Journal of Applied and Natural Science 8 (3): 1356 - 1365 (2016)

JANS

Heterosis in single cross inter and intra-specific hybrids of *Desi* cotton (*Gossipium arboreum* and *G. herbaceaum*) for their seed cotton yield, fibre quality and seed oil content

Rakesh Choudhary[1*], B. G. Solanki[2], Navin Chander Gahtyari[1], Tapas Paul[3] and D. M. Patel[2]

[1]Department of Genetics and Plant Breeding, G. B. Pant University of Agriculture & Technology, Pantnagar (UK), INDIA
[2]Main Cotton Research Station, Navsari Agricultural University, Surat- 395007 (Gujarat), INDIA
[3] ICAR Research Complex for NEH Region, Tripura Centre, INDIA
*Corresponding author. E-mail:- agrico.rakesh@gmail.com

Received: November 29, 2015; Revised received: April 30, 2016; Accepted: July 25, 2016

Abstract: The present investigation was carried out to assess the expression of *per se* performance and heterotic effect for fibre quality and seed oil content besides seed cotton yield, studied involving ten *desi* cotton (*Gossipium arboreum* and *G. herbaceaum*) genotypes and their 45 cross combinations in half diallel analysis. F-$_1$ hybrids GBhv- 282 x G 27 (67.36%), GBhv- 287 x 824 (58.14%), GBhv- 282 x GAM- 173 (35.00%), GBhv- 286 x G 27 (20.50%), and GBhv- 283 x 824 (18.75%) recorded highest per se performance and significant positive standard heterosis while the maximum heterobeltiosis for seed cotton yield per plant was exhibited by the hybrid GBhv- 287 x 824 (155.60 %) followed by GBhv- 282 x G 27 (151.29%) and GBhv- 282 x GAM- 173 (130.30%). Similar trend of heterosis for numbers of boll per plant were observed in above hybrids. For fibre quality traits none of the cross showed consistent high performance for all the characters. Cross GBhv- 283 x 824 was exhibited high standard heterosis for 2.5 % span length, fibre strength, fibre elongation percentage as well as for short fibre index (SFI) while cross GBhv- 286 x 824 were promising for 2.5 per cent span length, fibre strength and fibre fineness. In case of oil content intra-arboreum crosses resulted as better crosses and among them cross combination 824 x GAM- 173 was best. *Desi* cotton hybrids are having lower fibre quality and yield. So, improvement for yield and fibre quality of diploid native varieties through heterosis breeding provided better hybrids for rainfed farming.

Keywords: Diploid, Heterobeltiosis, Heterosis Breeding, Quantitative, Useful heterosis

INTRODUCTION

Cotton is a principle fiber, crop and plays a vital role as a cash crop in commerce of many countries. Cotton production, processing and trade in cotton goods provide employment to about 60 million people in India. It provides fibre for textile industry, cellulose from its lint, oil and protein rich meal from its seed (Ashok Kumar and Ravikesavan, 2011). The cotton seed, a by-product, is an important source of edible oil. Cotton seed is the second largest source of vegetable oil in the world. In India, secondary source of edible oil production is 19.90 lakh tons. Cotton seed oil is generally considered as healthy vegetable oil. The physical and chemical properties of cotton seed oil are well defined and in natural form have no cholesterol and are very low in trans fatty acid and hence termed as "*Heart oil*". When India got Independence, 97 per cent of the total cultivation was of Native diploid "*Desi*" cottons (varieties of *Gossypium arboreum* L. and *G. herbaceum* L). Gradually, *desi* varieties disappeared from the fields of Indian farmers with hybrids and *Bt* cotton replacing them in a very short time. This year, the cultivation has reached an abysmal low of three per cent. The *desi* varieties have ceded ground to the American varieties and now the situation is exactly the reverse, compared to that of 1947. Indian *desi* cotton is famous for its medicinal use due its absorbant ability and apart from surgical quality it is used general uses like textile, jeans, tea-coffee filters, fishing nets etc., whose demand is growing and the market price is very high. *Desi* varieties have resistance to pest and disease and can be grown with little rain and are suitable for dry-land and mixed farming.

Cotton breeders are trying to develop cotton varieties; those well adapt to poor environmental conditions and produce higher yields and better fiber quality along with increased tolerance to complexes of diseases and insect pests. Very less number of *desi* cotton hybrids are released in India and the development of new *desi* cotton hybrid with high yield and fibre quality is necessary for Indian cotton farming.

Heterosis is a performance of F_1/F_2 genotypic combinations and is useful in determining the most appropriate parents for specific traits (Khan *et al.*, 2010). Development of hybrid varieties is considered to be the quickest breeding method for exploiting the heterosis to improve yield potential of crop plants. Heterosis has

ISSN : 0974-9411 (Print), 2231-5209 (Online)

substantially remained as one of the significant developments in cotton breeding programs. The yield increase through intra- and inter-specific heterosis over the better parent or best commercial cultivar (useful heterosis) has been documented (Wei *et al.*, 2002; Yuan *et al.*, 2002; Zhang *et al.*, 2002; Khan *et al.* 2007a).

Several studies have been reported on seeds traits, but little work has been reported on the genetics and heterosis of cottonseed oil percentage in cotton breeding. A few reports in the literature (Khan *et al.*, 2007b; Ganapathy and Nadarajan, 2008; Sharma *et al.*, 2009; Khan *et al.*, 2010) have determined that cotton genotypes differ in oil percentage.

Seed quality generally increases with high level of seed oil but had inverse relationship with seed cotton yield. For a simultaneous selection of both quality and yield, knowledge of inter relationship between the components of quality and those of yield is a prerequisite. In cotton, heterosis studies for seed cotton yield and other fiber properties are many, But to know the nature and extent of heterosis for oil content with seed cotton yield and other traits are limited.

Therefore, the present investigation objective was to estimate genetic variation for mean performance of parents and their hybrids and to estimate the effects of heterosis in F_1 cross combinations, to obtain information about heterotic potential as to develop hybrid with improved yield, fibre quality along with high seed oil content in diploid cotton (*Gossipium arboreum* and *Gossipium herbaceaum*).

