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Combining Ability and Gene Action Studies in New Intra Hirsutum Hybrids with Suggested Breeding Strategies

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A B S T R A C T

The prime objective of any plant breeder is developing new cultivars with high yield. The present investigation aimed at estimating the general combining ability among parents and specific combining ability in hybrids for various yield and related traits in upland cotton. Forty hybrids were obtained by crossing 8 elite lines with 5 selected testers in a Line × Tester fashion. All 40 hybrids, 13 parents along with 3 checks were evaluated under rainfed condition during *kharif* 2017-18at Agriculture Research Station, Dharwad Farm. Analysis of variance showed significant differences among parents and hybrids for most characters indicating presence of genetic variability. The ratio between variance due to GCA to that of SCA was less than unity for all characters indicating preponderance of non-additive gene effects in the inheritance of characters. Among lines, FLT-36, CPD-462 and among testers, SCS-1061, registered significant positive *gca* effects for seed cotton yield. Cross CPD-462 × SCS-1061 recorded high seed cotton yield with positive significant *sca* effects.

Introduction

Cotton (*Gossypium spp*.) is a crop of prosperity having influence on man and matter and is called the 'King of fibre'. It is also rightly called as 'White Gold'. Cotton is one of the most important commercial crops and forms the back bone of Indian textile industry. India has the largest area under cotton (122.38 lakh ha) and is one of the largest producers (361.00 lakh bales) with productivity of501kg ha^{-1} (Anon., 2019).

Cotton breeding mainly focus on development of cultivars with early maturity, high seed cotton yield, combined with good fibre properties. To combine all these traits there is a need to identify suitable genotypes to be used in crossing programs to generate populations. Combining ability aids in the elucidation of nature and magnitude of gene action leading to selection of parents. The concept of combining ability was introduced by Sprague and Tatum (1942). General combining ability (*gca*) is average performance of a parent in a series of crosses and specific combining ability (*sca*) designates those cases in which certain combinations perform relatively better or worse than would be expected on the basis of average performance of lines involved. Though the *per se* performance of parents is very important, selection on the basis of combining ability effects is a more robust procedure.

Kempthorne (1957) introduced the Line × Tester analysis method which provides valuable information about general and specific combining ability variances, their effects thus helping in identification of good general combiners and specific promising cross combinations (Muthuswamy *et al.,* 2003).

Materials and Methods

The genetic material for present investigation consisted of 40 hybrids which were obtained by crossing the eight elite lines*viz.*,FLT-36, FLT-44, FLT-31, FLT-28, SG-1, SG-2, EL-4, CPD-462 with the five testers *viz.*, NNDC-30, NNDC-24, NNDC-59, IH-11 and SCS-1061 in L × T fashion along with three standard checks *viz.*, DHH-11, DHH-263 and Ajeet-199 Bt. All the above genotypes were never used in any hybridisation activity till now. Additionally, the genotypes were carefully chosen to represent diversity in plant type features also of which two traits, plant height and sympodial length, were dealt with in the present study. This investigation was carried out in Agricultural Research Station, Dharwad Farm during *kharif 2017*. The genetic material was laid out in a randomized block design with three replications. The spacing of 90 cm between the rows and 60 cm between plants within row for hybrids and 90 cm between the rows and 20 cm between plants for parents was followed. The hybrids and parents were randomised amongst themselves and were sown in separate but adjacent plots. Each entry was sown in two rows of 4.80 meters length. The crop was raised under rainfed condition. All agronomic management practices according to recommended package of practices were followed to raise a good crop. Suitable plant protection measures were carried out to control pests and diseases at appropriate time.

Results and Discussion

The analysis of variance (Table 1) revealed that there were significant differences among the genotypes for all thirteen characters investigated. The mean sum of squares for parents was significant for most of the characters except for number of seeds per boll, ginning outturn, lint index, sympodial length at 50 per cent plant height and SPAD values. The lines showed significant differences for most traits except for number of seeds per boll, ginning outturn, lint index and sympodial length at 50 per cent plant height and SPAD values.

