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Estimation of Standard Heterosis in Multiple Cross Derivatives of Upland Cotton (*Gossypium hirsutum* L.) for Yield, Plant Type and Fibre Quality

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ABSTRACT

A study was conducted to identify hybrids that possess compact plant characteristics during Kharif, 2014 by using 42 F_1 hybrids obtained by crossing six lines and seven testers in a Line x Tester mating design. All the 13 parents were selected by evaluating 52 stable multiple cross derivatives that possessed compact plant characteristics through combined use of metroglyph and SSR marker analysis. All the 42 hybrids along with their 13 parents and two checks (Suraj and NCS 954 Bt) were evaluated at three different locations viz., Aswaraopet, Warangal and Adilabad and the data was recorded on eighteen characters to select the hybrids having compact plant type traits like early flowering, short stature, zero or low number of monopodial branches, high number of short sympodia, average to high number of bolls per plant, yield per plant, optimum leaf area, high harvest index, boll weight, 100-seed weight and ginning outturn besides having desirable quality parameters that are amenable for High Density Planting System (HDPS). The results of the present study revealed that, the cross combinations MC 17-6 x MC 19-2, MC 23-2 x MC 17-2, MC 17-6 x MC 17-1, MC 9-1 x NH 630 and MC 4-3 x MC 3-2 were found to exhibit seed cotton yield per plant on par with both the checks along with short compact plant type characteristics besides showing significant standard heterosis for quality traits like ginning outturn, 2.5% span length, uniformity ratio and bundle strength. Hence, these hybrids could be further evaluated in multilocation testing for commercial release.

Key words: *Gossypium hirsutum L., Multiple Cross Derivatives, Compact plant types, Line x Tester analysis, Heterosis*

INTRODUCTION

Cotton is the most important fibre crop of India, providing raw material to the textile industry in the country. Despite stiff competition from synthetic fibres, cotton has its reputation as “King of the Fibres” due to its inherent properties.

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When compared to the leading countries of cotton cultivation, India is still not making striding increase in production even though nearly 45% of the cotton area is under hybrid varieties. Cotton hybrids that are presently under cultivation had inherent defect associated with the large bushy plant type[20]. World over during last three decades, efforts were made to develop compact plant types suitable for increased plant densities particularly in case of Brazil which had witnessed higher productivity (1522 kg/ha) due to use of compact sympodial varieties suited for high density planting[7]. This system enables higher number of plants at 1.5 to 2.5 lakhs / ha. However, in India the recommended plant density for cotton seldom exceeded 55000 plants/ha[22]. In recent years' cotton farmers in India are compelled to adopt High Density Planting System (HDPS) to reap higher yields even with Bt cotton hybrids, which augments cost of cultivation due to use of higher seed rate. The productivity of cotton can be enhanced by developing varieties suitable for HDPS with compact plant types when compared to the presently used robust types. Therefore, it is a priority area of research to develop open pollinated varieties/hybrids of cotton having compact plant characteristics suitable for high plant density to increase the productivity level particularly for the regions where the cotton is cultivated under rainfed conditions in shallow soils.

Heterosis is the superiority of the hybrid over the mid or better parent or over standard check and is the result of allelic and non-allelic interactions of genes under influence of particular environment. For commercial exploitation of heterosis, the magnitude of heterosis provides a basis for genetic diversity and is a guide to the choice of desirable parents for developing superior F_1 hybrids, so as to exploit hybrid vigour or building the better gene pool after growing in subsequent generations. The objective of the present study was to identify cross combinations that possess compact plant type characters *viz.*, short plant stature, earliness, low or zero number of monopodia, higher number of short sympodia, better boll number and boll weight, optimum leaf area, high harvest index along with desirable yield and better fibre quality that are amenable for high density planting system.

