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Research Article

Genetic analysis for estimating combining ability in *Gossypium hirsutum* L. x *Gossypium barbadense* L. hybrids

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Abstract
Two sets of 28 interspecific HxB hybrids generated in LxT fashion, along with their parents were evaluated for 11 yield and fibre quality parameters. GCA variances were lower than SCA variances for all the characters in both sets, as indicated by their lower ratios suggesting predominance of non-additive gene action. Based on both *per se* and *gca* effects, GJHV 374 BT, RAJAT BT, ICB 39 and CCB 141 in Set I and GJHV 374 BT, SURAJ BT, ICB 176 and SUVIN in Set II were found to be the best parents which could be utilized for the hybridization programme to obtain superior segregants with yield and fibre qualities. The hybrids *viz.,* RAJAT BTxICB 99, RAJAT BTxICB 34,SURAJ BTxICB 39, GJHV 374 BTxICB 264, SURAJ BTxICB 264 and SURAJ BTxICB 284 showed significant *sca* effects. Hence, it may be concluded that the above hybrids are the best specific combiners for different yield-contributing and fibre-quality traits. The *sca* effect was found to be positive in17 crosses and 11 crosses for single plant yield in set I and II, respectively. Similarly, six crosses each in sets I and II were found with a positive *sca* effect for fibre length.

Keywords: Cotton, combining ability, GCA, SCA, interspecific Bt hybrids

INTRODUCTION

A prominent and substantial position in the global economy is held by cotton, a significant commercial cash crop. It has an impact on the economies of numerous nations, including the USA, China, India, Pakistan, Uzbekistan, Australia, and Africa. About 90% of cotton produced worldwide is upland cotton (*Gossypium hirsutum* L.). The second most widely cultivated species is *Gossypium barbadense* L., which has extra-long, robust, and fine cotton (Lacape *et al*., 2007; Yu *et al*., 2011). The textile sector, which consumes 59% of the nation's total fibre production, is built on cotton (Dhuria, 2018). India is the only country in the world where all four domesticated cotton speciesviz., G. *hirsutum, G. barbadense, G. arboreum*, and *G. herbaceum* are farmed from the far north to the far south. The world's greatest agricultural producer, India cultivates about 10.5 mha to 12.50 m ha every year (cotcorp.org.in). Cotton consumption in India shot up from 310.41 lakh bales in 2016–17 to approximately 338 lakh bales (each weighing 170 kg) in 2021–22. In comparison to ten years ago, the growth rate has recently been expanding at a significantly higher rate. The output of cotton has significantly expanded in recent years, and it is predicted that in 2022–2023, it would be close to 351 lakh bales (Baghyalakshmi *et al.,* 2024).

Extra-Long Staple (ELS) cotton is defined as cotton fibres with an upper half mean length (UHML) of more than 32.5 mm. Since the native ELS cotton does not combine all the fibre properties to produce world-class yarn in the group of superfine counts, spinning mills import ELS cotton from countries like Egypt and the USA. About 10% of India's total cotton consumption (10.50 lakh bales) was imported in 2022–23 by the textile industry to suit their unique needs (cotcorp.org.in). The main strategy for increasing ELS cotton yield is the commercial exploitation of heterosis between *G. hirsutum* x *G. barbadense* (HxB) and systemic varietal improvement through hybridization (Kannan and Saravanan, 2016). *G. hirsutum* and *G.*

barbadense interspecific crossing is a helpful method for boosting genetic diversity among elite germplasm for fibre properties including fibre length and strength. Interspecific hybrids have a higher commercial potential than intraspecific hybrids, and interspecific hybrids have been shown to have reduced inbreeding depression (Baloch *et al*., 1993). According to Berger *et al*. (2011), although some interspecific crosses have lower yield potential and lint percent than commercial cultivars, introgression of genes from *G. barbadense* into *G. hirsutum* may lead to improved length and bundle strength.

Cotton breeder's main goal is to increase the yield per unit area, the yield of fibre, and improvements in the length, strength, and fineness of the fibre. Utilizing parents from genetically and geographically varied backgrounds will increase cotton output and fibre quality. One of the effective strategies for choosing ideal parents and crosses for use in pedigree breeding is the line x tester approach, which Kempthorne proposed in 1957 (Fellahi *et al*., 2013). Both additive (Zangi, 2010) and non-additive gene action (Tausif, 2008) for seed cotton output were found to be important in interspecific hybrid populations (*G. hirsutum* L. x *G. barbadense* L.). Early studies found that genes with additive and non-additive action govern variance in seed cotton yield and its constituent components. While exploring the hybrid development, the dominant gene action is the most needed. Similarly, the GCA and SCA also play a major role in parental selection based on the gene action. Line x Tester analysis (Kempthorne, 1957) is one of the many combining ability analysis designs, widely used to evaluate the combining ability of parents and crosses for various quantitative characters. With this background, a study was formulated to analyse two sets of 28 *Bt* HxB hybrid cotton and calculate GCA for parents, SCA for hybrids, and gene action, and to compare the performance of female parents in both sets to check for its stable performance before choosing the best parent that may be used in breeding programs for yield and fibre quality.

