

Combining Ability Studies for Yield and Yield Attributes in Bajra

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ABSTRACT

In this study combining ability and gene action were studied in eight quantitative attributes in pearl millet using seven male sterile lines and three restorers which were crossed in Line x Tester design. Analysis of variance for combining ability revealed significant differences among mean squares for lines, testers and lines x testers for all the characters except for spike girth, lines for spike length and lines x testers for days to maturity. These results are indicative of importance of both additive and non-additive genetic variances in the expression of these traits. The ratio of GCA variance and SCA variance indicated the predominance of non-additive gene action for all the eight characters studied, i.e. days to 50% flowering, days to maturity, plant height, number of productive tillers per plant, spike length, spike girth, dry fodder yield and grain yield. Among the lines, ICMA12222 and ICMA 94444 and the tester ICMR 07555 displayed high GCA effect for grain yield per plant. Significant and positive SCA effect for grain yield per plant was displayed by the cross ICMA 12222 x ICMR 07666 followed by ICMA 98444 x ICMR 07555, ICMA 98111 x ICMR 07555 and ICMA 88006 x ICMR 08111. These crosses have been identified as best combiners to give higher grain yield hybrids and could be further evaluated to confirm their stable superior performance.

Key words: Bajra, Combining ability, Heterosis, Gene action, Line x Tester analysis

Introduction

“Pearl millet (*Pennisetum glaucum* (L.) R. Brown) is the fifth prime tropical cereal crop after rice, wheat, maize and sorghum. It is staple food for 90 million poor people and cultivated in 30 million ha in the arid and semi-arid tropical regions of world (FAO, 2015)”. In India Bajra is grown in 7.41 million ha with a production of 10.3 million tonnes having productivity of 1391 kg/ha (Project co-ordinator review, 2021). It is an important food and fodder crop providing nutritional security besides food security in the arid and semiarid lands. Early maturity, drought and temperature tolerance, minimal input requirement and less mostly free from biotic and

abiotic stresses make it an ideal climate resilient crop. It is highly nutritious crop (iron and zinc rich) and hence designated as *nutricereal*. “The Bajra grain is a very rich source of protein, vitamins, and minerals in comparison with other cereals and is used for human consumption in diverse ways (Nambiar *et al.*, 2011).

“Discovery of A_1 cytoplasmic-nuclear male sterility (CMS) at Tifton, Georgia, USA (Brunken *et al.*, 1977) initiated the era of hybrid cultivar development in pearl millet, which led to the release of the first grain hybrid in India in 1965 (Athwal, 1965)”. The CMS source in pearl millet showed the way for grain yield augmentation with development and release of high yielding hybrids. There after several

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cytoplasmic genetic male sterility sources *viz.*, A₁, A₄, A₅, have resulted in the production and release of number of hybrids (Badurkar *et al.*, 2018). Hybrid vigour exploitation is considered to be one of biggest achievements of plant breeding in this crop. Cross pollinated nature and availability of male sterile lines in pearl millet made its feasible use to exploit hybrid vigour on commercial scale. Since yield is controlled by many factors, has low heritability hence direct selection for yield is not sufficiently effective. So, indirect selection for yield has to be done in the light of gene action, by selection of yield contributing traits.

Knowledge on combining ability, nature of gene action and heterosis is a pre-requisite for designing effective breeding strategies for the development of open-pollinated varieties (OPVS) and hybrids (Priyanka Solanki *et al.*, 2017). Testing parents for their combining ability is very important because many times the high yielding parents may not combine well to give good hybrids. Line x tester analysis helps in testing a large number of genotypes to assess the gene action and combining ability (Mungra *et al.*, 2015). Selection made on phenotypic performance alone does not lead to expected success in hybrid breeding. Combining ability studies provide useful information regarding selection of suitable parents for effective hybridization programme and at the same time elucidates the nature and magnitude of gene action. Therefore combining ability of parents is essential in choosing parents to produce good hybrids. The study also provides information on relative magnitude of GCA and SCA variances, which indicates the nature of gene action in terms of additive and non-additive genetic variances respectively. This knowledge in fact helps in exploiting heterosis for commercial purpose (Lakshmana *et al.*, 2011). The objectives of study were formulated to estimate combining ability and heterosis of pearl millet hybrids for yield, and other yield components and to identify superior pearl millet hybrids.

