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Study of genetic architecture for yield related traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract
The investigation on study of genetic architecture for yield related traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.] was carried out with an aim to study the combining ability and gene action for yield and yield contributing characters. The combination JMSA 20102 × 42182 R recorded highest magnitude of sca effect followed by JMSA 20071 × 42182 R, ICMA 08444 × GP-5 R, ICMA 03666 × GP-5 R and JMSA 20102 × 30133 R for grain yield per plant. Similarly, the combinations JMSA 20071 × 30133 R (ear head girth), ICMA 08444 × GP-5 R (number of effective tillers per plant), ICMA 05888 × GP-5 R (ear length), ICMA 03666 × 41530 R (test weight), JMSA 20071 × 42182 R (days to flowering, days to maturity), JMSA 20071 × 41530 R (plant height), JMSA 20102 × 42182 R (grain yield per plant, harvest index, protein content and zinc content) and JMSA 20102 × 41530 R (iron content) exhibited highly significant and maximum sca effects for the respective characters. The hybrid JMSA 20102 × 42182 R and ICMA 03666 × GP-5 R showed high *per se* performance and significant positive specific combining ability effect for grain yield per plant and some other important characters. Thus, these hybrids could commercially be exploited through heterosis breeding programme after testing in multi-location trials.

Keywords: Genetic architecture, hybrids, combining ability, harvest index, *per se* performance

Introduction
In India, after rice and wheat, pearl millet [*Pennisetum glaucum* (L) R. Br.] third important cereal food crop. In 2020, this crop occupied 7.41 million ha with an average production of 10.3 million tonnes with 1391kg/ha productivity. (Anonymous, 2021) [1]. In India Gujarat, Rajasthan, Haryana, Maharashtra, Uttar Pradesh and Karnataka are major pearl millet producing states where, it grows in *kharif* and in summer seasons. The combining ability studies give information about the selection for suitable parents in effective hybridization programme and also provide the nature as well as magnitude of gene action. Although, the gene action and nature changes with different genetic constitution of population involved in hybridization process, evaluation of the parents is necessary for combining ability analysis. To understand the nature of gene action responsible for the expression of different characters could be very handy in deciding the effectiveness of selection. The partition of the genetic variances into components like additive, dominance and epistatic will very useful in constructing the sound and effective breeding programme.

Materials and Methods
Plant materials: The experimental material consisting 35 genotypes *viz*. 24 hybrids or crosses developed from Line × Tester mating involved 6 lines, 4 testers and standard check (GHB 558).

Field experiments: The experimental material of 35 entries including 6 lines, 4 testers, their 24 crosses and one commercial check, was raised in Randomized Block Design with three replications in *kharif* 2019 at Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. Each entry was planted in a 3 meters long row in length with between and within row spacing of 60 × 15 cm. The two rows of each genotype were planted in each replication. Recommended agronomic practices and plant protection measures were adopted to raise healthy crop. Different twelve observations were recorded on days to flowering, days to maturity, plant height (cm), number of effective tillers per plant, ear head length (cm), ear head girth (cm), grain yield per plant (g), harvest index (%), test weight (g), protein content (%), iron content (ppm) and zinc content (ppm). The observations were recorded from randomly selected 5 plants from each genotype in each replication.

Data and statistical analysis

From each replication, 5 plants were randomly selected and the observations were recorded for each entry, in each replication for traits. The mean values of the traits measured in 35 entries in each replication were subjected to be analyzed for analysis of variance, estimation of standard error and critical difference *via* the method suggested by Panse and Sukhatme [12]. The variation among the hybrids was differentiated further into sources attributable to general as well as specific combining ability aspects according to the method described by Kempthorne (1957) [8] and modified by Arunachalam (1974) [2].

Results and Discussion

The analysis of variance for combining ability by differentiating the total genetic variance into general combining ability showing additive type of gene action and specific combining ability showing non additive type of gene action was carried out for twelve characters and presented in table 1. It exhibited that the mean square due to female lines were significant for all the yield attributing traits under study. Whereas, mean square due to male testers were also significant for all the characters under study. The mean square due to line × tester interaction was significant for all the yield components clearly indicates that experimental material had significant variability and also that gca and sca were involved in the genetic control of various characters.

