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Selection of Suitable Pearl Millet Hybrids for Arid and Semi-Arid Conditions through Combining Ability Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Present investigation was carried out to study combining ability effects for grain yield and its component traits in 77 hybrids of pearl millet. From the results of GCA effects, it was revealed that a number of parents namely, ICMA 98222, ICMA 93333, ICMA 30199, ICMA 30201 (female parents), and BIB 481-500, BIB 561-570 and BIB 571-581 (male parents) were found to be good general combiner for grain yield and most of its component characters. On the basis of GCA effects, lines ICMA 98222, ICMA 88004, ICMA 93333, ICMA 30199, ICMA 30201 and testes BIB 571-580, BIB 561- 570, BIB 511- 520, BIB 481- 500, BIB 531- 540 were good general combiner for more than nine yield contributing characters. The SCA effects of the crosses namely, ICMA 97111

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x BIB 561- 570, ICMA 98222 x BIB 481- 500, ICMA 88004 x BIB 501- 510 and ICMA 93333 x BIB 551-560 were significant and were identified as superior for seed yield and related traits over the environments. Therefore, these parents and hybrids were recommended for utilization in development of promising populations as well as hybrid development.

Keywords: GCA; SCA; line; tester; pearl millet.

1. INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a major warm-season cereal grown on 26 million ha in the arid and semi-arid tropical (SAT) regions of Asia (more than 10 million ha) and Africa (15-16 million ha). Pearl millet is a staple food for the majority of poor farmers and also an important fodder crop for livestock population in arid and semi-arid regions of India. It is an important boorish grain crop belonging to the family Poaceae (Gramineae) and give out as staple food for the millions of people flourishing under hunger.It is very palatable bristly cereal with the best nutritional outline (rich in tryptophan and cysteine). Pearl millet is not expensive as pearl but its nutritional quality is like a pearl because grain contains 8.5 to 15% protein, 5.03 to 6.0% fat, 1.05 to 1.7% crude fibre and 65.5 to 70% carbohydrates. As a food crop, pearl millet grain take over the highest amount of calories per 100 gram [1], which is mainly grant by carbohydrates, fats and proteins [2]. Its mineral content is also close with other cereals. That's why pearl millet is very important and cost effective crop for arid and semi-arid condition of world. The basic reason in any crop improvement programme is to enlarge the quality and yield potential of the crop. Manipulation of hybrid vigour is considered to be one of marvellous achievements of plant breeding in this crop. The selection of right type of parents to be included in hybridization programme is a deciding step for the breeder. The use of superior genetically worthy parents ensures much better success of breeding programme. This would require considerable and complete genetically studies of subsist germplasm as well as newly evolved promising lines. The lines that perform well in combinations are eventually of greater importance to the plant breeder. Information on combining ability lay out the guide line to the plant breeder in selecting the elite parents and desirable cross combinations to be used in expression of systematic breeding programme and at the same time provides means of understanding the nature of gene action involved in the inheritance of numerous traits.

2. METHODS AND MATERIALS

The experimental material for present study consisted of 11 male sterile lines (ICMA-04999, ICMA-88004, ICMA-93333, ICMA-97111, ICMA-97444, ICMA-98222, ICMA-10444, ICMA-30199, ICMA-30200, ICMA-30201 and ICMA-30209) and 7 testers (BIB 481-500, BIB 501-510, BIB 511-520, BIB 531-540, BIB 551-560, BIB 561-570 and BIB 571-580). The 77 crosses were generated using line x tester mating design at International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad during *summer*, 2019. These hybrids were grown in Randomized Block Design with three replications in three environments at Agricultural Research Station, Bikaner during *Kharif,* 2019. Each plot consisted of two rows each of 4 meter length with row spacing of 60 cm and plant to plant spacing of 15 cm. The observations were recorded on twelve morphological characters namely, days to 50% flowering, days to maturity, plant height (cm), productive tillers per plant, ear head length (cm), ear head diameter (cm), test weight (g), ear head weight (g), dry stover yield per plant (g), grain yield per plant (g), harvest index (%) and threshing index (%). The mean data were subjected to analysis for combining ability as per the method suggested by Kempthorne [3].

3. RESULTS AND DISCUSSION

Combining ability may be defined as the ability of a genotype to transmit superior attributes to its crosses. Fisher [4] was first recognized the importance of biometrical techniques to study the genetics of quantitative characters. The concept of combining ability in terms of genetic variation was first given by Sprague and Tatum [5] using single crosses in maize crop.Combining ability studies are useful in assessing the ability of parents and thus helps in selecting parents which, when crossed, would give rise to more desirable segregants during hybridization programme. It also helps in characterizing the nature and magnitude of a systematic breeding approach. The method of line x tester analysis developed by Kempthorne [3] is one such design, which has been extensively used both in

self as well as cross pollinated crops. This is of mainly two types.

3.1 General Combining Ability Effects

General combining ability indicates the average performance of a line in a series of cross combination. The estimates of general combining ability (GCA) effects of lines (gi) and testers (gj) were determined for each environment as well as over the environments for all the characters. The results obtained are presented in Tables 1 to 4 and is described for each environment as below. Table 1 indicated that in environment E_1, out of eleven lines, four lines for days to 50% flowering, five lines for days to maturity and out of seven tester only one possessed highly significantly negative GCA effects for both characters. For plant height (six lines and four testers), productive tillers per plant (three lines and testes), ear head length (three lines and two testers), ear head diameter (four lines and two testers), test weight (five lines and three testers), ear head weight (three lines and testers), dry stover yield per plant (three lines and testers), grain yield per plant (four lines and two testers), harvest index (four lines) and threshing index (three lines and one testers) had highly significantly positive GCA effects. Thus, these were considered as good general combiner for all these characters.

Perusal of Table 2 indicated that in environment E_2, out of eleven lines, three lines for days to maturity, three testers for days to 50% flowering and days to maturity in environment E_2 possessed highly significantly negative GCA effects. Two lines for plant height, three lines for ear head weight, dry stover yield per plant and threshing index. Four lines for grain yield, five lines for ear head length, test weight, harvest index and six lines for ear head diameter were found highly significantly positive GCA effects. One tester for plant height and ear head diameter, two testers for dry stover yield, grain yield and harvest index and threshing index, three testers for productive tillers per plant, ear head length, test weight and ear head weight were found good general combiner for all these characters.

Table 3 indicated that in environment E_3 that yield contributing characters like productive tillers per plant (four lines and three testers), ear head length (five lines and three testers), ear head diameter (five lines and one testes) and ear head weight (three lines and four testers) possessed highly significantly positive GCA effects. Thus, these were considered as good general combiner for all these characters. Eldie et al. [6], Krishnan et al. [7], Gavali et al. [8], Ladumor et al. [9], Saini et al. [10] and Santosh et al. [11] also reported various lines and testers having good combining ability behavior for yield and it's attributing characters in pearl millet.

