Forage Res., **41** (2) : pp. 78-84 (2015) **http://forageresearch.in**

COMBINING ABILITY STUDIES IN PEARL MILLET [*PENNISETUM GLAUCUM* (L.) R. BR.]

R. BHARDWAJ*, M. KAUR, R. S. SOHU AND D. P. SINGH

Department of Plant Breeding & Genetics
Punjab Agricultural University,
Ludhiana-141 004 (Punjab), India
**(e-mail : ruchipau@gmail.com)*

(Received : 10 September 2015; Accepted : 15 September 2015)

SUMMARY

Combining ability and heterosis estimates were worked out through line x tester analysis of 40 hybrids developed by crossing 10 pearl millet lines as males with four cytoplasmic male sterile (CMS) lines as females. Preponderance of non-additive gene effects was realized by higher values of specific combining ability (sca) compared to general combining ability (gca), ratio of variances of gca to sca for all the traits studied except for dry fodder yield. The estimates of gca effects indicated that PB 543A and PIB 258 were good general combiners for grain yield among the female and male parents, respectively. Cross combinations PB 543A x PIB 145, PB 543A x PIB 141 and PB 409A x PIB 141 were found to be the best specific combinations for grain yield. For grain yield, maximum MPH and BPH was observed by the cross PB 543A x PIB 136.

Key words : Pearl millet, line x tester, heterosis, grain yield

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an important coarse grain drought tolerant warm-season cereal and is commonly known as bajra in different parts of the world. It is a highly cross-pollinated diploid (2x=14) annual C_4 crop with protogynous flowering and wind-borne pollination mechanism, amenable for development of heterozygous populations, which can be utilized for the production of high grain yielding hybrids. Pearl millet provides nutritionally superior and staple food for millions of people. As the grain has higher levels of protein content with balanced amino acids, CHO and fat which are important in the human diet, and its nutritive value is considered to be comparable to rice and wheat. It is also cultivated as green fodder crop in some parts of the country. The green fodder is more palatable because it does not have HCN content as that of sorghum.

India is the largest producer of pearl millet both in terms of area (8.69 mha) and production (10.05 mt) with an average productivity of 1156 kg/ha in 2011-12 (Anonymous, 2013). In order to realize substantial production and varietal improvement in this allogamous crop, the study on gene effects controlling various characters is essential as high yielding parent or line may or may not combine well when used in hybridization. The knowledge of combining ability effects and the corresponding variances is important in the choice of selecting parents and it can be further used for exploiting heterosis to produce high performing new recombinants. Many biometrical procedures have been developed to obtain information on combining ability and line x tester analysis is one among them which is widely used to study combining ability of the parents to be chosen for heterosis breeding. It also provides a guideline to determine the value of source populations and appropriate procedures to be used in crop improvement programme. The recombination of different desirable traits spread over in different diverse genotypes is important to recombine for the improvement of yield and its related traits in any crop. In the present study, attempts were made to understand heterosis and combining ability in pearl millet.

MATERIALS AND METHODS

The material for study comprised four male sterile lines viz., ICMA 92333, ICMA 94333, PB 409A and PB 543A crossed with 10 inbred lines viz., PIB 213, PIB 626, PIB 686, PIB 306, PIB 145, PIB 141, PIB 226, PIB 136, PIB 121 and PIB 258. Crosses were attempted in a line x tester mating design using four male sterile lines as female parents and 10 inbred lines as testers during **kharif** 2013. Resulting 40 hybrids along with their 14 parents were raised in randomized block design with two replications at Research Farm, Forage and Millet Section, Department of Plant Breeding & Genetics, Punjab Agricultural University, Ludhiana during **kharif** 2014. Each hybrid accommodated two rows with a row length of 4 m. The row to row spacing of 50 cm and plant to plant spacing of 15 cm was maintained. Uniform and recommended cultural practices were followed to raise agronomically good crop. The observations were recorded on five randomly selected plants for seven characters viz., days to 50 per cent flowering, plant height, panicle length, panicle girth, number of tillers per plant, fodder yield and grain yield. The expression of heterosis was measured in terms of relative heterosis in relation to mid parent and better parent. Combining ability analysis was carried out as per the procedure of line x tester mating scheme (Kempthorne, 1957). Heterosis was calculated following method of Hayes *et al.* (1955).

