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Heterosis estimation for seed cotton yield and its component traits in interspecific hybrids of cotton

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Abstract
This investigation was undertaken to obtain information on magnitude of heterobeltiosis and standard heterosis for seed cotton yield and its component traits in interspecific hybrids of cotton. The experimental material comprised of five female parents, nine male parents and their resultant 45 hybrids developed by line × tester mating design and one standard check G. Cot. Hy. 102. The experiment was laid out in randomized complete block design with three replications at Regional Research Station, Anand Agricultural University, Anand during *Kharif*-2021. Among the 45 hybrids, 21 hybrids showed significantly positive heterosis over better parent and 11 hybrids showed positively significant heterosis over standard check G. Cot. Hy. 102 for seed cotton yield per plant. As per better parent heterosis, the best performing positively significant hybrids for seed cotton yield per plant were AHC-26 × ARBB-27, G. Cot-12 × GSB-43-1 and AHC-26 × DB-1502 while as per standard heterosis, the outstanding positively significant hybrids for seed cotton yield per plant were AHC-1 × DB-1502, AHC-1 × GSB-45 and AHC-26 × ARBB-27. These cross combinations can be further exploited in breeding programmes of cotton.

Keywords: Heterobeltiosis, standard heterosis, cotton, line × tester mating design

Introduction
Cotton is also known as White Gold as well as King of fiber crops and mainly often cross-pollinated crop which belongs to the family Malvaceae and genus *Gossypium*. Genus *Gossypium* includes approximately 50 species, out of which 43 are diploid and seven are tetraploid in nature but only four species are cultivated which are *G. hirsutum* L., *G. barbadense* L., *G. arboreum* L. and *G. herbaceum* L. Among the four cultivated species, *G. arboreum* L. and *G. herbaceum* L. are diploid (2n = 2x = 26) in nature and known as old world cotton while, *G. hirsutum* L. and *G. barbadense* L. are tetraploid (2n = 4x = 52) in nature and known as new world cotton. The species which are referred to as its progenitors are *G. africanum* L. and *G. raimondii* L. African linted diploid species (*G. africanum* L.) reached America through Pacific Ocean and after crossing with American lintless wild diploid species (*G. raimondii* L.) gave birth to tetraploid cotton. The chromosome doubling took place in nature resulting in the development of fertile amphidiploids (*G. hirsutum* L.).
India ranks first in terms of area (13.47 million hectares), while second in terms of production (12.88 million tonnes) among cotton growing countries after China, whereas, productivity is around 955.7 kg/ha in India (Anon., 2020) [1].
Cotton production in the country got momentum with release of the world's first cotton hybrid H-4 by Late Dr. C. T. Patel in the year 1970 from Main Cotton Research Station, GAU, Surat, Gujarat. The key characteristic of the species like, *G. hirsutum* L. having high yielding potential and *G. barbadense* L. has excellent fiber quality makes it possible to producing hybrids with higher yield and superior fiber quality through interspecific hybridization. India resides pioneer in commercialization of heterosis in cotton. Heterosis is the superiority of F_1 hybrid in a desirable direction over either or both of the parents and standard check is manifested via an increase in vigour, growth rate, size, yield, quality and other important characteristics. Exploitation of heterosis on commercial scale leads to develop a number of high yielding hybrids, which proved to be most important genetic tool in enhancing yield potential of crops and considered as the most important breakthrough in the field of crop improvement.

Material and Methods

For present investigation the crossing program was undertaken during *Kharif* 2020 and evaluation was carried out in *Kharif* 2021 at the Regional Research Station, Anand Agricultural University, Anand. The experimental material comprised of five lines (*G. hirsutum*), nine testers (*G. barbadense*), 45 hybrids and one standard check. These lines and testers were crossed in line × tester fashion to obtain 45 interspecific hybrids. The experiment was laid out in randomized complete block design with three replications. The lines were AHC-1 (L1), G. Cot-12 (L2), G. Cot-20 (L3), AHC-50 (L4) and AHC-26 (L5), and testers were ABC-1 (T1), ARBB-27 (T2). GSB-41 (T3), GSB-43-1 (T4), GSB-44 (T5), GSB-45 (T6), DB-1502 (T7), RHcb-1014 (T8) and DB-1602 (T9) and one standard check was G. Cot. Hy. 102. The seeds of 45 F_1s were produced by hand pollination and parent seeds were obtained by selfing of parents. The package of practices will be followed as per the recommendations for raising the good and healthy crop. Observations were recorded for 16 different characters *viz.*, days to 50% flowering, days to 50% boll bursting, plant height, monopodia per plant, sympodia per plant, bolls per plant, boll weight, ginning outturn, fiber fineness, fiber strength, fiber length, uniformity index, seed index, lint index, lint yield per plant and seed cotton yield per plant. The experimental plot wise mean values of five randomly selected plants were used in each statistical analysis for different characters. The estimation of heterosis over better parent and standard check is more realistic. Hence, in the present investigation, heterosis was estimated over better parent and standard check, referred to as heterobeltiosis and standard heterosis, respectively.

Results and Discussion

The analysis of variance showed that mean sum of squares (Table 1) due to genotypes was highly significant for seed cotton yield and its component traits. This indicated that experimental material used in the present study had sufficient variability for different characters. Parental variances were found highly significant for all the characters except uniformity index. The variance of hybrids were found highly significant for all the characters indicating the presence of significant genetic variability among the hybrids for all the characters under study. The analysis of variance for parents *vs*. hybrids were also found highly significant for all characters indicating significant amount of heterosis generated in the present investigation.

For days to 50% flowering and days to 50% boll bursting, the parent which took minimum days was considered to be a better parent and for monopodia per plant and fiber fineness, the parent with minimal value was considered to be a better parent and accordingly heterosis were calculated. For these characters heterotic effect in the negative direction were desirable. The heterotic effects were desirable in positive direction for all the remaining characters except mentioned above.

