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COMBINING ABILITY AND HETEROSIS FOR GRAIN YIELD AND ITS COMPONETS IN PEARLMILLET (*Pennisetum glaucum* (L.) R. BR.)

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ABSTRACT

Present experiment was conducted at Regional Agriculture research Station, Vijayapur (Karnataka) during the *kharif* season of 2015 with five male sterile lines (female parents) and eight restorers (male parents) of pearlmillet in line x tester fashion. In general combining ability analysis ICMA-00888 found maximum gca effects for grain yield, plant height, ear head length, number of productive tillers per plant, test weight and fodder yield followed by ICMA-96666. Maximum gca effects for days to 50% flowering was found in ICMA-88004 and for ear head girth in case of A5RLT-108. In specific combining ability analysis seven crosses viz., ICMA-00888 x A5RLT-108, ICMA-88004 x A5RLT-110, ICMA-00888 x A5RLT-116, ICMA-00888 x A5RLT-120, ICMA-96666 x A5RLT-108, ICMA-81A x A5RLT-123 and ICMA-81A x A5RLT-125 were identified as the best specific combiners for grain yield and major yield components. Analysis of sca effects revealed that good combining parents yield better hybrids, because parents with significant positive gca effects were involved more in selected crosses than those with non-significant gca effects and negative gca effects. In the present study, the involvement of atleast one good general combiner was found essential for obtaining combinations with high specific effects. Combining ability studies revealed that both general and specific combining ability variances were important but the estimates of sca variance were higher in magnitude for all the characters. Thus, indicating the predominance of non-additive gene action. The hybrid Kaveri was used as standard check hybrid. At the end ICMA-00888 x A5RLT-108 was selected as best cross since it has expressed high standard heterosis over standard check hybrid (Kaveri) for many of the traits studied for high grain yield.

KEYWORDS: Combining ability; Inbreds; Pearlmillet; heterosis and Line x Tester Analysis.

INTRODUCTION

Pearlmillet is considered as the fifth important cereal crop, and most important millet (constitutes more than 55% of global millet production) and is grown in over 40 countries, predominantly in Africa and the Indian subcontinent. In India, it is commonly known as bajra or bajri, and is mainly grown in Rajasthan, Maharashtra, Gujarat, Haryana, Uttar Pradesh, Karnataka, and Tamil Nadu. Pearlmillet occupies an area of 8.69 million ha with a production in the tune of 10.05 million metric tons and productivity of 1156 kg per ha in the country. While in Gujarat, it is grown on 1.07 million ha. with a production of 1.23 million metric tons and productivity of 1250 kg per ha (Anonymous, 2012). It is a cross pollinated annual C4 crop species that originated in western Africa and was introduced to eastern Africa and the Indian sub-continent some 2000 years ago. Its protogynous nature of flowering can be used to make hybrids. The principal aim of any breeding programme is to increase the yield potential.

Heterosis breeding has been recognized as the most suitable breeding methodology for augmenting yield in pearlmillet. Selection of suitable parents and assessment of degree of heterosis in the resulting crosses forms an important step. An extensive survey of Pearlmillet literature showed 40 per cent average better parent heterosis for grain yield (Virk, 1988.). Previous studies showed that, high amount of heterosis for grain yield and harvest index (Parmar *et al*, 2013) high magnitude of heterosis for grain yield (Patel *et al.*, 2016) and standard heterosis for grain yield (49.3 %), productive tiller (63.3 %), ear length (49.3%), ear girth (22.1%), ear weight (76.6%) and 1000 grain weight (86.7 %) (Vetriventhan *et al.*, 2008). Heterosis breeding was ideal for increasing yield in pearlmillet (Ramamoorthi and Nadarajan, 2001).

The yield is a complex character comprising of a number of components each of which is genetically controlled and susceptible to environmental fluctuations. The concept of combining ability is gaining importance in plant breeding as it provides valuable genetic information about the parents and the characters under study. It helps in assessing the breeding value of parental lines in terms of their superiority in hybrid combinations and also provides the information regarding the nature and extent of gene action involved in controlling the inheritance of characters in question, like yield and yield attributing characters, thus helps in deciding upon the future breeding strategy. Hence the present investigation based on '*line* x *tester*' analysis was designed, to study the extent of hybrid vigour in F_1 and collect the information regarding the genetic composition of various quantitatively inherited yield contributing traits including grain yield in pearlmillet.

MATERIALS & METHODS

The present study involving five male sterile lines and eight restorers of pearlmillet and crosses were affected by using Line x Tester mating design (Kempthorne, 1957) during summer, 2015. Resultant hybrids along with their parents and three standard checks were raised in Randomized Complete Block Design (RCBD) with three replications during *Kharif*, 2015. Each hybrid was accommodated in two rows with a row spacing of 45 cm and plant to plant spacing of 15cm. Uniform and recommended cultural practices were followed to raise agronomically good managed crop. The observations were recorded on five randomly selected competitive plants from each replication for 8 traits viz., Days to 50% flowering, Plant height (cm), Ear head length (cm), Ear head girth (cm), number of productive tillers per plant, Test weight (g), grain yield (kg per plot) and Fodder yield(kg per plot).

The expression of heterosis in 40 hybrids involving five lines and eight testers was measured in terms of relative heterosis in relation to mid parents, heterobeltiosis in relation to better parent and standard heterosis in comparison with three checks, the hybrid as the standard. Combining ability analysis was computed using line x tester procedure developed by (Kempthorne, 1957).

