The Bioscan 11(3):1905-1911,2016(Supplement on Genetics and Plant Breeding) www.thebioscan.com
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES

COMBINING ABILITY FOR SEED YIELD AND YIELD COMPONENT CHARACTERS IN PEARL MILLET [*PENNISETUM GLAUCUM* (L.) BR.]

KHUSHBU CHITTORA[1]* AND J. A. PATEL[2]
[1]Department of Genetics and Plant Breeding,
B.A. College of Agriculture, Anand Agricultural University, Anand - 388 110, Gujarat, INDIA
[2]Regional Research Station, Anand Agricultural University, Anand - 388 110, INDIA
e-mail: chittorakhushbu23@gmail.com

KEYWORDS
Pearl millet
Combining ability
Line × tester analysis
Potence ratio
Predictability ratio

Received on :
14.08.2016

Accepted on :
21.09.2016

***Corresponding author**

ABSTRACT

Significant mean sum of squares of both GCA and SCA for all the characters indicated the presence of both additive and non-additive gene actions. σ^2gca was significant only for total tillers per plant suggesting importance of only additive genetic variance for inheritance of the character whereas σ^2sca was significant for number of effective tillers per plant, average internode length, ear heads weight per plant, grains yield and panicle harvest index suggesting prime importance of non-additive genetic variance for inheritance. Above unity estimate of potence ratio and above one half (0.5) value of predictability ratio for plant height, ear head length, ear head girth, and total protein content suggested preponderance of additive genetic variance. Whereas, less than unity estimate of potence ratio and less than one half (0.5) value of predictability ratio for number of leaves per plant and dry fodder yield per plant suggested prime importance of non-additive genetic variance for inheritance of both the characters. Lines JMSA-9904 and ICMA-99555 were good general combiners for grain yield and other traits. In general for yield and other yield attributing traits the promising hybrids with significant standard heterosis and significant sca value were JMSA-9904 × AIB-15, JMSA-9904 × AIB-30 and ICMA-99555 × AIB-30.

INTRODUCTION

Pearl millet (*Pennisetum glaucam* (L.) R. Br., with 2n = 2x = 14, belongs to family Poaceae and it is indigenous to Abyssinian center of origin. It is a warm season, annual, C_4 and cross pollinated crop with wind pollination mechanism. It is well adapted to adverse agro climatic conditions like poor soils, inadequate and poorly distributed rainfall and short growing season, thereby it is highly preferred by the farmers of arid and semi arid regions. It is an important source of food and fodder of arid and semi-arid regions of India and Africa. India is the largest producer of this crop in Asia in terms of area and production. In India, pearl millet occupies an area of 9.61 million hectares with production of 10.37 million tones and productivity of 1079 kg/ha in 2011-12 (Anon,2012).

The improvement in this crop in India started as early as in 1920, but the real breakthrough was made when the first, and the most widely used cytoplasmic genetic male sterile line *tift* 23A was utilized (Burton, 1965), which permitted development of hybrids in India. With development and extensive testing of single crosses with Tift $23A_1$, Indian breeders could able to announce the release of 'HB–1' hybrid in 1965 (Athwal, PAU, 1965). Subsequently, availability of several cytoplasmic genetic male sterility systems have facilitated development and release of number of hybrids with increased seed yield, resistance to both biotic and abiotic stress, mainly downy mildew, drought tolerance and heat tolerance. Among the several breeding method heterosis breeding is considered to be one of the outstanding method for this crop.

Selection of parents on the basis of phenotypic performance alone is not a sound procedure since phenotypically superior lines may yield poor recombination. It is therefore, essential that parents should be chosen on the basis of their genetic value. The *per se* performance of parent may not necessarily reveal it to be a good or poor combiner. Therefore, gathering information on nature of gene effects and their expression in terms of combining ability is necessary (Khan and Dubey, 2015). Combining ability is a powerful tool to select good combiners and thus selecting the appropriate parental lines for hybridization programme. In addition, the information on nature of gene action will be helpful to develop efficient crop improvement programme. General combining ability is due to additive and additive x additive gene action and is fixable in nature, while specific combining ability is due to non-additive gene action which may be due to dominance or epistasis or both, and is non-fixable. The presence of non-additive genetic variance is the primary justification for initiating the hybrid breeding programme (Cockerham, 1961). Among the various mating designs, line x tester technique suggested by Kempthrone (1957) and reviewed by Singh and Chaudhary (1977) was used for evaluating parents and hybrids for their combining ability effects and also for understanding the nature of gene effects. Hence, the present investigation is deals with the study of the magnitude of components of genetic variance through combining ability analysis, general combining ability effect of parents and specific combing ability effect of cross combinations.

