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Heterosis and Combining Ability in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.)]

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Abstract

In the analysis of variance of 11 x 11 half diallel set of nine characters in *Kharif*-2013, Rahuri the mean sum of square due to treatments, parents and crosses were significant for all characters suggesting sustainable diversity among character studied. Mean sum of squares due to gca and sca were highly significant for all the characters revealing importance of both additive and non additive type of gene effects for expression of these traits. The maximum positive heterosis for grain yield was observed in DHLBI 967 x DHLBI 731 (119.88 %) followed by DHLBI 967 x S-12/30074 (100.56 %) and RHRBI 458 x DHLBI 967 (99.07 %). Among the crossses with positive significant SCA effects for grain yield, the frequency of good x good and good x average combiner was more. Among the top ten crosses, five hybrids had one parent good general combiner for grain yield. Three inbreds viz., RHRBI 138, DHLBI 731 and DHLBI 967 gave top yielding hybrid combinations. Among ten top performing hybrids, three hybrids viz., RHRBI 138 x DHLBI 731, DHLBI 967 x DHLBI 731 and RHRBI 458 x ICMB 98222 exhibited significant favorable heterobeltiosis, standard heterosis, GCA and SCA effects for yield and most of the related traits. The hybrids exhibiting high sca, heterosis and mean performance could be further exploited for obtaining desirable transgressive segregants from segregating populations and so as to identify high yielding superior genotypes.

Key words : *Pearl millet, heterosis, combining ability, GCA, SCA effects.*

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R.Br.] is the most important component of dryland system and grow extensively in *Kharif* season in Maharashtra. Maharashtra, pearl millet covers an area of 6.83 lakh hectares producing 4.98 lakh tones with productivity of 708 kg/ha (1). During 2019-20, pearl millet was grown in 7.41 million ha with average production of 10.3 million tones and 1391 kg/ha productivity (Anon. 2021). The major pearl millet growing states are Rajasthan, Maharashtra, Uttar Pradesh, Gujrat and Haryana contributing to 90% of total production in the country, Rajasthan contribute nearly 4.283 million tones, followed by Uttar Pradesh (1.302), Haryana (1.079), Gujrat (0.961), Maharashtra (0.66) and Tamil Nadu (0.084).The quantum jump (from 303 to 850 kg ha^{-1}) in the productivity of pearl millet was possible mainly through development of hybrids by the utilization of cytoplasmic genetic male sterility system. (2) was the first to develop cytoplasmic male sterile line *Tift 23A* bred at Tifton, Georgia, USA. The improvement in pearl millet needs attention for the characters like early flowering, grain yield $plant^{-1}$, grain yield ha^{-1}, earhead length and girth, protein content and number of tillers $plant^{-1}$. Keeping these things in view, the present study was planned, to estimate the heterosis for yield and its components and to estimate the general and specific combining ability of parents and hybrids, respectively.

Materials and Methods

The experimental material for the present study comprised of 11 inbred lines obtained from Bajra Research Scheme, College of Agriculture, Dhule and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana. These inbreds were crossed in diallel fashion to obtain F_1's excluding reciprocals during Summer 2013. Sufficient quantity of seed for 55 cross combinations was obtained. These 55 crosses along with eleven inbreds were used to study heterosis and combining ability. The 66 genotypes were raised in a randomized block design with three replications and two rows (of 3.0m length) plots per replication at Bajra research Scheme, College of Agriculture, Rahuri during Kharif, *2013* season. Standard agronomic practices were followed for raising and maintenance of plants. The observations were recorded on nine characters *viz*., days to 50 per cent flowering, days to maturity, plant height, number of effective tillers $plant^{-1}$, ear head length, ear head girth, grain yield per plot, fodder yield per plot and 1000 seed weight. Estimation of relative heterosis and heterobeltiosis as per (3) and Combining ability as per (4) were undertaken using INDOSTAT statistical package at Mahatma Phule Krishi Vidyapeeth, Rahuri. The details of theses inbreds are given below :

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Salient features of the pearl millet inbred lines used in the study.