MATERIALS AND METHODS

Genetic material: The material used in present study consisted of ten well adapted parental line of diploid cotton from diverse geographic origin, their 45 F_1 cross combination and one standard check (SC) G. Cot DH-7. Ten parents included five lines of *Gossypium herbaceum* cotton *viz.* GShv- 273/07, GBhv- 282, GBhv-283, GBhv- 286 and GBhv- 287 and five lines of *G. arboreum* cotton *viz.* 824, G 27, GAM- 141, GAM-165 and GAM- 173 **(Table 1).**

Experimental *desi*gn and field procedures: The *desi* cotton cultivars and F_1 cross combinations were evaluated in randomized block *desi*gn (RBD) with three replications at Main Cotton Research Station, Surat (Gujarat) India. Each genotype was grown in a row of 4 m length adopting a spacing of 120 cm between rows and 40 cm between the plants, so as to have 10 plants per row. Parents were crossed in a half–diallel (excluding reciprocals) fashion during *kharif* 2011-12 to generate a total 45 hybrids. The conventional hand emasculation and pollination method developed by Dock and Moll (1934) was followed and crossed bolls collected separately and ginned to obtain F_1 seeds. During *kharif* 2012-13, a set of 56 entries (10 parents and 45 F_1's and one standard check) were raised with three replications.

Sampling trait measurements and analysis:: In each genotypes and their cross combinations, data were recorded on five randomly selected plants per replication for eleven characters namely, seed cotton yield per plant (g), numbers of bolls per plant, boll weight (gm), 2.5 % span length (mm), fibre strength (g tex^{-1}), fibre fineness (mv), fibre elongation percentage (%), fibre maturity coefficient, short fibre index (SFI), fibre uniformity ratio (%) and seed oil content. Fibre quality parameters were analyzed using high volume instrument (HVI) (Premier Evolvics Pvt. Ltd., Coimbatore) in ideal condition (R.H. 65±2 % and temperature 27±2^{o}C) at CIRCOT, Regional Station, Surat. The oil content was determined by Nuclear Magnetic Resonance (NMR) technique.

Heterosis was estimated over the better parent (BP) as per the standard procedure of Meredith and Bridge (1972) and useful heterosis as per standard method suggested by Rai (1978) over the standard check (SC). Data were analyzed using standard statistical software (INDOSTAT) to work out the magnitude of heterosis expressed by the hybrids under evaluation overbetter parent and standard check.

RESULTS AND DISCUSSION

Evaluation of mean performance and heterotic effect is essential to know whether new hybrids are suitable for direct exploitation or can be used to isolate transgressive segregants from subsequent generation to develop a new variety. The direct exploitation of hybrids for commercial production mainly depends upon the nature and extent of heterosis. The magnitude of heterosis of all cross combinations was worked out for all the characters over better parent and standard check. **(Table 3)**

Analysis of variance: The analysis of variance of RBD revealed that mean sum of squares due to differences among the genotypes was significant for all the characters studied, which indicates existence of substantial variability in the in the breeding material to be exploited in the study **(Table 2).** The variance due to parents was highly significant for all the characters. The mean square due to hybrids was significant for all the characters except fibre maturity coefficient. Significance of variance in parents versus hybrids interaction provided adequacy for comparing the heterotic expression for all the characters except for fibre uniformity ratio and oil content.

Genetic variability in F_1 hybrids and their parents: The mean expression of 11 characters was recorded on all 10 genotypes and 45 hybrids. All the genotypes and F_1 hybrids differ significantly for all the characters. The mean performance of parents are presented in **Table-1** and the estimates of mean performance of hybrids are presented in **Table-3** along with magnitude of heterosis over better parent (Heterobeltiosis) and standard check

Table 1. Mean values of 10 parents and standard check for 11 characters under study.

PARENTS	SCY /Plant	No. Of Bolls/ Plant	Boll Weight (g)	2.5% Span length (mm)	g tex^{-1}	Micronaire Value	Fibre Elongation Percentage	Maturity Co Efficient	Short Fibre Index	Fibre Uniformity Ratio	Oil %
G. herbaceum											
GShv-273/07	87.27	39.90	2.19	23.7	20.20	5.00	5.60	0.84	13.90	51.00	16.23
GBhv- 282	78.16	42.22	1.85	24.5	17.60	4.70	4.90	0.82	12.40	51.00	16.01
GBhv- 283	58.14	26.22	2.24	25.1	18.80	4.50	5.40	0.82	13.20	49.00	17.14
GBhv- 286	52.07	19.98	2.62	23.2	17.30	5.60	5.10	0.84	15.60	49.00	16.75
GBhv- 287	78.73	33.88	2.33	25.6	18.90	5.10	5.40	0.84	13.30	48.00	16.62
G. arboreum											
824	82.49	38.59	2.14	30.1	22.70	4.20	6.20	0.84	10.30	44.00	16.88
G 27	88.80	42.82	2.08	18.7	13.60	6.90	4.50	0.75	6.50	56.00	16.70
GAM- 141	81.33	33.48	2.44	25.9	18.70	5.30	6.00	0.84	12.10	49.00	17.48
GAM- 165	97.70	38.22	2.56	28.5	18.10	4.90	5.40	0.83	13.40	43.00	17.77
GAM- 173	53.68	23.37	2.29	25.6	18.20	4.90	5.70	0.83	13.00	48.00	16.89
Check											
G. Cot DH- 7	133.34	65.75	2.03	24.0	17.90	6.10	5.60	0.85	14.50	49.00	17.08

Table 2. ANOVA for 11 characters in *desi* hybrid cotton(*Gossypium arboreum* L. and *G. herbaceum* L)

