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Research Article

Genetic studies of quantitative traits in interspecific hybrids of tetraploid cotton (*Gossypium hirsutum* L. X *Gossypium barbadense* L.)

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Abstract
Forty five inter specific hybrids between tetraploid species, *G. hirsutum* x *G. barbadense* derived involving nine diverse female parents of *G.hirsutum* and five pollen parents of *G.barbadense* were evaluated to study heterosis and combining ability for seed cotton yield and other characters *viz.*, days to 50% flowering, number of monopodia/plant, number of sympodia/plant, seed index, lint index and oil content. The hybrid G. 67 x GSB 19 exhibited positively significant standard heterosis for seed cotton yield/plant, seed and lint index. Combining ability analysis suggested preponderance of non-additive gene action for all the characters under study except for days to 50% flowering. The female parent,G. 67 and male parent GSB 19 depicted positive significant gca effects for seed cotton yield/plant, seed and lint index; while, hybrid G. 247 x Suvin had significant positive sca effects for seed cotton yield/plant, number of monopodia/plant, number of sympodia/plant and oil content.

Key words: Cotton, combining ability, heterosis, line x tester analysis, tetraploid

Introduction

Cotton, the king of fibre is one of the momentous and important cash crop exercising profound influence on economics and social affairs of the world. It is also called as “White Gold”. It belongs to family Malvaceae and series Hibisceae. India has been the traditional home of cotton where the existence of cotton thread is traced back to the Rigveda about 4000 B.C. (Senchina *et al.* 2003). India is not only the birth place of cotton, but also of the cotton industry. The species are distributed in arid to semiarid parts of the tropical and subtropical areas of the world(Wendel *et al.*2009). Most wild cotton species are diploid species, but the species domesticated from America and Pacific islands are tetraploid, due to a single hybridization event occurred around 2 million years ago. The tetraploid species are *G. hirsutum*, *G. barbadense*, *G. tomentosum*, *G. mustelinum*, and *G. darwinii* (Senchina *et al.* 2003). These tetraploid species comprises the majority of the cultivated cotton worldwide.The concept of interspecific hybridization is employed to improve desirable traits such as seed cotton yield, fibre quality, biotic and abiotic stress resistance of one species into another commercial species. Some workers had carried out the interspecific hybridization for yield improvement in coloured lint cotton (Punitha *et al.* 1999) as well as for oil and fibre quality (Singh *et al.* 2010).Therefore the present investigation was under taken with 14 modified genotypes having tetraploid background were chosen for improving seed cotton yield and other component traits with better oil content in the hybrids.

Material and methods

The experimental material consisted of 60 genotypes, comprising of nine lines of *G.hirsutum* (Narasimha, G. Cot. 100, G. Cot. 10, G. Cot. 16, BC 68 2, MCU 11, AC 738,G. 247 and G. 67) and five testers of *G.barbadense* (GSB 19, GSB 21, GSB 24, GSB 43 and Suvin). Their resultant 45 hybrids produced by line x tester mating design were evaluated along with one standard check hybrid G. Cot. Hy. 102. The experimental material was sown in a randomized block design with three replications during *kharif* 2010-11 at Regional Research Station, Anand Agricultural University, Anand (Gujarat). A single row of 4.5 meter length was assigned to each genotype with 10 plants having 45 cm intra row spacing and 120 cm inter row spacing. Five plants were randomly selected from each replication for each genotype and the average value per plot was computed for number of monopodia, number of sympodia, seed cotton yield (g) and seed index (g);whereas, lint index was calculated on formula basis. While, days to 50% flowering was recorded on plot basis and oil content (%) was estimated by NMR (Nuclear Magnetic Resonance) machine. Analysis of variance technique suggested by Panse and Sukhatme (1978) was followed to test the differences between the genotypes for all the characters under study. Heterosis was estimated in terms of two parameters, i.e. heterobeltiosis (Fonseca and Patterson, 1968) and standard heterosis (Meredith and Bridge, 1972). The variation among the hybrids was partitioned further into sources attributed to general combining ability (gca) and specific combining ability (sca) components in accordance with the procedure suggested by Kempthorne (1957).