MATERIALS AND METHODS

Plant materials: Four *G. hirsutum* cultivars (female) and 14 different *G.barbadense* accessions (male) were crossed in LxT fashion, to create the two sets of 28 hybrids each (total 56) (**Table 1**) and the same were employed in the current study.

The experiment was laid out in main fields of the ICAR-Central Institute for Cotton Research, Regional Station, Coimbatore, during *kharif* 2020–21 with 56 hybrids (2 sets of LxT crosses) and parents. Each entry was sown in 10 rows in each of the three replications laid out in a randomised complete block design. The recommended spacing of 90 x 60 cm was followed. After 15 days, the gaps were filled and the plants were thinned to keep

Table 1. Description of the parental genotype

Genotypes	Pedigree	Trait of importance
	Female (*G.hirsutum*)	
GJHV 374 Bt	GJHV 374 variety x BN Bt (Mon 531)	Bollworm tolerant
PKV 081 Bt	PKV-01 Variety x BN Bt (Mon 531)	Boll worm tolerant
RajatBt	Rajat Variety x BN Bt (Mon 531)	Boll worm tolerant
SurajBt	Suraj Variety x BN Bt (Mon 531)	Boll worm tolerant
	Male: Set I (*G. barbadense*)	
ICB 28	136 x 181 B x (B)	Cuticular waxy lines
ICB 34	SILS 7	More trichome
ICB 39	ICB 174-77	Compact type
ICB 99	32/2 R	Compact type
CCB 141	Suvinx (SuvinxGiza 70) S	Advance culture for yield
ICB 183	EC 9260	Early maturing
ICB 207	EC 98254	Less Gossypol Glands
	Set II (*G. barbadense*)	
CCB 143 B	-	High boll weight
ICB 174	SUDAN VS	High cuticular wax
ICB 176	Reselection SUVIN	Fiber quality
ICB 258	EC 111264/1	Early maturing
ICB 264	EC 37647	More gossypol glands
ICB 284	EC 136455	Resistant to sucking pests
SUVIN	Sujata x St.Vincent	Fibre Quality

one plant per hill. Recommended crop production and protection techniques were adopted for healthy crop status. Observations on number of sympodia per plant, number of bolls per plant, single boll weight (g), single plant yield (g), fiber length (UHML) (mm), fiber strength (g/tex), fiber fineness/micronaire value (µg/inch) data were collected on the five middle competitive plants selected randomly. The lint samples were submitted for evaluation of the fibre quality at the Regional Centre of the ICAR-Central Institute for Research on Cotton Technology in Coimbatore, Tamil Nadu (India).The mean values of the characters were analyzed in 56 hybrids as two different sets using the method advocated by Panse and Sukhatme (1964), and they were then analyzed for Analysis of Variance (ANOVA), Standard Error, and Critical Difference. Combining abilityof parents and hybrids was investigated as per the method of Kempthorne(1957).

RESULTS AND DISCUSSION

Combining ability analysis is useful to evaluate the breeding lines based on their breeding value and to identify suitable parents for hybridization and identification of superior cross combinations. It will help to understand the genetic architecture such as inheritance patterns and mode of gene action of various characters which facilitate the breeders to design an effective breeding programme for the genetic improvement of existing varieties. It is suggested that parents with good *per se* performance would result in better hybrids. The most commonly used mating design, Line × Tester provides information about estimates of additive and non-additive components of gene action. Two sets of 28 hybrids crossed in LxT fashion with common lines were evaluated in replicated trials to select the best combiners and the best-performing hybrids. The estimates of mean squares of variance

Table 2a. Set I: Analysis of variance showing mean squares and genetic contribution of genotypes for yield and fibre attributing characters

Source of variation	Df	Number of Sympodia per plant	Number of bolls per plant	Single boll weight (g)	Single plant yield (g)	Finer length (mm)	Fiber Strength (g/tex)	Fiber fineness /Mic (µ)
Replication	3	0.066	2.089	0.02	7.81*	0.18	0.47	0.001
Lines	3	17.78*	572.91*	0.57*	10103.42*	3.23*	6.03*	0.75*
Tester	6	4.84*	474.70**	0.46*	5761.63**	27.36*	11.67*	0.43*
Line x Tester	27	12.04*	408.87**	1.04	4730.36**	12.06*	9.99*	0.46*
Error	81	0.128	1.96	0.01	8.055	0.5	0.48	0.005
VAR OF GCA		-0.0240	0.8214	-0.0046	20.6545	0.0604	-0.0017	0.0006
VAR OF SCA		3.3372	89.4058	0.3275	870.7581	1.9847	2.4019	0.1044
Lines		16.41	15.57	6.06	23.73	2.97	6.71	18.16
Testers		8.94	25.80	9.63	27.07	50.41	25.96	20.62

*significant at 5% level; **significant at 1% level

Table 2b. Set II: Analysis of variance showing mean squares and genetic contribution of genotypes for yield and fibre attributing characters