MATERIALS AND METHODS

The experimental material for the present investigation was generated by crossing six CGMS lines *viz* JMSA-9904, JMSA-101, ICMA-08111, ICMA-92777, ICMA-96333 and ICMA-99555, obtained from Pearl Millet Research Station, Jamnagar with eight restorer pollinators *viz* AIB-6, AIB-10, AIB-14, AIB-15, AIB-17, AIB-20, AIB-28 and AIB-30; developed at Regional Research Station, AAU, Anand in line x tester manner, during summer 2014. Fourteen parents, 64 hybrids and two checks (GHB-538,GHB-558) were evaluated in Randomized Complete Block Design in three replications at the Regional Research Station, Anand Agricultural University, Anand during *kharif* 2014. All the recommended agronomic practices and plant protection measures were followed time to time to raise good crop. Five competitive plants from each experimental unit of every replication were randomly selected for recording observations for fifteen characters *viz*. days to 50% flowering, days to physiological maturity of grains, plant height (cm), number of total tillers per plant, number of effective tillers per plant, average internode length (cm), number of leaves per plant, earhead length (cm), earhead girth (cm), ear head weight per plant(g), grain yield per plant(g), dry fodder yield per plant(g), test weight (g), panicle harvest index (%) and total protein content (%).The observations taken for hybrids and parents were subjected to L×T analysis and the general combining ability effects of different crosses were worked out. The combining ability variance analysis was based on the method developed by Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis of variance for combining ability (Table1) revealed revealed that mean sum of squares due to GCA and SCA were significant for all the traits, it suggest that and non additive components of gene action. The genetic variance only due to gca effect (ó^{2}gca) was significant for number of total tillers per plant suggesting importance of only additive genetic variance for inheritance of the character, results were in accordance to Basarvaju *et al.*(1980) and Harer *et al.* (1990), However, in contrast to that, genetic variance only due to sca effects (ó^{2}sca) was significant for number of effective tillers per plant, average internode length, ear head weight, grains yield per plant and panicle harvest index. These results were in agreement of findings of Manga and Dubey (2004) and Dangariya *et al.* (2009) as they reported importance of only non-additive gene action for the inheritance of these traits.

Both σ^2gca and σ^2sca were significant for days to 50% flowering, days to physiological maturity of grain, plant height, number of leaves per plant, ear head length, earhead girth, dry fodder yield per plant, test weight and protein content, which revealed importance of both additive and non-additive components of genetic variance. The magnitude of either of component of genetic variance could be judged from the estimates of potence ratio and predictability ratio. However, above unity estimate of potence ratio and above one half (0.5) value of predictability ratio for plant height, ear head length, ear head girth, test weight and total protein content suggested preponderance of additive genetic variance, The results confirmed the findings Mohan *et al.*(1999), Manga and Dubey (2004), Dhuppe *et al.* (2006), Dangariya *et al.* (2009) and Jethva *et al.* (2011). Whereas, less than unity estimate of potence ratio and less than one half (0.5) value of predictability ratio for number of leaves per plant, dry fodder yield per plant suggested prime importance of non-additive genetic variance for inheritance of these characters, The predominance of sca effects over gca effects in the present study indicated the prime role of non-dominant gene action especially for number of effective tillers per plant, average internode length, number of leaves per plant, ear head weight, grains yield per plant , dry fodder yield per plant and panicle harvest index. Non additive gene action for grain yield was reported by Chavan and Nerkar (1994), Aher and Ugale (1995), Sahane *et al*. (1996), Karale *et al*. (1998), Latha and Shanmugasundaram (1998), Joshi *et al*. (2001), Rathore *et al*. (2004) and Dangaria *et al*. (2009)

General combining ability effects

The estimates of GCA effect (Table 2) revealed that for grain yield per plant CGMS lines JMSA-9904 and ICMA-96555 were found good general combiners. Line JMSA-9904 was also good general combiner for days to 50% flowering, days to physiological maturity of grains, plant height, number of total tillers per plant, number of effective tillers per plant, average internode length, number of leaves per plant, dry fodder yield per plant and panicle harvest index. Line ICMA-96555 was also good general combiner for ear head girth and panicle harvest index. Line JMSA-101 was found good general combiner for days to 50% flowering, days to physiological maturity of grains, number of leaves per plant, ear head length, ear heads weight per plant, dry fodder yield per plant and total protein content. On other hand, seed parents ICMA-08111, ICMA-96333 and ICMA-92777 were average or poor general combiners for most of the yield contributing characters. Among the testers, only pollen parent AIB-30 was found good general combiner for grain yield and it was also good general combiner for days to 50% flowering, number of leaves per plant, ear head length, ear head girth, dry fodder yield per plant and panicle harvest index.