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among the genotypes for all the characters studied, thus indicating the existence of considerable amount of genetic variability in the experimental material. Analysis of variance for combining ability revealed that the variance due to gca and sca was highly significant for all the traits studied. This indicates presence of adequate amount of variation in the experimental material. The significant mean squares due to line x tester interaction for these traits indicated that sca attributed heavily in the expression of these traits and provided the importance of dominance or non-additive variances for most of the traits. The significant mean squares of lines and testers also revealed the prevalence of additive variances for the traits studied. Occurrence of both additive and non-additive gene effects for yield and important yield component traits in pearl millet has been reported in earlier studies (Pethani *et al.*, 2004).

Major role of non-additive gene effects in the manifestation of all the traits except dry fodder yield was observed by higher value of specific combining ability variance (σ^2 sca) than the general combining ability variance (σ^2 gca) and the ratio of σ^2 gca/σ^2 sca being less than one (Table 1). Importance of non-additive genes for expression of yield and its components was also reported (Azhaguvel and Jayaraman, 1998; Yadav *et al.*, 2002; Parmar *et al.*, 2013).

The gca effects varied significantly for different characters and different parents under study (Table 2). However, to find the good parent for subsequent hybrid development, variation in gca effects was estimated among lines and testers for all the traits. For grain yield, two lines viz., PB 543A and PB 409A and among the testers, PIB 258, PIB 145, PIB 136, PIB 306, PIB 121 and PIB 686 exhibited highest and significant gca values for grain yield indicating the high concentration of favourable genes. PIB 686 is restorer parent of two PAU released hybrids. The best general combiners for panicle length among the lines were PB 409A and PB 543A and

TABLE 1
Analysis of variance for combining ability for different characters

Source	d. f.	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	No. of tillers	Dry fodder yield (g)	Grain yield (g)
				Mean sum of squares				
Replications	1	4.08*	0.06	4.28*	5.43*	0.01	0.21	23.14*
Lines	3	104.21*	6159.80*	114.77*	1.17*	1.98*	5.77*	2411.54*
Testers	9	15.53*	1064.06*	23.98*	1.64*	0.14*	0.31	1252.65*
Lines x testers	27	25.23*	1187.13*	28.66*	0.31	0.21*	0.61	1023.50*
Error	53	3.06	1.35	0.26	5.43	0.01	0.49	54.71
				Estimates of variance				
σ^2gca		2.47	173.19	2.91	0.12	0.06	0.17	57.76
σ^2sca		11.08	592.89	14.20	0.66	0.10	0.06	484.39
σ^2gca/σ^2sca		0.22	0.29	0.20	0.18	0.60	2.83	0.12

*Significant at P=0.05 level.

TABLE 2
Estimate of general combining ability (sca) effects of parents

Parents	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	No. of tillers	Dry fodder yield (g)	Grain yield (g)
Lines							
ICMA 92333	2.19*	26.29*	-0.49*	0.75*	0.21*	0.76*	-11.25*
ICMA 94333	1.59*	-9.96*	-3.12*	-0.45*	-0.27*	-0.38*	-7.55*
PB 409A	-2.26*	-8.06*	2.41*	-0.1	0.33*	0.00	8.55*
PB 543A	-1.11*	-8.28*	1.21*	-0.2	-0.27*	-0.38*	10.25*
C. D. (P=0.05)	0.679	0.452	0.198	0.216	0.026	0.271	2.872
Testers							
PIB 213	1.44*	-1.76*	0.73*	0.13	-0.14*	0.13	1.18
PIB 626	0.44	0.93*	0.54*	0.44*	0.11*	-0.03	-14.82*
PIB 686	1.81*	-11.01*	-2.64*	-0.63*	-0.14*	0.17	8.55*
PIB 306	1.06	0.12	2.67*	-0.06	0.17*	0.06	9.55*
PIB 145	0.31	6.18*	-0.58*	0.19	-0.02	0.03	15.93*
PIB 141	0.81	18.49*	-1.58*	-0.31	-0.02	0.16	-12.2*
PIB 226	-0.94	17.81*	1.67*	0.19	0.23*	0.16	-10.2*
PIB 136	-2.06*	-16.38*	-1.77*	-0.56*	-0.14*	-0.45	11.05*
PIB 121	-2.06*	-6.01*	1.67*	0.44*	-0.02	-0.02	8.8*
PIB 258	-0.81	-8.38*	-0.71*	0.19	-0.02	-0.20	17.82*
C. D. (P=0.05)	1.177	0.783	0.344	0.374	0.045	0.469	4.974