Source of variation	Df	Number of Sympodia per plant	Number of bolls per plant	Single boll weight (g)	Single plant yield (g)	Finer length (mm)	Fiber Strength (g/tex)	Fiber fineness / Mic (µ)
Replication	3	0.15	1.01	0.01	0.80*	0.34	0.19	0.00
Lines	3	2.13	269.49*	0.91*	5529.68**	7.96*	11.31*	0.87*
Tester	6	6.96*	372.93**	0.17	7045.58**	14.40*	19.40**	0.31*
Line x Tester	27	9.78*	281.52*	1.06*	4886.22*	9.36*	12.38*	0.34*
Error	81	0.36	1.20	0.01	1.70	0.50	0.55	0.00
VAR OF GCA		-0.0370	0.4744	-0.0053	13.7838	0.0241	0.0360	0.0013
VAR OF SCA		2.9119	62.9636	0.3413	1014.3730	1.8540	2.4185	0.0644
Lines		2.42	10.64	9.58	12.57	9.45	10.15	28.44
Testers		15.80	29.44	3.65	32.04	34.19	34.81	20.03
LxT		81.79	59.93	86.77	55.38	34.19	55.04	51.53

*significant at 5% level; **significant at 1% level for seven traits among the hybrids are furnished in **tables 2a&b**. Significant genotypic differences demonstrated that interspecific groups had enough genetic diversity to account for every observable trait. The significance of GCA and SCA variances suggested that both additive and dominant genes were having effects on the studied traits, which is also demonstrated by other studies (El-Fesheikawy *et al*., 2012, Al- Hibbiny, 2015, Baloch*et al*., 2014). The mean sum of squares for parents and crosses for all the evaluated traits was found to be significant. The GCA and SCA were showing similar pattern in both sets. In both set of crosses, for all characters, the GCA variance was less than the SCA variance, suggesting that the dominance gene action was predominant for all the evaluated traits. Similar results were also been reported by Giri *et al*. (2020) and Verma *et al.*(2021). The significance of influence of non-additive gene action on seed cotton yields of cotton in interspecific hybrid populations has been highlighted by Tausif (2008).

Genotypes with high *per se* and *gca* effects could be useful to develop desirable segregants in breeding programmes. The *gca* effect is due to additive gene action which is fixable. The *sca* effect is the index to determine the usefulness of a particular cross combination in the exploitation of heterosis. GCA variances were lower than SCA variances for all the characters in both sets, as indicated by their lower ratios indicating a predominance of non-additive gene action (dominant or epistasis) in the inheritance for all of these traits (Sprague and Tatum, 1942). In most of the research, for every character under study, the SCA variation was larger than the GCA variance, suggesting that non-additive gene action predominates in all characters (Indhubala et al., 2010). These results suggested that heterosis breeding was suitable for all the characteristics including fibre properties. Singh and Singh (1985) reported that parents with high *gca* effects would produce superior segregants in subsequent generation. The variance attributable to GCA was also less than SCA, demonstrating that non-additive gene action is predominated for yield and fibre traits. The selection of parents based on these characters need to be considered during the later generations.

Among the parents, the best general combiner was line GJHV 374 BT for the number of bolls, single plant yield and fibre length followed by SURAJ BT for bundle strength and fineness. RAJAT BT showed good *gca* for number of sympodial branches and the number of bolls. Similarly, among the testers, the parent with good GCA was ICB 99 for the Number of Sympodial branches, Number of bolls and single plant yield, CCB 141 for three fibre traits. ICB 34 and ICB 39 showed good *gca* effects for single plant yield. In set II, the lines *viz*., GJHV 374 BT, PKV 081 BT and SURAJ BT showed superior *per se* performance for five traits. Among testers, ICB 174 had superior *per se* performance for four yield traits. ICB 176 showed good mean performance for number of sympodial branches, single boll weight, fibre length and bundle strength. The parents CCB 143 B and ICB 264 showed good *per se* performance for three traits *viz*., single plant yield, fibre length and strength. SUVIN exhibited superior mean performance for number of sympodial, single boll weight and fibre length. While comparing both the sets, parent GJHV 374 BT was showing better combining ability for most of the traits (**Table 3a, 3b**). Genotypes with high *per se* performance and high *gca* effects could be useful in evolving desirable segregants in breeding programmes. Parents with good *per se* performance would give better hybrids Gilbert (1958).