Among the testers, significant differences were observed for number of monopodia, seed cotton yield, number of seeds per boll and ginning outturn. The interaction between lines and testers was significant for plant height, number of monopodia per plant, number of sympodia per plant and number of bolls per plant. The interaction between parents and hybrids was found to be significant for all traits except for SPAD values.

Table.1 Analysis of variance for yield and yield component characters in cotton (*G. hirsutum* L.)

Source of variation	df	DFF	PH	NMP	NSP	SL@50%	NBP	BW	NSP	SI	GOT	LI	SPAD	SCY
Replication	2	0.23	12.61	0.06	0.86	20.42	2.10	0.36	4.92	0.54	2.39	0.83	1.51	20500.67
Treatments	52	4.20**	428.11**	0.54**	4.30**	65.01**	40.73**	0.43**	7.93**	1.30**	10.01 **	1.06**	4.70**	190320.30**
Parents	12	4.07 *	474.18**	0.43**	8.31**	35.83	6.35**	0.31**	6.41	0.97**	8.74	0.46	4.80	61995.08**
Lines	7	5.22 **	472.28**	0.45**	11.05**	28.63	3.83*	0.41**	1.89	1.10*	2.34	0.10	5.03	59678.24*
Testers	4	1.99	95.36	0.44**	0.59	45.60	3.11	0.13	12.66**	0.86	19.73**	0.87	5.36	76341.59*
Lines *vs.* Testers	1	4.31	2002.82**	0.31**	19.94**	47.18	36.92**	0.29	13.10	0.46	9.62	1.28	0.95	20826.92
Parents *vs.* Crosses	1	17.18**	4151.20**	7.34**	60.64**	1073.87**	1430.07**	4.48**	96.96**	7.45**	120.04**	19.45**	0.49	701120.00**
Crosses	39	3.91**	318.47**	0.40**	1.62	48.12*	15.69**	0.36**	6.11*	1.25**	7.57	0.78 *	4.78*	165425.50**
Error	104	1.75	78.25	0.03	1.68	29.20	1.62	0.13	3.60	0.40	5.26	0.48	2.68	23666.29

Table.2 Analysis of variance for combining ability

Genetic Parameter	DFF	PH	NMP	NSP	SL@50%	NBP	BW	NSP	SI	GOT	LI	SPAD	SCY
σ^2 GCA	0.02	8.80	0.01	0.016	2.04	1.30	0.01	0.11	0.05	0.19	0.01	0.23	110.94
σ^2 SCA	1.16	79.87	0.11	0.019	5.72	2.34	0.06	0.48	0.20	1.02	0.16	0.25	44242.05
σ^2 GCA/σ^2 SCA	0.018	0.110	0.144	0.853	0.358	0.556	0.160	0.231	0.265	0.185	0.045	0.929	0.003
Contribution (%) of Lines	9.22	24.56	25.68	23.56	24.53	55.72	23.69	27.19	33.49	31.54	12.12	40.69	27.37
Contribution (%) of Testers	3.55	2.44	4.70	9.169	13.39	3.80	6.78	5.97	5.60	2.50	7.01	7.82	3.55
Contribution (%) of Line ×Tester	87.21	79.92	69.31	67.26	62.06	40.47	69.51	68.83	60.89	65.94	80.86	51.48	69.06

where, DFF= days to 50 per cent flowering, PH= plant height (cm), NMP= number of monopodia per plant, NSP= number of sympodia per plant, SL@50%= sympodial length at 50 per cent plant height(cm), NBP= number of bolls per plant, BW= boll weight(g), NSP= number of seeds per plant, SI= seed index (g), GOT= ginning outturn (g), LI= lint index (g), SPAD = Soil Plant Analysis Development meter values, SCY= Seed cotton yield (kg/ha)

Table.3 General combining ability of parents in Line × Tester analysis in cotton (*G. hirsutum* L.)

