FEASIBILITY OF HIGH DENSITY PLANTING SYSTEM AND ITS FERTILIZER REQUIREMENT IN COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

Field experiment was conducted on clay textured soil (Vertisols) during kharif 2014-15 and 2015-16 at Main Cotton Research Station, Navsari Agricultural University, Surat to study the "Feasibility of High Density Planting System (HDPS) and its fertilizer requirement in Cotton (Gossypium hirsutum L.)" using cv. G.Cot.16. The design of the experiment was factorial randomized block with eight treatment combinations comprising of two plant densities D_1 (45 x 10 cm spacing) and D_2 (60 x 10 cm spacing) and four fertilizer levels, F_1 (120-00-00 kg NPK + 15 kg $ZnSO_4$/ha), F_2 (120-30-00-15 kg NPK + 15 kg $ZnSO_4$/ha), F_3 (120-00-60 kg NPK + 15 kg $ZnSO_4$/ha) and F_4 (120-30-60 kg NPK + 15 kg $ZnSO_4$/ha) in addition an absolute control treatment (120 x 45 cm spacing with 160-00-00 kg NPK/ha) with three replications. Results indicated that HDPS treatment D_1 recorded significantly higher plant height, per cent ground cover at 80 days after sowing, higher number of bolls per m^2 area as well as seed cotton and stalk yield per hectare over treatment D_2. Different fertilizer levels could not significantly influence to important growth characters, yield attributes, seed cotton yield and stalk yield per hectare in pooled analysis. Interaction effect of plant density and fertilizer levels (D x F) was found to be non-significant with respect to all growth characters, yield attributes, seed cotton and stalk yield in pooled analysis. In comparison of HDPS with control, plant height, per cent ground cover at 80 and 110 days after sowing, number of bolls per m^2 and seed cotton well as stalk yield per hectare were significantly higher in HDPS than in control. Sympodial branches per plant, sympodial length (cm) at 50 per cent height, number of bolls per plant, boll weight (g), seed cotton yield per plant and harvest index recorded in HDPS were significantly lower than control.

KEY WORDS: Cotton, economics, fertilizer levels, High Density Planting System (HDPS)

INTRODUCTION

The production potential of cotton crop is the resultant effect of a number of interacting agronomical factors contributing their share. Among different factors, plant geometry and fertilizer management are important, which influences the growth, development and yield of cotton. Manipulation of row spacing, plant density and the spatial arrangements of cotton plants for obtaining higher yield have been attempted by agronomists for several decades. In different parts of India, cotton is planted in rows 90 to 120 cm apart and with spacing between two plants 45 to 50 cm. The recommended plant density for cotton seldom exceeded 55,000 plants/ha. The concept on high density cotton planting is

more popularly known as "Ultra Narrow Row (UNR)" cotton is popular in several countries and has been adopted after showing improvement in cotton productivity (Ali *et al*., 2010). Studies on narrow spaced cotton planting in many states of India are being carried out with distance between rows ranging from 30 to 60 cm (Venugopalan *et al*., 2013).

For better growth and production of cotton, nutrient management is the most important factor. Nitrogen, phosphorus and potash are the major nutrients. For every 100 kilogram of seed cotton produced the crop depletes the soil by 6-7 kg N, 1.9-2.5 kg P, 6-8 kg K (Singh and Blaise, 2000).

There is need to compare the possibility of high density planting system (HDPS) as compared to conventional method of sowing for cotton and its fertilizer requirement in South Gujarat condition. Keeping all these points in view, a research framework was made.

MATERIALS AND METHODS

Field experiments were conducted at Main Cotton Research Station, Navsari Agricultural University, Surat during *kharif* 2014-15 and 2015-16. The soil of experimental site was high in clay content (>35%) falling under *Vertisol* order. The soil was low in organic carbon and available nitrogen, medium in phosphorous and high in available potassium. The soil was slightly alkaline in reaction with normal electrical conductivity (Table 1).