Table 4 results showed the pool GCA effects in over the environment. Lines ICMA-88004, ICMA-93333 & ICMA-98222 for days to 50% flowering and days to maturity, lines ICMA-88004 & ICMA-93333 for plant height, lines ICMA-30201 for productive tillers per plant, lines ICMA-98222, ICMA-10444 & ICMA-30201 for ear head length, lines ICMA-98222, ICMA-10444, ICMA-30199 & ICMA-30201 for ear head diameter, lines ICMA-04999, ICMA-93333, ICMA-97111, ICMA-98222 & ICMA-10444 for test weight, line ICMA-98222 for ear head weight, lines ICMA-30199 & ICMA-30201 for dry stover yield per plant, lines ICMA-88004, ICMA-98222, ICMA-30199 & ICMA-30201 for grain yield per plant, lines ICMA-04999, ICMA-88004 & ICMA-30209 for harvest index, lines ICMA-04999, ICMA-88004 & ICMA-30201 for threshing index and tester BIB 571-580 for days to 50% flowering, BIB 511-520 for days to maturity, BIB 481-500 for plant height, BIB 561-570 for productive tillers per plant, BIB 571-580 for ear head diameter, BIB 501-510, BIB 531-540, BIB 561-570 for test weight, BIB 511-520 for ear head weight, BIB 561-570 for dry stover yield per plant, BIB 571-580 for grain yield were considered as good general combiner for all these characters.Similar results were also reported in pearl millet by Jeeterwal et al. [12], Krishnan et al. [7], Kumar et al. [13], Solanki et al. [14] and Badurkar et al. [15].

3.2 Specific Combining Ability Effects

Specific combining ability shows those effects in some definite combinations which significantly departed from what would be expected on the basis of average performance of the lines involved [5]. The estimates of specific combining ability (SCA) effects of crosses (S_{ij}) were determined for over the environments for all the characters (Table 5). As pearl millet is a fodder crop, high number of productive tillers per plant is desirable in this crop for seed yield as well as fodder yield, which is reflected by the positive combining ability effects. Perusal of Table 5 indicated that the SCA effects in over the

Table 1. GCA effects in E_1 environment for different characters in pearl millet

Lines (Females)	GCA Effect											
	Days to 50% flowering	**Days to maturity**	**Plant height (cm)**	**Productive tillers/ plant**	**Ear head length (cm)**	**Ear head diameter (cm)**	**Test weight (g)**	**Ear head weight (g)**	**Dry stover yield/ plant (g)**	**Grain yield/ plant (g)**	**Harvest index (%)**	**Threshing index (%)**
ICMA-04999	1.32*	1.23*	-11.38**	0.61**	-0.13	-2.25**	0.17**	-2.53	-20.06*	1.35	2.66**	2.91
ICMA-88004	-1.82**	-1.91**	2.45**	0.3*	-1.07**	-0.58	0.07	-6.58	-20.06*	5.2*	2.9**	5.5**
ICMA-93333	-3.01**	-3.1**	12.56**	0.16	-0.21	-1.39**	0.65**	1.99	50.89**	-3.03	-5.68**	-5.77**
ICMA-97111	-0.92	-1*	-0.1	0.06	-0.1	-1.06**	0.18**	-14.44**	-53.4**	-5.7**	2.61**	-0.12
ICMA-97444	-1.82**	-1.91**	4.16**	-0.2	-0.64	-1.25**	-0.92**	-13.01**	9.46	-2.23	-1.23	5.39**
ICMA-98222	-3.3**	-3.39**	-4.34**	-0.65**	1.83**	3.52**	1.4**	15.32**	-25.3**	10.39**	6.75**	-0.17
ICMA-10444	0.89	0.81	-6.64**	-0.46**	0.83*	1.09**	0.49**	-15.87**	-15.06	-8.65**	-1.89	2.44
ICMA-30199	3.13**	3.04**	4.75**	0.01	-2.58**	1.04**	-0.08	23.9**	76.6**	9.2**	-2.55*	-2.43
ICMA-30200	1.46**	1.38**	-6.93**	-0.16	0.55	-0.72*	-1.2**	-19.2**	-29.59**	-8.18**	-1.48	0.52
ICMA-30201	1.8**	2.19**	2.6**	0.48**	1.03**	1.13**	-0.24**	32.47**	25.65**	-3.89	-3.88**	-14.29**
ICMA-30209	2.27**	2.66**	2.87**	-0.16	0.49	0.47	-0.52**	-2.06	0.89	5.54**	1.78	6.01**
Testers (Males)	**GCA Effect**											
BIB 481- 500	0.41	0.32	3**	-0.61**	-1.33**	-1.1**	-0.53**	-15.3**	-21.02**	-2.16	1.06	8.04**
BIB 501-510	0.29	0.2	3.58**	-0.37**	1.45**	1.81**	0.41**	-11.36**	-18.44**	-5.7**	-0.58	-1.51
BIB 511-520	-0.71	-0.8*	-8.58**	-0.08	-0.15	0.96**	0.01	11.52**	2.32	-3	-0.26	-5.76**
BIB 531-540	-0.62	-0.71	9.13**	0.4**	0.97**	-1.19**	0.3**	-1.97	21.41**	-3.31*	-2.95**	-2.73
BIB 551-560	1.89**	1.81**	-5.89**	-0.34**	-0.35	-1.1**	-1.09**	-5.91	-19.81**	-1.34	0.66	2.05
BIB 561-570	-0.29	-0.38	-3.77**	0.64**	-0.11	0.2	0.94**	12.12**	20.5**	8.21**	1.35	1.16
BIB 571-580	-0.96*	-0.44	2.53**	0.36**	-0.48	0.44	-0.04	10.91**	15.04*	7.3**	0.71	-1.25
SE (GCA line)	0.52	0.51	0.8	0.15	0.32	0.31	0.05	4.08	7.95	2	1	1.75
(gi-gj lines)	0.74	0.72	1.13	0.21	0.46	0.43	0.08	5.77	11.24	2.83	1.41	2.48
(GCA tester)	0.42	0.4	0.64	0.12	0.26	0.24	0.04	3.26	6.34	1.59	0.8	1.4
(gi-gj tester)	0.59	0.57	0.9	0.17	0.37	0.35	0.06	4.61	8.97	2.25	1.13	1.98
CD(GCA line)	1.03	1	1.58	0.29	0.64	0.61	0.11	8.07	15.7	3.95	1.97	3.46
(gi-gj lines)	1.46	1.41	2.23	0.41	0.91	0.86	0.15	11.41	22.2	5.58	2.79	4.89
(GCA tester)	0.83	0.8	1.26	0.23	0.51	0.48	0.08	6.44	12.52	3.15	1.57	2.76
(gi-gj tester)	1.17	1.13	1.78	0.33	0.72	0.68	0.12	9.1	17.71	4.45	2.23	3.9