Sr. No.	Code	Inbred/parent	Source/Origin	Features
1.	P_1	RHRBI 138	MPKV	Bristled, drought tolerant, bold grains, good grain colour, broad and compact earhead
2.	P_2	RHRBI 458	MPKV	Bristled, drought tolerant, bold grains, broad and long earhead
3.	P_3	DHLBI 967	MPKV	Mid-tall, profuse tillering, bold grains, compact earhead
4.	P_4	DHLBI 731	MPKV	Profuse tillering, long earhead, compact earhead
5.	P_5	ICMB 98222	ICRISAT	Early, bold grains, compact earhead.
6.	P_6	S-12/30069	ICRISAT	Small grain, Low 'Fe'(44.54 mg/kg)
7.	P_7	S-12/30109	ICRISAT	Profuse tillering, late maturity, good grain colour.
8.	P_8	S-12/30071	ICRISAT	Profuse tillering, small grains, drought resistant.
9.	P_9	S-12/30060	ICRISAT	Bold grains, compact,broad and long earhead, high 'Fe' (107.12 mg/kg)
10.	P_{10}	S-12/30074	ICRISAT	Compact earhead, Bold grains, high 'Fe'(99.42 mg/kg)
11.	P_{11}	S-12/30088	ICRISAT	Early, semi-compact earhead, high Fe (91.68 mg/kg)

Results and Discussion

Analysis of variance in diallel set of nine characters in *Kharif*-2013, Rahuri is presented in table 1a. The mean sum of square due to treatments, parents and crosses were significant for all characters except mean sum of squares due to parents for fodder yield per plot. The significant difference among treatments, parents and hybrids were also observed for all characters suggesting sustainable diversity among them. The analysis of variance further revealed that the parents vs. hybrids differed significantly for all the character except number of tillers per plant showed presence of heterosis in hybrids for these traits. In previous studies such observations were also noted for yield and yield contributing characters in pearl millet by (5, 6).

The combining ability ANOVA for nine characters presented in Table-1b. Mean sum of squares due to GCA and SCA were highly significant for all the characters revealing importance of both additive and non additive type of gene effects for expression of these traits. Significant mean sum of square due to gca and sca were also reported by (7, 8, 9).

The cross combination DHLBI 731 x ICMB 98222 recorded highest significant negative heterosis for days to 50 % flowering (-13.85%) and days to maturity (-8.46 %) (Table-2), this cross combination will be helpful to isolate early genotypes. The range for relative heterosis was -18.69 (RHRBI 458 x S-12/30071) to 27.93 (ICMB 98222 x S-12 / 30060) for effective tillers plant^{-1} (Table-1). The cross combinations ICMB 98222 x S-12 / 30060(27.93 %), DHLBI 967 x S-12 / 30074(24.19 %) and RHRBI 138 x DHLBI 731(23.71 %) were the significantly high heterotic combinations for number of effective tillers plant^{-1}. Among 55 crosses three *viz.,* DHLBI 967 x S-12 / 30088, DHLBI 967 x ICMB 98222 and ICMB 98222 x S-12 / 30060 exhibited significantly positive standard heterosis in desirable direction for plant height. The cross S-12/30071 x S-12 / 30060 (-19.51) and DHLBI 967 x ICMB 98222 (13.82) exhibited the minimum and maximum relative heterosis, respectively for earhead length. Total fourteen crosses exhibited significant and positive relative heterosis for earhead girth. The crosses RHRBI 458 x DHLBI 967 (21.02 %) followed by DHLBI 967 x S-12/30074 (18.25 %) and DHLBI 967 x DHLBI 731 (13.40 %) recorded highest estimates of relative heterosis for earhead girth. Total twenty eight crosses exhibited significant positive relative heterosis for 1000 grain weight and S-12/30060 x S-12/30074 (26.72%) and S-12/30109 x S-12/30060 (26.21%) exhibited highest significant and positive relative heterosis for 1000 grain weight. The relative heterosis (%) for fodder yield ranged from -18.92 to 78.12 and significant and positive relative heterosis for this trait were observed in twenty nine crosses. The highest estimates of relative heterosis for fodder yield was observed in the cross RHRBI 458 x DHLBI 967 (78.12%).

