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Research Article

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

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Abstract
Forty five intra-hirsutum hybrids from a 10 × 10 diallel crossing excluding reciprocals along with their parents were evaluated for combining ability for seed cotton yield and its component traits in three environments during *kharif*, 2013-14. The pooled analysis of variance for combining ability revealed that, the variance due to SCA were higher than GCA variances for all the characters except for days to 50 per cent flowering and 2.5% span length indicating the predominance of non-additive gene action. The estimates of *gca* effects revealed that the parents NDLH 1938, RAH 1004 and L 770 were found to be best general combiners for yield and its component traits in desired direction. The crosses, NDLH 1938 × L 604, NDLH 1938 × RAH 1004 and NDLH 1938 × L 770, recorded high *per se* performance (202.18, 197.99 and 195.54 g) and significant positive *sca* effects (32.12, 22.82 and 19.46) for seed cotton yield plant^{-1}, respectively.

Key words
Combining ability, cotton, quality traits, seed cotton yield

Introduction

Cotton (*Gossypium* spp.) is the most important renewable natural fibre crop of global importance. In India, cotton is being grown over an area of 126.55 lakh ha with an annual production of 400 lakh bales (1 bale=170 kgs of lint) with a productivity of 537 kg lint / ha (AICCIP Annual Report, 2014-15). For developing potential hybrids in cotton, it is necessary to exploit the hybrid vigour available in cotton. The first step in a successful breeding programme is to select appropriate parents. There are several techniques for the evaluation of the genetic makeup of genotypes and diallel analysis is the one which is commonly being used. Combining ability analysis helps in identifying the parents with high general combining ability (GCA) and parental combinations with high specific combining ability (SCA) effects. The present experiment was carried out with an objective of finding out the combining ability of parents for seed cotton yield and yield attributes in three environments.

Materials and methods

The present investigation was carried out with the ten parents *viz.*, NDLH 1938, L 788, L 770, NA 1325, L604, SURABHI, RAH 1004, HYPS 152, MCU 5 and G COT 16 and forty five intra-specific cross combinations were made in diallel fashion without reciprocals. The evaluation of hybrids along with parents was done at three locations *i.e.*, Regional Agricultural Research Station, Lam Farm, Guntur, Agricultural Research Station, Jangamaheswarapuram and Agricultural Research Station, Darsi during *kharif*, 2013-14. Each entry was represented by following 120 x 60 cm spacing with 3 rows for each entry with a row length of 6 m. Recommended doses of fertilizers 120 N, 60 P_2O_5 and 40 K_2O kg/ha were applied in split doses. Observations were recorded on five randomly selected plants from each genotype per replication for the characters *viz*., plant height (cm), number of monopodia plant^{-1}, number of sympodia plant^{-1}, number of bolls plant^{-1}, boll weight (g), chlorophyll content (mg g^{-1} fresh weight), seed index (g), lint index (g), seed cotton yield plant^{-1} (g) and lint yield plant^{-1} (g). The data on days to 50% flowering, ginning out turn (%), 2.5% span length (mm), micronaire value (10^{-6}g/inch), bundle strength (g/tex), uniformity ratio and elongation (%) were recorded on plot basis. The fibre quality parameters were studied at Central Institute for Research on Cotton Technology (CIRCOT), RARS, Lam, Guntur, Andhra Pradesh by using HVT Expert 1201 high volume fibre tester instrument. The data was statistically analysed by following method 2 and model II of Griffing (1956).

Results and discussion

The pooled analysis of variance for combining ability over three locations recorded significant differences for most of the characters studied (Table 1). The differences among the parents and hybrids was significant for all the characters except for monopodia plant^{-1} and relative chlorophyll content for parents and monopodia plant^{-1} for hybrids. Whereas the differences among the parents vs hybrids were significant for the characters days to 50% flowering, boll weight, lint index, ginning out turn, uniformity ratio, elongation, seed cotton yield plant^{-1} and lint yield plant^{-1}. The analysis of variance for combining ability revealed that, the variance due to SCA were higher than GCA in pooled analysis for all the characters except for days to 50 per cent flowering and 2.5% span length indicating the predominance of non-additive gene action for all characters and

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additive gene action for days to 50 per cent flowering and 2.5% span length. Ashok Kumar and Ravikesavan (2008) and Deosarkar *et al*. (2009) also reported the similar type of results.

General combining ability effects of parents and specific combining ability effects of crosses over locations (pooled) were estimated and presented in tables 2 to 3 respectively. The estimate of GCA and SCA variances in pooled analysis is presented in table 4.

