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HETEROSIS AND COMBINING ABILITY FOR EARLINESS AND ITS RELATED TRAITS IN COTTON (*GOSSYPIUM HIRSUTUM* L.)

H. V. SOLANKI*, D. R. MEHTA, V. B. RATHOD AND P. A. VAVDIYA
Department of Genetics and Plant Breeding,
College of Agriculture, Junagadh Agricultural University, Junagadh - 362 001, Gujarat, INDIA
e-mail: solankiharpal21@gmail.com

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***Corresponding author**

ABSTRACT
A line x tester mating design comprises 10 lines and 5 testers of *Gossypium hirsutum* indicated preponderance of additive and non-additive gene action for days to 50% flowering, days to 50% boll brusting and seed cotton yield per plant respectively. Parent 76 IH 20 were the best general combiners to 50% flowering (-6.133), days to 50% boll brusting (-6.087) and seed cotton yield per plant (11.861). Crosses G.cot-12 x MR 786 for days to 50% flowering (-10.27); LRA 5166 x GJHV 503 (-9.65) and G.cot-12 x H 1316 (-6.78) for days to 50% boll brusting were the best specific combinations to exploit non-fixable components. The gca effects for all the traits indicated more or less similar trend in *per se* performance. Hence, parents having lower mean performance for days to 50 % flowering could be selected for exploiting earliness in cotton hybrids.

INTRODUCTION

Cotton is one of the most important commercial crops in India, playing a key role in national economy. Short duration and high yielding varieties are always required for better quality and lint production. Early maturing crops avoid disease and pest epidemics due to which plant breeders have positioned adequate pressure on the development of early maturing crop plants (Singh, 2004). Term earliness is particular to crop production that refers to harvest the crop as early as possible without incurring significant yield losses. Average vegetative growth period of cotton throughout the world is found to be 135-150 days (Kassianenko, 2003). India is pioneer in commercialization of heterosis in cotton. A noticeable heterosis is reported in cotton by many workers (Khadi *et al*., 1993). Even though heterosis occurs in cotton, it has not been utilized widely as compared to maize and castor due to difficulties in producing cheap commercial F_1 hybrid seed production. For better exploitation of heterosis in cotton, development of simple and economically viable hybrid seed production technique is essential. Commercial exploitation of heterosis is possible only when it is high and consistent across the diversified environments for large scale hybrid seed production. Exploiting heterosis is one of the methods used to increase cotton yields that have stagnated in recent years. The important reasons attributed for this is the lack of systematic efforts made to develop hybrid oriented populations, derived lines with improved combining ability and develop new hybrids based on such genetically diverse high combiner lines (Choudhary *et al*., 2014).

Combining ability described by Sprague and Tatum (1942) elucidates the nature and magnitude of gene action involved in the inheritance of yield and its component traits. For estimation of combining ability of parents, several biometrical tools have been developed for identifying desirable parents. Among these, line x tester (Kempthrone, 1957) analysis is one of the most useful techniques, suitable for identification of good cross combinations and parents to be used in crossing programme. The line × tester analysis technique has been extensively used to assess the combining ability of parents and crosses for different quantitative characters as well as to study the extent of heterosis for yield and yield contributing characters. The knowledge of nature and the magnitude of gene action controlling yield and yield components are very useful for development of the breeding procedures to be followed for crop improvement. Accordingly, the present investigation has been undertaken to determine heterosis and combining ability for earliness and its related traits through line x tester mating design.

