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Research Paper

ASSESSMENT OF HETEROSIS IN Bt COTTON (*Gossypium hirsutum* L.) HYBRID UNDER CONTRASTING PLANTING DENSITIES

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Abstract

Genetic investigation was taken up to assess the extent of heterosis in Bt cotton test crosses generated out of Line X Tester mating design involving parents with diverse plant architecture under contrasting planting densities. Randomized complete block design (RCBD) with three replicates was adopted to assess the performance of hybrids under conventional density (CDP) and high density planting (HDP) in the year 2015-16. Pooled analysis of variance (ANOVA) revealed significant variation among the genotypes which includes nine parents and 20 test crosses for phenological, yield and yield attributing traits. Significant differances between parents vs. test crosses indicated the presence of high magnitude of heterosis all the traits under the study. Substantially magnitude of mid parent (MP) and better parent (BP) heterosis exhibited by majority of crosses due to the involvement of genetically diverse parents with high combining ability. Test cross combination SC1104X1205 has been identified as most heterotic combination for economic yield and also for other essential component traits for commercial exploitation under both the planting densities. Consistancy in the performace of the shortlisted test cross under CDP and HDP plant density could be attributed to the versatility of plant architecture by virtue of having extremely contrasting line (tester) and tester (male) with bushy cum indeterminate and open cum determinate plant growth habit respectively.

Key words: *Line X Tester, Bt, heterosis, combining ability, plant architecture.*

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is an important fibre crop and plays a vital role as a cash crop in Indian economy. Development of new variety with high yield and fibre quality is the primary objective of all cotton breeders. Heterosis breeding is an important genetic tool to facilitate yield enhancement and help to enrich many other desirable quantitative and qualitative traits in crops. Heterosis or hybrid vigour is the increment in performance of a hybrid (F1 generation) in relation to parental average and can assume positive or negative values. Historically in India, an extent of 7 to 50 % yield heterosis has been reported from various studies with intra hirsutum tetraploid cotton hybrids. First intra hirsutum hybrid H4 (G-67 X American nectariless) was developed by C.T. Patel in 1971 and by early 90´s hybrid cultivar become popular and spread across the country with significant acreages. With the introduction of first and second generation transgenic insect resistance technologies in 2002 and 2006 respectively gave further fillip to the wide spread adoption of Bt cotton hybrids (11.6 million hacters in 2015). This has resulted in three folds increment in the productivity levels in short span of time (15).

As of 2015-16, India stood first with area 11.8 million hacters (33.23% of world area), second in production and second in production with 34.6 million bales (22.67% of world production. Interms of productivity levels, India has registered 495 kg lint/ha compared to average world average of 705 kg lint/ha (1) during the same time indicating wide gap and huge scope for genetic improvement and optimization of crop management practices. High density planting with compact determinate plant architecture is considered as one of the most important factors driving the high productivity levels in countrys such as Brazil (1476 kg lint /ha), Turkey (1433 kg lint/ha) and China (1352 kg lint/ha). On contrary, majority of the hybrids commercialized so far in India are with indeterminate and semi determinate type readily adapting to relatively low plant densities. As per Aphalo *et. al.* (2), the classical crop response to increased plant density and crowding is expressed in a typical optimum curve. Population yield increases while yield per plant decreases to a given plant density of maximum yield, after which the continued reduction in yield per plant with the increased density begin to reduce population yield. Thus, maximum yield is achieved with a population of undersized stressed plants shape. Plants in a dense population try to avoid shading by investing energy and resources in modifying growth and shape. By considering above hypothesis the present study was commissioned to assess the extent of heterosis under high density planting (HDP) vis-à-vis conventional density planting (CDP) with Bt test hybrids involving parental lines with diverse plant architecture and growth pattern.

MATERIAL AND METHODS

Nine parental lines with varying plant architecture (Table. 1) were selected and sourced from M/S Sri Satya Agri Biotech Pvt. Ltd. Guntur germplasm. Twenty test hybrids were evolved in Line x Tester mating design proposed by Kempthrone (5) by considering five Bt transgenic lines as females and non Bt lines as males through conventional hand emasculation and pollination. To estimate standard check heterosis, widely cultivated Bt cotton hybrid Mallika® with semi open plant architecture was included in the study.