The *gca* effects from pooled analysis revealed that none of the parent recorded significant *gca* effects for all the characters studied. Among the parents NDLH 1938 showed significant positive *gca* effects for number of sympodia plant^{-1}, number of bolls plant^{-1}, boll weight, seed index, lint index, micronaire, uniformity ratio and elongation, seed cotton yield plant^{-1} and lint yield plant^{-1}. It can be extensively used as parent in the breeding programme. The parent L 788 showed significant positive *gca* effects for plant height, number of sympodia plant^{-1}, seed index, lint index and micronaire. L 770 showed significant positive *gca* effects for seed index, lint index, ginning out turn % and lint yield plant^{-1}.

NA 1325 showed significant positive *gca* effects for seed index, lint index micronaire and uniformity ratio. L 604 showed significant positive *gca* effects for 2.5% span length. SURABHI showed significant positive *gca* effects for number of sympodia plant^{-1}, ginning out turn %, 2.5% span length and bundle strength. RAH 1004 showed significant positive *gca* effects for number of bolls plant^{-1}, lint index (g), ginning out turn %, micronaire (10^{-6}g/inch), uniformity ratio and elongation (%) and lint yield plant^{-1} (g). HYPS 152 showed significant positive *gca* effects for relative chlorophyll content, ginning out turn % and 2.5% span length. MCU 5 showed significant positive *gca* effects for seed index, 2.5% span length and bundle strength. G COT 16 showed significant positive *gca* effects for plant height, relative chlorophyll content, 2.5% span length, bundle strength and uniformity ratio. Where as the parents L 770, NA 1325, L 604 and SURABHI showed significant negative *gca* effects for days to 50% flowering. Senthil Kumar *et al.* (2013), Deosarkar *et al*. (2014) and Rajamani *et al*. (2014) also reported different parents with good general combining ability for seed cotton yield and yield contributing characters.

The hybrids NDLH 1938 × L 604 (-2.25), L 770 × HYPS 152 (-2.12), NDLH 1938 × SURABHI (-2.09), L 788 × NA 1325 (-1.85) and L 788 × SURABHI (-1.70) showed significant negative *sca* effects for days to 50 per cent flowering.

Out of forty five crosses five cross combinations, NA 1325 × HYPS 152 (6.37), L 770 × L 604 (5.81), L 770 × NA 1325 (5.49), L 788 × G COT 16 (5.32) and SURABHI × HYPS 152 (4.37) showed significant *sca* effects in desirable direction for plant height. The crosses, L 788 × SURABHI (1.26), L 770 × L 604 (0.92) and RAH 1004 × HYPS 152 (0.80) exhibited high significant positive *sca* effects in the desired direction for number of sympodia plant^{-1}. The hybrids NDLH 1938 × RAH 1004 (4.47), NDLH 1938 × L 770 (2.64), NA 1325 × G COT 16 (2.56), L 770 × L 604 (2.39) and NDLH 1938 × L 604 (2.25) exhibited high significant positive *sca* effects for number of bolls plant^{-1}.

The top five specific cross combinations based on *sca* effects identified for boll weight were L 770 × G COT 16 (0.71), SURABHI × HYPS 152 (0.65), NA 1325 × MCU 5 (0.58), NDLH 1938 × L 604 (0.48) and NDLH 1938 × SURABHI (0.29) & NDLH 1938 × L 604 (0.29). For seed index NA 1325 × HYPS 152 (1.82), NDLH 1938 × G COT 16 (1.50), L 770 × HYPS 152 (1.42) recorded significant positive *sca* effects. Based on *sca* effects for lint index the good crosses were NA 1325 × HYPS 152 (0.86), L 770 × G COT 16 (0.85), L 788 × RAH 1004 (0.85), L 770 × HYPS 152 (0.71) and MCU 5 × G COT 16 (0.63). The best five specific cross combinations identified among the forty five crosses for ginning out-turn (%) based on *sca* effects were SURABHI × RAH 1004 (2.99), SURABHI × HYPS 152 (2.14), L 770 × NA 1325 (1.85), L 788 × MCU 5 (1.43) and L 788 × RAH 1004 (1.34). For 2.5% span length the crosses NDLH 1938 × L 604 (1.89), L 788 × RAH 1004 (1.28), L 770 × RAH 1004 (1.12), NDLH 1938 × L 788 (0.92) and L 770 × L 604 (0.86) recorded the significantly positive *sca* effects. The best five specific cross combinations identified based on *sca* effects for micronaire value (10^{-6}g/inch) among them were NDLH 1938 × SURABHI (0.45), RAH 1004 × HYPS 152 (0.39), L 604 × RAH 1004 (0.29), RAH 1004 × MCU 5 (0.28) and L 788 × L 770 (0.27). For bundle strength the best crosses were NDLH 1938 × L 604 (1.24), L 788 × RAH 1004 (1.01), SURABHI × HYPS 152 (0.93), L 770 × G COT 16 (0.89) and NA 1325 × SURABHI (0.81). The top five crosses for uniformity ratio were L 604 × SURABHI (1.55), L 788 × L 770 (1.46), L 788 × G COT 16 (1.41), RAH 1004 × G COT 16 (1.30) and RAH 1004 × HYPS 152 (1.24). Three cross combinations showed significant *sca* effects in positive direction for elongation (%) were L 604 × HYPS 152 (0.16), NDLH 1938 × SURABHI (0.11), L 604 × G COT 16 (0.09) and RAH 1004 × HYPS 152 (0.11). The top five crosses for seed cotton yield plant^{-1} were NDLH 1938 × L 604 (32.12), SURABHI × HYPS 152 (24.85), NA 1325 × MCU 5 (24.53), NDLH 1938 × RAH 1004 (22.82) and L 770 × G COT 16 (22.56). Best five

