Combining Ability and Gene Action Analysis in Pearl Millet [*Pennisetum glaucum* (L) R.Br.]

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Abstract

A line x tester analysis of combining ability involved Seven male-sterile lines of different genotypes sources and five testers of Pearl millet developed in Gujarat (India).The present investigation was undertaken with the objectives to assess the gene action and magnitude and effects of combining ability of 35 hybrids resulted from line x tester mating design with the standard check (GHB 558). The analysis of variance for combining ability revealed the specific combining ability variance for male x female interaction was highly significant for all characters under study. The magnitude of SCA variances was higher than the GCA variances for all the characters. It indicates non-additive gene action in the inheritance of the traits. This was further supported by less magnitude of $\sigma^2_{gca}/\sigma^2_{sca}$ ratios.

The analysis of variance for parents and hybrids was highly significant for all traits indicated the existence of the appreciable amount of genetic variability in the experimental material. Among the male sterile lines, ICMA 96222 proved to be the best general combiner, followed by ICMA 07777. Whereas 18488 R, was the best of the inbreds. The crosses cross ICMA 06777 x 18805 R, ICMA 96222 x 18488 R and 07777 x 18488 R were superior to the standard check variety, GHB 558.

Keywords: Pearl millet, L x T design, combining ability, standard check, GCA and SCA

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Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] (also known under synonyms: *P. americanum* (L.) is an important millet crop of traditional farming systems in tropical and subtropical Asia and sub-Saharan Africa. It was introduced to India about 2000 B.C. [1]. Pearl millet is the fourth most important cereal crop in India, after rice, wheat and sorghum, where it is widely grown in the states of Rajasthan, Maharashtra, Gujarat and Haryana where the food security of the poorest population depends vastly on pearl millet production. It contains adequate amount of essential amino acids such as tryptophan, threonine, arginine, and lysine. It is used as a feed, fodder, construction material and even its potential as a source of biofuel is being explored [16].

Discovery of A*1* cytoplasmic-nuclear male sterility (CMS) at Tifton, Georgia, USA [3] initiated the era of hybrid cultivar development in pearl millet [*Pennisetum glaucum* (L). R. Br.], which led to the release of the first grain hybrid in India in 1965 [2]. Since then hundreds of commercial hybrids have been developed and released or commercialized. Hanna (1989)[7] identified an A*4* CMS system at Tifton, Georgia, USA in a wild grassy *Pennisetum glaucum* (L.) R. Br. subsp. *monodii* (Maire). Also, an A*5* CMS system was identified in a pearl millet gene pool (Brunken *et. al*,1977) [3]. Among the various CMS systems reported so far, A*4* and A*5* CMS systems were found to have the most stable male sterility(Rai *et. al*, 2006) [14] .

Since yield has low heritability, 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 and with the selection of yield traits. 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. In order to proceed with any breeding programme, the breeder has to know about the gene action and the genetic architecture of population. 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. Evaluation of crosses and identification of the superior cross combinations (combining ability) for yield and quality traits essential for effective manipulation through hybrid breeding.

Material and Methods

The experimental material consisted of seven maintainer lines used as female lines (ICMA -06777, ICMA -07777, ICMA-96222, ICMA-97111, ICMA-98444, ICMA-04999 and ICMA-05444) and five restorer lines used as testers (J18488-R, 18587-R, 18805–R, 17369-R and 17548-R), crossed in a Line x Tester mating design.

Parent material was sown during *kharif* of 2015 to carryout crossing based on line × tester analysis. The crosses have been done between seven selected lines and five selected testers. The 35 hybrids obtained from the crosses were sown in randomized block design with hybrids and parents represented one row having 4 meters length spaced at 45 cm between rows and 15 cm apart from plant to plant within row in the experimental field with sandy loam soil with pH 7.5, at Center for Crop Improvement, S. D. Agricultural University, Sardarkrushinagar- 385 506 (Gujarat) during summer 2016.

The observations were recorded on five randomly selected competitive plants of each genotype in each replication for various characters *i.e.* days to flowering (number of days from date of sowing to date of emergence of ear heads in 50 or more than 50 per cent of plants of each genotype was recorded on plot basis), days to maturity (number of days from the date of sowing to the date of physiological maturity of each genotype was recorded on plot basis), plant height (measured in centimeters from base of plant to tip of ear head of main shoot of selected plants), number of effective tillers per plant, ear head length(measured in centimeters from base to tip of ear head of main tiller of selected plants at maturity stage), ear head girth(maximum girth of ear head in middle part of main tiller of selected plants was recorded in millimeter for each genotype), test weight(weight of 1000 grains of each genotype was recorded in grams.), grain yield per plant(Grain yield of five selected plants of each genotype was weighed in grams and calculated on plant bases), harvest index (the economical yield (grain yield) and biological yield (dry fodder yield + grain yield) were recorded and harvest index was worked out by following formula)

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield of plant}}{\text{Total biological yield of the plant}} \times 100$$

The replication wise mean values were used in statistical analysis. The data were subjected to analysis of variance as per the procedure suggested by Sukhatme and Amble (1989)[15]. The combining ability analysis was performed for a Line x Tester matting design as per the method suggested by Kempthorne (1957)[9].