The gca effects of grain yield per plant ranged from -8.73 (ICMA 08444) to 8.25 (ICMA 03666). The female ICMA 03666 (8.25), JMSA 20102 (5.10) and ICMA 05888 (0.67) showed significant positive general combining ability effects indicating its good combining ability for this trait, whereas the male 42182 R (4.14) and 30133 R (2.45) showed significant positive general combining ability effects indicating its good combining ability for this trait. The female ICMA 08444 (-8.73) followed by JMSA 20071 (-4.58) showed significant negative general combining ability effects indicating its poor combining ability for grain yield per plant. Male 41530 R (-3.32) and GP 5 R (-3.27) showed significant negative general combining ability effects indicating its poor combining ability for grain yield per plant (Table 2). These results are in accordance with those reported by Badwal *et al.* (1972) [4], Chandrashekara *et al.* (2007) [5], Lakshmana *et al.* (2011) [9] and Gavali *et al.* (2018) [6].

The extent of sca effects for grain yield ranged between -18.82 (JMSA 20102 × 41530 R) to 18.04 (JMSA 20102 × 42182 R). The combination JMSA 20102 × 42182R (18.04) recorded highest sca effects for grain yield followed by JMSA 20071 × 42182 R (13.27), ICMA 08444 × GP-5 R (12.42), ICMA 03666 × GP-5 R (10.21) and JMSA20102 × 30133 R (6.64). Out of 24 crosses studied, 12 crosses showed significantly high sca effects for grain yield (Table 3). Similar results were also reported by Badwal *et al.* (1972) [4], Singh *et al.* (1974) [14], Gavali *et al.* (2018) [6] and Patel *et al.* (2018) [13].

The estimation of combining ability effects showed that none of the parents showed consistently significant gca effect (Table 1) and none of the combinations showed desirable specific combining ability effects for all the characters. However, on overa`ll basis the results of gca effects of the parents were classified as good, average and poor combiners for different traits presented in table 4.

Among parents ICMA 03666 female was good general combiner for grain yield per plant. It was also found good general combiner for plant height, number of effective tillers per plant, harvest index, test weight. JMSA 20102 female was good general combiner for grain yield per plant. It was also found good general combiner for harvest index (%), test weight (g), protein (%), iron (ppm). Whereas, the male 42182 R was good general combiner for grain yield per plant. It was also found good general combiner for days to flowering days to maturity, ear head girth and harvest index. The male 30133 R was good general combiner for grain yield per plant. It was also found good general combiner for days to flowering, harvest index, test weight, iron and zinc. This indicated that these parents can be presumed to possess large number of favorable alleles for producing superior hybrids or inbreds in pearl millet.

Comparative study of most promising hybrids showing high specific combining ability effects for seed yield with various character is presented in table 5. Top three ranking parent with respect to *per se* performance and gca effects and top three ranking hybrids with respect to *per se* performance and sca effects in pearl millet is presented in table 6.

The cross, JMSA 20102 × 42182 R had good × good combiner parents, showed high *per se* performance and significant positive specific combining ability effect for grain yield per plant, ear head length, harvest index, test weight and protein and iron content. This shows that it could be attributed to co-adaptation between favourable alleles of the parents involved. Thus, by using this cross, one can isolate pure breeding genotypes for plant height from proceeding generations because both the parents involved in the crosses which were good combiners and gene action was also primarily additive, which is fixable in nature. High *per se* performance of hybrids did not mean higher results of sca effects and that’s why attention on mean performance should be given. The crosses which exhibit higher sca effects did not always involve parents having high gca effects, which suggests the importance of intra allelic interactions for more than one character.