Grain yield is an attribute of economic importance, which attempted by breeders to improve by involving high yielding varieties or inbreds. The estimates of relative heterosis and heterobeltiosis for grain yield were significant and positive for twenty seven and seventeen crosses respectively, while none of cross exhibited negative significant relative heterosis The relative heterosis (%)ranged from -19.27 (S-12/30069 x S-12/30109) to 119.88 (DHLBI 967 x DHLBI 731).The cross combinations RHRBI 967 x DHLBI 731 (119.88%), RHRBI 967 x S-12/30074 (100.56%) and RHRBI 458 x RHRBI 967 (99.07%) had the highest estimates of heterosis and heterobeltiosis. These, results are in agreement with those (9, 10, 11).

Crosses with positive and significant SCA effects (Table-2) for grain yield were produced by almost all type of parental combinations (good x good, good x average, good x poor, average x good, average x average, poor x poor). The crosses with high SCA effects were in general combinations of parents with good x good, good x poor

Table-1a : Analysis of variance of 11 x 11 half diallel set of pearl millet.

Sources	DF	Days to 50% flowering	Days to maturity	Effective tillers/ plant	Plant height (cm)	Ear-head length (cm)	Ear-head girth (cm)	1000 Grain weight (g)	Grain yield per plot (kg)	Fodder yield per plot (kg)
Treat.	65	40.63**	63.38**	0.285**	788.12**	6.95**	1.60**	5.98**	0.086**	0.193**
Parents	10	38.16**	49.50**	0.362**	1620.63**	6.78**	2.04**	6.29**	0.019*	0.079**
Hybrids	54	40.98**	64.55**	0.277**	500.42*	6.77**	1.46**	5.80**	0.089**	0.198**
Parents Vs. Hybrids	1	46.26**	139.03**	0.001	7998.58	18.55**	4.75**	12.99**	0.573**	1.073**
Error	130	2.99	3.10	0.028	338.18	1.36	0.39	0.35	0.008	0.028

*,** significant at 5 and 1% level, respectively.

Table-1b : Combing ability ANOVA for nine characters of pearl millet.

Sources	DF	Days to 50% flowering	Days to maturity	Effective tillers/ plant	Plant height (cm)	Earhead length (cm)	Earhead girth (cm)	1000 Grain weight (g)	Grain yield per plot (kg)	Fodder yield per plot (kg)
gca	10	50.25**	59.10**	0.37**	558.84**	5.71**	1.42**	9.01**	0.090**	0.200**
sca	55	6.87**	14.22**	0.05**	208.86**	1.70**	0.37**	0.72**	0.018**	0.040**
Error	130	1.00	1.03	0.01	112.73	0.45	0.13	0.12	0.003	0.009
^{2}gca		3.79	4.47	0.03	34.32	0.40	0.10	0.68	0.007	0.015
^{2}sca		5.87	13.19	0.04	96.14	1.25	0.24	0.60	0.015	0.031
^{2}gca/ ^{2}sca		0.65	0.34	0.75	0.36	0.32	0.41	1.14	0.449	0.480

Table-2 : Range of heterosis for yield, its components and number of crosses exhibiting significant heterosis in pearl millet.

Characters	Range %	SE	Number crosses in desirable direction	No. of hybrids showing desirable significant heterosis over	
				MP	BP
Days to 50% flowering	-13.86 to 13.18	1.22	34	20	29
Days to maturity	-12.69 to 9.82	1.25	13	3	13
Effective tillers/plant	-18.69 to 27.93	0.12	27	11	1
Plant height (cm)	-6.46 to 34.79	12.99	44	16	5
Erahead length (cm)	-13.69 to 15.92	0.82	40	15	3
Erahead girth (cm)	-13.43 to 21.02	0.44	35	14	4
1000 grain weight (g)	-11.56 to 26.72	0.42	42	28	8
Grain yield per plot (kg)	-19.27 to 119.88	0.062	46	27	17
Fodder yield per plot (kg)	-18.92 to 78.12	0.12	45	25	13