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crosses for lint yield plant^{-1} were SURABHI × HYPS 152 (11.62), NDLH 1938 × L 604 (9.86), NDLH 1938 × RAH 1004 (9.13), L 770 × G COT 16 (8.30) and NA 1325 × MCU 5 (7.20).

From the present study, it was observed that the crosses, NDLH 1938 × L 604, NDLH 1938 × RAH 1004 and NDLH 1938 × L 770, recorded high *per se* performance (202.18, 197.99 and 195.54 g, respectively) for seed cotton yield plant^{-1} and significant positive *sca* effects (32.12, 22.82 and 19.46, respectively). These hybrids were also recorded high *per se* performance and significant positive *sca* effects for other important yield contributing characters like number of bolls per plant (NDLH 1938 × RAH 1004, NDLH 1938 × L 770 and NDLH 1938 × L 604), boll weight (NDLH 1938 × L 604), lint yield per plant (NDLH 1938 × RAH 1004, NDLH 1938 × L 770 and NDLH 1938 × L 604) and also for fibre quality traits like 2.5 % span length (NDLH 1938 × L 604), micronaire (NDLH 1938 × RAH 1004), bundle strength (NDLH 1938 × L 604), uniformity ratio (NDLH 1938 × RAH 1004) and elongation % (NDLH 1938 × RAH 1004). The results obtained are in accordance with the findings of Senthil Kumar *et al.* (2013), Tuteja and Manju Banga (2013), Deosarkar *et al.* (2014), Rajamani *et al.* (2014) and Patel and Pinal Chaudhari (2015).

It was observed that the cross combinations involving high × high general combiners produce crosses with significant *sca* effect indicating the role of additive and additive × additive genetic component of variance which could be easily improved through simple selection procedures. The crosses between high × low or low × high general combiners resulted in superior cross combinations due to complementary gene action which has arisen out of both additive and non-additive gene action. These crosses may likely throw superior trangressive segregants. These components may be exploited by adopting breeding procedures like cyclic hybridization, biparental mating and diallel selective mating system.

From the results on the combining ability, it can be concluded that the choice of the parents for crossing programme should be based not only on the *per se* performance and *gca* effects but also on *sca* effects of the cross combinations.

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Table 1. Analysis of variance of combining ability for different characters in cotton over three environments (pooled)