Table 1: Analysis of variances (mean squares) for various characters

Sources of variation			**df**	**DFF**	**DFBB**	**PH**	**MPP**	**SPP**	**BPP**	**BW**	**GOT**
Replications			2	4.82	26.74	680.47	0.23	3.70	234.13**	0.08	1.75
Genotypes			59	62.90**	223.23**	2572.69**	2.20**	21.25**	451.94**	1.12**	11.66**
(a)	Parents		13	92.36**	271.30**	1706.66**	2.92**	23.36**	178.01**	3.17**	10.13**
	i	Females	4	12.43**	29.93	3748.11**	1.60**	51.77**	198.56**	1.77**	3.74*
	ii	Males	8	6.34	147.42**	823.23**	3.06**	2.77	187.88**	0.25**	13.55**
	iii	Females *vs.* Males	1	1100.19**	2227.89**	608.30	7.14**	74.38**	16.92	32.15**	8.32**
(b)	Hybrids		44	55.44**	193.68**	771.20**	1.99**	11.52**	384.98**	0.48**	8.66**
(c)	Parents *vs.* Hybrids		1	66.84**	1121.71**	95634.68**	3.91**	438.59**	7365.50**	3.24**	164.84**
Check *vs.* Hybrids			1	4.48	0.182	34.72	0.27	4.61	45.56	0.32**	10.44**
Error			118	3.32	14.21	223.46	0.08	1.69	43.86	0.04	1.15
Total			179	22.98	83.24	1002.89	0.78	8.16	180.49	0.39	4.62

Table 1: Cont…

Sources of variation			df	FF	FS	FL	UI	SI	LI	LYPP	SCYPP
Replications			2	0.01	1.17	1.14	3.05	0.60	0.01	178.87	2996.33**
Genotypes			59	0.57**	11.67**	18.94**	3.31**	8.50**	0.95**	638.43**	7801.02**
(a)	Parents		13	0.66**	20.92**	23.24**	2.31	2.78**	0.81**	449.82**	4603.10**
	i	Females	4	1.00**	1.61*	5.45**	2.40	4.95**	1.76**	259.96**	2144.20*
	ii	Males	8	0.46**	7.61**	8.63**	2.08	2.03**	0.37**	137.26*	1161.56
	iii	Females *vs.* Males	1	0.91**	204.63**	211.20**	3.73	0.10	0.51*	3709.66**	41970.96**
(b)	Hybrids		44	0.28**	5.81**	6.31**	3.25**	4.59**	0.70**	511.69**	5739.23**
(c)	Parents *vs.* Hybrids		1	12.08**	160.85**	532.95**	15.20**	256.32**	14.67**	9282.65**	147889.78**
Check *vs.* Hybrids			1	0.41**	0.05	4.44*	6.86	6.65**	0.06	23.17	3.91
Error			118	0.02	0.61	0.71	1.87	0.24	0.11	59.60	625.48
Total			179	0.20	4.26	6.73	2.35	2.96	0.38	251.72	3017.09

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

(DFF – Days to 50% flowering, DFBB – Days to 50% boll bursting, PH – Plant height, MPP – Monopodia per plant, SPP – Sympodia per plant, BPP – Bolls per plant, BW – Boll weight, GOT – Ginning outturn, FF – Fiber fineness, FS – Fiber strength, FL – Fiber length, UI – Uniformity index, SI – Seed index, LI – Lint index, LYPP – Lint yield per plant, SCYPP – Seed cotton yield per plant)

Table 2: Estimation of Heterobeltiosis (HB) and Standard heterosis (SH) for days to 50% flowering, days to 50% boll bursting, plant height and monopodia per plant

Hybrids	DFF		DFBB		PH		MPP	
	HB	SH	HB	SH	HB	SH	HB	SH
L1 × T1	10.00**	0.48	14.63**	-0.26	16.16**	7.37	13.64	-7.41
L1 × T2	10.00**	0.48	15.22**	0.26	20.67**	21.58**	12.47	-8.37
L1 × T3	11.58**	1.92	17.91**	2.60	21.07**	11.91*	65.95**	35.21**
L1 × T4	8.42**	-0.96	8.96**	-5.19*	14.90**	6.21	86.39**	51.86**
L1 × T5	6.32**	-2.88	7.46**	-6.49**	13.81*	5.20	29.60**	5.59
L1 × T6	8.42**	-0.96	11.04**	-3.38	27.06**	17.44**	38.62**	12.94*
L1 × T7	4.21	-4.81*	4.48	-9.09**	13.50*	4.91	38.90**	-7.41
L1 × T8	4.21	-4.81*	4.78	-8.83**	13.78*	5.17	23.41**	0.54
L1 × T9	10.00**	0.48	17.91**	2.60	16.16**	7.37	43.19**	16.67*
L2 × T1	6.00**	1.92	14.71**	1.30	6.12	-7.74	-10.92	-9.27
L2 × T2	9.50**	5.29*	18.24**	4.42	3.92	4.71	23.62**	25.92**
L2 × T3	18.50**	13.94**	30.00**	14.81**	16.51**	-0.93	32.73**	35.19**
L2 × T4	2.50	-1.44	15.59**	2.08	17.69**	0.68	72.84**	76.05**
L2 × T5	4.00	0.00	14.12**	0.78	21.68**	3.47	-15.55*	-29.63**
L2 × T6	4.00	0.00	14.12**	0.78	17.08**	3.81	6.41	0.50
L2 × T7	1.50	-2.40	5.88*	-6.49**	21.90**	3.66	33.39**	-11.09
L2 × T8	2.00	-1.92	7.06*	-5.45*	26.22**	7.33	25.48**	18.51**
L2 × T9	8.00**	3.85	20.88**	6.75**	15.21*	-2.03	61.86**	64.86**
L3 × T1	19.37**	9.62**	28.48**	10.13**	23.76**	7.59	50.06**	0.03
L3 × T2	23.56**	13.46**	29.09**	10.65**	19.84**	20.75**	61.12**	7.41
L3 × T3	22.51**	12.50**	27.58**	9.35**	39.97**	17.11**	61.18**	7.44
L3 × T4	23.56**	13.46**	21.82**	4.42	35.30**	15.75**	61.10**	7.40
L3 × T5	10.99**	1.92	13.03**	-3.12	31.36**	10.29*	30.54**	-12.98*
L3 × T6	21.99**	12.02**	21.21**	3.90	18.49**	5.07	19.47*	-20.36**
L3 × T7	10.47**	1.44	11.52**	-4.42	19.69**	-2.10	58.37**	5.56
L3 × T8	9.95**	0.96	10.30**	-5.45*	24.11**	1.51	44.43**	-3.72
L3 × T9	24.08**	13.94**	27.27**	9.09**	28.81**	5.36	66.68**	11.11
L4 × T1	-0.53	-9.62**	2.57	-6.75**	6.41	-1.11	72.27**	14.83*
L4 × T2	9.52**	-0.48	16.57**	5.97*	6.25	7.05	47.25**	-1.85
L4 × T3	10.05**	0.00	16.86**	6.23*	15.81**	7.62	72.23**	14.80*
L4 × T4	8.99**	-0.96	16.86**	6.23*	16.68**	8.44	50.06**	0.02
L4 × T5	7.41**	-2.40	8.29**	-1.56	6.18	-1.32	58.37**	5.56
L4 × T6	7.41**	-2.40	15.71**	5.19*	8.22	0.57	30.60**	-12.95*
L4 × T7	5.29*	-4.33*	1.43	-7.79**	7.20	-0.38	11.11	-25.94**
L4 × T8	4.76*	-4.81*	4.29	-5.19*	13.21*	5.20	58.37**	5.56
L4 × T9	5.82*	-3.85	12.29**	2.08	17.65**	9.33	52.78**	1.83
L5 × T1	0.99	-1.92	6.25*	-2.86	36.53**	18.69**	1.68	12.97*
L5 × T2	0.99	-1.92	10.80**	1.30	15.87**	16.74**	8.33	20.36**
L5 × T3	18.81**	15.38**	25.85**	15.06**	41.11**	18.07**	21.63**	35.14**
L5 × T4	4.95*	1.92	17.33**	7.27**	33.51**	14.22**	31.57**	38.88**
L5 × T5	0.99	-1.92	4.83	-4.16	26.83**	6.49	46.68**	22.22**
L5 × T6	-4.95*	-7.69**	9.66**	0.26	24.32**	10.24*	17.63*	11.09
L5 × T7	-1.98	-4.81*	1.70	-7.01**	31.68**	1.74	33.33**	-11.13
L5 × T8	2.97	0.00	13.64**	3.90	32.81**	5.24	27.44**	20.37**
L5 × T9	2.97	0.00	5.68*	-3.38	28.54**	2.48	38.40**	53.76**
S.Em.±	1.49		3.08		12.21		0.23	
Range								
Minimum	-4.95	-9.62	1.43	-9.09	3.92	-7.74	-15.55	-29.63
Maximum	24.08	15.38	30.00	15.06	41.11	21.58	86.39	76.05
Signi. cross	31	16	38	23	38	12	38	23
Positive	30	09	38	12	38	12	37	18
Negative	01	07	00	11	00	00	01	05