MATERIAL AND METHODS

The material for present study was developed by crossing six and seven multiple cross derivatives of cotton in a line x tester mating design during *Rabi*, 2013-14 at Agricultural College, Aswaraopet. Thirteen multiple cross derivatives that possessed compact plant type characters were selected by evaluating 52 multiple cross derivatives through metroglyph analysis[2] for nine morphological traits followed by SSR marker analysis (Institute of Biotechnology, Rajendranagar, Hyderabad) during *Kharif*, 2013. All the 42 cross combinations and 13 parents along with two checks Suraj and NCS 954 Bt were evaluated at three different locations *viz.*, Aswaraopet, Warangal and Adilabad in a randomized block design replicated thrice at a spacing of 60 cm x 30 cm during *Kharif*, 2014. All the recommended cultural practices were followed to raise a good crop. The data were recorded for 18 characters *viz.*, days to 50% flowering, days to first boll bursting, plant height (cm), number of monopodial branches, earliness index, number of sympodial branches, length of the sympodial branches (cm), leaf area (cm^2), number of bolls per plant, boll weight (g), harvest index, 100-seed weight (g), seed cotton yield per plant (g pl^{-1}) and ginning outturn (%). The fibre was analyzed for quality parameters *viz.*, 2.5% span length (mm), uniformity ratio, bundle strength (g 10^{-3} / texture) and micronaire value (µg $inch^{-1}$) at Regional Quality Evaluation Unit, CIRCOT, Lam Farm, Guntur, Andhra Pradesh. The standard heterosis was calculated over standard checks.

RESULTS AND DISCUSSION

The mean sum of squares for all the traits has been presented in Table 1. Perusal of the data revealed that the mean sum of squares due to genotypes were highly significant for all the traits, indicating that the material selected for the present investigation was quite appropriate for further genetic analysis due to the existence of considerable amount of variability. The magnitude of heterosis (pooled) exhibited by different crosses over Suraj and NCS Bt checks for all the traits is presented in Table 2.

Among the 42 cross combinations, the cross number 32 (MC 17-6 x MC 19-2) exhibited standard heterosis in desired direction for seed cotton yield (4.04) and short plant stature (-5.39) with compact plant type characteristics *viz.*, days to 50% flowering (-7.97*), days to first boll bursting (-0.35), length of sympodial branches (-19.52*), boll weight (5.83), harvest index (17.71**), 100-seed weight (3.63) along with quality parameters like ginning out turn (2.04), 2.5% span length (3.41*), uniformity ratio (1.57*) and bundle strength. (5.52*). The cross number 42 (MC 23-2 x MC 17-2) had shown better standard heterosis for traits like yield per plant(2.53), plant height (-6.24), earliness (-5.98), leaf area (2.73), number of bolls per plant (5.82), harvest index (8.33), number of sympodial branches (4.86), length of the sympodia (-15.21) and ginning out turn (0.75) in desired direction that attributes to the plant type suitable for HDPS while the cross number 31 (MC 17-6 x MC 17-1) exhibited positive standard heterosis for number of sympodia (35.82**), leaf area (17.23), number of bolls per plant (27.53**), harvest index (7.29), 100-seed weight (3.82), bundle strength (4.26), yield per plant (15.69) and negative standard heterosis for length of the sympodial branches (-13.18). The cross 15 (MC 9-1 x NH 630)showed standard heterosis in desirable direction for the characters *viz.*, plant height (-4.52), days to 50% flowering (-5.07), leaf area (12.50), number of bolls per plant (10.63), number of sympodial branches (0.45), length of the sympodia (-9.74) and bundle strength (0.92) whereas the standard heterosis for days to 50% flowering (-4.17), number of sympodia (11.39), number of bolls per plant (12.93), length of the sympodia (-7.79), bundle strength (7.44**) and ginning out turn (8.51) in desired direction which attributes for short compact plant types by the cross number 2 (MC 4-3 x MC 3-2) along with better seed cotton yield per plant (5.90). The cross number 29 (MC 17-6 x NH 630) was found to be better for earliness characters like days to 50% flowering (-9.96**), days to first boll bursting (-1.26). The positive standard heterosis in respect of seed cotton yield per plant, number of sympodial branches, number of bolls per plant, boll weight, ginning outturn, 2.5% span length, bundle strength and micronaire value was also reported by the earlier workers Karademir *et al*[8]., Patel *et al*[10]., Pole *et al*[13]., Bagade *et al*[3]., Ganapathy *et al*[6]., Rauf *et al*[17]., Ranganatha *et al*[16]., Sawarkar *et al*[18]., Patil *et al*[11]., Basal *et al*[4]., Patil *et al*[12]., Tuteja and Manish[21], Wankhade *et al*[23]., Rajamani *et al*[15]., Ali *et al*[1]., Shakeel *et al*[19]., Khan *et al*[9]., Wu *et al*[24]., and Basal *et al*[5]. The negative standard heterosis for days to 50% flowering, plant height and length of the sympodial branches was also reported by Preetha and Raveendran[14], Ranganatha *et al*[16].