RESULTS & DISCUSSION

Analysis of variance for combining ability

The results of analysis of variance for combining ability indicated that the mean squares due to lines were found to be highly significant for days to 50% flowering, plant height, ear head length, ear head girth, test weight, yield per plot, and fodder yield (Table 1). In case of testers non significant values were obtained for all the characters, whereas the mean squares due to line x tester were found highly significant for all the characters under study except number of productive tillers per plant. The above results suggest that the parents used in this study are diverse and significant difference exists between them. Such variation in parents has also been reported earlier by Bhuri Singh, *et al.* (2014).

TABLE 1: Analysis of variance for combining ability for eight characters in Pearlmillet (Mean Sum of Squares)

Sources of variation	df	Days to 50% flowering	Plant height (cm)	Ear head length (cm)	Ear head girth (cm)	No. of pri. Tillers /plant	Test weight (g)	Grain Yield (Kg/Plot)	Fodder yield (kg/plot)
Replicates	1	20.000 **	41.472	0.171	0.413 **	0.085	1.741 *	0.062 **	0.435 **
Crosses	39	13.091 **	1291.507 **	21.358 **	0.262 **	0.400	7.775 **	0.186 **	1.202 **
Line Effect	4	32.481 *	7982.727 **	110.846 **	0.424	0.694	35.949 **	0.505 *	3.6741*
Tester Effect	7	14.621	615.609	15.897	0.275	0.419	2.841	0.193	0.526
Line x Tester Eff.	28	9.938 **	504.593 **	9.939 **	0.236 **	0.353	4.983 **	0.139 **	1.019 **
Error	39	0.692	13.722	1.450	0.025	0.271	0.285	0.003	0.23

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

TABLE 2. *Per se* performance of parents for eight character of Pearlmillet

Sl. No	Parents	Days to 50% flowering	Plant height (cm)	Ear head length (cm)	Ear head girth (cm)	No. of pri. Tillers/ plant	Test weight (g)	Grain Yield (Kg/Plot)	Fodder Yield (Kg/plot)
Lines (Females)									
1	ICMA-00888	44.50	156.60	20.10	2.46	2.45	0.57	0.565	1.700
2	ICMA-96666	43.50	147.90	19.20	2.52	1.95	0.82	0.815	1.400
3	ICMA-88004	48.00	164.70	23.20	2.59	1.85	0.70	0.695	1.800
4	ICMA-81A	47.50	169.40	20.90	2.41	3.05	0.63	0.630	1.800
5	ICMA-94555	46.50	153.50	21.60	2.89	1.90	0.72	0.715	2.150
Testers (Male)									
1	A5RLT-108	57.00	128.70	17.20	2.35	1.45	0.46	0.455	1.550
2	A5RLT-109	57.50	127.20	18.90	2.59	1.25	0.46	0.460	1.450
3	A5RLT-110	56.50	132.60	19.60	2.06	1.45	0.72	0.715	1.650
4	A5RLT-112	59.00	135.45	19.70	2.26	1.40	0.62	0.615	1.750
5	A5RLT-116	56.50	131.65	20.20	2.32	1.65	0.45	0.450	1.500
6	A5RLT-120	52.00	150.90	20.40	2.21	1.50	0.44	0.435	1.750
7	A5RLT-123	58.50	166.20	26.15	2.59	1.35	0.41	0.410	1.500
8	A5RLT-125	53.50	126.30	22.90	2.39	1.30	0.51	0.510	1.650

Estimates of general combining ability effects

General combining ability is largely attributed to the additivity of gene effects. While specific combining ability is associated with interaction effects which may be due to dominance and epistasis. The estimates of general and specific combining ability variance suggested the predominance of specific combining ability variance. The ratio between GCA/SCA suggests the predominance of non additive gene effects (Bhuri Singh, *et al.*, 2014). The predominance of non additive action in the expression of several yield component characters suggests that it can be exploited through the production of hybrids and composites. However, for the development of high yielding varieties general combining ability was more important (Mungra, *et al.*, 2015 and Patel, *et al.*, 2014). The estimates of gca effects for parents (Table 3) revealed that females ICMA-00888 and ICMA-96666 were the best combiner for grain yield and other yield components, such as plant height, ear head length, number of productive tillers per plant, test weight and fodder yield.

Among the male parents the gca effect for grain yield ranged from -0.199 to 0.458. Five parents recorded significant positive combining ability effects for yield. The genotypes A5RLT-108 and A5RLT-112 had the highest positive effect for grain yield, days to 50% flowering, plant height and test weight. The combining ability studies also revealed that among male parents, the genotypes A5RLT-112 for ear head length, the testers A5RLT-108, A5RLT-109 and A5RLT-110 for ear head girth, A5RLT-109, A5RLT-116 and A5RLT-125 for fodder yield recorded significant positive gca effect. These genotypes can be exploited through hybridization. There was generally close agreement between gca and perse performance (Table 2) of the lines for most of the characters.