In this study, the proportion of σ^2gca to σ^2sca was lesser than unity for all the yield attributing characters under study. Similar result was also reported by Mathur and Mathur (1983) [10] for all the traits except test weight, Harer *et al.* (1990) [7] for all the traits except effective tiller per plant, Yadav *et al.* (2012) [15] for all the traits, Mungra *et al.* (2015) [11] for all the traits except earhead girth and ear head length, Badurkar *et al.* (2018) [3] for all the traits. This indicates sca variance greater than gca variance. Thus, there is a dominance of non-additive gene action which can be useful in producing heterotic hybrids at commercial level as well as help in the production of transgressive segregants for selection of better recombinants for yield and other characters.

Table 1: Analysis of variance (Mean square) 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 (cm)	Grain yield per plant (g)	Harvest index (%)	Test weight (g)	Protein (%)	Iron (ppm)	Zinc (ppm)
Replication	2	11.35*	8.43*	198.97	0.12*	0.28	0.01	0.71	0.35	0.13	0.02	0.11	0.69
Crosses	23	28.16**	11.84**	1259.47**	0.88**	29.61**	0.21**	399.72**	184.07**	17.28**	3.25**	593.82**	93.05**
Female	5	21.58**	18.65**	3131.61**	0.76**	83.64**	0.11**	461.25**	146.33**	42.47**	1.84**	454.51**	164.43**
Male	3	71.94**	9.72*	1048.05*	1.44**	15.59**	0.87**	269.04**	63.16**	22.66**	0.26**	314.98**	121.44**
Female × males	15	21.60**	10.00**	677.71*	0.80**	14.40**	0.11**	405.35**	220.83**	7.80**	4.31**	696.02**	63.58**
Error	66	3.25	2.33	328.81	0.03	0.85	0.02	2.45	3.57	0.62	0.02	0.44	0.40
σ2 Females		-0.002	0.721	204.492**	-0.003	5.770**	0.001	4.658	-6.208	2.889**	-0.206	-20.126	8.404
σ2 Males		2.797*	-0.016	20.575	0.036	0.067	0.043**	-7.573	-8.760	0.826	-0.225	-21.169	3.215
σ2 gca		1.678	0.279	94.142*	0.020	2.348*	0.026*	-2.681	-7.739	1.651*	-0.218	-20.752	5.291
σ2 sca		6.117**	2.557**	116.300*	0.257**	4.517**	0.030**	134.300**	72.420**	2.394**	1.430**	231.860**	21.060**
σ2 gca/ σ2 sca		0.274	0.109	0.809	0.078	0.520	0.844	-0.020	-0.107	0.690	-0.152	-0.090	0.251

* and ** indicate significant at 5 per cent and 1 per cent levels of significance, respectively

Table 2: 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 (cm)	Grain yield per plant (g)	Harvest index (%)	Test weight (g)	Protein (%)	Iron (ppm)	Zinc (ppm)
Lines	ICMA 08444	-2.18**	-2.32**	-10.76*	-0.17**	-3.25**	0.11*	-8.73**	-5.67**	-1.63**	-0.61**	-6.47**	-3.18**
	JMSA 20071	0.74	-0.32	-26.79**	0.01	-1.65**	-0.10*	-4.58**	0.06	-0.79**	0.32**	6.64**	6.51**
	ICMA 09666	0.15	0.18	16.59**	-0.02	1.46**	-0.09*	-0.70	0.34	1.55**	-0.05	-6.40**	-1.30**
	ICMA 03666	1.82**	0.93*	12.48*	0.46**	-1.66**	0.08	8.25**	4.91**	1.13**	-0.27**	-2.30**	1.24**
	JMSA 20102	-0.60	0.43	5.74	-0.02	1.22**	0.07	5.10**	1.70**	2.18**	0.44**	7.49**	0.29
	ICMA 05888	0.07	1.10*	2.73	-0.27**	3.89**	-0.08	0.67	-1.34*	-2.45**	0.17**	1.03**	-3.55**
S.Em. ±		0.52	0.44	5.23	0.05	0.27	0.04	0.45	0.55	0.23	0.04	0.19	0.18
Testers	GP-5 R	1.49**	0.15	4.52	0.20**	-0.31	-0.29**	-3.27**	-1.11*	-1.51**	0.09**	-5.58**	-3.29**
	42182 R	-2.24**	-0.90*	-8.96*	0.29**	-0.60**	0.19**	4.14**	1.77**	-0.20	-0.16**	4.49**	0.64**
	30133 R	-1.13*	-0.13	7.88	-0.28**	-0.47*	-0.06	2.45**	1.39**	0.79**	-0.03	1.13**	2.98**
	41530 R	1.88**	0.88*	-3.44	-0.20**	1.38**	0.15**	-3.32**	-2.05**	0.91**	0.09*	-0.04	-0.33*
S.Em. ±		0.42	0.36	4.27	0.04	0.22	0.03	0.37	0.45	0.19	0.04	0.16	0.15