*Significant at P=0.05 level.

among the testers were PIB 306, PIB 226 and PIB 121. For panicle girth, line ICMA 92333 and testers PIB 626 and PIB 121 exhibited maximum gca.

Among the lines, PB 409A and PB 543A were the best general combiners for earliness, whereas among testers, PIB 136 and PIB 121 appeared to be the best general combiners for earliness. This indicated that the experimental material had differential nicking ability of the parents. For dwarf plant height, lines ICMA 94333, PB 409A, PB 543A and testers PIB 136 and PIB 686 appeared to be the best general combiners. The line PB 409A and tester PIB 226 exhibited highest gca for number of tillers. For dry fodder yield, line ICMA 92333 and tester PIB 686 appeared to be the best general combiners.

The estimates of sca effects and heterosis for different cross combinations are mentioned in Tables 3 and 4, respectively. Since yield per plant is ultimate goal of breeding and hybrid development programme, the estimates revealed that the crosses PB 543A x PIB 145, PB 543A x PIB 141 and PB 409A x PIB 141 were the best specific cross combinations for grain yield. It was also observed that crosses which showed significant sca effect for grain yield per plant, also exhibited significant heterosis and further such crosses invariably had one parent with significant gca effect. The present study and earlier reports by Latha and Shanmugasundaram (1998) and Lakshmana *et al*. (2011) clearly indicated that the grain yield was predominantly under the control of non-additive gene action. The study also indicated that even if one parent showed negative gca effect but its *per se* performance was high, it could yield good hybrid in a cross combination.

Best specific combination for earliness was derived from cross PB 543A x PIB 136 (-10.64). Both the parents exhibited negative gca effect indicating the role of complementary gene action in the inheritance of days to 50 per cent flowering. Best specific cross combination for panicle girth was ICMA 94333 x PIB 626 (2.14), whereas ICMA 94333 exhibited maximum negative gca for the trait. Highest specific cross combination for panicle length was observed in cross PB 543A x PIB 226 (7.34), which included both the parents with good gca.

The hybrid PB 409A x PIB 626 exhibited maximum sca for number of tillers. The female parent PB 409A also exhibited highest gca for this trait. Best specific combination for dry fodder yield was derived from ICMA 94333 x PIB 213. ICMA 94333 exhibited negative gca for this trait, whereas PIB 213 exhibited good gca. PIB 213 is the restorer parent of one of the PAU bred fodder hybrids.

The best crosses selected on the basis of sca

TABLE 3
Estimation of specific combining ability effects for different traits for the crosses