Results and discussion

Analysis of variance revealed that the mean squares due to genotypes were significant for all the characters under study. The parents and hybrids differed significantly for all the characters. This revealed the existence of considerable genetic variability among the parents and hybrids for all the characters. The mean squares due to parents *vs*. hybrids were significant for all the traits except oil content which suggested the presence of substantial amount of heterosis in crosses for these characters (Table 1).The estimates of heterobeltiosis (HB) varied from -6.00% (G. Cot. 100 x GSB 21) to 9.03% (MCU 11 x GSB 19) for days to 50 % flowering; -31.97% (BC 68 2 x GSB 19) to 108.54% (G. 247 x GSB 21) for number of monopodia/ plant; -18.22% (G. Cot. 100 x GSB 24) to 23.99% (G. 67 x GSB 19) for number of sympodia/plant;-71.71% (G. Cot. 100 x GSB 43) to 14.65% (G. 247 x Suvin) for seed cotton yield/plant; -49.65% (AC 738 x GSB 19) to 53.50% (Narasimha x GSB 21) for seed index;-52.97% (G. 67 x GSB 43) to 48.01% (G. 247 x Suvin) for lint index and -21.12% (G. 67 x GSB 43) to 26.73% (G. Cot. 100 x GSB 43) for oil content. Out of 45 interspecific hybrids 3, 13, 10, 8 and 6 F_1s had depicted significant better parent heterosis for days to 50% flowering, number of monopodia/plant, number of sympodia/plant, oil content and seed as well as lint index, respectively in desired directions. However none of the cross depicted positive significant heterobeltiosis for seed cotton yield/plant.The results were in accordance with the findings of Katageri and Kadapa (1989), Stoilova and Taofik (1998), Guvercin and Sunulu (2010) and Patel (2010).

Improvement in yield is one of the important objectives, so the superiority of hybrids over best cultivated hybrid is essential for increasing its commercial value. The estimates of standard heterosis (SH) ranged from -4.71% (G. Cot. 16 x GSB 43) to 20.41% (G. 67 x GSB 43) for days to 50% flowering; -36.59% (G. 247 x GSB 19) to 39.02% (G. 247 x GSB 21) for number of monopodia/plant; -16.58% (G. Cot. 100 x GSB 24) to 11.73% (G. 247 x Suvin) for number of sympodia/plant; -59.21% (G. Cot. 100 x GSB 43) to 17.50% (G. 67 x GSB 19) for seed cotton yield/plant; -40.24% (BC 68 2 x GSB 24) to 41.06% (G. Cot. 10 x GSB 19) for seed index; -55.77% (BC 68 2 x GSB 24) to 41.51% (G. 67 x GSB 19) for lint index and -26.54% (G. 67 x GSB 43) to 18.08% (G. Cot. 100 xGSB 43) for oil content. Out of 45 crosses, twocrosses depicted significant standard heterosis in desired direction for days to 50% flowering and number of monopodia/plant; while, only one F_1 registered significant positive standard heterosis for lint index and oil content. The hybrid, G. 67 x GSB 19 exhibited maximum seed cotton yield and highest standard heterosis (17.50 %) over control (Table 2). Several workers (Punitha *et al.* 1999,Solangi *et al.* 2001, Xiaoquan *et al.* 2008 and Patel *et al.* 2009) had also reported the presence of considerable degree of standard heterosis for days to 50% flowering, number of monopodia/plant, lint index, oil content and seed cotton yield/plant. In general, the crosses which had higher estimates of heterobeltiosis and standard heterosis for seed cotton yield also had positive heterotic effects for number of monopodia and number of sympodia/plant (Table 2). Therefore, heterotic effects for seed cotton yield/plant could be outcome of direct effects of the above stated component traits and indirect effect of other component character like oil content. Therefore, heterotic effects for seed cotton yield could be result of combinational heterosis. However, positive and negative estimates of heterosis for rest of the characters could have checked each other for expression of heterotic effects. Hence, to obtain maximum heterotic effects for seed cotton yield desired level of heterosis of each component character should be worked out to identify superior cross combinations.