and ** indicate significant at 5 per cent and 1 per cent levels of significance, respectively

Table 3: The estimates of specific combining ability (sca) for various characters in pearl millet

Hybrids	Days to flowering	Days to maturity	Plant height (cm)	Number of effective tiller per plant	Earhead length (cm)	Earhead girth (cm)	Grain yield per plant (g)	Harvest index (%)	Test weight (g)	Protein (%)	Iron (ppm)	Zinc (ppm)
ICMA 08444 × GP-5 R	-0.99	2.26*	-0.07	0.70**	0.75	-0.13	12.42**	5.57**	0.66	-0.85**	2.97**	1.20**
ICMA 08444 × 42182 R	0.40	-0.35	-1.12	-0.52**	-1.41*	-0.02	-9.11**	-5.30**	0.94*	0.05	-18.56**	-7.97**
ICMA 08444 × 30133 R	0.63	-0.79	-8.43	-0.02	-1.58**	-0.14	-6.52**	-4.12**	-0.78	-0.96**	12.82**	3.10**
ICMA 08444 × 41530 R	-0.04	-1.13	9.62	-0.16	2.23**	0.29**	3.21**	3.85**	-0.81	1.75**	2.77**	3.67**
JMSA 20071 × GP-5 R	6.76**	2.26*	1.83	-0.81**	-2.91**	-0.34**	-14.04**	-13.81**	-1.55**	1.13**	-10.59**	0.62
JMSA 20071 × 42182 R	-3.85**	-3.68**	17.71	0.43**	2.28**	0.05	13.27**	-3.02**	1.90**	-0.06	14.27**	0.09
JMSA 20071 × 30133 R	-0.96	1.21	6.67	0.20*	0.55	0.31**	-0.15	8.74**	0.11	-0.46**	3.43**	2.01**
JMSA 20071 × 41530 R	-1.96	0.21	-26.21*	0.19	0.09	-0.02	0.92	8.08**	-0.46	-0.61**	-7.11**	-2.72**
ICMA 09666 × GP-5 R	-0.65	0.76	-18.15	0.69**	-1.04	0.15	3.96**	5.04**	-1.75**	-1.07**	16.22**	6.63**
ICMA 09666 × 42182 R	1.40	0.49	3.33	-0.14	-0.70	-0.07	-4.49**	-0.22	0.56	-0.37**	-9.07**	-4.05**
ICMA 09666 × 30133 R	-0.04	0.04	-3.25	-0.17	0.13	-0.13	-4.23**	-0.10	-0.10	0.97**	-7.28**	-4.00**
ICMA 09666 × 41530 R	-0.71	-1.29	18.07	-0.38**	1.61**	0.06	4.76**	-4.72**	1.29**	0.47**	0.14	1.42**
ICMA 03666 × GP-5 R	-3.32**	-2.32*	0.37	0.20*	0.08	0.12	10.21**	0.75	-0.31	0.03	-1.51**	-4.49**
ICMA 03666 × 42182 R	0.07	1.07	-13.89	-0.22*	-1.44**	0.06	-17.86**	-2.09	-2.40**	-1.13**	1.02*	4.75**
ICMA 03666 × 30133 R	0.63	-0.04	18.87	-0.45**	-0.17	-0.01	1.83*	-1.53	0.03	1.35**	6.29**	-1.34**
ICMA 03666 × 41530 R	2.63*	1.29	-5.34	0.47**	1.54**	-0.17*	5.82**	2.87*	2.68**	-0.25**	-5.80**	1.08**
JMSA 20102 × GP-5 R	-3.24**	-2.15*	5.77	-0.18	0.46	0.12	-5.87**	8.59**	1.16*	0.43**	-22.62**	-6.00**
JMSA 20102 × 42182 R	2.15*	0.57	9.64	0.46**	2.43**	-0.15	18.04**	13.63**	-1.27**	1.91**	18.54**	6.80**
JMSA 20102 × 30133 R	1.04	0.79	-4.53	0.23*	1.68**	0.02	6.64**	-8.85**	1.36**	-1.84**	-18.02**	0.10
JMSA 20102 × 41530 R	0.04	0.79	-10.88	-0.51**	-4.57**	0.01	-18.82**	-13.36**	-1.25**	-0.49**	22.10**	-0.90*
ICMA 05888 × GP-5 R	1.43	-0.82	10.25	-0.60**	2.66**	0.08	-6.68**	-6.14**	1.78**	0.33**	15.54**	2.04**
ICMA 05888 × 42182 R	-0.18	1.90*	-15.67	-0.02	-1.15*	0.13	0.15	-3.01**	0.28	-0.41**	-6.19**	0.38
ICMA 05888 × 30133 R	-1.29	-1.21	-9.32	0.21*	-0.61	-0.04	2.42**	5.87**	-0.61	0.95**	2.75**	0.12
ICMA 05888 × 41530 R	0.04	0.13	14.74	0.40**	-0.90	-0.17	4.10**	3.28**	-1.45**	-0.87**	-12.09**	-2.54**
S.Em. ±	1.04	0.88	10.46	0.09	0.53	0.08	0.90	1.09	0.45	0.08	0.54	0.51
Range	-3.85 to 6.76	-3.68 to 2.26	-26.21 to 18.87	-0.81 to 0.70	-4.57 to 2.66	-0.34 to 0.31	-18.82 to 18.04	-13.81 to 13.63	-2.40 to 2.68	-1.84 to 1.91	-22.62 to 22.10	-7.97 to 6.80
No. of +ve significant	3	3	0	10	7	2	12	10	7	9	12	10
No. of -ve significant	3	3	1	7	6	2	9	9	6	12	11	9