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

Table 2. GCA effects in E_2 environment for different characters in pearl millet

Lines (Females)	GCA Effect											
	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers/ plant	Ear head length (cm)	Ear head diameter (cm	Test weight (g)	Ear head weight (g)	Dry stover yield/ plant (g)	Grain yield/ plant (g)	Harvest index (%)	Threshing index (%)
ICMA-04999	2.27**	2.43**	-7.75**	-0.29**	-2.43**	-1.92**	0.21**	-14.06**	-22.73**	-1.7	5.36**	10.71**
ICMA-88004	-3.49**	-3.52**	6.82**	-0.02	1.01**	0.99*	0.04	12.32**	-4.63	5.64**	2.28*	3.55
ICMA-93333	-3.97**	-4**	15.2**	-0.05	2.84**	1.19*	0.71**	16.03**	-2.25	3.64**	3.7**	-15.12**
ICMA-97111	0.17	0.14	-3.14	-0.66**	-2.68**	-2.75**	0.09*	-11.77**	-49.87**	-11.74**	-1.5	-5.95*
ICMA-97444	-0.4	-0.43	-1.39	0.32**	-1.12**	-3.14**	-0.87**	-8.11**	-27.97**	-3.32**	1	-7.27*
ICMA-98222	-2.49**	-2.52**	-1.08	0.14	1.63**	4.5**	1.47**	29.37**	26.32**	1.59	-3.19**	-21.61**
ICMA-10444	0.7*	0.67*	-3.83	-0.12	2.22**	1.19*	0.47**	-1.73	-1.77	-3.84**	-3.01**	-9.77**
ICMA-30199	3.65**	3.62**	2.27	0.19*	-2.26**	1.82**	-0.08	1.75	47.27**	6.97**	-5.06**	-0.72
ICMA-30200	1.51**	1.48**	-4.91*	0.03	-1.83**	-1.84**	-1.14**	-12.16**	-13.2**	-2.65**	2.63**	8.27**
ICMA-30201	0.46	0.43	0.19	0.48**	2.73**	1.76**	-0.3**	2.18	77.27**	9.16**	-4.97**	35.91**
ICMA-30209	1.6**	1.71**	-2.38	-0.02	-0.11	-1.79**	-0.6**	-13.82**	-28.44**	-3.74**	2.76**	2.01
Testers (Males)	**GCA Effect**											
BIB 481- 500	-0.29	-0.32	8.76**	0.36**	-0.63*	0.27	-0.41**	5.3**	43.29**	7.28**	-2.78**	13.47**
BIB 501-510	2.1**	2.07**	-7.49**	-0.56**	-1.33**	-2.3**	0.44**	3.78*	-11.56**	-6.39**	-3.02**	-13.43**
BIB 511-520	-0.75**	-0.78**	-1.08	0.4**	-1.61**	-0.64	0.01	13.66**	-8.23*	-0.42	-0.36	-15.66**
BIB 531-540	0.37	0.34	3.09	-0.36**	-0.04	-1.03**	0.32**	-17.06**	-10.65**	-4.93**	-1.13	3.94
BIB 551-560	1.83**	1.8**	0.63	-0.25**	1.17**	-0.82*	-1.12**	-7.94**	-15.5**	-0.6	5.44**	13.78**
BIB 561-570	-1.54**	-1.57**	-2.92	0.41**	0.88**	0.44	0.7**	2.57	12.68**	-0.02	-3.3**	-1.92
BIB 571-580	-1.72**	-1.54**	-0.99	0.01	1.57**	4.08**	0.05	-0.31	-10.04**	5.07**	5.13**	-0.17
SE (GCA line)	0.33	0.32	2.36	0.09	0.33	0.47	0.04	2.13	4.06	1	1	2.87
(GCA tester)	0.27	0.25	1.88	0.07	0.27	0.37	0.03	1.7	3.24	0.79	0.8	2.29
(gi-gj lines)	0.47	0.45	3.34	0.13	0.47	0.66	0.06	3.01	5.74	1.41	1.41	4.06
(gi-gj tester)	0.37	0.36	2.66	0.1	0.38	0.53	0.05	2.4	4.58	1.12	1.13	3.24
CD(GCA line)	0.66	0.63	4.66	0.18	0.66	0.92	0.09	4.21	8.02	1.97	1.97	5.67
(GCA tester)	0.52	0.5	3.72	0.14	0.53	0.74	0.07	3.36	6.4	1.57	1.57	4.52
(gi-gj lines)	0.93	0.89	6.59	0.25	0.93	1.3	0.12	5.95	11.34	2.78	2.79	8.02
(gi-gj tester)	0.74	0.71	5.26	0.2	0.74	1.04	0.1	4.75	9.05	2.22	2.23	6.4

