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Research Note

Assessment of combining ability and genetic parameters for yield and fiber traits in upland cotton (*Gossypium hirsutum* L.) using Line × Tester analysis

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Abstract
Seed cotton yield and fiber quality are two critical parameters that fundamentally define the economic and industrial value of cotton. The present work focused on improving cotton genotypes both for yield and quality parameters through intraspecific crosses. Estimation of combining ability parameters for forty-five *Gossypium hirsutum* genotypes employed the Line × Tester mating design. Significant ($p \leq 0.01$) differences in mean squares values were observed across all studied traits for the genotypes. Regarding parental lines, P2-103 and P1-190 demonstrated the highest positive general combining ability (*gca*) effects for seed cotton yield per plant, boll weight, and number of bolls per plant, thereby being identified as exceptional combiners. From the comprehensive set of forty-five crosses, P1-62×Suraksha and P2-36×Subiksha emerged with notable positive specific combining ability (*sca*) effects across multiple traits. Non-additive genetic variance (σ^2D) predominantly exceeded additive genetic variance (σ^2A) for most traits, suggesting potential exploitation of superior cross combinations through heterosis breeding strategies.

Keywords: Cotton, Line x Tester, combining ability, GCA, SCA

Cotton (*Gossypium hirsutum*) is a remarkable plant that transcends its botanical origins to become a global economic powerhouse, with a rich evolutionary history spanning millions of years (Flachs, 2019). Originating in multiple continental regions including Africa, Asia, and the Americas, cotton has evolved from wild species to a critical agricultural commodity that supports millions of livelihoods worldwide. The genus *Gossypium* comprises approximately 50 species, divided into eight distinct genome groups, with only four species domesticated for commercial production: *Gossypium hirsutum* (upland cotton), *Gossypium barbadense* (extra-long staple cotton), *Gossypium arboreum*, and *Gossypium herbaceum* (Viot and Wendel., 2023). Belonging to the Malvaceae family, it typically grows 3-6 feet tall, featuring broad, lobed leaves and distinctive flowers that develop into cotton bolls. Each cotton fiber is a single elongated cell with a complex, twisted structure, composed primarily of cellulose (Nickerson *et al*. 1940). Economically, cotton stands as one of the most valuable agricultural commodities globally, with an industry valued at over $100 billion annually (Roche, 2014). Major producing nations include China, India, the United States, Brazil, and Pakistan.

Seed cotton yield and fiber quality are two critical parameters that fundamentally define the economic and industrial value of cotton. The primary attributes—fiber length, strength, micronaire, uniformity, elongation, and maturity—collectively define the cotton's potential across diverse applications. Fiber strength directly influences fabric durability and resistance to mechanical stress, while micronaire measures fiber fineness and maturity, impacting yarn formation and processing efficiency. The intricate relationship between yield and fiber strength is a central focus of cotton research. Genetic strategies aim to develop cultivars that simultaneously optimize both parameters, recognizing that increased yield should not come at the expense of fiber quality.

To achieve higher lint yield with good fiber strength in cotton, it is essential to select appropriate parents for a successful breeding programme. Line x Tester analysis provides a systematic approach for finding of suitable parents and F_1 hybrids for various investigated traits. Line × tester analysis is an important biometrical tool which shows the ability of genotypes to combine in general and specific cross combinations and provides information on GCA and SCA variances and effects. Combining ability describes the breeding value of parental lines in hybrid production. The foundational work by Sprague and Tatum (1942) established that general combining ability (*gca*) effects arise from additive gene action, while specific combining ability (*sca*) effects stem from non-additive genetic mechanisms, including dominance and epistatic interactions. Building on this understanding, Kempthorne (1957) demonstrated that broad-based genotypes could serve as testers to evaluate the general combining ability of lines, similar to the top cross method. He further explained that line × tester analysis represents an advancement of this approach by incorporating multiple testers. Following these established principles, this study aimed to evaluate both the gca effects of parental lines and the sca effects of their crosses to understand yield potential and fiber quality characteristics.

The proposed research was executed during *kharif* 2022 at botany garden, Department of Genetics and Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India, which is situated in the Northern Transitional zone (Zone 8) of Karnataka. Three high fiber strength cotton lines collected from All India Coordinated Research Project on *Cotton, Coimbatore, Tamil Nadu were employed as testers while fifteen low fiber strength and good yield genotypes selected from RILs (recombinant inbred lines) derived from Raichur Agronomically Superior Parent (*RHAP) , developed at Main Research Station, University of Agricultural Sciences, Raichur were employed as lines. The intra-specific hybridisation was effected in Line x Tester fashion following Doak's (1934) method during *kharif*, 2022. Forty five cross combinations thus obtained were raised in a Randomized Block Design (RBD) with two replications adopting a spacing of 90 cm (row to row) and 60 cm (plant to plant). Yield parameters namely, number of bolls per plant (NBPP), number of sympodial branches per plant (NSPP), number of monopodia per plant (NMPP), boll weight (BW) and seed cotton yield per plant (SCYP) were recorded from five competitive plants selected randomly from each genotype. Fiber and seed quality traits namely, seed index (SI), lint index (LI), and ginning percentage (GOT) were assessed from representative samples from each genotype. Thirty to seventy grams of lint sample was used to analyse the five fibre quality traits namely, uniformity index (%), fibre strength

Table 1. Analysis of variance for seed cotton yield, yield components and fibre quality traits among parents and crosses

Source of variation	Mean sum of squares														
	d.f.	NMPP	NSPP	NBPP	BW	SCYP	PH	SI	GOT	LI	FL (mm)	UI	FF (µg/ inch)	FS (g/tex)	E (%)
Replicates	1	0.08	0.38	33.53	0.64	11.46	17.85	0.00	2.57	0.03	0.07	0.00	0.15	0.37	0.05
Treatments	62	0.417*	10.15**	69.26**	0.41**	568.40**	386.69**	0.76**	8.86**	0.34**	4.07**	4.30**	0.16*	2.46**	0.19**
Parents	17	0.529*	6.48**	87.34**	0.30**	301.24**	319.81**	0.96**	10.28**	0.55**	4.68**	4.16*	0.19**	3.71**	0.44**
Lines	14	0.262	4.77**	86.11**	0.28**	273.96**	308.33**	0.95**	12.10**	0.57**	3.73**	2.34	0.16*	1.99*	0.50**
Testers	2	0.167	12.66**	39.50**	0.56**	579.50**	266.66**	0.71*	2.00**	0.36**	8.76**	16.16**	0.48**	13.22**	0.00
Lines *vs* Testers	1	5.00**	18.05**	200.55**	0.093	126.67**	586.80**	1.64**	1.42**	0.67*	9.90**	5.68	0.03	8.71**	0.51*
Parent *vs* Crosses	1	0.45	5.207*	108.65**	0.065*	29.56	607.63**	2.52**	5.33*	1.19	7.26*	0.07	0.86**	10.45**	0.88*
Crosses	44	0.37*	11.69	61.37*	0.467	683.87**	407.51*	0.64	8.39*	0.25	3.76**	4.45**	0.13	1.80	0.07
Error	62	0.23	1.29	5.69	0.044	16.20	26.78	0.06	1.70	0.04	0.02	1.32	0.01	0.07	0.07

