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Combining ability studies of GMS based hybrids in cotton (*Gossypium hirsutum* L.)

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Abstract
A study was carried out to estimate the GCA of the parents and SCA of the hybrids. Three lines were crossed with eight testers to obtain 24 hybrids in line x tester design. The magnitude of GCA variances were higher for days to 50 per cent flowering, sympodia per plant, boll weight and ginning outturn while SCA variances were higher for plant height, bolls per plant, seed cotton yield per plant, seed index, 2.5 per cent span length, fibre fineness and fibre strength. Among the parents: G(T)-84, TCH 1716, CCH 15-1 and TCH 321 were found to be best general combiners for seed cotton yield/plant. Parent TCB 37 and GSB 21 are good combiners for fibre quality traits. Crosses S-D-2 x CCH 15-1, GMS Gregg x CPD 1501 and G(T)-84 x TCH 1824 recorded higher and significant SCA effects as well as high *per se* performance for seed cotton yield.

Keywords: genetic male sterile, line x tester design, combining ability, *Gossypium hirsutum*

Introduction
Cotton (*Gossypium hirsutum* L.) is an important fibre crop and plays a vital role in commerce of many countries such as USA, China, India, Pakistan, Uzbekistan, Turkey, Australia, Greece, Brazil, Egypt *etc*., where climatic conditions suits its growth, which includes periods of hot and dry weather and adequate moisture. The concept of combining ability plays an important role in the identification of parents and development of superior lines or hybrids. Studies have indicated that the genotypes found good in performance might not necessarily produce desirable progenies when used in hybrid development. It is therefore, necessary to identify promising line based on combining abilities combinations using appropriate mating design. There is a need to search for the divergent line in the cotton with superior combining abilities. The choice of suitable parents for the development of desired hybrid depends on the selection of parents based on combining ability. This necessitates the study of combining ability effects of crosses for the selection of superior parents and hybrids. To study the combining ability of a number of parents, Line x Tester analysis is the most appropriate procedure. The Line x Tester analysis is one of the simplest and efficient methods of evaluating large number of inbreds/parents for their combining ability. Based on the information from Line x Tester analysis production of commercially viable hybrid is possible. The purposes of this research were to estimate the GCA and SCA effects for yield, its components and fibre quality traits.

Material and Methods
Twenty four GMS based American cotton hybrids, developed during *kharif* 2017 by using three lines and eight testers in line x tester mating design along with one standard check (GN.Cot.Hy-14) constituted the present experiment material. The experiment was conducted in a RBD with three replications at Main Cotton Research Station, Athwa farm, N.A.U, Surat. Each entry was planted in a single row of 4.5 m length spaced at 1.20 m apart. Plant to plant distances was 45 cm. Hand emasculation was followed for crossing work. Data was collected on 5 randomly selected plants in each replication on thirteen characters *viz.*, Days to 50 per cent flowering, plant height, sympodia per plant, bolls per plant, boll weight (g), seed cotton yield per plant (g), seed index (g), ginning outturn (%), 2.5 per cent span length, fibre fineness and fibre strength. General combining ability and specific combining ability variances were estimated with method suggested by Kempthorne (1957) [6] for Line x Tester analysis.

Results and Discussion
Analysis of variances for combining ability revealed that general combining ability (GCA) variances were significant for days to 50 per cent flowering, sympodia per plant, bolls per plant, boll weight, seed cotton yield per plant, ginning outturn and fibre length (Table 1).

On the other hand, specific combining ability variances were significant for plant height, bolls per plant, fibre length and fibre strength. The estimates of components of variances (GCA and SCA) and their ratio (σ^2gca/ σ^2sca) indicated that both additive and non additive variances were important in inheritance of characters. Significance of both the variances had been reported by Swetha *et al*. (2018) [11], Dhamyanthi and Rathinavel (2017) [3], Kannan and Saravanan (2016) [5], Solanki *et al*. (2015) [10], Dave *et al*. (2015) [2], Pandit *et al*. (2014) [8].

