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Estimation of heterosis and combining ability for grain yield and its components in pearl millet (*Pennisetum glaucum* (L.) R. Br.)

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Abstract

A present experiment was conducted at Centre for Crop Improvement, S.D.A.U., S. K. Nagar during the summer season of 2018 with nine male sterile lines (female parents) and five restorers (male parents) of pearl millet in line x tester mating fashion. In relation with grain yield per plant, hybrid ICMA 92333 x 16110 R was recorded highest and significantly positive relative heterosis (142.34%), heterobeltiosis (116.34%) and standard heterosis (36.69). In general combining ability analysis ICMA 01555 found maximum GCA effects for grain yield, ear head girth, ear head length, number of productive tillers per plant and test weight. In specific combining ability analysis five crosses viz, ICMA92333 x 16110 R, ICMA 05444 x 15001 R, ICMA 07111 x 15208 R, ICMA-01555 x 15208 R and ICMA 05888 x 16066 R were identified as the best specific combiners for grain yield and major yield components. The magnitude of sca variances was higher than the GCA variances for all the characters, revealed that non additive gene action were involved in the inheritance of all the character under study. Analysis of sca effects revealed that good combining parents yield better hybrids, because parents with significant positive GCA effects were involved more in selected crosses than those with non-significant GCA effects and negative GCA effects. In the present study, the involvement of at least one good general combiner was found essential for obtaining combinations with high specific effects. Combining ability studies revealed that both general and specific combining ability variances were important but the estimates of sca variance were higher in magnitude for all the characters. Thus, indicating the predominance of nonadditive gene action. The cross ICMA 92333 x 16110 R (average x poor combiner parents) and ICMA 05444 x 15001 R and ICMA 05888 x 16066 R (good x poor combiner parents) recorded high *per se* performance, significant and positive mid parent, better parent and standard heterosis as well as positive specific combining ability effect for grain yield, number of effective tiller per plant and harvest index.

Keywords: Combining ability. GCA, SCA, Pearl millet

Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br., $2n=2x=14$, Family - Gramineae) is warm season, annual, C_4 plant and a highly cross-pollinated crop with the advantages of huge genetic variability and availability of efficient cytoplasmic genetic male sterility system. The protogynous flower morphology of pearl millet makes it a highly cross-pollinated crop with extent of out crossing above 85 per cent and thereby it is highly heterozygous and heterogeneous. In India, pearl millet occupies an area of 7.4 million hectares and production of 9.13 million tonnes with productivity of 1237 kg/ha (Anonymous, 2017-18) [1]. The major growing states in India are Rajasthan, Maharashtra, Gujarat, Haryana, Uttar Pradesh and Karnataka, where, it is grown both in *kharif* and *summer* seasons. In Gujarat, *kharif* season pearl millet occupy an area of 1.53 lakh hectare and production of 2.83 lakh tonnes with productivity of 1853 kg/ha. Whereas, in *summer* season pearl millet occupy an area of 2.44 lakh hectare and production of 6.35 lakh tonnes with productivity of 2598 kg/ha.

The exploitation of hybrid vigour has been proved to be a potential method of boosting productivity in many cross pollinated crops. Existence of substantial degree of heterosis for seed yield and other traits has also been reported by several workers in pearl millet. The best examples of the success of hybrid technology in crop plants are in cotton, corn, castor, sorghum, rice, tobacco and pearl millet (Banga and Banga, 1998) [4]. The combining ability studies provide useful information regarding the selection of suitable parents for effective hybridization programme and at the same time elucidates the nature and magnitude of gene action. Since, the nature of gene action varies with genetic architecture of population involved

in hybridization, it is necessary to evaluate the parents for their combining ability. Hence the present investigation based on 'line x tester' analysis was designed, to study the extent of hybrid vigour in F_1 and collect the information regarding the genetic composition of various quantitatively inherited yield contributing traits including grain yield in pearl millet.

Materials and Methods

A Present study involving nine CMS lines viz ICMA 91777, ICMA 92333, ICMA 04999, ICMA 05444, ICMA 97111, ICMA 01555, ICMA 05888, ICMA 07111 and ICMA 04111 and five restorer pollinators viz. 15001 R, 16066 R, 15743 R, 16110 R and 15208 R and one standard check hybrids GHB-558 were obtained from Centre for Crop Improvement, S.D.A.U., S. K. Nagar, Gujarat. Male sterile lines (female) and testers (males) were crossed in line x tester mating design during *khariif* 2017 and evaluated in Randomized Complete Block design at the Centre for Crop Improvement, S.D.A.U., S. K. Nagar, Gujarat during *summer* 2018 with two replications.

Five competitive plants from each experimental unit of every replication were selected randomly for recording observations on component characters viz., Days to 50% flowering, days to maturity, plant height (cm), number of effective tiller per plant, ear head length (cm), ear head girth (cm), leaf area (cm^2), grain yield per plant, test weight (g) and harvest index (%). While observation for days to flowering and days to maturity recorded on plot basis. Significance of difference among the genotypes for the characters studied, as suggested by Panse and Sukhatme (1985)^[9]. The expression of heterosis in 45 hybrids involving nine CMS lines and five testers was measured in terms of mid parent, better parent and standard heterosis in comparison with standard check GHB-558.

Results and Discussion

Analysis of variance for the experimental design

Analysis of variance (Table 1) revealed that mean sum of square due to parents and hybrids were significant for all the character, which indicated the existence of real amount of genetic variability in the parental material used in the study. The mean sum of squares due to genotypes was highly significant for all the traits under investigation. Further, partitioning of the genotypes variance into parents, hybrids and parents vs. hybrids revealed that the parents as well as hybrids exhibited significant differences for all the characters. This indicated the existence of appreciable amount of genetic variability in the experimental material of the present study.

Heterosis

Magnitudes of per cent heterosis of hybrids over mid parent (relative heterosis), better parent (heterobeltiosis) and standard parent (standard heterosis) for different characters in pearl millet hybrids have been presented in Table 2 to 7.

For days to flowering, With respect to heterosis for early flowering, negative heterosis of hybrids was considered desirable (Arulselvi *et al.*, 2006)^[2]. highest and significant negative relative heterosis and heterobeltiosis was observed in the cross ICMA 92333 x 15208 R. High significant negative standard heterosis was observed in ICMA 05888 x 15208 R and ICMA 05444 x 16110 R. Earliness in flowering had also been reported by Manga and Dubey (2004)^[7]. For days to maturity, highest and significant negative relative heterosis, heterobeltiosis and standard heterosis was observed in the

cross ICMA 97111 x 16110 R. The present findings are in accordance with Chotaliya *et al.* (2009)^[5].

For plant height, none of the negative significant hybrids obtain in relative heterosis and heterobeltiosis. The present finding corroborate with Rafiq *et al.* (2016)^[12]. One cross ICMA 04111 x 15208 R (-34.37%) was exhibited desirable standard heterosis. These results were in agreement with Yadav *et al.* (2006) and Rafiq *et al.* (2016)^[12].

The hybrid combination ICMA 05444 x 15001 R was recorded highly significant positive relative heterosis (63.64%), heterobeltiosis (63.64%) and standard heterosis (44.00%) for the trait number of effective tiller per plant. Similar result found by Azhaguvel *et al.* (1998)^[3] and Vetriventhan *et al.* (2008)^[15].

The cross ICMA 92333 x 16110 R was recorded highly significant positive relative heterosis (71.72%), heterobeltiosis (33.07%) and standard heterosis (31.50%) for the trait ear head length. Similar result found by Azhaguvel *et al.* (1998)^[3] and Patil *et al.* (2008)^[11].