Specific combining ability effects

The estimates of specific combining ability (Table 3) effect by enlarge provide information on role of non additive gene action (intra and inter-allelic interactions) in the expression of heterosis. The result narrated in table 3 revealed that out of 48 F$_1$S evaluated 12 F$_1$S *viz*. JMSA-9904 x AIB-15 (G x A), JMSA-9904 x AIB-30 (G x G), JMSA-101 x AIB-28 (A x P), ICMA-08111 x AIB-17 (P x A), ICMA-99555 x AIB-30 (G x G), JMSA-9904 x AIB-10 (G x P), ICMA-96333 x AIB-20 (P x P), ICMA-99555 x AIB-15 (G x P), ICMA-96333 x AIB-15 (P x A), ICMA-08111 x AIB-6 (P x A), ICMA-08111 x AIB-20 (P x P) and ICMA-92777 x AIB-6 (A x A) registered significant and positive sca effects for grain yield per plant. None of the crosses depicted desirable sca effects for all the characters.

In the present investigation, the best five hybrids based on the mean grain yield per plant along with the standard heterosis over the check hybrid GHB-538 and GHB-558 were compared for their sca effects and gca effects of corresponding parents (Table 4) The different estimates revealed that the best performing hybrids with high mean seed yield and positive significant sca effects for grain yield generated from either high x average (JMSA-9904 x AIB-15) high x high (JMSA-9904 ×

Table 1: Analysis of variance for combining ability for various characters in pearlmillet

Source of variation	D.F.	Days to 50 % flowering	Days to maturity of grains	Plant height	Number of total tillers per plant	Number of effective tillers per plant	Average internode length	Number of leaves per plant	Ear head length	Ear head girth	Ear heads weight per plant	Grain yield per plant	Dry fodder yield per plant	Test weight	Panicle harvest index	Total protein content
Replications	2	3.34	4.92	94.77	0.53	0.31	0.97	24.81	5.13	1.06	81.66	30.42	85.05	0.16	0.97	0.54
Lines	5	102.50**	136.66**	2921.96**	1.09*	0.15	12.6	744.37**	160.17**	7.36**	288.22	191.47	10905.82**	24.70**	118.95	9.46**
Testers	7	20.86	18.52	1239.65**	0.40	0.17	7.09	318.47	16.47	1.77	72.97	97.79	2687.01	4.68	86.53	2.65*
Lines x Testers	35	20.4**	24.01**	289.28**	0.32	0.30**	8.37**	288.48**	17.73**	1.099**	383.58**	226.42**	3386.53**	3.29**	110.86**	1.06**
Error	94	2.11	3.04	74.12	0.25	0.094	0.88	18.64	1.24	0.37	53.98	28.60	129.24	0.11	18.85	0.17
$\sigma^2_{gca(lines)}$	-	3.42**	4.64**	109.69**	0.028*	-0.01	0.18	19.00**	5.50**	0.26**	-3.97	-1.46	313.30**	0.89**	0.34	0.35**
$\sigma^2_{gca(testers)}$	-	0.02	-0.35	52.80	0.004	-0.01	-0.07	1.67	-0.07	0.04	-17.26	-7.15	-38.86	0.08	-1.35	0.09
$\sigma^2_{gca(Av.)}$	-	1.96**	2.50**	85.31**	0.0180*	0.003	0.072	11.56**	3.36**	0.16**	-9.6	-3.89	162.37**	0.54**	-0.38	0.23**
σ^2_{sca}	-	6.11**	7.31**	71.72**	0.03	0.07**	2.50**	89.85**	5.50**	0.24**	109.87**	65.94**	1090.76**	1.05**	30.67**	0.30**
Potence ratio	-	1.16	1.23	4.30	-	-	-	0.46	2.20	2.42	-	-	0.54	1.85	-	2.77
Predictability ratio	-	0.39	0.40	0.70	-	-	-	0.20	0.54	0.57	-	-	0.022	0.51	-	0.60
σ^2_A	-	3.93	5.00	170.62	0.04	-0.01	0.14	23.14	6.72	0.33	-19.33	-7.79	324.75	1.09	-0.77	0.48
σ^2_D	-	6.11	7.31	71.72	0.03	0.07	2.50	89.85	5.50	0.24	109.87	65.94	1090.76	1.06	30.67	0.30
$(\sigma^2_D/\sigma^2_A)^{0.5}$	-	1.24	1.20	0.64	0.70	2.64	4.22	1.97	0.90	0.85	2.38	2.90	1.82	0.98	6.31	0.79