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 3: Estimation of Heterobeltiosis (HB) and Standard heterosis (SH) for sympodia per plant, bolls per plant, boll weight and ginning outturn

Hybrids	SPP		BPP		BW		GOT	
	HB	SH	HB	SH	HB	SH	HB	SH
L1 × T1	9.02	18.71**	5.45	-8.40	-33.37**	13.71**	-14.24**	1.33
L1 × T2	11.09*	20.97**	-10.48	-20.12*	-30.59**	18.46**	-14.82**	-4.40
L1 × T3	3.78	13.01*	24.49	-12.78	-23.30**	30.90**	-10.14**	0.85
L1 × T4	0.29	9.21	90.54**	33.49**	-34.19**	12.32**	-8.01**	3.24
L1 × T5	1.46	10.49*	18.83	-8.88	-32.72**	14.83**	-9.20**	2.80
L1 × T6	20.75**	31.49**	73.14**	21.30*	-24.91**	28.15**	-9.90**	2.67
L1 × T7	9.65*	19.40**	72.53**	34.56**	-25.01**	27.98**	-17.21**	2.84
L1 × T8	0.59	9.54	68.40**	22.37*	-29.80**	19.81**	-13.03**	4.65
L1 × T9	15.46**	25.73**	-11.11	-24.26*	-33.49**	13.51**	-16.63**	1.13
L2 × T1	4.85	9.54	10.22	-4.26	-20.16**	9.95*	-17.86**	-2.94
L2 × T2	2.70	7.29	15.25	2.84	-19.42**	10.96*	-15.32**	-9.46**
L2 × T3	-16.44**	-12.71*	49.56**	-19.64*	-21.57**	8.01	-0.35	4.28
L2 × T4	-14.61**	-10.80*	80.63**	22.49*	-27.62**	-0.32	-6.76*	-2.04
L2 × T5	4.55	9.22	21.91	-6.51	-25.70**	2.32	-6.04*	6.38*
L2 × T6	-0.02	4.45	85.27**	-0.24	-18.76**	11.88*	-12.84**	-0.69
L2 × T7	6.04	10.78*	37.03**	6.86	-30.06**	-3.68	-13.52**	7.42*
L2 × T8	16.40**	21.60**	40.55**	2.13	-28.21**	-1.14	-15.16**	2.08
L2 × T9	-0.90	3.53	-9.31	-22.72*	-35.08**	-10.60*	-19.93**	-2.87
L3 × T1	11.79*	17.45**	38.96**	22.84*	8.21*	24.69**	-12.53**	3.36
L3 × T2	0.92	6.03	24.93*	11.48	-6.61	7.62	-12.51**	-4.20
L3 × T3	-3.00	1.91	2.41	-9.47	-3.47	11.23*	-6.87*	1.97
L3 × T4	-10.87*	-6.35	41.63**	25.21**	-12.71**	0.59	5.70*	15.73**
L3 × T5	9.10	14.63**	5.62	-6.63	-12.60**	0.72	-5.02	7.54*
L3 × T6	14.65**	20.47**	1.34	-10.41	-4.26	10.33*	-5.31	7.90*
L3 × T7	5.48	10.82*	24.90*	10.41	-10.46*	3.19	-13.38**	7.59*
L3 × T8	-2.99	1.92	18.88	5.09	-7.03	7.14	-11.66**	6.30*
L3 × T9	3.36	8.60	25.44*	10.89	-30.36**	-19.75**	-7.89**	11.74**
L4 × T1	-11.63**	5.48	52.04**	32.07**	-18.12**	-4.09	-5.31*	11.89**
L4 × T2	-18.08**	-2.22	9.81	-2.01	-10.83**	4.45	-7.57**	3.57
L4 × T3	-2.13	16.82**	7.93	-11.36	-6.75	9.24	4.02	16.56**
L4 × T4	-11.98**	5.06	-3.17	-20.47*	-10.50**	4.84	5.56*	18.29**
L4 × T5	-12.49**	4.45	50.58**	23.67*	-9.96*	5.47	-0.47	12.69**
L4 × T6	-15.14**	1.29	18.59	-2.60	-6.75	9.24	-4.85	8.42**
L4 × T7	-6.63	11.45*	26.95*	4.26	-7.86	7.93	-8.94**	13.11**
L4 × T8	-19.68**	-4.13	45.10**	19.17*	-3.97	12.49**	-5.14	14.14**
L4 × T9	-7.42	10.50*	-32.64**	-42.60**	8.10*	26.63**	-6.35*	13.61**
L5 × T1	47.29**	19.70**	26.16*	9.59	-21.56**	18.80**	-14.54**	0.99
L5 × T2	31.52**	12.73*	33.95**	19.53*	-15.77**	27.56**	-12.02**	1.43
L5 × T3	20.62**	7.59	-18.95	-50.89**	-18.67**	23.17**	-14.75**	-1.71
L5 × T4	22.39**	6.05	-9.08	-38.34**	-28.48**	8.32	-8.01**	6.06
L5 × T5	40.18**	24.15**	30.40*	0.00	-14.07**	30.14**	-11.72**	1.78
L5 × T6	22.58**	17.14**	41.41*	-14.32	-7.99*	39.34**	-8.52**	5.47
L5 × T7	41.09**	17.78**	36.27**	6.27	-12.16**	33.03**	-13.93**	6.91*
L5 × T8	37.34**	18.15**	24.43	-9.59	-16.16**	26.96**	-15.16**	2.08
L5 × T9	14.23**	7.01	-13.75	-26.51**	-22.06**	18.04**	-13.54**	4.88
S.Em.±	1.06		5.41		0.15		0.88	
Range								
Minimum	-19.68	-12.71	-32.64	-50.89	-35.08	-19.75	-19.93	-9.46
Maximum	47.29	31.49	90.54	34.56	8.21	39.34	5.70	18.29
Signi. cross	25	24	24	20	37	27	38	18
Positive	16	22	23	11	02	25	02	17
Negative	09	02	01	09	35	02	36	01