TABLE 3: Estimates of General combining ability effects of Parents for eight characters in Pearlmillet

Sl. No	Parents	Days to 50% flowering	Plant height (cm)	Ear head length (cm)	Ear head girth (cm)	No. of pri. Tillers /plant	Test weight (g)	Grain Yield (Kg/Plot)	Fodder Yield (Kg/plot)
Lines (Females)									
1	ICMA-00888	-0.513 *	28.216 **	3.735 **	0.124 **	0.369 **	0.159 **	0.458 **	2.126 **
2	ICMA-96666	-0.513 *	20.154 **	0.285	0.044	0.369 **	0.159 **	0.458 **	2.126 **
3	ICMA-88004	2.300 **	-19.040 **	-3.159 **	-0.091 *	-0.131	-0.212 **	-0.768 **	0.157
4	ICMA-81A	0.363	-15.259 **	-1.721 **	-0.235 **	-0.081	-0.174 **	-0.130 **	-2.043 **
5	ICMA-94555	-1.325 **	-14.071 **	0.860 **	0.159 **	-0.050	0.119 **	0.276 **	0.226
SE(G_{ij})		0.2393	1.2728	0.2980	0.0440	0.1329	0.0148	0.0429	0.1303
SE(G_i- G_j)		0.3384	1.8000	0.4215	0.0622	0.1879	0.0209	0.0607	0.1843
Testers (Males)									
1	A5RLT-108	1.525 **	11.588 **	-1.119 **	0.199 **	-0.145	0.100 **	0.271 **	-0.850 **
2	A5RLT-109	1.725 **	-0.252	0.381	0.136 *	0.115	0.152 **	0.131 *	0.370 *
3	A5RLT-110	0.625 *	-1.943	-0.439	0.115 *	0.135	-0.114 **	-0.179 **	-0.060
4	A5RLT-112	0.025	11.978 **	2.481 **	-0.080	0.045	0.159 **	0.261 **	0.060
5	A5RLT-116	-0.675 *	-0.952	-0.259	0.077	-0.105	0.045 *	-0.019	0.390 *
6	A5RLT-120	-1.175 **	-7.213 **	-1.679 **	-0.020	0.065	-0.101 **	0.091	0.000
7	A5RLT-123	-1.575 **	-4.453 **	-0.069	-0.305 **	-0.385 *	-0.227 **	-0.359 **	-0.650 **
8	A5RLT-125	-0.012	-8.753 **	0.701	-0.123 *	0.275	-0.475	-0.199 **	0.740 **
SE($G_{i\ j}$)		0.3027	1.6100	0.3770	0.0556	0.1681	0.0187	0.0543	0.1649
SE($G_i – G_j$)		0.4281	2.2769	0.5331	0.0787	0.2377	0.0265	0.0768	0.2332

* Significant at 5% level. ** Significant at 1% level

Estimates of specific combining ability effects

Among forty hybrids, only ICMA-00888 x A5RLT-108, ICMA-88004 x A5RLT-110, ICMA-00888 x A5RLT-116, ICMA-00888 x A5RLT-120, ICMA-81A x A5RLT-123 and ICMA-81A x A5RLT-125 showed the best performance with significantly positive sca effect for grain yield. The genotypes with high gca effects for many characters did not always produce combinations with high sca effects. Two hybrids, ICMA-96666 x A5RLT-109 and ICMA-88004 x A5RLT-110 recorded significant positive effects for all the characters studied. In majority of the cases, showing high combining ability thus supporting earlier report (Khandagale et al., 2014, Jagendra Sing and Ravi Sharma, 2014 and Bhadalia *et al.,* 2014). Best specific combinations for earliness was derived from the hybrid ICMA-94555(o) x A5RLT-112. However, the genotype ICMA-94555 had negative effect and A5RLT-112 had positive indicating the role of dominance gene action for days to 50% flowering (Table 4).

Heterosis

Magnitudes of per cent heterosis of hybrids over mid parent (relative heterosis), better parent (heterobeltiosis) and standard parent (standard heterosis) for different characters in pearlmillet hybrids have been presented in Table 5. For days to 50 per cent flowering, highest and significant negative relative heterosis, heterobeltiosis and standard heterosis was observed in the cross ICMA-81A x A5RLT-123 (-8.49). Earliness in flowering had also been reported by Karad, and Harer (2004).

With respect to heterosis for early flowering, negative heterosis of hybrids was considered desirable (Arulselvi *et al.,* 2006). For plant height, highly significant negative relative heterosis (-39.08 per cent), heterobeltiosis (-39.35 per cent) and standard heterosis (-27.48 per cent) was recorded for plant height by the cross ICMA-88004 x A5RLT-123. These results are in agreement with Patel *et al.,* (2014).

The hybrid combination ICMA-00888 x A5RLT-112 recorded highly significant positive relative heterosis (58.29 per cent), heterobeltiosis (56.72 per cent) and standard heterosis (23.05 per cent) for the trait ear head length. Estimate of heterosis for ear length and girth were low (Ramamoorthi and Govindarasu, 2001).