Crosses	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	No. of tillers	Dry fodder yield (g)	Grain yield (g)
ICMA 92333A x PIB 213	-0.44	22.71*	4.24*	-0.25	-0.33*	-0.16	24.13*
ICMA 92333A x PIB 626	0.06	19.52*	-0.57	-0.06	-0.58*	0.10	9.63*
ICMA 92333A x PIB 686	-3.81*	-3.04*	-2.38*	-1.00*	-0.33*	-0.60	5.75
ICMA 92333A x PIB 306	-3.56*	21.08*	-1.94*	0.44	0.61*	0.06	-12.25*
ICMA 92333A x PIB 145	-1.31	22.27*	4.81*	0.94*	0.04	0.45	-3.13
ICMA 92333A x PIB 141	1.19	20.21*	-0.69	-0.318	0.04	0.76	-8.50
ICMA 92333A x PIB 226	0.94	23.14*	-0.94*	-0.31	0.79*	0.92*	-6.50
ICMA 92333A x PIB 136	3.06*	-59.92*	-3.26*	-0.06	-0.33	-0.76	5.75
ICMA 92333A x PIB 121	3.06*	-23.29*	-0.94*	0.94*	0.04	-0.44	-25.50*
ICMA 92333A x PIB 258	0.81	-42.69*	1.68*	-0.31	0.04	-0.33	10.63*
ICMA 94333A x PIB 213	-0.84	-3.04*	-1.38*	0.45	0.14*	1.01*	-24.08*
ICMA 94333A x PIB 626	-0.84	-4.23*	6.56*	2.14*	-0.11	-0.08	-5.75
ICMA 94333A x PIB 686	-0.71	-2.04*	1.24*	1.20*	0.14*	-0.37	-18.95*
ICMA 94333A x PIB 306	-0.46	-26.92*	-2.07*	-0.86*	-0.17*	-0.38	14.55*
ICMA 94333A x PIB 145	-0.21	-7.48*	-1.57*	-0.61*	0.02	-0.12	-11.33*
ICMA 94333A x PIB 141	1.29	16.96*	-0.32	0.39	0.02	-0.28	10.80*
ICMA 94333A x PIB 226	-0.46	-36.11*	-7.32*	-0.61*	-0.23	-0.25	22.30*
ICMA 94333A x PIB 136	2.66	17.83*	1.37*	-1.36*	0.14*	0.31	9.55*
ICMA 94333A x PIB 121	0.16	22.46*	2.93*	-0.86*	0.02	0.03	5.79
ICMA 94333A x PIB 258	-0.59	22.58*	0.56	1.38*	0.02	0.13	-8.08
PB 409A x PIB 213	-2.59	-6.19*	-1.41*	0.10	0.04	-0.83	17.83*
PB 409A x PIB 626	-3.09*	0.87	0.03	-0.71*	0.798	-0.49	-18.18*
PB 409A x PIB 686	4.04*	5.81	5.47*	0.35	0.04	0.66	22.45*
PB 409A x PIB 306	-1.21	3.18*	2.66*	0.29	-0.27*	0.67	-22.05*
PB 409A x PIB 145	-0.46	-10.38*	-4.09*	-0.21	-0.08	-0.02	-27.93*
PB 409A x PIB 141	-2.96	-13.44*	-0.59	-0.96*	-0.08	0.07	39.70*
PB 409A x PIB 226	-1.21	-11.76*	0.91*	0.04	-0.33*	-0.11	-16.80*
PB 409A x PIB 136	4.91*	12.18*	0.84*	0.29	0.04	0.28	-23.55*
PB 409A x PIB 121	-1.08	1.06	0.41	0.79*	-0.08	-0.32	22.20*
PB 409A x PIB 258	3.66*	18.68*	-4.22*	0.04	-0.08	0.08	6.32
PB 543A x PIB 213	3.86*	-13.47*	-1.46*	-0.30	0.14*	-0.02	-17.88*
PB 543A x PIB 626	3.86*	-16.16*	-6.02*	-1.36*	-0.11	0.47	9.13*
PB 543A x PIB 686	0.49	-0.72	-4.33*	-0.55	0.14*	0.31	-9.25*
PB 543A x PIB 306	5.24*	2.66*	1.36*	0.14	-0.17*	-0.35	19.75*
PB 543A x PIB 145	1.99	-4.41*	0.86*	-0.11	0.02	-0.31	42.38*
PB 543A x PIB 141	0.49	-23.72*	1.61*	0.89*	0.02	-0.55	42.00*
PB 543A x PIB 226	0.74	24.72*	7.36*	0.89*	-0.23*	-0.56	1.00
PB 543A x PIB 136	-10.64*	29.91*	1.04*	1.14*	0.14*	0.17	8.25
PB 543A x PIB 121	-2.14	-0.22	-2.39*	-0.86*	0.02	0.73	-2.50
PB 543A x PIB 258	-3.88	1.41	1.98	0.14	0.02	0.12	-8.88

*Significant at P=0.05 level.