** and ** represents significant at 5% and 1% level of significance, respectively*

Table 3. GCA effects in E_3 environment for different characters in pearl millet

Lines (Females)	GCA Effect											
	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers/ plant	Ear head length (cm)	Ear head diameter (cm)	Test weight (g)	Ear head weight (g)	Dry stover yield/ plant (g)	Grain yield/ plant (g)	Harvest index (%)	Threshing index (%)
ICMA-04999	2.47**	2.46**	-8.01**	-0.17*	-2.1**	-1.91**	0.2**	-13.92**	-25.37**	-0.78	4.56**	1.44
ICMA-88004	-3.48**	-3.54**	6.56**	-0.02	1.1**	0.53	0.02	16.8**	5.35	1.6	6.53**	7.39**
ICMA-93333	-3.86**	-4.02**	15.42**	-0.04	2.7**	1.2**	0.7**	15.13**	16.3**	2.93**	-6.16**	3.95*
ICMA-97111	-0.00433	0.13	-3.4	-0.37**	-2.88**	-2.74**	0.15**	-11.3**	-40.84**	-7.88**	1.14	3.26
ICMA-97444	-0.29	-0.45	-1.65	0.2**	-0.41	-3.12**	-0.89**	-11.54**	-26.32**	1.07	3.56**	-0.54
ICMA-98222	-2.05**	-2.54**	-1.34	0.13*	1.72**	4.52**	1.44**	26.08**	28.44**	0.84	-1.93*	13**
ICMA-10444	0.38	0.65*	-2.66	-0.07	1.41**	1.2**	0.36**	1.32	-11.32**	-1.16	-3.21**	-9.1**
ICMA-30199	3.76**	3.6**	2.96	0.18**	-2.02**	1.84**	-0.09**	-0.58	39.63**	3.93**	-0.98	-9.44**
ICMA-30200	1.61**	1.46**	-5.17*	-0.08	-1.64**	-1.54**	-1.16**	-12.97**	-16.56**	-2.69**	2*	-6.34**
ICMA-30201	0.38	0.41	-0.07	0.25**	2.48**	1.78**	-0.22**	1.8	64.39**	4.22**	-7.67**	-1.82
ICMA-30209	1.09**	1.84**	-2.64	-0.02	-0.35	-1.77**	-0.51**	-10.82**	-33.7**	-2.07*	2.16*	-1.8
Testers (Males)	**GCA Effect**											
BIB 481- 500	-0.25	-0.34	9.11**	0.31**	-0.97**	0.17	-0.43**	4.81**	37.14**	4.87**	0.36	-1.38
BIB 501-510	2.12**	2.05**	-7.14**	-0.41**	-0.88**	-2.28**	0.35**	3.9**	-15.43**	-5.58**	1.1	3.32*
BIB 511-520	-0.76**	-0.8**	-1.34	0.3**	-1.52**	-0.62	-0.04	15.56**	-14.83**	0.63	1.24	-2.76*
BIB 531-540	0.3	0.32	2.83	-0.39**	-0.07	-1.01**	0.28**	-16.86**	-12.55**	-4.97**	-3.06**	-4.66**
BIB 551-560	1.63**	1.78**	0.37	-0.1	0.93**	-0.81*	-1.15**	-8.98**	-20.58**	0.87	0.11	4.69**
BIB 561-570	-1.43**	-1.58**	-2.57	0.25**	1.24**	0.45	0.91**	4.05**	23.35**	0.3	0.76	0.82
BIB 571-580	-1.61**	-1.43**	-1.25	0.03	1.27**	4.1**	0.07**	-2.47*	2.9	3.87**	-0.5	-0.03
SE (GCA line)	0.25	0.32	2.25	0.07	0.25	0.42	0.03	1.54	3.43	0.86	0.96	1.68
(GCA tester)	0.2	0.25	1.79	0.05	0.2	0.34	0.02	1.23	2.73	0.69	0.77	1.34
(gi-gj lines)	0.36	0.45	3.18	0.09	0.35	0.6	0.04	2.17	4.85	1.22	1.36	2.37
(gi-gj tester)	0.28	0.36	2.53	0.07	0.28	0.48	0.03	1.73	3.87	0.97	1.09	1.89
CD(GCA line)	0.5	0.62	4.44	0.13	0.5	0.83	0.06	3.03	6.77	1.71	1.9	3.32
(GCA tester)	0.4	0.5	3.54	0.1	0.4	0.67	0.05	2.42	5.4	1.36	1.52	2.64
(gi-gj lines)	0.71	0.88	6.28	0.18	0.7	1.18	0.09	4.29	9.57	2.41	2.69	4.69
(gi-gj tester)	0.56	0.7	5.01	0.15	0.56	0.94	0.07	3.42	7.64	1.92	2.15	3.74

** and ** represents significant at 5% and 1% level of significance, respectively*

Table 4. GCA effects in over the environment for different characters in pearl millet

Lines (Females)	GCA Effect											
	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers/ plant	Ear head length (cm)	Ear head diameter (cm)	Test weight (g)	Ear head weight (g)	Dry stover yield/ plant (g)	Grain yield/ plant (g)	Harvest index (%)	Threshing index (%)
ICMA-04999	1.95**	2.04**	-9.04**	0.05	-1.55**	-2.03**	0.19**	-10.17**	-22.72**	-0.38	4.2**	5.02**
ICMA-88004	-2.94**	-2.99**	5.28**	0.09	0.35*	0.31	0.04	7.51**	-6.45*	4.15**	3.9**	5.48**
ICMA-93333	-3.65**	-3.7**	14.39**	0.02	1.78**	0.33	0.69**	11.05**	21.64**	1.18	-2.71**	-5.65**
ICMA-97111	-0.19	-0.25	-2.21*	-0.32**	-1.89**	-2.18**	0.14**	-12.5**	-48.04**	-8.44**	0.75	-0.94
ICMA-97444	-0.87**	-0.93**	0.37	0.11	-0.72**	-2.5**	-0.89**	-10.89**	-14.94**	-1.49	1.11	-0.81
ICMA-98222	-2.76**	-2.82**	-2.25*	-0.13*	1.72**	4.18**	1.44**	23.59**	9.82**	4.27**	0.54	-2.93*
ICMA-10444	0.76**	0.71**	-4.38**	-0.21**	1.49**	1.16**	0.44**	-5.42**	-9.39**	-4.55**	-2.7**	-5.48**
ICMA-30199	3.48**	3.42**	3.32**	0.13*	-2.29**	1.57**	-0.08**	8.35**	54.5**	6.7**	-2.86**	-4.2**
ICMA-30200	1.49**	1.44**	-5.67**	-0.07	-0.97**	-1.37**	-1.17**	-14.77**	-19.78**	-4.5**	1.05	0.82
ICMA-30201	0.9**	1.01**	0.91	0.4**	2.08**	1.56**	-0.25**	12.15**	55.77**	3.16**	-5.51**	6.6**
ICMA-30209	1.83**	2.07**	-0.72	-0.07	0.01	-1.03**	-0.54**	-8.9**	-20.42**	-0.09	2.23**	2.07
Testers (Males)						**GCA Effect**						
BIB 481- 500	-0.06	-0.12	6.96**	0.02	-0.98**	-0.22	-0.46**	-1.73	19.81**	3.33**	-0.45	6.71**
BIB 501-510	1.5**	1.44**	-3.68**	-0.45**	-0.26	-0.92**	0.4**	-1.23	-15.14**	-5.89**	-0.83	-3.87**
BIB 511-520	-0.74**	-0.79**	-3.67**	0.21**	-1.09**	-0.1	0	13.58**	-6.91**	-0.93	0.21	-8.06**
BIB 531-540	0.04	-0.01	5.02**	-0.12*	0.29*	-1.08**	0.3**	-11.96**	-0.6	-4.4**	-2.38**	-1.15
BIB 551-560	1.85**	1.79**	-1.63	-0.23**	0.58**	-0.91**	-1.12**	-7.61**	-18.63**	-0.35	2.07**	6.84**
BIB 561-570	-1.12**	-1.18**	-3.09**	0.43**	0.67**	0.36	0.85**	6.25**	18.85**	2.83**	-0.39	0.02
BIB 571-580	-1.46**	-1.14**	0.1	0.13**	0.79**	2.87**	0.03	2.71*	2.63	5.41**	1.78**	-0.49
SE (GCA line)	0.23	0.23	1.12	0.06	0.18	0.23	0.03	1.62	3.19	0.8	0.57	1.25
(GCA tester)	0.19	0.18	0.89	0.05	0.14	0.19	0.02	1.29	2.54	0.64	0.45	1
(gi-gj lines)	0.33	0.32	1.58	0.09	0.25	0.33	0.04	2.29	4.51	1.13	0.81	1.77
(gi-gj tester)	0.26	0.25	1.26	0.07	0.2	0.26	0.03	1.83	3.59	0.9	0.64	1.41
CD(GCA line)	0.46	0.44	2.2	0.12	0.35	0.46	0.05	3.18	6.26	1.57	1.12	2.46
(GCA tester)	0.37	0.35	1.75	0.1	0.28	0.37	0.04	2.54	5	1.25	0.89	1.96
(gi-gj lines)	0.65	0.63	3.11	0.17	0.49	0.65	0.07	4.5	8.86	2.22	1.58	3.48
(gi-gj tester)	0.52	0.5	2.48	0.14	0.39	0.52	0.06	3.59	7.06	1.77	1.26	2.78