Combining ability and heterosis for grain yield and its componets in pearlmillet

TABLE 4: Estimates of specific combining Ability effects of crosses for eight characters in Pearlmillet

Sl. No.	Croses	Days to 50% flowering	Plant height (cm)	Ear head length (cm)	Ear head girth (cm)	No. of pr. Tillers/plant	Test weight (g)	Grain Yield (Kg/Plot)	Fodder Yield (Kg/plot)
1	ICMA-00888 x A5RLT-108	2.413 **	-22.556 **	-1.125	0.085	-0.299	0.572 **	1.323 **	0.194
2	ICMA-00888 x A5RLT-109	3.213 **	-4.716	-0.625	0.103	0.091	-0.101 *	-0.438 **	1.074 **
3	ICMA-00888 x A5RLT-110	0.313	-0.326	-0.805	-0.361 **	-0.279	-0.240 **	-0.928 **	-2.746 **
4	ICMA-00888 x A5RLT-112	-3.088 **	-7.096	3.325 **	-0.126	0.361	-0.273 **	-0.468 **	-1.016 **
5	ICMA-00888 x A5RLT-116	-0.388	-7.616 *	-2.985 **	-0.083	0.111	0.322 **	0.813 **	0.004
6	ICMA-00888 x A5RLT-120	-0.388	12.794 **	-0.565	0.349 **	0.341	0.017	0.853 **	1.144 **
7	ICMA-00888 x A5RLT-123	-1.488 *	7.184	2.875 **	0.279 *	-0.259	-0.046	-0.348 **	0.994 *
8	ICMA-00888 x A5RLT-125	-0.588	22.334 **	-0.095	-0.248	-0.069	-0.252 **	-0.808 **	0.354
9	ICMA-96666 x A5RLT-108	1.225	0.706	-2.275 *	-0.185	0.476	0.201 **	0.816 **	-0.413
10	ICMA-96666 x A5RLT-109	0.025	3.046	0.525	0.108	0.416	0.304 **	0.506 **	0.517
11	ICMA-96666 x A5RLT-110	-1.875 **	7.736 *	2.795 **	0.314 *	0.196	-0.005	-0.034	-2.253 **
12	ICMA-96666 x A5RLT-112	0.725	16.966 **	-1.425	0.429 **	-0.514	0.127 **	0.276 *	1.878 **
13	ICMA-96666 x A5RLT-116	-0.075	26.896 **	0.665	-0.218	0.286	-0.174 **	-0.944 **	1.398 **
14	ICMA-96666 x A5RLT-120	-0.575	-1.294	0.085	-0.231	-0.534	-0.333 **	-0.804 **	1.788 **
15	ICMA-96666 x A5RLT-123	0.325	-21.754 **	-0.225	-0.156	-0.084	-0.202 **	-0.054	-1.263 **
16	ICMA-96666 x A5RLT-125	0.225	-32.304 **	-0.145	-0.063	-0.244	0.083	0.236	-1.653 **
17	ICMA-88004 x A5RLT-108	-1.400 *	16.750 **	1.619	0.330 *	0.051	-0.218 **	-0.453 **	0.313
18	ICMA-88004 x A5RLT-109	-5.100 **	17.940 **	2.819 **	-0.097	0.241	0.020	0.188	-1.108 **
19	ICMA-88004 x A5RLT-110	0.331	2.630	0.639	0.239	0.271	0.311 **	1.148 **	3.373 **
20	ICMA-88004 x A5RLT-112	-1.900 **	8.860 *	0.369	0.469 **	-0.189	0.143 **	0.158	1.053 **
21	ICMA-88004 x A5RLT-116	2.300 **	-23.560 **	-3.141 **	-0.493 **	-0.689	-0.053	0.038	-0.827 *
22	ICMA-88004 x A5RLT-120	3.300 **	-7.950 *	0.029	-0.396 **	-0.209	-0.132 **	-0.523 **	-2.688 **
23	ICMA-88004 x A5RLT-123	3.200 **	17.560**	-1.781*	0.149	0.441	0.079	-0.123	-1.288 **
24	ICMA-88004 x A5RLT-125	-0.400	2.890	-0.551	-0.203	0.081	-0.151 **	-0.433 **	1.173 **
25	ICMA-81A x A5RLT-108	6.819	4.181 **	-0.241	0.301	0.538	-0.346 **	-1.340 **	0.962 *
26	ICMA-81A x A5RLT-109	-9.541 *	-1.819 *	-0.108	-0.259	0.338	-0.368 **	-0.600 **	0.343
27	ICMA-81A x A5RLT-110	-5.501	-0.349	0.078	0.171	0.938	0.153 **	0.260 *	0.822 *
28	ICMA-81A x A5RLT-112	-7.271	-0.269	0.023	0.261	4.538 **	-0.130 **	-0.180	-0.897 *
29	ICMA-81A x A5RLT-116	-5.691	2.321 **	0.121	0.061	-1.763 *	-0.116 **	-0.100	-0.577
30	ICMA-81A x A5RLT-120	-3.931	-0.409	0.008	0.391	-1.763 *	0.180 **	0.290 *	-0.738
31	ICMA-81A x A5RLT-123	28.159 **	-1.669	-0.012	-0.809 *	-2.363 **	0.301 **	0.840 **	1.563 **
32	ICMA-81A x A5RLT-125	-3.041	-1.989 *	0.131	-0.119	-0.463	0.326 **	0.830 **	-1.478 **
33	ICMA-94555(o) x A5RLT-108	-1.719	-2.400 **	0.010	-0.530	-2.775 **	-0.209 **	-0.346 **	-1.056 **
34	ICMA-94555(o) x A5RLT-109	-6.729	-0.900	-0.007	-0.490	1.525 *	0.145 **	0.344 **	-0.826 *
35	ICMA-94555(o) x A5RLT-110	-4.539	-2.280 *	-0.271 *	-0.360	0.625	-0.220 **	-0.446 **	0.804 *
36	ICMA-94555(o) x A5RLT-112	-11.459 **	-2.000 *	-0.796 **	0.080	-0.275	0.133 **	0.214	-1.016 **
37	ICMA-94555(o) x A5RLT-116	9.971 **	3.140 **	0.672 **	0.230	-0.075	0.022	0.194	0.004
38	ICMA-94555(o) x A5RLT-120	0.381	0.860	0.269 *	0.010	-0.575	0.268 **	0.184	0.494
39	ICMA-94555(o) x A5RLT-123	3.971	0.800	-0.261 *	0.710	0.325	-0.132 **	-0.316 *	-0.006
40	ICMA-94555(o) x A5RLT-125	10.121 **	2.780 **	0.382 **	0.350	1.225	-0.007	0.174	1.604 **
$SE(S_{ij})$		0.6768	3.6000	0.8430	0.1244	0.3758	0.0419	0.1214	0.3687
$SE(S_{ij} - S_{kl})$		0.9572	5.0912	1.1922	0.1760	0.5314	0.0592	0.1717	0.5214
$SE(S_{ij} - S_{ik})$		0.8289	4.4091	1.0324	0.1524	0.4602	0.0513	0.1487	0.4515