Field experiment was conducted in the year 2015-2016 at the research farm of department of Botany, Pratishthan Mahavidyalaya, Paithan, Aurangabad with deep black cotton soil, situated at latitude 19°44' N, longitude 73°59' E. The study consisted of 30 entries such as 20 test hybrids, nine corresponding parental lines and one standard commercial check hybrid. Randomized block design involving three replicates was adopted to evaluate the test material, wherein each plot consisted of two rows of six meter length.. To assess response of test hybrids with contrasting plant densities, paired trial was conducted with same design in higher density planting (HDP) and conventional density planting (CDP). Based on the previous studies, planting density of 37037 plants/ha @ 90X30 cm spacing with supplmentary sprays of chloro mepiquat chloride (Lihocin® 0.2ml/litre of water) @ 60DAS + 90DAS and 18518 plants/ha @ 90x60cm spacing was considered as HDP and CDP respectively. The crop was raised under protected irrigation system with standard agronomic practices of the region.

Data on key traits influencing directly or indirectly on final yield such as days to 50% flowering, days to first boll opening, plant height (cm), number of monopodial branches, number of sympodial branches, number of bolls per plant, boll weight (g) has been collected. Along with this seed cotton yield per hectare which is considered as economic yield was worked out by extrapolating the gross plot yield (kg) and subjected for the analysis. Analysis of variance for line x tester was done as suggested by Singh and Chaudhary (10). The per cent heterosis over mid parent, better parent and standard heterosis were estimated as per Turner (4) and Hayes *et. al* (13).

RESULTS AND DISCUSSION

Analysis of variance (ANOVA):

The pooled analysis of variance involving conventional density planting (CDP) and high density planting found to be highly significant (Table.2) for genotypes (parents and their F1s) for days to 50% flowering, days to first boll opening, plant height (cm), number of monopodial branches, number of sympodial branches, number of bolls per plant, boll weight (g) and seed cotton yield (kg/ha). This indicated the presence of substantial genetic variability among genotypes for all the characters studied. Significant variation was observed for genotype and planting densities interaction for all the traits owing to contrasting differances in planting densities, same kind of effects was observed by studies of Nidagundi *et. al.* (8) involving contrasting environments. Hence heterosis was estimated for CDP and HDP separately to find the varying response of the test crosses involving varying plant architecture. The mean squares due to hybrids (test crosses) as well as parents vs. hybrids (test crosses) comparison for all the traits were found highly significant, indicating manifestation of substantial heterosis by test crosses in the present investigation, which is in conformity with the previous studies of Kencharaddi *et.al*. (6) and Solanki *et.al* (11).

Average heterosis:

Average relative heterosis for test crosses was worked out (Table.3) for phenological traits viz., days to 50% flowering, days to first boll opening, plant height (cm), number of monopodial branches and number of sympodial branches which are influencing the final yield by indirectly impacting the plant architecture and maturity. As well as yield componensts traits such as number of bolls per plant and boll weight which are directly affecting final economical yield (seed cotton yield expressed as kilo grams per hectare). The results indicated that the phenomenon of heterosis was of a general occurrence for almost all the characters under study. However, the magnitude of heterosis varied with traits, which corroborates with the findings of Monicashree *et.al* (7).

Heterosis for economic yield:

Cotton bolls with burst open fibers and seeds is considered as economic yield and referred as seed cotton yield or kapas yield, expressed as kilo grams per hectare of land. Estimation of heterotic effects is necessary to identify the new cross combinations that are suitable for commercial exploitation as F1 hybrid cultivar. Hence, heterosis over mid parent (MP), better parent (BP) and standard check (SC) was worked out for the test crosses under the study (Table.4). Majority of crosses recorded significant magnitude of mid parent (MP) and better parent (BP) heterosis under both planting densities owing to the involvement of genetically diverse parents with high general combining ability. Similar kind of phenomenon was observed by Yuksel *et.al* (13). For the practical purpose standard check heterosis (SC) heterosis is considered as criterion to select the potential test crosses for commercial exploitation. By considering Mallika BG II hybrid with semi open plant architecture as check, the standard heterosis was found to be in the range of -17.50 to 12.26% and -28.28% to 19.79 under conventional and high density plantings respectively. Among the test crosses SC1104X1205 and SC1104X1206 consistantly exhibited higly significant heterosis under contrasting planting densities. This could be attributed to the versatility of hybrid plant architecture by virtue of having extremely contrasting parents with bushy and open plant type as well as indeterminate to determinate growth pattern to adapt to crowding stress. Wells *et. al.*(14) demonstrated that F1 hybrid plants have a relatively high biomass, intercept more light and assimilate more than their parents. This relative advantage is diminished as plants are crowded towards mutual shading. Hence it is very much essential have optimum plant canopy for efficient photosynthesis to harness the heterosis for yield under varying plant densities.