Source of variations	d.f.	SCY/Plant	No. Of Bolls/ Plant	Boll Weight (g)	2.5% Span length (mm)	g tex^{-1}	Micronaire Value	Fibre Elongation Percentage	Maturity Coefficient	Short Fibre Index	Fibre Uniformity Ratio	Oil %
Replications	2	1.059	10.68	0.02	0.72	0.08	0.09	0.23	0.10	0.07	0.38	0.20
Genotypes	54	4703.52**	1027.40**	0.25**	17.96**	17.15**	1.38**	0.66**	0.001**	21.95**	15.11**	0.83**
Parents	9	744.60**	196.50**	0.16**	28.28**	15.75**	1.65**	0.76**	0.002**	18.20**	39.87**	0.84**
Hybrids	44	5193.64**	1096.95**	0.26**	15.54**	15.00**	1.34**	0.50**	0.001	22.81**	10.23**	0.84**
Parents *vs.* Hybrids	1	18768.42**	5445.44**	0.42**	31.53**	124.43**	0.66**	6.87**	0.02**	17.83**	6.98	0.05
Error	108	149.02	27.60	0.02	0.68	0.70	0.09	0.12	0.0006	0.31	3.27	0.09
SE±		7.05	3.03	0.08	0.48	0.48	0.17	0.20	0.14	0.10	1.04	0.17

*, ** significant at 5 per cent and 1 per cent levels of probability, respectively.

Table 3. *Per se* performance and heterosis over better parent (BP) and standard check (SC) for 11 different traits regarding to yield, fibre quality and oil content of *desi* cotton (*Gossypium arboreum* L. and *G. herbaceum* L.) hybrids.

Sr. No.	Crosses	Seed cotton yield/ plant (g)			No. of Bolls/ plant			Boll Weight (g)		
		Mean	BP	SC	Mean	BP	SC	Mean	BP	SC
1	GShv- 273/07 x GBhv -282	90.62	3.84	-32.03**	39.11	-7.38	-40.52**	2.31	5.48	13.79*
2	GShv- 273/07 x GBhv- 283	66.83	-23.42*	-49.88**	29.69	-25.60*	-54.85**	2.29	2.23	12.81*
3	GShv- 273/07 x GBhv- 286	69.81	-20.01	-47.64**	30.82	-22.76*	-53.13**	2.26	13.74**	11.33*
4	GShv- 273/07 x GBhv- 287	74.88	-14.19	-43.84**	26.73	-33.02**	-59.35**	2.81	20.60**	38.42**
5	GShv- 273/07 x 824	151.28	73.35**	13.46	68.60	71.92**	4.33	2.20	0.46	8.37
6	GShv- 273/07 x G 27	136.76	54.00**	2.57	71.70	67.46**	9.05	1.91	-12.79*	-5.91
7	GShv- 273/07 x GAM- 141	123.67	41.71**	-7.25	56.85	42.47**	-13.54*	2.17	-11.07*	6.90
8	GShv- 273/07 x GAM- 165	96.00	-1.73	-28.00**	39.78	-0.31	-39.50**	2.42	-5.47	19.21**
9	GShv- 273/07 x GAM- 173	98.84	13.26	-25.87**	44.05	10.39	-33.01**	2.25	-1.75	10.84*
10	GBhv- 282 x GBhv- 283	59.46	-23.93	-55.41**	22.66	-46.34**	-65.54**	2.65	18.30**	30.54**
11	GBhv- 282 x GBhv- 286	76.78	-1.77	-42.42**	34.60	-18.05	-47.38**	2.23	-14.89**	9.85
12	GBhv- 282 x GBhv- 287	85.87	9.08	-35.60**	38.97	-7.70	-40.72**	2.20	-5.58	8.37
13	GBhv- 282 x 824	75.66	-8.28	-43.26**	36.15	-14.40	-45.03**	2.09	-2.34	2.96
14	GBhv- 282 x G 27	223.15	151.29**	67.36**	97.40	127.48**	48.14**	2.29	10.10	12.81*
15	GBhv- 282 x GAM- 141	152.33	87.30**	14.25	62.00	46.85**	-5.70	2.47	1.23	21.67**
16	GBhv- 282 x GAM- 165	117.18	19.95	-12.12	44.73	5.94	-31.96**	2.62	2.34	29.06**