* Significant at 5% level. ** Significant at 1% level.

TABLE 5: Magnitude of *per cent* heterosis of hybrids over mid parent (relative heterosis), better parent (heterobeltiosis) and standard parent (standard heterosis) for different characters in pearlmillet

Sl. No.	Croses	Days to 50% flowering			Plant height (cm)			Ear head length (cm)			Ear head girth (cm)		
		Percent Heterosis over											
		Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent
1	ICMA-00888 x A5RLT-108	9.36**	-2.63	7.77**	11.53**	1.60	14.46**	25.74**	16.67**	-8.40	31.81**	28.86**	29.65**
2	ICMA-00888 x A5RLT-109	10.78**	-1.74	9.71**	16.35**	5.43	18.78**	30.51**	26.62**	-0.59	23.76**	20.66**	27.81**
3	ICMA-00888 x A5RLT-110	3.96*	-7.08**	1.94	16.04**	7.15*	20.72**	23.17**	21.64**	-4.49	17.99*	7.32	7.98
4	ICMA-00888 x A5RLT-112	-6.28**	-17.80**	-5.83**	19.81**	11.72**	25.86**	58.29**	56.72**	23.05**	14.65*	8.94	9.61
5	ICMA-00888 x A5RLT-116	0.00	-10.62**	-1.94	12.06**	3.13	16.19**	11.41*	11.14	-12.30*	20.63**	17.07*	17.79*
6	ICMA-00888 x A5RLT-120	3.63*	-3.85*	-2.91	14.24**	12.16**	26.37**	15.80**	14.95*	-8.40	37.69**	30.69**	31.49**
7	ICMA-00888 x A5RLT-123	-5.83**	-17.09**	-5.83**	7.06*	3.97	24.32**	23.24**	8.99	11.33*	13.27*	10.42	16.97*
8	ICMA-00888 x A5RLT-125	3.06	-5.61**	-1.94	29.81**	17.27**	32.12**	22.33**	14.85**	2.73	3.71	2.24	2.86
9	ICMA-96666 x A5RLT-108	7.46**	-5.26**	4.85*	26.03**	17.85**	25.40**	3.57	-1.82	-26.37**	15.93*	12.13	15.34*
10	ICMA-96666 x A5RLT-109	4.95**	-7.83**	2.91	19.81**	11.43**	18.56**	21.52**	20.57**	-9.57*	19.49**	17.76*	24.74**
11	ICMA-96666 x A5RLT-110	0.00	-11.50**	-2.91	19.64**	13.46**	20.72**	26.80**	25.51**	-3.91	42.83**	28.63**	32.31**
12	ICMA-96666 x A5RLT-112	1.46	-11.86**	0.97	34.78**	29.11**	37.37**	19.79**	18.27**	-8.98	33.40**	25.45**	29.04**
13	ICMA-96666 x A5RLT-116	1.00	-10.62**	-1.94	34.47**	27.08**	35.22**	14.97**	12.13*	-11.52*	10.35	5.96	9.00
14	ICMA-96666 x A5RLT-120	3.66*	-4.81*	-3.88*	2.74	1.72	10.43**	4.29	1.23	-19.34**	8.15	1.59	4.50
15	ICMA-96666 x A5RLT-123	-1.96	-14.53**	-2.91	-13.53**	-18.29**	-2.30	-3.20	-16.06**	-14.26**	-8.13	-9.46	-4.09
16	ICMA-96666 x A5RLT-125	5.15**	-4.67*	-0.97	-11.80**	-18.22**	-12.99**	8.31	-0.44	-10.94*	6.83	4.17	7.16
17	ICMA-88004 x A5RLT-108	3.81*	-4.39*	5.83**	3.03	-8.23*	8.74*	-4.46	-16.81**	-24.61**	29.55**	23.55**	30.88**
18	ICMA-88004 x A5RLT-109	-3.32*	-11.30**	-0.97	-3.73	-14.69**	1.08	4.51	-5.17	-14.06**	4.63	4.63	10.84
19	ICMA-88004 x A5RLT-110	5.26**	-2.65	6.80**	-16.92**	-25.02**	-11.15**	-11.21*	-18.10**	-25.78**	31.38**	16.80*	23.72**

Table 5. (Contd...)