General combining ability effects

An overall appraisal of GCA effects (Table 2) revealed that among females, GMS Gregg was found to be good general combiner for boll weight and fibre strength (Balakrishna *et al.*, 2017) [1] while female parent S-D-2 was found to be good general combiner for the traits like days to 50 per cent flowering, seed cotton yield per plant, fibre length and G(T)-84 was found good combiner for sympodia per plant and bolls per plant. (Dhamyanthi and Rathinavel, 2017, Balakrishna *et al.*, 2017) [3, 1]. Thus, different parents according to its transmitting ability may be useful in future breeding programme as parent to combine the yield and its attributes in hybrid. Among male parents, TCH 1716 was noticed to be good general combiner for bolls per plant, seed cotton yield per plant and fibre length while TCH 321 was noticed to be good general combiner for bolls per plant, seed cotton yield per plant and ginning outturn. (Kumar *et al.*, 2017, Dhamyanthi and Rathinavel, 2017) [9, 3].

For the most important economic character seed cotton yield per plant and yield attributing characters bolls per plant, four parents *viz.*, G(T)-84, TCH 1716, CCH 15-1 and TCH 321 recorded positive significant GCA effects. Whereas for boll weight, only one parent GMS Gregg observed good general combiner. This parents can be used in future breeding programme for improving seed cotton yield of cotton. In respect of yield attributing traits for ginning outturn two parents observed good general combiners *viz.*, BGDS 1033 and TCH 321.

Considering the fiber quality traits, parents S-D-2 and TCH 1716 noticed good general combiners for 2.5 per cent span length. While for fibre fineness, none of the parents were noticed to be a good general combiners. Considering the fiber strength, parents GMS Gregg, Suraj and RAH 1069 were observed to be a good general combiner. So looking to the overall position the above parents may improve fiber quality of cotton as parents. Hence, it can be used in future breeding programme for quality improvement. In the present study, the GCA effects of parents were not positively and significantly associated with their mean values for majority of characters. However, this was not true for all the characters in all the cases, suggesting that inter allelic interaction were important for these complementary epistatic effects. A close relationship between parents, *per se* performance and their GCA effects is important in the choice of parents for crossing programme.

Specific combining ability effects

Based on estimation of SCA effects, the crosses S-D-2 x CCH 15-1 and GMS Gregg x CPD 1501 exhibited high SCA effects for seed cotton yield per plant (Table 3). So, both the hybrids may be useful for release after multilocation testing. In case of 50 per cent flowering cross S-D-2 x TCH 321observed promising as it possessed significant SCA effects. In respect to plant height, many of the crosses showed positive effects but none were significant for SCA effect. While in case of most important yield attributing traits *i.e.* number of bolls per plant, crosses GMS Gregg x CPD 1501, S-D-2 x CCH 15-1 and G(T)-84 x TCH 1824 had registered significant and positive SCA effects which also reflected in seed cotton yield. Thus, they showed direct relationship with seed cotton yield and number of bolls per plant.

Considering the fiber quality, top two ranking crosses *viz.*, GMS Gregg x TCH 1716 and G(T)-84 x TCH 1824 exhibited high and positive SCA effects for 2.5 per cent span length. While GMS Gregg x RAH 1069, G(T)-84 x CPD 1501 and S-D-2 x TCH 321 exhibited high and positive SCA effects for fiber strength. But none of the crosses registered significant and negative SCA effects in desired direction for fiber fineness.

Table 1: Mean squares due to general and specific combining ability for different characters in cotton (*G. hirsutum* L.)

Sources of variation	d.f	DF	PH	SPP	BPP	BW	SCYP
Replications	2	1.46	58.90	6.66*	7.15	0.33	114.02
Crosses	23	23.01**	87.19	3.35*	24.38**	0.32*	31.67
Line effect	2	51.99*	120.79	17.16**	67.65	1.20*	8.48
Tester effect	7	42.49**	37.49	2.20	23.51	0.28	85.48**
Error	46	5.39	60.97	1.85	5.99	0.16	102.64
σ^2gca		2.47**	1.43	0.47**	2.48*	0.03**	2.43**
σ^2sca		0.88	17.24*	0.02	4.67**	0.02	26.38
σ^2gca / σ^2sca		2.80	0.08	23.50	0.53	1.50	0.09

*, ** significant at 5% and 1 % levels of probability, respectively

Table 1: Cont…

Sources of variation	d.f	SI	GO	SL	FF	FS
Replications	2	14.42**	8.34	99.03**	54.00**	68.35**
Crosses	23	0.85	7.22*	3.90**	0.38	6.87**
Line effect	2	1.60	3.63	7.28	0.23	11.19
Tester effect	7	0.55	16.58**	5.77	0.30	5.25
Error	46	0.59	3.50	1.01	0.26	0.39
σ^2gca		0.03	0.44**	0.33**	0.00	0.47
σ^2sca		0.12	0.08	0.49*	0.06	2.23**
σ^2gca / σ^2sca		0.25	5.5	0.67	0.00	0.21