Parents	Days to 50% flowering	Plant height (cm)	Number of monopodia per plant	Number of sympodia per plant	Sympodial length at 50% plant height (cm)	Number of bolls per plant	Boll weight (g)	Number of seeds per boll
Lines								
FLT-36	-0.67*	-3.34	0.20**	0.42	1.76	3.79**	0.18	-0.73
FLT-44	-0.01	-6.58**	-0.16**	0.51	1.20	0.34	-0.19	-0.63
FLT-31	0.19	-1.24	0.20**	-0.00	-0.78	0.06	0.23*	-1.16*
FLT-28	0.49	3.23	0.093	0.08	2.99*	-0.73*	-0.22*	0.22
SG-1	0.13	0.39	0.00	-0.47	-0.86	-2.42**	-0.17	0.70
SG-2	0.27	11.36**	-0.33**	0.20	1.04	-1.29**	-0.01	1.09*
EL-4	-0.29	-2.25	-0.14**	-0.38	-2.23	0.38	0.09	0.52
CPD-462	-0.12	-1.56	0.14**	-0.36	-3.12*	-0.14	0.08	-0.03
S.Ed	0.29	2.36	0.04	0.441	1.27	0.34	0.09	0.53
CD at 5%	0.57	4.71	0.09	0.87	2.54	0.68	0.19	1.05
Testers								
NNDC-30	0.02	0.28	-0.03	0.01	2.06*	0.65*	0.02	-0.13
NNDC-24	-0.13	0.31	-0.08*	0.32	1.25	0.23	0.15*	-0.03
NNDC-59	-0.22	1.48	0.03	0.03	-0.40	-0.49	-0.02	-0.44
IH-11	0.39	-3.05	0.13**	-0.37	-1.81	0.08	-0.11	-0.01
SCS-1061	-0.06	0.97	-0.04	0.01	-1.10	-0.48	-0.04	0.61
S.Ed	0.22	1.87	0.03	0.34	1.00	0.27	0.07	0.42
CD at 5%	0.45	3.72	0.07	0.69	2.00	0.54	0.15	0.83

Table 3. Contd…..

Parents	Seed index (g)	Ginning outturn (%)	Lint index (g)	SPAD meter value	Seed cotton yield (kg/ha)	UHML (mm)	Fibre strength (g/tex)	Micronaire (µg/inch)
Lines								
FLT-36	-0.29	0.61	-0.02	1.25**	248.63**	-0.64	0.11	0.05
FLT-44	-0.34*	1.54**	0.20	0.35	-76.17	0.07	0.53	0.01
FLT-31	0.13	0.08	0.12	0.46	-109.50*	0.69	1.25	0.05
FLT-28	-0.08	-0.50	-0.19	-0.14	-90.30*	0.69	0.33	-0.14
SG-1	0.01	-1.20*	-0.32*	-1.01*	-68.88	-0.70	-1.42	-0.09
SG-2	0.89**	-1.22*	0.20	-1.32**	-48.50	-0.02	-1.06	0.16
EL-4	-0.16	0.38	0.01	0.56	-6.43	0.13	0.21	-0.03
CPD-462	-0.16	0.30	-0.02	-0.14	151.16**	-0.20	0.03	-0.01
S.Ed	0.17	0.50	0.16	0.40	41.95			
CD at 5%	0.34	1.01	0.31	0.80	83.53			
Testers								
NNDC-30	-0.07	-0.09	-0.08	-0.39	-16.55	-0.10	-0.35	-0.08
NNDC-24	-0.14	-0.22	-0.16	-0.01	34.03	-0.16	-0.55	0.08
NNDC-59	0.01	-0.24	-0.04	-0.37	-49.52	0.09	0.18	0.01
IH-11	0.28*	0.16	0.22	0.32	-34.78	0.01	0.37	-0.07
SCS-1061	-0.07	0.39	0.06	0.45	66.83*	0.16	0.35	0.06
S.Ed	0.13	0.40	0.12	0.32	33.17			
CD at 5%	0.27	0.80	0.25	0.63	66.04			

*, ** significant at 5 and 1 per cent respectively

Table.4 Specific combining ability effects of intra hirsutum hybrids for yield and yield component characters