Evaluation of breeding materials for general combining ability and specific combining ability as well as to study the extent of heterosis for yield and yield contributing characters are pre-requisites for any breeding programme aimed in development of hybrids. The breeding methods to be adopted for improvement of a crop depend on the nature of gene action involved in the inheritance of economically important traits. Besides its use in selection of potential parents and superior crosses, combining ability also provide information on the nature and magnitude of gene effects involved in the expression of quantitative traits. Keeping in view all these aspects, the present study in cotton is undertaken with the following objectives. 1) To estimate heterobeltiosis and standard heterosis for seed yield and its components, 2) To estimate general and specific combining ability (GCA and SCA) of the parents and crosses, respectively. 3) To estimate the nature and magnitude of gene action involved in the inheritance of quantitative traits

MATERIALS AND METHODS

Five diverse parents (G.cot-18, G.cot-12, LRA 5166, BC 68-2, 76 IH 20) and ten lines (MR 786, GISV 254, GTHV 95/145, GBHV 148, GJHV 503, GBHV 170, BS 27, BS 279, H 1316, GJHV 460) were used to generate fifty cross combinations by using line x tester mating design. These fifty crosses along with fifteen parents and one check (G. Cot. Hy. 12) were grown in randomized block design with three replications. One row of each hybrid and parent was sown at spacing of 120 x 45 cm during 2010-11 at Cotton Research Station, Junagadh Agricultural University, Junagadh, Gujarat. Five randomly selected plants were chosen from each row to record observations on seed cotton yield, days to 50% flowering and days to 50% ball brushting. The combining ability analysis was workedout by the method suggested by Kempthorne (1957). Heterobeltiosis and standard heterosis were calculated by using following formulas.

Heterobeltiosis

It was calculated as the deviation of F_1 from the better parent (Fonseca and Patterson, 1968) and was expressed as per cent basis by the following formula

$$\text{Heterobeltiosis (\%)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \text{X } 100$$

Where,

$\overline{F_1}$ = Mean performance of F_1

$\overline{BP}$ = Mean performance of better parent of the respective cross

Standard Heterosis

It was calculated as the deviation of F_1 from the standard hybrid (G.cot.Hy.12) and expressed on per cent basis by the following formula

$$\text{Standard heterosis (\%)} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \text{x} 100$$

Where,

$\overline{F_1}$ = Mean performance of F_1.

$\overline{SC}$ = Mean performance of standard check.

RESULTS AND DISCUSSION

The analysis of variance for parents and their hybrids (Table 1) revealed significant differences among genotypes, parents and hybrids for all the three traits suggesting the presence of considerable genetic variation with respect to these traits. Variance due to parents vs. hybrids was also significant which reflected overall heterosis as group for all the three characters.

Table 1: Analysis of variance for experiment design of different characters in cotton

Source	d.f.	Days to 50 % flowering	Days to 50 % boll brusting	Seed cotton yield per plant (g)
Replications	2	19.22	18.83	1008.31
Genotypes	64	287.40**	222.61**	4003.17**
Parents (P)	14	303.09**	154.43**	3062.76**
Hybrids (H)	49	288.25**	239.93**	4057.11**
P. Vs H.	1	26.00	328.37**	14525.67**
Error	128	7.03	10.19	345.77

Table 2: Analysis of variance for combining ability and variance components for different characters in cotton

Source	d.f.	Days to 50 % flowering	Days to 50 % boll brusting	Seed cotton yield per plant
Replications	2	10.687	16.987	1077.910*
Lines	9	110.800** + +	69.138**	6126.782*
Testers	4	3024.450** + +	2201.993** + +	3860.791*
Lines x Testers	36	28.602**	64.627**	3561.516**
Error	98	7.299	10.429	344.820
Variance components				
σ^2l		6.900	3.914	385.464
σ^2t		100.572	73.052	117.199
σ^2lt		7.101	18.066	1072.232
σ^2gca		69.348	50.006	206.621
σ^2sca		7.101	18.066	1072.232
σ^2sca/σ^2gca		0.102	0.361	5.189
Per cent contribution				
Lines		7.060	5.293	27.737
Testers		85.650	74.918	7.768
Lines × Testers		7.290	19.789	64.495

*, ** Significant at 5 % and 1 % levels, respectively when tested against error mean square; +, + + Significant at 5 % and 1 % levels, respectively when tested against lines x testers interaction mean square