17	GBhv- 282 x GAM- 173	180.00	130.30**	35.00**	83.86	98.60**	27.54**	2.14	-6.40	5.58
18	GBhv- 283 x GBhv- 286	95.00	63.40**	-28.75**	39.08	49.08**	-40.56**	2.42	-7.63	19.21**
19	GBhv- 283 x GBhv- 287	92.33	17.28	-30.75**	42.68	25.97*	-35.09**	2.17	-6.87	6.90
20	GBhv- 283 x 824	158.33	91.93**	18.75*	76.56	98.37**	16.44*	2.07	-7.59	1.97
21	GBhv- 283 x G 27	105.57	18.88	-20.82**	54.56	27.42**	-17.02*	1.94	-13.39**	-4.43
22	GBhv- 283 x GAM- 141	95.01	16.82	-28.74**	34.29	2.43	-47.85**	2.76	13.11**	35.96**
23	GBhv- 283 x GAM- 165	65.86	-32.59**	-50.61**	22.41	-41.36**	-65.91**	2.94	14.84**	44.83**
24	GBhv- 283 x GAM- 173	73.99	27.26	-44.51**	38.27	45.99**	-41.79**	1.95	-14.85**	-3.94
25	GBhv- 286 x GBhv- 287	111.00	40.99**	-16.75*	50.94	50.34**	-22.53**	2.18	-16.79**	7.39
26	GBhv- 286 x 824	122.22	48.16**	-8.34	61.70	59.86**	-6.16	1.98	-24.43**	-2.46
27	GBhv- 286 x G 27	160.67	80.92**	20.50**	79.59	85.89**	21.05**	2.02	-23.03**	-0.66
28	GBhv- 286 x GAM- 141	89.60	10.16	-32.80**	48.35	44.43**	-26.47**	1.86	-29.01**	-8.37
29	GBhv- 286 x GAM- 165	54.93	-43.77**	-58.80**	29.09	-23.88*	-55.75**	1.89	-27.86**	-6.90
30	GBhv- 286 x GAM- 173	79.33	47.78*	-40.50**	37.36	59.85**	-43.17**	2.13	-18.70**	4.93
31	GBhv- 287 x 824	210.86	155.60**	58.14**	93.09	141.22**	41.59**	2.30	-1.29	13.30*
32	GBhv- 287 x G 27	146.73	65.23**	10.04	72.29	68.83**	9.94	2.02	-13.30**	-0.49
33	GBhv- 287 x GAM- 141	150.57	85.12**	12.92	72.73	114.68**	10.62	2.07	-15.16**	1.97
34	GBhv- 287 x GAM- 165	128.74	31.78**	-3.45	62.83	64.39**	-4.44	2.05	-19.92**	0.99
35	GBhv- 287 x GAM- 173	134.63	71.01**	0.97	68.84	103.18**	4.69	1.96	-15.88**	-3.45
36	824 x G 27	73.16	-17.62	-45.13**	35.85	-16.27	-45.48**	2.10	-2.02	3.28
37	824 x GAM- 141	73.00	-11.51	-45.25**	38.23	-0.94	-41.86**	1.90	-22.13**	-6.40
38	824 x GAM- 165	81.64	-16.43	-38.77**	42.37	9.78	-35.56**	1.93	-22.48**	-4.76
39	824 x GAM- 173	54.50	-33.93**	-59.13**	32.53	-15.71	-50.52**	1.68	-26.64**	-17.24**
40	G 27 x GAM- 141	70.10	-21.06	-47.43**	39.52	-7.72	-39.90**	1.77	-27.46**	-12.81*
41	G 27 x GAM- 165	86.33	-11.63	-35.25**	45.90	7.21	-30.19**	1.88	-26.56**	-7.39
42	G 27 x GAM- 173	51.16	-42.39**	-61.63**	31.50	-26.43**	-52.09**	1.62	-29.26**	-20.20**
43	GAM- 141 x GAM- 165	92.14	-5.68	-30.90**	50.87	33.10**	-22.63**	1.81	-29.30**	-10.84*
44	GAM- 141 x GAM- 173	62.28	-22.43	-53.29**	36.06	7.73	-45.16**	1.73	-29.10**	-14.78**
45	GAM- 165 x GAM- 173	58.20	-40.43**	-56.35**	29.11	-23.84*	-55.73**	1.99	-22.27**	-1.97
	S.E. (d) ±		9.97	9.97		4.29	4.29		0.11	0.11
	CD 0.05		19.76	19.76		8.50	8.50		0.21	0.21
	CD 0.01		26.14	26.14		11.25	11.25		0.28	0.28