** Significant at 1 % level   * Significant at 5 % level

NMPP - Number of monopodial branches per plant; SCYP - Seed cotton yield per plant (g); LI - Lint index;FS- Fibre Strength (g/tex.); NSPP- Number of sympodial branches per plant; PH- Plant height (cm); FL-Fiber length (mm);E - Elongation percentage (%); NBPP- Number of bolls per plant; SI - Seed index;UI - Uniformity Index (%); BW - Boll weight (g) ;GOT - Ginning outturn (%); FF- Fibre fineness (µg/inch.)

(g/tex), fiber length (mm), elongation (%) and fiber fineness (μg /inch) in a high-volume instrument (HVI). All the biometrical analyses were carried out using INDOSTAT software.

The analysis of variance for combining ability, presented in **Table 1**, revealed highly significant mean square values for lines, testers, and their interactions (line × tester) across all studied traits. These significant differences demonstrate substantial genetic variability among the genotypes for all the characteristics under investigation. Sivia *et al*. (2017) and Manonmani *et al.* (2020) also observed significant differences among studied traits.

The mean performance of parents and their hybrids (**Table 2 and Table 3**) revealed that, among female lines, P3-59 (121.00 gm), P2-103 (118.00 gm) and P1-190 (114.00 gm) recorded highest kapas yield per plant and Sunantha (123.50 gm) was leading among testers. Number of bolls per plant was higher among the lines P3-59 (51.00 gm), P3-135 (51.00 gm), P3-47 (49.00 gm) and tester Sunantha (51.00 gm) while, boll weight was higher in P2-103 (4.30 gm), P3-59 (4.25 gm), P3-135 (4.15 gm) and tester Sunantha (4.50 gm). Among the 45 cross combinations, highest kapas yield of 130 gm was recorded by P1- 62 × Suraksha with boll weight of 3.70 gm, number of bolls per plant being 55.00 and low fiber strength (24.05 g/tex).

Gene action refers to the mode of gene expression within a genetic population. Understanding gene action is crucial for plant breeders, as it provides critical insights for parental selection in hybridization programs and helps determining the most appropriate breeding method for improving quantitative traits. The genetic architecture underlying quantitative traits was investigated through the partitioning of genetic parameters across two replications, with detailed results presented in **Table 3.**

Table 2. Mean performance of parents for different characters

Parents	NMPP	NSPP	NBPP	BW	SCYP	PH	SI	GOT	LI	FL (mm)	UI	FF (μg/ inch)	FS (g/tex)	E (%)
Lines														
P1- 62	2.00	16.50	39.00	3.90	111.00	192.50	6.30	38.50	3.95	25.30	83.50	3.10	24.50	5.10
P1 – 103	2.50	14.00	33.00	3.10	86.00	157.50	5.90	32.50	2.84	28.05	84.50	3.15	25.95	5.95
P1- 82	2.00	14.50	34.00	3.30	91.00	162.50	5.10	31.00	2.29	27.05	83.00	3.35	25.75	5.75
P1-50	2.50	15.00	34.00	3.90	110.00	172.50	4.90	37.00	2.88	26.14	83.50	3.70	24.90	5.85
P1-190	2.00	17.50	43.00	4.05	114.00	182.50	4.95	33.00	2.42	25.95	83.50	3.55	24.55	5.45
P2 - 17	2.50	16.50	32.50	3.30	88.00	162.50	5.00	31.00	2.25	28.05	80.50	3.05	26.95	5.70
P2 - 7	2.00	16.00	35.00	3.90	100.00	182.50	5.70	35.00	3.07	29.25	83.00	3.70	26.60	5.30
P2 - 103	2.50	18.50	41.00	4.30	118.00	192.50	6.25	32.50	3.01	27.15	82.50	3.65	26.25	5.95
P2-3	2.00	18.00	45.00	3.70	103.00	195.00	6.60	32.00	3.11	29.55	84.50	3.40	27.35	5.85
P2-36	2.00	16.50	39.00	3.30	86.00	182.50	5.95	33.50	3.00	26.70	81.50	3.70	25.20	6.05
P3 - 11	3.00	18.50	45.00	3.90	111.00	192.50	6.90	37.00	4.05	26.15	82.50	3.60	27.45	4.95
P3 – 59	2.00	19.50	51.00	4.25	121.00	195.00	6.95	31.00	3.12	25.35	82.50	4.15	26.25	4.20
P3 – 54	2.50	16.00	46.00	3.50	100.00	175.00	6.00	33.50	3.02	25.85	82.50	3.30	24.40	5.85
P3-47	3.00	17.50	49.00	3.90	100.00	185.00	6.50	35.50	3.58	26.25	81.50	3.40	25.50	5.95
P3-135	2.50	17.00	51.00	4.15	113.00	182.50	6.15	36.50	3.54	25.35	82.50	3.45	25.85	5.55
Mean	**2.33**	**16.77**	**41.17**	**3.76**	**103.47**	**180.83**	**5.94**	**33.97**	**3.08**	**26.81**	**82.77**	**3.48**	**25.83**	**5.56**
Testers														
Sunantha	3.50	21.00	51.00	4.50	123.50	205.00	7.00	34.50	3.69	29.40	81.50	2.85	29.15	5.85
Suraksha	3.00	16.00	42.50	3.70	90.00	185.00	5.85	33.50	2.95	29.45	83.00	3.55	30.05	5.95
Subhiksha	3.50	19.00	49.00	3.50	112.00	185.00	6.70	35.50	3.69	25.80	87.00	3.80	29.25	5.85
Mean	**3.33**	**18.67**	**47.50**	**3.90**	**108.50**	**191.67**	**6.52**	**34.50**	**3.44**	**28.22**	**83.83**	**3.40**	**29.48**	**5.88**
Overall mean	**2.83**	**17.72**	**44.33**	**3.83**	**105.98**	**186.25**	**6.23**	**34.23**	**3.26**	**27.51**	**83.30**	**3.44**	**27.65**	**5.72**