*and ** indicate significant at 5 per cent and 1 per cent levels of significance, respectively

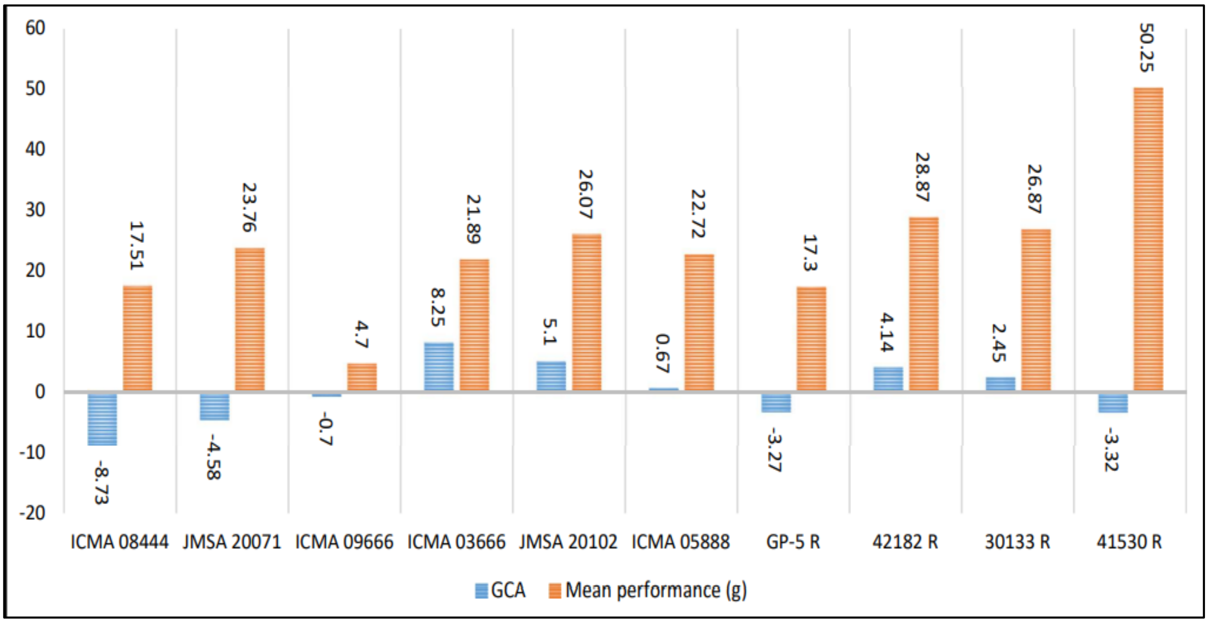

Fig 1: Graphical representation of GCA and mean performance for grain yield per plant (g)

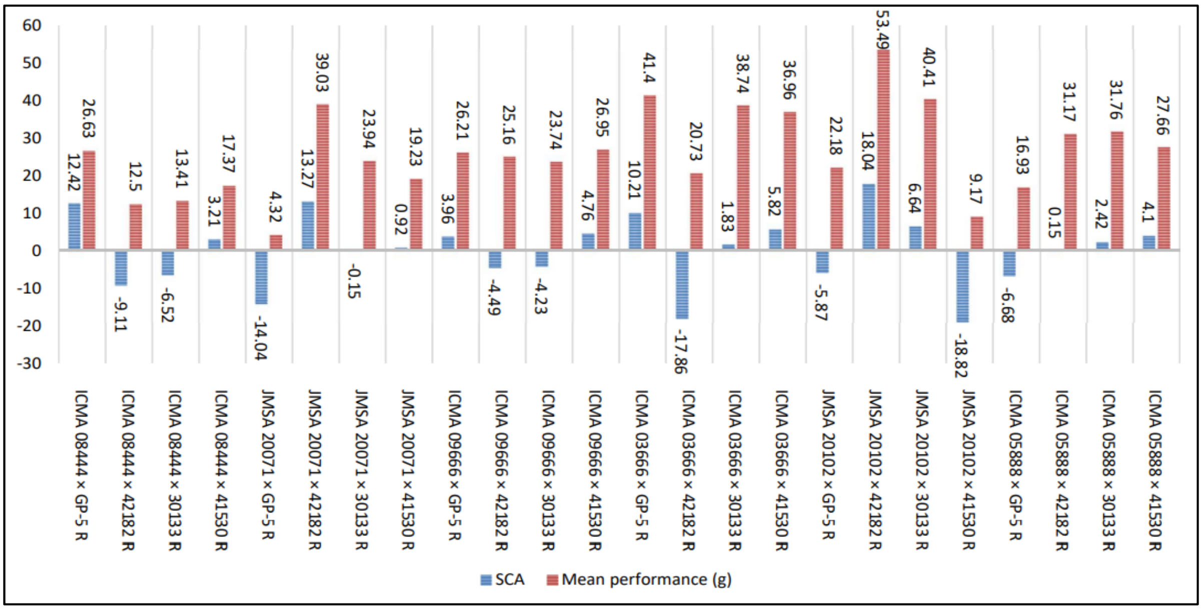

Fig 2: Graphical representation of SCA and mean performance for grain yield per plant (g)

Table 4: Summary table showing general combining ability effects of parents for various characters in pearl millet