*, ** Significant at 5 % and 1 % levels, respectively.

Table 3 Contd…..

Sr. No.	Crosses	2.5 per cent span length			Fibre strength (g tex^{-1})			Fibre fineness (mv)		
		Mean	BP	SC	Mean	BP	SC	Mean	BP	SC
1	GShv- 273/07 x GBhv -282	25.9	5.85*	8.06**	21.80	8.09*	21.97**	4.60	-2.13	-24.59**
2	GShv- 273/07 x GBhv- 283	25.1	-0.13	4.58	20.30	0.66	13.59**	4.80	7.41	-20.77**
3	GShv- 273/07 x GBhv- 286	25.2	6.18*	5.00	22.90	13.53**	28.12**	4.40	-12.00*	-27.87**
4	GShv- 273/07 x GBhv- 287	25.7	0.39	7.08*	20.40	1.16	14.15**	4.80	-4.00	-21.31**
5	GShv- 273/07 x 824	27.3	-9.29*	13.89**	23.40	3.23	30.91**	4.50	7.94	-25.68**
6	GShv- 273/07 x G 27	25.1	5.62	4.44	18.60	-7.76*	4.10	6.20	24.00**	1.64
7	GShv- 273/07 x GAM- 141	26.6	2.70	10.83**	20.80	3.14	16.39**	5.00	0.00	-18.03**
8	GShv- 273/07 x GAM- 165	28.2	-1.05	17.50**	21.90	8.58*	22.53**	5.10	4.08	-16.39**
9	GShv- 273/07 x GAM- 173	27.7	8.20**	15.42**	21.20	5.12	18.62**	5.10	4.08	-16.39**
10	GBhv- 282 x GBhv- 283	26.6	5.84*	10.83**	21.00	11.50**	17.32**	4.60	1.48	-25.14**
11	GBhv- 282 x GBhv- 286	25.3	3.27	5.42	18.30	3.78	2.23	5.10	9.22	-15.85**
12	GBhv- 282 x GBhv- 287	24.8	-2.99	3.47	20.50	8.27*	14.53**	4.90	4.26	-19.67**
13	GBhv- 282 x 824	24.8	-17.70**	3.33	20.90	-7.78	16.95**	4.90	17.46**	-19.13**
14	GBhv- 282 x G 27	25.6	4.49	6.67*	22.10	25.52**	23.65**	6.40	36.17**	4.92
15	GBhv- 282 x GAM- 141	27.6	6.56*	15.00**	22.50	19.93**	25.51**	5.60	19.15**	-8.20*
16	GBhv- 282 x GAM- 165	28.5	0.00	18.75**	21.20	17.10**	18.62**	5.10	7.80	-16.94**
17	GBhv- 282 x GAM- 173	27.6	7.94**	15.14**	22.00	20.84**	23.09**	5.10	9.22	-15.85**
18	GBhv- 283 x GBhv- 286	26.7	6.23*	11.25**	19.80	5.13	10.61**	5.20	15.56**	-14.75**
19	GBhv- 283 x GBhv- 287	28.8	12.50**	20.00**	21.80	15.32**	21.97**	5.50	22.22**	-9.84*
20	GBhv- 283 x 824	30.3	0.55	26.25**	24.10	6.17*	34.64**	4.60	9.52	-24.59**
21	GBhv- 283 x G 27	23.8	-5.31	-0.83	19.20	1.95	7.26	6.50	44.44**	6.56
22	GBhv- 283 x GAM- 141	26.5	2.19	10.28**	20.30	7.79*	13.41**	5.20	15.56**	-14.75**
23	GBhv- 283 x GAM- 165	24.8	-12.98**	3.33	19.60	4.07	9.50*	5.00	11.11*	-18.03**
24	GBhv- 283 x GAM- 173	27.7	8.20**	15.42**	23.00	22.12**	28.49**	5.20	15.56**	-14.75**
25	GBhv- 286 x GBhv- 287	30.1	17.58**	25.42**	20.80	9.86**	16.20**	5.50	7.84	-9.84*
26	GBhv- 286 x 824	32.0	6.19**	33.33**	23.70	4.41	32.40**	4.30	2.38	-29.51**
27	GBhv- 286 x G 27	23.3	0.43	-2.92	19.60	13.49**	9.68*	6.00	7.14	-1.64
28	GBhv- 286 x GAM- 141	25.9	0.00	7.92**	20.60	9.96**	15.08**	4.80	-9.43*	-21.31**
29	GBhv- 286 x GAM- 165	24.3	-14.62**	1.39	21.40	18.20	19.74**	4.30	-12.24*	-29.51**
30	GBhv- 286 x GAM- 173	24.2	-5.47*	0.83	18.50	1.46	3.35	6.10	24.49**	0.00
31	GBhv- 287 x 824	29.1	-3.43	21.25**	22.50	-0.88	25.70**	4.90	15.87**	-20.22**
32	GBhv- 287 x G 27	24.7	-3.52	2.92	21.40	13.03**	19.55**	5.50	7.84	-9.84*
33	GBhv- 287 x GAM- 141	27.4	5.79*	14.17**	21.60	14.08**	20.67**	4.50	-11.11*	-25.68**
34	GBhv- 287 x GAM- 165	26.8	-5.96*	11.67**	21.60	14.26**	20.86**	5.50	11.56*	-10.38**
35	GBhv- 287 x GAM- 173	28.0	9.37**	16.67**	23.00	21.65**	28.68**	4.80	-2.04	-21.31**
36	824 x G 27	30.4	1.00	26.81**	22.00	-2.94	23.09**	3.80	-9.52**	-37.70**
37	824 x GAM- 141	22.3	-26.00**	-7.08*	15.90	29.81**	-10.99**	6.40	52.38**	4.92
38	824 x GAM- 165	21.8	-27.65**	-9.17**	14.70	-35.10**	-17.69**	6.30	50.00**	3.28
39	824 x GAM- 173	25.2	-16.37**	5.00	20.30	-10.43**	13.59**	5.70	35.71**	-6.56
40	G 27 x GAM- 141	24.8	-4.25	3.33	17.50	-6.41	-2.05	6.10	15.72**	0.55
41	G 27 x GAM- 165	24.0	-15.67**	0.14	18.90	4.41	5.77	5.80	18.37**	-4.92
42	G 27 x GAM- 173	21.1	-17.58**	-12.08**	13.20	-27.61**	-26.26**	6.50	32.65**	6.56
43	GAM- 141 x GAM- 165	27.1	-4.91*	12.92**	20.20	8.01*	13.04**	5.90	20.41**	-3.28
44	GAM- 141 x GAM- 173	26.2	1.29	9.31**	23.40	25.09**	30.91**	5.40	10.20*	-11.48**
45	GAM- 165 x GAM- 173	25.4	-10.88**	5.83*	21.40	17.55**	19.74**	5.70	16.33**	-6.56
	S.E. (d) ±		0.67	0.67		0.68	0.68		0.24	0.24
	CD 0.05		1.34	1.34		1.35	1.35		0.48	0.48
	CD 0.01		1.77	1.77		1.79	1.79		0.63	0.63