Table 2: Estimates of general combining ability(GCA) effects

Parents	Days to 50 % flowering	Days to maturity of grains	Plant height	Number of total tillers per plant	Number of effective tillers per plant	Average internode Length	Number of leaves per plant	Earhead length	Ear head girth	Ear heads weight per plant	Grain yield per plant	Dry fodder yield per plant	Test weight	Panicle harvest index	Total protein Content
Lines															
JMSA-9904	-1.99**	-2.60**	-14.37**	0.34**	0.13*	-0.43*	7.62**	-0.58*	0.29	0.22	2.38*	20.58**	-0.40**	2.55*	-0.60**
JMSA-101	-1.78**	-0.81*	15.51**	-0.13	0.09	0.54*	3.46**	4.46**	-1.05**	5.69**	1.88	19.19**	-1.00**	-2.42*	1.02**
ICMA-0811	3.47**	4.53**	4.13*	0.10	-0.09	0.36	2.43**	1.49**	0.02	-1.10	-1.51	-2.05	1.23**	-0.58	-0.50**
ICMA-92777	1.26**	-0.51	3.07	0.06	-0.02	-0.30	-4.85**	-2.01**	0.56**	-3.47*	-1.64	-15.54**	1.33**	0.95	0.45**
ICMA-96333	-0.74*	-0.47	-11.24**	-0.29**	-0.05	-1.01**	-1.32	-1.33**	-0.14	-3.27	-4.09**	11.15**	-0.45**	-2.60*	-0.04
ICMA-99555	-0.24	-0.14	2.88	-0.11	-0.06	0.83**	-7.33**	-2.03**	0.34*	1.93	2.99**	-33.33**	-0.70**	2.11*	-0.32**
S.E (gi) ±	0.29	0.35	1.75	0.10	0.06	0.20	0.86	0.23	0.12	1.49	1.09	2.32	0.06	0.88	0.09
S.E.(gi - gj) ±	0.42	0.49	2.47	0.15	0.09	0.28	1.22	0.32	0.17	2.11	1.21	3.22	0.09	1.24	0.12
CD.5% .(gi - gj)	0.84	0.99	4.93	0.29	0.18	0.56	2.43	0.64	0.31	4.20	3.06	6.51	0.19	2.48	0.24
Testers															
AIB-6	-1.03**	-1.04*	-15.68**	-0.02	-0.12	0.49*	-3.60**	0.58	0.09	1.51	1.22	-16.04**	0.07	0.63	-0.25**
AIB-10	1.53**	1.46**	8.19**	-0.12	0.05	0.85*	4.43**	-0.92**	0.07	-0.01	-2.13	7.36**	-0.33**	-2.72**	0.47**
AIB-14	0.64	0.63	-1.01	0.26*	-0.01	-0.55*	-3.77**	-0.45	-0.52**	0.18	1.76	-4.31	-0.15	1.85	-0.39**
AIB-15	1.31**	0.35	1.50	-0.27*	0.07	-0.19	4.40**	0.02	0.48**	3.01	2.00	20.03**	0.35**	0.05	0.04
AIB-17	-0.36	-0.54	7.89**	0.06	0.12	0.66**	-6.68**	-0.26	0.03	-0.54	0.62	3.17	0.24**	1.34	-0.38**
AIB-20	-1.08**	-1.60**	-1.55	0.12	0.05	0.03	3.08**	-1.12**	-0.47**	-0.46	-3.08*	9.74**	0.09	-3.66**	0.69**
AIB-28	0.14	0.79	-6.77**	-0.02	-0.02	-1.06**	0.52	0.59*	0.06	-4.05*	-2.92*	-12.16**	0.72**	-0.17	-0.16
AIB-30	-1.14**	-0.04	7.39**	0.00	-0.15	-0.14	1.64	1.74**	0.35*	0.36	2.53*	7.78**	-0.99**	2.67**	0.02
S.E (gi) ±	0.35	0.41	2.02	0.122	0.074	0.23	1.00	0.26	0.14	1.73	1.26	2.67	0.078	1.02	0.09
S.E. (gi-gj) ±	0.49	0.58	2.85	0.17	0.10	0.32	1.41	0.37	0.18	2.44	1.39	3.77	0.11	1.44	0.13
CD .5% (gi - gj)	0.97	1.15	5.69	0.34	0.20	0.64	2.81	0.74	0.36	4.85	3.53	7.52	0.22	2.87	0.27