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 4: Estimation of Heterobeltiosis (HB) and Standard heterosis (SH) for fiber fineness, fiber strength, and fiber length and uniformity index

Hybrids	FF		FS		FL		UI	
	HB	SH	HB	SH	HB	SH	HB	SH
L1 × T1	2.50	10.81**	0.00	5.99**	-2.61	-2.51	2.35	3.57**
L1 × T2	-13.04**	8.11*	2.13	5.68**	15.48**	3.87	1.16	3.57**
L1 × T3	-5.00	2.70	-1.83	1.26	-7.86**	-14.99**	-1.18	0.00
L1 × T4	-17.78**	0.00	7.28**	6.94**	13.52**	4.74*	2.35	3.57**
L1 × T5	-8.89**	10.81**	1.83	5.36**	13.64**	1.55	1.16	3.57**
L1 × T6	-15.22**	5.41	8.20**	4.10*	10.19**	0.39	2.38	2.38
L1 × T7	-19.57**	0.00	11.42**	1.58	15.28**	-3.68	-1.16	1.19
L1 × T8	0.00	5.41	6.64**	1.26	8.72**	1.26	2.38	2.38
L1 × T9	-11.36**	5.41	4.56*	8.52**	2.65	1.26	1.16	3.57**
L2 × T1	-5.13	0.00	1.49	7.57**	-3.77	-3.68	2.35	3.57**
L2 × T2	-5.13	0.00	2.74	6.31**	9.03**	-1.93	1.16	3.57**
L2 × T3	-10.26**	-5.41	-5.20**	-2.21	12.89**	4.16*	-1.18	0.00
L2 × T4	-10.26**	-5.41	6.65**	6.31**	9.12**	0.68	0.00	1.19
L2 × T5	-7.69*	-2.70	0.91	4.42*	9.74**	-1.93	1.16	3.57**
L2 × T6	-5.13	0.00	8.85**	4.73*	4.46*	-4.84*	3.57**	3.57**
L2 × T7	-5.13	0.00	15.22**	5.05*	13.84**	-4.55*	0.00	2.38
L2 × T8	-12.82**	-8.11*	6.98**	1.58	2.49	-4.55*	1.19	1.19
L2 × T9	-15.38**	-10.81**	1.52	5.36**	0.00	-1.35	-3.49**	-1.19
L3 × T1	5.00	13.51**	-6.25**	-0.63	-4.64*	-4.55*	0.00	1.19
L3 × T2	-16.33**	10.81**	4.88*	8.52**	10.97**	-0.19	1.16	3.57**
L3 × T3	-2.50	5.41	0.31	3.47	7.23**	-1.06	-1.18	0.00
L3 × T4	-17.78**	0.00	9.49**	9.15**	9.75**	1.26	1.18	2.38
L3 × T5	-13.33**	5.41	3.66	7.26**	11.36**	-0.48	0.00	2.38
L3 × T6	-20.41**	5.41	6.23**	2.21	-4.46*	-12.96**	0.00	1.19
L3 × T7	-18.75**	5.41	15.22**	5.05*	13.19**	-5.42**	0.00	2.38
L3 × T8	0.00	5.41	8.64**	3.15	4.67*	-2.51	1.18	2.38
L3 × T9	-9.09**	8.11*	-3.04	0.63	0.59	-0.77	-1.16	1.19
L4 × T1	10.00**	18.92**	-2.68	3.15	-4.06*	-3.97	1.18	2.38
L4 × T2	-12.24**	16.22**	-0.61	2.84	15.81**	4.16*	0.00	2.38
L4 × T3	-10.00**	-2.70	-2.14	0.95	6.92**	-1.35	0.00	1.19
L4 × T4	-13.33**	5.41	-1.27	-1.58	14.47**	5.61**	1.18	2.38
L4 × T5	-8.89**	10.81**	-6.10**	-2.84	9.09**	-2.51	0.00	2.38
L4 × T6	-18.37**	8.11*	2.95	-0.95	9.24**	-0.48	1.19	1.19
L4 × T7	-12.50**	13.51**	2.77	-6.31**	16.32**	-2.80	0.00	2.38
L4 × T8	2.56	8.11*	1.66	-3.47	6.85**	-0.48	3.57**	3.57**
L4 × T9	-15.91**	0.00	-9.42**	-5.99**	0.00	-1.35	-1.16	1.19
L5 × T1	15.00**	24.32**	-2.38	3.47	2.61	2.71	-1.16	1.19
L5 × T2	-12.50**	13.51**	-4.57*	-1.26	16.77**	5.03*	-1.16	1.19
L5 × T3	-12.50**	-5.41	-8.26**	-5.36**	12.89**	4.16*	-2.33	0.00
L5 × T4	-13.33**	5.41	9.18**	8.83**	11.64**	3.00	0.00	2.38
L5 × T5	0.00	21.62**	-6.10**	-2.84	9.42**	-2.22	0.00	2.38
L5 × T6	-8.33**	18.92**	1.64	-2.21	13.06**	3.00	0.00	2.38
L5 × T7	-6.25*	21.62**	3.11	-5.99**	19.10**	-0.48	0.00	2.38
L5 × T8	10.26**	16.22**	3.32	-1.89	12.46**	4.74*	-1.16	1.19
L5 × T9	-4.55	13.51**	-6.69**	-3.15	3.63	2.22	-2.33	0.00
S.Em.±	0.12		0.64		0.69		1.12	
Range								
Minimum	-20.41	-10.81	-9.42	-6.31	-7.86	-14.99	-3.49	-1.19
Maximum	15.00	24.32	15.22	9.15	19.10	5.61	3.57	3.57
Signi. cross	32	21	23	22	36	14	03	11
Positive	03	19	15	18	32	07	02	11
Negative	29	02	08	04	04	07	01	00