The analysis of variance for combining ability was carried out for seed cotton yield and other characters i.e., days to 50% flowering, number of monopodia/plant, number of sympodia/plant, seed index, lint index and oil content (%). Analysis of variance for combining ability revealed that mean squares due to lines (females) were highly significant for all the traits; while, mean squares due to testers (males) were significant for all the traits except number of sympodia/plant. The mean squares due to hybrids were highly significant for all the traits. However, the ratio of variance components suggested the preponderance of non-additive type of gene action for all the traits except days to 50% flowering (Table 3). This study thus substantiates the findings of Punitha *et al.* (1999), Patel *et al.* (2009), Saravanan *et al.* (2010) and Patel (2010).

Estimates of general and specific combining ability: The estimates of gca and sca effects ranged from -3.55 (BC 68 2) to 8.05 (G. 67) and-4.67 (G. Cot. 100 x GSB 21) to 2.81 (G. Cot. 100 x GSB 24)for days to 50% flowering; -0.65 (G. Cot. 16) to 0.63 (Narasimha) and -1.04 (G. 247 x GSB 19) to 1.70 (G. 247 x GSB 21) for number of monopodia/plant; -1.96 (G. Cot. 100) to 1.50 (BC 68 2) and -4.22(G. 247 x GSB 43) to 4.02(Narasimha x GSB 43)for number of sympodia/plant; -41.02 (G. Cot. 100) to 44.62 (G. 67) and -52.98 (G. Cot. 16 x GSB 24) to 76.65(G. 247 x Suvin) for seed cotton yield per plant; -1.72 (GSB 24) to 1.48 (G. Cot. 16) and -4.31 (G. Cot. 16 x GSB 19) to 6.24 (G. Cot. 10 x GSB 19) for seed index;-0.66 (GSB 24) to 1.03 (G. 67) and-1.66 (G. 67 x GSB 21) to 2.53 (G. 67 x GSB 19) for lint index and -1.13 (G. 67) to 1.55 (G. Cot. 100) and -2.17 (G. 247 x GSB 24) to 2.56 (G. Cot. 100 x GSB 43) for oil content, respectively (Tables 4 and 5). Out of 14 parents, six females and one male exhibited significant gca effects in desired direction for days to 50% flowering. Three females and one male exhibited significant positive gca effects for number of monopodia/plant and seed cotton yield/plant, While, three female and two male parents recorded significant gca effects for oil content. However, an overall appraisal of general combining ability effects revealed that among the females and males, G. 67and GSB 19 depicted significant and positive gca effects for seed cotton yield/plant, seed index and lint index (Table 4). The results were in fidelity with reports of Zangi *et al.*(2009), Saravanan *et al.* (2010) and Singh *et al.* (2010). Out of 45 hybrids, seven hybrids were found significantly negative sca effects for days to 50% flowering; whereas, 14 hybrids registered positively significant sca effects for seed cotton yield/plant, seed index and oil content. While, six hybrids recorded significant and positive sca effects for number of sympodia/plant; whereas, 12 and 11 hybrids depicted significant and positive sca effects for number of monopodia/plant and lint index, respectively. The perusal of data on sca effects revealed that none of the hybrid was consistently superior for all traits under study. Among the 45 hybrids,G. 247 x Suvin was found promising due to their significant positive sca effects for seed cotton yield/plant, number of monopodia/plant, number of sympodia/plant and oil content(Table 5).This study thus coincides with the findings of Patel *et al.* (2009), Bbebe *et al.* (2010) and Singh *et al.* (2010). The crosses of tetraploid cotton which are found to be superior for economic traits could be tried for commercial cultivation.

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Table1. Analysis of variance for various characters in interspecific crosses of cotton

Sources of variation	d.f.	Day to 50% flowering	Number of monopodia/plant;	Number of sympodia/ plant	Seed cotton yield/ plant (g)	Seed Index (g)	Lint Index	Oil content (%)
Replications	2	6.2	0.4	2.87	181.62	3.19	0.91	0.23
Genotypes (G)	59	217.96**	1.60**	16.78**	12302.82**	26.50**	5.13**	4.78**
Parents (P)	13	780.54**	1.87**	17.64**	30676.54**	27.02**	7.50**	3.03**
Females (F)	8	1253.20**	1.69**	2.57	10175.49**	21.33**	6.08**	3.43**
Male (M)	4	5.23	0.67**	8.69	1890.5**	29.68**	3.82**	1.48**
(F *vs*M)	1	100.57**	8.1**	173.96**	309829.1**	61.95**	33.6**	5.98**
Hybrids (H)	44	40.81**	1.43**	11.91**	5889.50**	27.18**	4.45**	5.33**
Female	8	176.29**	2.63**	19.55**	11166.53**	18.94**	4.13**	9.33**
Male	4	7.85**	1.08**	7.42	4454.91**	38.38**	7.01**	5.72**
F x M	32	11.06**	1.18**	10.56**	4749.57**	27.84**	4.22**	4.28**
P *vs* H	1	880.4**	6.26**	232.73**	61430.5**	13.46**	3.74**	0.10
Check *vs*H	1	15.27**	0.29	0.73	9648.52**	3.90	6.04**	7.63**
Error	118	2.22	0.15	4.23	440.15	1.42	0.33	0.34