Cross	Days to 50% flowering	Plant height (cm)	Number of monopodia per plant	Number of sympodia per plant	Sympodial length at 50% plant height (cm)	Boll weight (g)	Number of bolls per plant	Number of seeds per boll
FLT-36 × NNDC-30	-2.50**	4.73	0.11	0.14	3.15	0.40	-2.47**	0.54
FLT-36 × NNDC-24	1.69*	5.49	-0.36**	0.30	3.29	-0.27	1.07	-0.48
FLT-36 × NNDC-59	1.01	-9.60	0.50**	-0.07	-1.03	-0.22	2.24**	0.49
FLT-36 × IH-11	-0.67	-4.53	-0.18	0.53	-2.63	0.13	-0.31	1.74
FLT-36 × SCS-1061	0.47	3.90	-0.07	-0.91	-2.78	-0.04	-0.53	-2.30
FLT-44 × NNDC-30	-0.68	2.77	-0.19	0.05	0.60	0.05	-0.29	0.41
FLT-44 × NNDC-24	0.17	-11.62*	0.06	-1.25	-5.75*	-0.01	0.43	-0.18
FLT-44 × NNDC-59	0.60	-12.22*	0.13	0.63	-4.74	-0.35	1.71*	0.09
FLT-44 × IH-11	0.46	9.31	0.17	-0.16	4.01	0.11	-1.86*	0.74
FLT-44 × SCS-1061	-0.56	11.75*	-0.17	0.72	5.88*	0.20	0.00	-1.06
FLT-31 × NNDC-30	1.59*	1.97	0.51**	-0.16	-0.02	-0.06	1.82*	-0.58
FLT-31 × NNDC-24	-1.69*	6.26	0.43**	0.73	4.52	0.09	-0.68	-0.68
FLT-31 × NNDC-59	0.29	2.70	-0.35**	-1.24	-1.85	0.41	1.01	-0.31
FLT-31 × IH-11	-0.36	-9.22	-0.65**	0.62	-1.73	-0.32	-0.88	0.98
FLT-31 × SCS-1061	0.16	-1.71	0.06	0.04	-0.93	-0.11	-1.27	0.59
FLT-28 × NNDC-30	-1.07	-22.17**	-0.17	0.14	-0.86	-0.14	3.24**	-2.14
FLT-28 × NNDC-24	-0.14	8.38	-0.19	0.03	3.17	0.33	-0.86	1.35
FLT-28 × NNDC-59	1.98**	6.89	-0.11	-0.33	1.73	0.00	-1.29	0.06
FLT-28 × IH-11	-0.25	1.89	0.78**	0.46	-3.12	-0.10	-0.16	0.92
FLT-28 × SCS-1061	-0.50	5.00	-0.29**	-0.31	-0.92	-0.07	-0.92	-0.19
SG-1 × NNDC-30	1.79**	14.59**	-0.08	0.90	-2.67	-0.49*	-1.84*	-1.15
SG-1 × NNDC-24	-0.12	0.09	0.10	-0.86	0.13	0.20	1.84*	0.40
SG-1 × NNDC-59	-1.80**	-10.60*	-0.02	-0.24	-0.54	-0.31	-1.42	0.85
SG-1 × IH-11	-1.12	-6.80	0.04	-0.24	1.87	-0.21	0.83	-0.89
SG-1 × SCS-1061	1.25	2.70	-0.03	0.44	1.21	0.81**	0.59	0.79
SG-2 × NNDC-30	0.47	-7.57	-0.41**	-1.17	0.08	0.05	0.43	1.08

SG-2 × NNDC-24	0.10	-6.21	0.63**	0.71	-5.88*	-0.07	1.79*	-0.51
SG-2 × NNDC-59	-0.16	3.29	-0.22*	0.61	6.77*	-0.26	0.20	-1.50
SG-2 × IH-11	0.54	10.75*	-0.25*	0.07	-2.27	0.51*	-0.16	-1.44
SG-2 × SCS-1061	-0.96	-0.26	0.26*	-0.23	1.30	-0.23	-2.26**	2.37*
EL-4 × NNDC-30	1.01	8.57	0.33**	0.01	3.25	-0.22	-0.30	2.68*
EL-4 × NNDC-24	0.79	-5.32	-0.48**	0.57	1.45	-0.15	-2.24**	0.58
EL-4 × NNDC-59	-1.18	-2.35	0.05	-0.53	-4.84	0.51*	-1.16	-0.17
EL-4 × IH-11	-0.79	3.90	-0.10	-0.53	3.51	0.19	1.59*	-1.21
EL-4 × SCS-1061	0.17	-4.79	0.20	0.48	-3.36	-0.31	2.12**	-1.89
CPD-462 × NNDC-30	-0.60	-2.90	-0.09	0.06	-3.52	0.41	-0.58	-0.85
CPD-462 × NNDC-24	-0.82	2.92	-0.18	-0.24	-0.93	-0.10	-1.34	-0.48
CPD-462 × NNDC-59	-0.73	21.89**	0.02	1.18	4.50	0.23	-1.30	0.49
CPD-462 × IH-11	2.20**	-5.30	0.19	-0.75	0.36	-0.30	0.95	-0.85
CPD-462 × SCS-1061	-0.04	-16.59**	0.04	-0.25	-0.41	-0.23	2.28**	1.69
S.Ed	0.64	5.29	0.10	0.69	2.85	0.22	0.77	1.18
CD at 5%	1.29	10.54	0.21	1.38	5.68	0.44	1.54	2.36