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 5: Estimation of Heterobeltiosis (HB) and Standard heterosis (SH) for seed index, lint index, lint yield per plant and seed cotton yield per plant

Hybrids	SI		LI		LYPP		SCYPP	
	HB	SH	HB	SH	HB	SH	HB	SH
L1 × T1	16.27**	-9.94**	-5.45	-8.23	-20.65*	2.72	-12.15	1.04
L1 × T2	19.51**	-7.34*	-4.29	-12.84**	-32.04**	-12.02	-20.06*	-8.04
L1 × T3	25.58**	-2.74	8.02	-1.63	-13.18	12.40	-3.35	11.17
L1 × T4	21.07**	-5.71*	8.25	-1.43	16.44	50.75**	26.92**	45.99**
L1 × T5	23.09**	-4.66	8.78	-0.94	-19.13*	4.69	-11.53	1.76
L1 × T6	29.69**	7.29*	11.85*	11.92*	21.48*	57.27**	33.15**	53.15**
L1 × T7	17.66**	-8.86**	3.98	-5.31	26.64**	63.95**	38.73**	59.57**
L1 × T8	20.61**	-6.58*	9.33	-0.44	16.88	51.32**	25.41*	44.25**
L1 × T9	20.15**	-6.94*	1.13	-5.53	-34.15**	-14.75	-27.06**	-16.10
L2 × T1	20.79**	-7.83**	-8.91	-11.58*	28.26	0.44	39.09*	3.62
L2 × T2	26.86**	-1.64	0.55	-14.14**	17.05	-1.84	39.89**	9.24
L2 × T3	20.82**	-7.27*	21.75**	-2.00	14.82	-10.29	15.51	-13.95
L2 × T4	16.44**	-9.32**	6.11	-11.81*	51.24**	18.18	61.53**	20.33
L2 × T5	22.44**	-7.51**	11.92*	0.91	21.78	-4.84	20.46	-10.26
L2 × T6	21.51**	0.53	-0.45	-0.39	37.19*	7.20	44.48**	7.63
L2 × T7	22.48**	-12.12**	11.19*	-2.72	38.30*	8.07	35.38*	0.85
L2 × T8	32.38**	-5.02	10.18	-2.27	26.90	-0.84	30.30*	-2.93
L2 × T9	28.88**	-7.53**	-4.94	-11.20*	-17.53	-35.56**	-10.71	-33.48**
L3 × T1	25.84**	-3.98	3.76	0.71	39.96**	50.11**	47.55**	44.71**
L3 × T2	21.54**	-5.77*	4.09	-11.12*	5.28	12.92	20.25	17.94
L3 × T3	22.81**	-5.74*	20.31**	-3.15	-4.92	1.97	1.83	-0.12
L3 × T4	17.35**	-8.60**	35.82**	12.88**	34.84**	44.62**	27.34*	24.89*
L3 × T5	22.38**	-7.56**	13.55*	2.38	-8.02	-1.35	-6.66	-8.45
L3 × T6	9.27**	-9.60**	0.66	0.72	-1.24	5.93	-0.15	-2.07
L3 × T7	36.95**	-12.65**	10.66	-3.18	11.29	19.37	13.14	10.96
L3 × T8	34.57**	-8.66**	12.17*	-0.51	8.90	16.80	11.90	9.75
L3 × T9	27.43**	-9.98**	12.88*	5.44	-8.17	-1.51	-10.22	-11.95
L4 × T1	5.81	-19.26**	-2.48	-5.34	28.74*	36.38**	29.53*	22.00
L4 × T2	3.88	-19.46**	-0.98	-15.45**	-1.93	3.89	6.32	0.14
L4 × T3	9.58**	-15.89**	30.87**	5.45	5.91	12.19	1.93	-4.00
L4 × T4	8.88*	-15.20**	30.25**	8.26	-9.83	-4.48	-14.26	-19.24
L4 × T5	9.72*	-17.12**	9.02	-1.70	38.32**	46.53**	37.94**	29.92**
L4 × T6	14.45**	-5.31	6.03	6.09	8.17	14.59	11.97	5.46
L4 × T7	13.24**	-22.43**	5.66	-7.55	17.16	24.11	16.32	9.56
L4 × T8	19.37**	-18.23**	11.32*	-1.26	31.62**	39.43**	29.68*	22.14
L4 × T9	12.99**	-20.17**	2.66	-4.10	-27.42*	-23.11	-27.98*	-32.17**
L5 × T1	25.27**	9.08**	3.50	10.56*	27.22*	31.02*	45.53**	29.83**
L5 × T2	24.71**	8.59**	3.69	10.77*	45.91**	50.27**	65.57**	47.72**
L5 × T3	21.23**	5.56*	-3.43	3.16	-44.17**	-42.50**	-34.60**	-41.65**
L5 × T4	22.17**	6.38*	8.32	15.71**	-33.67**	-31.69*	-27.53*	-35.35**
L5 × T5	28.61**	11.99**	7.41	14.74**	26.13*	29.90*	42.93**	27.51*
L5 × T6	29.74**	12.97**	14.02**	21.81**	19.87	23.45	31.34*	17.18
L5 × T7	17.23**	2.08	4.98	12.15*	39.41**	43.57**	50.31**	34.10**
L5 × T8	19.24**	3.83	0.07	6.90	11.27	14.60	25.56*	12.02
L5 × T9	19.14**	3.74	3.72	10.79*	-13.45	-10.87	-4.49	-14.79
S.Em.±	0.40		0.27		6.30		20.42	
Range								
Minimum	3.88	-22.43	-8.91	-15.45	-44.17	-42.50	-34.60	-41.65
Maximum	36.95	12.97	35.82	21.81	51.24	63.95	65.57	59.57
Signi. cross	43	35	13	16	21	16	26	15
Positive	43	07	13	09	14	13	21	11
Negative	00	28	00	07	07	03	05	04