Eight treatment combinations of two plant densities (D_1: 2,22,222 plants/ha sown at 45 x 10 cm spacing and D_2: 1,66,666 plants/ha sown at 60 x 10 cm spacing) and four fertilizer levels (F_1: 120-00-00 kg NPK + 15 kg $ZnSO_4$/ha, F_2: 120-30-00 kg NPK + 15 kg $ZnSO_4$/ha, F_3:120-00-60 kg NPK + 15 kg $ZnSO_4$/ha and F_4: 120-30-60 kg NPK + 15 kg $ZnSO_4$/ha) in addition an absolute control treatment (120 x 45 cm spacing with 160-00-00 kg NPK/ha) were embedded in factorial randomized block design with three replications. The experiments were conducted with variety G. Cot. 16. Nutrients through chemical fertilizers were applied as per treatments.

RESULTS AND DISCUSSION

Effect on growth parameters

Effect of plant densities on growth parameters

The effect of plant densities on all the growth parameters was found to be significant except ground cover at 110 days after sowing (Table 2). High density planting treatment D_1 recorded significantly higher plant height (142.3 cm) over the height (131.6 cm) recorded in lesser plant density (D_2). The higher plant height in narrow plant spacing might be due to elongated inter-nodes in an attempt to reach exposed solar energy at upper canopy levels. Similar findings were also reported by Ali *et al.* (2009) and Nadeem *et al.* (2010). Treatment D_1 recorded significantly higher per cent ground cover (97.0 %) over D_2 (75.8 %) at 80 DAS. At initial stage, the vertical and horizontal growth of cotton plant remains comparatively slow. However, at 80 DAS, the crop covered more ground area in treatment D_1 than D_2. The reason attributed this significant effect is due to comparatively less availability of area per plant (450 cm^2) and higher plant population (2,22,222 plants/ha) in treatment D_1 as compared to D_2 (600 cm^2 area/plant and 1,66,666 plants/ha). Philip and Cothren (2000) observed that plant canopy closure occurred more rapidly in narrow row spacings than wider row spacings. Treatment D_2 recorded significantly higher number of sympodial branches per plant (9.48) and longer sympodial length (36.89 cm) as compared to D_1 (8.01 and 28.87 cm).. The increase in number of sympodial branches per plant and sympodial length at 50 per cent height in wider spacing might be due to more availability of space and less

competition among crop plants for nutrients, soil moisture and sunlight. Similar results were observed for these traits in past by Obasi and Msaakpa (2005), Ali *et al.* (2009) and Nadeem *et al.* (2010).

Effect of fertilizer levels on growth parameters

The effect of all the growth characters studied was found to be non-significant among different fertilizer levels (Table 2). Due to application of similar quantity of nitrogen, a nutrient responsible for vegetative growth of plant, in each treatment the plants failed to show any significant difference with respect to all the growth characters. Similar non-significant effect of fertilizer application growth characteristics have been reported by Gadhiya *et al.* (2009) and Kaur *et al.* (2011).

Interaction effect (D x F) of plant densities and fertilizer levels on growth parameters

Interaction effect of plant density and fertilizer levels (D x F) was found to be non-significant with respect to all the growth characters studied.

Control vs Rest on growth parameters

The average plant height (136.9 cm) recorded in high density planting system (HDPS) was significantly higher than 113.5 cm recorded in control (Table 2). This may be due to that narrow plant spacings in HDPS might have enhanced the inter-node elongation for receiving solar energy at upper canopy levels than control. These results are in conformity with the findings of Awan *et al.* (2011) and Sawan (2016). In comparison of planting systems, the per cent ground cover recorded in HDPS was significantly higher (86.4% at 80 and 97.5% at 110 DAS) than control at 80 and 110 DAS (55.0% at 80 and 76.8% at 110 DAS) (Table 2). Due to lower number of plants per hectare (18,518 plants/ha) and higher available area per plant (0.54 m^2/plant), control treatment recorded significantly lower ground cover than that of HDPS at 80 and 110 DAS. Plant canopy closure occurred more rapidly in narrow spacing as compared to wider spacing as observed by Philip and Cothren (2000). The number of sympodial branches per plant recorded in control was 19.38 and as against 8.74 in HDPS. These results are in line with those reported by Obasi and Msaakpa (2005), Ali *et al.* (2009) and Nadeem *et al.* (2010). The average sympodial length (cm) at 50 per cent height in HDPS was significantly lower than control (Table 2). The increase in sympodial length in wider spacing (control) might be due to more availability of space and less competition among crop plants for light, nutrients and free space in wider spaced control than HDPS.