For ear head girth, hybrid ICMA 07111 x 15208 R was recorded highly significant positive relative heterosis (45.60%) and heterobeltiosis (15.75%) and high significant positive standard heterosis (13.17%) observed in cross ICMA 05444 x 16066 R. The results were in agreement with Rafiq *et al.* (2016)^[12].

In case of leaf area per plant, cross combination showed ICMA 97111 x 15743 R was highly significant positive relative heterosis (134.64%) and heterobeltiosis (71.65%). Same result found by Patil *et al.* (2008)^[11]. High significant positive standard heterosis (23.48) observed in cross ICMA 07111 x 16066 R. Similar results were found by Deore *et al.* (1997)^[6].

In relation with grain yield per plant, hybrid ICMA 92333 x 16110 R was recorded highest and significantly positive relative heterosis (142.34%), heterobeltiosis (116.34%) and standard heterosis (36.69). The results were substantiate the finding of Azhaguvel *et al.* (1998)^[3], Ramamoorthi and Govindarasu (2000) and Salagarkar *et al.* (2016)^[14].

For harvest index, hybrid ICMA 92333x 16110 R recorded significantly positive relative heterosis (64.23%), heterobeltiosis (59.63%) and standard heterosis (16.01%). The results substantiate the finding of Manga and Dubey (2004)^[7]. For test weight, cross ICMA 01555 x 15208 R was recorded significantly positive relative heterosis (22.34%), heterobeltiosis (18.14%) and standard heterosis (10.30%). The results substantiate the finding of Azhaguvel *et al.* (1998)^[3] and Patil *et al.* (2008)^[11].

Analysis of variance for combining ability

The results of analysis of variance for combining ability indicated that the mean squares due to lines (females) were found to be highly significant for ear head length and leaf area per plant (Table 8). In case of testers (males) non significant values were obtained for all the characters, except ear head length and harvest index. Whereas, the mean squares due to line x tester were found highly significant for all the characters under study. The magnitude of sca variances was higher than the gca variances for all the characters, revealed that non additive gene action were involved in the inheritance of all the character under study. The above results suggested that the parents used in this study were diverse and significant difference exists between them.

Estimates of general combining ability effects

General combining ability is largely attributed to the additivity of gene effects. While specific combining ability is associated with interaction effects which may be due to dominance and epistasis. The estimates of general and specific combining ability variance suggested the predominance of specific combining ability variance. However, for the development of high yielding varieties general combining ability was more important (Mungra, *et al.*, 2014 and Patel, *et al.*, 2014)^[8, 10].

The estimates of gca effects for parents (Table 9) revealed that female ICMA-01555 were the best combiner for grain yield and other yield components, such as ear head length, ear head girth, number of productive tillers per plant and test weight. Among the male parents the gca effect for grain yield ranged from -0.73 to 5.71. The genotypes 16066 R had the highest positive effect for grain yield, ear head length, ear head girth, number of effective tillers per plant, test weight and harvest index. The combining ability studies also revealed that among male parents, the tester 16110 R had high negative and significant effect for days to flowering, days to maturity

and high positive and significant effect for ear head length.

Estimates of specific combining ability effects

Among forty five hybrids, five hybrids ICMA92333 x 16110 R, ICMA 05444 x 15001 R, ICMA 07111 x 15208 R, ICMA-01555 x 15208 R and ICMA 05888 x 16066 R showed the best performance with significantly positive sca effect for grain yield (Table 10). High sca effects of these crosses for seed yield per plant were accompanied by high sca effects for number of effective tiller per plant, earhead length and earhead girth. The crosses exhibited high sca effect did not always involved parents possessing high gca effects indicating major role of non additive gene effects in expression of this traits. One hybrids, ICMA 92333 x 16110 R recorded significant positive effects for all the characters studied except days to flowering, days to maturity and plant height. Best specific combinations for earliness was derived from the hybrid ICMA 05888 x 16066 R. However, the genotype ICMA 05888 had negative effect and 16066 R had non significant negative indicating the role of dominance gene action for days to flowering.

Table 1: Analysis of variance (Mean square) for parents and hybrids for seed yield and its component characters in pearl millet.

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	Number of effective tiller per plant	Earhead length (cm)	Earhead girth (mm)	Leaf area per plant (cm ²)	Grain yield per plant (g)	Harvest index (%)	Test weight (g)	Seed setting (%)
Replication	1	10.38	4.10	28.85	0.15	0.36	0.37	21611.55	2.06	0.40	0.70	1.79
Genotype	58	43.89**	93.31**	2276.18**	0.34**	44.03**	22.86**	384137.47**	129.61**	70.12**	1.39**	420.83**
Parents	13	80.37**	115.24**	1978.10**	0.12*	63.36**	30.77**	717189.12**	41.60**	47.26**	1.88**	292.87**
Female	8	81.26**	118.00**	497.69*	0.07	60.65**	25.11**	83673.32**	47.81**	33.52**	2.01**	142.94**
Male	4	80.35**	73.40**	998.71**	0.19*	4.41*	2.50	668655.42**	34.59**	86.54**	0.50	15.67
Female vs. Male	1	73.35**	260.58**	17739.01**	0.17	320.83**	189.09**	5979450.48**	19.91	0.02	6.27**	2601.14**
Parents vs. hybrids	1	61.37**	193.12**	59764.81**	0.016	516.55**	172.44**	8112859.74**	1921.64**	391.05**	5.17**	888.70**
Hybrids	44	32.71**	84.56**	1057.68**	0.49**	27.58**	17.12**	110083.07**	114.89**	69.58**	1.16**	448.00**
Error	58	3.23	4.07	201.72	0.06	2.78	1.87	24478.90	8.99	9.29	0.21	10.51

* and ** significant at P = 0.05 and P = 0.01 levels, respectively.

Table 2: Estimates of heterosis in percentage in F1 hybrid over mid parent, better parent and standard check GHB 558 for days to flowering and days to maturity in pearl millet.

Sr. No.	Hybrids	Days to flowering			Days to maturity		
		MP	BP	SC	MP	BP	SC
1	ICMA 91777 x 15001 R	-7.95**	-4.35	11.11**	-7.44**	-5.08*	4.35
2	ICMA 91777 x 16066 R	0.47	8.00*	9.09*	-6.19**	-1.85	-1.24
3	ICMA 91777 x 15743 R	3.48	3.48	20.20**	7.65**	7.95**	18.01**
4	ICMA 91777 x 16110 R	-0.92	4.85	9.09*	-12.67**	-8.47**	0.62
5	ICMA 91777 x 15208 R	-8.20**	-2.61	13.13**	-2.49	-0.56	9.32**
6	ICMA 92333 x 15001 R	-9.92**	-7.63*	10.10**	-5.49**	-3.37	6.83**
7	ICMA 92333 x 16066 R	7.34*	17.00**	18.18**	9.41**	14.81**	15.53**
8	ICMA 92333 x 15743 R	-18.45**	-17.39**	-4.04	-11.30**	-10.80**	-2.48
9	ICMA 92333 x 16110 R	-3.17	3.88	8.08*	-11.29**	-7.30**	2.48
10	ICMA 92333 x 15208 R	-19.84**	-16.10**	0.00	-13.81**	-12.36**	-3.11
11	ICMA 04999 x 15001 R	-6.67*	3.96	6.06	-1.73	6.25*	5.59*
12	ICMA 04999 x 16066 R	-6.47*	-6.00	-5.05	-10.56**	-10.00**	-10.56**
13	ICMA 04999 x 15743 R	-4.63	1.98	4.04	-2.38	2.50	1.86
14	ICMA 04999 x 16110 R	-5.88	-4.95	-3.03	-12.99**	-3.75	-4.35
15	ICMA 04999 x 15208 R	-1.74	11.88**	14.14**	2.91	10.63**	9.94**
16	ICMA 05444 x 15001 R	6.48*	25.00**	16.16**	6.59**	20.27**	10.56**
17	ICMA 05444 x 16066 R	10.42**	15.22**	7.07	-6.45**	-2.03	-9.94**
18	ICMA 05444 x 15743 R	14.98**	29.35**	20.20**	14.20**	25.00**	14.91**
19	ICMA 05444 x 16110 R	-6.67*	-1.09	-8.08*	-15.20**	-2.03	-9.94**
20	ICMA 05444 x 15208 R	-15.84**	1.09	-6.06	6.02**	18.92**	9.32**
21	ICMA 97111 x 15001 R	-0.91	13.54**	10.10**	-1.19	10.67**	3.11
22	ICMA 97111 x 16066 R	-4.08	-2.08	-5.05	3.85	8.00**	0.62