Table 3: Range of *per se* performance, heterobeltiosis (H) and standard heterosis (SH), their best five crosses and number of significant crosses in desirable direction for different characters in cotton

Character	Range of			Best five crosses				No. of significant crosses in desirable direction	
	Per se	H (%)	SH (%)	H	Value (%)	SH (%)	Value (%)	H (%)	SH (%)
Days to 50 % flowering	59.67 to 92.67	-15.96 to 46.70	4.07 to 61.63	G.cot-18 x GTHV95/145	-15.96			4	0
				G.cot-18 x GJHV 460	-8.78				
				G.cot-18 x H 1316	-8.49				
				G.cot-18 x GBHV 170	-7.17				
				-		-			
Days to 50 % boll brusting	101.67 to 133.33	to 25.16 -12.91	-8.41 to 20.12	76 IH 20 x GBHV 170	-12.91	76 IH 20 x MR 786	-8.41	13	5
				76 IH 20 x H 1316	-12.36	G.cot-18 x MR 786	-5.11		
				G.cot-18 x H 1316	-12.36	LRA 5166 x GJHV 503	-5.11		
				G.cot-18 x BS 27	-11.81	BC 68-2 x MR 786	-4.80		
				BC 68-2 x GJHV 460	-9.44	76 IH 20 x GBHV 170	-4.80		
Seed cotton yield per plant	112.42 to 253.93	-42.02 to 92.67	-40.12 to 35.27	G.cot-12 x BS 279	92.67	G.cot-12 x H 1316	35.27	17	6
				BC 68-2 x BS 27	82.29	76 IH 20 x GBHV 170	33.67		
				G.cot-12 x GJHV 460	70.16	LRA 5166 x GJHV 503	24.39		
				76 IH 20 x GBHV 170	62.40	76 IH 20 x BS 27	23.04		
				G.cot-12 x H 1316	60.71	G.cot-12 x GJHV 460	20.95		

Table 4: Estimates of gca effects and men performance of 15 parents for different characters in cotton

Sr. No.	Parents	Days to 50 % flowering	Days to 50 % boll brusting	Seed cotton yield per plant
	Lines			
1	MR 786	-5.400**	-3.987**	-23.121**
		62.00	104.67	127.68
2	GISV 254	-1.600*	-2.320**	-33.435**
		60.67	110.33	193.89
3	GTHV 95/145	-1.267	-1.720*	-6.060
		71.00	115.67	212.55
4	GBHV 148	-1.867**	-0.853	-19.058**
		59.33	108.00	172.01
5	GJHV 503	1.800*	1.680*	3.747
		67.00	109.67	121.79
6	GBHV 170	4.200**	1.880*	28.870**
		74.33	123.00	154.52
7	BS 27	2.533**	0.213	11.936*
		62.67	122.00	107.11
8	BS 279	1.533*	0.947	4.225
		71.00	115.67	107.07
9	H 1316	-0.067	2.613**	10.337*
		70.67	127.33	158.01
10	GJHV 460	0.133	1.547	22.561**
		68.33	120.00	133.44
SE(g_i) ±		0.698	0.834	4.795
SE(g_i-g_j) ±		0.986	1.179	6.781
	Testers			
1	G.cot-18	-3.400**	-4.853**	-17.644**
		85.33	121.33	167.57
2	G.cot-12	17.867**	14.980**	7.096*
		96.67	129.00	114.17
3	LRA-5166	-3.900**	-1.553**	-3.059
		62.67	117.67	157.96
4	BC 68-2	-4.433**	-2.487**	1.747
		63.33	123.33	115.57
5	76 IH 20	-6.133**	-6.087**	11.861**
		65.00	121.33	150.71
SE(g_i) ±		0.493	0.590	3.390
SE(g_i-g_j) ±		0.698	0.834	4.795