Heterotic combinations:

Heterosis % in desirable direction for top three test crosses with potential commercial value for phenological, yield and yield component traits under contrasting plant densities were shortlisted (Table. 5). The early maturing hybrids are desirable to avoid the terminal stress during water limiting condition and amenable double cropping system, hence heterosis in negative direction was considered to be desirable for days to 50% flowering and days to first boll opening under both the planting densities. Significant negative heterosis in the present investigation for these maturity traits in agreement with the findings of Sawarkar *et. al* (9). In order to achive compact plant architecture with minimum plant to plant competition under higher density planting (HDP) for plant height and number of monopodial branches heterosis in negative direction was also considered as desirable. For rest of the traits in the both the planting densities heterosis in positive direction was considered as desirable and shortlisted test crosses were found to be having significant magnitude of heterosis. By taking into consideration of key traits including economical yield under both the planting densities, SC1104X1205 found to be most heterotic and exhibited significant superiority over commercial check hybrid.

CONCLUSION

The present study unveiled the possibility of evolving highly heterotic combinations with versatile plant architecture to suit the contrasting planting density by choosing the parents with diverse plant type and growth pattern. Versatility in the plant architecture is essential to exploit higher three dimensional space with lesser horizontal growth to improve the seed cotton yield. Test cross, SC1104X1205 has been identified as most heterotic combination for economic yield and other essential traits under both the planting densities and proposed for commercial explotation through large scale trials in varied agro climatic regions.

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Table 1: Salient features of parental lines used for the development of test crosses.

Sl.No.	Line/Tester	Name	Bt/Non Bt	Plant type	Growth pattern	Boll size
1	Line	SC1104	Bt	Bushy	Indeterminate (ID)	Big
2	Line	SC1112	Bt	Open	Semi determinate (SD)	Medium
3	Line	SC1117	Bt	Semi open	Semi determinate (SD)	Medium
4	Line	SC1132	Bt	Semi open	Semi determinate (SD)	Big
5	Line	SC1134	Bt	Open	Determinate (D)	Small
6	Tester	SC1115	Non Bt	Bushy	Indeterminate (ID)	Small
7	Tester	SC1133	Non Bt	Semi open	Semi determinate (SD)	Big
8	Tester	SC1205	Non Bt	Open	Determinate (D)	Medium
9	Tester	SC1206	Non Bt	Open	Extremely Determinate (ED)	Small

Table 2: Pooled analysis of variances for phenological, commercial yield and yield component traits.

Source	df	Mean sum of squares							
		DFF	DFBO	PH	NMB	NSB	NBP	BW	SCY
Replications	2	1.3	0.9	11	0.01	0.2	5	0.02	6035
Planting densities	1	18.7**	2.1*	62890**	26.26**	228.5**	4035**	8.35**	88913115**
Genotypes	28	69.0**	151.2**	253**	3.10**	3.1**	280**	1.16**	1156646**
Genotypes X Planting densities	28	2.3*	1.2*	139**	0.16*	2.1**	37**	0.08**	350072**
Parents	8	146.7**	198.8**	457**	5.97**	1.6**	123**	2.73**	452885**
Crosses	19	36.6**	136.9**	180**	3.38**	3.4**	215**	1.23**	405354**
Crosses vs parents	1	62.0**	46.7**	52*	0.14*	8.6**	2793**	0.85**	21061290**
Error	112	0.9	0.4	2	0.02	0.1	2	0.01	6743

** Significant (5 % level), ** Significant (1 % level)*

df: Degrees of freedom, DFF: Days to 50% flowering, DFBO: Days to first boll opening, PH: Plant height (cm), NMB: Number of monopodial branches, NSB: Number of sympodial branches, NBP: Number of bolls per plant, BW: Boll weight (g) and SCY: Seed cotton yield (Kg/ha)

Table 3: Means values of parents vis-vis crosses and average heterosis % for phenological, yield and yield component traits.

