated thrice. The studies included two genotypes (G_1: Rahc-1011, G_2: Rahc-1012), three spacings (S_1: 60 cm x 15 cm, S_2: 60 cm x 30 cm, S_3: 60 cm x 45 cm) and three fertilizer levels **(**F_1: 75 % RDF, F_2: 100 %

RDF, F_3: 125 % RDF). New compact cotton genotypes (Rahc-1011 and Rahc-1012) were used for sowing. Rahc-1011 is a *Gossypium hirsutum* variety of cotton developed by cotton section, MARS, Raichur. The crop matures in 150-160 days with a yield potential of 25-30 q ha^{-1} under irrigated conditions. Boll size is medium and its average weight is 3-4 g with 4-5 locules. Rahc-1012 is a *Gossypium hirsutum* variety of cotton developed by MARS, Raichur. It is suitable for high density planting and it can be grown under irrigated situation. The crop matures in 150 – 160 days with the yield of 26-30 q ha^{-1}. Bolls size is medium and its average weight is 3-4 g. Half the dose of nitrogen and potassium, entire dose of phosphorous in the form of urea, muriate of potash (MOP) and diammonium phosphate (DAP), respectively were band placed as per the treatments. Fertilizers were applied 4-5 cm deep and 5 cm away from the plant at 30 days after sowing. Remaining half dose of nitrogen and potassium in the form of urea and MOP was top dressed in two equal splits at 60 and 90 days after sowing in the ring formed 5 cm away from the plant. The soil of the experimental site was deep black and clay in texture with the available nitrogen (190.00 kg ha^{-1}), phosphorus (23.90 kg ha^{-1}), potassium (250.00 kg ha^{-1}) and organic carbon content (0.68 %).

Results and discussion

Genotypic effect

The seed cotton yield of compact genotypes did not differ significantly because of their genetic makeup. However, Rach-1012 genotype recorded higher (1816 kg ha^{-1}) seed cotton yield but it was on par with Rahc-1011 genotype (1754 kg ha^{-1}). The probable reason of this might be the variation in the genetic constitution of the variety which has responded better in harvesting the maximum bolls and good boll weight. These results are in conformity with the finding of Gadade *et al.* (2015) [5]. Among the two genotypes, Rahc-1012 recorded significantly higher plant height (120.46 cm), number of sympodial branches per plant (16.78), Leaf area (57.69 dm^2) and dry matter production (165.54 g/plant) when compared to Rahc-1011 (115.28, 15.85, 52.50 dm^2 and 158.96 g, respectively) (Table.1). Dry matter production and its distribution in the reproductive parts invariably depend upon the magnitude and persistence of photosynthetic capacity of plant. Photosynthetic capacity of plant was reflected on dry matter accumulation in leaves, leaf area and LAI.

Table 1: Effect of high density planting and nutrient management on growth attributes of compact cotton genotypes