Note: NMPP - Number of monopodial branches per plant; NSPP- Number of sympodial branches per plant; NBPP- Number of bolls per plant; BW - Boll weight (g); SCYP - Seed cotton yield per plant (g); PH- Plant height (cm); SI - Seed index; GOT - Ginning outturn (%); LI - Lint index; FL-Fiber length (mm); UI - Uniformity Index (%); FF- Fibre fineness (μg/inch.); FS- Fibre Strength (g/tex.); E - Elongation percentage (%).

Table 3. Mean performance of yield and fiber quality traits of *Gossypium hirsutum* hybrids

	Crosses	NMPP	NSPP	NBPP	BW	SCYP	PH	SI	GOT	LI	FL (mm)	UI	FF (µg/ inch)	FS (g/tex)	E (%)
1	P1- 62 × Suraksha	**1.00**	20.50	**55.00**	3.70	**130.00**	162.50	6.10	37.00	3.58	25.50	84.00	3.05	24.05	5.05
2	P1 –103 × Suraksha	2.00	17.00	45.00	4.05	101.50	132.50	5.60	34.00	2.88	27.85	83.50	3.55	25.75	5.85
3	P1- 82 × Suraksha	1.50	15.00	45.00	3.05	84.00	140.00	6.10	37.50	3.63	26.85	85.00	3.65	24.75	5.95
4	P1-50 × Suraksha	2.50	15.00	44.00	3.30	92.00	162.50	6.90	31.50	3.17	28.65	82.50	3.35	25.75	5.85
5	P1-190 × Suraksha	**1.00**	22.00	51.00	3.70	109.00	195.00	7.20	30.50	3.13	29.05	83.50	2.95	26.35	5.95
6	P2 - 17 × Suraksha	3.00	20.50	46.00	4.05	135.50	182.50	6.50	31.00	2.90	28.05	84.50	3.25	25.85	5.85
7	P2 - 7 × Suraksha	2.50	17.00	47.00	4.20	99.00	172.50	5.80	37.00	3.38	26.30	82.50	2.85	25.05	5.35
8	P2 - 103 × Suraksha	3.00	19.50	51.00	4.50	97.00	187.50	6.10	37.50	3.63	27.05	82.00	3.45	25.25	5.65
9	P2-3 × Suraksha	2.00	20.50	41.00	3.40	110.00	172.50	7.10	36.00	**4.01**	27.80	84.50	3.25	25.55	5.85
10	P2-36 × Suraksha	2.50	15.00	33.50	3.20	75.50	150.00	6.50	34.00	3.35	26.75	83.50	3.05	24.85	5.85
11	P3 - 11 × Suraksha	2.50	17.00	39.00	4.10	92.00	182.50	7.00	33.00	3.42	25.45	83.00	3.55	23.85	5.85
12	P3 – 59 × Suraksha	3.00	17.00	41.00	4.40	106.00	187.50	7.20	35.00	3.86	27.20	84.00	3.75	24.75	5.85
13	P3 – 54 × Suraksha	2.00	18.50	45.00	4.60	86.00	185.00	6.60	34.50	3.47	24.85	83.50	3.55	23.85	5.30
14	P3-47 × Suraksha	2.50	20.50	53.00	**4.70**	112.50	195.00	7.00	33.00	3.46	28.80	82.00	3.45	26.25	5.85
15	P3-135 × Suraksha	3.00	17.00	47.00	3.30	101.00	182.50	7.00	35.00	3.75	25.80	82.50	3.25	24.05	5.55
16	P1- 62 × Sunantha	2.00	17.50	49.00	3.50	111.00	190.00	6.50	32.00	3.06	27.10	82.00	3.05	25.35	5.85
17	P1 – 103 × Sunantha	2.50	18.50	51.00	3.70	88.50	177.50	5.50	36.50	3.17	27.55	84.00	3.35	25.05	5.85
18	P1- 82 × Sunantha	2.00	17.00	47.00	3.30	112.00	192.50	6.70	33.50	3.38	28.15	81.00	3.05	25.95	5.85
19	P1-50 × Sunantha	2.00	17.00	46.00	3.35	75.00	187.50	6.60	34.00	3.40	28.30	82.00	3.25	26.05	5.85
20	P1-190 × Sunantha	2.50	14.50	44.00	3.75	95.00	172.50	7.00	32.50	3.38	28.35	80.00	3.15	25.95	5.55
21	P2 - 17 × Sunantha	2.50	16.50	47.00	4.00	106.50	182.50	7.00	35.00	3.75	25.75	82.00	3.05	24.25	5.95
22	P2 - 7 × Sunantha	2.50	18.00	51.00	4.15	109.00	187.50	6.90	35.50	3.80	28.55	85.00	3.75	25.95	5.85
23	P2 - 103 × Sunantha	2.50	19.00	45.00	4.00	119.00	177.50	6.50	32.50	3.13	**30.35**	84.50	2.85	27.35	5.95
24	P2-3 × Sunantha	3.00	17.50	41.00	3.70	123.00	162.50	6.90	35.00	3.72	27.15	81.00	3.35	25.05	5.85
25	P2-36 × Sunantha	2.00	15.00	42.00	3.20	110.00	180.00	7.00	35.00	3.74	27.05	81.00	3.05	25.35	6.05
26	P3 - 11 ×Sunantha	3.00	19.50	47.00	3.50	129.00	172.50	6.30	36.50	3.62	29.45	80.50	3.55	26.35	5.85
27	P3 – 59 × Sunantha	2.50	20.00	50.50	4.10	97.00	157.50	6.30	37.00	3.71	30.15	84.50	3.25	27.85	5.85
28	P3 – 54 × Sunantha	3.00	**23.00**	47.00	4.30	86.00	172.50	5.30	33.00	2.62	29.35	84.00	3.45	26.15	5.85
29	P3-47 × Sunantha	2.00	12.50	39.00	2.90	71.00	182.50	5.00	35.50	2.76	26.85	80.50	3.55	25.70	6.15
30	P3-135 × Sunantha	2.50	13.50	43.00	3.10	68.50	165.00	5.20	36.00	2.90	28.85	84.50	3.35	25.80	5.95
31	P1- 62 × Subiksha	3.00	19.00	53.00	4.30	111.00	182.50	6.50	36.00	3.66	25.80	82.50	3.25	24.05	5.55
32	P1 – 103 × Subiksha	3.00	20.50	49.50	**4.70**	114.00	187.50	6.10	37.00	3.59	27.10	82.00	3.05	25.35	5.85
33	P1- 82 × Subiksha	2.50	15.00	43.00	4.10	80.00	182.50	5.60	35.00	3.01	27.55	84.00	3.35	25.05	5.85
34	P1-50 × Subiksha	3.00	17.50	40.00	3.70	100.00	195.00	5.80	37.50	3.48	28.15	81.00	3.05	25.95	5.85
35	P1-190 × Subiksha	2.50	13.50	43.00	3.10	86.00	175.00	6.00	36.00	2.89	28.00	84.50	3.25	26.05	5.85
36	P2 – 17 × Subiksha	3.00	16.50	49.00	3.45	93.50	182.50	5.90	34.50	3.11	28.35	80.00	3.15	25.95	5.55
37	P2 – 7 × Subiksha	3.00	16.50	43.00	3.40	119.50	187.50	6.60	33.50	3.32	25.75	82.00	3.05	24.25	5.95
38	P2 – 103 × Subiksha	2.50	13.50	37.00	4.10	100.00	172.50	5.90	36.00	3.32	28.55	85.00	3.75	25.95	5.85
39	P2-3 × Subiksha	2.00	17.00	41.00	3.10	112.50	192.50	6.30	30.50	2.77	30.35	84.50	2.85	27.35	5.95
40	P2-36 × Subiksha	3.00	19.00	49.00	3.70	99.00	197.50	7.00	31.00	3.12	27.15	81.00	3.35	25.05	5.85
41	P3 – 11 × Subiksha	3.00	19.50	41.00	4.10	91.00	182.50	6.30	35.00	3.39	28.00	84.50	3.75	25.35	5.85
42	P3 – 59 × Subiksha	2.50	18.50	35.00	3.30	98.50	182.50	6.20	36.00	3.49	27.25	84.00	3.65	25.25	5.85
43	P3 – 54 × Subiksha	3.50	20.00	42.00	3.45	112.00	195.00	6.90	36.50	3.97	25.45	85.00	3.05	23.75	5.65
44	P3-47 × Subiksha	2.00	14.50	33.00	3.30	87.00	162.50	5.90	31.00	2.65	25.85	82.50	3.15	24.05	5.95
45	P3-135 × Subiksha	3.00	17.50	37.00	3.50	100.00	172.50	6.10	35.00	3.26	28.40	83.00	3.15	26.05	5.85
	Nano (Check)	2.40	14.30	38.00	4.15	89.00	157.50	8.00	33.15	4.05	30.50	87.50	3.40	25.00	6.15
	Sahana (Check)	2.50	17.90	41.00	4.20	93.00	163.00	8.25	34.60	4.40	27.80	83.50	4.35	27.10	5.85
	DHH-11(Check)	2.60	19.90	42.50	4.10	105.00	176.00	8.10	35.80	4.60	29.90	85.50	3.15	25.80	6.05
	DHH-263(Check)	2.20	20.20	41.50	3.95	125.50	179.00	8.25	**41.00**	5.80	28.20	82.50	3.05	26.10	5.85
	MRC70717(Check)	1.80	14.00	39.50	3.50	107.50	**200.00**	**8.50**	40.05	6.25	29.50	80.50	3.55	26.10	6.05