23	ICMA 97111 × 15743 R	5.21	15.63**	12.12**	-12.88**	-5.33	-11.80**
24	ICMA 97111 × 16110 R	4.52	8.33*	5.05	-18.02**	-6.00*	-12.42**
25	ICMA 97111 × 15208 R	-13.78**	1.04	-2.02	-6.59**	4.00	-3.11
26	ICMA 01555 × 15001 R	-3.39	1.79	15.15**	-7.65**	-6.11**	4.97
27	ICMA 01555 × 16066 R	11.32**	18.00**	19.19**	-8.19**	-3.09	-2.48
28	ICMA 01555 × 15743 R	-4.85	-3.57	9.09*	-2.25	-1.14	8.07**
29	ICMA 01555 × 16110 R	-1.40	2.91	7.07	-10.16**	-6.67**	4.35
30	ICMA 01555 × 15208 R	-5.39*	1.79	15.15**	-6.59**	-5.56*	5.59*
31	ICMA 05888 × 15001 R	0.00	18.89**	8.08*	-14.88**	-4.67	-11.18**
32	ICMA 05888 × 16066 R	-2.11	3.33	-6.06	13.46**	18.00**	9.94**
33	ICMA 05888 × 15743 R	8.29**	23.33**	12.12**	5.52*	14.67**	6.83**
34	ICMA 05888 × 16110 R	5.70	13.33**	3.03	-15.70**	-3.33	-9.94**
35	ICMA 05888 × 15208 R	-18.72**	-1.11	-10.10**	2.99	14.67**	6.83**
36	ICMA 07111 × 15001 R	-15.10**	-14.05**	5.05	-9.78**	-8.79**	3.11
37	ICMA 07111 × 16066 R	-7.69**	2.00	3.03	-4.65*	1.23	1.86
38	ICMA 07111 × 15743 R	-8.47**	-6.09	9.09*	2.79	4.55	14.29**
39	ICMA 07111 × 16110 R	-4.46	3.88	8.08*	-9.57**	-6.59**	5.59*
40	ICMA 07111 × 15208 R	-12.80**	-9.92**	10.10**	-0.55	0.00	13.04**
41	ICMA 04111 × 15001 R	-3.25	-2.46	20.20**	-5.41**	-4.89*	8.70**
42	ICMA 04111 × 16066 R	3.60	15.00**	16.16**	-0.58	6.17*	6.83**
43	ICMA 04111 × 15743 R	-3.80	-0.87	15.15**	3.33	5.68*	15.53**
44	ICMA 04111 × 16110 R	-1.33	7.77*	12.12**	-13.23**	-10.87**	1.86
45	ICMA 04111 × 15208 R	-15.54**	-13.11**	7.07	-5.98**	-5.98**	7.45**
S.Em. ±		3.13	3.61	3.61	3.52	4.06	4.06
Range		-19.84 to +14.98	-17.39 to +29.35	-10.10 to +20.20	-18.02 to +14.20	-12.36 to +25	-12.42 to +18.01
Significant Heterosis		23	21	28	33	29	28
No. of + ^{ve} significant		6	15	26	7	14	21
No. of - ^{ve} significant		17	6	2	26	15	7

* and ** significant at P = 0.05 and P = 0.01 levels, respectively

Table 3: Estimates of heterosis in percentage in F1 hybrid over mid parent, better parent and standard check GHB 558 for Plant height and Number of effective tillers in pearl millet.

Sr. No.	Hybrids	Plant height (cm)			Number of effective tiller per plant		
		MP	BP	SC	MP	BP	SC
1	ICMA 91777 × 15001 R	82.87**	122.53**	20.16*	16.67	7.69	12.00
2	ICMA 91777 × 16066 R	9.49	66.93**	-9.87	-5.66	-7.41	0.00
3	ICMA 91777 × 15743 R	63.10**	114.57**	15.86	2.04	-3.85	0.00
4	ICMA 91777 × 16110 R	58.55**	95.52**	5.57	-9.43	-11.11	-4.00
5	ICMA 91777 × 15208 R	48.41**	104.93**	10.65	21.74*	7.69	12.00
6	ICMA 92333 × 15001 R	77.48**	139.07**	9.26	4.35	0.00	-4.00
7	ICMA 92333 × 16066 R	-12.50	49.67*	-31.60**	-5.88	-11.11	-4.00
8	ICMA 92333 × 15743 R	63.80**	139.74**	9.56	-10.64	-12.50	-16.00
9	ICMA 92333 × 16110 R	84.49**	152.05**	15.19	33.33**	25.93**	36.00**
10	ICMA 92333 × 15208 R	2.04	57.22**	-28.15**	-4.55	-12.50	-16.00
11	ICMA 04999 × 15001 R	29.54*	64.58**	-17.31	-19.15*	-24.00*	-24.00*
12	ICMA 04999 × 16066 R	10.53	76.99**	-11.08	7.69	3.70	12.00
13	ICMA 04999 × 15743 R	58.34**	117.95**	9.50	4.17	0.00	0.00
14	ICMA 04999 × 16110 R	46.02**	88.07**	-5.51	3.85	0.00	8.00
15	ICMA 04999 × 15208 R	53.90**	122.65**	11.86	-6.67	-16.00	-16.00
16	ICMA 05444 × 15001 R	64.13**	82.69**	15.35	63.64**	63.64**	44.00**
17	ICMA 05444 × 16066 R	13.51	56.23**	-1.36	-6.12	-14.81	-8.00
18	ICMA 05444 × 15743 R	56.41**	87.30**	18.25*	-15.56	-17.39	-24.00*
19	ICMA 05444 × 16110 R	35.43**	52.64**	-3.63	18.37*	7.41	16.00
20	ICMA 05444 × 15208 R	44.50**	81.11**	14.35	4.76	0.00	-12.00
21	ICMA 97111 × 15001 R	57.81**	61.03**	19.79*	-20.00*	-28.57**	-20.00*
22	ICMA 97111 × 16066 R	-5.86	17.09	-12.89	12.73	10.71	24.00*
23	ICMA 97111 × 15743 R	47.84**	61.43**	20.10*	-1.96	-10.71	0.00
24	ICMA 97111 × 16110 R	42.61**	47.19**	9.50	-12.73	-14.29	-4.00
25	ICMA 97111 × 15208 R	19.12*	35.72**	0.97	-12.50	-25.00**	-16.00
26	ICMA 01555 × 15001 R	34.09**	63.83**	-12.14	-28.00**	-35.71**	-28.00**
27	ICMA 01555 × 16066 R	18.35*	81.26**	-2.78	23.64**	21.43*	36.00**
28	ICMA 01555 × 15743 R	49.00**	96.84**	5.57	1.96	-7.14	4.00
29	ICMA 01555 × 16110 R	36.28**	68.74**	-9.50	-12.73	-14.29	-4.00
30	ICMA 01555 × 15208 R	60.98**	123.25**	19.73*	33.33**	14.29	28.00**
31	ICMA 05888 × 15001 R	29.26**	35.40**	-4.27	10.64	4.00	4.00
32	ICMA 05888 × 16066 R	24.17**	59.25**	12.59	23.08**	18.52*	28.00**
33	ICMA 05888 × 15743 R	26.95**	42.55**	0.79	12.50	8.00	8.00

