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Combining ability analysis for seed cotton yield and its attributing traits in upland cotton (*Gossypium hirsutum* L.)

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ABSTRACT: The present investigation aims to obtain information on the magnitude of gca variances and gca effects for individual parents and sca variances and sca effects of *Gossypium hirsutum* hybrids for seed cotton yield and its attributes *viz.*, days to first flower (earliness), bolls/plant, boll weight, plant height, monopodia and sympods/plant. Five females crossed with ten testers in line x tester mating fashion resulting 50 hybrids were obtained. Fifty hybrids along with their 15 parents and one standard check were raised during *kharif* 2016-2017 in a randomized block design with three replications at CCS Haryana Agricultural University, Cotton Research Station, Sirsa. The study revealed that Gregg 45, MESR 17, SR 38 and Pusa 31 among the males while, the H1300 and H1098i among females were found to be good general combiner with highest *per se* performance for all the traits studied. Among the crosses, H1117 x LRA 5166 (poor x poor GCA), H1226 x SR 38 (good x good GCA), H1098i x PUSA 31 (good x good GCA) and H1300 x AVB SM 277 (good x poor GCA) exhibited high *per se* performance with good SCA effects for seed cotton yield and its yield attributes in desirable direction. The magnitude of SCA variance was greater than GCA variance for all the traits that specified predominance of non additive gene action which is important in exploitation of heterosis through hybrid breeding.

Key words : *Gossypium hirsutum* L., GCA, line x tester analysis, SCA variance, seed cotton yield

Cotton is mainly grown for fibre purpose and also provides lint, oil and protein rich meal from its seed. It is grown in nearly 10.5 million hectares which is almost 34.6 per cent of the world cotton acreage with a total production and productivity of 35.1 m bales and 568 kg/ha; respectively (Anonymous, 2017).

There is a need to improve the productivity of cotton crop by developing high yielding cotton varieties or hybrids. Yield is a complex polygenically inherited character resulting from multiplicative interaction of its contributing characters. Thus, effective improvement in yield may be brought about through selection on yield component characters. Hybridization is the most potent technique for breaking yield barriers by developing suitable high yielding hybrids exhibiting high economic or useful heterosis.

In heterosis breeding programme, selection of parents on the basis of morphological features alone might not be a sound procedure since phenotypically superior lines may yield poor recombinants in the segregating generations. Therefore, it is essential that the parents be chosen on the basis of their combining ability. Combining ability analysis is the most widely used biometrical tool for selection of prospective parents, to formulate breeding procedure which also provide information on nature of gene action as well as magnitude of gene effects involved in the expression of quantitative traits. In the present investigation an attempt was made to obtain information on the magnitude of gca and sca variances and gca and sca effects for individual parents and crosses over the check hybrid HHH 223 for seed cotton yield and its component characters.

Selection of parental material : The parental lines used in the present investigation were selected on the basis of their genetic divergence. Large number of genetic accessions were assessed and five female parents (testers) *viz.,* HGMS 1, H1226, H1098i, H1117 and H1300 and ten male parents (lines) *viz.,* PUSA 31, AVB SM 277, Sudan Arban Cotton, LRA 5166, Gregg 45, SR 38, N 65, GCA 182, MESR 17 and GJHS 16 were selected based on their agronomical superiority during *kharif* 2015-2016.

Hybrid development : All the parental genotypes were planted and fifty American cotton hybrids were developed by crossing five females (testers) and ten males (lines) in a line x tester mating fashion during *kharif* 2015-2016. Maximum number of crosses were made to develop enough F_1. Some of the buds of parents were also selfed.

Field layout : Fifty F_1 seed crosses along with their 15 parents and one standard check hybrid HHH 223 were evaluated in randomized block design (RBD) with three replications at CCS Haryana Agricultural University, Cotton Research Station, Sirsa during *kharif* 2016-2017. A spacing of 67.5 cm between rows and 60 cm between plants was adopted.