*, ** Significant at 5 % and 1 % levels, respectively

Heterosis over better parent and standard check for three characters are presented in Table 2. For days to 50 % flowering, 4 and none of the crosses showed significant and positive heterobeltiosis and standard heterosis with range of -15.96 to 46.70% and 4.07 to 61.63%, respectively. The cross combination G.cot-18 x GTHV 95/145 recorded the highest heterobeltiosis (-15.96%). Similar findings were also reported by Tomar and Singh (1993), Basal and Turgut (2003), and Ganapathy and Nadarajan (2008) for this trait.

The heterotic expression for days to 50 % boll brusting ranged from -12.91 to 25.16 % over better parent and -8.41 to 20.12 % over standard check. Among fifty hybrids, 76 IH 20 x GBHV

Table 5: Estimates of sca effects for various characters in five selected crosses of cotton

Characters	Range of sca	Best five cross combination	Sca effect	No. of significant crosses in desirable direction
Days to 50 % flowering	-10.27 to 4.73	G.cot-12 x MR 786	-10.27	5
		G.cot-18 x GTHV 95/145	-4.13	
		LRA 5166 x GJHV 503	-4.03	
		76 IH 20 x GBHV 170	-3.53	
		BC 68-2 x BS 27	-3.23	
Days to 50 % boll brusting	-9.65 to 9.42	LRA 5166 x GJHV 503	-9.65	8
		G.cot-12 x H 1316	-6.78	
		G.cot-18 x H 1316	-6.28	
		BC 68-2 X GJHV 254	-5.25	
		76 IH 20 x H 1316	-5.05	
Seed cotton yield per plant	-50.72 to 69.74	G.cot-12 x H 1316	69.74	11
		BC 68-2 x GISV 254	66.86	
		LRA 5166 X GJHV 503	66.06	
		76 IH 20 x GBHV 170	43.46	
		G.cot-18 x GTHV 95/145	42.11	

Table 6: Estimates of sca effects for various characters in some selected cotton crosses.

Sr.No.	Crosses	Days to 50 % flowering	Days to 50 % boll brusting	Seed cotton yield per plant
1	G.cot-18 x GTHV 95/145	-4.13**	-2.28	42.11**
2	G.cot-18 x GBHV 170	-0.27	2.12	23.61*
3	G.cot-18 x H 1316	-0.33	-6.28**	-14.27
4	G.cot-12 x MR 786	-10.27**	5.15**	22.49*
5	G.cot-12 x BS 279	-0.20	-2.78	41.89**
6	G.cot-12 x H 1316	-0.93	-6.78**	69.74**
7	G.cot-12 x GJHV 460	3.87*	-1.71	30.64**
8	LRA-5166 x GJHV 503	-4.03**	-9.65**	66.06**
9	BC 68-2 x GISV 254	-0.43	-1.38	66.86**
10	BC 68-2 x GTHV 95/145	-0.77	-3.65*	-24.53**
11	BC 68-2 x GBHV 148	0.83	-4.85**	19.62
12	BC 68-2 x BS 27	-3.23*	-0.25	30.23**
13	BC 68-2 x GJHV 460	-0.17	-5.25**	-34.12**
14	76 IH 20 x GBHV170	-3.53*	-4.98**	43.46**
15	76 IH 20 x BS 27	0.47	2.02	40.42**
16	76 IH 20 x H 1316	-0.60	-5.05**	-4.41
	SE(s_{ij}) ±	1.560	1.864	10.721
	SE(s_{ij}-s_{kl}) ±	2.206	2.637	15.162
	SE(s_{ij}-s_{ik}) ±	1.709	2.042	11.744

*, ** Significant at 5 % and 1 % levels, respectively

170 (-12.91%) and 76 IH 20 x MR 786 (-8.41%) showed highest, significant and negative heterobeltiosis and standard heterosis, respectively for days to 50 % boll brusting. Shunmugavalli and Das (1995) also reported varying magnitude of heterosis for this character.