34	ICMA 05888 × 16110 R	30.45**	38.27**	-2.24	-26.92**	-29.63**	-24.00*
35	ICMA 05888 × 15208 R	34.11**	57.28**	11.20	28.89**	16.00	16.00
36	ICMA 07111 × 15001 R	41.75**	62.72**	-2.78	-10.64	-16.00	-16.00
37	ICMA 07111 × 16066 R	10.34	57.35**	-5.99	-3.85	-7.41	0.00
38	ICMA 07111 × 15743 R	40.79**	74.16**	4.06	-4.17	-8.00	-8.00
39	ICMA 07111 × 16110 R	41.35**	64.34**	-1.82	-19.23*	-22.22*	-16.00
40	ICMA 07111 × 15208 R	28.20**	66.16**	-0.73	46.67**	32.00**	32.00**
41	ICMA 04111 × 15001 R	72.08**	111.52**	12.29	-8.33	-15.38	-12.00
42	ICMA 04111 × 16066 R	28.95**	98.86**	5.57	-13.21	-14.81	-8.00
43	ICMA 04111 × 15743 R	63.38**	117.22**	15.31	10.20	3.85	8.00
44	ICMA 04111 × 16110 R	21.28	51.08**	-19.79*	-1.89	-3.70	4.00
45	ICMA 04111 × 15208 R	-11.44	23.63	-34.37**	-17.39	-26.92**	-24.00*
S.Em. ±		24.78	28.62	28.62	0.40	0.47	0.47
Range		-11.44 to +84.49	+17.09 to 139.74	-34.37 to +20.16	-28.00 to +63.4	-29.63 to +63.64	-28.00 to +44.00
Significant Heterosis		36	43	9	14	12	13
No. of + ^{ve} significant		36	43	5	9	5	7
No. of - ^{ve} significant		0	0	4	5	7	6

Table 4: Estimates of heterosis in percentage in F1 hybrid over mid parent, better parent and standard check GHB 558 for Ear head length and Ear head girth in pearl millet.

Sr. No.	Hybrids	Ear head length (cm)			Ear head girth (mm)		
		MP	BP	SC	MP	BP	SC
1	ICMA 91777 × 15001 R	8.98	-7.29	5.12	10.60*	9.30	3.92
2	ICMA 91777 × 16066 R	15.30*	0.00	8.27	8.19*	4.73	6.39
3	ICMA 91777 × 15743 R	4.80	-6.25	-5.51	-5.97	-6.03	-10.54*
4	ICMA 91777 × 16110 R	33.33**	20.32**	18.90**	-10.80*	-11.61*	-15.96**
5	ICMA 91777 × 15208 R	18.38**	4.14	9.06	-6.99	-8.10	-12.62**
6	ICMA 92333 × 15001 R	29.11**	-4.51	8.27	-5.04	-8.42	-14.97**
7	ICMA 92333 × 16066 R	23.49**	-7.27	0.39	-15.72**	-22.08**	-20.85**
8	ICMA 92333 × 15743 R	13.20	-12.89	-12.20	-0.13	-4.82	-9.39*
9	ICMA 92333 × 16110 R	71.72**	33.07**	31.50**	17.43**	12.97*	5.45
10	ICMA 92333 × 15208 R	30.69**	-0.75	3.94	-16.76**	-19.71**	-25.47**
11	ICMA 04999 × 15001 R	-2.95	-20.14**	-9.45	10.13*	-1.56	-8.60
12	ICMA 04999 × 16066 R	24.51**	4.36	12.99	-1.75	-15.63**	-14.30**
13	ICMA 04999 × 15743 R	-1.81	-15.23*	-14.57*	-0.49	-12.16*	-16.38**
14	ICMA 04999 × 16110 R	7.09	-6.77	-7.87	7.09	-4.65	-10.99*
15	ICMA 04999 × 15208 R	12.83	-4.14	0.39	8.78	-2.90	-9.88*
16	ICMA 05444 × 15001 R	5.96	11.11	25.98**	25.61**	11.96*	3.96
17	ICMA 05444 × 16066 R	-20.47**	-14.55*	-7.78	29.89**	11.41*	13.17**
18	ICMA 05444 × 15743 R	0.35	12.11	12.99	-4.04	-15.39**	-19.45**
19	ICMA 05444 × 16110 R	5.47	19.12**	17.72**	3.09	-8.35	-14.42**
20	ICMA 05444 × 15208 R	-17.53**	-9.77	-5.51	-1.64	-12.31*	-18.61**
21	ICMA 97111 × 15001 R	21.70**	-0.69	12.60	-5.66	-11.07*	-17.38**
22	ICMA 97111 × 16066 R	50.98**	25.45**	35.83**	17.14**	6.02	7.70
23	ICMA 97111 × 15743 R	16.89*	0.00	0.79	2.58	-4.37	-8.96
24	ICMA 97111 × 16110 R	31.18**	13.15	11.81	7.72	1.35	-5.39
25	ICMA 97111 × 15208 R	8.93	-8.27	-3.94	-1.12	-6.72	-13.42**
26	ICMA 01555 × 15001 R	31.76**	6.60	20.87**	15.49**	1.24	-6.00
27	ICMA 01555 × 16066 R	52.76**	25.82**	36.22**	21.40**	2.49	4.11
28	ICMA 01555 × 15743 R	0.92	-14.45*	-13.78*	16.50**	1.05	-3.81
29	ICMA 01555 × 16110 R	35.20**	15.54*	14.17*	17.11**	2.42	-4.39
30	ICMA 01555 × 15208 R	43.69**	19.92**	25.69**	31.57**	15.35**	7.07
31	ICMA 05888 × 15001 R	10.28	2.43	16.14*	4.56	0.73	-6.47
32	ICMA 05888 × 16066 R	13.79*	8.00	16.93*	8.54*	0.25	1.83
33	ICMA 05888 × 15743 R	18.09**	16.02*	16.93*	-1.74	-6.46	-10.96*
34	ICMA 05888 × 16110 R	15.66**	14.74*	13.39*	-19.29**	-22.44**	-27.60**
35	ICMA 05888 × 15208 R	14.62*	10.53	15.75*	-7.13	-10.52*	-16.94**
36	ICMA 07111 × 15001 R	25.12**	-6.60	5.91	37.43**	9.24	1.43
37	ICMA 07111 × 16066 R	33.81**	1.45	9.84	26.53**	-2.61	-1.10
38	ICMA 07111 × 15743 R	18.09*	-8.20	-7.48	33.89**	5.45	0.38
39	ICMA 07111 × 16110 R	52.67**	19.52**	18.11**	30.46**	3.49	-3.39
40	ICMA 07111 × 15208 R	52.84**	21.05**	26.77**	45.60**	15.75**	7.43
41	ICMA 04111 × 15001 R	-10.30	-27.43**	-17.72**	19.45**	7.43	-0.25
42	ICMA 04111 × 16066 R	-3.09	-20.18**	-13.58*	5.97	-8.33	-6.88
43	ICMA 04111 × 15743 R	1.38	-14.06*	-13.39*	22.77**	9.21	3.96

44	ICMA 04111 × 16110 R	14.22*	-2.39	-3.54	4.43	-6.48	-12.70**
45	ICMA 04111 × 15208 R	-4.50	-20.30**	-16.54*	4.06	-6.40	-13.12**
S.Em. ±		2.90	3.35	3.35	2.38	2.75	2.75
Range		-20.47 to +52.84	-27.43 to +33.07	-17.72 to +36.22	-19.29 to +45.60	-22.44 to 15.75	-27.60 to +13.17
Significant Heterosis		28	19	22	24	15	22
No. of + ^{ve} significant		26	11	16	20	5	1
No. of - ^{ve} significant		2	8	6	4	10	21

* and ** significant at P = 0.05 and P = 0.01 levels, respectively.