Planting densities	Mean and heterosis %	DFF	DFBO	PH	NMB	NSB	NBP	BW	SCY
CDP	Parents mean	60.0	122.3	151.5	2.19	16.0	39.2	5.02	2135
	Crosses mean	62.0	121.1	154.0	2.12	17.2	49.0	5.14	2640
	Average heterosis %	2.7	-1.0	1.5	-3.46	7.1	24.9	2.50	24
HDP	Parents mean	61.1	122.0	116.1	1.27	14.6	31.0	5.42	3224
	Crosses mean	62.0	121	114.5	1.41	14.5	38.6	5.60	4223
	Average heterosis %	1.6	-0.9	-1.3	11.05	-1.2	24.5	3.27	31
Pooled	Parents mean	60.5	122.1	133.8	1.73	15.3	35.1	5.22	2679
	Crosses mean	61.8	121.0	134.1	1.76	15.8	43.7	5.37	3431
	Average heterosis %	2.1	-1.0	0.3	1.85	3.1	24.7	2.90	28

Table 4: Mean (kg/ha), mid parent (MP), better parent (BP) and standard check (SC) heterosis % for seed cotton yield.

Crosses	CDP				HDP			
	Mean	MP	BP	SC	Mean	MP	BP	SC
SC1104 X 1115	2770	21.05**	13.69**	0.00	3940	14.97**	7.98**	-2.39
SC1104 X 1133	2438	7.57**	1.94	-12.04**	3825	12.32**	6.07*	-5.24*
SC1104 X 1205	3108	46.58**	47.87**	12.26**	4835	50.41**	49.97**	19.79**
SC1104 X 1206	3095	62.30**	84.71**	11.82**	4499	54.72**	40.36**	11.45**
SC1112 X 1115	2738	22.85**	12.42**	-1.11	4266	27.68**	16.93**	5.70**
SC1112 X 1133	2871	30.16**	20.16**	3.68*	4168	25.55**	15.59**	3.27
SC1112 X 1205	2487	20.66**	18.36**	-10.14**	4666	49.11**	44.73**	15.60**
SC1112 X 1206	2484	34.39**	48.25**	-10.26**	4342	53.84**	43.10**	7.57**
SC1117 X 1115	2746	18.67**	12.80**	-0.78	4140	19.32**	13.46**	2.56
SC1117 X 1133	3056	33.33**	27.91**	10.37**	3511	1.82	-2.63	-13.02**
SC1117 X 1205	2637	22.70**	20.11**	-4.79*	4433	36.09**	34.72**	9.82**
SC1117 X 1206	2563	32.38**	16.74**	-7.47**	4401	49.17**	33.76**	9.03**
SC1132 X 1115	2545	8.14**	4.44*	-8.14**	3890	10.41**	6.62**	-3.62
SC1132 X 1133	2436	4.57*	1.94	-12.04**	2895	-17.35**	-19.73**	-28.28**
SC1132 X 1205	2625	20.06**	15.65**	-5.24**	4395	32.72**	29.31**	8.88**
SC1132 X 1206	2609	32.39**	15.10**	-5.69**	4509	50.47**	32.67**	11.61**

SC1134 X 1115	2508	13.01**	2.92	-9.48**	4062	22.34**	11.32**	0.63
SC1134 X 1133	2455	11.81**	2.71	-11.37**	4343	31.56**	20.45**	7.61**
SC1134 X 1205	2343	14.22**	11.45**	-15.38**	4767	53.27**	47.87**	18.11**
SC1134 X 1206	2284	24.27**	14.20**	-17.50**	4570	62.99**	52.47**	13.21**
Range	2436 to 3095	4.57 to 62.30	1.94 to 84.71	-17.50 to 12.26	2895 to 4835	-17.35 to 62.99	-19.73 to 52.47	-28.28 to 19.79