** and ** represents significant at 5% and 1% level of significance, respectively*

Table 5. SCA Effects in over the environment for different characters in pearl millet

Crosses	SCA Effects											
	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers/ plant	Ear head length (cm)	Ear head diameter (cm)	Test weight (g)	Ear head weight (g)	Dry stover yield/ plant (g)	Grain yield/ plant (g)	Harvest index (%)	Threshing index (%)
ICMA 04999 × BIB 481-500	-4.34**	-4.43**	18.88**	-0.58**	1.62**	3.57**	0.64**	16.69**	10.75	1.87	0.01	-11.14**
ICMA 88004 × BIB 481-500	-0.45	-0.39	7.31*	-0.96**	-2.46**	-1.4*	-1.77**	7.34	-4.41	-3.54	-5.92**	-19.82**
ICMA 93333 × BIB 481-500	-0.29	-0.23	-0.93	-0.37*	-4.96**	1.03	1.13**	-5.65	-3.61	-5.24*	-3.77*	-9.25**
ICMA 97111 × BIB 481-500	-2.2**	-2.14**	11.66**	0	1.24*	4.25**	0.62**	11.8**	4.96	-0.62	-6.55**	-18.67**
ICMA 97444 × BIB 481-500	4.71**	4.77**	-2.26	0.02	2.23**	-2.47**	1.16**	-9.26*	-40.92**	-5.79**	-0.17	-2.19
ICMA 98222 × BIB 481-500	-3.51**	-3.46**	0.9	1.39**	7.03**	4.84**	2.3**	48.48**	111.54**	35.89**	14.93**	9.4**
ICMA 10444 × BIB 481-500	4.19**	4.24**	-16.99**	-0.39*	-5.06**	-9.51**	-1.62**	-38.4**	-119.25**	-12.28**	14.44**	12.92**
ICMA 30199 × BIB 481-500	-0.75	-0.69	-0.27	0.85**	0.2	1.3*	1.93**	7.05	-23.14**	3.13	0.47	-3.82
ICMA 30200 × BIB 481-500	-3.21**	-3.15**	7.25*	0.77**	2.23**	3.76**	-2.01**	30.73**	54.48**	2.67	-9.95**	-19.77**
ICMA 30201 × BIB 481-500	0.82	0.72	2.84	0.44**	2.61**	2.45**	-0.95**	-32.52**	105.59**	5.11*	-4.28**	65.81**
ICMA 30209 × BIB 481-500	5.01**	4.77**	-28.4**	-1.17**	-4.68**	-7.81**	-1.43**	-36.25**	-96**	-21.19**	0.79	-3.47
ICMA 04999 × BIB 501-510	5.44**	5.35**	-11.12**	-0.43**	-3.36**	-5.59**	-1.04**	-33.27**	-55.41**	-11.13**	-1.85	6.02
ICMA 88004 × BIB 501-510	-4.78**	-4.73**	10.28**	0.53**	5.98**	6.59**	3.38**	55.16**	110.54**	33.46**	9.8**	8.34*
ICMA 93333 × BIB 501-510	1.82**	1.88**	2.13	0	-1.61**	-2.29**	-0.65**	-29.49**	-15.33	-4.68*	-5.83**	6.67*
ICMA 97111 × BIB 501-510	-3.52**	-3.47**	5.59	0.41*	6.7**	7.16**	0.94**	57.4**	32.13**	6.94**	-7.7**	-10.57**
ICMA 97444 × BIB 501-510	-0.62	-0.57	5.99*	-0.12	2.38**	6.19**	-1.14**	-17.77**	15.7	-7.79**	-4.74**	-8.22*
ICMA 98222 × BIB 501-510	-2.51**	-2.46**	7.26*	-0.01	1.25*	3.41**	-0.41*	29.09**	-45.73**	-5.45*	-3.49*	-6.98*
ICMA 10444 × BIB 501-510	-4.59**	-4.54**	14.41**	0.54**	-1.11*	0.33	-0.19	5.88	20.7*	-1.73	-7.69**	-12.69**
ICMA 30199 × BIB 501-510	0.47	0.53	1.06	-0.2	-0.59	-5.85**	0.14	-12.34**	79.59**	-1.2	-9.19**	-6.18
ICMA 30200 × BIB 501-510	1.9**	1.96**	-7.23*	-0.13	-1.38**	-2.31**	0.21	-15.55**	-41.68**	-2.11	8.91**	10.88**
ICMA 30201 × BIB 501-510	3.15**	3.05**	-17.21**	-0.39*	-4.6**	-5.88**	1.19**	-23.8**	-91.68**	-7.67**	11.2**	-7.08*
ICMA 30209 × BIB 501-510	3.24**	2.99**	-11.16**	-0.2	-3.66**	-1.75**	-2.44**	-15.31**	-8.82	1.36	10.57**	19.8**
ICMA 04999 × BIB 511-520	-6.77**	-6.86**	5.1	0.33*	7.45**	5.36**	1.21**	9.15*	61.91**	4.47*	-10.22**	-8.21*
ICMA 88004 × BIB 511-520	-2.55**	-2.49**	-4.28	-0.43**	1.36**	0.27	2.81**	24.24**	-39.91**	-12.28**	-3.89*	-7.85*
ICMA 93333 × BIB 511-520	-0.61	-0.56	-3.48	0.56**	0.11	0.93	-0.27	-27.63**	-30.23**	-5.2*	-1.17	3.02
ICMA 97111 × BIB 511-520	2.82**	2.87**	-7.01*	-0.17	-1.49**	-3.3**	-0.8**	-23.74**	-26.1**	-0.8	-6.07**	-3.24
ICMA 97444 × BIB 511-520	-3.95**	-3.89**	8.48**	0.6**	3.32**	3.52**	-0.7**	19.87**	38.58**	11.14**	-1.81	1.54
ICMA 98222 × BIB 511-520	7.83**	7.89**	-7.78*	-0.86**	-6.75**	-7.24**	-0.13	-56.28**	-70.63**	-9.41**	9.01**	14.47**
ICMA 10444 × BIB 511-520	0.31	0.36	1.83	0.37*	2.09**	0.73	0.95**	50.51**	105.24**	19.86**	-4.24**	1.48
ICMA 30199 × BIB 511-520	0.15	0.21	-4.86	-0.81**	-3.26**	0.64	-1.49**	18.4**	46.91**	-8.5**	4.68**	-10.42**