With respect to *sca* effects of Set I, out of 28 crosses, 13 crosses showed positive and significant *sca* effects for number of sympodial branches, 12 crosses showed positive and significant *sca* effects for number of bolls. Positive and significant *sca* effects were observed in eight crosses for single boll weight, 17 crosses in single plant yield, six crosses in fibre length and strength, 10 crosses in fibre fineness. Among the crosses, cross RAJAT BTxICB 99 showed desirable *sca* effects for six traits *viz*., Number of Sympodial branches, Number of bolls, Single boll weight, Single plant yield, fibre length and fineness. The cross GJHV 374 BTxICB 28, RAJAT BTxICB 34 exhibited desirable *sca* effects for five traits. The cross GJHV 374 BTxCCB141 ,PKV 081 BT xICB 99 , PKV 081 BTBtxCCB 141 , SURAJ BTxICB 39 and SURAJ BTxICB 183 showed positive and significant *sca*effects for four traits (**Table 3a, b**). In set II, single plant yield and fibre fineness exhibited positive and significant *sca* effects for 12 crosses. The cross GJHV 374 BTxICB 264, SURAJ BT x ICB 264 and SURAJ BTxICB 284 showed desirable *sca*effects for the number of Sympodial branches, Number of bolls, Single boll weight, Single plant yield and fiber fineness. These results are in agreement with studies conducted by Abd El-Bary *et al*. (2008), Karademir *et al*. (2009) and AL-Hibbiny (2015). The cross GJHV 374 BTxICB 176, PKV 081 BTxICB 284, and SURAJ BT x SUVIN showed desirable significance for four characters. The cross RAJAT BTxICB99 showed a significantly high mean value for six traits except for fibre fineness. GJHV 374 BTxICB 28and GJHV 374 BTxCCB141 showed significant *per se* performance for six traits. The cross, SURAJ BTxICB39 andSURAJ BTxCCB 141 showed significant mean performance for five traits. For both single plant yield and fibre quality traits, the crosses GJHV 374 BTxICB 28, GJHV 374 BTxCCB141 ,RAJAT BTxICB 28, RAJAT BTxICB 99 and SURAJ BTxICB 28 showed better *per se* performance. In set II, GJHV 374 BTxICB 174, GJHV 374 BTxICB 176, GJHV 374 BTxICB 264, GJHV 374 BTxSUVIN, RAJAT BTxSUVIN and SURAJ BTxICB 284 showed better *per se* performance for five traits namely number of bolls, boll wt, single plant yield, fiber length and mic value. For fibre quality traits, GJHV 374 BTxCCB 143 B, GJHV 374 BTxICB 174, GJHV 374 BTxSUVIN showed good performance.

Table 3a. Set I: General Combining ability of parents and specific combining ability of hybrids for yield and fibre components of the parents

Parents	Number of Sympodia per plant	Number of bolls per plant	Single boll weight (g)	Single plant yield (g)	Finer length (mm)	Fiber Strength (g/tex)	Fiber fineness / Mic (μ)
Lines							
GJHV 374 BT	-0.65**	5.35**	0.03	28.22**	0.46 **	-0.07	-0.14 **
PKV 081 BT	0.53**	-5.65**	0.11**	-5.90**	-0.01	-0.46 **	-0.13 **
RAJAT BT	0.83**	0.78**	-0.21**	-10.07**	-0.10	-0.12	0.07 **
SURAJ BT	-0.72**	-0.48	0.07**	-12.25**	-0.35 *	0.65 **	0.20 **
Testers							
ICB 28	-0.19*	1.19**	-0.11**	3.06**	-1.41 **	0.48 **	0.20 **
ICB 34	0.12	1.95**	-0.22**	17.23**	0.29	-0.67 **	-0.17 **
ICB 39	0.31**	-5.21**	0.09**	19.71**	0.01	-0.24	0.09 **
ICB 99	0.89**	9.77**	-0.07**	17.98**	0.69 **	0.67 **	-0.23 **
CCB 141	0.12	-0.46	0.30**	-15.99**	1.30 **	0.75 **	0.17 **
ICB 183	-0.82**	-0.17	0.04	-19.34**	1.24 **	0.53 **	-0.07 **
ICB 207	-0.44**	-7.07**	-0.02	-22.64**	-2.11 **	-1.53 **	0.01
Crosses							
GJHV 374 BTxICB 28	1.84**	-2.23**	0.00	13.06**	1.66 **	1.71 **	0.16 **
GJHV 374 BTxICB 34	1.52**	-4.94**	-0.00	-52.22**	0.51	-0.61	-0.02
GJHV 374 BTxICB 39	0.58**	-0.97	-0.22**	26.41**	-0.86 *	-1.06 **	-0.01
GJHV 374 BTxICB 99	-3.00**	-7.30**	0.53**	4.93**	-2.19 **	-1.70 **	-0.02
GJHV 374 BTxCCB 141	-0.23	16.52**	-0.23**	13.01**	1.80 **	2.24 **	0.04
GJHV 374 BTxICB 183	0.71**	-4.92**	-0.00	12.76**	-0.19	-0.18	-0.37 **
GJHV 374 BTxICB 207	-1.42**	3.83**	-0.08	-17.95**	-0.74 *	-0.40	0.23 **
PKV 081 BTxICB 28	0.40*	-7.63**	-0.11*	-42.13**	-0.44	-1.86 **	-0.13 **
PKV 081 BTxICB 34	-1.41**	3.56**	0.09	23.10**	-0.32	-0.02	0.09 **
PKV 081 BTxICB 39	-1.60**	7.73**	-0.33**	10.62**	-0.24	-0.26	-0.06
PKV 081 BTxICB 99	2.32**	-14.65**	-0.41**	-27.15**	1.58 **	2.96 **	0.43 **
PKV 081 BTxCCB 141	1.59**	7.72**	0.19**	18.12**	0.44	-1.00 **	-0.34 **
PKV 081 BTxICB 183	-0.47**	-3.31**	0.59**	6.37**	-0.59	0.25	-0.01
PKV 081 BTxICB 207	-0.84**	6.58**	-0.02	11.07**	-0.42	-0.07	0.02
RAJAT BTxICB 28	-0.64**	6.95**	-0.01	10.44**	-0.87 *	0.25	0.12 **
RAJAT BTxICB 34	0.79**	1.98**	-0.24**	5.67**	0.00	1.59 **	0.09 *
RAJAT BTxICB 39	-0.39*	-5.37**	-0.53**	1.79	0.10	0.40	-0.54 **
RAJAT BTxICB 99	1.86**	13.97**	1.15**	48.32**	2.72 **	0.49	0.17 **
RAJAT BTxCCB 141	-2.21**	-11.25**	-0.07	-25.91**	-2.14 **	-2.91 **	0.18 **
RAJAT BTxICB 183	1.23**	0.76	-0	-32.76**	-0.72 *	-0.34	-0.01
RAJAT BTxICB 207	-0.64**	-7.04**	-0.22**	-7.56**	0.90 *	0.52	-0.01
SURAJ BTxICB 28	-1.60**	2.91**	0.12*	18.63**	-0.35	-0.11	-0.15 **
SURAJ BTxICB 34	-0.91**	-0.61	0.15**	23.45**	-0.20	-0.95 **	-0.16 **
SURAJ BTxICB 39	1.41**	-1.39*	1.07**	-38.82**	1.00 **	0.92 **	0.61 **
SURAJ BTxICB 99	-1.18**	7.98**	-1.26**	-26.10**	-2.11 **	-1.75 **	-0.58 **
SURAJ BTxCCB 141	0.84**	-12.99**	0.10*	-5.22**	-0.09	1.67 **	0.13 **
SURAJ BTxICB 183	-1.47**	7.47**	-0.51**	13.63**	1.50 **	0.27	0.39 **
SURAJ BTxICB 207	2.91**	-3.38**	0.32**	14.43**	0.25	-0.05	-0.23 **
SE	0.18	0.70	0.05	1.42	0.35	0.35	0.03
SED	0.25	0.99	0.07	2.01	0.49	0.49	0.05
CD @ 5%	0.50	1.96	0.13	3.97	0.98	0.97	0.10
CD @ 1 %	0.66	2.60	0.18	5.28	1.31	1.29	0.13