Treatments		Plant height (cm)				Number of sympodial branches				Leaf area (dm^2 $plant^{-1}$)				Dry matter production (g $plant^{-1}$)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
G_1	S_1	103.77	113.60	116.77	111.38	12.57	14.03	15.89	14.16	29.02	35.82	41.21	35.35	106.37	130.28	154.50	130.38
	S_2	110.00	115.77	121.80	115.86	14.60	16.67	17.56	16.28	39.42	55.18	72.22	55.60	144.93	171.31	192.17	169.47
	S_3	113.33	119.00	123.50	118.61	15.10	17.56	18.65	17.10	49.98	71.01	78.69	66.56	149.37	175.43	206.32	177.04
	Mean	108.00	114.88	115.93	115.28	14.09	16.09	17.37	15.85	39.47	54.00	64.04	52.50	133.56	159.01	184.33	158.96
G_2	S_1	115.93	124.33	124.67	121.60	14.01	15.89	16.97	15.62	33.75	40.83	43.36	39.31	119.87	139.17	153.51	137.52
	S_2	116.67	119.00	120.63	118.80	14.60	17.13	19.22	16.98	45.08	54.50	82.90	60.83	149.61	174.30	192.73	172.21
	S_3	120.00	118.20	125.00	121.06	16.18	17.96	19.04	17.73	60.08	78.81	79.87	72.92	166.67	189.20	204.81	186.89
	Mean	116.48	120.51	121.68	120.46	14.93	16.99	18.41	16.78	46.30	58.05	68.71	57.69	145.38	167.56	183.68	165.54
S_1		109.85	118.97	120.72	116.51	13.29	14.96	16.43	14.89	31.39	38.32	42.29	37.33	113.12	134.72	154.00	133.95
S_2		111.78	117.38	119.22	116.13	14.60	16.90	18.39	16.63	42.25	54.84	77.56	58.22	147.27	172.80	192.45	170.84
S_3		115.08	120.20	123.50	119.60	15.64	17.76	18.85	17.41	55.03	74.91	79.28	69.74	158.02	182.32	205.57	181.97
Mean		112.81	118.35	121.22	117.46	14.51	16.54	17.89	17.8	42.89	56.03	66.37	55.10	139.47	163.28	184.00	162.25
		S. Em.±		C.D. (0.05)		S. Em.±		C.D. (0.05)		S. Em.±		C.D. (0.05)		S.Em.±		C.D. (0.05)	
Genotypes (G)		1.34		3.85		0.17		0.48		0.86		2.47		1.61		4.64	
Spacing (S)		1.64		NS		0.21		0.59		1.05		3.03		1.98		5.68	
Fertilizers (F)		1.64		4.72		0.21		0.59		1.05		3.03		1.98		5.68	
G at same/different level of S		2.32		NS		0.29		NS		1.49		NS		2.80		NS	
G at same/different level of F		2.32		NS		0.29		NS		1.49		NS		2.80		NS	
S at same/different level of F		2.84		NS		0.36		NS		1.82		5.24		3.42		NS	
G x S x F		4.02		NS		0.50		NS		2.58		NS		4.84		NS	

NS: Non significant

G_1: Rahc-1011 G_2: Rahc-1012

F_1: 75% RDF (60:40:40 NPK kg ha^{-1}) S_1: 60 cm x 15 cm (1, 11, 111 plants ha^{-1})

F_2: 100% RDF (80:50:50 NPK kg ha^{-1}) S_2: 60 cm x 30 cm (55,555 plants ha^{-1})

F_3: 125% RDF (100:50:50 NPK kg ha^{-1}) S_3: 60 cm x 45 cm (37,037 plants ha^{-1})

Effect of plant spacing

Significantly higher seed cotton yield was obtained with spacing of 60 cm x 30 cm (1922 kg ha^{-1}) over 60 cm x 45 cm (1566 kg ha^{-1}) and which was on par with 60 cm x 15 cm (1868 kg ha^{-1}) which was mainly due to higher plant population per unit area. Significantly higher seed cotton yield per plant was recorded with spacing of 60 cm x 45 cm (44.75 g $plant^{-1}$) when compared to spacing of 60 cm x 30 cm (38.33 g $plant^{-1}$) and 60 x 15 cm (18.68 g $plant^{-1}$) this may be attributed to production of higher number of sympodial branches, number of bolls per plant, boll weight, seed index and higher number of good opened bolls (Table.2) due to less competition for growth and development and more availability of nutrients and sunlight, it resulted in better nourishment and plant growth (Bhalerao *et al.*, 2010) [3]. Significantly higher harvest index was recorded in 60 cm x 45 cm spacing when compared to 60 cm x 30 cm and 60 x 15 cm spacing because of higher economic yield per plant. Tomar *et al.* (2000) [11] found that closer intra row planting gave numerically higher seed cotton yield than wider intra row spaced crop. Significant differences in the seed cotton yield under different spacing was because of variation in growth and yield components *viz.*, dry matter production and its distribution into different plant parts, number of sympodial branches per plant, number of bolls per plant, boll weight and yield per plant.