The extent of heterosis for seed cotton yield per plant ranged from -42.02 to 92.67 % and -40.12 to 35.27 % over better parent and standard check, respectively. Among fifty hybrids, seventeen and six hybrids showed significant and positive heterosis over better parent and standard heterosis, respectively. Three cross combinations *viz.,* G.cot-12 x GJHV 460, 76 IH-20 x GBHV 170 and G.cot-12 x H 1316 showed significant and positive heterobeltiosis and standard heterosis for seed cotton yield per plant. The results reported in the present investigation are in agreement with workers of Khan *et al.*, 2009; Jyotiba *et al.*, 2010; Basal *et al.*, 2011; Geddam *et al.*, 2011; Kaushik and Shastry 2011; Patil *et al.*, 2011 and Lyngdoh *et al.*, 2013.

Analysis of variance for combining ability revealed that the mean squares due to lines, testers and lines x testers were significant for all the three characters when tested against error mean square (Table 3), indicating the importance of both additive and non-additive genetic variances in the expression of these characters. The components of genetic variance estimated indicated that the magnitude of variance due to testers (ó^{2}t) was higher than those of lines (ó^{2}l) and lines x testers (ó^{2}lt) for days to 50% flowering and days to 50% ball brushting. The reverse was true in case of seed cotton yield per plant. The variance due to gca was higher in magnitude for days to 50% flowering and days to 50% boll brusting than that due to sca indicating the preponderance of additive type of genetic variation for governing both these traits. Sakhare *et al.* (2005), Patel *et al.* (2007) and Palve (2009) also reported the predominance of additive gene action for the expression of days to 50% flowering and days to 50% boll brusting. Variance due to sca was higher in magnitude for seed cotton yield per plant than that due to gca indicating the preponderance of non-additive type of genetic variation for seed cotton yield. Ashok kumar and Ravikesavan (2010), Senthil kumar *et al.* (2010) and Jatoi *et al.* (2011) also reported the predominance of non-additive gene action in the expression of seed cotton yield per plant.

The estimates of gca effects (Table 4) revealed that among lines MR 786, GISV 254, GBHV 148 and among testers G.cot-18, LRA 5166, BC 68-2 and 76 IH 20 were good general combiners for days to 50% flowering. Likewise, for days to 50% boll brusting, three lines *viz* MR 786, GISV 254, GTHV 95/145 and four testers namely G.cot-18, LRA 5166, BC 68-2 and 76 IH 20 were good general combiners. On the other hand, four lines namely GBHV 170, GJHV 460, BS 27 and H 1316 and two testers (76 IH 20 and G.cot-12) were good general combiners for seed cotton yield per plant.

The perusal of sca effects (Table 5) revealed that crosses G.cot-12 x MR 786 for days to 50% flowering; G.cot-12 x H 1316 and LRA 5166 x GJHV 503 for days to 50% boll brusting and G.cot-12 x H 1316 and BC 68-2 x GBHV 148 for seed cotton yield plant were the best specific combinations to exploit non-fixable components.

A parent showing lower mean performance generally proved to be good combiners for earliness, indicating that earliness could be effectively incorporated in a hybrid by selecting parents on the basis of their *per se* performance (Table 4) for these three characters. However, it is very difficult to record all these three traits (to defect earliness) at an early stage of growth of cotton. Hence, it is essential to emphasize only on one character by which earliness could be detected. The present study revealed that the gca effects of parents for all the three traits indicated earliness. Hence, among three traits, parents having lower mean performance for number of days to 50 % flowering should be selected for exploiting earliness in hybrids.

Since additive and non-additive components of genetics variances were important for all three traits, the exploitation of both types of gene action would be imperative and recurrent selection for hybrid varieties would prove to the most effective for inducing earliness and productivity in cotton.

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