MP = Mid parent, BP = Better parent

and good x average or average x poor GCA effects. This was represented in best three hybrids for grain yield ha^{-1} *viz.,* RHRBI 138 x DHLBI 731 (good x good), DHLBI 967 x DHLBI 731 (good x good), and RHRBI 458 x ICMB 98222 (average x good) had significant desired SCA effects and significant heterotic response over better parents. The frequency of good x average was more among top 10 hybrids, in five hybrids *viz.,* DHLBI 967 x DHLBI 731, DHLBI 967 x DHLBI 731, RHRBI 458 x ICMB 98222, DHLBI 967 x S-12/30074, RHRBI 138 x S-12/30060 and RHRBI 458 x DHLBI one of their parent found to be good general combiner (Table-3). (8, 11) reported presence of at least one or average general combiner for high SCA effects in most of the traits. The high yield potential in cross combination (high x low) might be attributed due to good combiner while heterosis involved in high x high combiners involved interaction between positive x positive effects.

In the present study, low x low combinations also produced by hybrids with high SCA and this can be attributed due to over dominance or epistasis. In present investigation the performance of hybrids *viz.,* RHRBI 138 x DHLBI 731, DHLBI 967 x DHLBI 731, and RHRBI 458 x ICMB 98222 recorded higher heterosis and showed positive significant SCA effects for grain yield and yield contributing characters. Similar results were reported by (7, 8, 11).

Table-3 : Three best performing cross combinations, their GCA and SCA effects, heterosis and heterobeltiosis for various traits in pearl millet.

S. No.	Character	Best performing hybrids	GCA effects			SCA effects	Heterosis (%)	Heterobeltiosis (%)
			P1		P2			
1.	Days to 50% flowering	DHLBI 731 x ICMB 98222	P	x	A	-5.53**	-13.85**	-15.15**
		DHLBI 731 x S-12/30109	P	x	A	-4.58**	-13.86**	-13.33**
		RHRBI 458 x S-12/30074	G	x	P	-3.15**	-4.49	-7.45**
2.	Days to maturity	RHRBI 458 x S-12/30069	A	x	P	-9.10**	-12.36**	-16.73**
		DHLBI 731 x ICMB 98222	P	x	A	-8.46**	-12.69**	-15.30**
		DHLBI 731 x S-12/30109	P	x	A	-5.87**	-11.24**	-11.57**
3.	Effective tillers/plant	DHLBI 967 x S-12/30074	G	x	P	0.448**	24.19**	2.69
		ICMB 98222 x S-12/30060	G	x	P	0.423**	27.93**	22.27**
		RHRBI 138 x DHLBI 731	P	x	G	0.367**	23.71**	3.81
4.	Plant height (cm)	DHLBI 967 x S-12/30088	P	x	A	25.49*	24.91**	24.31**
		ICMB 98222 x S-12/30060	A	x	A	22.87*	34.79**	17.71**
		DHLBI 731 x S-12/30069	P	x	A	18.90	14.95**	12.93
5.	Erahead length (cm)	RHRBI 138 x DHLBI 731	G	x	G	2.87**	14.33**	13.82**
		DHLBI 731 x ICMB 98222	G	x	A	2.60**	15.92**	11.49**
		RHRBI 458 x DHLBI 967	A	x	A	2.35**	12.17**	9.46**
6.	Erahead girth (cm)	RHRBI 458 x DHLBI 967	G	x	A	1.63**	21.02**	8.74**
		S-12/30069 x S-12/30088	P	x	P	1.31**	12.20**	10.77**
		RHRBI 458 x S-12/30074	G	x	A	0.79*	-2.47	-8.76*
7.	1000 grain weight (g)	S-12/30109 x S-12/30060	P	x	G	1.58**	26.21**	0.78
		S-12/30060 x S-12/30074	G	x	P	1.54**	26.72**	5.51
		RHRBI 458 x ICMB 98222	A	x	G	1.32**	20.18**	15.93**
8.	Grain yield per plot (kg)	RHRBI 138 x DHLBI 731	G	x	G	0.281**	90.22**	84.03**
		DHLBI 967 x DHLBI 731	G	x	G	0.278**	119.88**	91.00**
		RHRBI 458 x ICMB 98222	A	x	G	0.232**	74.60**	55.40**
9.	Fodder yield per plot (kg)	RHRBI 458 x DHLBI 967	A	x	A	0.526**	78.12**	58.33**
		RHRBI 138 x DHLBI 731	G	x	G	0.393**	49.37**	47.50**
		S-12/30069 x S-12/30071	P	x	P	0.311**	32.20**	33.00**

*,** Significant at 5 and 1 per cent probability levels, respectively,
G = Good parent having significant GCA effect in desired direction,
A = Average parent having either positive or negative but non-significant GCA effect,
P = Poor parent having significant GCA effects in undesired direction,
P_1 = First parent and P_2 = Second parent.