*, ** Significant at 5 % and 1 % levels, respectively.

Table 3. Contd…..

	Crosses	Fibre elongation percentage			Maturity coefficient			Short Fibre Index (SFI)		
		Mean	BP	SC	Mean	BP	SC	Mean	BP	SC
1	GShv- 273/07 x GBhv -282	5.70	1.79	1.79	0.84	0.00	-1.18	10.40	-16.13**	-28.28**
2	GShv- 273/07 x GBhv- 283	5.50	-1.79	-1.79	0.84	0.00	-1.18	10.60	-19.70**	-26.90**
3	GShv- 273/07 x GBhv- 286	5.60	0.00	0.00	0.84	0.00	-1.18	12.30	-11.51**	-15.17**
4	GShv- 273/07 x GBhv- 287	5.50	-1.79	-1.79	0.84	0.00	-1.18	9.50	-28.57**	-34.48**
5	GShv- 273/07 x 824	6.20	0.00	10.71*	0.85	1.19	0.00	9.40	-8.74*	-35.17**
6	GShv- 273/07 x G 27	5.90	5.36	5.36	0.86	2.38	1.18	11.70	80.00**	-19.31**
7	GShv- 273/07 x GAM- 141	5.90	-1.67	5.36	0.85	1.19	0.00	11.60	-4.13	-20.00**
8	GShv- 273/07 x GAM- 165	6.50	16.07**	16.07**	0.86	2.38	1.18	8.00	-40.30**	-44.83**
9	GShv- 273/07 x GAM- 173	6.20	8.77	10.71*	0.85	1.19	0.00	9.90	-23.85**	-31.72**
10	GBhv- 282 x GBhv- 283	5.90	9.26	5.36	0.84	2.44	-1.18	10.60	-14.52**	-26.90**
11	GBhv- 282 x GBhv- 286	5.60	9.80	0.00	0.83	-1.19	-2.35	11.00	-11.29**	-24.14**
12	GBhv- 282 x GBhv- 287	5.60	3.70	0.00	0.84	0.00	-1.18	14.00	12.90**	-3.45
13	GBhv- 282 x 824	5.80	-6.45	3.57	0.85	1.19	0.00	12.50	21.36**	-13.79**
14	GBhv- 282 x G 27	6.60	34.69**	17.86**	0.88	7.32**	3.53	12.00	84.62**	-17.24**
15	GBhv- 282 x GAM- 141	6.40	6.67	14.29**	0.87	3.57	2.35	8.30	-31.40**	-42.76**
16	GBhv- 282 x GAM- 165	6.30	16.67**	12.50*	0.85	2.41	0.00	8.80	-29.03**	-39.31**
17	GBhv- 282 x GAM- 173	6.10	7.02	8.93	0.86	3.61	1.18	9.20	-25.81**	-36.55**
18	GBhv- 283 x GBhv- 286	5.60	3.70	0.00	0.85	1.19	0.00	10.20	-22.73**	-29.66**
19	GBhv- 283 x GBhv- 287	6.40	18.52**	14.29**	0.87	3.57	2.35	8.90	-32.58**	-38.62**
20	GBhv- 283 x 824	6.50	4.84	16.07**	0.86	2.38	1.18	7.00	-32.04**	-51.72**
21	GBhv- 283 x G 27	6.10	12.96*	8.93	0.87	6.10*	2.35	13.00	100.00**	-10.34**
22	GBhv- 283 x GAM- 141	5.60	-6.67	0.00	0.85	1.19	0.00	11.10	-8.26*	-23.45**
23	GBhv- 283 x GAM- 165	5.30	-1.85	-5.36	0.84	1.20	-1.18	12.70	-3.79	-12.41**
24	GBhv- 283 x GAM- 173	6.40	12.28*	14.29**	0.86	3.61	1.18	10.40	-20.00**	-28.28**
25	GBhv- 286 x GBhv- 287	6.20	14.81**	10.71*	0.86	2.38	1.18	6.80	-48.87**	-53.10**
26	GBhv- 286 x 824	6.20	0.00	10.71*	0.84	0.00	-1.18	7.20	-30.10**	-50.34**
27	GBhv- 286 x G 27	6.30	23.53**	12.50*	0.86	2.38	1.18	13.60	109.23**	-6.21*
28	GBhv- 286 x GAM- 141	5.90	-1.67	5.36	0.84	0.00	-1.18	12.90	6.61	-11.03**
29	GBhv- 286 x GAM- 165	5.50	1.85	-1.79	0.83	-1.19	-2.35	13.90	3.73	-4.14
30	GBhv- 286 x GAM- 173	6.10	7.02	8.93	0.86	2.38	1.18	14.20	9.23**	-2.07
31	GBhv- 287 x 824	6.50	4.84	16.07**	0.85	1.19	0.00	7.00	-32.04**	-51.72**
32	GBhv- 287 x G 27	6.30	16.67**	12.50*	0.86	2.38	1.18	13.20	103.08	-8.97**
33	GBhv- 287 x GAM- 141	6.20	3.33	10.71*	0.84	0.00	-1.18	10.90	-9.92**	-24.83**
34	GBhv- 287 x GAM- 165	6.30	16.67**	12.50*	0.86	2.38	1.18	10.00	-24.81**	-31.03**
35	GBhv- 287 x GAM- 173	6.40	12.28*	14.29**	0.85	1.19	0.00	9.30	-28.46**	-35.86**
36	824 x G 27	6.10	-1.61	8.93	0.82	-2.38	-3.53	10.30	58.46**	-28.97**
37	824 x GAM- 141	5.30	-14.52**	-5.36	0.84	0.00	-1.18	15.90	54.37**	9.66**
38	824 x GAM- 165	5.30	-14.52**	-5.36	0.83	-1.19	-2.35	16.70	62.14**	15.17**
39	824 x GAM- 173	5.70	-8.06	1.79	0.86	2.38	1.18	14.50	40.78**	0.00
40	G 27 x GAM- 141	5.40	10.00*	-3.57	0.85	1.19	0.00	14.30	120.00**	-1.38
41	G 27 x GAM- 165	5.70	5.56	1.79	0.85	2.41	0.00	15.60	140.00**	7.59*
42	G 27 x GAM- 173	4.90	-14.04**	-12.50*	0.83	0.00	-2.35	19.20	195.38**	32.41**
43	GAM- 141 x GAM- 165	6.40	6.67	14.29**	0.86	2.38	1.18	11.80	-2.48	-18.62**
44	GAM- 141 x GAM- 173	5.90	-1.67	5.36	0.87	3.57	2.35	14.00	15.70**	-3.45
45	GAM- 165 x GAM- 173	5.90	3.51	5.36	0.87	4.82*	2.35	13.90	6.92*	-4.14
	S.E. (d) ±		0.28	0.28		0.02	0.02		0.45	0.45
	CD 0.05		0.56	0.56		0.04	0.04		0.90	0.90
	CD 0.01		0.74	0.74		0.05	0.05		1.19	1.19

*, ** Significant at 5 % and 1 % levels, respectively.

Table 3. Contd…..