Sl. No.	Croses	Days to 50% flowering			Plant height (cm)			Ear head length (cm)			Ear head girth (cm)		
		Percent Heterosis over											
		Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent
20	ICMA-88004 x A5RLT-112	-1.87	-11.02**	1.94	-4.28	-12.78**	3.35	0.93	-6.68	-15.43**	27.37**	18.15*	25.15**
21	ICMA-88004 x A5RLT-116	7.18**	-0.88	8.74**	-33.66**	-40.32**	-29.28**	-29.03**	-33.62**	-39.84**	-8.05	-12.93	-7.77
22	ICMA-88004 x A5RLT-120	13.00**	8.65**	9.71**	-31.78**	-34.64**	-22.55**	-21.33**	-26.08**	-33.01**	-6.04	-12.93	-7.77
23	ICMA-88004 x A5RLT-123	5.16**	-4.27*	8.74**	-39.08**	-39.35**	-27.48**	-31.31**	-35.18**	-33.79**	-2.90	-2.90	2.86
24	ICMA-88004 x A5RLT-125	5.42**	0.00	3.88*	-19.64**	-28.99**	-15.86**	-17.79**	-18.32**	-25.98**	-5.82	-9.46	-4.09
25	ICMA-81A x A5RLT-108	4.31**	-4.39*	5.83**	-2.72	-14.40**	4.32	22.31**	11.48	-8.98	4.41	3.11	1.64
26	ICMA-81A x A5RLT-109	3.81*	-5.22**	5.83**	-21.24**	-31.05**	-15.97**	-5.53	-10.05	-26.56**	2.20	-1.35	4.50
27	ICMA-81A x A5RLT-110	3.85*	-4.42*	4.85*	-21.09**	-29.66**	-14.28**	-3.95	-6.94	-24.02**	22.94**	12.86	11.25
28	ICMA-81A x A5RLT-112	7.04**	-3.39*	10.68**	-13.86**	-22.49**	-5.54	10.59*	7.42	-12.30*	6.81	2.49	1.02
29	ICMA-81A x A5RLT-116	-3.85*	-11.50**	-2.91	-20.31**	-29.19**	-13.71**	8.52	6.70	-12.89**	15.34*	13.07	11.45
30	ICMA-81A x A5RLT-120	-0.50	-4.81*	-3.88*	-27.91**	-31.85**	-16.94**	-12.11*	-13.16*	-29.10**	8.87	4.36	2.86
31	ICMA-81A x A5RLT-123	-8.49**	-17.09**	-5.83**	-10.43**	-11.28**	8.13*	-21.36**	-29.25**	-27.73**	-11.60	-14.67*	-9.61
32	ICMA-81A x A5RLT-125	1.98	-3.74*	0.00	-22.37**	-32.23**	-17.41**	-13.47**	-17.25**	-25.98**	5.62	5.19	3.68
33	ICMA-94555(o) x A5RLT-108	-4.35**	-13.16**	-3.88*	-2.45	-10.33**	-0.97	-0.52	-10.65	-24.61**	19.47**	8.30	28.02**
34	ICMA-94555(o) x A5RLT-109	3.85*	-6.09**	4.85*	-13.93**	-21.30**	-13.09**	10.12	3.24	-12.89**	11.31*	5.54	24.74**
35	ICMA-94555(o) x A5RLT-110	0.97	-7.96**	0.97	-15.20**	-20.98**	-12.73**	-2.43	-6.94	-21.48**	12.74*	-4.33	13.09
36	ICMA-94555(o) x A5RLT-112	-4.27**	-14.41**	-1.94	-11.20**	-16.42**	-7.70*	12.83*	7.87	-8.98	-19.88**	-29.24**	-16.36*
37	ICMA-94555(o) x A5RLT-116	-2.91	-11.50**	-2.91	-4.05	-10.88**	-1.58	22.97**	18.98**	0.39	41.02**	26.99**	50.10**
38	ICMA-94555(o) x A5RLT-120	-0.51	-5.77**	-4.85*	-20.53**	-21.21**	-12.99**	4.76	1.85	-14.06**	24.31**	9.69	29.65**
39	ICMA-94555(o) x A5RLT-123	-5.71**	-15.38**	-3.88*	-20.36**	-23.41**	-8.42*	-1.36	-9.94*	-8.01	-14.05*	-18.51**	-3.68
40	ICMA-94555(o) x A5RLT-125	3.00	-3.74*	0.00	-7.70*	-15.86**	7.09	18.20**	14.85**	2.73	20.45**	10.03	30.06**

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Table 5. (Contd...)