Results and Discussion

The analysis of variance depicting mean squares due to genotypes were highly significant for all the characters are presented in **Table 1**. 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 traits. This indicated the existence of appreciable amount of genetic variability in the experimental material.

The mean squares obtained in analysis of variance for combining ability and estimated components of genetic variance for various characters are presented in **Table 2**.

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)	No. of effective tillers per plant	Ear head length (cm)	Ear head girth(mm)	Test weight (g)	Grain yield per plant (g)	Harvest index (%)
Replication	2	3.13	1.68	866.36	0.03	1.65	3.51	0.35	9.53	2.89
Genotype	46	71.08**	86.15**	5163.65**	1.00**	38.68**	72.66**	5.10**	46.63**	169.69**
Parents	11	73.48**	80.13**	6504.91**	0.91**	26.50**	61.00**	6.32**	15.07**	170.07**
Female	6	50.54**	96.08**	891.96*	0.40**	26.79**	83.30**	7.44**	21.47**	125.04**
Male	4	57.43**	53.43**	217.37	1.89**	32.08**	42.56**	5.38**	8.95	226.64**
Female vs. male	1	275.33**	91.21**	65332.80**	0.03	2.47	0.96	3.39**	1.11	213.99**
Parents vs. hybrids	1	41.46**	124.47**	41908.36**	0.45**	133.51**	283.43**	1.75**	123.42**	39.97*
hybrids	34	71.17**	86.97**	3648.98**	1.05**	39.83**	70.23**	4.81**	54.59**	173.38**
Error	92	1.54	0.96**	333.65	0.02	2.87	2.30	0.16	6.15	7.74
*, ** Significant at P=0.05 and P=0.01 levels respectively.										

Table 2 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	No. of effective tillers per plant	Ear head length	Ear head girth	Test weight	Grain yield per plant	Harvest index
Replication	2	4.06	2.6	602.52	0.11 *	2.183	3.64	0.317	6.45	4.16
Crosses	34	71.17 **	86.97 **	3648.98 **	1.04 **	39.82 **	70.23**	4.80**	54.59 **	173.37 **
Females (Line)	6	195.68 **	308.08 **	4683.52	1.41	50.66 *	207.16**	11.10**	71.45	650.57**
Males (Tester)	4	48.62	91.73 *	7414.11	0.42	148.16 **	115.80 *	8.93 *	58.07	44.41
Females × males	24	43.80 **	30.89 **	2762.827 **	1.06 **	19.05 **	28.40 **	2.54**	49.79 **	75.57 **
Error	68	1.43	0.99	440.62	0.02	2.67	2.99	0.18	5.89	9.19
σ^2 Females		10.12 **	18.47 **	128.05	0.02	2.10 *	11.91 **	0.57 **	1.44	38.33 **
σ^2 Males		0.22	2.89 *	221.49	-0.03	6.14 **	4.16 *	0.30 *	0.39	-1.48
σ^2gca		4.35 **	9.38 **	182.55 **	0.01	4.46 **	7.39 **	0.41 **	0.83 *	15.10**
σ^2sca		14.08 **	9.97 **	809.72 **	0.34 **	5.39**	8.70**	0.79**	14.54 **	22.60 **
σ^2gca / σ^2sca		0.30	0.94	0.22	-0.029	0.82	0.84	0.52	0.05	0.66

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

Table 3 Estimation of general combining ability (gca) effects of parents for various characters in pearl millet