Crosses	SCA Effects											
	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers/ plant	Ear head length (cm)	Ear head diameter (cm)	Test weight (g)	Ear head weight (g)	Dry stover yield/ plant (g)	Grain yield/ plant (g)	Harvest index (%)	Threshing index (%)
ICMA 30200 × BIB 511-520	6.03**	6.08**	-11.55**	-0.84**	-5.22**	-6.34**	-2.44**	-50.36**	-83.25**	-14.96**	6.94**	20.37**
ICMA 30201 × BIB 511-520	-1.94**	-2.05**	7.9**	0.86**	-0.04	3.93**	1.64**	22.39**	-11.02	12.04**	6.18**	-4.7
ICMA 30209 × BIB 511-520	-1.31*	-1.56**	15.65**	0.39*	2.43**	1.49*	-0.79**	13.44**	8.5	3.63	0.6	-6.46
ICMA 04999 × BIB 531-540	2.78**	2.7**	-3.24	0.3	-1.24*	-2.34**	1.05**	17.47**	12.26	0.95	9.4**	-5.96
ICMA 88004 × BIB 531-540	10.68**	10.73**	-33.88**	0.29	-5.72**	-7.72**	-3.42**	-46.65**	-97.34**	-20.14**	4.77**	8.77**
ICMA 93333 × BIB 531-540	-1.17	-1.11	2.57	0.41*	1.37**	-1.36*	-0.37	29.58**	37.9**	13.17**	6.28**	-1.21
ICMA 97111 × BIB 531-540	2.93**	2.98**	-7.78*	-0.19	-4.51**	-1.86**	-2.1**	3.14	12.03	4.45*	1.39	-0.24
ICMA 97444 × BIB 531-540	-4.94**	-4.89**	7.59*	0.12	2.15**	1.93**	1.14**	27.07**	6.71	7.94**	-0.84	-7.72*
ICMA 98222 × BIB 531-540	-0.5	-0.45	4.85	-0.26	1.39**	-2.37**	0.56**	-20.18**	-66.39**	-10.6**	2.48	1.7
ICMA 10444 × BIB 531-540	-1.36*	-1.3*	7.75*	-0.47**	0.58	4.36**	0.65**	-1.16	-27.73**	0.45	1.6	-1.75
ICMA 30199 × BIB 531-540	-0.74	-0.69	1.5	-0.59**	0.5	1.68**	-0.73**	-13.83**	-48.29**	-6.13**	-1	2.91
ICMA 30200 × BIB 531-540	-3.31**	-3.25**	7.79*	-0.25	3.53**	3.58**	1.27**	-4.04	60.44**	-0.15	-10.14**	2.66
ICMA 30201 × BIB 531-540	-2.84**	-2.94**	7.5*	-0.41*	-0.29	1.71**	2.32**	-19.29**	9.33	1.85	-3.03*	9.4**
ICMA 30209 × BIB 531-540	-1.53*	-1.78**	5.36	1.04**	2.23**	2.38**	-0.37	27.87**	101.07**	8.21**	-10.92**	-8.55*
ICMA 04999 × BIB 551-560	2.65**	2.56**	-9.81**	-0.27	-8.65**	-5.12**	-2.51**	-29.88**	-67.48**	-11.11**	1.98	14.92**
ICMA 88004 × BIB 551-560	-1.91**	-1.86**	10.94**	0.08	2.41**	3.84**	1.95**	-2.9	20.69*	8.03**	0.3	11.07**
ICMA 93333 × BIB 551-560	-2.2**	-2.14**	6.29*	0.12	5.71**	7.18**	3.83**	78.57**	69.26**	17.67**	-1.36	-6.42
ICMA 97111 × BIB 551-560	5.45**	5.51**	-20.97**	-0.86**	-7.1**	-4.81**	-1.23**	-28.1**	-31.05**	-9.71**	9.05**	11.92**
ICMA 97444 × BIB 551-560	6.91**	6.97**	-27.53**	-0.8**	-6.59**	-4.44**	-2.58**	-28.39**	-75.26**	-12.77**	10.81**	18.16**
ICMA 98222 × BIB 551-560	-0.98	-0.92	4.15	-0.19	3.21**	0.36	0.01	-4.53	44.42**	1.13	-8.84**	-13.17**
ICMA 10444 × BIB 551-560	-3.05**	-3**	6.45*	0.53**	4.45**	2.38**	1.52**	0.04	56.96**	-0.82	-9.4**	-7.43*
ICMA 30199 × BIB 551-560	-1.77**	-1.71**	5.86	-0.06	3.81**	2.78**	-0.33	13.48**	0.85	7.37**	0.07	3.52
ICMA 30200 × BIB 551-560	1.1	1.16	-2.54	-0.27	-3.43**	-3.49**	0.23	-7.61	-24.86**	-3.53	3.05*	-6.94*
ICMA 30201 × BIB 551-560	-2.75**	-2.86**	7.23*	1.25**	2.68**	-1.41*	-3.17**	-7.53	-17.09*	-3.76	-3.81*	-17.74**
ICMA 30209 × BIB 551-560	-3.45**	-3.7**	19.93**	0.47**	3.5**	2.73**	2.28**	16.85**	23.55**	7.5**	-1.86	-7.88*
ICMA 04999 × BIB 561-570	-0.24	-0.33	-5.81	0.68**	0.79	4.62**	1.28**	16.45**	45.85**	13.56**	0.57	2.01
ICMA 88004 × BIB 561-570	-4.36**	-4.3**	2.26	0.39*	-1.1*	2.79**	-0.98**	-13.45**	36.25**	-1.18	-3.07*	-7.13*
ICMA 93333 × BIB 561-570	-1.98**	-1.92**	-5.1	0.2	0.63	-1.44*	0.07	-28.1**	7.04	-10.77**	-8.89**	-9.86**
ICMA 97111 × BIB 561-570	-5.77**	-5.71**	12.46**	1.22**	2.59**	0.64	3.35**	-2.88	34.5**	1.73	0.98	5.05
ICMA 97444 × BIB 561-570	-3.31**	-3.25**	-0.37	0.95**	-3.66**	-2.58**	2.66**	5.5	39.18**	-3.44	-9.29**	-15.38**
ICMA 98222 × BIB 561-570	-4.86**	-4.81**	-2.44	0.71**	-2.09**	2.53**	3**	36.02**	94.42**	2.36	-14.07**	-5.05
ICMA 10444 × BIB 561-570	0.06	0.11	-11.52**	0.51**	-0.26	-1.27*	-0.38	-0.51	9.18	2.07	5.65**	0.63