Data analysis : Data were recorded on five randomly selected plants from each genotype in each replication for various quantitative characters *viz.*, days to first flower (DF), plant height (PH) (cm) monopods/plant (MP/P), sympods/plant (SP/P), bolls/plant (BP/P), boll weight (BW) (g), seed cotton yield/plant (SCY/P) (g).

Statistical analysis : The data were analyzed for general combining ability and specific combining ability variances by following the method suggested by Kempthorne (1957) for line x tester analysis.

Combining ability analysis is an imperative tool for choice of the desirable parents coupled with the information regarding nature and magnitude of gene controlling quantitative

Table 1. Analysis of variance for different characters under study in upland cotton

Source of Variation	Degree of freedom	Days to first flower	Plant height	Mono-pods/ plant	Sympods/ plant	Bolls/ plant	Boll weight (g)	Seed cotton yield/ plant
Replication	2	1.03	200.2	1.98	0.52	16.8	0.06	105.6
Treatment	64	12.8*	275.7*	4.24 *	19.5*	157.9*	0.09*	902.0*
Error	128	4.79	80.9	0.47	1.89	26.3	0.03	95.9

and qualitative traits. Knowledge on gene action and combining ability helps in recognizing the best combiners, which may be hybridized either to exploit heterosis or to produce the transgressive segregants in F_2 and subsequent generations.

The analysis of variance (Table 1) indicated that the mean squares of genotypes for all the characters investigated were significantly different, indicating the presence of variability among hybrids and their parents.

The analysis of variance for combining ability analysis revealed that genetic variances for female and male parents recorded highly significant effects for all the characters. Line x Tester interactions were also found highly significant for all the characters studied. Relative importance of general and specific combining abilities has assessed by estimating components of variances and were then expressed in the ratio of GCA/SCA (Table 2).

The magnitude of SCA variance was greater than GCA variance for all the traits indicating dominance of non additive gene action which is important for exploitation of heterosis through hybrid breeding. Patil *et al.* (2011), Deosarkar *et al.* (2014), Faldu *et al.* (2015), Ali *et al.* (2016), Rathva *et al.* (2017) and Sivia *et al.* (2017) have reported predominance of SCA variance in upland cotton for plant morphological, yield and its component characters.

General combining ability is the average performance of a genotype in cross combinations involving a set of other genotypes. The GCA effect imitate the breeding value of parental genotypes and it assist in recognizing genotypes to be used for developing superior populations. Estimates of general combining ability (GCA) effects of fifteen parents comprising five female parents and ten male parents for all the characters studied are presented in Table 3.

Best combining female and male parents along with poorest combiners for various traits are presented in Table 4. Perusal of the table revealed that among female parents, H1300 was the best combiner for the characters *viz.*, days to first flower (earliness), monopods/plant, bolls/plant, boll weight and seed cotton yield/plant. Whereas; female parent H1098i was second best combiner which combined the best for earliness, plant height (dwarfness), bolls/plant and seed

Table 2. Combining ability analysis for different characters in *Gossypium hirsutum* L.

Source of Variation	Degree of freedom	Days to first flower	Plant height (cm)	Mono-pods/ plant	Sympods/ plant	Bolls/ plant	Boll weight (g)	Seed cotton yield/ plant
Replications	2	1.76	255.5	1.73	0.56	13.4	0.04	113.6
Lines	9	18.7*	463.4*	7.90*	8.47*	117.7*	0.06*	1292.2*
Testers	4	24.0*	665.1*	4.11*	6.43*	332.3*	0.13*	1763.2*
Line x Testers	36	8.54*	160.8*	3.15*	17.5*	121.9*	0.05*	653.7*
Error	98	4.20	76.9	0.52	1.50	26.1	0.02	97.5
ó^2 GCA		0.57	17.93	0.12	0.45	4.58	0.01	38.84
ó^2 SCA		1.45	27.99	0.87	5.34	31.95	0.02	185.63
ó^{2}GCA/ó^{2}SCA		0.39	0.64	0.14	0.08	0.14	0.50	0.21

Table 3 General combining ability effect of parents for different characters in *Gossypium hirsutum* L