*, ** significant at 5 % and 1 % levels, respectively.

Table 2. Manifestation of heterobeltiosis (HB) and standard heterosis (SH) for different characters in five top ranking heterotic crosses for seed cotton yield/plant.

Traits	Heterobeltiosis (HB)					Standard heterosis (SH)				
	G.247 x Suvin	G.Cot.16 x GSB 19	AC 738 x GSB 19	G.Cot.16 x GSB43	G.247 x GSB 21	G.67 x GSB 19	AC 738 x GSB 19	G.247 x Suvin	G.Cot.10 x GSB 24	G.67 x GSB 21
DFF	-1.55	1.04	1.57	-4.71*	0.53	19.88**	1.57	-0.53	-2.10	16.74**
NMP	30.93**	0.00	40.00**	-14.95	108.54**	-4.15	8.05	3.17	-14.63	-4.88
NSP	18.09*	21.79*	8.93	5.97	11.68	11.48	1.90	11.73	1.37	-4.57
SCY	14.65	13.43	-3.89	-4.82	-5.16	17.50*	10.52	8.51	6.45	4.46
SI	14.19	-36.55**	-46.73**	2.63	4.59	39.87**	-24.29**	-12.44	-36.14**	-21.16**
LI	48.01**	-32.69**	-42.09**	9.61	27.12*	41.51**	-28.69**	-14.26	-50.16**	-29.33**
OC	12.08**	-1.39	12.38**	-8.96*	-6.28	-13.42**	-3.96	3.81	-16.13**	-16.79**

DFF:Days to 50% flowering; NMP:Number of monopodia/plant; NSP: Number of sympodia/ plant; SCY: Seed cotton yield/ plant (g); SI: Seed Index (g); LI: Lint Index; OC: Oil content (%) ; *, ** significant at 5 % and 1 % levels, respectively.

Table 3. Analysis of variance and variance estimates of combining ability for different characters in cotton

Sources of variation	d.f.	Day to 50% flowering	Number of monopodia/plant	Number of sympodia/ plant	Seed cotton yield/ plant (g)	Seed Index (g)	Lint Index	Oil content (%)
Replication	2	4.71	0.62*	0.0092	52.38	3.87	0.97	0.15
Hybrids (H)	-44	40.81**	1.43**	11.91**	5889.50**	27.18**	4.45**	5.33**
Line effect (L)	8	176.29**	2.63**	19.55**	11166.52**	18.94**	4.13**	9.33**
Tester effect (T)	4	7.85*	1.08**	7.42	4454.91**	38.38**	7.01**	5.72**
L x T	32	11.06**	1.18**	10.56**	4749.57**	27.84**	4.22**	4.28**
Error	88	2.33	0.14	3.84	402.45	1.47	0.33	0.36
Estimates								
σ^2 gca (Line)		11.02**	0.10**	0.60**	427.80**	-0.59**	-0.01**	0.34**
σ^2 gca(Tester)		-0.12*	0.00	-0.12	-10.91**	0.39**	0.10**	0.05**
σ^2 gca (pooled)		7.30**	0.066**	0.36**	281.56**	-0.26**	0.026**	0.243**
σ^2 sca		2.91**	0.35**	2.24**	1449.04**	8.79**	1.29**	1.31**
σ^2 A		15.43	0.13	0.56	583.08	0.16	0.26	0.62
σ^2 D		11.65	1.39	8.95	5796.17	35.16	5.18	5.23
$[\sigma^2 D/\sigma^2 A]^{1/2}$		0.86	3.26	3.99	3.15	14.82	4.46	2.90

