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Research Article

Combining ability and gene action for grain yield and agronomic traits in pearl millet restorer lines

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Abstract

The experimental material consisted of ten restorer lines and their 45 F_1s developed through half diallel mating design, was evaluated in Randomized Complete Block Design with three replications to study inheritance of grain yield and component characters.The analysis of variance for combining ability revealed that mean squares due to parents and F_1s were significant for all characters studied except number of effective tillers per plant, thereby suggesting the importance of both additive and non additive gene effects. However, potence ratio and predictability ratio depicted preponderance of non-additive gene effectfor all the characters except number of effective tillers per plant, average earhead length, average earhead and girth.Among the parents,AIB-34 was only good general combiner for grain yield per plant. While, in case of hybrids, AIB-9 x AIB-34 and AIB-9 x AIB-29 were good specific combiners for grain yield per plant, number of effective tillers per plant and average earhead weight.

Key words:
Pearl millet, combining ability, gene action, restorer line

Introduction:

The improvement in bajra crop in India started as early as in 1920, but the real breakthrough was made when the first, and the most widely used cytoplasmic genetic male sterile line *Tift* 23A was utilized (Burton, 1965), which permitted development of hybrids in India. Subsequently, availability of several cytoplasmic genetic male sterility sourceshas facilitated development and release of number of high yielding hybrids with increased drought tolerance and resistance to biotic stress. (Burton,1983; Andrews and Kumar, 1992).In heterosis breeding programme, it is essential to study and evaluate available promising diverse parental lines for their hybrid nicking ability. The information on the magnitude and nature of existing genetic variation among restorer parents is essentially needed to infer about their genetic potential. Combining ability study is regarded useful to select good combining parents, which on crossing would produce more desirable hybrids and/or segregants.

In pearl millet selection of parents, inbreds/restorers for hybridization is an important aspect for crop improvement programme. Selection of parents based on their *per se* performance and combining ability is a pre-requisite for development of new inbreds as a restorer parents. As such study indented to determine combining ability, which not only provides information regarding choice of parents, but it also simultaneously illustrates the nature and magnitude of gene effects. Among the various mating designs, diallel technique suggested by Schmidt (1919) and Hayman (1954), and elaborated by Griffing (1956) is a useful methodology for evaluating parents and crosses for their combining ability effects and also for understanding the nature of gene effects. In addition to Griffing (1956) approach, Hayman (1954) numerical approach would provide detail account of components of gene effect and related parameters.

Material and methods

The ten diverse restorer lines *viz*., AIB-3, AIB-4, AIB-6, AIB-9, AIB-13, AIB-19, AIB-21, AIB-26, AIB-29 and AIB-34 developed at Regional Research Station, Anand Agricultural University, Anand were crossed in all possible combinations excluding reciprocals during Summer2011. The experimental material comprised of ten parents, their 45 crosses and two standard check hybrids (GHB-558, GHB 538) were evaluated in Randomized Complete Block Design with three replications during *Kharif*2011-12 at Regional Research Station, Anand Agricultural University, Anand. Each entry was accommodated in a single row of 2.0 m length with spacing of 60 x 15 cm as an experimental unit. All the recommended agronomic practices and plant protection measures were followed time to time to raise good crop. Five competitive plants from each experimental unit of every replication were selected randomly for recording observations on different metric characters. The mean values were subjected to statistical analysis as suggested by Snedecor and Cochran(1967)and reviewed by Panse and Sukhatme (1978). Combining ability analysis was performed as per Griffing (1956) Model-I and method-II. After observing adequacy of additive dominance model, the components of genetic variation *viz.* D, H_1, H_2, F, h^2 and E were estimated (Hayman, 1954).

Result and Discussion

The analysis of variance for combining ability (Table-1) revealed that mean squares due to GCA and SCA were significant for all the characters except number of effective tillers per plant, thereby revealing an importance of both additive and non-additive gene effectsfor the inheritance of characters under study. However, the estimates of both σ^2_{GCA} and σ^2_{SCA} variance due to GCA and variance due to SCA were significant for average earhead length and average earhead girth which also revealing importance of both additive and non-additive genetic variances. thevariance due to SCA (σ^2_{SCA})was significant for rest of the characters except number of effective tillers per plant, which promptly suggested importance of non-additive genetic variance. The results were in accordance with the findings of Joshi *et al.* (2001), Rathore *et al.* (2004) and Dangariya *et al.*(2009) as they reported importance of non-additive gene action.