Sl. No.	Croses	No. of pr. Tillers/plant			Test weight (g)			Grain Yield (Kg/Plot)			Fodder Yield (Kg/plot)		
		Percent Heterosis over											
		Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent
1	ICMA-00888 x A5RLT-108	35.90	8.16	82.76 *	176.92 **	164.71 **	57.89 **	203.92 **	174.34 **	25.00 **	3.02	-11.20 *	36.20 **
2	ICMA-00888 x A5RLT-109	78.38 **	34.69	127.59 **	65.08 **	52.94 **	-8.77	81.46 **	64.60 **	-25.00 **	23.08 **	5.60	61.96 **
3	ICMA-00888 x A5RLT-110	51.28 *	20.41	103.45 **	7.46	5.88	-36.84 **	-17.97 *	-26.57 **	-57.66 **	-16.36 **	-28.40 **	9.82
4	ICMA-00888 x A5RLT-112	81.82 **	42.86	141.38 **	56.52 **	54.29 **	-5.26	29.66 **	24.39 *	-38.31 **	-2.92	-13.60 **	32.52 **
5	ICMA-00888 x A5RLT-116	51.22 *	26.53	113.79 **	131.25 **	117.65 **	29.82 **	145.32 **	120.35 **	0.40	8.97 *	-2.80	49.08 **
6	ICMA-00888 x A5RLT-120	77.22 **	42.86	141.38 **	123.19 **	120.00 **	35.09 **	59.00 **	40.71 **	-35.89 **	21.99 **	3.20	58.28 **
7	ICMA-00888 x A5RLT-123	28.95	0.00	68.97	37.50 **	29.41 **	-22.81 **	24.10 *	7.08	-51.21 **	17.48 **	-3.20	48.47 **
8	ICMA-00888 x A5RLT-125	76.00 **	34.69	127.59 **	13.43	11.76	-33.33 **	14.42	8.85	-50.40 **	12.72 **	2.80	57.67 **
9	ICMA-96666 x A5RLT-108	73.53 **	51.28	103.45 **	150.85 **	138.71 **	29.82 **	77.95 **	38.65 **	-8.87	-21.59 **	-28.83 **	-3.07
10	ICMA-96666 x A5RLT-109	96.87 **	61.54 *	117.24 **	128.07 **	124.14 **	14.04 *	101.57 **	57.67 **	3.63	0.25	-9.46	23.31 **
11	ICMA-96666 x A5RLT-110	73.53 **	51.28	103.45 **	57.38 **	45.45 **	-15.79 *	-7.19	-12.88	-42.74 **	-31.50 **	-38.29 **	-15.95 *
12	ICMA-96666 x A5RLT-112	28.36	10.26	48.28	100.00 **	80.00 **	10.53	55.94 **	36.81 **	-10.08 *	6.47	0.00	36.20 **
13	ICMA-96666 x A5RLT-116	55.56 *	43.59	93.10 *	13.79	10.00	-42.11 **	10.67	-14.11	-43.55 **	4.78	-1.35	34.36 **
14	ICMA-96666 x A5RLT-120	24.64	10.26	48.28	20.63 *	8.57	-33.33 **	-36.80 **	-51.53 **	-68.15 **	10.89 *	-1.35	34.36 **
15	ICMA-96666 x A5RLT-123	30.30	10.26	48.28	51.72 **	46.67 **	-22.81 **	-34.69 **	-50.92 **	-67.74 **	-24.48 **	-34.68 **	-11.04
16	ICMA-96666 x A5RLT-125	63.08 *	35.90	82.76 *	73.77 **	60.61 **	-7.02	35.85 **	10.43	-27.42 **	-22.90 **	-25.68 **	1.23
17	ICMA-88004 x A5RLT-108	51.52	35.14	72.41	-10.45	-16.67	-47.37 **	-32.17 **	-43.88 **	-68.55 **	17.46 **	2.21	13.50 *
18	ICMA-88004 x A5RLT-109	90.32 **	59.46 *	103.45 **	23.08 *	11.11	-29.82 **	17.75	-2.16	-45.16 **	15.65 **	1.12	11.04
19	ICMA-88004 x A5RLT-110	81.82 **	62.16 *	106.90 **	53.62 **	47.22 **	-7.02	0.00	-1.40	-43.15 **	67.95 **	47.19 **	60.74 **

Table 5. (Contd...)