*, ** significant at 5% and 1% levels, respective

Table 4. Estimates of general combining ability (gca) effects of parents for various character in cotton

Parents	DFF	NMP	NSP	SCY	SI	LI	OC
Females							
Narasimha	-2.15**	0.63**	-1.05*	20.32**	-0.44	-0.49**	0.28*
G. Cot. 100	2.12**	0.14	-1.96**	-41.02**	0.13	0.07	1.55**
G. Cot. 10	-1.61**	0.29**	-1.13**	22.04**	-0.76**	-0.49**	-0.91**
G. Cot. 16	-1.21**	-0.65**	0.79	-9.81*	1.48**	0.25*	-0.03
BC 68 2	-3.55**	-0.45**	1.50**	-20.53**	-0.85**	- 0.37**	0.14
MCU 11	0.72*	0.13	0.22	-28.03**	1.48**	0.55**	-0.45**
AC 738	-0.95**	-0.35**	1.03*	7.37	-0.84**	-0.29*	0.17
G. 247	-1.41**	-0.10	0.46	5.05	-1.42**	-0.27*	0.38**
G. 67	8.05**	0.35**	0.15	44.62**	1.22**	1.03**	-1.13**
S. E. (lines)	0.32	0.08	0.42	4.26	0.26	0.12	0.13
Males							
GSB 19	0.35	-0.05	0.56	15.80**	1.02**	0.47**	0.09
GSB 21	-0.73**	0.31**	-0.67*	5.74	0.84**	0.24**	-0.75**
GSB 24	0.46*	-0.21**	0.12	1.65	-1.72**	-0.66**	0.48**
GSB 43	0.35	0.05	-0.40	-18.87**	-0.77**	-0.43**	-0.03
Suvin	-0.43	-0.11	0.40	-4.33	0.63**	0.38**	0.20*
S. E.(testers)	0.23	0.06	0.29	3.02	0.18	0.09	0.09

DFF:Days to 50% flowering; NMP:Number of monopodia/plant; NSP: Number of sympodia/ plant; SCY: Seed cotton yield/ plant (g); SI: Seed Index (g); LI: Lint Index; OC: Oil content (%) ;
*, ** Significant at 5 % and 1 % levels, respectively.

Table 5: Estimates of specific combining ability (sca) effects of hybrids for characters in cotton