Effect of fertilizer levels

In the present investigation, the yield attributing characters were significantly (Table 2 and 3) influenced by different

level of fertilizer application. Significantly higher values were noticed with 125 per cent RDF (11.02, 15.32 and 3.44 g; number of good opened bolls per plant, total number of bolls harvested per plant, boll weight (g), respectively). These parameters were significantly higher than that recorded with 75 per cent RDF (8.38, 13.55 and 3.24 g; number of good opened bolls per plant, total number of bolls harvested per plant, boll weight, respectively) and it was on par with 100 per cent RDF (10.57, 15.23 and 3.33 g; number of good opened bolls per plant, total number of bolls harvested per plant, boll weight, respectively). Dhillon *et al.* (2006) [4] recorded significant increase in boll weight due to higher phosphate content in cotton throughout the boll development stage with higher level of fertilizer. The increase in the yield attributing characters with 125 per cent RDF might be due to significantly higher amount of dry matter production and its accumulation in reproductive parts and leaf area up to the harvest. These results are in compliance with the findings of Bastia (2000) [2] and Solanke *et al.* (2000) [10]. Harvest index of cotton differed significantly due to application of RDF. Significantly higher harvest index was recorded with 125 per cent RDF (0.24) when compared to 100 per cent RDF (0.18) and 75 per cent RDF (0.16). This is due to significantly higher economical yield obtained with higher fertilizer application.

Table 2: Effect of high density planting and nutrient management on yield attributes of compact cotton genotypes

Treatments		Good opened bolls plant^{-1}				Bad opened bolls plant^{-1}				Total number of bolls plant^{-1}				Harvest index			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
G_1	S_1	5.19	6.10	6.50	5.93	6.20	5.27	5.00	5.49	11.40	11.37	11.50	11.42	0.12	0.12	0.22	0.15
	S_2	9.10	12.50	12.80	11.47	4.63	4.23	4.07	4.31	13.73	16.74	16.87	15.78	0.15	0.18	0.24	0.19
	S_3	10.20	12.8	13.20	12.07	4.80	4.77	4.40	4.66	15.00	17.57	17.60	16.72	0.21	0.23	0.23	0.22
	Mean	8.16	10.47	10.83	9.82	5.21	4.76	4.49	4.82	13.38	15.22	15.32	14.64	0.16	0.18	0.23	0.19
G_2	S_1	5.80	6.30	6.80	6.30	5.80	5.30	4.53	5.21	11.60	11.65	11.38	11.54	0.13	0.11	0.23	0.16
	S_2	9.40	12.80	13.50	11.90	4.83	3.80	3.73	4.12	14.24	16.60	17.23	16.02	0.16	0.19	0.26	0.20
	S_3	10.6	12.90	13.30	12.27	4.75	4.53	4.03	4.44	15.35	17.43	17.33	16.70	0.20	0.23	0.23	0.22
	Mean	8.6	10.67	11.20	10.16	5.13	4.54	4.10	4.59	13.73	15.23	15.31	14.76	0.16	0.18	0.24	0.19
S_1		5.50	6.20	6.65	6.12	6.00	5.28	4.77	5.35	11.50	11.51	11.44	11.48	0.12	0.12	0.22	0.15
S_2		9.25	12.65	13.15	11.68	4.73	4.02	3.90	4.55	13.98	16.67	17.05	15.90	0.16	0.19	0.25	0.20
S_3		10.4	12.85	13.25	12.17	4.77	4.65	4.22	4.22	15.17	17.5	17.47	16.71	0.20	0.23	0.23	0.22
Mean		8.38	10.57	11.02	9.99	5.17	4.65	4.29	4.70	13.55	15.23	15.32	14.70	0.16	0.18	0.24	0.19
		S. Em.±		C.D. (0.05)		S. Em.±		C.D.(0.05)		S. Em.±		C.D. (0.05)		S.Em.±		C.D. (0.05)	
Genotypes (G)		0.14		NS		0.08		NS		0.26		NS		0.00		NS	
Spacing (S)		0.17		0.49		0.10		0.30		0.32		0.91		0.01		0.02	
Fertilizers (F)		0.17		0.49		0.10		0.30		0.32		0.91		0.01		0.02	
G at same/different level of S		0.24		NS		0.15		NS		0.45		NS		0.01		NS	
G at same/different level of F		0.24		NS		0.15		NS		0.45		NS		0.01		NS	
S at same/different level of F		0.29		0.85		0.18		NS		0.55		1.58		0.01		0.04	
G x S x F		0.42		NS		0.25		NS		0.78		NS		0.01		NS	