Table 5: Estimates of heterosis in percentage in F1 hybrid over mid parent, better parent and standard check GHB 558 for Leaf area per plant (cm²) and Grain yield/plant(g) in pearl millet.

Sr. No.	Hybrids	Leaf area per plant (cm ²)			Grain yield per plant (g)		
		MP	BP	SC	MP	BP	SC
1	ICMA 91777 × 15001 R	33.69**	-1.40	0.39	31.36**	26.87**	-0.75
2	ICMA 91777 × 16066 R	-7.05	-38.77**	-6.71	17.85*	15.60	-5.97
3	ICMA 91777 × 15743 R	69.66**	44.68**	-0.81	5.97	5.88	-17.16*
4	ICMA 91777 × 16110 R	78.51**	43.25**	14.53	27.35**	15.10	-9.95
5	ICMA 91777 × 15208 R	65.93**	36.49**	2.33	66.05**	43.08**	11.94
6	ICMA 92333 × 15001 R	33.09**	-5.52	-3.80	10.05	-7.51	-32.59**
7	ICMA 92333 × 16066 R	-15.05	-45.60**	-17.13	38.65**	11.62	-9.20
8	ICMA 92333 × 15743 R	42.20**	15.43	-20.86*	43.14**	17.04	-8.58
9	ICMA 92333 × 16110 R	59.54**	22.42	-2.12	142.34**	116.34**	36.69**
10	ICMA 92333 × 15208 R	11.26	-12.65	-34.51**	23.65	16.04	-34.33**
11	ICMA 04999 × 15001 R	33.87*	-18.28	-16.79	17.47	7.85	-21.39**
12	ICMA 04999 × 16066 R	-1.46	-43.46**	-13.86	25.52**	9.79	-10.70
13	ICMA 04999 × 15743 R	80.75**	20.02	-17.72	31.31**	16.88	-8.71
14	ICMA 04999 × 16110 R	82.50**	16.92	-6.52	9.42	7.48	-32.09**
15	ICMA 04999 × 15208 R	53.32**	-0.34	-25.28**	20.85	16.53	-28.98**
16	ICMA 05444 × 15001 R	47.41**	-7.96	-6.29	67.99**	57.46**	31.22**
17	ICMA 05444 × 16066 R	-2.92	-43.39**	-13.76	17.52*	16.12	-3.23
18	ICMA 05444 × 15743 R	70.23**	16.56	-20.09*	17.10*	13.43	-5.47
19	ICMA 05444 × 16110 R	51.53**	-0.24	-20.24*	11.71	-1.79	-18.16*
20	ICMA 05444 × 15208 R	71.92**	15.00	-13.78	21.78*	2.24	-14.80
21	ICMA 97111 × 15001 R	39.07**	-8.78	-7.12	38.37**	21.84*	-11.19
22	ICMA 97111 × 16066 R	6.36	-35.74**	-2.10	74.18**	46.48**	19.15*
23	ICMA 97111 × 15743 R	134.64**	71.65**	17.68	33.33**	14.01	-10.95
24	ICMA 97111 × 16110 R	69.19**	18.19	-5.50	46.75**	37.80**	-12.94
25	ICMA 97111 × 15208 R	33.51*	-4.97	-28.76**	34.07**	32.75*	-24.88**
26	ICMA 01555 × 15001 R	22.29	-16.51	-14.99	20.00	4.44	-23.88**
27	ICMA 01555 × 16066 R	19.90*	-25.41**	13.64	86.76**	55.35**	26.37**
28	ICMA 01555 × 15743 R	61.40**	24.51	-14.64	38.04**	16.72	-8.83
29	ICMA 01555 × 16110 R	66.15**	21.75	-2.66	7.01	-0.79	-37.31**
30	ICMA 01555 × 15208 R	63.65**	22.44	-8.20	122.72**	117.58**	23.13**
31	ICMA 05888 × 15001 R	40.52**	3.02	4.89	-0.34	-0.68	-27.11**
32	ICMA 05888 × 16066 R	10.68	-27.42**	10.58	66.08**	57.95**	28.48**
33	ICMA 05888 × 15743 R	92.13**	62.58**	11.46	6.08	2.87	-19.65*
34	ICMA 05888 × 16110 R	16.91	-6.84	-25.52**	29.51**	20.51*	-11.57
35	ICMA 05888 × 15208 R	40.57**	14.78	-13.94	16.36	3.05	-24.38**
36	ICMA 07111 × 15001 R	76.85**	16.37	18.49	-1.33	-3.88	-26.12**
37	ICMA 07111 × 16066 R	33.83**	-18.95**	23.48*	23.90**	20.49*	-1.99
38	ICMA 07111 × 15743 R	113.86**	57.13**	7.72	11.08	10.19	-13.93
39	ICMA 07111 × 16110 R	71.65**	20.38	-3.76	15.99	5.66	-18.78*
40	ICMA 07111 × 15208 R	100.03**	42.95**	7.17	88.44**	63.59**	25.75**
41	ICMA 04111 × 15001 R	35.33**	7.41	9.36	15.89	7.68	-21.52**
42	ICMA 04111 × 16066 R	-14.28	-40.32**	-9.08	46.93**	29.97**	5.72
43	ICMA 04111 × 15743 R	80.40**	68.88**	15.78	28.03**	15.29	-9.95
44	ICMA 04111 × 16110 R	44.72**	26.48*	1.12	45.80**	45.08**	-8.33
45	ICMA 04111 × 15208 R	58.87**	42.79**	7.06	19.42	13.72	-28.86**
S.Em. ±		273.07	315.32	315.32	5.23	6.04	6.04
Range		-15.05 to +134.64	-45.60 to 71.65	-34.51 to +23.48	-1.33 to +142.34	-7.51 to +117.58	-37.31 to +36.69
Significant Heterosis		35	19	8	28	16	24
No. of + ^{ve} significant		35	10	1	28	16	7
No. of - ^{ve} significant		0	9	7	0	0	17

Table 6: Estimates of heterosis in percentage in F1 hybrid over mid parent, better parent and standard check GHB 558 for Harvest index (%) and test weight (g) in pearl millet