Table 3b. Set II: General Combining ability of parents and specific combining ability of hybrids for yield and fibre components of the parents

Parents	Number of Sympodia per plant	Number of bolls per plant	Single boll weight (g)	Single plant yield (g)	Finer length (mm)	Fiber Strength (g/tex)	Fiber fineness / Mic (µ)
Lines							
GJHV 374 BT	-0.01	-1.81**	0.05**	-0.01	0.76**	0.63**	0.20**
PKV 081 BT	0.38**	-3.42**	-0.02	-13.24**	-0.14	0.33*	-0.00
RAJAT BT	-0.12	2.29**	-0.23**	-6.21**	-0.50**	-0.14	0.03*
SURAJ BT	-0.26*	2.94**	0.20**	19.46**	-0.12	-0.82**	-0.23**
Testers							
CCB 143 B	-1.03**	-7.17**	0.08**	-11.15**	0.16	-0.53**	-0.14**
ICB 174	-0.40**	2.58**	-0.18**	-17.91**	-0.48**	-0.81**	-0.08**
ICB 176	-0.28	3.77**	0.09**	21.09**	0.75**	1.24**	0.03
ICB 258	0.72**	-2.48**	-0.05	-6.89**	-0.27	-0.39*	-0.13**
ICB 264	0.72**	1.02**	-0.05	-15.97**	-0.89**	-1.09**	0.13**
ICB 284	0.47**	-4.23**	-0.01	-6.66**	-0.95**	-0.26	0.23**
SUVIN	-0.21	6.52**	0.11**	37.49**	1.68**	1.84**	-0.02
Crosses							
GJHV 374 BTxCCB 143 B	-2.37**	-1.94**	-0.04	-13.48**	-0.41	1.18**	-0.04
GJHV 374 BTxICB 174	1.51**	1.06	0.09	-13.72**	0.22	0.39	0.25**
GJHV 374 BTxICB 176	-1.37**	1.13*	0.03	7.78**	1.17**	-0.33	0.09*
GJHV 374 BTxICB 258	0.63*	-10.88**	-0.35**	19.56**	-1.04**	-1.11**	0.22**
GJHV 374 BTxICB 264	1.38**	5.38**	0.21**	30.05**	-0.07	-0.48	0.11**
GJHV 374 BTxICB 284	-0.12	7.13**	0.07	8.73**	-0.31	-1.46**	-0.56**
GJHV 374 BTxSUVIN	0.32	-1.87**	0.00	-38.92**	0.44	1.81**	-0.06
PKV 081 BTxCCB 143 B	-0.01	7.67**	0.30**	21.84**	-1.76**	-2.27**	-0.07
PKV 081 BTxICB 174	0.12	-2.08**	0.06	0.11	1.44**	0.22	0.10**
PKV 081 BTxICB 176	1.99**	-2.02**	0.20**	-10.39**	1.29**	0.52	-0.16**
PKV 081 BTxICB 258	0.24	8.98**	-0.78**	13.18**	-1.21**	-0.01	0.20**
PKV 081 BTxICB 264	1.49**	-3.02**	1.11**	-4.03**	-1.27**	0.19	-0.28**
PKV 081 BTxICB 284	-1.26**	1.02	-0.04	2.06**	1.02**	3.12**	0.24**
PKV 081 BTxSUVIN	-2.57**	-8.52**	-0.85**	-22.79**	0.49	-1.77**	-0.03
RAJAT BTxCCB 143 B	1.74**	-6.79**	-0.03	-6.98**	0.42	-1.14**	-0.22**
RAJAT BTxICB 174	0.12	15.96**	0.40**	19.39**	0.25	-0.73	-0.10**
RAJAT BTxICB 176	-0.26	1.52**	-0.66**	37.19**	-2.78**	0.74*	0.03
RAJAT BTxICB 258	-0.51	-2.73**	0.70**	-6.84**	1.17**	1.57**	-0.03
RAJAT BTxICB 264	-0.01	-1.98**	-0.51**	4.40**	0.68	-0.56	0.18**
RAJAT BTxICB 284	-1.01**	-7.73**	-0.36**	-20.96**	-0.40	0.77*	0.18**
RAJAT BTxSUVIN	-0.07	1.77**	0.45**	-26.21**	0.67	-0.66	-0.04
SURAJ BT x SUVIN	0.63*	1.06	-0.23**	-1.39*	1.76**	2.22**	0.33**
SURAJ BTxCCB 143 B	-1.74**	-14.94**	-0.54**	-5.78**	-1.91**	0.12	-0.25**
SURAJ BTxICB 174	-0.37	-0.62	0.43**	-34.58**	0.32	-0.93*	0.04
SURAJ BTxICB 176	-0.37	4.63**	0.42**	-25.91**	1.08**	-0.45	-0.40**
SURAJ BTxICB 258	-2.87**	-0.38	-0.81**	-30.42**	0.65	0.85*	-0.01
SURAJ BTxICB 264	2.38**	1.63**	0.34**	10.17**	-0.31	-2.43**	0.14**
SURAJ BTxICB 284	2.32**	8.63**	0.40**	87.92**	-1.59**	0.62	0.14**
SE	0.30	0.55	0.05	0.65	0.35	0.37	0.03
SED	0.42	0.78	0.07	0.92	0.50	0.52	0.05
CD @ 5 %	0.83	1.53	0.15	1.82	0.99	1.04	0.10
CD @ 1 %	1.11	2.04	0.19	2.42	1.32	1.38	0.13