effects indicated that the crosses between high x high, high x low and low x low gca combinations produced high sca effects. This suggested that both additive as well as non-additive gene actions operated in the inheritance of traits. The present results are in consonance with those of Latha and Shanmugasundaram (1998) and Rasal and Patil (2003). Thus, high sca effects or heterosis for any cross does not necessarily depend on the gca effects of the parents involved. The superiority of that cross may be due to complementary type of gene interaction which can be exploited in the subsequent generations to obtain best cross combinations. The low x low gca combination resulted in high sca effects revealing that the genes were dispersed and when they

TABLE 4
Range of heterosis and number of crosses showing heterosis in desirable direction

Trait	Heterosis (%) over mid parent		Heterosis (%) over better parent	
	Range	No. of crosses	Range	No. of crosses
Days to 50% flowering	-18.75 to 8.7	30	-17.71 to 11.36	23
Plant height (cm)	-6.17 to 111.97	2	26.29 to 246.63	0
Panicle length (cm)	-26.25 to 144.44	35	-34.44 to 131.58	27
Panicle girth (cm)	-17.65 to65.96	36	-27.59 to 57.14	26
No. of tillers	-65.22 to 100.00	12	-69.23 to 66.67	4
Fodder yield	-73.29 to 173.33	21	-82.00 to 262.86	21
Grain yield	-50.86 to 318.75	31	-62.61 to 294.12	26

were combined together, they showed the complementary effect.

For grain yield, highest relative heterosis (MPH) and heterobeltosis (BPH) were observed by the cross PB 543A x PIB 136 (Table 5). This heterotic hybrid involved parents with high gca effect, it implied the significant parental contribution to heterosis through additive gene effects. Vetriventhan *et al*. (2008) also observed high magnitude of heterosis for grain yield. For earliness, negative relative heterosis and heterobeltosis to the magnitude of -1.03 to -18.75 per cent and -2.04 to -17.71 per cent, respectively, were observed. The maximum negative MPH (-18.75%) was observed in PB 543A x PIB 213 and BPH (-17.71%) in PB 409A x PIB 306. The lines PB 409A (-2.26) showed highest negative gca followed by PB 543A (-1.11) for this trait. With respect to heterosis for early flowering, negative heterosis of hybrids was considered desirable. Highest negative heterosis was recorded by cross PB 543A x PIB 141 (-6.17%), for the trait plant height. Here, the line PB 543A exhibited second highest negative gca for plant height, while PIB 141 exhibited highest positive gca for this trait. The dwarf plant height is desirable for breeding hybrids for grain purpose since vegetative part is not desirable. In case of panicle length, highest relative heterosis and heterobeltosis were recorded in ICMA 94333 x PIB 258. For panicle girth, highest relative heterosis and heterobeltosis were observed by the cross ICMA 94333 x PIB 686 and ICMA 94333 x PIB 258. For total number of tillers, the hybrid ICMA 92333 x PIB 226 observed highest positive relative heterosis and heterobeltosis. For dry fodder yield, the cross combination PB 409A x PIB 686 showed highest relative heterosis and PB 409A x PIB 226 showed maximum heterobeltosis. PIB 226 showed high positive gca for this trait. The cross combination PB 409A x PIB 686 also showed sixth highest sca for dry fodder yield. These results indicated that highly heterotic hybrids (crosses showing heterosis over their better parents) could be obtained from parents with any combination of gca i. e. H x H, H x L, L x H and L x L. However, the frequency of heterotic hybrids was comparatively more in H x L or L x H type of crosses. Several examples are available in published literature where high x low crosses have provided high frequency and higher magnitude of heterosis. Genotypes with high gca possessed genes capable of expressing high phenotypic effects but prevented from doing so by the retarding effect of residual genetic background (RGB). Likewise genotypes with low gca possessed low genes capable of expressing extremely low phenotypic effects but again prevented from doing so by enhancing effect of RGB.