Materials and Methods

In the present study the experimental material consisted of seven male sterile lines used as female lines (MS 842 A, MS 12222, MS 88006, MS 94446, MS 97333, MS 98111 and MS 98444) and three restorer lines used as testers (R 07666, R 07555 and R 08111), crossed in a Line x Tester mating design. Parent material was sown during *Rabi* 2020-21 to

carryout crossing. The crosses were done between seven lines and three selected testers. The 21 hybrids obtained from the crosses were sown in randomized block design with hybrids and parents in two rows having 4 meters length, with a spacing of 45 cm between rows and 15 cm between the plants at Agricultural Research Station, Perumallapalle during *Kharif* 2021. Observations were recorded on five randomly selected competitive plants of each genotype in each replication for characters days to flowering, days to maturity, plant height (cm), number of effective tillers per plant, spike length (cm), spike girth (cm), fodder yield (t/ha), grain yield per plant (q/ha). Data were subjected to analysis of variance as per the procedure suggested by Sukhatme and Amble (1989). The observations taken for hybrids and parents were subjected to line x tester analysis. Combining ability analysis was performed as per the method suggested by Kempthorne (1957).

Results and Discussion

Analysis of variance for combining ability and estimation of variance components for grain yield and its components were presented in Table 1. Pooled analysis of variance for combining ability with respect to yield and yield components revealed significant differences among mean squares for lines, testers and lines x testers for all the characters except for spike girth, lines for spike length and lines x testers for days to maturity. These results are indicative of importance of both additive and non-additive genetic variances in the expression of these traits. Variance components indicated that the magnitude of variance due to GCA was lower as compared to magnitude of SCA for all the characters which indicated greater role of non-additive genetic variance in the inheritance of these characters. Ratio of GCA variance and SCA variance is less than unity, which further indicated the predominance of non-additive gene action for all the eight characters studied. Findings of the present investigation for grain yield per plant and its attributing traits were in close conformity with the findings of Reshma *et al.* (2019), Chittora and Patel (2016) and Badurkar *et al.*, 2018.

The estimates of GCA of parents (seven females and three males) and SCA effects of crosses (21), for all the eight characters were presented in Table 2 and 3, respectively. Combining ability analysis of GCA effects (Table 2) indicated that none of the parents was good general combiner for all the charac-

ters studied. However among the lines, ICMA 842 was found to be good general combiners for days to flowering and plant height, ICMA 12222 for number of tillers per plant, fodder yield and grain yield, ICMA 94444 for plant height and grain yield and ICMA 98444 for days to flowering, spike girth and fodder yield. Among the testers ICMR 07666 was good combiner for number of productive tillers per plant, ICMR 07555 for fodder and grain yield and ICMR 08111 for plant height and spike length. Among lines ICMA 12222 and ICMA 94444 and in testers ICMR 07555 were good general combiners for fodder and grain yield and considered as the potential parents which could be utilized in further

breeding programme. Latha and Shanmugasundaram (1998) clearly indicated that the grain yield/plant is predominantly under the control of non-additive gene action. The study indicated that the lines ICMA 12222 and ICMA 94444 and tester ICMR 07555 were also having desirable *per se* performance, which suggested that the *per se* performance can be considered as a reliable criterion for selecting parents for hybridization. These results are similar to the studies by Mungra *et al.*, 2015 and Suryawanshi *et al.*, 2021.