Note**:** NMPP - Number of monopodial branches per plant; NSPP- Number of sympodial branches per plant; NBPP- Number of bolls per plant; BW - Boll weight (g); SCYP - Seed cotton yield per plant (g); PH- Plant height (cm); SI - Seed index; GOT - Ginning outturn (%); LI - Lint index; FL-Fiber length (mm); UI - Uniformity Index (%); FF- Fibre fineness (µg/inch.); FS- Fibre Strength (g/tex.); E - Elongation percentage (%).

The analysis of genetic variance components indicated that non-additive genetic variance (σ^2D) substantially outweighed additive genetic variance (σ^2A) across an extensive array of traits, encompassing plant architecture parameters (monopodia and sympodia per plant, plant height), yield-defining components (boll weight, seed cotton yield per plant), seed characteristics (seed index, ginning outturn, lint index), and critical fiber properties (length, uniformity index, fineness, strength, and elongation percentage). This striking predominance of non-additive gene action strongly indicates that strategic hybridization would be an exceptionally promising breeding approach for enhancing these economically vital traits. The paramount importance of non-additive effects was further substantiated by the degree of dominance surpassing unity for multiple traits, demonstrating that over-dominance emerges as a fundamental genetic mechanism governing their expression.

Several studies have explored the genetic variances influencing cotton traits, revealing complex inheritance patterns. El-Fesheikawy *et al*. (2018) reported that dominance genetic variance (σ^2D) was consistently positive and exceeded additive genetic variance (σ^2A) across yield, yield components, and fiber quality characteristics. This suggests that dominance genetic effects play a crucial role in determining these traits while fiber properties and yield components are primarily governed by dominance variance. Building on these findings, Sorour *et al*. (2013) emphasized the importance of dominance effects in traits such as boll weight, seed cotton yield per plant, and number of bolls per plant. Conversely, they observed that additive gene effects were more significant for lint yield per plant, lint percentage and seed index. AL-Hibbiny (2020) demonstrated that the role of non-additive genetic variance was more substantial for yield-related traits. However, for fiber quality traits, additive genetic variance emerged as the predominant genetic component, highlighting the complexity of genetic inheritance across different cotton yield and yield attributes.

The analysis of proportional contributions of lines, testers, and their interactions to the total variance for yield and fiber quality traits (**Table 4**) revealed that the genetic contributions of lines were substantially higher than those of testers for all studied traits. The line × tester interaction variance components were notably significant, suggesting the predominance of non-additive genetic effects for the investigated traits. These findings indicate the importance of genetic interactions beyond simple additive gene action in determining trait variability. These results warrant further investigation into the general and specific combining abilities of the parental lines and their crosses. These observations align with the findings of Madugula *et al*. (2023) who reported significant line × tester interaction effects for most traits, with exceptions in micronaire and elongation percentage. Sawarkar *et al*. (2015) and Chapara and Satish, (2020) documented significant line × tester interactions for key fiber characteristics, including upper half mean length, elongation percentage, fiber strength, and ginning out-turn.