Female parents	Degree of freedom	Plant height	Mono-pods/ plant	Sympods/ plant	Bolls/ plant	Boll weight (g)	Seed cotton yield/ plant
HGMS-1	1.28*	0.44	0.14	0.71*	-4.33*	-0.09*	-6.67*
H1098i	-0.61*	-3.88*	0.07	0.04	2.16*	-0.02	5.75*
H1117	0.47	7.59*	-0.63*	-0.39*	-1.91*	0.04*	-6.70*
H1226	-0.17	-3.96*	0.06	-0.44*	1.45	-0.02	2.43
H1300	-0.96*	-0.18	0.34*	0.07	4.78*	0.07*	10.18*
SE(d)	0.33	1.43	0.11	0.20	0.83	0.02	1.61
Male parents							
PUSA 31	-0.24	2.49	0.21	-1.18*	2.04*	0.06	6.08*
AVB SM-277	-1.21*	-3.34	0.27	0.53*	-0.42	-0.12*	-11.39*
Sudan arban cotton	-0.36	-5.47*	-0.15	-0.58*	-1.97*	0.02	-3.35
LRA5166	-0.27	7.90*	-0.29*	0.285	-0.99	0.08*	-4.57*
Gregg 45	0.77	4.92*	0.21	-0.74*	4.97*	0.06*	10.48*
SR-38	-0.56	-9.62*	0.27	-0.03	2.78*	0.09*	11.59*
N 65	-0.51	1.45	0.62*	-0.58*	-2.46*	-0.02	0.54
GCA 182	2.25*	0.59	0.34*	0.37	0.35	0.01	-0.24
MESR-17	-1.19*	5.44*	-1.92*	0.78*	2.29*	0.02	7.81*
GJHS-16	1.33*	-4.37*	0.42*	1.15*	-2.61*	-0.08*	-15.9*
SE(d)	0.51	2.15	0.17	0.30	1.25	0.03	2.42

*Significance at 5% level.

cotton yield/plant followed by female parent H1117 which was the best combiner for plant height (tallness) and boll weight.

Among male parents, Gregg 45 was the best general combiner for plant height (tallness), number of bolls/plants, boll weight and seed cotton yield. While MESR 17 was the second-best general combiner for days to first flower (earliness), plant height (tallness), sympods/ plant, bolls/plant and seed cotton yield, followed by SR 38 for plant height(dwarfness), bolls/plant, boll weight and seed cotton yield. These findings are in line with the studies of Kumar *et al.* (2013) Sawarkar *et al.* (2015), Gnanasekaran and Padmavathi (2017), Reddy *et al.* (2017) and Sivia *et al.* (2017).

Estimates of specific combining ability (SCA) effects of combinations for various characters are presented in Table 5. Best specific cross combinations for various characters are presented in Table 6. The perusal of this table revealed that high negative SCA effect for days to first flower (earliness) in desirable direction was depicted by cross H1226 x Gregg 45 (-3.56) and H1117 x MESR 17 (-2.74) which were a combination of good x poor and poor x good combining parent respectively, specifying that both additive and nonadditive variance were important for these characters. Similar type of findings were reported by Gnanasekaran and Padmavathi (2017) and Sivia *et al.* (2017).

The cross combinations viz., H1226 x PUSA 31 (15.6) (poor x good), H1226 x GJHS-16 (11.7) (poor x poor), H1226 x Gregg 45 (11.2) (poor

Table 4. Best and poorest general combiner parents for different characters

Characters	Female parents		Male parents	
	Best combiner	Poorest Combiner	Best Combiner	Poorest Combiner
Days to first flower	H1300(-0.96*)	HGMS-1(1.28*)	AVB SM-277(-1.21*)	GCA 182(2.25*)
Plant height (cm)	H1117(7.59*)	H1226(-3.96*)	LRAA 5166(7.90*)	SR-38(-9.62*)
Monopods/plant	H1300(0.34*)	H1117(-0.63*)	N 65(0.62*)	MESR-17(-1.92*)
Sympods/plant	HGMS-1(0.71*)	H1226(-0.44*)	GJHS-16(1.15*)	PUSA 31(-1.18*)
Bolls/plant	H1300(4.78*)	HGMS-1(-4.33*)	Gregg 45(4.97*)	GJHS-16(-2.61*)
Boll weight (g)	H1300(0.07*)	HGMS-1(-0.09*)	SR-38(0.09*)	AVB SM-277(-0.12*)
Seed cotton yield/plant (g)	H1300(10.18*))	H1117(-6.70*)	SR-38(11.59*)	GJHS-16(-15.9*)