Table 4a. Set I: Mean performance of hybrids for yield and fibre related traits

Crosses	Number of Sympodia per plant	Number of bolls per plant	Single boll weight (g)	Single plant yield (g)	Finer length (mm)	Fiber Strength (g/tex)	Fiber fineness / Mic (μ)
GJHV 374 BTxICB 28	20.8	71.5	4.8	182.1	35.9	36.6	3.4
GJHV 374 BTxICB 34	20.8	69.5	4.7	131.0	36.4	33.1	2.9
GJHV 374 BTxICB 39	20.0	66.3	4.8	212.1	34.8	33.1	3.2
GJHV 374 BTxICB 99	17.0	75.0	5.4	188.9	34.1	33.4	2.8
GJHV 374 BTxCCB 141	19.0	88.6	5.0	163.0	38.7	37.4	3.3
GJHV 374 BTxICB 183	19.0	67.4	5.0	159.4	36.7	34.7	2.6
GJHV 374 BTxICB 207	17.3	69.3	4.8	125.4	32.8	32.5	3.3
PKV 081 BTxICB 28	20.5	55.1	4.8	92.8	33.3	32.6	3.2
PKV 081 BTxICB 34	19.0	67.0	4.9	172.2	35.1	33.3	3.0
PKV 081 BTxICB 39	19.0	64.0	4.8	162.2	34.9	33.5	3.1
PKV 081 BTxICB 99	23.5	56.6	4.5	122.7	37.4	37.6	3.3
PKV 081 BTxCCB 141	22.0	68.8	5.5	134.0	36.9	33.8	2.9
PKV 081 BTxICB 183	19.0	58.0	5.6	118.9	35.8	34.8	3.0
PKV 081 BTxICB 207	19.0	61.0	5.0	120.3	32.6	32.4	3.1
RAJAT BTxICB 28	19.8	76.1	4.6	141.2	32.8	35.1	3.6
RAJAT BTxICB 34	21.5	71.9	4.2	150.6	35.4	35.3	3.2
RAJAT BTxICB 39	20.5	57.3	4.2	149.2	35.2	34.5	2.8
RAJAT BTxICB 99	23.3	91.7	5.8	194.0	38.5	35.5	3.2
RAJAT BTxCCB 141	18.5	56.2	4.9	85.8	34.2	32.2	3.6
RAJAT BTxICB 183	21.0	68.5	4.6	75.6	35.6	34.5	3.2
RAJAT BTxICB 207	19.5	53.8	4.4	97.5	33.9	33.3	3.3
SURAJ BTxICB 28	17.3	70.8	5.0	147.2	33.1	35.5	3.5
SURAJ BTxICB 34	18.3	68.0	4.9	166.2	34.9	33.5	3.1
SURAJ BTxICB 39	20.8	60.1	6.1	106.4	35.8	35.8	4.1
SURAJ BTxICB 99	18.8	84.4	3.6	117.4	33.4	34.0	2.6
SURAJ BTxCCB 141	20.0	53.2	5.4	104.3	36.0	37.5	3.7
SURAJ BTxICB 183	16.8	74.0	4.5	119.8	37.6	35.9	3.7
SURAJ BTxICB 207	21.5	56.2	5.3	117.3	33.0	33.5	3.2
GJHV 374 Bt	28	23	5.43	62.52	26.4	24.1	4.2
PAU 018 Bt	22	31	4.54	64.84	24.5	22.9	4.2
RajatBt	29	38	3.93	64.13	26.8	25.2	3.7
SurajBt	24	34	5.23	62.94	24.9	23.1	4.0
Mean of Lines	26	32	4.8	63.6	25.7	23.8	4.0
ICB 28	17	40	4.80	39.07	35.3	38.4	3.8
ICB 34	19	27	3.22	33.31	32.8	33.9	4.7
ICB 39	17	23	3.35	34.56	28.5	30.3	3.9
ICB 99	12	10	3.93	31.58	31.8	34.8	3.3
CCB 141	20	40	4.71	50.69	38.2	40.1	4.2
ICB 183	13	30	3.43	27.84	34.1	37.0	3.9
ICB 207	11	17	3.30	23.42	31.4	33.1	4.0
Mean of tester	15	26	3.8	34.4	33.2	35.4	4.0
Mean of parents	19	28	4.2	45.0	30.4	31.2	4.0
General mean of hybrids	19.8	67.1	4.9	137.8	35.2	34.5	3.2
SE	0.2	0.7	0.0	1.4	0.4	0.3	0.0