Source of variation	Days to 50 % flowering	Plant height (cm)	No. of monopodia plant^{-1}	No. of sympodia plant^{-1}	No. of bolls plant^{-1}	Boll weight (g)	Chlorophyll content (mg g^{-1} fresh weight)	Seed index (g)	Lint index (g)
Environments	58.44**	27224.59**	5.09**	261.14**	4534.32**	117.56**	0.15**	168.61**	86.68**
Blocks within Environments	2.65*	88.18	0.12**	1.79	9.45*	0.03	0.02	0.13	0.04
Treatments	78.73**	143.57**	0.05	5.50**	39.97**	0.86**	0.02**	12.43**	2.30**
Parents	117.66**	152.90**	0.04	2.75*	39.39**	0.36**	0.01	8.83**	1.46**
Hybrids	60.43**	141.51**	0.05	6.12**	40.98**	0.84**	0.02**	13.44**	2.47**
Parents *vs*.Hybrids	533.87**	150.25	0.03	2.96	0.81	6.22**	0.00	0.44	2.50**
Treatment × Environments	0.99	200.29**	0.07**	6.29**	34.99**	0.63**	0.01**	9.89**	1.68**
Parent × Environments	1.01	166.38**	0.07*	5.05**	22.63**	0.80**	0.01	4.41**	1.15**
Hybrids × Environments	0.95	208.70**	0.07**	5.39**	38.25**	0.58**	0.01**	11.16**	1.82**
Parent *vs*.Hybrids × Env.	2.29	135.24	0.04	57.23**	2.97	1.41**	0.07**	3.63**	0.22**
Error	1.22	46.89	0.04	1.12	4.04	0.07	0.01	0.14	0.03
Total	9.89	201.53	0.07	3.79	33.14	0.75	0.01	4.30	0.99
GCA	126.13**	97.34**	0.01	4.53**	38.06**	0.38**	0.01**	9.63**	1.60**
SCA	6.27**	37.96**	0.02	1.30**	8.38**	0.27**	0.01**	3.05**	0.60**
Environments	19.48**	9074.86**	1.70**	87.05**	1511.44**	39.19**	0.05**	56.20**	28.89**
GCA*Environments	0.40	142.66**	0.03**	3.20**	16.01**	0.26**	0.00	5.19**	0.63**
SCA*Environments	0.31	51.58**	0.02**	1.88**	10.79**	0.20**	0.00**	2.92**	0.54**
Error	0.41	15.63	0.01	0.37	1.35	0.02	0.00	0.05	0.01

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

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Table 1. Contd.,

Source of variation	Ginning out turn (%)	2.5% span length (mm)	Micronaire value (10^{-6} g/inch)	Budnle strength (g/tex)	Uniformity ratio	Elongation (%)	Seed cotton yield plant^{-1} (g)	Lint yield plant^{-1} (g)
Environments	157.97**	62.47**	6.26**	0.19	119.09**	0.04	348887.50**	42201.89**
Blocks within Environments	0.59	2.30	0.04	2.03*	2.79	0.05	179.06	23.61
Treatments	23.57**	18.45**	0.93**	7.84**	14.35**	0.11**	2510.85**	331.03**
Parents	22.42**	36.81**	0.45**	11.41**	16.68**	0.22**	1845.91**	236.15**
Hybrids	23.57**	15.11**	1.05**	7.29**	13.18**	0.08**	2451.83**	349.57**
Parents *vs*.Hybrids	33.77**	0.26	0.03	0.31	45.18**	0.10*	11092.01**	369.03**
Treatment × Environments	28.50**	10.52**	0.74**	4.45**	7.63**	0.05**	1503.05**	245.62**
Parent × Environments	29.99**	11.21**	0.50**	3.90**	10.69**	0.07**	974.56**	203.68**
Hybrids × Environments	28.79**	10.25**	0.78**	4.45**	6.68**	0.04**	1570.03**	252.75**
Parent *vs*.Hybrids × Env.	2.01	16.29**	0.80**	9.18**	22.12**	0.03	3312.68**	309.10**
Error	1.50	1.95	0.02	0.79	1.54	0.02	341.59	26.21
Total	10.44	5.88	0.30	2.37	4.77	0.04	2241.78	278.22
GCA	15.41**	25.57**	0.82**	7.57**	12.69**	0.09**	1698.65**	273.97**
SCA	6.34**	2.27**	0.21**	1.62**	3.20**	0.02**	664.61**	77.62**
Environments	52.66**	20.82**	2.09**	0.06	39.70**	0.01	116295.83**	14067.30**
GCA*Environments	19.11**	9.51**	0.19**	3.31**	3.76**	0.02**	598.79**	104.15**
SCA*Environments	7.58**	2.31**	0.26**	1.12**	2.30**	0.01**	481.46**	77.42**
Error	0.50	0.65	0.01	0.26	0.51	0.01	113.86	8.74

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

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Table 2. General combining ability effects of ten parents for yield and yield components in cotton at three locations (pooled)