Table.4 Contd…..

Cross	Seed index (g)	Ginning outturn (%)	Lint index (g)	SPAD meter value	Seed cotton yield (kg/ha)	UHML (mm)	Fibre strength (g/tex)	Micronaire (µg/inch)
FLT-36 × NNDC-30	0.25	-1.04	-0.12	-1.05	-15.44	0.72	-0.57	0.06
FLT-36 × NNDC-24	-1.07**	0.77	-0.48	0.83	-45.53	-0.60	-0.69	0.46
FLT-36 × NNDC-59	0.34	0.06	0.21	0.07	46.85	1.28	0.90	-0.06
FLT-36 × IH-11	0.18	-1.52	-0.32	1.20	-3.38	-1.32	-3.09	-0.31
FLT-36 × SCS-1061	0.31	1.73	0.71	-1.05	17.49	0.18	0.18	0.14
FLT-44 ×NNDC-30	0.41	0.29	0.35	0.85	-70.14	-0.30	0.02	-0.17
FLT-44 × NNDC-24	0.42	0.96	0.55	1.24	122.93	0.14	2.54	-0.43
FLT-44 × NNDC-59	-0.57	1.03	-0.10	-0.73	145.32	-0.12	0.72	0.31
FLT-44 × IH-11	0.18	-1.22	-0.22	-1.93*	-120.58	-2.12	-0.67	-0.07
FLT-44 ×SCS-1061	-0.44	-1.08	-0.59	0.58	-77.53	1.57	1.92	-0.17
FLT-31 × NNDC-30	0.05	1.15	0.34	-1.14	-126.81	-0.06	0.20	0.02