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Fig 1: Field view of cotton evaluation block at RRS, AAU, Anand (*Kharif* 2021-22)

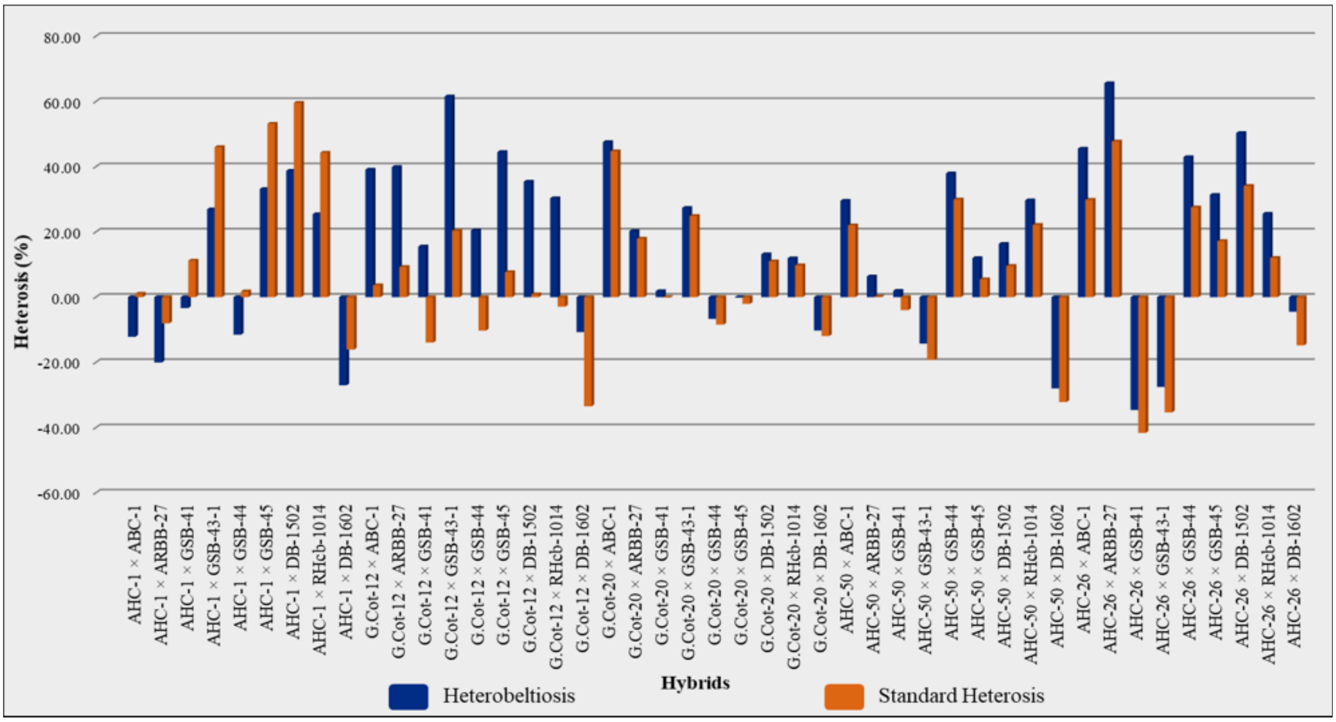

Fig 2: Heterobeltiosis and standard heterosis of all hybrids for seed cotton yield per plant

Days to 50% flowering

As per better parent heterosis, the best performing negatively significant hybrids for days to 50% flowering were AHC-26 × GSB-45 (-4.95%), AHC-26 × DB-1502 (-1.98%) and AHC-50 × ABC-1 (-0.53%). As per standard heterosis, the best performing negatively significant hybrids were AHC-50 × ABC-1 (-9.62%), AHC-26 × GSB-45 (-7.69%) and AHC-1 × DB-1502, AHC-1 × RHcb-1014, AHC-50 × RHcb-1014, AHC-26 × DB-1502 (-4.81%). The results are in close agreement with Gohil *et al.* (2017) [3], Vavdiya *et al.* (2019) [14] and Udaya *et al.* (2020) [13] for both heterobeltiosis and standard heterosis while, Malathi *et al.* (2019) [6] showed similar results for heterobeltiosis and Sawarkar *et al.* (2015) [11] showed similar results for standard heterosis only.

Days to 50% boll bursting

According to better parent heterosis, none of the hybrids showed negatively significant heterotic effects for days to 50% boll bursting. While, as per the standard heterosis, best performing negatively significant hybrids were AHC-1 × DB-1502 (-9.09%), AHC-1 × RHcb-1014 (-8.83%) and AHC-50 × DB-1502 (-7.79%). The outcome of this experiment is in contradictory for heterobeltiosis however, it shows similarity for standard heterosis with the results of Sawarkar *et al.* (2015) [11] and Vavdiya *et al.* (2019) [14].

Plant height

The best performing positively significant hybrid for plant height as per better parent heterosis were AHC-26 × GSB-41 (41.11%), G. Cot-20 × GSB-41 (39.97%) and AHC-26 × ABC-1 (36.53%). As per standard heterosis, the best performing positively significant hybrids were AHC-1 × ARBB-27 (21.58%), G. Cot-20 × ARBB-27 (20.75%) and AHC-26 × ABC-1 (18.69%). Significantly positive heterobeltiosis and standard heterosis was also reported by Gohil *et al.* (2017) [3], Malathi *et al.* (2019) [6], Vavdiya *et al.* (2019) [14] and Naik *et al.* (2020b) [9]. Gnanasekaran and Thiyagu (2021) [21] reported similar findings for standard heterosis.