The positive standard heterosis for quality traits *viz.*, ginning out turn (17.03**), bundle strength (10.99**) and micronaire value (7.50**) was exhibited by the cross number 23 (MC 16-3 x MC 3-2) whereas cross 32 (MC 17-6 x MC 19-2) was found to be a better cross for 2.5 % span length (3.41*), uniformity ratio (1.57*) and bundled strength (5.52*). These cross combinations can be exploited further for development of short compact plant types with good quality parameters.

In the present investigation, five crosses viz., MC 17-6 x MC 19-2, MC 23-2 x MC 17-2, MC 17-6 x MC 17-1, MC 9-1 x NH 630 and MC 4-3 x MC 3-2 were found to exhibit seed cotton yield per plant on par with both the checks used in the study in addition to possessing some compact short sympodial plant characteristics besides showing standard heterosis for quality traits. Hence, these hybrids could be exploited further for development of short compact plant types. Hence, these hybrids have to be tested in multilocation testing for commercial release.

Table 1: Pooled analysis of variance for yield and yield components in cotton

Source of variation	d.f.	Days to 50 % flowering	Days to first boll bursting	Plant height (cm)	Number of monopodial branches	Earliness index	Number of sympodial branches	Length of the sympodial branches (cm)	Leaf area (cm^2)	Number of bolls per plant
Replications	2	0.014	0.008	3.034	0.197	0.016	1.051	1.260	27775.340	1.291
Genotypes	170	35.329***	16.024***	138.176***	0.412***	67.580***	11.505***	12.391***	515033.200***	20.327***
Error	340	4.021	2.398	11.925	0.075	10.743	2.062	2.825	70249.290	3.464
Total	512	14.401	6.913	53.810	0.187	29.573	5.193	5.995	217765.500	9.054

Table 1 (cont.)

Source of variation	d.f.	Boll weight (g)	Harvest index (%)	100 – Seed weight (g)	Seed Cotton yield (g/plant)	Ginning out turn (%)	2.5 % span length (mm)	Uniformity ratio	Bundle strength (g 10^{-3}/texture)	Micronaire value (µg inch^{-1})
Replications	2	0.008	0.003	0.160	0.547	1.793	0.339	0.095	0.110	0.045
Genotypes	170	0.508***	0.005***	3.815***	263.963**	33.103***	3.896***	3.732**	5.545***	0.551***
Error	340	0.040	0.001	0.210	26.461	3.555	1.111	2.535	1.632	0.023
Total	512	0.196	0.002	1.407	105.218	13.359	2.033	2.923	2.925	0.198

* Significant at 5 % level, ** significant at 1 % level

Table 2: Superior crosses with *per se* performance and heterosis for seed cotton yield per plant, plant type and fibre quality over three environments (pooled)