The selection of parental lines represents a pivotal decision point in cotton breeding programs focused on optimizing seed cotton yield and fiber characteristics. Plant breeders traditionally evaluate potential parents through their phenotypic performance and general combining ability (GCA). It serves as robust indicator of a parent's average performance across multiple cross combinations. The

Table 4. Additive, dominance variances and proportional contribution of lines, testers and their interactions for different traits

Variances/ Sources/ percent contribution	NMPP	NSPP	NBPP	BW	SCYP	PH	SI	GOT	LI	FL (mm)	UI	FF (µg/ inch)	FS (g/tex)	E (%)
Additive and dominance variances														
σ^2 A	-0.005	-0.074	2.847	0.001	3.072	4.555	0.013	0.058	0.003	0.025	0.004	0.000	0.015	0.001
σ^2 D	0.132	6.161	0.682	0.193	293.617	130.734	0.120	2.595	0.068	1.540	1.511	0.061	0.676	0.030
σ^2 A / σ^2 D	-0.036	-0.012	18.920	0.007	0.011	0.035	0.109	0.022	0.041	0.016	0.003	-0.001	0.022	0.016
Degree of Dominance	5.259	9.158	0.036	11.637	9.776	5.357	3.034	6.712	4.926	7.797	19.176	35.835	6.820	7.842
Proportional contribution of lines, testers and their interactions to total variance for different traits														
Line (%)	14.63	24.64	44.74	35.3	43.79	53.01	67	46.32	48.91	37.9	34.49	30.19	41.4	36.1
Tester (%)	0.41	1.26	10.12	6.14	0.06	1.97	3.21	1.47	6.07	9.66	3.41	5.57	8.37	10.39
Line × Tester (%)	84.96	74.11	45.14	58.56	56.15	45.01	29.79	52.21	45.02	52.43	62.1	64.24	50.23	53.51

NMPP - Number of monopodial branches per plant; SCYP - Seed cotton yield per plant (g)t;LI - Lint index; FS- Fibre Strength (g/tex.); NSPP- Number of sympodial branches per plant; PH- Plant height (cm); FL-Fiber length (mm);E - Elongation percentage (%); NBPP- Number of bolls per plant; SI - Seed index;UI - Uniformity Index (%); BW - Boll weight (g); GOT - Ginning outturn (%);FF- Fibre fineness (µg/inch.)

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Table 5. Estimates of *gca* for yield, yield attributes and fiber quality traits of cotton

Genotypes	NMPP	NSPP	NBPP	BW	SCYP	PH	SI	GOT	LI	FL (mm)	UI	FF (µg/ inch)	FS (g/tex)	E (%)
P1- 62	-0.13	-0.03	1.39	-0.14	1.93	-32.77**	-0.43**	1.65*	0.01	-0.84**	1.27*	0.13*	-0.56**	-0.18**
P1 – 103	0.20	1.63*	2.72*	-0.05	18.93**	2.22	0.48**	-3.51**	-0.28*	1.08**	0.61	-0.10	0.57**	0.08*
P1- 82	-0.13	1.46*	2.05*	0.29*	-1.23	-0.27	-0.05	2.32**	0.32**	-0.52**	0.11	-0.10	-0.13	-0.18**
P1-50	0.03	-1.20*	-6.44**	0.16	-12.06**	-4.44*	0.514**	-0.51	0.18*	-1.10**	0.61	0.16**	-0.92**	0.05
P1-190	-0.13	1.13	4.05**	0.46**	13.26**	9.72**	0.49**	-0.34	0.20*	-1.09**	-0.22	0.13*	-0.69**	-0.23**
P2 - 17	0.20	0.13	4.72**	-0.23*	10.60**	8.88**	-0.11	-0.51	-0.15	0.02	-0.55	-0.13*	0.04	0.05
P2 - 7	-0.30**	-1.53*	1.39	-0.04	-11.06**	3.05	0.49**	-0.68	0.16	-0.11	-1.55*	-0.13*	0.00	-0.02
P2 - 103	0.03	0.63	4.39**	0.21*	13.76**	-1.94	0.41**	-0.18	0.19*	1.10**	0.61	0.03	0.70**	0.08*
P2-3	-0.13*	0.63	2.22*	-0.14	8.76**	-7.77**	0.16	1.65*	0.33**	1.30**	-0.88	0.00	1.10**	0.11*
P2-36	-0.13	-1.20*	-1.28	-0.30	-28.06**	-4.44*	-1.20**	0.32	-0.59**	0.77**	0.11	0.16**	0.47**	0.18**
P3 - 11	0.20	0.63	1.22**	0.63**	-1.57	6.38*	-0.28*	1.48*	0.07	-0.75**	-0.05	-0.07	-0.59**	-0.05
P3 – 59	0.03	-1.70**	-2.94*	-0.31**	-10.06**	6.38*	-0.45**	0.32	-0.18*	0.69**	-1.88**	-0.13*	0.57**	-0.05
P3 – 54	-0.13	`0.21	-3.94**	-0.202*	7.43**	6.38*	-0.08	-1.178*	-0.21*	0.64**	0.94	-0.07	0.43**	0.11*
P3-47	0.20	1.46*	-2.61*	-0.04	-7.06**	9.72**	0.13	-0.51	-0.02	-0.11	0.27	0.29**	-0.20	0.05
P3-135	0.20	-0.20	-6.94**	-0.31**	-3.56*	-1.11	-0.06	-0.34	-0.06	-1.00**	0.61	-0.16**	-0.79**	0.01
S.Em.	0.20	0.46	0.97	0.09	1.64	2.11	0.10	0.53	0.08	0.06	0.47	0.04	0.11	0.04
C.D.95 %	0.40	0.94	1.96	0.17	3.31	4.26	0.20	1.07	0.17	0.13	0.95	0.09	0.22	0.07
Sunantha	0.67	0.36**	2.58	0.03	12.56**	10.61**	0.51*	0.02	0.61**	-0.59**	-0.12	0.01	-0.48*	-0.08
Suraksha	-0.80*	-0.10	-4.42*	-0.26	-12.26***	-13.38**	-0.24	-0.31	-0.52***	0.32***	-0.25	-0.04	6.79**	0.08
Subhiksha	0.13	-0.27	1.84	0.23	-0.30	-2.22	-0.26	0.29	-0.10	0.26***	0.37	0.03	11.27**	0.00
S.Em.	0.09	0.21	0.44	0.04	0.73	0.94	0.04	0.24	0.04	0.03	0.21	0.02	0.05	0.02
C.D. 0.5 %	0.18	0.42	0.88	0.08	1.48	1.90	0.09	0.48	0.08	0.06	0.42	0.04	0.10	0.03