Effect on yield attributes

Effect of plant densities on yield attributes

Different plant densities could not cause any significant effect on boll weight whereas it produced significant differences in number of bolls per plant, number of bolls per m^2 area and seed cotton yield (g/plant) (Table 3). Treatment D_2 recorded significantly higher number of bolls per plant (5.08) number of bolls per m2 (93.6) as compared to D_1 (4.21 and 84.7). The boll numbers per plant might be decreased with closer spacing due to -due to greater inter with increase ,However .plant competition in number of plants per unit area at closer spacing (D_1), it compensated for the decline and consequently resulted in significantly higher boll number per m^2 area in closer spacing (D1). Venugopalan *et al.* (2011), Sawan (2016) and Sankat *et al*. (2017) also observed an increase in boll number per unit area at elevated plant populations. Treatment D_2 recorded significantly higher seed cotton yield per plant (14.30 g) as compared to D_1 (12.01 g). Higher plant population (D_1) suppresses the plant growth parameters resulting in lower number of sympodial per plant and consequently resulted in lower seed cotton yield per plant. Similar findings

were also observed by Manjunatha *et al.* (2010). Significantly higher value of harvest index was recorded in treatment D_2 (18.22) over D_1 (15.55). Significantly higher stalk yield per hectare was recorded in narrow spacing (D_1) as compared to wider spacing (D_2) (Table 3). Due to reflection of significant differences in stalk yield, significantly lower value of harvest index was recorded in treatment D_1. Similar observation was also made by Madavi *et al.* (2017).

Effect of fertilizer levels on yield attributes

The influence of fertilizer levels on boll weight, number of bolls per plant and bolls per m^2 was found to be non-significant. Such findings are in close confirmation with the findings of Nehra and Gumber (2012) for boll weight and Singh *et al*. (2012) for number of bolls per plant. Seed cotton yield per plant was not significantly affected by different fertilizer levels. Due to medium initial value of available P_2O_5 and higher initial value of K_2O content in experimental soil, these two nutrients might not have produced their significant effect on seed cotton yield plant and harvest index. The non significant responses of phosphorus and potash were also reported by Khistaria *et al*. (1980).

Interaction effect (D x F) of plant densities and fertilizer levels on yield attributes

Interaction effect of plant density and fertilizer levels (D x F) was found to be non-significant with respect to all the yield attributes evaluated. Nadeem *et al*. ((2010 reported non-significant interaction effect of spacing and nitrogen levels on average boll weight (g).

Control vs Rest on yield attributes

The average number of bolls per plant recorded in HDPS (4.65) was significantly lower than control (34.69) and this might be due to greater inter-plant competition for space, sun light, moisture and nutrients. Obasi and Msaakpa (2005), Ali *et al*., (2009), Nadeem *et al*. (2010) and Jahedi *et al*. (2013) also reported significantly higher number of bolls per plant in wider plant spacing in cotton. The average number of bolls per m^2 area recorded in HDPS was significantly higher (89.1) than control (64.2). The higher number of plants per unit area at closer spacing might be increased the boll number per m^2 area in HDPS than control. This results were also in conformity with the results of Sawan (2016) and Sankat *et al*. (2017). The average boll weight in HDPS (3.06 g) was significantly lower than control (3.77 g). The greater boll weight at higher plant spacing might be due to less competition and more availability of resources. This results are in line with those of Obasi and Msaakpa (2005) and Sawan (2016). The average seed cotton yield per plant recorded in HDPS was significantly lower (13.15 g/plant) than control (115.43 g/plant). The better development of various yield attributes in wider spacing (control) might be due to low degree of inter plant competition for moisture, nutrients and solar energy reflecting in higher vegetative growth and yield attributes including seed cotton yield per plant. Manjunatha *et al*. ((2010obtained significantly higher seed cotton yield per plant with wider spacing than narrow spacings.