NS: Non significant

G_1: Rahc-1011
G_2: Rahc-1012
F_1: 75% RDF (60:40:40 NPK kg ha^{-1})
S_1: 60 cm x 15 cm (1, 11, 111 plants ha^{-1})
F_2: 100% RDF (80:50:50 NPK kg ha^{-1})
S_2: 60 cm x 30 cm (55,555 plants ha^{-1})
F_3: 125% RDF (100:50:50 NPK kg ha^{-1})
S_3: 60 cm x 45 cm (37,037 plants ha^{-1})

Table 3: Effect of high density planting and nutrient management on yield attributes and seed cotton yield of compact cotton genotypes

Treatments		Boll weight (g)				Seed index (100 seeds)				Seed cotton yield (g)				Seed cotton yield (kg)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
G_1	S_1	3.00	3.10	3.21	3.10	7.43	7.97	8.10	7.83	15.60	18.91	20.48	18.33	1560	1891	2047	1833
	S_2	3.26	3.30	3.36	3.31	7.60	7.87	8.33	7.93	29.21	41.25	43.01	37.82	1461	2062	2150	1891
	S_3	3.50	3.60	3.83	3.64	7.80	8.14	8.43	8.12	35.70	46.08	50.16	43.98	1249	1613	1756	1539
	Mean	3.25	3.33	3.47	3.35	7.61	7.99	8.29	7.96	26.84	35.41	37.88	33.38	1423	1855	1984	1754
G_2	S_1	2.95	3.00	3.10	3.02	7.12	7.40	7.43	7.32	17.11	18.90	21.08	19.03	1711	1890	2108	1903
	S_2	3.20	3.25	3.32	3.26	7.42	7.57	7.80	7.59	30.08	41.60	44.82	38.83	1537	2080	2241	1953
	S_3	3.55	3.75	3.80	3.70	7.87	7.88	8.11	7.95	37.63	48.38	50.54	45.52	1317	1693	1769	1593
	Mean	3.23	3.33	3.41	3.32	7.47	7.61	7.78	7.62	28.27	36.29	38.81	34.46	1522	1888	2039	1816
S_1		2.98	3.05	3.15	3.06	7.28	7.68	7.77	7.58	16.36	18.91	20.78	18.68	1635	1891	2078	1868
S_2		3.23	3.28	3.34	3.28	7.51	7.72	8.07	7.76	29.65	41.43	43.91	38.33	1499	2071	2196	1922
S_3		3.53	3.68	3.82	3.67	7.83	8.01	8.27	8.04	36.67	47.23	50.35	44.75	1283	1653	1762	1566
Mean		3.24	3.33	3.44	3.34	7.54	7.8	8.03	7.79	27.56	35.85	38.35	33.92	1473	1871	2012	1785
		S. Em.±		C.D. (0.05)		S. Em.±		C.D. (0.05)		S. Em.±		C.D. (0.05)		S. Em.±		C.D. (0.05)	
Genotypes (G)		0.04		NS		0.08		0.22		0.40		NS		23		NS	
Spacing (S)		0.05		0.14		0.09		0.27		0.50		1.43		28		79	
Fertilizers (F)		0.05		0.14		0.09		0.27		0.50		1.43		28		79	
G at same/different level of S		0.07		NS		0.13		NS		0.71		NS		39		NS	
G at same/different level of F		0.07		NS		0.13		NS		0.71		NS		39		NS	
S at same/different level of F		0.08		NS		0.16		NS		0.86		2.48		48		137	
G x S x F		0.12		NS		0.23		NS		1.22		NS		68		NS	