Parent	Days to 50 % flowering	Plant height (cm)	No. of monopodia plant^{-1}	No. of sympodia plant^{-1}	No. of bolls plant^{-1}	Boll weight (g)	Chlorophyll content (mg g^{-1} fresh weight)	Seed index (g)	Lint index (g)
NDLH 1938	0.02	0.91	-0.03	0.53**	2.31**	0.22**	-0.03**	0.33**	0.17**
L 788	0.63**	2.83**	0	0.33**	-0.19	0.02	-0.01	0.80**	0.06**
L 770	-2.07**	0.27	-0.01	0.16	-0.55**	0.04	0	0.51**	0.32**
NA 1325	-2.27**	0.04	0	0.02	-1.15**	0.04	-0.02*	0.33**	0.27**
L 604	-2.04**	-3.39**	-0.02	-0.67**	-1.07**	-0.05	0.01	-0.34**	-0.15**
SURABHI	-1.09**	0.56	0	0.26**	0	-0.08**	0	-0.46**	-0.22**
RAH 1004	0.60**	0.83	0.02	-0.03	1.10**	-0.17**	-0.01	-0.28**	0.05**
HYPS 152	0.69**	-0.69	0	-0.35**	0.11	-0.02	0.02**	-0.93**	-0.32**
MCU 5	3.09**	0.19	0.02	0	-0.21	0.02	0	0.10**	-0.05**
G COT 16	2.44**	-1.55*	0.01	-0.26**	-0.36	-0.02	0.03**	-0.06	-0.14**
S E (gi)	**0.100**	**0.625**	**0.018**	**0.096**	**0.183**	**0.024**	**0.007**	**0.034**	**0.016**

Parent	Ginning out turn (%)	2.5% span length (mm)	Micronaire value (10^{-6} g/inch)	Budnle strength (g/tex)	Uniformity ratio	Elongation (%)	Seed cotton yield plant^{-1} (g)	Lint yield plant^{-1} (g)
NDLH 1938	-0.02	-0.49**	0.24**	-0.06	0.54**	0.06**	18.79**	6.72**
L 788	-1.17**	-0.19	0.09**	-0.05	0	-0.04**	0.14	-2.49**
L 770	0.32**	0.14	-0.06**	-0.22**	-0.64**	-0.01	-0.51	1.28**
NA 1325	0.2	-1.08**	0.14**	-0.85**	0.28*	-0.06**	-3.57*	-0.49
L 604	-0.28*	0.53**	-0.07**	0.08	-0.42**	-0.05**	-6.51**	-2.68**
SURABHI	0.28*	0.65**	-0.19**	0.47**	-0.28*	0.01	-2.77	-1.06*
RAH 1004	0.83**	-1.65**	0.18**	-0.52**	1.33**	0.10**	-1.41	1.35**
HYPS 152	0.93**	0.55**	-0.10**	0.05	-0.18	0	-0.78	0.49
MCU 5	-0.42**	0.71**	-0.08**	0.43**	-0.59**	-0.01	-1.3	-1.54**
G COT 16	-0.67**	0.83**	-0.16**	0.66**	-0.03	0.01	-2.08	-1.58**
S E (gi)	**0.111**	**0.127**	**0.013**	**0.080**	**0.113**	**0.013**	**1.687**	**0.467**

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

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Table 3. Specific combining ability effects of 45 hybrids of cotton for yield and yield components in cotton at three different locations (pooled) during *kharif*, 2013-14