*, ** significant at 5% and 1 % levels of probability, respectively

DF	= Days to 50 per cent flowering	SI	=	Seed index (g)
PH	= Plant height (cm)	GO	=	Ginning outturn (%)
SPP	= Sympodia per plant	SL	=	2.5 per cent Span length (mm)
BPP	= Bolls per plant	FF	=	Fibre fineness (mv)
BW	= Boll weight (g)	FS	=	Fibre strength (g/tex)
SCYP	= Seed cotton yield per plant (g)			

Table 2: Estimation of GCA effects of parents for various characters in cotton (*G. hirsutum* L.)

Parents	DF	PH	SPP	BPP	BW	SCYP	SI	GO	FL	FF	FS
Lines											
GMS Gregg	0.19	-2.58	-0.88**	-1.78**	0.23**	-0.45	-0.28	-0.44	-0.03	0.06	0.74**
S-D-2	1.36*	1.41	0.07	0.23	-0.03	0.67*	0.20	0.22	0.56**	0.05	-0.59**
G(T)-84	-1.55**	1.17	0.80**	1.55**	-0.20*	-0.22	0.08	0.22	-0.53*	-0.11	-0.14
S. E. (g_i)	0.51	1.52	0.27	0.43	0.07	0.30	0.14	0.34	0.20	0.10	0.12
Testers											

BGDS 1033	0.29	2.08	0.52	-1.32	0.12	-0.02	-0.11	1.66**	-0.41	-0.22	-0.07
CPD 1501	-2.43**	-0.19	-0.37	-1.23	0.07	-1.46	0.10	0.06	-0.88*	0.03	-0.13
TCH 1716	2.58**	-0.12	0.20	1.00*	0.18	6.03**	0.24	-1.60**	1.38**	-0.22	-1.37**
TCH 1824	2.63**	3.10	0.81	0.05	-0.22	-3.85*	-0.17	-2.23**	-0.38	0.00	-0.17
CCH 15-1	-1.21	1.08	-0.03	0.80*	-0.17	-1.52	-0.19	0.90	0.45	-0.09	0.29
Suraj	0.27	-1.87	-0.70	0.49	-0.11	-1.07	-0.28	0.41	0.55	0.23	1.22 **
RAH 1069	-3.25**	-3.05	-0.29	-2.45**	0.24	-1.02	0.43	-0.38	0.25	0.03	0.62**
TCH 321	1.11	-1.02	-0.13	2.65**	-0.10	2.92*	-0.00	1.18*	-0.95**	0.23	-0.39
S. E. (g_i)	0.84	2.48	0.45	0.40	0.12	1.40	0.24	0.55	0.33	0.16	0.19

*, ** significant at 5% and 1 % levels of probability, respectively

DF	=	Days to 50 per cent flowering	SI	=	Seed index (g)
PH	=	Plant height (cm)	GO	=	Ginning outturn (%)
SPP	=	Sympodia per plant	SL	=	2.5 per cent Span length (mm)
BPP	=	Bolls per plant	FF	=	Fibre fineness (mv)
BW	=	Boll weight (g)	FS	=	Fibre strength (g/tex)
SCYP	=	Seed cotton yield per plant (g)			

Table 3: Estimation of SCA effects of hybrids for various characters in cotton (*G. hirsutum* L.)