*Significance at 5% level.

x good) and H1098i x LRA 5166 (9.50) (poor x good) showed significant positive SCA effects in desirable direction for plant height (Tallness). This was a combination of poor x good combining parent indicating that dominance variance was important for tallness (plant height). For dwarfness, the crosses H1098i x GCA 182 (-11.4) (good x poor), H1300 x AVB SM-277 (-9.625) (good x good), H1226 x LRA 5166 (- 9.17) (good x poor) and H1226 x N 65 (-8.55) (good x poor) exhibited highest negative SCA effects. Therefore, SCA effects of these crosses is mainly due to additive gene action. These results were found in accordance with Kumar *et al.* (2013) and Sivia *et al.* (2017).

Two hybrid combinations, H1098i x LRA 5166 (1.54) and H1117 x PUSA 31 (1.42) showed highest significant positive SCA effects for increased monopods/plant which were the combination of good x poor and poor x good respectively. For sympods/plant cross combinations, H1117 x PUSA 31 (3.92) (poor x poor), H1226 x GCA 182 (3.67) (poor x good) and H1300 x Sudan arban cotton (2.77) (good x poor) registered highest significant positive SCA effects. These results observed in accordance with earlier workers Baloch *et al.* (2010), Rajamani *et al.* (2014) and Rathva *et al.* (2017).

For bolls/plant, cross combinations H1226 x SR 38 (11.9) (good x good), H1226 x GCA 182 (11.8) (good x good), H1300 x Sudan arban cotton (8.25) (good x poor) and H1117 x LRA 5166 (7.86) (poor x poor) revealed significant positive SCA effects. While the highest SCA effect for boll weight was recorded by the crosses H1117 x LRA 5166 (0.24) (good x good) and HGMS 1 x LRA 5166 (0.21) (poor x good). Out of fifty cross combinations, crosses H1117 x LRA 5166 (29.7) (poor x poor), H1226 x SR 38 (23.6) (good x good), H1117 x SR 38 (20.8) (poor x good), HGMS 1 x LRA 5166 (18.6) (poor x poor), H1098i x PUSA 31 (15.8) (good x good), H1226 x Sudan arban cotton (15.5) (good x poor) and H1300 x AVB SM 277 (13.1) (good x poor) registered highest significant positive SCA effects for seed cotton yield. Above crosses were the combinations of good x good, good x poor, poor x good and poor x poor combining parent pinpointing that additive and nonadditive gene action was responsible for significant SCA effects for seed cotton yield and its contributing characters. Above findings were found to be similar with earlier researchers, Deosarkar *et al.* (2009), Sawarkar *et al.* (2015), Reddy *et al.* (2017) and Sivia *et al.* (2017).

Table 5. Specific combining ability effects of crosses for different characters in *Gossypium hirsutum* L