Sprague and Tatum (1942) reported that the SCA effect is due to non-additive genetic proportion. It is an important parameter for judging and selecting

Table 1. Analysis of variance for combining ability for eight characters in pearl millet

Source of variation	df	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of productive tillers/plant	Spike length (cm)	Spike girth (cm)	Dry fodder yield (t/ha)	Grain yield (q/ha)
Replications	1	74.67**	126.88**	1.45	0.38	0.1	1.01	0.52	0.82
Lines	6	23.15**	22.82**	504.65**	0.32*	5.65	1.2	15.95**	108.34**
Testers	2	18.88**	13.74*	1622.89**	1.45**	36.17**	1.12	16.33**	437.28**
Line x Testers	12	22.52**	22.54	436.88**	0.46**	14.32**	1.02	5.63**	132.17**
Error	20	2.22	2.73	100.79	0.08	3.46	0.77	0.45	9.68
GCA variance		0.007	0.031	5.427	0.002	0.016	0.003	0.163	0.913
SCA variance		10.152	9.906	168.041	0.188	5.428	0.125	2.593	61.244
GCA variance / SCA variance		0.001	0.003	0.032	0.012	0.003	0.020	0.063	0.015

* indicates significance at 5% and ** indicates significance at 1%

Table 2. Estimates of GCA effects for eight characters in pearl millet

Lines	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of productive tillers/plant	Spike length (cm)	Spike girth (cm)	Dry fodder yield (t/ha)	Grain yield (q/ha)
ICMA 842	3.12 **	3.29 **	11.60 *	-0.30 *	-1.51	-0.41	-1.69 **	-5.63 **
ICMA 12222	-0.88	-0.88	-2.9	0.47 **	-0.68	-0.21	2.71 **	5.87 **
ICMA 88006	-0.21	0.29	-7.5	-0.03	-0.55	-0.09	-0.95 **	-2.36
ICMA 94444	-1.55 *	-1.38	11.56 *	-0.06	0.59	-0.07	0.04	4.97 **
ICMA 97333	-2.38 **	-2.55 **	-12.44 **	-0.03	0.82	-0.16	-1.18 **	1.49
ICMA 98111	-0.21	-0.38	2.76	-0.06	0.09	-0.04	-0.66 *	-2.55
ICMA 98444	2.12 **	1.62 *	-3.07	0	1.25	0.98 *	1.73 **	-1.8
Testers								
ICMR 07666	-1.26 **	-1.10 *	-5.63 *	0.33 **	0.02	-0.31	0.21	-0.69
ICMR 07555	1.02 *	0.83	-6.79 *	-0.01	-1.62 **	0.08	0.96 **	5.90 **
ICMR 08111	0.24	0.26	12.41 **	-0.31 **	1.60 **	0.24	-1.17 **	-5.21 **
SE(GCA for line)	0.6078	0.6747	4.0986	0.1176	0.7595	0.3581	0.2734	1.2704
SE(SCA for tester)	0.3979	0.4417	2.6832	0.077	0.4972	0.2344	0.179	0.8317
C.D 1% (lines)	2.4498	2.7192	6.5196	0.4739	3.0613	1.4434	1.1021	5.1202
C.D 1% (testers)	1.6038	1.7801	0.8146	0.3102	2.0041	0.9449	0.7215	3.352

* indicates significance at 5% and ** indicates significance at 1%

superior cross combinations, which might be exploited through heterosis breeding programme. The results of specific combining ability effects for the crosses were presented in Table 3. Significant and positive SCA effect for grain yield per plant was displayed by the cross combinations of ICMA 12222 x ICMR 07666 followed by ICMA 98444 x ICMR 07555, ICMA 98111 x ICMR 07555 and ICMA 88006 x ICMR 08111. These crosses exhibiting high SCA effects involved parents possessing high GCA effects, thereby suggesting that intra allelic interactions were important. It was also observed that, crosses, which showed significant SCA effect for grain yield, also exhibited significant heterosis and further, such crosses invariably had one parent with significant GCA effect. The high SCA effect no doubt revealed high heterotic response, but it might also be accompanied by poor GCA effect for parents. Similar results were found in the studies by Ghislain Kanfany *et al.*, 2018 and Kana Ram Kumawat *et al.*, (2019).