However, no direct association between the general combining abilities of the parents involved in the crosses and heterotic response was noticed in the study which revealed that choice of best cross combination on the basis of high sca or *per se* performance would not necessarily be the one which would give high heterosis. Thus, gca, sca and *per se* performance of the crosses are equally important for transgressive breeding. In the present study, both additive and non-additive types of gene actions were important in governing all the traits studied. Therefore, bi-parental mating and/or diallel selective mating which may allow inter-mating of the selected genotypes in different cycles and exploit both additive and non-additive gene effect could be useful in the genetic improvement of the characters of pearl millet. Inclusion of F_1 hybrids showing high heterosis with significant sca effect and having at least one good general combiner parent may produce desirable transgressive segregants in advance generations.

TABLE 5

Top ranking of parents and specific cross combinations for different traits on the basis of gca, *per se* performance, sca and heterosis

Trait	Parent gca effect	*Per se* performance	*Per se* performance	sca effect	Most heterotic (MPH)	Most heterotic (BPH)
Days to 50% flowering	PB 409A	PIB 141	PB 543AA x PIB 136	PB 543AA x PIB 136	PB 543AA x PIB 213	PB 409AA x PIB 306
	PIB 136	PIB 226	PB 409AA x PIB 121	PB 543AA x PIB 258	PB 409AA x PIB 306	PB 543AA x PIB 213
	PIB 121	PIB 145	PB 543AA x PIB 258	ICMA 92333A x PIB 686	PB 409AA x PIB 121	PB 409AA x PIB 136
	PB 543A	ICMA 94333	PB 409AA x PIB 626	ICMA 92333A x PIB 306	PB 409AA x PIB 136	PB 409AA x PIB 121
	PIB 226	PB 543A	PB 543AA x PIB 121	PB 409AA x PIB 626	PB 409AA x PIB 686	PB 409AA x PIB 686
Plant height (cm)	PIB 136	PB 409A	ICMA 92333A x PIB 136	ICMA 92333A x PIB 136	PB 543AA x PIB 141	PB 543AA x PIB 306
	PIB 686	ICMA 92333	ICMA 94333A x PIB 306	ICMA 92333A x PIB 258	PB 543AA x PIB 145	PB 543AA x PIB 145
	ICMA 94333	ICMA 94333	ICMA 94333A x PIB 226	ICMA 94333A x PIB 226	ICMA 94333A x PIB 145	PB 543AA x PIB 141
	PIB 258	PIB 258	ICMA 92333A x PIB 258	ICMA 94333A x PIB 306	ICMA 92333A x PIB 136	PB 543AA x PIB 121
	PB 543A	PB 543A	PB 543AA x PIB 213	PB 543AA x PIB 141	ICMA 94333A x PIB 141	PB 543AA x PIB 213
Panicle length (cm)	PIB 306	PIB 141	PB 543AA x PIB 226	ICMA 94333A x PIB 258	ICMA 94333A x PIB 258	ICMA 94333A x PIB 258
	PB 409A	PIB 226	PB 409AA x PIB 306	PB 409AA x PIB 258	PB 543AA x PIB 258	PB 409AA x PIB 258
	PIB 226	PIB 306	PB 409AA x PIB 686	ICMA 92333A x PIB 258	PB 409AA x PIB 258	ICMA 92333A x PIB 258
	PIB 121	PB 543A	PB 543AA x PIB 306	PB 409AA x PIB 121	PB 409AA x PIB 121	PB 409AA x PIB 121
	PB 543A	PIB 686	PB 409AA x PIB 226	PB 543AA x PIB258	ICMA 92333A x PIB 258	PB 543AA x PIB 258
Panicle girth (cm)	ICMA 92333	PIB 626	ICMA 92333A x PIB 121	ICMA 94333A x PIB 626	ICMA 94333A x PIB 686	ICMA 92333A x PIB 258
	PIB 626	PIB 226	ICMA 94333A x PIB 626	ICMA 94333A x PIB 258	ICMA 92333A x PIB 121	ICMA 94333A x PIB 686
	PIB 121	PIB 306	ICMA 92333A x PIB 145	ICMA 94333A x PIB 686	PB 543AA x PIB 258	PB 409AA x PIB 258
	PIB 145	PIB 141	ICMA 92333A x PIB 626	PB 543AA x PIB 136	ICMA 92333A x PIB 145	ICMA 92333A x PIB 145
	PIB 226	PIB 121	ICMA 92333A x PIB 306	ICMA 92333A x PIB 145	ICMA 92333A x PIB 258	ICMA 92333A x PIB 121
Number of tillers	PB 409A	PB 543A	ICMA 92333A x PIB 226	PB 409AA X PIB 626	ICMA 92333A x PIB 226	ICMA 92333A x PIB 226
	PIB 226	PIB 686	PB 409AA x PIB 626	ICMA 92333A x PIB 226	PB 409AA x PIB 306	PB 409AA x PIB 306
	ICMA 92333	PIB 258	ICMA 92333A x PIB 306	ICMA 92333A x PIB 306	ICMA 92333A x PIB 306	ICMA 92333A x PIB 306
	PIB 306	ICMA 92333	ICMA 92333A x PIB 145	ICMA 94333A x PIB 213	ICMA 94333A x PIB 213	ICMA 94333A x PIB 213
	PIB 626	PB 409A	ICMA 92333A x PIB 141	ICMA 94333A x PIB 686	ICMA 92333A x PIB 145	ICMA 92333A x PIB 145
Fodder yield	ICMA 92333	PIB 141	ICMA 92333A x PIB 226	ICMA 94333A x PIB 213	PB 409AA x PIB 686	PB 409AA x PIB 226
	PIB 686	PIB 626	ICMA 94333A x PIB 226	ICMA 92333A x PIB 226	PB 409AA x PIB 136	PB 409AA x PIB 136
	PIB 141	PB 543A	PB 409AA x PIB 226	ICMA 92333A x PIB 141	ICMA 94333A x PIB 213	PB 409AA x PIB 121
	PIB 226	PIB 306	PB 543AA x PIB 226	PB 543AA x PIB 121	ICMA 92333A x PIB 306	PB 543AA x PIB 213
	PIB 213	PIB 686	ICMA 92333A x PIB 141	PB 409AA x PIB 306	ICMA 92333A x PIB 145	PB 409AA x PIB 686