Hybrids	Days to 50 % flowering	Plant height (cm)	No. of monopodia plant^{-1}	No. of sympodia plant^{-1}	No. of bolls plant^{-1}	Boll weight (g)	Chlorophyll content (mg g^{-1} fresh weight)	Seed index (g)	Lint index (g)
NDLH 1938 × L 788	0.41	1.14	-0.14*	0.44	1.08	-0.05	0.04	0.39**	0.1
NDLH 1938 × L 770	-0.67*	0.83	0.07	-0.08	2.64**	0.29**	-0.02	-0.53**	-0.41**
NDLH 1938 × NA 1325	-1.02**	-0.5	0.01	0.44	0.72	-0.20*	-0.01	-0.61**	-0.12*
NDLH 1938 × L 604	-2.25**	-2.34	0.1	-0.42	2.25**	0.48**	-0.02	0.77**	0.32**
NDLH 1938 × SURABHI	-2.09**	-4.70*	-0.07	0.58	0.74	0.29**	0.03	-0.44**	-0.01
NDLH 1938 × RAH 1004	0.66	-0.35	-0.12*	0.03	4.47**	0.1	-0.10**	-0.15	0.18**
NDLH 1938 × HYPS 152	-0.54	1.59	-0.01	0.36	-1.97**	0.05	0.02	-0.67**	-0.53**
NDLH 1938 × MCU 5	-0.72*	3.62	0.07	0.24	-3.21**	-0.27**	-0.01	-0.15	0.08
NDLH 1938 × G COT 16	-0.29	-1.33	-0.02	-0.06	-2.61**	-0.03	-0.05	1.50**	0.31**
L 788 × L 770	-1.61**	-2.03	0.03	-0.56	0	0.08	0.02	0.04	-0.22**
L 788 × NA 1325	-1.85**	0.6	-0.03	0.3	-0.5	0.11	0	0.57**	-0.06
L 788 × L 604	-1.31**	1.52	0.02	0.27	0.83	0.16	-0.02	0.39**	-0.16**
L 788 × SURABHI	-1.70**	2.19	0.01	1.26**	-0.52	-0.35**	-0.03	1.17**	0.54**
L 788 × RAH 1004	0.16	3.91	0.1	-0.88**	-0.26	0.1	-0.04	0.91**	0.85**
L 788 × HYPS 152	0.52	-2.46	-0.05	-0.1	0.68	-0.02	0.04	-0.36**	0.08
L 788 × MCU 5	0.23	-2.46	0.05	-0.83*	-1.31*	-0.02	-0.08**	-0.90**	-0.20**
L 788 × G COT 16	1.10**	5.32*	0.07	-0.37	-0.44	0.30**	-0.01	-1.75**	-0.60**
L 770 × NA 1325	0.28	5.49**	-0.06	0.58	-1.12	-0.36**	0.05	-0.62**	0.03
L 770 × L 604	0.28	5.81**	0.05	0.92**	2.39**	-0.13	0.06*	-0.82**	-0.22**
L 770 × SURABHI	0.44	3.81	-0.06	0.34	-0.39	-0.13	0	0.53**	-0.15**
L 770 × RAH 1004	-0.25	-0.2	-0.01	0.62	0.09	0.27**	0.02	0.45**	-0.11*
L 770 × HYPS 152	-2.12**	-4.07	0.1	-1.49**	-1.45*	0.16	-0.03	1.42**	0.71**

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

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Table 3. Contd.,

Hybrids	Days to 50 % flowering	Plant height (cm)	No. of monopodia plant^{-1}	No. of sympodia plant^{-1}	No. of bolls plant^{-1}	Boll weight (g)	Chlorophyll content (mg g^{-1} fresh weight)	Seed index (g)	Lint index (g)
L 770 × MCU 5	-1.30**	-0.91	-0.02	0.2	-0.3	-0.11	-0.02	-0.53**	-0.39**
L 770 × G COT 16	-0.32	0.44	0.08	0.02	-0.47	0.71**	0.07**	1.28**	0.85**
NA 1325 × L 604	0.81*	-4.63*	0.09	-0.85**	-1.90**	0.1	-0.02	-1.92**	-1.02**
NA 1325 × SURABHI	-0.13	-6.85**	0.01	-1.07**	1.13	-0.15	0.03	1.09**	0.09
NA 1325 × RAH 1004	-0.72*	3.61	-0.09	0.09	-0.08	0.08	-0.04	1.33**	0.41**
NA 1325 × HYPS 152	-1.25**	6.37**	0.08	0.49	1.83**	0.13	0.01	1.82**	0.86**
NA 1325 × MCU 5	-0.43	3.67	-0.01	0.37	1.03	0.58**	-0.07**	0.17	-0.07
NA 1325 × G COT 16	-0.22	2.7	-0.03	0.3	2.56**	0.25**	0.03	0.63**	0.01
L 604 × SURABHI	0.08	1.96	-0.09	-0.38	0.03	-0.02	-0.07**	0.82**	0.58**
L 604 × RAH 1004	-0.72*	3.23	0.13*	0.14	-0.08	0.26**	0.05	-0.28*	-0.39**
L 604 × HYPS 152	0.52	2.27	-0.09	-0.15	-0.04	0.33**	0.03	0.37**	-0.47**
L 604 × MCU 5	-0.55	-4.91*	-0.04	-0.64*	-3.27**	0.11	0.01	-0.68**	-0.26**
L 604 × G COT 16	-0.46	-0.37	-0.03	-0.39	-0.53	-0.59**	0.01	-0.2	0.07
SURABHI × RAH 1004	-0.45	-4.03	-0.06	-0.26	-1.26*	-0.28**	0.07*	-2.28**	-0.76**
SURABHI × HYPS 152	-0.76*	4.37*	0.17**	0.17	0	0.65**	-0.01	-0.94**	-0.11*
SURABHI × MCU 5	0.51	-1.04	-0.06	-0.91**	-0.14	0.12	0.06*	0.55**	-0.08
SURABHI × G COT 16	0.27	-3.7	-0.06	-0.53	-0.84	-0.15	-0.05*	-0.51**	-0.42**
RAH 1004 × HYPS 152	-1.35**	-0.31	0.03	0.80*	0.12	-0.14	-0.02	-0.18	-0.29**
RAH 1004 × MCU 5	-0.85*	-0.89	0.02	0.1	0.6	0.13	0.05	-0.59**	-0.19**
RAH 1004 × G COT 16	-0.87*	0.88	0.06	0.4	0.84	0.04	0.01	-1.82**	-0.41**
HYPS 152 × MCU 5	0.72*	0.2	-0.01	0.05	-0.23	-0.22**	0.05	-0.39**	-0.32**
HYPS 152 × G COT 16	-1.08**	-4.53*	-0.04	-1.46**	-1.30*	-0.37**	-0.02	-0.79**	-0.25**
MCU 5 × G COT 16	-1.14**	-1.25	0.05	0.28	1.03	0.1	-0.02	1.28**	0.63**
S E (Sij)	**0.303**	**1.884**	**0.054**	**0.291**	**0.553**	**0.073**	**0.023**	**0.102**	**0.050**