Estimates of mean, SCA effects and standard heterosis of top five hybrids for different characters were shown in Table 4. It was observed that out of

21 crosses five top crosses *viz.*, ICMA 12222 x ICMR 07666 followed by ICMA 98444 x ICMR 07555, ICMA 98111 x ICMR 07555, ICMA 94444 x ICMR 07555 and ICMA 12222 x ICMR 07555 were highly heterotic in desirable direction for grain yield.

Estimates of per se performance, SCA and GCA effects and standard heterosis for top five hybrids for grain yield are presented in Table 5. Crosses ICMA 12222 x ICMR 07666, ICMA 98444 x ICMR 07555, ICMA 98111 x ICMR 07555, ICMA 94444 x ICMR 07555 and ICMA 12222 x ICMR 07555 have been identified as best hybrids for improving grain yield and could be further evaluated to confirm their stable superior performance of hybrids thus produced.

Conclusion

Lines ICMA 12222 and ICMA 94444 and tester ICMR 07555 were good general combiners for fodder and grain yield and considered as the potential parents which could be utilized in further breeding programme. GCA and SCA variances indicated the predominance of non-additive gene action in the

Table 3. Estimates of SCA effects for eight characters in pearl millet

S. No.	Cross	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of productive tillers / plant	Spike length (cm)	Spike girth (cm)	Dry fodder yield (t/ha)	Grain yield (q/ha)
1	ICMA 842 x ICMR 07666	1.1	0.93	-6.34	-0.36	-1.76	-0.14	-0.71	-0.85
2	ICMA 842 x ICMR 07555	2.31 *	2.50 *	16.92 *	0.08	1.09	-0.28	-0.33	-0.59
3	ICMA 842 x ICMR 08111	-3.40 **	-3.43 **	-10.58	0.28	0.67	0.41	1.04 *	1.44
4	ICMA 12222 x ICMR 07666	2.60 *	2.1	10.86	0.77 **	2.41	0.41	1.08 *	11.62 **
5	ICMA 12222 x ICMR 07555	2.31 *	2.67 *	-26.78 **	-0.49 *	-4.05 **	-0.43	1.10 *	-4.93 *
6	ICMA 12222 x ICMR 08111	-4.90 **	-4.76 **	15.92 *	-0.29	1.64	0.01	-2.19 **	-6.69 **
7	ICMA 88006 x ICMR 07666	-2.07	-1.57	-15.64 *	0.37	-0.82	0.3	0.98	3.65
8	ICMA 88006 x ICMR 07555	-3.86 **	-4.00 **	12.02	-0.39	0.32	-0.5	-2.16 **	-11.26 **
9	ICMA 88006 x ICMR 08111	5.93 **	5.57 **	3.62	0.01	0.5	0.2	1.18 *	7.61 **
10	ICMA 94444 x ICMR 07666	0.26	0.1	3.6	-0.50 *	-2.96 *	0.03	-2.17 **	-3.03
11	ICMA 94444 x R 07555	0.48	0.67	-4.75	0.45 *	0.59	-0.21	2.13 **	-0.63
12	ICMA 94444 x ICMR 08111	-0.74	-0.76	1.15	0.05	2.37	0.18	0.04	3.66
13	ICMA 97333 x ICMR 07666	-0.4	-0.24	3.1	0.37	1.11	0.36	0.85	4.03
14	ICMA 97333 x ICMR 07555	-1.69	-1.67	-11.25	-0.39	0.95	-0.38	-1.41 **	-2.59
15	ICMA 97333 x ICMR 08111	2.1	1.9	8.15	0.01	-2.06	0.01	0.56	-1.44
16	ICMA 98111 x ICMR 07666	-3.07 **	-3.40 **	9.2	-0.50 *	-1.96	-0.3	-0.56	-8.17 **
17	ICMA 98111 x ICMR 07555	1.64	1.67	6.35	0.55 *	1.79	0.05	-0.44	8.69 **
18	ICMA 98111 x ICMR 08111	1.43	1.74	-15.55 *	-0.05	0.17	0.25	1.00 *	-0.52
19	ICMA 98444 x ICMR 07666	1.6	2.1	-4.77	-0.16	3.98 **	-0.67	0.51	-7.25 **
20	ICMA 98444 x ICMR 07555	-1.19	-1.83	7.49	0.18	-0.68	1.74 *	1.12 *	11.32 **
21	ICMA 98444 x ICMR 08111	-0.4	-0.26	-2.71	-0.02	-3.30 *	-1.07	-1.63 **	-4.07