Note: NMPP - Number of monopodial branches per plant; NSPP- Number of sympodial branches per plant; NBPP- Number of bolls per plant; BW - Boll weight (g); SCYP - Seed cotton yield per plant (g); PH- Plant height (cm); SI - Seed index; GOT - Ginning outturn (%); LI - Lint index; FL-Fiber length (mm); UI - Uniformity Index (%); FF- Fibre fineness (µg/inch.); FS- Fibre Strength (g/tex.); E - Elongation percentage (%).

present investigation demonstrated significant genetic variation across multiple traits. The presence of highly significant mean squares for GCA revealed substantial genetic diversity among parental lines and confirmed the prevalence of additive genetic effects (**Table 5**). While the significant GCA mean squares indicated additive gene action, the highly significant specific combining ability (SCA) mean squares suggested the concurrent influence of non-additive genetic control mechanisms.Among the parental lines evaluated, P2-103 and P1-190 emerged as exceptional performers, exhibiting superior positive *gca* across multiple traits. Their performance was particularly noteworthy for seed cotton yield per plant (13.76 and 13.26), boll weight (0.21 and 0.46), and number of bolls per plant (4.39 and 4.05). A particularly intriguing finding involved line P2-7, which displayed a negative *gca* (-3.00) for monopodial branch frequency. In cotton improvement programs, this characteristic is actually advantageous, as reduced monopodial branching typically correlates with enhanced plant architecture efficiency and improved resource allocation.Among the testers, Sunantha showed the highest significant positive *gca* for seed cotton yield per plant (12.56), while Suraksha (6.79) and Subhiksha (11.27) excelled in fiber strength traits. Previous research by Singh and Chaudhary (1985), and Khokhar *et al.* (2018) has highlighted that high *gca* typically result from additive gene effects or additive × additive gene interactions. Parents demonstrating a significant positive relationship between mean performance and *gca* likely possess a higher number of additive genes, making them valuable for varietal improvement and development programs (**Table 7**). These findings suggest that the identified lines and testers could be promising candidates for future cotton breeding efforts, potentially contributing to improved yield and quality.

Specific combining ability effects (*sca*) represents the unique performance of inbred parents when crossed in specific combinations. As highlighted by Nduwumuremyi *et al.* (2013), SCA serves as a crucial parameter for identifying superior hybrid combinations and indicates the presence of non-additive gene action.

Table 6. Estimates of *sca* for yield, yield attributes and fiber quality traits of cotton crosses