Cross	DF	PH	NMP	NSP	NBP	BW	SCY/P
HGMS 1 x PUSA 31	1.50	-6.33	-0.86*	-1.76*	-5.14*	-0.04	-13.4*
HGMS 1 x AVB SM 277	2.55*	-1.58	-0.34	-0.14	-1.77	0.06	6.98
HGMS 1 x Sudan arban cotton	-1.96*	-2.19	1.26*	0.14	-0.13	0.03	-10.9*
HGMS 1 x LRA 5166	-0.55	3.34	-0.19	-0.14	6.36*	0.21*	18.6*
HGMS 1 x Gregg 45	0.99	3.58	0.64*	0.56	5.40*	0.04	9.32*
HGMS 1 x SR 38	-1.26	-0.29	-1.76*	0.59	-7.28*	-0.18*	-20.4*
HGMS 1 x N 65	-2.48*	4.21	-0.19	1.14*	3.37	0.03	7.55
HGMS 1 x GCA 182	2.00*	3.74	0.92*	-0.81	2.26	0.06	-1.21
HGMS 1 x MESR 17	1.70*	1.39	0.02	-0.14	-3.75	-0.03	-5.31
HGMS 1 x GJHS 16	-2.50*	-5.88	0.51	0.57	0.69	0.01	9.86*
H1098i x PUSA 31	-0.11	-6.00	0.96*	-1.51*	5.60*	0.11*	15.8*
H1098i x AVB SM 277	0.53	6.50	0.56*	-4.56*	5.37*	-0.24*	-5.84
H1098i x Sudan arban cotton	0.68	-3.03	-0.51	0.06	3.55	0.07	13.5*
H1098i x LRA 5166	1.43	9.50*	1.54*	2.02*	-4.26*	0.16*	-14.8*
H1098i x Gregg 45	0.13	1.32	-0.88*	-1.69*	-0.89	-0.08	0.83
H1098i x SR 38	0.13	-7.72*	0.72*	1.59*	-3.87	-0.05	-10.2*
H1098i x N 65	-1.84*	7.62*	-0.13	2.72*	4.94*	0.06	7.09
H1098i x GCA 182	-1.44	-11.4*	-2.01*	-1.56*	-7.86*	0.02	-3.82
H1098i x MESR 17	1.10	8.22*	-1.16*	0.94	-0.14	0.00	1.12
H1098i x GJHS 16	-0.61	-5.05	0.91*	1.99*	-2.44	0.07	-3.58
H1117x PUSA 31	-0.69	-8.23*	1.42*	3.92*	0.49	0.08	-6.23
H1117 x AVB SM 277	-0.22	1.36	-0.82*	2.46*	-3.47	0.04	-7.03
H1117 x Sudan arban cotton	1.18	-1.09	-0.89*	-4.09*	-15.1*	-0.27*	-23.4*
H1117 x LRA 5166	-1.91*	2.19	-0.92*	1.54*	7.86*	0.24*	29.7*
H1117 x Gregg 45	2.30*	0.84	1.25	2.41*	-1.13	-0.04	-11.6*
H1117x SR 38	-0.71	8.06*	-0.82*	-4.31*	5.49*	0.13*	20.8*
H1117 x N 65	2.00*	-0.11	-0.25	2.24*	0.13	0.10	-6.75
H1117 x GCA 182	-0.77	-0.91	0.45	-2.21*	-4.44*	-0.14*	-13.8*
H1117x MESR 17	-2.74*	0.49	1.22*	-1.21*	6.05*	-0.01	12.5*
H1117 x GJHS 16	1.56	-2.61	-0.64*	-0.74	4.09	0.15*	5.98
H1226x PUSA 31	-0.46	15.6*	0.22	-1.11*	-1.12	-0.04	-5.58
H1226 x AVB SM 277	-0.41	3.33	-0.02	1.17*	-5.56*	0.01	-7.17
H1226 x Sudan arban cotton	0.08	3.38	-1.00*	1.12*	3.39	0.08	15.5*
H1226 x LRA 5166	0.75	-9.17*	-0.95*	-2.74*	-11.2*	-0.01	-28.2*
H1226 x Gregg 45	-3.56*	11.2*	-0.29	1.54*	-5.45*	-0.01	-8.94
H1226 x SR 38	1.70*	-7.55*	0.90*	1.57*	11.9*	0.19*	23.6*
H1226 x N 65	0.40	-8.55*	0.30	-3.88*	-3.02	0.08	4.71
H1226 x GCA 182	0.21	8.32*	0.83*	3.67*	11.8*	0.02	18.1*
H1226 x MESR 17	-0.76	-5.87	0.27	1.42*	0.30	0.00	0.44
H1226 x GJHS 16	2.05*	11.7*	-0.25	-2.78*	-1.10	-0.28*	-12.5*
H1300 x PUSA 31	-0.26	4.97	-1.73*	0.46	0.17	0.01	9.44*
H1300 x AVB SM 277	-2.46*	-9.62*	0.62*	1.07*	5.43*	0.14*	13.1*
H1300 x Sudan arban cotton	0.03	2.93	1.14*	2.77*	8.25*	0.09	5.43
H1300 x LRA 5166	0.28	-5.87	0.52	-0.68	1.27	-0.21*	-5.35
H1300 x Gregg 45	0.15	5.45	-0.73*	-2.81*	2.07	0.09	10.3*
H1300 x SR 38	0.15	7.50*	0.96*	0.56	-6.24*	0.03	-13.7*
H1300 x N 65	1.93*	-3.17	0.27	-2.23*	-5.43*	-0.26*	-12.6*
H1300 x GCA 182	-0.01	0.20	-0.19	0.91	-1.83	0.05	0.79
H1300 x MESR 17	0.70	-4.23	-0.34	-1.01*	-2.45	0.03	-8.61
H1300 x GJHS 16	-0.51	1.83	-0.53	0.96	-1.24	0.05	1.20
SE(d)	1.00	4.30	0.34	0.60	2.50	0.07	4.82