Crosses	DFF	NMP	NSP	SCY	SI	LI	OC
Narasimha X GSB 19	-0.48	0.33*	-0.47	-14.16	-2.26**	-0.95**	0.65*
Narasimha X GSB 21	0.93	-0.67**	-1.58	39.74**	4.65**	1.64**	-0.92**
Narasimha X GSB 24	0.41	0.32*	0.12	7.67	1.34*	0.22	-0.79**
Narasimha X GSB 43	-1.48*	-0.24	4.02**	-13.25	-1.39**	-0.29	0.36
Narasimha XSuvin	0.63	0.25	-2.09*	-20.01*	-2.34**	-0.63*	0.70**
G.Cot.100 XGSB 19	-0.08	-0.35*	1.27	-37.48**	2.54**	1.09**	-0.28
G. Cot. 100 X GSB 21	-4.67**	0.39*	1.06	25.32**	-1.32*	-0.17	-0.83**
G. Cot. 100 X GSB 24	2.81**	0.15	-1.76*	25.22**	-2.26**	-0.71**	-1.55**
G. Cot. 100 X GSB 43	1.92**	0.15	-1.07	-22.13**	-0.43	-0.54*	2.56**
G. Cot. 100 X Suvin	0.03	-0.35*	0.49	9.07	1.47**	0.33	0.10
G. Cot. 10 X GSB 19	-0.68	0.83**	-1.52	-23.50**	6.24**	2.21**	0.41
G. Cot. 10 X GSB 21	0.06	-0.79**	-1.69*	-31.72**	-1.54**	-0.31	0.41
G. Cot. 10 X GSB 24	-2.46**	-0.37*	1.85*	48.83**	-1.38**	-0.54*	-0.17
G. Cot. 10 X GSB 43	1.32*	0.10	1.14	-29.69**	-0.05	-0.17	-0.81**
G. Cot. 10 X Suvin	1.76**	0.23	0.23	36.08**	-3.28**	-1.19**	0.16
G. Cot. 16 X GSB 19	-0.75	0.48**	1.62	46.45**	-4.31**	-1.60**	0.89**
G. Cot. 16 X GSB 21	1.66*	0.02	0.09	-22.37**	3.78**	1.11**	-0.42
G. Cot. 16 X GSB 24	1.81**	-0.29	-1.80*	-52.98**	-1.62**	-0.38	1.22**
G. Cot. 16 X GSB 43	-4.41**	-0.15	-0.95	44.05**	3.10**	1.07**	0.02
G. Cot. 16 X Suvin	1.70**	-0.06	1.04	-15.15	-0.95	-0.2	-1.70**
BC 68 2 X GSB 19	0.25	-0.53**	0.38	-3.39	-2.46**	-1.12**	-1.73**
BC 68 2 X GSB 21	-0.01	0.21	1.04	-9.47	0.96	0.23	-0.39
BC 68 2 X GSB 24	-1.86**	-0.20	0.88	-25.87**	-1.84**	-1.02**	1.63**
BC 68 2 X GSB 43	1.25	0.81**	-2.06*	52.60**	-0.8	0.43	-0.28
BC 68 2 XSuvin	0.36	-0.30	-0.25	-13.88	4.19**	1.49**	0.78**
MCU 11 X GSB 19	1.32*	-0.63**	-2.81**	-40.93**	0.49	-0.61*	-1.04**
MCU 11 X GSB 21	0.06	0.07	-0.81	9.33	-1.44**	0.13	0.53*
MCU 11 X GSB 24	-0.13	0.56**	0.60	60.84**	-2.52**	-0.35	2.24**
MCU 11 X GSB 43	-0.35	-0.13	2.35**	2.93	0.75	0.31	-0.94**
MCU 11 X Suvin	-0.90	0.13	0.68	-32.18**	2.72**	0.51*	-0.78**
AC 738 X GSB 19	-0.68	1.05**	-0.62	58.92**	-2.45**	-0.52*	0.80**
AC 738 X GSB 21	0.06	-0.38*	-0.12	-50.77**	-0.43	-0.79**	-0.40
AC 738 X GSB 24	0.21	-0.22	1.12	15.06	1.96**	1.00**	0.29
AC 738 X GSB 43	-0.68	-0.05	0.98	7.00	3.55**	1.48**	-0.37
AC 738 XSuvin	1.10	-0.39*	-1.36	-30.21**	-2.62**	-1.17**	-0.32
G. 247 X GSB 19	-0.88	-1.04**	-0.48	-24.01**	-1.89**	-1.03**	-0.51*
G. 247 X GSB 21	0.86	1.70**	2.11*	22.46**	-0.76	-0.18	0.82**
G. 247 X GSB 24	0.67	-0.31	0.06	-33.21**	3.89**	1.45**	-2.17**
G. 247 X GSB 43	0.12	-1.01**	-4.22**	-41.89**	-1.36**	-0.68**	0.31
G. 247 X Suvin	-0.77	0.65**	2.54**	76.65**	0.11	0.43	1.55**
G. 67 X GSB 19	1.99**	-0.15	2.63**	38.11**	4.10**	2.53**	0.82**
G. 67 X GSB 21	1.06	-0.55**	-0.11	17.48*	-3.90**	-1.66**	1.20**
G. 67 X GSB 24	-1.46*	0.34*	-1.06	-45.57**	2.42**	0.33	-0.69**
G. 67 X GSB 43	2.32**	0.51**	-0.18	0.37	-3.33**	-1.62**	-0.84**
G. 67 X Suvin	-3.90**	-0.16	-1.28	-10.38	0.71	0.42	-0.49
S.E. (Sij) ±	0.65	0.16	0.83	8.53	0.52	0.25	0.26
CD at 5%	1.27	0.31	l1.62	16.71	1.01	0.49	0.50

DFF:Days to 50% flowering; NMP:Number of monopodia/plant; NSP: Number of sympodia/ plant; SCY: Seed cotton yield/ plant (g); SI: Seed Index (g); LI: Lint Index; OC: Oil content (%) .
*, ** Significant at 5 % and 1 % levels, respectively