Sr. No	Crosses	Fibre uniformity ratio			Oil content (%)		
		Mean	BP	SC	Mean	BP	SC
1	GShv- 273/07 x GBhv -282	51.00	0.00	4.08	16.58	2.16	-2.93*
2	GShv- 273/07 x GBhv- 283	53.00	3.92	8.16**	16.58	-3.27*	-2.93*
3	GShv- 273/07 x GBhv- 286	50.00	-1.96	2.04	15.44	-7.82**	-9.60**
4	GShv- 273/07 x GBhv- 287	53.00	3.92	8.16**	16.28	-2.05	-4.68**
5	GShv- 273/07 x 824	50.00	-1.96	2.04	15.93	-5.63**	-6.73**
6	GShv- 273/07 x G 27	51.00	-8.93**	4.08	16.40	-1.80	-3.98**
7	GShv- 273/07 x GAM- 141	48.00	-5.88*	-2.04	16.97	-2.92*	-0.64
8	GShv- 273/07 x GAM- 165	51.00	0.00	4.08	16.37	-7.88**	-4.16**
9	GShv- 273/07 x GAM- 173	49.00	-3.92	0.00	16.17	-4.26**	-5.33**
10	GBhv- 282 x GBhv- 283	50.00	-1.96	2.04	16.42	-4.20**	-3.86**
11	GBhv- 282 x GBhv- 286	51.00	0.00	4.08	16.84	0.54	-1.41
12	GBhv- 282 x GBhv- 287	48.00	-5.88*	-2.04	15.92	-4.21**	-6.79**
13	GBhv- 282 x 824	50.00	-1.96	2.04	16.36	-3.08*	-4.22**
14	GBhv- 282 x G 27	49.00	-12.50**	0.00	17.29	3.53*	1.23
15	GBhv- 282 x GAM- 141	51.00	0.00	4.08	16.80	-3.89**	-1.64
16	GBhv- 282 x GAM- 165	49.00	-3.92	0.00	16.30	-8.27**	-4.57**
17	GBhv- 282 x GAM- 173	50.00	-1.96	2.04	17.52	3.73**	2.58
18	GBhv- 283 x GBhv- 286	50.00	2.04	2.04	17.05	-0.53	-0.18
19	GBhv- 283 x GBhv- 287	48.00	-2.04	-2.04	17.05	-0.53	-0.18
20	GBhv- 283 x 824	49.00	0.00	0.00	15.99	-6.71**	-6.38**
21	GBhv- 283 x G 27	52.00	-7.14**	6.12*	16.49	-3.79**	-3.45*
22	GBhv- 283 x GAM- 141	49.00	0.00	0.00	16.69	-4.52**	-2.28
23	GBhv- 283 x GAM- 165	50.00	2.04	2.04	17.12	-3.66**	0.23
24	GBhv- 283 x GAM- 173	48.00	-2.04	-2.04	17.29	0.88	1.23
25	GBhv- 286 x GBhv- 287	50.00	2.04	2.04	16.74	-0.06	-1.99
26	GBhv- 286 x 824	46.00	-6.12*	-6.12*	16.84	-0.24	-1.41
27	GBhv- 286 x G 27	52.00	-7.14**	6.12*	17.22	2.81	0.82
28	GBhv- 286 x GAM- 141	48.00	-2.04	-2.04	17.39	-0.51	1.81
29	GBhv- 286 x GAM- 165	49.00	0.00	0.00	16.11	-9.34**	-5.68**
30	GBhv- 286 x GAM- 173	49.00	0.00	0.00	16.63	-1.54	-2.63
31	GBhv- 287 x 824	51.00	6.25*	4.08	16.45	-2.55	-3.69**
32	GBhv- 287 x G 27	49.00	-12.50**	0.00	17.47	4.61**	2.28
33	GBhv- 287 x GAM- 141	48.00	-2.04	-2.04	16.76	-4.12**	-1.87
34	GBhv- 287 x GAM- 165	50.00	4.17	2.04	17.18	-3.32*	0.59
35	GBhv- 287 x GAM- 173	49.00	2.08	0.00	17.52	3.73**	2.58
36	824 x G 27	44.00	-21.43**	-10.20**	16.79	-0.53	-1.70
37	824 x GAM- 141	51.00	4.08	4.08	16.93	-3.15*	-0.88
38	824 x GAM- 165	51.00	15.91**	4.08	17.56	-1.18	2.81*
39	824 x GAM- 173	47.00	-2.08	-4.08	17.86	5.74**	4.57**
40	G 27 x GAM- 141	48.00	-14.29**	-2.04	17.25	-1.32	1.00
41	G 27 x GAM- 165	48.00	-14.29**	-2.04	16.86	-5.12**	-1.29
42	G 27 x GAM- 173	50.00	-10.71**	2.04	17.34	2.66	1.52
43	GAM- 141 x GAM- 165	47.00	-4.08	-4.08	16.63	-6.42**	-2.63
44	GAM- 141 x GAM- 173	46.00	-6.12*	-6.12*	17.58	0.57	2.93*
45	GAM- 165 x GAM- 173	47.00	-2.08	-4.08	17.14	-3.55**	0.35
	S.E. (d) ±		1.48	1.48		0.24	0.24
	CD 0.05		2.93	2.93		0.47	0.47
	CD 0.01		3.87	3.87		0.62	0.62

*, ** Significant at 5 % and 1 % levels, respectively.

(Standard Heterosis).

Estimates of heterosis

Expression of heterosis for yield and yield attributing characters: The seed cotton yield of diploid cotton is generally contributed by numbers of boll and boll weight in intraspecific hybrids and numbers of boll in interspecific hybrids (Singh *et al.*, 1975 and Bhatade, 1983).

Mean range for no. of bolls/ plant varied from 22.41 (GBhv- 283 x GAM- 165) to 97.40 (GBhv- 282 x G 27). Among 45 hybrids, 22 hybrids exhibited significant positive heterotic effect over their respective better parent. The cross GBhv- 287 x 824 was associated with maximum heterobeltiosis (141.22 %). Five hybrids demonstrated positive siginificant standard heterosis for no. of bolls/ plant. According to standard heterosis, promising cross combinations for no. of bolls/ plant were GBhv- 287 x 824 (41.59 %), GBhv-282 x GAM- 173 (27.54 %) and GBhv- 286 x G 27 (21.05 %). High heterotic expression for this particular trait would be useful for obtaining higher seed cotton yield. The significant heterosis for no. of bolls/plant (*Gossypium spp.*) which resulted in high yield was also recorded by Patil *et al.* (2009), Jyotiba *et al.* (2010), Patel *et al.* (2010), Sekhar babu *et al.* (2011) and Ashokkumar and Ravikesavan (2013).

In case of boll weight, mean performance of crosses showed that the cross GBhv- 283 x GAM- 165 (2.94 g) recorded the highest mean performance. The hybrid GShv- 273/07 x GBhv- 287 depicted the highest significant positive heterobeltiosis of 20.60 per cent. Fourteen hybrids noticed with positive significant standard heterosis, the highest value was observed for the cross GBhv- 283 x GAM- 165 (44.83 %). Other researchers, Patil *et al.* (2009), Jyotiba *et al.* (2010), Patel *et al.* (2010), Sekhar babu *et al.* (2011) and Tyagi *et al.* (2014) also found significant heterosis for *Gossypium spp.* boll weight.