The magnitude of either of component of genetic variance could be judged from the estimates of potence ratio and predictability ratio. Above one value of potence ratio and above one half value of predictability ratio suggested preponderance of additive genetic variance for average earhead length. The results confirmed the findings Mohan *et al.*(1999) Manga and Dubey(2004), Shanmuganathan *et al.*(2005), Dhuppe *et al.*(2006), Dangariya *et al. (*2009) and Jethva *et al.* (2011). While, for the characters average earhead girth, potence ratio revealed preponderance of additive genetic variance, but predictability ratio suggested equal importance of both additive and non-additive genetic variance. For rest of the characters none of the above ratios was worked out as their *gca* values were non-significant which promptly indicated importance of only non-additive genetic variance.Similar findings were also reported by Shanmuganathan *et al.* (2005), Dangariya *et al.* (2009) and Jethva, *et al.*(2011). All the characters except average earhead length, had above one (>1) estimate of average degree of dominance, which revealed that over dominance behavior of interacting alleles. whereas, average earhead length showed partial dominance.

The validity of hypothetical assumptions underlying diallel analysis as postulated by Hayman (1954) was tested by 't^2' test. The non-significant value of 't^2' estimate probably suggests fulfillment of the assumptions and confirms the validity of the hypothesis. The 't^2' value was non-significant for plant height, average earhead length, average earhead weight, test weight, harvest index and total protein content. For these characters the estimates component of genetic variation and related parameters are furnished in Table 2.

Significance of additive (D) and both the dominance components (H_1 and H_2) of gene effect revealed that the characters plant height, average earhead length, average earhead weight, test weight, harvest index and total protein content were governed by both additive and as well as non-additive gene actions, while the value of average degree of dominance more than unity indicated over dominance behaviour of interacting alleles for all the above listed characters except average earhead length.

The symmetrical distribution of increasing and decreasing alleles in the parents was observed for plant height, average earhead length and average earhead weight as for these characters the estimate of $H_2/4H_1$ ratio was closed to expected value of 0.25. The positive estimates of 'F' parameter and above unity ratio of dominant and recessive genes (KD/KR) for all these characters indicated that dominant genes were more frequent than recessive. The significant and positive estimates of h^2 suggested evidence for net dominance sum over loci for all the characters except harvest index, and above unity values of h^2/H_2 ratio suggested presence of more than one dominant gene or group of genes.The estimates of narrow sense heritability werelow for plant height, average earhead weight and test weight,moderate for harvest indexand total protein contentand high for average earhead length.

The perusal of the results (Table 3) in respect to *gca* effect of parents revealed that the only parent AIB-34 was good general combiner for grain yield per plant, , whereas, rest of the parents except AIB-6 and AIB-19 were average general combiners. The parent AIB-34 was also good general combiner for average ear head girth, dry fodder yield per plant and harvest index, while, it was average general combiner for rest of the characters except average earhead length and protein content. Though the parent AIB-21 was average general combiner for grain yield per plant, but it was good general combiner for average earhead weight, average grain weight per earhead, dry fodder yield per plant and total protein content.

The *per se* performance of parents along with their*gca* effect could be a better criteria for selection of superior parents in future breeding programme. In present investigation, the results revealed that the most of the parents had relatively high degree of correspondence between *per se* performance and their *gca* effects for most of the characters, which could be ascribed to existence of genes, which showed additivity. Therefore, in selection of parents for varietal development programme, due weightage should also be given to *per se* performance along with their *gca* effect.

The estimates of specific combining ability effect by and large provide information on role of intra and inter-allelic interactions in the expression of heterosis and inheritance of a character. The top three crosses on the basis of their *per se* performance, heterobeltiosis, standard heterosis and *sca* effect for different characters are displayed in Table 4. The results revealed that the crosses which had high *per se* performance also depicted higher heterotic effects and high estimate of *sca* effect for all the growth and developmental attributes. Among the evaluated crosses, no single cross combination had desirable significant *sca* effect for all the characters under study. However, in respect to *gca* effect of parents involved in a particular cross, crosses could be grouped in to resultant of six different categories of good, average and poor general combiner parents *viz*. G x G, G x A, A x A, A x P and P x P. In general, the crosses, which exhibited high *sca* effect did not always involved both good general combiner parents with high *gca* effect, there by suggesting importance of intra and as well as inter-allelic interactions. The high *sca* effect of crosses in general corresponded to their high heterotic response, but these might also be accompanied by poor and/or average *gca* effect of the parents. For grain yield per plant total six crosses exhibited significant positive *sca* effect, and out of ten parents eight parents involved in these crosses, of which only one parent AIB-34 was good general combiner, and one parent AIB-6 was poor general combiner, therefore cross combinations were of resultant of A x G, A x A and P x A *gca* effect of parents, and high *sca* or heterotic effects could be because of intra and inter allelic interactions.