Sr. No.	Hybrids	Harvest index (%)			Test weight (g)		
		MP	BP	SC	MP	BP	SC
1	ICMA 91777 × 15001 R	32.07**	21.69**	18.24*	7.67	4.99	-1.74
2	ICMA 91777 × 16066 R	9.26	4.41	11.32	-9.72*	-10.52*	-14.74**
3	ICMA 91777 × 15743 R	25.78**	18.45*	15.09*	-4.19	-5.60	-8.97*
4	ICMA 91777 × 16110 R	-3.29	-17.51*	-19.85**	7.86*	3.65	5.22
5	ICMA 91777 × 15208 R	10.81	8.93	9.56	4.43	4.30	-2.38
6	ICMA 92333 × 15001 R	3.01	-2.79	-20.39**	-2.50	-10.81*	-20.69**
7	ICMA 92333 × 16066 R	34.65**	13.22	20.71**	11.37*	-1.20	-5.86
8	ICMA 92333 × 15743 R	26.47**	16.77*	0.23	13.42**	0.09	-3.48
9	ICMA 92333 × 16110 R	64.23**	59.63**	16.01*	21.36**	4.78	6.36
10	ICMA 92333 × 15208 R	5.43	-9.20	-8.67	9.26*	-2.21	-8.70*
11	ICMA 04999 × 15001 R	-0.14	-7.59	-11.04	2.33	-0.51	-11.53**
12	ICMA 04999 × 16066 R	3.85	-1.19	5.35	16.21**	9.32*	4.16
13	ICMA 04999 × 15743 R	0.89	-4.58	-8.13	-1.32	-7.69	-10.98*
14	ICMA 04999 × 16110 R	24.42**	6.54	2.57	-2.54	-10.96*	-9.61*
15	ICMA 04999 × 15208 R	-19.04**	-20.78**	-20.32**	-0.59	-5.59	-11.85**
16	ICMA 05444 × 15001 R	46.70**	43.87**	22.56**	14.20**	14.20**	1.56
17	ICMA 05444 × 16066 R	12.39	1.09	7.78	1.61	-1.78	-6.41
18	ICMA 05444 × 15743 R	-13.21	-13.54	-25.78**	-6.07	-9.73*	-12.95**
19	ICMA 05444 × 16110 R	47.72**	33.34**	13.58	-12.57**	-17.99**	-16.75**
20	ICMA 05444 × 15208 R	-5.83	-13.04	-12.53	-1.28	-3.63	-10.02*
21	ICMA 97111 × 15001 R	15.60*	14.17	-4.13	2.11	0.72	-10.43*
22	ICMA 97111 × 16066 R	19.22**	6.55	13.61	-0.81	-5.38	-9.84*
23	ICMA 97111 × 15743 R	27.49**	26.10**	8.24	-0.38	-5.51	-8.88*
24	ICMA 97111 × 16110 R	23.12**	11.85	-6.08	-3.41	-10.55*	-9.20*
25	ICMA 97111 × 15208 R	-5.67	-13.46	-12.96	5.09	1.23	-5.49
26	ICMA 01555 × 15001 R	8.12	5.40	-9.11	0.44	-0.67	-11.67**
27	ICMA 01555 × 16066 R	23.56**	11.75	19.14**	13.11**	8.17	3.07
28	ICMA 01555 × 15743 R	-0.84	-1.07	-14.69*	7.06	1.80	-1.83
29	ICMA 01555 × 16110 R	13.15	1.58	-12.41	-6.65	-13.35**	-12.04**
30	ICMA 01555 × 15208 R	8.98	1.20	1.79	22.34**	18.14**	10.30*
31	ICMA 05888 × 15001 R	9.29	-1.71	0.77	5.92	4.99	-6.64
32	ICMA 05888 × 16066 R	16.09**	13.87*	21.40**	8.84*	4.32	-0.59
33	ICMA 05888 × 15743 R	-5.76	-13.43	-11.24	5.33	0.38	-3.20
34	ICMA 05888 × 16110 R	-3.09	-19.12**	-17.08*	-9.18*	-15.51**	-14.23**
35	ICMA 05888 × 15208 R	-8.42	-9.29	-7.00	4.63	1.27	-5.45
36	ICMA 07111 × 15001 R	22.16**	20.73*	-1.13	-7.25	-13.09**	-11.58**
37	ICMA 07111 × 16066 R	2.07	-10.69	-4.77	3.60	0.31	2.06
38	ICMA 07111 × 15743 R	-1.69	-5.05	-18.50*	-14.00**	-16.24**	-14.78**
39	ICMA 07111 × 16110 R	26.37**	17.39	-6.12	-4.62	-4.72	-3.07
40	ICMA 07111 × 15208 R	21.06**	8.66	9.28	10.02*	5.49	7.32
41	ICMA 04111 × 15001 R	9.33	2.76	-4.35	21.48**	9.73*	-2.43
42	ICMA 04111 × 16066 R	14.70*	7.42	14.53*	8.85*	-4.61	-9.11*
43	ICMA 04111 × 15743 R	-10.39	-13.88	-19.83**	0.71	-12.20**	-15.53*
44	ICMA 04111 × 16110 R	15.74*	0.52	-6.43	10.75*	-5.50	-4.07
45	ICMA 04111 × 15208 R	-14.79*	-17.97*	-17.49*	17.83**	4.17	-2.75
S.Em. ±		5.32	6.14	6.14	0.80	0.92	0.92
Range		-19.04 to +64.23	-20.78 to 59.63	-25.78 to 22.56	-14.00 to +22.34	-17.99 to +18.14	-20.69 to +10.30
Significant Heterosis		21	13	17	19	15	23
No. of + ^{ve} significant		19	9	8	15	4	1
No. of - ^{ve} significant		2	4	9	4	11	22

* and ** significant at P = 0.05 and P = 0.01 levels, respectively.

Table 7: Estimates of heterosis in percentage in F1 hybrid over mid parent, better parent and standard check GHB 558 for Seed setting (%) in pearl millet.

Sr. No.	Hybrids	Seed setting (%)		
		MP	BP	SC
1	ICMA 91777 × 15001 R	-2.41	21.69**	18.24*
2	ICMA 91777 × 16066 R	6.54	4.41	11.32
3	ICMA 91777 × 15743 R	2.47	18.45*	15.09*
4	ICMA 91777 × 16110 R	0.34	-17.51*	-19.85**
5	ICMA 91777 × 15208 R	-33.31**	8.93	9.56
6	ICMA 92333 × 15001 R	-22.97**	-2.79	-20.39**