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

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Table 3. Contd.,

HYBRIDS	Ginning out turn (%)	2.5% span length (mm)	Micronaire value (10^{-6} g/inch)	Budnle strength (g/tex)	Uniformity ratio	Elongation (%)	Seed cotton yield plant^{-1} (g)	Lint yield plant^{-1} (g)
NDLH 1938 × L 788	-1.19**	0.92*	0.14**	0.74**	-1.59**	-0.03	5.33	1.56
NDLH 1938 × L 770	-0.29	0.77	-0.19**	0.71**	-0.32	0	19.46**	3.18*
NDLH 1938 × NA 1325	1.21**	-0.08	-0.14**	-0.59*	-0.37	-0.05	-5.47	-0.92
NDLH 1938 × L 604	0.38	1.89**	-0.27**	1.24**	-0.34	-0.02	32.12**	9.86**
NDLH 1938 × SURABHI	-0.21	-0.29	0.45**	0.03	0.51	0.11*	13.57*	4.81**
NDLH 1938 × RAH 1004	1.20**	-0.48	0.21**	-0.34	0.85*	0.07	22.82**	9.13**
NDLH 1938 × HYPS 152	-1.23**	0.31	-0.05	0.37	-0.35	0	-7.83	-4.47**
NDLH 1938 × MCU 5	1.02**	-0.07	0.17**	-0.04	-0.24	-0.02	-24.96**	-7.61**
NDLH 1938 × G COT 16	-1.46**	0.57	-0.28**	0.59*	-1.98**	-0.05	-15.13**	-8.58**
L 788 × L 770	-0.76*	-0.7	0.27**	-0.32	1.46**	0.04	1.49	-1.94
L 788 × NA 1325	-1.38**	-0.49	-0.10*	-0.75**	-0.39	0.02	1.8	-1.63
L 788 × L 604	-3.05**	-0.3	-0.05	0.05	-0.1	0.06	10.95	-0.45
L 788 × SURABHI	-0.51	0.76	0.10*	0.5	-1.36**	-0.05	-13.07*	-4.65**
L 788 × RAH 1004	1.34**	1.28**	0.18**	1.01**	-1.06**	0.03	-0.78	1.11
L 788 × HYPS 152	0.6	-1.05*	-0.24**	-0.75**	0.96*	0.02	1.33	2.6
L 788 × MCU 5	1.43**	0.02	-0.11*	0.04	-0.81*	0.02	-8.13	-0.98
L 788 × G COT 16	1.01**	-0.21	-0.46**	0.28	1.41**	0	10.43	4.16**
L 770 × NA 1325	1.85**	-0.46	0.05	0.02	0.37	0.01	-17.04**	-5.01**
L 770 × L 604	1.29**	0.86*	-0.12*	0.38	-0.12	0.05	5.88	5.01**
L 770 × SURABHI	-1.16**	-0.79	0.09	-1.37**	0.84*	-0.16**	-5.51	-4.29**
L 770 × RAH 1004	-0.24	1.12**	-0.47**	0.13	-2.46**	-0.18**	15.28**	5.14**
L 770 × HYPS 152	0.16	0.08	0.17**	0.1	-0.01	0.06	-1.57	-0.96