Parents	Days to flowering	Days to maturity	Plant height	No. of effective tillers per plant	Ear head length	Ear head girth	Test weight	Grain yield per plant	Harvest index
ICMA 06777	7.02 **	7.63**	-19.31 **	0.27 **	-2.45 **	3.19 **	-0.09	1.28 *	0.84
ICMA 07777	1.96 **	4.17**	-9.43 *	0.17 **	-0.21	2.59 **	0.38**	1.52 *	-3.17 **
ICMA 96222	-1.77 **	-1.42 **	20.78 **	-0.52 **	3.27**	-0.32	1.36 **	3.46 **	10.99 **
ICMA 97111	-3.63 **	-4.22 **	11.90 *	0.31**	-0.96 *	-2.80 **	0.55 **	-2.81 **	5.30 **
ICMA 98444	-0.77 *	-0.96 **	-6.49	-0.27 **	-0.90 *	0.85 *	-0.32 **	-0.53	-0.84
ICMA 04999	-2.83 **	-5.16 **	-18.61 **	-0.04	1.30 **	-6.81 **	-1.28 **	-1.74**	-9.17**
ICMA 05444	0.02	-0.02	21.17 **	0.06	-0.04	3.29 **	-0.59 **	-1.17	-3.94 **
S.Em. ±	0.64	0.50	9.41	0.08	0.87	0.78	0.21	1.27	1.43
18488 R	0.75 **	2.23**	23.54 **	-0.01	4.35**	0.98**	1.04 **	2.32 **	1.11
18587 R	2.08 **	2.09 **	7.18	0.10 **	0.42	1.54 **	-0.04	0.29	-0.00
18805 R	-1.96 **	-1.47 **	7.28	0.12 **	-0.63	2.47 **	0.06	0.59	0.72
17369 R	-0.67 *	-0.47 *	-22.92 **	-0.23 **	-2.25**	-2.34 **	-0.65 **	-1.81 **	0.67
17548 R	-0.2	-2.38 **	-15.08 **	0.00	-1.89 **	-2.65 **	-0.41 **	-1.39 *	-2.50 **
S.Em. ±	0.54	0.42	7.95	0.07	0.73	0.66	0.17	1.08	1.21

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

The result revealed that the mean squares due to females were highly significant for days to flowering, days to maturity, ear head length, ear head girth, test weight and harvest index. This indicated significant contribution of females towards general combining ability variance component for these traits. The hybrids exhibited significant negative general combining ability effects were also a good combiner for early maturity. The results were in accordance with Gill *et al.* (1974)[6] and Chavan and Nerkar (1994)[5].

The mean squares due to males were significant for days to maturity, ear head length, ear head girth, test weight and grain yield per plant. This indicated the importance of males for their contribution towards general combining ability variance components. The line × tester mean squares exhibited significance for all plant traits. The ratio of σ^2_{gca} / σ^2_{sca} was less than unity for all the characters under study (Table 2). This suggested greater role of non-additive genetic variance in the inheritance of all the traits under study. Among parents, ICMA 07777, ICMA 96222 and 18488 R were good general combiner for grain yield per plant, plant height, number of effective tillers per plant. The female ICMA 96222 was found as good general combiner for characters like grain yield per plant, days to flowering,

days to maturity, test weight, harvest index. While ICMA 07777 was good combiner for days to flowering, ear head girth and test weight and harvest index. Among males, 18488-R was found as a good combiner for grain yield per plant, ear head length, ear head girth and test weight (**Table 3**).

This suggested that parents might be presumed to have relatively greater number of favorable alleles for developing superior hybrids/varieties of pearl millet (**Table 4**). Out of 35 hybrids, three hybrids *viz*., ICMA 07777 × 18488 R (9.53), ICMA 06777 × 18805 R (9.17) and ICMA 96222 × 18587 R (5.42) exhibited significant positive specific combining ability effects for grain yield per plant. Earlier significant GCA and SCA effects in pear millet for grain yield and component traits also reported by Jagendra Singh *et al.* (2014)[8], Patel *et al.* (2014)[12], Khandagale *et al*. (2014)[10], Priyanka (2015)[13] and Mungra *et al* (2015)[11].