CDP: Conventional density planting, HDP: High density planting

Table 5. Heterosis % in desirable direction for top three crosses with potential commercial value for phenological, yield and yield component traits under contrasting plant densities

Traits	CDP				HDP			
	Crosses	MP	BP	SC	Crosses	MP	BP	SC
DFF	SC1104 X 1206	-5.48**	-15.46**	-15.90**	SC1134 X 1206	6.46**	0.00	-10.82**
	SC1134 X 1206	7.12**	1.76	-11.28**	SC1104 X 1206	-0.86	-12.18**	-10.82
	SC1132 X 1206	4.73**	-4.32**	-9.23**	SC1132 X 1206	2.62**	-7.85**	-9.28**
DFBO	SC1134 X 1206	-7.63**	-11.33**	-15.53**	SC1134 X 1206	-7.05**	-11.51**	-14.32**
	SC1104 X 1206	-5.72**	-11.98**	-11.05**	SC1104 X 1206	-6.03**	-12.53**	-11.14**
	SC1134 X 1205	-1.83**	-3.87**	-8.42**	SC1134 X 1205	-1.83**	-4.66**	-7.69**
PH	SC1134 X 1206	6.15**	4.56**	7.26**	SC1132 X 1206	-12.42**	-21.18**	-19.28**
	SC1117 X 1206	2.83**	-0.30	5.64**	SC1112 X 1133	1.79	0.32	-16.06**
	SC1132 X 1205	8.14**	4.58**	5.26**	SC1132 X 1205	-7.37	-16.88**	-14.30**
NMB	SC1104 X 1133	-9.87**	-12.50**	26.51**	SC1134 X 1206	-100.00**	-100.00**	-100.00**
	SC1117 X 1133	0.00	-13.27**	18.07**	SC1132 X 1206	-33.33**	-66.67**	-70.59**
	SC1132 X 1133	8.29**	-13.27**	18.07**	SC1112 X 1206	61.54**	-19.23	-58.52**
NSB	SC1134 X 1206	24.33**	17.17**	15.31**	SC1132 X 1206	7.66**	0.00	7.06**
	SC1134 X 1205	18.62**	12.22**	9.54**	SC1104 X 1133	8.61**	6.05**	4.42**
	SC1134 X 1133	16.63**	10.66**	7.36**	SC1117 X 1133	7.46**	4.93**	3.31**
NBP	SC1134 X 1205	40.00**	35.82**	26.39**	SC1134 X 1205	40.09**	35.90**	35.90**
	SC1104 X 1205	34.65**	33.59**	18.75**	SC1134 X 1206	46.08**	27.35**	27.35**
	SC1134 X 1206	40.09**	18.66**	10.42**	SC1104 X 1205	43.01**	25.45**	17.95**
BW	SC1132 X 1115	6.42**	-0.97*	7.92**	SC1104 X 1115	13.27**	8.92**	6.67**
	SC1132 X 1205	7.55**	-1.03*	7.86**	SC1132 X 1205	7.39**	-2.34	4.99**
	SC1104 X 1115	7.82**	4.97**	3.99**	SC1104 X 1205	12.74**	7.04**	4.82*
SCY	SC1104 X 1205	46.58**	47.87**	12.26**	SC1104 X 1205	50.41**	49.97**	19.79**
	SC1104 X 1206	62.30**	84.71**	11.82**	SC1134 X 1205	53.27**	47.87**	18.11**
	SC1117 X 1133	33.33**	27.91**	10.37**	SC1112 X 1205	49.11**	44.73**	15.60**

MP: Mid parent, BP: Better parent, SC: Standard check
CDP: Conventional density planting, HDP: High density planting
DFF: Days to 50% flowering, DFBO: Days to first boll opening, PH: Plant height (cm), NMB: Number of monopodial branches, NSB: Number of sympodial branches, NBP: Number of bolls per plant, BW: Boll weight (g) and SCY: Seed cotton yield (Kg/ha)

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