	Crosses	NMPP	NSPP	NBPP	BW	SCYP	PH	SI	GOT	LI	FL (mm)	UI	FF (µg/ inch)	FS (g/tex)	E (%)
1	P1- 62 × Suraksha	-0.50**	2.60*	7.24**	2.19**	25.06**	14.77**	0.07	0.81	0.15	-0.63**	-0.04	-0.29**	8. 41*	0.47**
2	P1 –103 × Suraksha	-0.33	-4.53**	-5.08*	-0.38*	-29.93**	-20.22**	-0.03	0.47	0.04	0.66**	-0.87	0.24*	0.14	0.05
3	P1- 82 × Suraksha	0.00	-2.36*	-1.42	0.16	-2.76	-7.72*	-0.65**	0.14	-0.35*	-0.15	-0.37	-0.25*	0.14	-0.17*
4	P1-50 × Suraksha	-0.16	-1.70*	-6.42**	-0.70**	-15.43**	-26.05**	-0.47*	-0.02	-0.25	0.87**	0.12	-0.32**	0.74**	0.08
5	P1-190 × Suraksha	-0.50	-0.53	-5.42*	0.39*	-30.26**	-5.22	-0.35*	0.31	-0.14	-1.03**	0.95	0.20*	-0.48*	-0.17*
6	P2 - 17 × Suraksha	-0.83*	-0.53	-2.08	-0.01	27.40**	0.61	0.16	-2.02*	-0.19	0.09	-0.21	-0.02	0.28	0.08
7	P2 - 7 × Suraksha	-0.33	0.63	-1.75	-0.35*	-16.93**	3.94	-0.35*	0.14	-0.16	1.42**	0.78	0.17*	1.01**	0.15*
8	P2 - 103 × Suraksha	-0.16	-0.53	3.24	0.19	-7.76*	8.94*	0.02	1.14	0.19	0.46**	1.62	0.50**	0.21	0.05
9	P2-3 × Suraksha	-0.50	-3.53**	-6.58**	-0.40*	-1.76	7.27	0.32	-1.18	-0.06	-1.23**	-0.87	-0.15*	-0.78**	0.22**
10	P2-36 × Suraksha	0.50	6.30**	1.91	0.86**	11.06**	-3.55	0.04	-1.85	-0.20	1.59**	1.12	0.07	0.64*	-0.04
11	P3 - 11 × Suraksha	0.16	0.46	2.41	-0.06	9.56*	-4.38	0.32	-0.02	0.18	-0.42**	-0.21	0.10	-0.38	-0.11
12	P3 – 59 × Suraksha	0.33	1.30	5.57*	0.28	7.06*	8.11**	-0.20	2.64*	0.26	0.47**	0.12	-0.02	0.34	0.18*
13	P3 – 54 × Suraksha	0.50	0.46**	0.57	-0.13	9.06*	0.61	0.22	0.14	0.12	-1.87**	-1.71*	-0.09	-1.21**	0.12
14	P3-47 × Suraksha	0.16	-0.36	5.24*	-0.01	3.06	7.27**	0.36*	-3.02*	-0.27	0.27*	-2.04*	-0.15*	0.21	0.08
15	P3-135 × Suraksha	0.66	2.30*	2.57	0.03	12.56**	15.61**	0.51*	2.31*	0.61**	-0.52**	1.62	0.09	-0.48*	-0.07
16	P1- 62 × Sunantha	-0.46	-0.40	-0.75	0.30*	-3.26	-11.72*	-0.18	-1.85	-0.35*	0.78**	-0.41	0.06	0.67*	0.17*
17	P1 – 103 × Sunantha	0.20	2.93**	3.91*	-0.12	17.23**	15.77**	0.45*	-0.18	0.18	0.13	0.25	-0.30**	0.13	0.01
18	P1- 82 × Sunantha	0.53	0.60	4.57*	0.32*	-4.60	10.77*	-0.11	0.97	0.08	-0.32*	-0.74	0.19*	-0.26	-0.02
19	P1-50 × Sunantha	-0.13**	0.76	1.07	0.05	1.23	9.94*	0.21	-0.68	0.02	-1.34**	-0.24	0.02	-0.86**	-0.05
20	P1-190 × Sunantha	0.03	1.93*	4.57*	0.35*	16.40**	8.27	0.28	-0.85	0.09	1.98**	-0.41	-0.03	1.30**	0.22**
21	P2 - 17 × Sunantha	0.70*	0.93	1.91	0.05	-24.93**	-8.38*	-0.59*	2.81**	0.09	-0.37*	1.92*	0.12	-0.62*	-0.05
22	P2 - 7 × Sunantha	0.20	-1.40	-1.75	-0.09	3.23	-7.55*	0.28	-1.02	-0.09	0.55**	-1.07	-0.07	0.30	-0.28**
23	P2 - 103 × Sunantha	-0.13	0.93	-0.75	-0.09	2.40	2.44	-0.13	-1.52	-0.29*	1.33**	1.25	-0.53**	1.00**	0.01
24	P2-3 × Sunantha	0.53	1.43	0.41	-0.24	17.40**	3.27	-0.08	0.64	0.05	0.23*	-1.24	0.19*	-0.39*	-0.12
25	P2-36 × Sunantha	-0.46	-3.73**	-4.08*	-0.67**	-3.76	9.94*	-0.01	0.97**	0.12	-1.82**	-2.24*	0.02	-0.41*	0.11
26	P3 - 11 ×Sunantha	0.20	2.43*	0.91	0.18	12.73**	4.11	0.16	1.31	0.28	-0.04	-0.57	-0.23*	0.30	0.04
27	P3 – 59 × Sunantha	-0.63	-2.23*	-1.42	-0.46*	-6.76*	-8.38*	0.23	-2.02*	-0.14	-0.29*	1.25	0.02	-0.16	0.04
28	P3 – 54 × Sunantha	0.03	-2.06*	-3.42*	0.42*	-10.26**	-10.88*	-0.23	2.97*	0.30*	0.06	1.42	0.46**	-0.12	-0.12
29	P3-47 × Sunantha	0.20	0.60	-0.75	0.25	-4.76	-4.22	-0.04	1.31	0.18	0.20	1.58	0.09	-0.09	-0.05
30	P3-135 × Sunantha	-0.80*	-2.73*	-4.42*	-0.26	-12.26**	-13.38**	-0.24	-2.85*	-0.52**	-1.04**	-0.74	-0.03	-0.79**	0.07
31	P1- 62 × Subiksha	-0.03	-2.23*	-6.48**	-0.40*	-21.80**	-3.05	0.10	1.04	0.20	-0.15	0.45	0.22*	-0.25	0.29**
32	P1 – 103 × Subiksha	0.13	1.60	1.17	0.51*	12.70**	4.44	-0.41*	-0.28	-0.23	-0.80**	0.62	0.06	-0.28	-0.06
33	P1- 82 × Subiksha	-0.53	1.76*	-3.15	-0.48*	7.36*	-3.05	0.76**	-1.12	0.27	0.48**	1.12	0.06	0.11	0.19*
34	P1-50 × Subiksha	0.30	0.93	5.34*	0.64**	14.20**	16.11**	0.25	0.71	0.25	0.46**	0.12	0.29**	0.11	-0.03
35	P1-190 × Subiksha	0.46	-1.40	0.84	-0.75**	13.86**	-3.05	0.06	0.54	0.12	-0.95**	-0.54	-0.17*	-0.82**	-0.05
36	P2 – 17 × Subiksha	0.13	-0.40	0.17	-0.05	-2.46	7.77*	0.43*	-0.78	0.10	0.28*	-1.71*	-0.10	0.34	-0.03
37	P2 – 7 × Subiksha	0.13	0.76	3.51*	0.44*	13.70**	3.61	0.06	0.87	0.17	-1.98**	0.28	-0.10	-1.32**	0.13*
38	P2 – 103 × Subiksha	0.30	-0.40	-2.48	-0.10	5.36	-11.38*	0.10	0.37	0.10	-1.80**	-2.87**	0.02	-1.22**	-0.06
39	P2-3 × Subiksha	-0.03	2.10*	6.17**	0.64**	-15.63**	-10.55*	-0.24	0.54	-0.04	0.99**	2.12*	-0.03	1.17**	-0.10
40	P2-36 × Subiksha	-0.03*	2.56	2.18**	1.18*	7.30**	-6.38	-0.03	0.87*	0.08	0.23*	1.12	-0.10	2.24**	-0.07
41	P3 – 11 × Subiksha	-0.36	-2.90**	-3.32	-0.12	-22.30**	0.27	-0.49*	-1.28	-0.47*	0.46**	0.78	0.12	0.07	0.06
42	P3 – 59 × Subiksha	0.30	0.93	-4.15*	0.17	-0.30	0.27	-0.03	-0.62	-0.11	-0.18	-1.37	-0.04	-0.18	-0.23**
43	P3 – 54 × Subiksha	-0.53	1.60	2.84	-0.28	1.20	10.27*	0.02	-3.12*	-0.43*	1.86*	0.28	-0.37**	1.34**	-0.01
44	P3-47 × Subiksha	-0.36	-0.23	-4.48*	-0.25	1.70	-3.05	-0.31	1.71	0.09	-0.48**	0.45	0.06	-0.12	-0.03
45	P3-135 × Subiksha	0.13	0.43	1.84	0.22	-0.30	-2.22	-0.26	0.54	-0.09	1.56**	-0.87	0.02	1.27**	-0.01
	S.Em.	0.34	0.80	1.68	0.14	2.84	3.65	0.174	0.92	0.14	0.10	0.81	0.07	0.19	0.06
	C.D.95 %	0.68	1.61	3.40	0.30	5.73	7.37	0.35	1.85	0.29	0.22	1.63	0.14	0.38	0.12

Note: NMPP - Number of monopodial branches per plant; NSPP- Number of sympodial branches per plant; NBPP- Number of bolls per plant; BW - Boll weight (g); SCYP - Seed cotton yield per plant (g); PH- Plant height (cm); SI - Seed index; GOT - Ginning outturn (%); LI - Lint index; FL-Fiber length (mm); UI - Uniformity Index (%); FF- Fibre fineness (µg/inch.); FS- Fibre Strength (g/tex.); E - Elongation percentage (%).