*, ** Significant at 5 % and 1 % level of significance respectively

Table 3: Estimates of specific combining ability effect of hybrids

Crosses	Days to 50 % flowering	Days to maturity of grains	Plant height	total tillersper plant	Number of effective tillers per plant	Average internode length	Number of leaves per plant	Earhead length	Ear head girth	Ear heads weight per plant	Grain yield per plant	Dry fodder yield per plant	Test weight	Panicle harvest index	Total protein content
JMSA-9904 x AIB-6	4.32**	4.21**	-1.07	-0.06	-0.26	1.04	-6.08*	-1.65*	-0.02	-6.24	-6.61*	-19.83**	0.37**	-3.34	-0.19
JMSA-9904 x AIB-10	0.10	-0.96	-8.21	0.11	0.17	-0.03	6.22*	-0.54	0.06	0.07	7.82*	21.65**	-0.30	10.67**	-0.25
JMSA-9904 x AIB-14	-1.35	-2.79**	7.06	-0.47	0.38*	0.82	0.49	2.40**	0.46	8.82*	5.79	17.60**	1.12**	0.36	0.80**
JMSA-9904 x AIB-15	-3.68**	-4.85**	-2.12	0.45	0.27	0.31	4.52	2.76**	0.23	10.75*	9.79**	15.61*	-0.45**	3.03	0.49*
JMSA-9904 x AIB-17	-2.68**	-1.29	0.80	0.06	0.05	-0.59	-10.13**	-0.86	-0.42	-8.82*	-7.68*	-22.56**	0.72**	-1.59	-0.23
JMSA-9904 x AIB-20	2.38**	4.43**	-9.50	0.33	-0.40*	-2.08**	1.94	-3.34**	-0.18	-11.62**	-10.88	12.35	-0.56**	-4.50	-0.32
JMSA-9904 x AIB-28	1.15	2.71**	-3.35	-0.06	-0.42*	-0.06	-8.00**	-1.00	1.01**	-2.83	-7.67*	-50.00**	0.53**	-8.15**	-0.53*
JMSA-9904 x AIB-30	-0.24	-1.46	16.41**	-0.35	0.22	0.60	11.05**	2.22**	0.02	9.87*	9.44**	25.18**	-0.04	3.51	0.23
JMSA-101 x AIB-6	2.44**	2.42*	-3.28	0.26	-0.04	-1.02	-4.82	-1.85**	-0.87*	13.14**	4.74	-19.64**	-0.73**	-4.19	-0.73**
JMSA-101 x AIB-10	0.22	0.58	13.84**	-0.50	-0.41*	-0.25	10.32**	1.13	-0.04	-10.80*	-4.39	-14.44*	-0.03	3.39	1.12**
JMSA-101 x AIB-14	-2.22**	-0.92	-8.89	0.39	0.37*	-1.78**	7.25**	-2.49**	0.65	-1.29	4.50	14.40*	-0.90**	6.83**	-0.84**
JMSA-101 x AIB-15	-1.89*	-0.64	-13.21**	-0.36	-0.43*	2.14**	-4.49	-3.21**	-0.02	-4.37	-17.08**	-9.58	0.16	-18.24**	0.46*
JMSA-101 x AIB-17	4.78**	3.92**	11.57**	-0.35	-0.21	1.49**	-10.17**	-2.71**	0.00	-0.53	2.27	-41.37**	-1.58**	3.21	-0.42
JMSA-101 x AIB-20	-3.17**	-4.69**	-3.66	0.39	0.46**	-1.58**	-6.53**	2.71**	0.19	-8.17	-5.09	8.86	0.85**	-0.06	0.63**
JMSA-101 x AIB-28	-2.39**	-1.75	5.77	0.06	-0.01	-0.03	15.95**	6.76**	-0.72*	10.61*	13.08**	44.83**	1.16**	7.19**	0.20
JMSA-101 x AIB-30	2.22**	1.08	-2.13	0.11	0.28	1.04	-7.50**	-0.32	0.81*	1.41	1.97	16.93**	-1.07**	1.86	-0.42
ICMA-08111 x AIB-6	-0.14	-2.25*	1.07	-0.23	0.13	1.39**	1.80	1.71**	0.88*	6.67	7.73*	36.77**	-0.19	3.34	0.65**
ICMA-08111 x AIB-10	-1.03	-0.08	-6.49	0.41	0.23	-1.74**	-4.43	-0.38	0.53	3.88	-6.71*	-5.19	-0.69**	-12.34**	-0.86**
ICMA-08111 x AIB-14	-0.81	0.08	-0.95	0.29	0.17	0.46	-1.86	-2.67**	-0.46	2.76	0.29	-0.43	0.30	-2.25	0.26
ICMA-08111 x AIB-15	-1.81*	-1.64	-6.86	0.08	-0.43*	-1.97**	-2.80	-2.10**	-0.03	-2.90	3.72	-11.66	0.80**	7.01**	0.39
ICMA-08111 x AIB-17	-1.47	0.92	4.43	0.16	-0.21	0.49	17.22**	3.58**	0.05	16.51**	11.55**	51.06**	1.39**	0.67	0.54*
ICMA-08111 x AIB-20	1.25	0.64	5.43	-0.17	0.46**	-0.91	-8.71**	-0.88	-0.51	12.49**	6.70*	-16.17*	0.32	-1.75	-0.48*
ICMA-08111 x AIB-28	3.03**	0.92	-1.84	-0.43	-0.01	2.17**	-8.92**	-0.09	0.22	-21.71**	-10.69**	-40.05**	-1.44**	6.25*	-0.58*
ICMA-08111 x AIB-30	0.97	1.42	5.23	-0.12	0.28	0.11	7.70**	0.83	-0.67	-17.70**	-12.60**	-14.32*	-0.49**	0.92	0.60**