Crosses	SCA Effects											
	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers/ plant	Ear head length (cm)	Ear head diameter (cm)	Test weight (g)	Ear head weight (g)	Dry stover yield/ plant (g)	Grain yield/ plant (g)	Harvest index (%)	Threshing index (%)
ICMA 30199 × BIB 561-570	-1.44*	-1.38*	-7.62*	0.85**	-0.36	-1.04	2.29**	1.82	-5.82	4.26*	-0.53	1.75
ICMA 30200 × BIB 561-570	-4.34**	-4.29**	4.22	1.55**	2.81**	3.14**	3.02**	36.05**	29.58**	17.13**	5.59**	-7.46*
ICMA 30201 × BIB 561-570	-2.2**	-2.3**	-2.76	-0.42*	-0.7	2.92**	2.19**	93.58**	118.47**	8.46**	-6.55**	-36.43**
ICMA 30209 × BIB 561-570	-4.23**	-4.48**	-1.55	0.65**	0.05	3.7**	3.02**	7.96	3.55	0.83	2.48	-3.19
ICMA 04999 × BIB 571-580	-5.8**	-4.89**	6.08*	0.99**	3.49**	4.56**	2.35**	27.56**	50.85**	10.34**	-2.65	-11.79**
ICMA 88004 × BIB 571-580	-2.91**	-2.86**	7.43*	1.12**	-0.37	0.68	1.01**	0.43	32.91**	4.59*	-4.75**	-7.52*
ICMA 93333 × BIB 571-580	-1.86**	-1.81**	-1.41	0.11	-1.15*	1.01	-0.78**	6.9	-6.29	4.01	11.98**	2.89
ICMA 97111 × BIB 571-580	-5.99**	-5.94**	6.13*	0.63**	2.68**	2.98**	2.19**	6.56	32.28**	6.96**	6.14**	1.6
ICMA 97444 × BIB 571-580	-5.09**	-5.03**	8.18**	0.25	0.29	2.91**	2.44**	27.17**	74.74**	19.67**	3.29*	-0.34
ICMA 98222 × BIB 571-580	-1.75**	-1.7**	-6.86*	0.25	-3.93**	3.53**	-2.36**	-8.42*	-8.91	-4.98*	-2.78	-14.52**
ICMA 10444 × BIB 571-580	-1.83**	-1.78**	-1.86	-0.06	-0.6	8.03**	2.05**	7.82	13.63	1.4	-3.13*	-7.31*
ICMA 30199 × BIB 571-580	-2.22**	-2.16**	4.41	0.97**	-0.2	5.54**	1.17**	9.6*	8.63	10.04**	2.74	-1.91
ICMA 30200 × BIB 571-580	-4.45**	-4.4**	2.12	0.2	1.56**	6.71**	2.7**	34.94**	64.03**	9.91**	-7.16**	-13.89**
ICMA 30201 × BIB 571-580	-0.53	0.48	-5.43	-0.3	0.44	1.35*	-0.23	-8.64*	-54.87**	-7.09**	-2.47	-23.41**
ICMA 30209 × BIB 571-580	-4.01**	-2.14**	0.26	-0.16	0.24	4.33**	2.69**	9.63*	26.88**	8.61**	-4.43**	-4.41
SE (S_{CA})	0.62	0.6	3.03	0.16	0.51	0.64	0.2	4.28	8.43	2.11	1.51	3.31
SE (Sij-Skl)	0.88	0.84	4.28	0.23	0.71	0.91	0.28	6.05	11.92	2.99	2.13	4.69
CD 5%(SCA)	1.22	1.17	5.95	0.32	0.99	1.26	0.39	8.41	16.57	4.15	2.96	6.51
CD 5%(Sij-Skl)	1.73	1.65	8.41	0.45	1.4	1.78	0.56	11.9	23.43	5.87	4.19	9.21

** and ** represents significant at 5% and 1% level of significance, respectively*

Table 6. Estimation of combining ability variances for grain yield per plant and its components evaluated in different environments

Environment	Source of variation	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers/ plant	Ear head length (cm)	Ear head diameter (cm)	Test weight (g)	Ear head weight (g)	Dry stover yield/ plant (g)	Grain yield/ plant (g)	Harvest index (%)	Threshing index (%)
E_1	σ^2gca	2.33	2.42	41.2	0.17	0.99	1.8	0.47	181.98	751.49	32.91	5.68	23.04
	σ^2sca	9.69	10.3	224.82	0.55	8.04	10.95	2.97	1241.61	5687.54	301.77	22.03	113.36
	σ^2gca/σ^2sca	0.24	0.23	0.18	0.30	0.12	0.16	0.15	0.14	0.13	0.10	0.25	0.20
E_2	σ^2gca	3.59	3.58	26.87	0.13	2.69	4.57	0.44	135.25	793.89	28.22	13.14	168.86
	σ^2sca	17.86	17.81	90.82	0.58	22.84	28	3.09	1176.2	4592.47	177.72	122.89	1317.19
	σ^2gca/σ^2sca	0.20	0.201	0.29	0.22	0.11	0.16	0.14	0.11	0.17	0.15	0.10	0.12
E_3	σ^2gca	3.39	3.58	27.53	0.07	2.30	4.53	0.46	141.5	735.55	13.92	8.3	22.74
	σ^2sca	18.97	17.79	91.45	0.34	22.44	29.15	3.14	1185.53	4436.25	86.49	175.3	120.84
	σ^2gca/σ^2sca	0.17	0.20	0.30	0.20	0.10	0.15	0.14	0.11	0.16	0.16	0.04	0.18
Pooled	σ^2gca	3.01	2.99	25.17	0.06	1.34	2.74	0.45	106.88	545.97	18.07	4.86	23.96
	σ^2sca	12.80	12.87	117.60	0.35	14.33	17.6	3.06	946.79	3365.56	123.6	51.61	187.29
	σ^2gca/σ^2sca	0.235	0.232	0.21	0.17	0.09	0.15	0.14	0.11	0.16	0.14	0.09	0.12