Table 7. Parents with high *per se* performance and *gca* effects for different traits

S.No.	Parents	Characters		
		***Per se* performance**	***gca* effects**	***Per se* performance and *gca* effects**
Lines				
1	P1- 62	NMPP, BW, PH, GOT, SI, LI, UI	NSPP, GOT, UI, FF (µg/ inch),	GOT
2	P1 – 103	FL (mm), UI, FS (g/tex), E (%)	NSPP, SCYP, FL, E (%)	E (%),
3	P1- 82	NMPP, FL (mm), UI, E (%)	BW, LI	-
4	P1-50	BW, SCYP, GOT, UI, FF (µg/inch), E (%)	SI, LI, FF (µg/ inch)	-
5	P1-190	NMPP, NBPP, BW, SCYP, PH (cm), UI, FF (µg/inch),	BW, SCYP, PH (cm), SI, LI, FF (µg/ inch)	-
6	P2 - 17	NMPP, BW, SCYP, FL (mm), FS (g/tex), E (%),	SCYP, PH (cm)	SCYP
7	P2 - 7	GOT, LI, FL (mm), UI, FF (µg/inch), FS (g/tex),	NMPP, NBPP, SI	-
8	P2 - 103	NSPP, BW, SCYP, PH (cm), SI, FF (µg/inch), FS (g/tex), E (%)	NMPP, BW, SCYP, SI, LI, FL, FS (g/tex), E (%),	BW, SCYP, SI, FS (g/tex), E (%)
9	P2-3	NMPP, NSPP, NBPP, SI, FL (mm), UI, FS (g/tex), E (%)	GOT, LI, FL, FS (g/tex), E (%)	FL (mm), E (%)
10	P2-36	PH (cm), SI, FF (µg/inch), E (%)	FL (mm), FF (µg/ inch), FS (g/tex), E (%)	FF (µg/ inch), E (%)
11	P3 - 11	NSPP, NBPP, BW, SCYP, PH (cm), SI, GOT, LI, FF (µg/inch), FS (g/tex),	NBPP, PH (cm), GOT,	NBPP, GOT
12	P3 – 59	NMPP, NSPP, NBPP, BW, SCYP, PH (cm), SI, FF (µg/inch), FS (g/tex)	PH, FL(mm)	PH (cm)
13	P3 – 54	NBPP, SI, GOT, E (%)	PH, FL(mm), FS (g/tex), E (%)	E (%)
14	P3-47	NSPP, NBPP, BW, PH (cm), SI, GOT, E (%)	PH (cm), FF (µg/ inch)	PH (cm)
15	P3-135	NSPP, NBPP, BW, SCYP, PH (cm), SI, GOT, LI, FS (g/tex)	-	-
Testers				
16	Sunantha	NSPP, NBPP, BW, SCYP, PH (cm), SI, GOT (%), LI, FL (mm), FS (g/tex)	NSPP, SCYP, PH (cm), LI	SCYP, PH (cm), LI
17	Suraksha	FL (mm), FF (mm), FS (g/tex)	NMPP, FL (mm)	FL (mm)
18	Subhiksha	NSPP, NBPP, SCYP, SI, GOT (%), LI, UI, FF (mm), E (%)	FL (mm), FS (g/tex)	-

Note: NMPP - Number of monopodial branches per plant; NSPP- Number of sympodial branches per plant; NBPP- Number of bolls per plant; BW - Boll weight (g); SCYP - Seed cotton yield per plant (g); PH- Plant height (cm); SI - Seed index; GOT - Ginning outturn (%); LI - Lint index; FL-Fiber length (mm); UI - Uniformity Index (%); FF- Fibre fineness (µg/inch.); FS-Fibre Strength (g/tex.); E - Elongation percentage (%).

Among the 45 crosses evaluated, two combinations , P1-62 × Suraksha and P2-36 × Subiksha, demonstrated particularly noteworthy performance. The cross P1-62 × Suraksha exhibited significant positive *sca* for multiple traits, including seed cotton yield per plant (25.06), number of bolls per plant (7.24), sympodial branches per plant (2.60), boll weight (2.19), fiber strength (8.41), and elongation percentage (0.47) (**Table 6**). Similarly, P2-36 × Subiksha showed promising *sca* for number of bolls per plant (2.18), boll weight (1.18), seed cotton yield per plant (7.30), ginning out turn (0.87), fiber length (0.23), and fiber strength (2.24). However, it is worth noting that no single hybrid combination demonstrated positive and significant values across all evaluated yield and quality parameters, a finding that aligns with previous research by Giri *et al*. (2020).

The crosses exhibiting positive and significant *sca* emerged from various parental combinations, including good × good, good × poor, and poor × poor general combining abilities. Superior hybrid combinations typically included at least one parent with favourable, moderate, or even poor *gca* . Particularly interesting were the crosses between one good and one poor general combiner, as these combinations could potentially produce desirable transgressive segregants. This outcome is possible when the additive gene complexes from the superior combiner act synergistically with complementary epistatic effects from the poor combiner to enhance desirable traits. These findings correspond with the conclusions reported by El-Mansy *et al*. (2020) and Madugula *et al.* (2023). Keerthivarman *et al*. (2022) revealed that majority of the crosses had non-additive or dominant gene action while assessing cotton crosses by L× T design.

These studies collectively underscore the intricate genetic mechanisms governing cotton trait development, emphasizing the variable roles of additive and dominance genetic variances across different trait categories. The good general combiners from this study P2-103 and P1-190 can be utilized as a parents in cotton breeding program. The superior cross combinations P1-62 × Suraksha and P2-36 × Subiksha based on their high *sca* for yield and yield attributes may be utilized as hybrid cultivar after thorough evaluation over seasons and locations.

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