ICMA-92777 x AIB-6	-3.60**	-3.88**	7.19	0.41	0.12	-0.04	5.12	2.42**	0.28	5.69	6.96*	22.49**	0.67**	4.00	-0.03
ICMA-92777 x AIB-10	1.51	0.96	-0.01	0.45	0.22	-0.98	-4.11	-1.21	-0.46	3.52	2.66	-17.56**	-0.19	0.16	0.03
ICMA-92777 x AIB-14	2.07*	0.13	-5.66	0.00	0.20	-1.10	0.39	1.96**	0.38	4.20	-0.82	-2.86	-2.14**	-4.59	0.16
ICMA-92777 x AIB-15	2.07*	2.74**	2.33	-0.14	0.18	-0.56	-12.81**	1.39**	0.23	-19.70**	-11.07**	-44.09**	0.36*	3.56	-0.88**
ICMA-92777 x AIB-17	-1.93*	-3.04**	-5.41	-0.40	0.09	-0.23	1.94	2.16**	0.10	-1.78	0.56	21.19**	1.19**	2.56	0.08
ICMA-92777 x AIB-20	1.46	3.35**	-3.39	-0.46	-0.11	0.28	1.04	-1.16	-0.82**	4.84	-0.03	-24.51**	-0.88**	-4.53	0.39
ICMA-92777 x AIB-28	1.57	1.29	12.02**	0.08	-0.51**	2.14**	16.33**	-2.76**	0.22	-0.97	-2.94	63.27**	-0.54**	-3.81	-0.21
ICMA-92777 x AIB-30	3.15**	-1.54	-7.08	0.06	-0.22	0.49	-7.92**	-2.81**	0.07	4.18	4.68	-17.93**	1.54**	2.65	0.46*
ICMA-96333 x AIB-6	-0.93	-3.58**	2.57	-0.30	0.07	-0.43	0.92	1.30*	0.60	-17.21**	-7.88**	-19.98**	-0.08	5.10*	-0.14
ICMA-96333 x AIB-10	0.85	1.58	5.77	-0.14	-0.03	1.41**	-11.78**	0.23	0.07	-1.81	0.57	10.87	0.42**	2.23	-0.04
ICMA-96333 x AIB-14	-0.26	0.08	-0.64	-0.25	-0.52**	0.16	-0.04	1.16	-0.18	-12.89**	-10.43**	21.10**	1.45**	-3.03	-0.45*
ICMA-96333 x AIB-15	1.40	2.03*	12.28**	-0.19	0.08	2.60**	15.72**	-0.89	0.52	12.02**	8.93**	23.94**	0.04	1.50	-0.60**
ICMA-96333 x AIB-17	4.07**	3.92**	10.80**	0.02	0.13	0.47	-0.87	-0.64	-0.31	0.80	-2.10	-5.66	1.00**	-3.97	0.03
ICMA-96333 x AIB-20	-0.87	-1.03	-2.24	0.09	0.28	1.23**	17.81**	0.59	0.69*	14.12**	13.56**	43.55**	-0.60**	5.73*	0.56*
ICMA-96333 x AIB-28	-3.10**	-2.42*	-8.47	0.43	0.53**	-2.34**	-7.74**	-0.72	-1.13**	16.67**	7.56*	-7.45	0.07	-4.06	1.10**
ICMA-96333 x AIB-30	1.15	-0.58	-20.07**	0.34	-0.30	-3.10**	-14.02**	-1.04	0.27	-11.71**	-10.21**	-66.36**	-2.31**	-3.50	0.46*
ICMA-99555 x AIB-6	-2.10*	3.08**	-6.49	-0.09	0.10	-0.93	3.06	-1.92**	-0.87*	-2.05	-4.93	0.18	-0.05	-4.91	0.43
ICMA-99555 x AIB-10	-1.65	-2.08*	-4.89	-0.32	-0.23	1.60**	3.77	0.77	-0.16	5.14	0.05	4.67	0.78**	-4.12	0.00
ICMA-99555 x AIB-14	2.57**	3.42**	9.07	0.04	-0.50**	1.44**	-6.23*	-0.36	-0.84*	-1.61	0.67	-49.81**	0.17	2.68	0.60**
ICMA-99555 x AIB-15	3.90**	2.36*	7.55	0.16	-0.30	-2.52**	-0.14	2.05**	-0.23	4.19	5.70	25.78**	-0.90**	3.14	0.13
ICMA-99555 x AIB-17	-2.76**	-4.42**	-22.19**	0.50	-0.19	-1.62**	2.01	-1.54**	0.58	-6.18	-4.59	-2.66	-1.27**	-0.88	-0.01
ICMA-99555 x AIB-20	-1.04	-2.69**	13.40**	-0.16	-0.26	3.06**	-5.55	2.08**	0.63	-11.67**	-4.26	-24.09**	0.86**	5.12*	-0.7
ICMA-99555 x AIB-28	-0.26	-0.75	-4.13	-0.09	-0.06	-1.87**	-7.63**	-2.19**	0.40	-1.78	0.65	-10.59	0.17	2.59	0.02
ICMA-99555 x AIB-30	1.35	1.08	7.64	-0.04	0.24	0.85	10.69**	1.12	0.50	13.94**	6.72*	56.52**	0.24	3.61	0.41
Range of SCA effects	-3.68 to 4.78	-4.85 to 4.43	-22.19 o 16.41	-0.50 to 0.53	-0.52 to 0.53	-3.10 to 03.06	-14.02 to 17.81	-3.34 to 6.76	-1.13 to 1.01	-21.71 to 16.67	-17.08 to 13.56	-66.36 to 63.27	-2.31 to 1.54	-18.24 to 10.67	-0.88 to 1.12
S.E (Sij) +	0.85	1.006	4.97	0.30	0.17	0.58	2.64	0.64	0.35	4.24	3.08	6.56	0.18	2.50	0.23
S.E.(sij-skl)	1.19	1.418	7.00	0.42	0.25	0.79	3.45	0.90	0.49	5.98	4.34	9.25	0.26	3.53	0.33
CD. 5 % (sij-skl)	2.38	2.82	13.94	0.84	0.50	1.57	6.88	1.77	0.97	11.72	8.50	18.13	0.52	6.92	0.65