Character	Superior cross combination	*Per se* performance	Heterosis over mid parent	Heterosis over better parent	Heterosis over Suraj	Heterosis over (NCS 954 Bt)
Days to 50 % flowering	MC 9-1 x NH 630	58	0.10	-2.05	-4.03	-5.07
	MC 23-2 X MC 3-2	55	-6.40*	-9.14**	-8.97**	-9.96**
	MC 17-6 x NH 630	55	-2.83	-2.93	-8.97**	-9.96**
	MC 9-1 X MC 22-2	55	-0.50	-7.10*	-8.97**	-9.96**
Days to first boll bursting	MC 16-3 x NH 630	94	-0.53	-1.97	-2.87	-3.10
	MC 5-1 x MC 17-1	96	-0.91	-3.24	-0.57	-0.80
	MC 9-1 x MC 11-1	96	-1.76	-2.71	-0.92	-1.15
Plant height	MC 9-1 x NH 630	76.04	-4.47	-6.22	-3.51	-4.52
	MC 17-6 x MC 19-2	75.35	-2.66	-12.18**	-4.39	-5.39
	MC 23-2 x MC 22-2	74.67	-7.88	-13.15**	-11.80*	-12.73**
	MC 23-2 x NH 630	69.60	-6.58	-10.91*	-11.69*	-12.61**
	MC 4-3 x MC 17-2	74.95	-4.59	-7.91	-4.90	-5.90
No. of Monopodia	MC 5-1 x MC 3-2	0.21	-70.44**	-77.85**	-57.33	-15.79
	MC 9-1 x MC 22-2	0.19	-82.77**	-89.37**	-62.67	-26.32
	MC 9-1 x MC 11-1	0.21	-19.23	-48.78	-58.00	-17.11
	MC 9-1 x MC 17-2	0.18	-57.43	-57.94	-64.67	-30.26
	MC 16-3 x MC 22-2	0.16	-86.05**	-91.08**	-68.67	-38.16
Earliness index	MC 4-3 x MC 17-1	68.46	5.77**	-3.60**	6.35**	-1.09
	MC 17-6 x NH 630	66.87	13.33 **	12.74**	3.86 **	-3.40 **
No. of sympodia	MC 9-1 x NH 630	17.76	-1.73	-4.88	4.18	0.45
	MC 17-6 x MC 19-2	17.65	-3.84	-4.04	3.50	-0.21
	MC 23-2 x MC 17-2	18.54	0.58	-1.30	8.76	4.86
	MC 4-3 x MC 3-2	19.70	12.20 *	11.92 *	15.52**	11.39
Length of sympodia	MC 16-3 x NH 630	12.41	-14.03	-18.16	-24.41 **	-29.32**
	MC 23-2 x MC 11-1	12.70	-13.83	-16.02	-22.60*	-27.63**
	MC 17-6 x MC 22-2	13.25	-14.31	-15.21	-19.27*	-24.52**
	MC 16-3 x MC 3-2	13.24	-9.24	-14.42	-19.35 *	-24.59**
	MC 17-6 x MC 19-2	14.13	-1.33	-7.67	-13.93	-19.52*
Leaf area	MC 9-1 x NH 630	2512.00	29.85**	19.56	15.99	12.50
	MC 4-3 x MC 22-2	2199.80	33.82**	21.87	1.58	-1.49
	MC 17-6 x MC 17-1	2617.64	43.76**	42.34**	20.87	17.23
	MC 16-3 x MC 17-2	2245.00	17.66	14.49	3.67	0.54
	MC 17-6 x MC 17-2	2343.80	26.89*	26.33*	8.23	4.96
No. of bolls per plant	MC 4-3 x MC 3-2	20.35	28.84 **	27.52**	15.16	12.93
	MC 9-1 x NH 630	19.94	11.77	7.63	12.82	10.63
	MC 17-6 x MC 17-1	22.98	41.51 **	37.86**	30.06 **	27.53**