*Significance at 5% level.

Table 6. Best and poor specific cross combinations for different characters along with *per se* performance

Characters	Best cross combinations				Poor cross combinations	Mean performance
	1st cross	Mean performance	2nd cross	Mean performance		
Days to first flower	H1226 x Gregg 45 (-3.56*)	53.8	H1117 x MESR-17 (-2.74*)	53.3	HGMS-1 x AVB SM-277 (2.55*)	59.4
Plant height (cm)	H1226 x PUSA 31 (15.58*)	164.3	H1226 x Gregg 45 (11.18*)	140.0	H1098i x GCA 182 (-11.35*)	135.6
Monopods/plant	H1098i x LRA 5166 (2.54*)	6.58	H1117 x PUSA 31 (2.31*)	6.25	H1098i x GCA 182x GCA 182(-3.01*)	3.7
Sympods/plant	H1117 x PUSA 31 (3.92*)	16.5	H1226 x GCA 182 (3.67*)	17.8	H1098i x AVB SM 277 (-4.56*)	8.17
Bolls/plant	H1226 x SR-38 (11.90*)	63.03	H1226 x GCA 182 (11.88*)	59.1	H1117x Sudan arban cotton(-11.41*)	30.4
Boll weight (g)	H1117 x LRA 5166 (0.24*)	3.56	HGMS-1 x LRA 5166 (0.21*)	3.39	H1300 x PUSA 31 (-0.30*)	3.35
Seed cotton yield/ plant (g)	H1117 x LRA 5166 (29.7*)	139.3	H1226 x SR-38 (23.6*)	155.3	H1226 x LRA 5166x LRA 5166 (-28.4*)	87.4

From the present study, it was observed that the hybrid combinations, H1117 x LRA 5166 (poor x poor), H1226 x SR 38 (good x good), H1098i x PUSA 31 (good x good) and H1300 x AVB SM 277 (good x poor) recorded high *per se* performance (139.3, 155.3, 148.4 and 133.1 respectively) and significant positive sca effects (29.70, 23.59, 15.78 and 13.06, respectively) for seed cotton yield/plant. These outcomes reported that study of SCA effects alone is not suitable for choosing parents for hybridization programme but study of their heterotic effect is also necessary as reported by Baloch *et al.* (2010), Kencharaddi *et al.* (2015) and Sivia *et al.* (2017).

CONCLUSION

Based on the *per se* performance and gca effects the parents *viz.,* Gregg 45, MESR 17 and SR 38 among males while H1300 and H1098i among females were identified to be the best combiners for further utilization as parents for hybridization and selection programmes. Similarly, the hybrid combinations *viz.*, H1117 x LRA 5166, H1226 x SR 38, H1098i x PUSA 31 and H1300 x AVB SM 277 registered high sca effects along with high per se performance for seed cotton yield/plant and its component traits, which was the combination of either both good combining parent; one good and one poor combiner parent or both poor combining parents. This indicated that both additive and nonadditive gene action were important for this character. Hence, these crosses could be promising to be exploited for hybrid cotton development for different characters.

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