Sl. No.	Croses	No. of pr. Tillers/plant			Test weight (g)			Grain Yield (Kg/Plot)			Fodder Yield (Kg/plot)		
		Percent Heterosis over											
		Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent	Mid parent	Better parent	Standard parent
20	ICMA-88004 x A5RLT-112	50.77	32.43	68.97	18.31 *	16.67	-26.32 **	23.66 **	16.55	-34.68 **	32.52 **	11.79 *	33.74 **
21	ICMA-88004 x A5RLT-116	2.86	-2.70	24.14	3.03	-5.56	-40.35 **	-12.66	-28.06 **	-59.68 **	13.33 *	-4.59	14.72 *
22	ICMA-88004 x A5RLT-120	46.27	32.43	68.97	-29.58 **	-30.56 **	-56.14 **	-51.33 **	-60.43 **	-77.82 **	-7.49	-17.92 **	-12.88
23	ICMA-88004 x A5RLT-123	65.62 *	43.24	82.76 *	-27.27 **	-33.33 **	-57.89 **	-34.84 **	-48.20 **	-70.97 **	6.08	-3.09	-3.68
24	ICMA-88004 x A5RLT-125	87.30 **	59.46 *	103.45 **	-39.13 **	-41.67 **	-63.16 **	-42.74 **	-50.36 **	-72.18 **	37.65 **	13.59 *	43.56 **
25	ICMA-81A x A5RLT-108	24.44	-8.20	93.10 *	-25.37 **	-30.56 **	-56.14 **	-44.70 **	-52.38 **	-75.81 **	-14.21 **	-14.92 *	-5.52
26	ICMA-81A x A5RLT-109	16.28	-18.03	72.41	13.85	2.78	-35.09 **	-39.45 **	-47.62 **	-73.39 **	-7.00	-7.26	1.84
27	ICMA-81A x A5RLT-110	31.11	-3.28	103.45 **	39.13 **	33.33 **	-15.79 *	-13.01	-18.18 *	-52.82 **	-6.18	-6.18	2.45
28	ICMA-81A x A5RLT-112	32.58	-3.28	103.45 **	35.21 **	33.33 **	-15.79 *	-7.63	-8.73	-53.63 **	-27.61 **	-30.77 **	-17.18 *
29	ICMA-81A x A5RLT-116	10.64	-14.75	79.31 *	33.33 **	22.22 *	-22.81 **	-12.04	-24.60 *	-61.69 **	-20.86 **	-24.49 **	-9.20
30	ICMA-81A x A5RLT-120	36.26	1.64	113.79 **	52.11 **	50.00 **	-5.26	17.37	-0.79	-49.60 **	-21.94 **	-23.03 **	-15.95 *
31	ICMA-81A x A5RLT-123	-34.09	-52.46 **	0.00	69.70 **	55.56 **	-1.75	19.23	-1.59	-50.00 **	0.00	-4.49	4.29
32	ICMA-81A x A5RLT-125	28.74	-8.20	93.10 *	71.01 **	63.89 **	3.51	50.88 **	36.51 **	-30.65 **	-28.65 **	-33.50 **	-15.95 *
33	ICMA-94555(o) x A5RLT-108	19.40	5.26	37.93	43.24 **	23.26 **	-7.02	24.79 **	2.10	-41.13 **	-27.23 **	-37.89 **	-2.45
34	ICMA-94555(o) x A5RLT-109	46.03	21.05	58.62	77.78 **	48.84 **	12.28 *	93.19 **	58.74 **	-8.47	-13.56 **	-26.56 **	15.34 *
35	ICMA-94555(o) x A5RLT-110	46.27	28.95	68.97	10.53	-2.33	-26.32 **	-29.37 **	-29.37 **	-59.27 **	-2.30	-17.19 **	30.06 **
36	ICMA-94555(o) x A5RLT-112	69.70 *	47.37	93.10 *	64.10 **	48.84 **	12.28 *	69.92 **	58.04 **	-8.87	-21.06 **	-30.47 **	9.20
37	ICMA-94555(o) x A5RLT-116	57.75 *	47.37	93.10 *	58.90 **	34.88 **	1.75	55.36 **	26.57 **	-27.02 **	-9.29 *	-19.92 **	25.77 **
38	ICMA-94555(o) x A5RLT-120	61.76 *	44.74	89.66 *	53.85 **	39.53 **	5.26	74.78 **	40.56 **	-18.95 **	-3.50	-19.14 **	26.99 **
39	ICMA-94555(o) x A5RLT-123	84.62 **	57.89 *	106.90 **	12.33	-4.65	-28.07 **	-14.67	-32.87 **	-61.29 **	-11.96 **	-28.12 **	12.88
40	ICMA-94555(o) x A5RLT-125	106.25 **	73.68 *	127.59 **	42.11 **	25.58 **	5.26	33.88 **	60.78 **	-8.89	5.63	-4.69	49.69 **

For ear head girth, hybrid ICMA-96666 x A5RLT-110 recorded highly significant positive relative heterosis (42.83), heterobeltiosis (28.63) and standard heterosis (32.31) and the cross ICMA-94555(o) x A5RLT-116 was atpar with ICMA-96666 x A5RLT-110 in all type of estimates. Cross combination showed ICMA-94555(o) x A5RLT-125 highly significant positive relative heterosis (106.25), heterobeltiosis (73.68) and standard heterosis (127.59) for the trait Number of productive tillers per plant and the cross ICMA-96666 x A5RLT-109 was atpar with ICMA-94555(o) x A5RLT-125 in all type of estimates (14 and 15). For test weight, hybrid ICMA-00888 x A5RLT-108 recorded highest and significantly positive relative heterosis (176.92), heterobeltiosis (164.71) and standard heterosis (57.89). Cross ICMA-00888 x A5RLT-108 showed highest and significantly positive relative heterosis (203.92 per cent), heterobeltiosis (174.34 per cent) and standard heterosis (25.00 per cent) for grain yield per plot and for fodder yield per plot. The hybrid ICMA-88004 x A5RLT-110 recorded highest and significantly positive relative heterosis (67.95 per cent), heterobeltiosis (47.19 per cent) and standard heterosis (60.74 per cent) (Arulselvi *et al.*, 2006).

CONCLUSION

From the above results it can be concluded that most of the characters are governed by additive gene action. The *perse* performance has influence on the combining ability of the parents, wide variability was not observed in parental lines selected for this study. Although the parents differed significantly for days to 50% flowering, plant height, ear length and test weight. They did not show significant difference for important characters such productive tillers per plant, grain yield and fodder yield. Hence, it is necessary to select diverse parental lines to develop high yielding hybrids/varieties.

The general expectation of the pearlmillet farmers is mainly focused on level of superiority of newly released hybrids than the local standard hybrids, which is grown widely. So there is a compulsion need for the breeder to evaluate the newly developed hybrids with such standard hybrids for yield or any other desirable characters. With this point of views the hybrids generated in the present investigation were evaluated and selected on their standard heterosis values. The hybrid Kaveri was used as standard hybrid. At the end ICMA-00888 x A5RLT-108 was selected as best cross since they expressed high standard heterosis over standard hybrid (Kaveri) for many of the traits studied for high grain yield.

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