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Table 4b. Set II: Mean performance of parents and hybrids for yield related traits

Crosses	Number of Sympodia per plant	Number of bolls per plant	Single boll weight (g)	Single plant yield (g)	Finer length (mm)	Fiber Strength (g/tex)	Fiber fineness / Mic (µ)
GJHV 374 BTxCCB 143 B	17.3	43.5	5.1	57.1	36.8	36.6	3.2
GJHV 374 BTxICB 174	21.8	56.3	4.9	50.1	36.8	35.5	3.5
GJHV 374 BTxICB 176	19.0	57.5	5.1	110.6	39.0	36.8	3.5
GJHV 374 BTxICB 258	22.0	39.3	4.6	94.4	35.8	34.4	3.5
GJHV 374 BTxICB 264	22.8	59.0	5.2	95.8	36.1	34.3	3.6
GJHV 374 BTxICB 284	21.0	55.5	5.1	83.8	35.8	34.2	3.0
GJHV 374 BTxSUVIN	20.8	57.3	5.1	80.3	39.2	39.6	3.3
PKV 081 BTxCCB 143 B	20.0	51.5	5.3	79.2	34.6	32.8	3.0
PKV 081 BTxICB 174	20.8	51.5	4.8	50.7	37.2	35.0	3.2
PKV 081 BTxICB 176	22.8	52.8	5.3	79.2	38.2	37.4	3.0
PKV 081 BTxICB 258	22.0	57.5	4.1	74.8	34.7	35.2	3.2
PKV 081 BTxICB 264	23.3	49.0	6.0	48.5	34.0	34.7	3.0
PKV 081 BTxICB 284	20.3	45.8	4.9	63.9	36.3	38.5	3.6
PKV 081 BTxSUVIN	18.3	49.0	4.2	83.2	38.4	35.7	3.1
RAJAT BTxCCB 143 B	21.3	42.8	4.8	57.4	36.4	33.5	2.8
RAJAT BTxICB 174	20.3	75.3	5.0	77.0	35.6	33.6	3.0
RAJAT BTxICB 176	20.0	62.0	4.2	133.8	33.8	37.1	3.3
RAJAT BTxICB 258	20.8	51.5	5.4	61.8	36.7	36.3	3.0
RAJAT BTxICB 264	21.3	55.8	4.2	64.0	35.6	33.5	3.5
RAJAT BTxICB 284	20.0	44.8	4.4	47.9	34.5	35.6	3.6
RAJAT BTxSUVIN	20.3	65.0	5.3	86.8	38.2	36.3	3.1
SURAJ BT x SUVIN	20.0	51.3	5.0	88.7	38.1	36.1	3.1
SURAJ BTxCCB 143 B	18.3	45.0	4.5	77.5	33.8	33.8	2.6
SURAJ BTxICB 174	19.8	60.5	5.7	87.7	37.3	34.8	3.0
SURAJ BTxICB 176	20.8	59.5	5.6	68.4	37.0	33.6	2.4
SURAJ BTxICB 258	18.3	58.0	4.3	54.8	36.0	34.2	3.1
SURAJ BTxICB 264	23.3	54.8	5.5	104.7	35.0	31.8	3.3
SURAJ BTxICB 284	22.5	72.5	5.7	226.6	36.3	36.9	3.1
GJHV 374 Bt	28	23	5.43	62.52	26.4	24.1	4.2
PAU 018 Bt	22	31	4.54	64.84	24.5	22.9	4.2
RajatBt	29	38	3.93	64.13	26.8	25.2	3.7
SurajBt	24	34	5.23	62.94	24.9	23.1	4.0
Mean of Lines	26	32	4.8	63.6	25.7	23.8	4.0
CCB 143 B	14	17	4.92	39.36	33.9	38.0	3.2
ICB 174	22	62	4.63	44.83	31.3	33.9	3.5
ICB 176	19	18	3.89	30.72	36.9	37.5	4.2
ICB 258	21	65	3.24	35.81	35.3	38.4	3.8
ICB 264	19	32	3.25	47.71	35.1	37.3	4.2
ICB 284	14	33	4.23	22.66	34.1	35.0	4.2
suvin	19	19	3.85	31.63	36.8	36.9	4.2
Mean of tester	18	35	4.0	36.10	34.77	36.70	3.88
Mean of parents	21	34	4.3	46.10	31.46	32.02	3.92
General mean of hybrids	20.7	54.4	5.0	81.7	36.3	35.3	3.2
SE	0.3	0.5	0.1	0.7	0.4	0.4	0.0