** and ** represents significant at 5% and 1% level of significance, respectively*

environments ranged from -1.17 (ICMA 30209 x BIB 481-500) to 1.55 (ICMA 30200 x BIB 561-570). Out of total 77 crosses, crosses viz., (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in pooled analysis for number of productive tillers per plant. Thus, these were considered as good specific combiner for productive tillers per plant. As long ear heads are desirable in pearl millet, positive combining ability effects were considered. Perusal of Table 5 indicated that the SCA effects in over the environments ranged from -8.65 (ICMA 04999 x BIB 551-560) to 7.45 (ICMA 04999 x BIB 511-520). Out of total 77 crosses, ten crosses viz., (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in pooled analysis. Thus, these were considered as good specific combiner for ear head length. As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered. Perusal of Table 5 indicated that the SCA effects in over the environments ranged from -9.51 (ICMA 10444 x BIB 481-500) to 8.03 (ICMA 10444 x BIB 571-580). Out of total 77 crosses, eleven crosses viz., (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for ear head diameter.The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 5 indicated that the SCA effects in over the environments ranged from -50.36 (ICMA 30200 x BIB 511-520) to 93.58 (ICMA 30201 x BIB 561-570). Out of total 77 crosses, eight crosses viz., (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment. Thus, these were considered as good general combiner for ear head weight. The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 5 indicated that the SCA effects in over the environments ranged from -21.19 (ICMA 30209 x BIB 481-500) to 35.89 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, nine crosses viz., (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment. Thus, these were considered as good specific combiner for grain yield per plant. Izge et al. [16], Singh and Sharma [17], Rafiq et al. [18], Eldie et al. [6], Krishnan et al. [7], Siddique et al. [19], Gavali et al. [8] and Ladumor et al. [9] also reported some specific combiners for various traits in pearl millet.

Perusal of Table 6 indicated the magnitude of variance due to GCA was lower as compared to magnitude of SCA for all the characters in all the environments. Significant variance due to GCA and SCA indicated the importance of additive as well as non-additive components in the inheritance of majority of the characters. The ratio of variances due to GCA/SCA was less than unity which indicated the preponderance of non-additive components for all the characters in all the environments. Similar results were also reported in pearl millet by Krishnan et al. [7], Kumar et al. [13], Solanki et al. [14] and Badurkar et al. [15].

4. CONCLUSION

Nature and magnitude of combining ability provide an idea about relative role of fixable and non- fixable gene effects in the inheritance of different characters *i.e* .it helps in identifying suitable parents for crossing programme. The choice of the most suitable breeding method mainly depends on the combining ability behavior and nature of gene action involved in the control of the traits of interest to the breeder. The comprehensive analysis of the combining ability involved in the inheritance of quantitative traits and in the phenomenon of heterosis is necessary for the evaluation of various possible breeding procedures (Allard, 1960). In present investigation, the magnitude and direction of GCA and SCA effects in most of the cases for

grain yield per plant and its component traits frequently changed from environment to environment, which complicated the problem of identification of promising parents and crosses. However, In this present investigation, out of eleven lines tested, nine lines depicted good GCA effects for various characters. Thus these lines were considered good general combiner for different characters. On the other hand, out of seven testers tested, the tester BIB 571-580, BIB 561- 570 BIB 511- 520, BIB 481- 500 and BIB 531- 540 was found good general combiner. Out of 77 hybrids, 29 hybrids exhibited best specific cross combinations with significant SCA effects for various traits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Burton GW, Wallance AT, Rachie KO. Chemical composition and nutritive value of pearl millet [*Pennisetum glaucum* (L.) R. Br.] grain. Crop Science. 1972;2(2):187-189.
2. Flech H. Introduction to Nutrition.Macmillan publication USA. 1981;42.
3. Kempthorne O. An Introduction to Genetic Statistics. John Wiley and Sons Inc. New York. 1957;458-471.
4. Fisher RA. The correlation between relatives on the supposition of mendelian inheritance. Transactions of the Royal Society of Edinburgh. 1918;52:399-433.
5. Sprague GF, Tatum LA. General vs specific combining ability in single crosses of corn. Journal of the American Society of Agronomy. 1942;34:22-23.
6. Eldie YD, Ibrahim AES, Ali AM. Combining ability analysis for grain yield and its components in pearl millet.Gezira Journal of Agricultural Science. 2009;7(1):1-10.
7. Krishnan MRR, Patel MS, Gami RA, Bhadauria HS, Patel YN. Genetic analysis in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. International Journal of Current Microbiology and Applied Sciences. 2017;6(11):900-907.
8. Gavali RK, Kute NS, Pawar VY, Patil HT. Combining ability analysis and gene action studies in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Electronic Journal of Plant Breeding. 2018;9(3):908-915.
9. Ladumor VL, Mungra KD, Parmar SK, Sorathiya JS, Vansjaliya HG. Grain iron, zinc and yield genetics in pearl millet (*Pennisetum glaucum* L. R. Br.).International Journal of Current Microbiology and Applied Sciences. 2018;7(9):242-250.
10. Saini LK, Solanki KL, Gupta PC, Saini H, Singh AG. Combining ability studies for grain yield and component traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. International Journal of Chemical Studies. 2018;6(1):1939-1944.
11. Santosh T, Sadhana K, Reddy GA, Patil HT. Assessment of combining ability and gene action in pearl millet (*Pennisetum glaucum* (L.) R. Br.) using line x tester analysis. International Journal of Pure & Applied Bioscience. 2018;6(2):172-177.
12. Jeeterwal RC, Sharma LD, Nehra A. Combining ability studies through diallel analysis in pearl millet [*Pennisetum glaucum* (L.) R.Br.] under varying environmental conditions. Journal of Pharmacognosy and Phytochemistry. 2017;6(4):1083-1088.
13. Kumar M, Gupta PC, Kumar P, Barupal H. Assessment of combining ability and gene action for grain yield and its component traits in pearlmillet [*Pennisetum glaucum* (L.) R. Br.]. Journal of Pharmacognosy and Phytochemistry. 2017a;6(3):431-434.
14. Solanki KL, Bhinda MS, Gupta PC, Saini H, Saini LK. Combining ability and gene action studies for grain yield and component characters in pearl millet [*Pennisetum glaucum* (L.) R. Br.] under arid condition of Rajasthan. International Journal of Pure and Applied Bioscience. 2017;5(4):2121-2129.
15. Badurkar SB, Pole SP, Toprope VN, Ingle NP. Combining ability for grain yield and its related traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. International Journal of Current Microbiology and Applied Sciences. 2018;6:956-961.
16. Izge AU, Kadams AM, Gungula DT. Heterosis and inheritance of quantitative characters in a diallel cross of pearl millet (*Pennisetum glaucum* L.). Journal of Agronomy. 2007;6(2):278- 285.
17. Singh J, Sharma R. Assessment of combining ability in pearl millet using line x tester analysis.Advances in Crop Science and Technology. 2014;2(4):1-4.

18. Rafiq SM, Kumar BS, Rao UP. Combining ability studies using diverse cytoplasm for grain yield and its components in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Plant Archives. 2016;16(2):588-593.

19. Siddique M, Irshad-Ul-Haq M, Khanum S, Kamal N, Ullah MA. Combining ability studies of grain yield and related traits in pearl millet. Research in Plant Biology. 2017;7:21-23.

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