*, ** Significant at 5 % and 1 % level of significance respectively.

Table 4: Estimates of mean seed yield, standard heterosis and sca effect for five best hybrids

Characters	Crosses	SCA effect	*Per se* performance of hybrids	Standard heterosis over		GCA effect		GCA status of parents
				GHB-538	GHB-558	Line	Tester	
Grain yield per plant	JMSA-9904 x AIB-15	9.79**	63.59	19.40**	14.11*	2.38*	2.00	H x A
	JMSA-9904 x AIB-30	9.44**	63.33	19.07**	13.75*	2.38*	2.53*	H x H
	ICMA-99555 x AIB-30	6.72*	61.49	16.65*	11.17*	2.99*	2.53*	H x H
	JMSA-101 x AIB-28	13.08**	61.24	16.31*	10.81	1.88	-2.92*	A x L
	ICMA-08111 x AIB-17	11.55**	59.86	14.37*	8.75	-1.51	0.62	A x A

AIB-30, ICMA-99555 x AIB-30), average x average (ICMA-08111x AIB-17); average × low (JMSA-101 x AIB-28) general combiner parents for grain yield. The involvement of at least one good general combiner was also reported by Gupta and Singh (1973); Pethani and Kapoor(1985); Navale et al(1991) and Joshi et al., (2000).

The crosses with significant standard heterosis involving high x low or low x high general combiner parents indicate dominance type of gene action. For grain yield per plant, these hybrids with high *per se* performance and significant sca effects involved high× high, high x average or high × poor general combiner indicating the significance of both additive and non-additive gene action in governing the trait. It is in conformity with the results of Navale et al. (1991), Chavan and Nerkar (1994) and Joshi et al.(2000). Whereas, the crosses ICMA-08111 x AIB-17 and JMSA-101 x AIB-28 involved average x average and average x poor general combiner parents epistatic gene action for grain yield. The present study indicated that the hybrids JMSA-9904 x AIB-15, JMSA-9904 x AIB-30 ICMA-99555 x AIB-30 had high mean seed yield per plant and standard heterosis over both the check GHB-538 and GHB-558 as the significant outcome of the study on heterosis and combining ability. The results need to be further strengthened for the genotype x environment (G × E) interaction of these best five hybrids over different seasons and location.

REFERENCES

Aher, V. B. and Ugale, S. D. 1995. Heterosis in pearl millet. *J. Maharashtra Agric. Univ.* **20(2):** 217-220.