NS: Non significant

G1: Rahc-1011
F1: 75% RDF (60:40:40 NPK kg ha-1)
F2: 100% RDF (80:50:50 NPK kg ha-1)
F3: 125% RDF (100:50:50 NPK kg ha-1)

G2: Rahc-1012
S1: 60 cm x 15 cm (1, 11, 111 plants ha-1)
S2: 60 cm x 30 cm (55,555 plants ha-1)
S3: 60 cm x 45 cm (37,037 plants ha-1)

Interaction effects

Interaction effects between spacing and fertilizer levels were found to be significant for seed cotton yield. Spacing of 60 cm x 30 cm with application of 125 per cent RDF recorded significantly higher seed cotton yield (2196 kg ha^{-1}) when compared to other treatments combinations and it was on par with 60 cm x 15 cm with 125 per cent RDF (2078 kg ha^{-1}) and 60 cm x 30 cm spacing with 100 per cent RDF (2071 kg ha^{-1}). Lower seed cotton yield was recorded in 60 cm x 45 cm spacing with 75 per cent RDF (1283 kg ha^{-1}). The differences in seed cotton yield due to planting geometry and fertilizer can be related to their differential responses of growth and yield contributing characters.

The variation in seed cotton yield in various treatments combination can be traced back to variation in growth and yield attributes like number of sympodial branches per plant, leaf area, dry matter production, higher number of bolls per plant, higher number of good opened bolls per plant and boll weight could be most relevant cause for achieving higher seed cotton yield per hectare which might be due to higher plant population per unit area and higher levels of fertilizer dose. Higher number of bolls per plant and mean boll weight may be responsible for increased seed cotton yield per plant under 60 cm x 45 cm spacing with 125 per cent RDF. However, yield components like seed cotton per plant (50.35 g), number of bolls per plant (17.47), number of good opened bolls per plant (13.25) and higher boll weight (3.82 g) were significantly higher under 60 cm x 45 cm spacing with 125 per cent RDF as compared to rest of treatment combinations (Table 2 and 3) but this treatment combination failed to compensate significant yield per hectare due to lower plant population per unit area. Whereas, 60 cm x 30 cm with 125 per cent RDF (2196 kg ha^{-1}), 60 cm x 15 cm with 125 per cent RDF (2078 kg ha^{-1}) and 60 cm x 30 cm spacing with 100 per cent RDF (2071 kg ha^{-1}) recorded higher seed cotton yield. The number of bolls and boll weight were increased significantly with increased plant spacing and increased fertilizer levels which could be due to less competition between the plants and availability of resources. Moola Ram and Giri (2006) [8] opined that increased growth and yield components with applied higher levels of fertilizers. Lower seed cotton yield and seed cotton yield per plant at closer spacing and with lower levels of fertilizers was probably due to less space available for light, moisture and nutrient (Pandagale *et al*., 2009) [9].

Conclusion

Based on the results, it can be concluded that Rahc-1011 and Rahc-1012 are suitable genotypes under rainfed condition. Among the different population levels, 55,555 plants ha^{-1} at 60 cm x 30 cm spacing was found to be optimum over 60 cm x 15 cm and 60 cm x 45 cm spacings. Application of 125 per cent RDF recorded significantly higher seed cotton yield and net returns when compared to 100 and 75 per cent RDF. The spacing of 60 cm x 30 cm along with 125 per cent RDF recorded significantly higher seed cotton yield.

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