Sr. No.	Parents	Days to flowering	Days to maturity	Plant height (cm)	Number of effective tiller per plant	Earhead length (cm)	Earhead girth (cm)	Grain yield per plant (g)	Harvest index (%)	Test weight (g)	Protein (%)	Iron (ppm)	Zinc (ppm)
Female Parents (Lines)													
1	ICMA 08444	G	G	G	P	P	G	P	P	P	P	P	P
2	JMSA 20071	A	A	G	A	P	P	P	A	P	G	G	G
3	ICMA 09666	A	A	P	A	G	P	A	A	G	A	P	P
4	ICMA 03666	P	P	P	G	P	A	G	G	G	P	P	G
5	JMSA 20102	A	A	A	A	G	A	G	G	G	G	G	A
6	ICMA 05888	A	P	A	P	G	A	A	P	P	G	G	P
Male Parents (Testers)													
1	GP-5 R	P	A	A	G	A	P	P	P	P	G	P	P
2	42182 R	G	G	G	G	P	G	G	G	A	P	G	G
3	30133 R	G	A	A	P	P	A	G	G	G	A	G	G
4	41530 R	G	P	A	P	G	G	P	P	G	G	A	P

Table 5: Comparative study of most promising hybrids showing high specific combining ability effects for seed yield with various character

Hybrids	Grain yield per plant (g)	Days to flowering	Days to maturity	Plant height (cm)	Number of effective tiller per plant	Earhead length (cm)	Earhead girth (cm)	Harvest index (%)	Test weight (g)	Protein (%)	Iron (ppm)	Zinc (ppm)
JMSA 20102 × 42182 R	18.04**	2.15*	0.57	9.64	0.46**	2.43**	-0.15	13.63**	-1.27**	1.91**	18.54**	6.80**
JMSA 20071 × 42182 R	13.27**	-3.85**	-3.68**	17.71	0.43**	2.28**	0.05	-3.02**	1.90**	-0.06	14.27**	0.09
ICMA 08444 × GP-5 R	12.42**	-0.99	2.26*	-0.07	0.70**	0.75	-0.13	5.57**	0.66	-0.85**	2.97**	1.20**
ICMA 03666 × GP-5 R	10.21**	-3.32**	-2.32*	0.37	0.20*	0.08	0.12	0.75	-0.31	0.03	-1.51**	-4.49**
JMSA 20102 × 30133 R	6.64**	1.04	0.79	-4.53	0.23*	1.68**	0.02	-8.85**	1.36**	-1.84**	-18.02**	0.10

* and ** indicate significant at 5 per cent and 1 per cent levels of significance, respectively

Table 6: Top three ranking parent with respect to *per se* performance and *gca* effects and three top ranking hybrids with respect to *per se* performance and *sca* effects and heterosis over better parent and standard check (GHB-558) in pearl millet