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

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Table 3. Contd.,

Hybrids	Ginning out turn (%)	2.5% span length (mm)	Micronaire value (10^{-6} g/inch)	Budnle strength (g/tex)	Uniformity ratio	Elongation (%)	Seed cotton yield plant^{-1} (g)	Lint yield plant^{-1} (g)
L 770 × MCU 5	-0.64	-0.02	0.18**	-0.08	-0.83*	0.04	-4.46	-3.67*
L 770 × G COT 16	0.90*	-0.71	-0.10*	0.89**	0.66	0.02	22.56**	8.30**
NA 1325 × L 604	-1.16**	-0.31	0.20**	-0.36	-0.39	0	-6.3	-3.70*
NA 1325 × SURABHI	-1.88**	0.51	0.11*	0.81**	0.25	0.08	-2.02	-3.71*
NA 1325 × RAH 1004	-0.97*	0.6	0.08	-0.49	0.21	-0.10*	3.03	-0.8
NA 1325 × HYPS 152	-0.22	0.63	0.03	0.51	-0.42	0.02	13.63*	3.99*
NA 1325 × MCU 5	-0.52	0.36	-0.01	0.01	-0.43	-0.05	24.53**	7.20**
NA 1325 × G COT 16	-0.97*	0.03	0.23**	0.19	0.13	0.08	20.67**	5.51**
L 604 × SURABHI	0.96*	-0.09	0.26**	0.77**	1.55**	0.09	0.09	1.42
L 604 × RAH 1004	-1.40**	-1.59**	0.29**	-0.78**	0.87*	-0.04	6.98	0.32
L 604 × HYPS 152	-3.35**	0.03	0.11*	0.77**	0.19	0.16**	14.18*	0.96
L 604 × MCU 5	0.41	-0.4	-0.32**	-0.37	0.4	-0.15**	-8.84	-1.65
L 604 × G COT 16	1.13**	0.09	0.24**	-0.1	-0.79*	0.09*	-18.97**	-5.24**
SURABHI × RAH 1004	2.99**	0.86*	-0.37**	0.2	-0.52	0.01	-15.77**	-2.46
SURABHI × HYPS 152	2.14**	0.22	-0.55**	0.93**	-1.44**	-0.07	24.85**	11.62**
SURABHI × MCU 5	-2.02**	0.01	-0.15**	-1.03**	-0.31	-0.06	5	-0.68
SURABHI × G COT 16	-1.15**	0.67	-0.44**	0.45	-1.62**	-0.13**	-9.4	-4.49**
RAH 1004 × HYPS 152	-1.07**	-0.39	0.39**	-0.44	1.24**	0.11*	-3.67	-2.58
RAH 1004 × MCU 5	0.66	-2.19**	0.28**	-0.61*	0.01	0.05	7.66	3.05
RAH 1004 × G COT 16	0.4	-0.5	0.22**	-0.89**	1.30**	-0.10*	3.7	6.19**
HYPS 152 × MCU 5	-0.73	0.86*	-0.23**	-0.18	-0.67	-0.10*	-7.56	-3.52*
HYPS 152 × G COT 16	0.92*	-1.77**	-0.06	-1.66**	-0.95*	-0.18**	-18.50**	-5.75**
MCU 5 × G COT 16	0.03	-0.07	0.12**	-0.03	0.25	0.01	8.07	2.96
S E (Sij)	**0.337**	**0.384**	**0.041**	**0.244**	**0.342**	**0.040**	**5.087**	**1.409**

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

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Table 4. Estimates of gca and sca variances for yield and yield components in cotton at different environments and pooled over three environments

Source	σ^2GCA	σ^2SCA	σ^2GCA/σ^2SCA
Days to 50 % flowering	3.49	1.95	1.79
Plant height (cm)	2.27	7.44	0.30
No. of monopodia plant^{-1}	0.00	0.00	-0.10
No. of sympodia plant^{-1}	0.12	0.31	0.38
No. of bolls plant^{-1}	1.02	2.34	0.44
Boll weight (g)	0.01	0.08	0.12
Chlorophyll content (mg g^{-1} fresh weight)	0.00	0.00	0.21
Seed index (g)	0.27	1.00	0.27
Lint index (g)	0.04	0.20	0.22
Ginning out turn (%)	0.41	1.95	0.21
2.5% span length (mm)	0.69	0.54	1.29
Micronaire value (10^{-6} g/inch)	0.02	0.07	0.34
Bundle strength (g/tex)	0.20	0.45	0.45
Uniformity ratio	0.34	0.90	0.38
Elongation (%)	0.00	0.01	0.45
Seed cotton yield plant^{-1} (g)	44.02	183.58	0.24
Lint yield plant^{-1} (g)	7.37	22.96	0.32