Anonymous 2012. Website <http:// www.agricoop.nic.in> All-India area, production and yield of bajra from 1950-51 to 2009-2010 along with percentage coverage under irrigation. State wise yield of bajra. Directorate of Economics and Statistics, Department of Agriculture and Cooperation.1999-2000 to 2009-10 as per Final Forecast Reports.

Athwal, D. S. 1965. Hybrid Bajra-1 marks a new era. *Indian Farming*, **15**: 6-7.

Basavaraju, R., Safeeulla, K. M. and Murthy, B. R. 1980. Combining ability in pearl millet. *Indian J. Genet.,* **40(3):** 528-536.

Burton, G. W. (1965). Pearl millet Tift 23A released. *Crops and Soil,* **17:** 19.

Chavan, A. A. and Nerkar, Y. S. 1994. Heterosis and combining ability studies for grain yield and its components in pearl millet. *J. Maharashtra Agric. Univ.* **19(1):** 58-61.

Dangariya, C. J., Chotalia, J. M., Savaliya, J. J., Davda, B. K. and Pansuriya, A. G. 2009. Combining ability analysis in pearl millet [*Pennisetum glaucum* (L). R. Br.]. *Agril. Sci. Digest.* **294:** 287-290.

Dhuppe, M. V., Chavan, A. A., Phad, D.S. and Chandankar, G. D. 2006. Combining ability studies in pearl millet. *J. Maharashtra Agril. Uni.* **312:** 146-148.

Gupta, V. P. and Singh, T. P. 1971. Combining ability for grain yield and its component in pearl millet. *Indian J. Genet.* **33(2):** 183-188.

Harer, P. N., Navale, P. A. and Harinarayana, G. 1990. Heterosis and combining ability studies in pearl millet. *J. Maharashtra Agric. Univ.* **15(1):** 48-51.

Jethva, A. S., Raval, L., Madriya, R. B., Mehta, D. R. and Mandavia, C. 2011. Combining ability over environments for grain yield and its related traits in pearl millet. *Crop improve.* **381:** 92-96.

Joshi, H. J., Dhaduk, H. L., Mehata, D. R. and Pethani, K. V. 2000. Line x Tester analysis over environment in pearlmillet(*Pennisetum glaucum* (L.) R. Br). *Agric. Sci. Digest.* **20(4):** 244-247.

Joshi, H. J., Mehta, D. R., Dhaduk, H. L. and Pethani, K. V. 2001. Combining ability of restorers in pearl millet. (*Pennisetum glaucum* (L.) R. Br). *Agric. Sci. Digest.* **21(3):** 161-163.

Karale, M. U., Ugale, S. D., Suryavanshi, Y. B. and Patil, B. D. 1998. Studies on combining ability for grain yield and its components in pearl millet. *Indian J. Agric. Res.* **32(1):** 1-5.

Kempthrone, O. 1957. An introduction to genetic statistics. John Willey and Sons. Inc., New York.

Khan, R. and Dubey, R. B., 2015. Combining ability analysis for nutritional quality and yield in maize (*Zea mays* L.). *The bioscan.* **10(2):** 785-788.

Latha, R. and Shanmugasundaram, P. 1998. Combining ability studies involving new male sterile lines in pearl millet. *Madras Agric. J.* **85(3-4):** 160-163.

Manga, V. K. and Dubey, L. K. 2004. Identification of suitable inbreds based on combining ability in pearl millet (*Pennisetum glaucum*). *Indian J. Agric. Sci.* **742:** 98-101.

Mohan, C., Kandasamy, G. and Senthil, N. 1999. Exploitation of heterosis and selection of superior combiners in pearl millet.*Ann. Agric. Res.* **201:** 91-93.

Navale, P. A., Kanade, B. C., Sarawate, C. D. and Harinarayana, G. 1991. Combining ability analysis of newly developed male sterile lines and restorer in pearl millet. *J. Maharashtra Agril. Uni.* **16(1):** 17-19.

Pethani, K. V. and Kapoor, R. L. 1985. Combining ability and genotype x environment interaction for dry fodder yield in pearl millet. *Gujart Agril.Univ. Res. J.* **11(1):** 1-9.

Rathore, V. S., Singhania, D. L. and Jakhar, M. L. 2004. Combining ability of diverse restorers of pearl millet [*Pennisetum glaucum* (L.) R. Br.] for grain yield and its components. *Indian J. Genet.* **64(3):** 239-240.

Sahane, D. V., Tetali, S., Kulkarni, V. M. and Wattamwar, M. J. 1996. Combining ability of newly developed restorers in pearl millet. *J. Maharashtra Agric. Univ.* **21(1):** 42-45.