* indicates significance at 5% and ** indicates significance at 1%

Table 4. Estimates of mean, SCA effects and standard heterosis of top five hybrids for different characters.

Character		ICMA 12222x ICMR 07666	ICMA 98444x ICMR 07555	ICMA 98111x ICMR 07555	ICMA 94444x ICMR 07555	ICMA 12222x ICMR 07555
Days to 50% flowering	Mean	47.5	49.0	49.5	47.0	49.5
	SCA	2.60 *	-1.19	1.64	0.48	2.31 *
	SH	-4.04	-1.01	0	-5.05	0
Days to maturity	Mean	79.0	79.5	81.0	79.0	81.5
	SCA	2.1	-1.83	1.67	0.67	2.67 *
	SH	-3.07	-2.45	-0.61	-3.07	0
Plant height (cm)	Mean	178.0	173.3	178.0	175.7	139.2
	SCA	10.86	7.49	6.35	-4.75	-26.78 **
	SH	12.44	9.48	12.44	10.99	-12.07
No. of productive tillers /plant	Mean	3.0	1.6	1.9	1.8	1.4
	SCA	0.77 **	0.18	0.55 *	0.45 *	-0.49 *
	SH	172.73 **	45.45	72.73 **	63.64 *	27.27
Spike length (cm)	Mean	25.4	22.6	23.9	23.2	17.3
	SCA	2.41	-0.68	1.79	0.59	-4.05 **
	SH	-6.27	-16.61 *	-11.81	-14.39 *	-36.16 **
Spike girth (cm)	Mean	2.8	5.7	3.0	2.7	2.4
	SCA	0.41	1.74 *	0.05	-0.21	-0.43
	SH	-1.75	100.00 **	5.26	-5.26	-17.54
Dry fodder yield (t/ha)	Mean	8.20	8.00	4.05	7.32	8.96
	SCA	1.08 *	1.12 *	-0.44	2.13 **	1.10 *
	SH	79.93 **	75.44 **	-11.18	60.53 **	96.60 **
Grain yield (q/ha)	Mean	46.94	45.56	42.18	40.38	36.98
	SCA	11.62 **	11.32 **	8.69 **	-0.63	-4.93 *
	SH	58.58 **	53.92 **	42.50 **	36.42 **	24.93 *

* indicates significance at 5% and ** indicates significance at 1%

Table 5. Estimates of per se performance, sca and gca effects and standard heterosis of top five hybrids for grain yield.

Cross	Per se performance of hybrids	SCA effect	Standard heterosis % over best check 86M01	GCA effects	
				Line	Tester
ICMA 12222 x R 07666	46.94	11.62 **	58.58 **	5.87 **	-0.69
ICMA 98444 x R 07555	45.56	11.32 **	53.92 **	-1.8	5.90 **
ICMA 98111 x R 07555	42.18	8.69 **	42.50 **	-2.55	5.90 **
ICMA 94444 x R 07555	40.38	-0.63	36.42 **	4.97 **	5.90 **
ICMA 12222 x R 07555	36.98	-4.93 *	24.93 *	5.87 **	5.90 **

inheritance for yield and yield components. The present study revealed that the crosses ICMA 12222 x ICMR 07666, ICMA 98444 x ICMR 07555, ICMA 98111 x ICMR 07555, ICMA 94444 x ICMR 07555 and ICMA 12222 x ICMR 07555 were the top five hybrids and exhibited high standard heterosis for grain yield. Therefore the cross combinations are considered to produce high yielding hybrids.

Conflict of Interest: None

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