Conclusions

Among the parents RHRBI 138, DHLBI 731 RHRBI 458 and ICMB 98222 gave top yielding hybrid combinations. In the present study, among top ten cross combinations three crosses *viz.,* RHRBI 138 x DHLBI 731, DHLBI 967 x DHLBI 731, and RHRBI 458 x ICMB 98222 exhibited significant favorable heterobeltiosis, standard heterosis, GCA and SCA effects for grain yield and most of the component traits, could be further exploited for obtaining desirable transgressive segregants from segregating populations and so as to identify high yielding superior genotypes.

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Table-4 : Best crosses having mean performance, significant specific combiners and heterosis for grain yield and their performance over other traits in pearl millet during Kharif-2013.

	Cross combination	Mean GY	sca effect	Heterosis % over		Significant sca effects in desirable direction to related characters	Significant heterosis in desirable direction to related characters
				MP	BP		
1 x 4	RHRBI 138 x DHLBI 731	1.009	0.281**	90.22	84.03	Days to 50% flowering, days to matuity, number of tillers/plant, 1000 grain wt, fodder yield per plot, grain Fe	Days to 50% flowering, days to matuity, number of tillers/plant, earhead length , earhead girth, 1000 grain wt, grain yield per plot, fodder yield per plot, grain Fe, grain Zn
3 x 4	DHLBI 967 x DHLBI 731	0.979	0.278**	119.88	91.00	Days to matuity, 1000 grain wt, fodder yield per plot, grain Fe	Days to matuity, earhead girth, 1000 grain wt, grain yield per plot, fodder yield per plot , grain Fe
2 x 5	RHRBI 458 x ICMB 98222	0.920	0.232**	74.60	55.40	Days to 50% flowering, 1000 grain wt, fodder yield per plot , grain Fe	Days to 50% flowering, days to matuity, plant height, 1000 grain wt, grain yield per plot, fodder yield per plot , grain Fe
3 x 10	DHLBI 967 x S-12/30074	0.866	0.226**	100.56	78.42	Number of tillers/plant, earhead girth, fodder yield per plot	Number of tillers/plant, earhead girth, 1000 grain wt, grain yield per plot, fodder yield per plot
1 x 9	RHRBI 138 x S-12/30060	0.972	0.208**	75.61	32.25	1000 grain wt	Earhead girth, 1000 grain wt, grain yield per plot, fodder yield per plot, grain Fe, grain Zn
2 x 3	RHRBI 458 x DHLBI 967	0.836	0.192**	99.07	81.03	Number of tillers/plant, earhead length , earhead girth, 1000 grain wt, fodder yield per plot , grain Fe, grain Zn	Number of tillers/plant, earhead length , earhead girth, 1000 grain wt, grain yield per plot, fodder yield per plot , grain Fe
7 x 9	S-12/30109 x S-12/30060	0.808	0.187**	52.03	44.76	1000 grain wt, fodder yield per plot, grain Fe, grain Zn	1000 grain wt, grain yield per plot, fodder yield per plot , grain Fe
6 x 8	S-12/30069 x S-12/30071	0.468	0.128**	24.18	14.95	Earhead length, Fodder yield per plot, grain Fe	Days to 50% flowering, days to matuity, earhead length, fodder yield per plot
5 x 9	ICMB 98222 x S-12/30060	0.908	0.126**	57.90	53.42	Number of tillers/plant, plant height, fodder yield per plot	Number of tillers/plant, plant height, 1000 grain wt, grain yield per plot, fodder yield per plot, grain Fe
1 x 5	RHRBI 138 x ICMB 98222	0.882	0.119**	54.64	48.96	Fodder yield per plot	Number of tillers/plant, plant height, earhead girth, 1000 grain wt, grain yield per plot, fodder yield per plot , grain Fe

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