Monopodia per plant

As per better parent heterosis, the best performing negatively significant hybrid were G. Cot-12 × GSB-44 (-15.55%) and G. Cot-12 × ABC-1 (-10.92%). As per standard heterosis, the best performing negatively significant hybrids were G. Cot-12 × GSB-44 (-29.63%), AHC-50 × DB-1502 (-25.94%) and G. Cot-20 × GSB-45 (-20.36%). These results are in concurrence with Gohil *et al.* (2017) [3], Vavdiya *et al.* (2019) [14] and Sudha *et al.* (2020) [12] for heterobeltiosis and standard heterosis. Udaya *et al.* (2020) [13] and Gnanasekaran and Thiyagu (2021) [21] reported significantly negative standard heterosis only.

Sympodia per plant

According to better parent heterosis, the best performing positively significant hybrid were AHC-26 × ABC-1 (47.29%), AHC-26 × DB-1502 (41.09%) and AHC-26 × GSB-44 (40.18%). As per standard heterosis, the best performing positively significant hybrids were AHC-1 × GSB-45 (31.49%), AHC-1 × DB-1602 (25.73%) and AHC-26 × GSB-44 (24.15%). The present findings are in fidelity with the reports of Gohil *et al.* (2017) [3], Malathi *et al.* (2019) [6], Vavdiya *et al.* (2019) [14] and Sudha *et al.* (2020) [12] for heterobeltiosis and standard heterosis and Udaya *et al.* (2020) [13] for standard heterosis only.

Bolls per plant

The best performing positively significant hybrid as per better parent heterosis were AHC-1 × GSB-43-1 (90.54%), G. Cot-12 × GSB-45 (85.27%) and G. Cot-12 × GSB-43-1 (80.63%). As per standard heterosis, the best performing positively significant hybrids were AHC-1 × DB-1502 (34.56%), AHC-1 × GSB-43-1 (33.49%) and AHC-50 × ABC-1 (32.07%). The present findings are in accordance with the reports of Patel *et al.* (2015) [10], Gohil *et al.* (2017) [3], Vavdiya *et al.* (2019) [14], Naik *et al.* (2020b) [9] and Sudha *et al.* (2020) [12] for both heterobeltiosis and standard heterosis while, with reports of Malathi *et al.* (2019) [6], Hibbiny *et al.* (2020) [5] and Hamed and Said (2021) [4] for heterobeltiosis only and with *Sawarkar et al.* (2015) [11], Monicashree *et al.* (2017) [7], Udaya *et al.* (2020) [13] and Gnanasekaran and Thiyagu (2021) [21] for standard heterosis only.

Boll weight

As per better parent heterosis, the best performing positively significant hybrid for boll weight were G. Cot-20 × ABC-1 (8.21%) and AHC-50 × DB-1602 (8.10%). As per standard heterosis, the best performing positively significant hybrids were AHC-26 × GSB-45 (39.34%), AHC-26 × DB-1502 (33.03%) and AHC-1 × GSB-41 (30.90%). These results are in akin with the reports of Patel *et al.* (2015) [10], Gohil *et al.* (2017), Vavdiya *et al.* (2019) [14], Naik *et al.* (2020b) [9] and Sudha *et al.* (2020) [12] for both heterobeltiosis and standard heterosis while, Malathi *et al.* (2019) [6], Hibbiny *et al.* (2020) [5] and Hamed and Said (2021) [4] found similar results only for heterobeltiosis. Gnanasekaran and Thiyagu (2021) [21] reported significant positive standard heterosis for boll weight.

Ginning outturn

According to better parent heterosis, the best performing positively significant hybrid for ginning outturn were G. Cot-20 × GSB-43-1 (5.70%), AHC-50 × GSB-43-1 (5.56%) and AHC-50 × GSB-41 (4.02%). As per standard heterosis, the best performing positively significant hybrids were AHC-50 × GSB-43-1 (18.29%), AHC-50 × GSB-41 (16.56%) and G. Cot-20 × GSB-43-1 (15.73%). Above results were in close agreement with Vavdiya *et al.* (2019) [14] and Naik *et al.* (2020b) [9] for heterobeltiosis and standard heterosis both. While, significant and positive standard heterosis was also reported by Patel *et al.* (2015) [10], Udaya *et al.* (2020) [13] and Gnanasekaran and Thiyagu (2021) [21].

Fiber fineness

The best performing negatively significant hybrid as per better parent heterosis were G. Cot-20 × GSB-45 (-20.41%), AHC-1 × DB-1502 (-19.57%) and G. Cot-20 × DB-1502 (-18.75%). As per standard heterosis, the best performing negatively significant hybrids were G. Cot-12 × DB-1602 (-10.81%), G. Cot-12 × RHcb-1014 (-8.11%) and G. Cot-12 × GSB-41, G. Cot-12 × GSB-43-1, AHC-26 × GSB-41 (-5.41%). The results of this investigation show similarity with the earlier works of Naik *et al.* (2020a) for heterobeltiosis and standard heterosis. Sawarkar *et al.* (2015) [11], Hibbiny *et al.* (2020) [5] and Hamed and Said (2021) [4] reported similar findings for heterobeltiosis while, Monicashree *et al.* (2017) [7] and Gnanasekaran and Thiyagu (2021) [21] reported similar findings for standard heterosis only.

Fiber strength

As per better parent heterosis, the best performing positively significant hybrid were G. Cot-12 × DB-1502, G. Cot-20 × DB-1502 (15.22%), AHC-1 × DB-1502 (11.42%) and G. Cot-20 × GSB-43-1 (9.49%). As per standard heterosis, the best performing positively significant hybrids were G. Cot-20 × GSB-43-1 (9.15%), AHC-26 × GSB-43-1 (8.83%) and AHC-1 × DB-1602, G. Cot-20 × ARBB-27 (8.52%). As observed in the present investigation, Naik *et al.* (2020a) had also reported the significantly positive heterobeltiosis and standard heterosis while, Hibbiny *et al.* (2020) [5] and Hamed and Said (2021) [4] reported significant positive heterobeltiosis and Sawarkar *et al.* (2015) [11], Monicashree *et al.* (2017) [7] and Gnanasekaran and Thiyagu (2021) [21] reported significant and positive standard heterosis for fiber strength.