Effect on yield

Effect of plant density on yield

Treatment D_1 recorded significantly higher seed cotton yield (2321 kg/ha) and stalk yield (12.80 t/ha) over treatment D_2 (2112 kg/ha and 9.75 t/ha, respectively. The yield increase at higher plant density was primarily due to more number of bolls per m^2 since the effect of boll weight was not significant. The results are supported by findings of Awan *et al*. (2011) and Venugopalan *et al*. (2011). The increase in stalk yield in treatment D_1 might be due to comparatively higher number of plants per

ha and significantly higher plant height over treatment D_2 contributed their effect on addition of biomass. The present findings are in close agreement with Darawsheh *et al.* (2009).

Effect of fertilizer levels on yield

Different fertilizer levels could not influence the seed cotton and stalk yield per hectare (Table 3). The influence of nitrogen and zinc might not have influenced significantly due to same level of these two nutrients in all the treatments. Due to medium initial value of available P_2O_5 and high initial value of K_2O content in experimental soil might not have produced their significant effect on seed cotton yield. The non-significant responses of phosphorus and potash were also reported by Khistaria *et al*. (1980).

Interaction effect (D x F) on yield

Interaction effect of plant densities and fertilizer levels (D x F) was found to be non-significant with respect to seed cotton yield (kg/ha) and stalk yield (t/ha).

***Control vs Rest* on yield**

The average seed cotton yield and stalk yield produced in HDPS (2217 kg/ha and 11.28 t/ha) was significantly higher than control (1851 kg/ha and 7.59 t/ha). This increase in seed cotton yield and stalk yield might be due to significantly higher number of plants per ha and higher number of bolls per m^2 area in HDPS as compared to control. The results are supported with the findings of Venugopalan *et al.* (2011) and Awan *et al*. (2011) for seed cotton yield and of Darawsheh *et al.* (2009) for stalk yield.

Economics

The values of 1,34,083 ₹/ha, 92,207 ₹/ha and 2.20 were recorded as gross realization, net realization and B:C Ratio, respectively in treatment D_1. These results are in accordance with those reported by Paslawar *et al*. (2015). The values of 1,31,093 ₹/ha, 88,301 ₹/ha and 2.06 were recorded in F_4 level as gross realization, net realization and B:C ratio, respectively. In comparisons of control *vs.* rest, higher values of gross realization (1,27,553 ₹/ha) and net realization (68,139 ₹/ha) along with Benefit: Cost ratios (2.07) were recorded in Treatment D_1 as compared to remaining treatments as well as control. These results are in agreement with the findings of Manjunatha *et al.* (2010).

CONCLUSION

For obtaining higher seed cotton yield and net monetary realization, *hirsutum* cotton (variety: G.Cot.16) should be grown with high density planting system (2,22,222 plants/ha sown at 45 x 10 cm spacing) and the crop should be fertilized with 120-00-00 kg NPK/ha along with application of 15 kg $ZnSO_4$/ha on *Vertisols* of South Gujarat.

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Table 1: Initial soil properties

Characteristics	Values of Soil at cm Depth			
	Kharif 2014-15		*Kharif* 2015-16	
	0-22.5 cm	22.5-45.0 cm	0-22.5 cm	22.5-45.0 cm
Physical Properties				
Sand (%)	24.01	16.52	23.06	16.09
Silt (%)	22.16	18.20	22.13	17.21
Clay (%)	53.78	64.97	54.63	67.43
Textural class	Clayey		Clayey	
Chemical Properties				
Organic carbon (%)	0.48	0.43	0.49	0.44
Available N (kg/ ha)	189.5	187.1	187.7	182.6
Available P_2O_5 (kg/ha)	42.7	38.6	44.9	40.7
Available K_2O (kg/ha)	467.0	456.4	459.0	451.8
Available Zn (ppm)	1.94	1.77	1.90	1.72
$EC_{2.5}$ (dS/m)	0.45	0.40	0.48	0.42
$pH_{2.5}$	7.61	7.69	7.68	7.71

Table 2: Effect of plant density and fertilizer levels on different growth and yield attributing characters of cotton