Sr. No.	Crosses	DF	PH	SPP	BPP	BW	SCYP	SI	GO	FL	FF	FS
1.	GMS Gregg x BGDS 1033	-0.61	-1.21	-0.68	-0.35	-0.12	-1.60	0.01	0.15	0.56	0.10	0.65
2.	GMS Gregg x CPD 1501	0.51	-0.90	-0.40	-0.10	0.11	1.34*	-0.37	-1.01	-0.36	0.43	-1.37**
3.	GMS Gregg x TCH 1716	-1.10	-4.08	0.44	4.98**	-0.39	-0.49	-0.58	-1.72	1.46*	-0.39	-0.14
4.	GMS Gregg x TCH 1824	2.18	1.27	-0.66	0.00	0.01	0.89	0.23	0.41	-1.16*	0.07	1.15**
5.	GMS Gregg x CCH 15-1	0.23	0.77	-0.22	-1.88	0.23	-1.27	-0.14	0.80	0.50	-0.52	-0.11
6.	GMS Gregg x Suraj	-0.12	-3.58	0.44	-0.90	0.13	0.78	0.17	0.23	-0.2	0.33	-1.14**
7.	GMS Gregg x RAH 1069	-1.99	0.90	1.45	0.71	-0.11	-0.10	-0.21	0.58	0.00	-0.16	2.45**
8.	GMS Gregg x TCH 321	0.89	6.82	-0.36	-2.46	0.13	0.45	0.90*	0.54	-0.80	0.13	-1.48**
9.	S-D-2 x BGDS 1033	1.01	5.62	0.50	-1.43	0.35	1.10	-0.65	0.63	0.56	-0.18	0.99**
10.	S-D-2 x CPD 1501	0.07	5.24	-0.87	-0.52	-0.01	-1.78	0.29	0.08	0.43	0.05	-0.83*
11.	S-D-2 x TCH 1716	0.98	-2.88	-0.10	-1.56	0.12	0.71	0.31	-0.08	-1.03	0.01	0.69*
12.	S-D-2 x TCH 1824	-0.78	2.20	0.72	1.98	-0.30	-2.06	-0.26	-0.21	-0.26	0.08	-0.10
13.	S-D-2 x CCH 15-1	0.38	3.74	0.63	0.56	0.04	3.43*	0.09	0.28	-0.50	0.48	-0.76*
14.	S-D-2 x Suraj	1.36	-2.99	-0.10	-0.58	0.08	-0.84	0.34	-0.03	-0.30	0.05	0.79*
15.	S-D-2 x RAH 1069	0.50	-8.66 *	-1.02	1.90	-0.22	0.43	0.62	-1.01	0.20	-0.35	-2.10**
16.	S-D-2 x TCH 321	-3.54 *	-2.28	0.24	-0.34	-0.07	-1.00	-0.76	0.35	0.90	-0.15	1.31**
17.	G(T)-84 x BGDS 1033	-0.39	-4.41	0.17	1.78	-0.23	0.50	0.64	-0.78	-1.13	0.07	-1.65**
18.	G(T)-84 x CPD 1501	-0.59	-4.34	1.27	0.62	-0.09	0.44	0.08	0.93	-0.06	-0.48	2.21**
19.	G(T)-84 x TCH 1716	0.11	6.97	-0.34	-3.41**	0.26	-0.22	0.27	1.80	-0.43	0.37	-0.55
20.	G(T)-84 x TCH 1824	-1.39	-3.48	-0.05	-1.99	0.28	1.16*	0.03	-0.20	1.43*	-0.15	-1.05**
21.	G(T)-84 x CCH 15-1	-0.61	-4.52	-0.40	1.31	-0.27	-2.16	0.04	-1.08	0.00	0.04	0.88*
22.	G(T)-84 x Suraj	-1.24	6.57	-0.33	1.49	-0.21	0.05	-0.52	-0.19	0.50	-0.38	0.34
23.	G(T)-84 x RAH 1069	1.49	7.75	-0.43	-2.61*	0.33	-0.33	-0.41	0.43	-0.20	0.51	-0.35
24.	G(T)-84 x TCH 321	2.64	-4.54	0.12	2.80*	-0.06	0.55	-0.13	-0.90	-0.10	0.01	0.16
	S.E. S_{ij} ±	1.46	4.30	0.79	1.24	0.22	0.57	0.42	0.96	0.57	0.29	0.34

*, ** significant at 5% and 1 % levels of probability, respectively

DF	=	Days to 50 per cent flowering	SI	=	Seed index (g)
PH	=	Plant height (cm)	GO	=	Ginning outturn (%)
SPP	=	Sympodia per plant	SL	=	2.5 per cent Span length (mm)
BPP	=	Bolls per plant	FF	=	Fibre fineness (mv)
BW	=	Boll weight (g)	FS	=	Fibre strength (g/tex)
SCYP	=	Seed cotton yield per plant (g)			

Conclusion

The good general combining parents when crossed do not always result into crosses having high SCA effects. Similar results have been reported by Lanjewar *et al.* (2017) [7], Shivakumar *et al.* (2017) [9] and Jayade *et al.* (2013) [4]. By studying the parents, general combiners and specific cross combinations it was revealed that good x good, good x poor, poor x good, poor x poor and good x average combinations produced high performing crosses and could be exploited for practical breeding which is expected to throw stable performing transgressive segregants carrying fixable genes. The SCA effects represent dominance and epistatic effects and can be related to heterosis.

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