Fiber length

According to better parent heterosis, the best performing positively significant hybrid were AHC-26 × DB-1502 (19.10%), AHC-26 × ARBB-27 (16.77%) and AHC-50 × DB-1502 (16.32%). As per standard heterosis, the hybrids AHC-50 × GSB-43-1 (5.61%), AHC-26 × ARBB-27 (5.03%) and AHC-1 × GSB-43-1, AHC-26 × RHcb-1014 (4.74%) were best performing. Naik *et al.* (2020a) had also reported significant and positive heterobeltiosis and standard heterosis. Similar results were also reported by Hamed and Said (2021) [4] for heterobeltiosis and Patel *et al.* (2015) [10], Sawarkar *et al.* (2015) [11], Gohil *et al.* (2017) [3] and Gnanasekaran and Thiyagu (2021) [21] for standard heterosis.

Uniformity index

As per better parent heterosis, the best performing positively significant hybrid for were G. Cot-12 × GSB-45, AHC-50 × RHcb-1014 (3.57%), AHC-1 × GSB-45, AHC-1 × RHcb-1014 (2.38%) and AHC-1 × ABC-1, AHC-1 × GSB-43-1, G. Cot-12 × ABC-1 (2.35%) for uniformity index. As per standard heterosis, the best performing positively significant hybrids were AHC-1 × GSB-44 (3.57%), G. Cot-12 × ABC-1 (3.57%) and AHC-50 × RHcb-1014 (3.57%). Hibbiny *et al.*

(2020) [5] and Hamed and Said (2021) [4] also reported significant positive heterobeltiosis while, Monicashree *et al.* (2017) [7] and Gnanasekaran and Thiyagu (2021) [21] reported significantly positive standard heterosis only.

Seed index

As per better parent heterosis, the best performing positively significant hybrid for seed index were G. Cot-20 × DB-1502 (36.95%), G. Cot-20 × RHcb-1014 (34.57%) and G. Cot-12 × RHcb-1014 (32.38%). As per standard heterosis, the best performing positively significant hybrids were AHC-26 × GSB-45 (12.97%), AHC-26 × GSB-44 (11.99%) and AHC-26 × ABC-1 (9.08%) for seed index. Similar results were obtained by Gohil *et al.* (2017) [3], Malathi *et al.* (2019) [6], Vavdiya *et al.* (2019) [14] and Naik *et al.* (2020b) [9] for both heterobeltiosis as well as standard heterosis while, Hibbiny *et al.* (2020) [5] and Hamed and Said (2021) [4] found significant positive heterobeltiosis and Monicashre *et al.* (2017), Sudha *et al.* (2020) [12], Udaya *et al.* (2020) [13] and Gnanasekaran and Thiyagu (2021) [21] found significantly positive standard heterosis for seed index.

Lint index

The best performing positively significant hybrid according to better parent heterosis were G. Cot-20 × GSB-43-1 (35.82%), AHC-50 × GSB-41 (30.87%) and AHC-50 × GSB-43-1 (30.25%). As per standard heterosis, the best performing positively significant hybrids were AHC-26 × GSB-45 (21.81%) followed by AHC-26 × GSB-43-1 (15.71%) and AHC-26 × GSB-44 (14.74%). Significant and positive heterobeltiosis and standard heterosis were also reported by Gohil *et al.* (2017) [3], Vavdiya *et al.* (2019) [14] and Sudha *et al.* (2020) [12]. Hibbiny *et al.* (2020) [5], and Hamed and Said (2021) [4] also found significant positive heterobeltiosis while, Udaya *et al.* (2020) [13] and Gnanasekaran and Thiyagu (2021) [21] found significant positive standard heterosis.

Lint yield per plant

As per better parent heterosis, the best performing positively significant hybrid were G. Cot-12 × GSB-43-1 (51.24%), AHC-26 × ARBB-27 (45.91%) and G. Cot-20 × ABC-1 (39.96%). As per standard heterosis, the hybrids AHC-1 × DB-1502 (63.95%), AHC-1 × GSB-45 (57.27%) and AHC-1 × RHcb-1014 (51.32%) were best performing. The results are in conformity with the reports of Patel *et al.* (2015) [10], Gohil *et al.* (2017) [3] and Sudha *et al.* (2020) [12] for heterobeltiosis as well as standard heterosis while, Hibbiny *et al.* (2020) [5] and Hamed and Said (2021) [4] got similar results for heterobeltiosis.

Seed cotton yield per plant

According to better parent heterosis, the best performing positively significant hybrid for seed cotton yield per plant were AHC-26 × ARBB-27 (65.57%) followed by G. Cot-12 × GSB-43-1 (61.53%) and AHC-26 × DB-1502 (50.31%). While, as per standard heterosis, the outstanding and positively significant hybrids were AHC-1 × DB-1502 (59.57%), AHC-1 × GSB-45 (53.15%) and AHC-26 × ARBB-27 (47.72%). The earlier investigation of Patel *et al.* (2015) [10], Sawarkar *et al.* (2015) [11], Gohil *et al.* (2017) [3], Malathi *et al.* (2019) [16], Vavdiya *et al.* (2019) [14] and Naik *et al.* (2020) showed agreement with the present result of heterobeltiosis and standard heterosis and those of Hibbiny *et al.* (2020) [5], Sudha *et al.* (2020) [12] and Hamed and Said (2021) [4] showed similarly significant positive heterobeltiosis. The earlier studies of Monicashree *et al.* (2017) [7], Udaya *et al.* (2020) [13], Gnanasekaran and Thiyagu (2021) [21] supports the present result of positive and significant SH.

Conclusions

Significant levels of desirable heterobeltiosis and standard heterosis was registered in the current investigation for seed cotton yield per plant and its component traits. These suggests the possibility for improvement of cotton through heterosis breeding. Out of 45 hybrids developed, AHC-1 × DB-1502, AHC-1 × GSB-45, AHC-26 × ARBB-27, AHC-1 × GSB-43-1 and G. Cot-20 × ABC-1 were most promising cross combinations for seed cotton yield per plant on the basis of standard heterosis. Therefore, these cross combinations may be favoured for commercial cultivation as hybrids after critical evaluation in varied environments or over locations. These hybrids may also be further advanced for development of superior desirable recombinants as improved varieties.

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