Mean values are considered as an important criterion to evaluate the performance of hybrid. The results showed that the hybrids RAJAT BTxICB 99 , GJHV 374 BTxICB 99 , GJHV 374 BTxCCB 141 (Set I),RAJAT BTxICB 174 andSURAJ BTxICB 284 (Set II) had more number of bolls, GJHV 374 BTxICB 99 , SURAJ BTxICB 39 , PKV 081 BTxCCB 141 , PKV 081 BTxICB 183 , SURAJ BTxCCB 141 (Set I), PKV 081 BTxICB 264andSURAJBTxICB 174(Set II) exhibited the highest single boll weight(g)), GJHV 374 BTxICB 39 , GJHV 374 BTxICB 28, GJHV 374 BTxICB 99 (SetI), RAJAT BTxICB 176andSURAJBTxICB 284 (Set II) had recorded highest single plant yield (g plant-1). Further, GJHV 374 BTxCCB 141 , GJHV 374 BTxICB 34, GJHV 374 BTxICB 183 , RAJAT BTxICB 99 , GJHV 374 BTxICB 176, GJHV 374 BTxSUVIN and PKV 081 BTxSUVIN hybrids among both the sets had higher fiber length (mm)and GJHV 374 BTxCCB 141 , PKV 081 BTxICB 99 , SURAJ BTxCCB 141 , GJHV 374 BTxSUVIN and PKV 081 BTxICB 284 with good bundle strength (g tex-1). Hybrid SURAJ BTxICB39 showed a micronaire value of above 4 µg/inch. In the entire lot, GJHV 374 BTxICB 28, GJHV 374 BTxCCB 141 , RAJAT BT x ICB 99 , SURAJ BT x ICB 28 and SURAJ BT x CCB 141 hybrids were considered as the best hybrids for yield and fibre quality traits in set I and in set II, GJHV 374 BTxICB 174, GJHV 374 BTxICB 176, GJHV 374 BTxICB 264, GJHV 374 BTxSUVIN, RAJAT BT x SUVIN and SURAJ BT x ICB 284 were identified as the best hybrids (**Table 4a,b**). Generally, the parent GJHV 374 BT could be considered as the best parent for yield traits followed by SURAJ BT and RAJAT BT for fibre traits to generate new hybrids combined with both yield and fibre traits.

The present investigation based on LxT analysis of H x B hybrids showed that the variance attributable to GCA was less than SCA, demonstrating that non-additive gene action is predominated for yield and fibre traits which was in accordance to the study carried out by Deshmukh *et al.* (2022) and Sukrutha *et al.* (2023)**.** The GCA was significant for single plant yield in SURAJ BT and for fibre length in GJHV 374 BT among the female parents. Among the male parents, ICB 39 and ICB 176 were having significantly high GCA for yield and the parents CCB 141 and SUVIN exhibited for fibre quality. These parents were considered to be a good general combiner for yield and quality traits. The *sca* effect was found to be positive in 17 crosses and 11 crosses for single plant yield in set I and II, respectively. Similarly, 6 crosses each in set I and II were found with positive *sca*effect for fibre length. The female parents GJHV 374 Bt, Suraj Bt and the male parents ICB 39, CCB 141, ICB 176 andSuvinwere the best combiners. In both the sets, a similar pattern of results pertaining to the GCA of parents was observed indicating that the parents with the best GCA remains unaltered with the male parents selected.

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