FLT-31 × NNDC-24	0.32	-0.16	0.12	0.85	-16.89	0.75	1.82	-0.02
FLT-31 × NNDC-59	-0.26	-2.58*	-0.86*	-0.68	376.65**	1.05	-1.83	-0.05
FLT-31 × IH-11	-0.43	1.46	0.17	0.24	88.58	1.27	2.72	-0.11
FLT-31 × SCS-1061	0.32	0.13	0.24	0.73	-321.53**	-2.00	-4.77	0.27
FLT-28 ×NNDC-30	-0.93*	2.47*	0.10	0.97	301.32**	-0.46	0.62	0.14
FLT-28 × NNDC-24	0.47	-1.92	-0.22	-1.71	-20.93	0.92	1.40	-0.21
FLT-28 × NNDC-59	0.61	0.02	0.39	-0.22	-152.87	-1.40	-1.72	0.20
FLT-28 × IH-11	-0.07	-0.91	-0.30	0.62	-109.44	-0.72	-0.74	0.27
FLT-28 × SCS-1061	-0.07	0.34	0.04	0.35	-18.07	0.48	0.18	-0.18
SG-1 × NNDC-30	0.26	0.20	0.15	0.15	-163.60	0.18	1.34	0.00
SG-1 × NNDC-24	0.11	1.08	0.37	-0.60	239.51*	-0.10	-0.62	0.16
SG-1 × NNDC-59	-0.42	-1.81	-0.68	0.68	-142.04	1.24	1.10	-0.11
SG-1 × IH-11	-0.52	0.49	-0.19	0.59	118.96	-0.62	-0.92	-0.14
SG-1 × SCS-1061	0.57	0.01	0.35	-0.82	-52.82	0.51	1.01	0.08
SG-2 × NNDC-30	-0.46	-0.10	-0.32	-0.11	99.35	0.19	0.19	-0.30
SG-2 × NNDC-24	-0.82*	0.79	-0.26	-0.24	144.10	-1.03	-0.83	0.22
SG-2×NNDC-59	-0.07	0.20	-0.04	0.94	-206.17*	-0.13	0.89	0.15
SG-2 × IH-11	1.47**	1.44	1.33**	0.55	56.08	-1.03	-0.85	-0.04
SG-2 × SCS-1061	-0.12	-2.34*	-0.71	-1.14	-93.37	-1.51	-2.51	0.15
EL-4 × NNDC-30	-0.18	-2.79*	-0.83*	0.82	-180.21	0.93	0.71	0.07
EL-4 × NNDC-24	0.11	-0.90	-0.18	-1.52	-127.96	2.07	1.39	-0.32
EL-4 × NNDC-59	0.53	1.02	0.61	0.81	164.75	-0.04	-1.18	0.14
EL-4 × IH-11	-0.54	1.42	0.02	-0.16	248.68**	0.24	0.30	-0.18
EL-4 × SCS-1061	0.07	1.25	0.39	0.06	-105.27	0.52	0.48	-0.44
CPD-462 ×NNDC-30	0.61	-0.18	0.33	-0.49	155.52	0.22	0.20	0.36
CPD-462 ×NNDC-24	0.47	-0.64	0.10	1.15	-295.23**	-0.38	1.16	-0.06
CPD-462 × NNDC-59	-0.16	2.04	0.48	-0.87	-232.50*	0.64	0.40	-0.03
CPD-462 ×IH-11	-0.28	-1.17	-0.49	-1.10	-278.91**	-0.32	0.42	0.20
CPD-462 × SCS-1061	-0.64	-0.05	-0.42	1.30	651.12**	-0.88	-1.80	0.01
S.Ed	0.38	1.14	0.36	0.91	93.82			
CD at 5%	0.77	2.27	0.71	1.81	186.79			

*, ** significant at 5 and 1 per cent respectively

The mean sum of squares with respect to hybrids was found to be significant for all traits except for number of sympodia per plant and ginning outturn. This depicted the presence of considerable genetic difference among the hybrids.

The results of ANOVA for combining ability are given in Table 2. The ratio between GCA variance to SCA variance was less than unity for all the traits investigated indicating predominance of non-additive gene action for all yield and its component traits. These results were in accordance with the earlier findings of Deshpande *et al.,* (2008), Basal *et al.,* (2011), Alkuddsi *et al.,* (2013)and Monicashree *et al.,* (2017).

The combining ability study revealed that among lines, FLT-36 was a good general combiner for number of bolls per plant and seed cotton yield, FLT-44was a good general combiner for ginning outturn and a negative general combiner for number of monopodia per plant and FLT-31 was a good general combiner for boll weight.

Among testers, NNDC-30 was a good general combiner for sympodial length at 50 per cent plant height and number of bolls per plant, NNDC-24 was a good general combiner for boll weight and SCS-1061 was a good general combinerfor seed cotton yield (Table 3). These parents can be utilized in crop improvement programs via multiple or strategic crossing schemes to develop high yielding varieties and also varieties that could fit in to high density planting. Less plant height, and sympodial length with fewer or no monopodia are traits which help in breeding compact genotypes to suit high density planting.

Among crosses,CPD-462 × SCS-1061, FLT-28 × NNDC-30, EL-4 × IH-11 had high *sca* effects for seed cotton yield, number of bolls per plant and ginning outturn (Table 4). Crosses which exhibited positive *sca* effects for different traits could be exploited in heterosis breeding.

Finally, the present study showed that combining ability of parents and hybrids is important in deciding the breeding strategy. Superior lines FLT-36, FLT-44, FLT-31, EL-1, CPD-462 and testers NNDC-30, IH-11 and SCS-1061 with high *gca* effects for yield and its components can be used in generating populations to extract new varieties. Also, ideotype considerations to breed genotypes for specific growing conditions have also been pointed out.

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