Treatments	Plant Height (cm)	Per Cent Ground Cover at 80 Days After Sowing	Per Cent Ground Cover at 110 Days After Sowing	Number of Sympodial Branches Per Plant	Sympodial Length (cm) at 50 Per Cent eight	Number of Bolls Per Plant	Number of Bolls Per m^2 Area	Boll Weight (g)	Seed Cotton Yield Per Plant (g)
Plant Density (D)									
D_1 : 45 x 10 cm	142.3	97.0	98.4	8.01	28.87	4.21	93.6	3.04	12.01
D_2 : 60 x10 cm	131.6	75.8	96.6	9.48	36.89	5.08	84.7	3.08	14.30
S. Em. ±	2.41	1.36	0.96	0.20	0.56	0.07	1.32	0.02	0.28
CD at 5 %	7.0	4.0	NS	0.58	1.62	0.20	3.8	NS	0.82
Fertilizer Levels (F) (N:P:K:$ZnSO_4$ kg/ha)									
F_1:120:00:00:15	134.7	84.5	97.4	8.62	33.61	4.49	86.8	3.04	12.44
F_2:120:30:00:15	138.9	87.3	97.6	8.92	32.95	4.59	88.1	3.07	13.32
F_3:120:00:60:15	136.9	86.5	97.2	8.79	31.77	4.75	91.0	3.01	13.50
F_4:120:30:60:15	137.1	87.3	97.8	8.64	33.19	4.75	90.7	3.12	13.36
S. Em. ±	3.40	1.92	1.36	0.28	0.79	0.10	1.87	0.03	0.40
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (D x F)									
S. Em. ±	4.81	2.72	1.93	0.396	1.117	0.139	2.64	0.046	0.565
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean (T)	136.9	86.4	97.5	8.74	32.88	4.65	89.1	3.06	13.15
C: Control	113.5	55.0	76.8	19.38	62.50	34.69	64.2	3.77	115.43
C *vs.* T*									
S. Em. ±	4.28	2.54	1.95	0.44	1.10	0.43	2.46	0.04	0.93
CD at 5 %	12.3	7.3	5.6	1.26	3.15	1.25	7.1	0.12	2.67
CV (%)	8.6	7.7	4.8	11.1	8.3	7.3	7.2	3.7	10.5

Control=Recommended spacing (120 x 45 cm) and Fertilizer (160:00:00 kg NPK/ha) * Control vs. Treatment

Table 3: Effect of plant density and fertilizer levels on seed cotton yield, stalk yield and economics of cotton

Treatments	Seed Cotton Yield (kg/ha)	Stalk Yield (t/ha)	Cost of Cultivation (₹/ha)	Gross Realization (₹/ha)	Net Realization (₹/ha)	Benefit: Cost Ratio
Plant Density (D)						
D_1 : 45 x 10 cm	2321	12.80	41876	134083	92207	2.20
D_2 : 60 x10 cm	2112	9.75	41253	121038	79785	1.93
S. Em. ±	39.09	0.26	--	--	--	--
CD at 5 %	113.6	0.75	--	--	--	--
Fertilizer Levels (F) (N:P:K:$ZnSO_4$ kg/ha)						
F_1:120:00:00:15	2148	10.47	40338	123378	83040	2.06
F_2:120:30:00:15	2205	11.60	41638	127103	85465	2.05
F_3:120:00:60:15	2236	11.32	41492	128640	87148	2.10
F_4:120:30:60:15	2277	11.72	42792	131093	88301	2.06
S. Em. ±	55.28	0.366	--	--	--	--
CD at 5 %	NS	NS	--	--	--	--
Interaction (D x F)						
S. Em. ±	78.18	0.517	--	--	--	--
CD at 5 %	NS	NS	--	--	--	--
Mean (T)	2217	11.28	41565	127553	85988	2.07
C: Control	1851	7.59	35341	103480	68139	2.07
C *vs.* T*						
S. Em. ±	69.06	0.454	--	--	--	--
CD at 5 %	198.5	1.31	--	--	--	--
CV (%)	8.6	11.2	--	--	--	--

Control=Recommended spacing (120 x 45 cm) and Fertilizer (160:00:00 kg NPK/ha) * Control vs. Treatment

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