	MC 4-3 x MC 22-2	21.54	41.29 **	34.93**	21.86 *	19.49*
	MC 23-2 x MC 17-2	19.08	12.49	2.93	7.92	5.82
Boll weight	MC 23-2 x MC 3-2	3.92	46.58**	41.30**	9.59	14.38*
	MC 17-6 x MC 19-2	3.63	26.55**	21.95**	1.40	5.83
	MC 17-6 x MC 17-2	3.44	17.34**	10.85	-3.91	0.29
	MC 16-3 x MC 17-2	3.53	12.54*	11.36	-1.40	2.92
Harvest index	MC 17-6 x MC 19-2	0.38	10.78 *	7.62	14.14 *	17.71 **
	MC 9-1 x MC 3-2	0.37	12.56 *	8.74	13.13 *	16.67 **
	MC 17-6 x MC 3-2	0.37	9.45	4.76	11.11	14.58*
	MC 23-2 x MC 3-2	0.36	14.89 **	12.50*	9.09	12.50 *
	MC 16-3 x MC 17-2	0.36	16.13 **	14.89*	9.09	12.50 *
100-seed weight	MC 9-1 x MC 19-2	11.04	27.15 **	20.62**	7.47 *	7.29 *
	MC 16-3 x MC 17-2	11.28	31.32 **	10.12**	9.83 **	9.66 **
	MC 17-6 x MC 19-2	10..66	13.87**	11.35**	3.80	3.63
	MC 23-2 x MC 17-1	11.60	47.43 **	35.99**	12.95 **	12.77**
	MC 23-2 x MC 22-2	11.46	34.65 **	34.39**	11.62 **	11.44**
Seed cotton yield per plant	MC 4-3 x MC 3-2	66.44	57.52 **	49.24 **	9.00	5.90
	MC 9-1 x NH 630	64.97	30.05 **	23.70 **	5.73	2.71
	MC 17-6 x MC 19-2	65.16	36.12**	35.28**	7.10	4.04
	MC 17-6 x MC 17-1	69.12	44.09 **	36.71 **	19.08 *	15.69
	MC 23-2 x MC 17-2	61.26	24.74**	17.04	5.54	2.53
Ginning outturn	MC 5-1 x MC 11-1	36.77	1.19	-2.54	5.86	8.87 **
	MC 17-6 x MC 19-2	35.74	11.92**	11.04**	2.76	5.68
	MC 16-3 x MC 3-2	40.98	9.17 **	-1.79	16.48 **	19.80 **
	MC 16-3 x MC 17-1	40.10	17.98 **	10.00 **	20.59 **	24.03 **
2.5% span length	MC 23-2 x MC 17-1	31.19	10.45 **	10.16**	4.08 **	3.19 *
	MC 17-6 x MC 19-2	31.26	7.39 **	7.33 **	4.30 **	3.41*
	MC 4-3 x MC 11-1	30.49	2.90 *	-2.14	1.75	0.87
	MC 23-2 x NH 630	30.48	8.90 **	8.21 **	1.71	0.84
Uniformity ratio	MC 17-6 x MC 19-2	47.98	1.83**	1.37*	1.30 *	1.57*
	MC 17-6 x MC 3-2	46.80	2.25**	1.90**	0.91	1.18
Bundle strength	MC 17-6 x MC 17-2	22.93	7.51 **	3.52	4.50	7.82**
	MC 5-1 x MC 17-1	22.99	18.10 **	11.18**	16.62 **	20.33**
	MC 23-2 x MC 3-2	23.10	10.32 **	3.87	5.26 *	8.60**
	MC 17-6 x NH 630	22.89	8.35 **	3.30	4.27	7.59**
Micronaire value	MC 16-3 x NH 630	4.09	19.88 **	17.98**	1.91	21.01 **
	MC 16-3 x MC 11-1	4.16	15.13 **	10.64**	3.65 **	23.08**
	MC 23-2 x MC 11-1	3.67	12.28 **	-2.30*	-8.47 **	8.68**
	MC 17-6 x MC 11-1	3.77	10.89 **	0.18	-6.15 **	11.44**

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

CONCLUSION

The results of the present study revealed that, the cross combinations *viz*., five crosses viz., MC 17-6 x MC 19-2, MC 23-2 x MC 17-2, MC 17-6 x MC 17-1, MC 9-1 x NH 630 and MC 4-3 x MC 3-2 were found to exhibit seed cotton yield per plant on par with both the checks used in the study in addition to possessing some compact short sympodial plant characteristics besides showing standard heterosis for quality traits. Hence, these hybrids could be exploited further for development of short compact plant types. The best multiple cross derivatives and cross combinations identified in the present study could be further evaluated under HDPS along with studies on root, biochemical and physiological traits related to drought tolerance to identify plant types suitable for light soils under rainfed conditions at increased plant densities. Further, genetic analysis of the cotton genotypes may possibly have taken up by using EST-SSR markers for understanding the expression of traits under HDPS. While breeding the genotypes for HDPS, priority should also be given to study the variability for inherent seed dormancy among the genotypes, which could be used for identification of varieties that can avoid germination of seeds due to rains coinciding with maturity stage.

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