7	ICMA 92333 × 16066 R	-5.33	13.22	20.71**
8	ICMA 92333 × 15743 R	8.99*	16.77*	0.23
9	ICMA 92333 × 16110 R	-79.88**	59.63**	16.01*
10	ICMA 92333 × 15208 R	-10.87**	-9.20	-8.67
11	ICMA 04999 × 15001 R	-19.97**	-7.59	-11.04
12	ICMA 04999 × 16066 R	-5.47	-1.19	5.35
13	ICMA 04999 × 15743 R	-8.36*	-4.58	-8.13
14	ICMA 04999 × 16110 R	-80.81**	6.54	2.57
15	ICMA 04999 × 15208 R	-7.60	-20.78**	-20.32**
16	ICMA 05444 × 15001 R	-2.43	43.87**	22.56**
17	ICMA 05444 × 16066 R	-8.43	1.09	7.78
18	ICMA 05444 × 15743 R	11.06*	-13.54	-25.78**
19	ICMA 05444 × 16110 R	-79.26**	33.34**	13.58
20	ICMA 05444 × 15208 R	1.01	-13.04	-12.53
21	ICMA 97111 × 15001 R	-12.13**	14.17	-4.13
22	ICMA 97111 × 16066 R	-11.86**	6.55	13.61
23	ICMA 97111 × 15743 R	-4.03	26.10**	8.24
24	ICMA 97111 × 16110 R	0.59	11.85	-6.08
25	ICMA 97111 × 15208 R	-10.68**	-13.46	-12.96
26	ICMA 01555 × 15001 R	-11.81**	5.40	-9.11
27	ICMA 01555 × 16066 R	-11.84**	11.75	19.14**
28	ICMA 01555 × 15743 R	-22.15**	-1.07	-14.69*
29	ICMA 01555 × 16110 R	-1.50	1.58	-12.41
30	ICMA 01555 × 15208 R	1.98	1.20	1.79
31	ICMA 05888 × 15001 R	3.05	-1.71	0.77
32	ICMA 05888 × 16066 R	1.47	13.87*	21.40**
33	ICMA 05888 × 15743 R	12.14**	-13.43	-11.24
34	ICMA 05888 × 16110 R	-5.41	-19.12**	-17.08*
35	ICMA 05888 × 15208 R	15.27**	-9.29	-7.00
36	ICMA 07111 × 15001 R	-17.12**	20.73*	-1.13
37	ICMA 07111 × 16066 R	-13.44**	-10.69	-4.77
38	ICMA 07111 × 15743 R	-30.93**	-5.05	-18.50*
39	ICMA 07111 × 16110 R	-23.87**	17.39	-6.12
40	ICMA 07111 × 15208 R	-14.72**	8.66	9.28
41	ICMA 04111 × 15001 R	-13.16**	2.76	-4.35
42	ICMA 04111 × 16066 R	-44.57**	7.42	14.53*
43	ICMA 04111 × 15743 R	-12.76**	-13.88	-19.83**
44	ICMA 04111 × 16110 R	-9.76*	0.52	-6.43
45	ICMA 04111 × 15208 R	-11.30**	-17.97*	-17.49*
S.Em. ±		5.66	6.53	6.53
Range		-80.81 to +15.27	-5.88 to -83.09	-80.85 to +13.66
Significant Heterosis		28	39	17
No. of + ^{ve} significant		4	0	1
No. of - ^{ve} significant		24	39	16

* and ** significant at P = 0.05 and P = 0.01 levels, respectively

Table 8: Analysis of variance for combining ability and estimates of components of variance for various characters in pearl millet

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	Number of effective tiller per plant	Earhead length (cm)	Earhead girth (mm)	Leaf area per plant (cm ²)	Grain yield per plant (g)	Harvest index (%)	Test weight (g)	Seed setting (%)
Replication	1	13.61	22.50*	15.33	0.05	0.032	1.77	43629.58	0.28	0.90	0.86*	13.18
Crosses	44	32.72**	84.56**	1057.68**	0.41**	27.58**	17.12**	110083.06**	114.89**	69.58**	1.16**	448.00**
Female	8	52.75	105.80	826.18	0.15	57.91**	22.98	260869.07**	49.15	35.16	0.59	445.72
Male	4	49.01	176.79	2088.32	0.32	49.55*	25.46	99731.66	190.48	222.39*	1.36	926.52
Female x males	32	25.67**	67.47**	986.72**	0.48**	17.25**	14.86**	73680.49**	121.87**	59.08**	1.28**	388.75**
Error	44	3.42	4.29	230.55	0.06	3.19	2.07	24721.96	11.18	10.21	0.19	10.78

* and ** significant at P = 0.05 and P = 0.01 levels, respectively.

Table 9: Estimation of general combining ability (gca) effects of parents for various characters in pearl millet

	Parents	Days to flowering	Days to maturity	Plant height (cm)	Number of effective tiller per plant	Earhead length (cm)	Earhead girth (mm)	Leaf area per plant (cm ²)	Grain yield per plant (g)	Harvest index (%)	Test weight (g)	Seed setting (%)
Lines	ICMA 91777	2.46**	2.40**	11.24*	0.09	0.12	0.37	112.32*	1.78	3.64**	0.18	5.52**
	ICMA 92333	-0.53	0.50	-11.26*	-0.03	-0.08	-1.82**	-186.32**	-0.32	1.34	-0.03	-8.87**
	ICMA 04999	-2.13**	-2.20**	-6.90	-0.113	-2.64**	-1.52**	-192.24**	-4.65**	-2.08*	-0.19	-7.99**
	ICMA 05444	-0.83	-0.20	11.43*	0.07	0.52	-0.03	-171.86**	2.70**	1.15	-0.30*	-6.17**
	ICMA 97111	-1.73**	-6.40**	9.62*	-0.09	1.20*	-0.15	-8.04	0.25	0.54	-0.28	6.08**
	ICMA 01555	2.76**	0.70	-2.47	0.17*	2.52**	1.92**	-11.59	1.89*	-0.67	0.41**	8.02**
	ICMA 05888	-3.03**	-2.20**	3.21	0.15*	2.32**	-1.52**	36.93	-0.82	-0.48	0.02	6.32**
	ICMA 07111	-0.23	3.50**	-5.16	-0.05	1.00	2.39**	259.28**	0.72	-1.18	0.24	-1.30
	ICMA 04111	3.26**	3.90**	-9.70*	-0.17*	-4.99**	0.36	161.51**	-1.52	-2.25*	-0.06	-1.62
	S.Em. ±	1.14	1.28	9.05	0.15	1.06	0.87	99.71	1.91	1.94	0.29	2.07
Testers	15001R	1.87**	0.62	4.64	-0.14*	0.21	0.62	49.54	-2.42**	0.24	-0.23*	1.60*
	16066R	-0.62	-1.65**	-13.30**	0.21**	1.11**	1.77**	51.25	5.71**	5.91**	0.23*	1.74*
	15743R	1.65**	3.23**	15.41**	-0.091	-2.72**	-0.41	38.93	-1.08	-2.94**	-0.30*	3.68**
	16110R	-1.45**	-4.54**	-5.00	0.02	1.53**	-0.89**	-15.98	-1.48*	-1.07	-0.02	-12.51**
	15208R	-1.45**	2.34**	-1.75	-0.002	-0.13	-1.09**	-123.74**	-0.73	-2.15**	0.33**	5.49**
	S.Em. ±	0.85	0.95	6.75	0.11	0.79	0.65	74.32	1.42	1.45	0.22	1.54

* and ** significant at P = 0.05 and P = 0.01 levels, respectively.

Table 10: The estimates of specific combining ability (sca) for various characters in pearl millet