REFERENCES

Anonymous, 2013 : http://www.indiastat.com.

Azhaguvel, P., and N. Jayaraman, 1998 : Combining ability and heterosis of some productivity traits in pearl millet. *Trop. Agric. Res.*, **10** : 425-432.

Hayes, H. K., F. F. Immer, and D. C. Smith, 1955 : Methods of Plant Breeding. In : *McGraw Hill Book Co. Inc.*, New York.

Kempthorne, O. 1957 : In : *An Introduction to Genetics Statistics*. John Willey and Sons, New York. pp. 545.

Lakshmana, D., B. D. Biradar, D. Madalah, and R. B. Jolli, 2011 : Combining ability studies on A_1 source cytoplasmic male sterility system in pearl millet, *Indian J. Agric. Res*., **46** : 46-61.

Latha, R., and P. Shanmugasundaram, 1998 : Combining ability studies involving new male sterile lines in pearl millet. *Madras Agric. J.*, **85** : 160-163.

Parmar, R. S., N. B. Patel, H. N. Leua, and S. P. Singh, 2013 : Combining ability and heterosis for grain yield and its traits in pearl millet (*Pennisetum glaucum* (L.) R. Br.). *Prog. Res.*, **8** : 19-23

Pethnani, K. V., Atara, S. D., and B. A. Monpara, 2004 : Heterosis and combining ability for plant and seed characters in pearl millet. *National J. Pl. Improv.*, **6** : 115-118.

Rasal, P. N., and H. S. Patil, 2003 : Line x tester analysis in pearl millet. *Agric. Sci. Digest*, **23** : 171-174.

Vetriventhan, M., A. Nirmalakumari, and S. Ganapathy, 2008 : Heterosis for grain yield components in pearl millet (*Pennisetum glaucum* (L.) R. Br.). *World J. Agric. Sci.* **4** : 657-660.

Yadav, O. P., P. S. Sabharwal, C. R. Beniwal, and Hanuman, 2002 : Combining ability study or some newly developed male sterile lines for forage attributes in pearl millet. *Forage Res.*, **27** : 277-280.