Sr. No.	Characters	Best performing parent (*per se* performing)	Best combiners	Best performing hybrids (*per se* performance)		Best performing hybrids (*sca* effect)		
				Hybrid	Parent tatus	Hybrid	*sca* effect	parent status
1	Days to flowering	JMSA 20071	42182 R	JMSA 20071 × 42182 R	A × G	JMSA 20071 × 42182 R	-3.85	A × G
		ICMA 08444	ICMA 08444	ICMA 08444 × 42182 R	G × G	ICMA 03666 × GP-5 R	-3.32	P × P
		ICMA 05888 /GP-5 R	30133 R	ICMA 08444 × 30133 R	G × G	JMSA 20102 × GP-5 R	-3.24	A × P
2	Days to maturity	JMSA 20071	ICMA 08444	JMSA 20071 × 42182 R	A × G	JMSA 20071 × 42182 R	-3.68	A × G
		ICMA 08444	42182 R	ICMA 08444 × 42182 R	G × G	ICMA 03666 × GP-5 R	-2.32	P × A
		30133 R	JMSA 20071	ICMA 08444 × 30133 R	G × A	JMSA 20102 × GP-5 R	-2.15	A × A
3	Plant height (cm)	ICMA 09666	JMSA 20071	JMSA 20071 × 41530 R	G × A	JMSA 20071 × 41530 R	-26.21	G × A
		JMSA 20102	ICMA 08444	ICMA 05888 × 42182 R	A × G	ICMA 09666 × GP-5 R	-18.15	P × A
		ICMA 05888	42182 R	ICMA 08444 × 42182 R	G × G	ICMA 05888 × 42182 R	-15.67	A × G
4	No. of effective tiller per plant	42182 R	ICMA 03666	ICMA 09666 × GP-5 R	A × G	ICMA 08444 × GP-5 R	0.70	P × G
		GP-5 R	42182 R	ICMA 03666 × GP-5 R	G × G	ICMA 09666 × GP-5 R	0.69	A × G
		ICMA 03666	GP-5 R	ICMA 08444 × GP-5 R	P × G	ICMA 03666 × 41530 R	0.47	G × P
5	Earhead length (cm)	ICMA 05888	ICMA 05888	ICMA 05888 × GP-5 R	G × A	ICMA 05888 × GP-5 R	2.66	G × A
		41530 R	ICMA 09666	ICMA 09666 × 41530 R	G × G	JMSA 20102 × 42182 R	2.43	G × P
		ICMA 03666	41530 R	ICMA 05888 × 41530 R	G × G	JMSA 20071 × 42182 R	2.28	P × P
6	Earhead girth(cm)	ICMA 08444	42182 R	ICMA 08444 × 41530 R	G × G	JMSA 20071 × 30133 R	0.31	P × A
		41530 R	41530 R	ICMA 03666 × 42182 R	A × G	ICMA 08444 × 41530 R	0.29	G × G