Crosses	Days to flowering	Days to maturity	Plant height (cm)	Number of effective tiller per plant	Earhead length (cm)	Earhead girth (mm)	Leaf area per plant (cm ²)	Grain yield per plant (g)	Harvest index (%)	Test weight (g)	Seed setting (%)
ICMA 91777 × 15001 R	-2.57*	-2.12	14.66	0.34*	-0.73	2.29*	-75.87	3.88	4.68*	0.54	0.85
ICMA 91777 × 16066 R	-1.08	-4.34**	-17.00	-0.31	-0.83	1.87	-197.94	-6.35**	-3.98	-1.34**	6.81**
ICMA 91777 × 15743 R	2.14	6.27**	-3.21	-0.01	-0.50	-1.03	-85.67	-4.06	6.50**	-0.19	0.17
ICMA 91777 × 16110 R	-0.24	0.04	0.21	-0.22	1.45	-2.18*	229.18*	-0.75	-10.52**	1.08**	16.08**
ICMA 91777 × 15208 R	1.76	0.16	5.35	0.20	0.61	-0.97	130.29	7.29**	3.32	-0.09	-23.92**
ICMA 92333 × 15001 R	-0.08	1.78	19.16	0.05	0.27	-1.20	151.81	-6.82**	-9.77**	-1.32**	-2.04
ICMA 92333 × 16066 R	6.42**	11.06**	-30.40**	-0.29	-2.63*	-4.12**	-75.75	-5.55*	2.38	-0.16	9.57**
ICMA 92333 × 15743 R	-6.86**	-8.33**	8.89	-0.29	-2.00	1.51	-126.65	1.49	2.35	0.63	15.42**
ICMA 92333 × 16110 R	2.26	3.44*	38.61**	0.90**	4.85**	6.45**	245.74*	20.10**	7.32**	1.42**	-26.86**
ICMA 92333 × 15208 R	-1.74	-7.94**	-36.25**	-0.38*	-0.49	-2.65**	-195.15	-9.21**	-2.29	-0.57	3.91
ICMA 04999 × 15001 R	-0.48	3.48*	-29.10**	-0.36*	-1.67	0.41	-62.34	2.01	-2.29	-0.16	1.72
ICMA 04999 × 16066 R	-3.48**	-7.24**	-0.86	0.19	3.13*	-2.45*	-14.45	-1.19	-0.86	1.10**	11.66**
ICMA 04999 × 15743 R	-1.26	-2.13	4.42	0.19	-0.04	-0.90	-67.41	5.77**	2.15	-0.03	6.05*
ICMA 04999 × 16110 R	-1.64	0.64	0.05	0.28	-2.59*	1.20	177.16	-3.22	4.92*	-0.16	-27.74**
ICMA 04999 × 15208 R	6.86**	5.26**	25.49*	-0.30	1.17	1.74	-32.97	-2.73	-3.92	-0.75*	8.32
ICMA 05444 × 15001 R	3.22*	5.48**	6.52	1.16**	4.17**	2.70**	95.15	15.81**	9.05**	1.38**	7.29**
ICMA 05444 × 16066 R	1.22	-8.74**	-3.14	-0.49**	-5.23**	4.32**	-33.05	-6.17**	-3.02	0.05	2.93
ICMA 05444 × 15743 R	5.44**	6.37**	0.55	-0.59**	3.80**	-3.31**	-128.06	-0.28	-8.73**	-0.14	11.85**
ICMA 05444 × 16110 R	-5.44**	-5.86**	-15.18	0.30	0.75	-1.32	-75.59	-4.97*	6.47**	-0.84*	-29.55**
ICMA 05444 × 15208 R	-4.44**	2.76	11.26	-0.38*	-3.49**	-2.38*	141.55	-4.38*	-3.77	-0.45	7.49**
ICMA 97111 × 15001 R	1.12	5.68**	15.68	-0.28	0.08	-3.59**	-82.81	1.20	-1.93	0.05	-4.64*
ICMA 97111 × 16066 R	-3.88**	5.96**	-20.38*	0.47**	5.09**	2.80**	0.63	5.27*	0.10	-0.34	-4.82*
ICMA 97111 × 15743 R	2.34	-8.93**	5.41	0.17	0.02	-0.03	347.98**	-0.04	6.63**	0.87	-2.70
ICMA 97111 × 16110 R	1.96	-1.66	8.33	-0.04	-1.43	1.52	10.15	-0.43	-1.45	-0.03	18.01**
ICMA 97111 × 15208 R	-1.54	-1.04	-9.03	-0.32	-3.77**	-0.69	-275.95*	-5.99**	-3.35	0.03	-5.85*
ICMA 01555 × 15001 R	-0.88	0.08	-24.98*	-0.74**	0.87	-2.24*	-212.47	-5.53*	-2.87	-0.76*	-3.54
ICMA 01555 × 16066 R	3.62**	-3.64*	8.41	0.51**	3.87**	-0.35	270.79*	6.54**	3.71	0.38	-3.96
ICMA 01555 × 15743 R	-3.66**	-0.03	-6.50	0.01	-5.00**	0.55	-195.99	-0.82	-2.11	0.36	-15.17**
ICMA 01555 × 16110 R	-1.54	4.74**	-10.98	-0.3	-2.15	-0.25	61.88	-11.86**	-2.99	-1.03**	17.66**
ICMA 01555 × 15208 R	2.46	-1.14	34.06**	0.52**	2.41*	3.40**	75.80	11.68**	4.25	1.07**	5.00*
ICMA 05888 × 15001 R	1.42	-10.02**	-17.66	0.07	-0.13	1.05	75.78	-4.12	1.23	0.17	-2.81
ICMA 05888 × 16066 R	-3.08*	9.26**	28.13**	0.33	-0.83	2.40*	170.39	10.10**	4.51*	0.37	-4.25
ICMA 05888 × 15743 R	3.64**	1.87	-20.08	0.13	3.00*	0.73	197.63	-2.46	-0.80	0.61	-1.27
ICMA 05888 × 16110 R	2.26	-3.86**	-4.66	-0.78**	-2.15	-3.80**	-373.81**	1.20	-5.20*	-0.88**	5.02*
ICMA 05888 × 15208 R	-4.24**	2.76	14.28	0.24	0.11	-0.39	-70.00	-4.71*	0.26	-0.26	3.31
ICMA 07111 × 15001 R	-2.88*	-4.22**	-6.84	-0.22	-1.41	-0.48	83.81	-5.26*	1.11	-0.59	0.75
ICMA 07111 × 16066 R	-1.38	-2.94*	5.80	-0.17	-1.31	-2.39*	166.51	-3.69	-6.14	0.44	3.15
ICMA 07111 × 15743 R	-0.66	2.17	-6.31	-0.07	-1.88	0.24	-88.04	-1.70	-3.24	-0.88**	-13.21**
ICMA 07111 × 16110 R	1.96	2.94*	4.41	-0.38*	0.37	-0.42	-227.59*	-3.24	0.25	0.12	9.10**

ICMA 07111 × 15208 R	2.96*	2.06	2.95	0.84**	4.23**	3.04**	65.30	13.90**	8.02**	0.91**	0.21
ICMA 04111 × 15001 R	1.12	-0.12	22.59*	-0.01	-1.42	1.05	26.94	-1.17	0.78	0.71*	2.43
ICMA 04111 × 16066 R	1.62	0.66	29.43**	-0.25	-1.27	-2.10*	-287.13*	1.65	3.30	-0.49	-21.09**
ICMA 04111 × 15743 R	-1.16	2.77	16.82	0.45**	2.61*	3.34**	146.20	2.14	-2.75	-0.64	-1.14
ICMA 04111 × 16110 R	0.46	-0.46	-20.76*	0.24	0.86	-1.19	-47.13	3.20	1.19	0.31	18.29**
ICMA 04111 × 15208 R	-2.04	-2.84	-48.09**	-0.44*	-0.78	-1.11	161.31	-5.81**	-2.52	0.10	1.51
S.Em. ±	2.56	2.87	20.24	0.33	2.38	1.95	222.97	4.27	4.34	0.66	4.62
Range	-6.86 to +6.86	-10.02 to +11.06	-48.09 to +38.61	-0.78 to +1.16	-5.23 to +5.09	-4.12 to +6.45	-373.81 to +347.98	-11.86 to +20.10	-10.52 to +9.05	-1.34 to +1.42	-29.55 to +18.29
No. of + ^{ve} significant	7	10	6	8	10	9	4	9	9	7	12
No. of - ^{ve} significant	10	12	7	9	6	11	4	13	4	8	10

* and ** significant at P = 0.05 and P = 0.01 levels, respectively

Conclusions

The cross ICMA 92333 × 16110 R (average × poor combiner parents) and ICMA 05444 × 15001 R and ICMA 05888 × 16066 R (good × poor combiner parents) recorded high *per se* performance, significant and positive mid parent, better parent and standard heterosis as well as positive specific combining ability effect for grain yield, number of effective tiller per plant and harvest index. This indicated to obtain desirable transgressive segregants in F₂ and subsequent generation, may be used for development of better agronomical traits inbreds lines for strengthening breeding programme.

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