The range of mean value among cross combination for seed cotton yield/ plant varied from 51.16 g (947.40 kg/ ha) to 223.15 g (4132.40 kg/ ha). The extent of heterosis for seed cotton yield/ plant ranged from -43.77 to 155.60 per cent and -61.63 to 67.36 per cent over BP and SC, respectively. Among 45 hybrids, 17 showed significant positive heterosis over better parent while five hybrids indicated significant positive standard heterosis. Cross combinations, GBhv- 282 x G 27 (67.36 %), GBhv- 287 x 824 (58.14 %), GBhv- 282 x GAM- 173 (35.00 %), GBhv- 286 x G 27 (20.50 %) and GBhv- 283 x 824 (18.75 %) were the top ranking heterotic crosses showed positive significant economic heterosis for seed cotton yield/ plant. Patil *et al.* (2009), Jyotiba *et al.* (2010), Patel *et al.* (2010), Saravanan and Koodalingam *et al.* (2011), Sekhar babu *et al.* (2011) and Ashokkumar and Ravikesavan (2013) also investigated significant heterosis for seed cotton yield/ plant.

Expression of heterosis for Fibre quality traits: In recent years, more emphasis is laid on quality traits from seed cotton yield in diploid cotton. For 2.5 % span length, 13 and 27 hybrids exhibited significant heterosis in desired direction over better parent and standard check repectively. Among them the cross GBhv-286 x GBhv- 287 (17.58 %) was superior for heterobeltiosis and cross GBhv-286 x 824 (33.33 %) recorded maximum standard heterosis. The earlier researchers, Jyotiba *et al.* (2010), Sekhar babu *et al.* (2011), Rajamani *et al.* (2009) and Patil *et al.* (2012) also suggested improvement of fibre quality through heterosis as they recorded significant heterosis for different fibre quality traits in *Gossypium spp.*.

As regards to the fibre strength, the heterobeltiosis ranged from -35.10 to 29.81 and cross 824 x GAM-141 (29.81 %) reported the maximum heterobeltiosis. Cross combinations GBhv-283 x 824 (34.64 %), GBhv -286 x 824 (32.40 %), GShv-273/07 x 824 and GAM-141 x GAM-173 (30.91 %) were on the top position for standard heterosis. The results corroborated the findings of Jyotiba *et al.* (2010) and Sekhar babu *et al.* (2011) for heterosis for the fibre strength trait in *Gossypium spp.*

For micronaire value, hybrid GBhv-286 x GAM-165 (-12.24 %) observed maximum heterobeltiosis while hybrid 824 x G 27 (-37.70 %) recorded maximum standard heterosis in *desi*red direction. Majority of the cross combinations showed negative economic heterotic effect and decrease in micronaire value are an indication of fibre fineness. Kumar *et al.* (2003), Rajamani *et al.* (2009), Jyotiba *et al.* (2010), Sekhar babu *et al.* (2011) and Tuteja and Agrawal *et al.* (2013) but in contradiction of Patil *et al.* (2012) also reported the heterosis for fibre fineness in other cotton genotypes

For fibre elongation percentage, the hybrids manifested significant heterobeltiosis, varied from -14.52 in 824 x GAM- 141 and 824 x GAM- 165 to 34.69 in GBhv- 282 x G 27 over better parental value in positive direction. Heterobeltiosis for fibre elongation percentage showed that the crosses GBhv-282 x G 27 (34.69 %), GBhv-286 x G 27 (23.53 %) and GBhv-283 x GBhv-287 (18.52 %) were on top positions. In comparison with standard check, 18 hybrids exhibited positive standard heterosis and superior cross combinations over standard check were GBhv- 282 x G- 27 (17.86 %) and GShv- 273/07 x GAM- 165, GBhv- 283 x 824 and GBhv- 287 x 824 (16.07 %).

Fibre maturity is an important criterion for judging the suitability of lint for spinning. Formation of neps in the cotton while spinning is mainly due to the presence of immature fibres which accounts for breakage of yarn. Heterobeltiosis for fibre maturity coefficient showed that only two hybrids *viz.*, GBhv-282 x G 27 (7.32 %) and GBhv-283 x G 27 (6.10 %) had significantly positive heterobeltiosis. None of the hybrids showed significantly positive standard heterosis. For short fibre index (SFI), hybrid GBhv-286 x GBhv-287 (-53.10 %) depicted maximum standard heterosis in *desi*red direction. The occurance of heterosis for fibre maturity in *Gossypium spp.* was also reported by Kumar *et al.* (2003) and Patel *et al.* (2007a). For fibre uniformity ratio, only 2 and 4 hybrids reported positive heterosis over better parent and check respectively. Hybrids 824 x GAM-165 (15.91 %) and GBhv-287 x 824 (6.25 %) were observed highly significant for heterobeltiosis. Hybrids GShv-273/07 x GBhv-283 and GShv-273/07 x GBhv-287 (8.16 %) were observed superior over check.

In case of oil content, among 45 hybrids only 5 and 3 hybrids exhibited the significant positive heterobeltiosis and standard heterosis respectively. In case of heterosis over better parent only five hybrids *viz.* 824 x GAM- 173 (5.74 %), GBhv- 287 x G 27 (4.61 %), GBhv- 282 x GAM- 173, GBhv- 287 x GAM- 173 (3.73 %) and GBhv- 282 x G 27 (3.53 %). The range of standard heterosis varied from -9.60 % (GShv-273/07 x GBhv- 286) to 4.57 % (827 x GAM-173). Also, these results are in accordance with results of Ashokkumar and Ravikesavan (2013) in *Gossypium hirsutum* genotypes. Magnitude of heterosis for seed oil content was higher in intra and interspecific arboreum hybrids in comparison to intra herbaceaum hybrids.

Conclusion

Very less number of hybrids in diploid cotton are released in India, and hence the improvement in our native diploid cotton species which are sturdy in nature and provide better resistance against biotic and abiotic stress becomes imperative. Our study was aimed to exploit heterosis in *desi* cotton (*Gossypium arboreum* L. and *G. herbaceum* L) hybrids for yield, fibre quality as well as oil content. In the present experiment crosses GBhv- 282 x G 27, GBhv- 287 x 824, GBhv- 282 x GAM- 173, GBhv- 286 x G 27 and GBhv - 283 x 824 appeared to more promising for seed cotton yield/ plant. Boll number was the major yield contributing trait. Fibre quality as well as oil quality was higher in intra and interspecific arboreum hybrids.

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