		42182 R	ICMA 08444	ICMA 08444 × 42182 R	G × G	ICMA 09666 × GP-5 R	0.15	P × P
7	Grain yield per plant (g)	41530 R	ICMA 03666	JMSA 20102 × 42182 R	G × G	JMSA 20102 × 42182 R	18.04	G × G
		42182 R	JMSA 20102	ICMA 03666 × GP-5 R	G × P	JMSA 20071 × 42182 R	13.27	P × G
		30133 R	42182 R	JMSA 20102 × 30133 R	G × G	ICMA 08444 × GP-5 R	12.42	P × P
8	Harvest index (%)	41530 R	ICMA 03666	JMSA 20102 × 42182 R	G × G	JMSA 20102 × 42182 R	13.63	G × G
		JMSA 20102	42182 R	JMSA 20071 × 30133 R	A × G	JMSA 20071 × 30133 R	8.74	A × G
		42182 R	JMSA 20102	JMSA 20102 × GP-5 R	G × P	JMSA 20102 × GP-5 R	8.59	G × P
9	Test weight (g)	41530 R	JMSA 20102	ICMA 03666 × 41530 R	G × G	ICMA 03666 × 41530 R	2.68	G × P
		JMSA 20102	ICMA 09666	JMSA 20102 × 30133 R	G × G	JMSA 20071 × 42182 R	1.90	A × G
		42182 R	ICMA 03666	ICMA 09666 × 41530 R	G × G	ICMA 05888 × GP-5 R	1.78	P × P
10	Protein (%)	41530 R	JMSA 20102	JMSA 20102 × 42182 R	G × P	JMSA 20102 × 42182 R	1.91	G × P
		JMSA 20102	JMSA 20071	JMSA 20071 × GP-5 R	G × G	ICMA 08444 × 41530 R	1.75	P × G
		ICMA 09666	ICMA 05888	ICMA 08444 × 41530 R	P × G	ICMA 03666 × 30133 R	1.35	P × A
11	Iron(ppm)	JMSA 20071	JMSA 20102	JMSA 20102 × 42182 R	G × G	JMSA 20102 × 41530 R	22.10	G × A
		JMSA 20102	JMSA 20071	JMSA 20102 × 41530 R	G × A	JMSA 20102 × 42182 R	18.54	G × G
		41530 R	42182 R	JMSA 20071 × 42182 R	G × G	ICMA 09666 × GP-5 R	16.22	P × P
12	Zinc(ppm)	JMSA 20071	JMSA 20071	JMSA 20071 × 30133 R	G × G	JMSA 20102 × 42182 R	6.80	A × G
		JMSA 20102	30133 R	JMSA 20102 × 42182 R	A × G	ICMA 09666 × GP-5 R	6.63	P × P
		41530 R	ICMA 03666	JMSA 20071 × 42182 R	G × G	ICMA 03666 × 42182 R	4.75	G × G

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