Table 4 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

Sr. No.	Characters	Best performing parent (*per se* performing)	Best combiners	Best performing hybrids (*per se* performing)	Status of parents	Hybrids with high sca effects	GCA of the parents	SCA effects
1.	Days to flowering	ICMA 96222	ICMA 97111	ICMA 04999 x 17369 R	G x G	ICMA 07777 x 18805 R	P x G	-5.77
		ICMA 97111	ICMA 04999	ICMA 04999 x 18805 R	G x G	ICMA 05444 x 17548 R	A x A	-5.26
		ICMA 07777	18805 R	ICMA 97111 x 17548 R	G x A	ICMA 98444 x 17548 R	G x A	-5.13
2.	Days to maturity	ICMA 96222	ICMA 04999	ICMA 04999 x18805 R	G x G	ICMA 07777 x 18805 R	P x G	-6.12
		ICMA 06777	ICMA 97111	ICMA 04999 x 17369 R	G x G	ICMA 97111 x 18587 R	G x P	-3.62
		17548 R	17548 R	ICMA 04999 x 17548 R	G x P	ICMA 05444 x 17369 R	A x G	-3.5
3.	Plant height (cm)	ICMA 07777	17369	ICMA 04999 x 17548 R	G x G	ICMA 06777 x 18587 R	G x A	-63.66
		ICMA 06777	ICMA 06777	ICMA 06777 x 18587 R	G x A	ICMA 04999 x 17548 R	G x G	-60.89
		ICMA 98444	ICMA 04999	ICMA 06777 x 17369 R	G x G	ICMA 07777 x 17369 R	G x G	-38.43
4.	No. of effective tillers/ plant	18805	ICMA 97111	ICMA 97111 x 18587 R	G x P	ICMA 97111 x 18587 R	G x P	1.08
		ICMA 07777	ICMA 06777	ICMA 07777x 18805 R	G x P	ICMA 98444 x 17548 R	P x A	0.94
		18488	ICMA 07777	ICMA 06777 x 17548 R	G x A	ICMA 04999 x 18488 R	A x A	0.70
5.	Ear head length (cm)	18488	18488	ICMA 96222 x 18488 R	G x G	ICMA 06777 x 18805 R	P x A	4.36
		ICMA 07777	ICMA 96222	ICMA 04999 x 18488 R	G x G	ICMA 96222 x 17369 R	G x P	4.10
		17369	ICMA 04999	ICMA 96222 x 18587 R	G x A	ICMA 98444 x 17548 R	P x P	2.80
6.	Ear head girth (mm)	ICMA 07777	ICMA 05444	ICMA 06777 x 18805 R	G x G	ICMA 06777 x 17369 R	G x P	6.07
		18587	ICMA 06777	ICMA 05444 x 18488 R	G x G	ICMA 04999 x 18587 R	P x G	3.42
		18488	ICMA 07777	ICMA 07777 x 18805 R	G x G	ICMA 98444 x 17548 R	G x P	3.29
7.	Test weight (g)	ICMA 07777	ICMA 96222	ICMA 07777 x 18488 R	G x G	ICMA 07777 x 18488 R	G x G	1.50
		17369 R	18488 R	ICMA 96222 x 18587 R	G x A	ICMA 06777 x 18805 R	A x A	1.32
		18488 R	ICMA 97111	ICMA 96222 x 18488 R	G x G	ICMA 96222 x 18587 R	G x A	1.08
8.	Grain yield/ plant (g)	17548 R	ICMA 96222	ICMA 07777 x 18488 R	G x G	ICMA 07777 x 18488 R	G x G	9.53**
		ICMA 96222	18488 R	ICMA 06777 x 18805 R	G x A	ICMA 06777 x 18805 R	G x A	9.17**
		ICMA 98444	ICMA 07777	ICMA 96222 x 18488 R	G x G	ICMA 96222 x 18587 R	G x A	5.42**
9.	Harvest Index (%)	17548 R	ICMA 96222	ICMA 96222 x 17369 R	G x A	ICMA 04999 x 17548 R	P x P	7.17
		ICMA 96222	ICMA 07777	ICMA 96222 x 17548 R	G x P	ICMA 07777 x 17548 R	P x P	6.70
		ICMA 98444	ICMA 06777	ICMA 96222 x 18488 R	G x A	ICMA 98444 x 18805 R	A x A	6.05
		ICMA 05444	ICMA 98444	ICMA 98444 x 17369 R	G x P	ICMA 05444 x 18805 R	G x G	1.54
		ICMA 18587	18805 R	ICMA 97111 x 18587 R	A x A	ICMA 98444 x 17548 R	G x A	1.46

In general all characters of the crosses showing positive and negative combining ability effect, involved either good × good, average × good, good × poor, average × average, average × poor and poor × poor general combiners. Crosses between good × poor and poor × good combiners could be attributed to lack of co-adaptation between favourable alleles of the parents involved. Generally the cross showing high sca effects for grain yield per plant also exhibited high or average or poor sca effects for yield components (Table 4).

This indicated that yield is a complex dependent character which depends on a number of independent component characters.

Conclusions

The cross ICMA 07777 × 18488 R showed significant positive specific combining ability effect and high sca effects involving one good general combiner, indicated additive × dominance type of interaction, which can produce desirable transgressive segregate in subsequent generations, also used for exploiting commercial cultivation. The cross ICMA 06777 × 18805 had good × average combiner parents, high *per se* performance and positive specific combining ability effect for grain yield per plant, test weight, ear head length and harvest index. The cross ICMA 96222 × 18488 R had good × good combiner parent, significant positive specific combining effect for grain yield per plant test weight and ear head length. This indicated to obtain desirable transgressive sergeants in F_2 or subsequent generation, may be used for development of pollinated CMS line as female parent and pollen fertility restorer line as male parent for future breeding programme of grain yield per plant, production of high yielding hybrids and for commercial purpose.

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