Among the good specific combiner crosses for grain yield, crosses AIB-9 x AIB-34 and AIB-9 x AIB-29 were also good specific combiners for number of total tillers per plant, number of effective tillers per plant, mean earhead weight and other growth and developmental characters. The cross AIB-6 x AIB-21 was also good specific combiner for average earhead girth, average earhead weight, average earhead length and average grain weight per earhead. While, the rest of the good specific combiner crosses, AIB-3 x AIB-26, AIB-4 x AIB-21 and AIB-19 x AIB-26 were good specific combiners for at least three component characters among average earhead girth, average grain weight per earhead, plant height, number of effective tillers per plant, dry fodder yield per plant and harvest index. The crosses exhibited high *sca* effects for grain yield per plant also registered desirable *sca* effect for other yield component characters, but those might not necessarily have higher *sca* effect for the said characters, which suggested cumulative effect of various yield contributing attributes as high *sca* effect for grain yield, and thereby high heterotic effects as well.

On the basis of Hayman (1954) numerical and Griffing (1956) Model-I, Method-II approaches, and through potence and predictability ratios, the character average earhead length was largely influenced by additive gene effect, and it had also high estimate of narrow sense heritability. For the characters plant height, number of effective tillers per plant, average earhead girth, harvest index and total protein content both additive and non additive gene effects were important with preponderance of non-additive gene effect, which had been reflected with low to moderate estimates of narrow sense heritability and over dominance behaviour of interacting alleles; while, only non-additive gene effect was important for average earhead weight, average grain weight per earhead, grain yield per plant, dry fodder yield per plant and test weight, for these characters heritability estimates were low and interacting alleles showed over dominance behaviour.

Based on the results obtained, it can be concluded that the hybrid AIB-9 x AIB-34 depicted the highest relative heterosis, heterobeltiosis, standard heterosis and *sca* effect for grain yield per plant, therefore, this cross may be further exploited to get desirable segregants for restorer lines.

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

Source of variation	df.	Plant height	Number of effective tillers per plant	Average earhead length	Average earhead girth	Average earhead weight	Average grain weight per earhead	Grain yield per plant	Test weight	Dry fodder yield per plant	Harvest index	Total protein content
Mean squares												
GCA	9	209.61 **	0.15	27.99**	1.18**	27.17**	11.60**	41.81 *	0.39*	798.33**	72.09**	0.59**
SCA	45	257.75 **	0.08	3.93**	0.28**	33.41**	10.03**	56.60**	0.25*	899.89**	55.15**	0.56**
Error	108	22.96	0.72	1.06	0.03	8.02	3.00	21.53	0.16	57.38	12.44	0.03
Estimates												
σ^2gca ($\sum gi^2$)		-4.01	0.01	2.01**	0.08 **	-0.52	0.13	-1.23	0.01	-8.46	1.41	0.01
σ^2sca ($\sum\sum sij^2$)		234.79**	-0.64	2.87**	0.25 **	25.39**	7.03**	35.07**	0.09**	842.51**	42.71**	0.53**
Potence ratio		-	-	3.49	1.50	-	-	-	-	-	-	-
Predictability ratio		-	-	0.58	0.38	-	-	-	-	-	-	-
σ^2A		-8.02	0.01	4.01	0.15	-1.04	0.26	-2.46	0.02	-16.92	2.82	0.01
σ^2D		234.79	-0.64	2.87	0.25	25.39	7.03	35.07	0.09	842.51	42.71	0.53
$(\sigma^2D/\sigma^2A)^{0.5}$		5.04	7.40	0.85	1.29	4.94	5.18	14.22	1.96	7.05	3.89	10.30

*,** Significant at 0.05 and 0.01 probability levels, respectively.

Table 2. Components of genetic variation for plant height, average earhead length, average earhead weight, test weight, harvest index and total protein content.

Genetic components and parameters	Plant height	Average earhead length	Average earhead weight	Test weight	Harvest index	Total protein content
D	93.80 *	15.12 **	11.04	0.13	85.01 **	0.77 **
H_1	710.49 **	10.71 **	96.64 **	0.75**	246.21 **	2.37 **
H_2	641.55 **	9.55 **	88.93 **	0.52**	164.41 **	1.87 **
h^2	3105.69 **	32.90 **	234.60 **	0.42**	2.54	1.52 **
F	92.40	8.19 **	10.93	0.23	144.67 *	1.11 **
E	22.97 *	1.07 **	8.02 **	0.16 **	12.45	0.03
$(H_1/D)^{1/2}$	2.75	0.84	2.96	2.38	1.70	1.75
$H_2/4H_1$	0.23	0.22	0.23	0.17	0.17	0.20
KD/KR	1.44	1.95	1.40	2.15	3.00	2.40
h^2/H_2	4.84	3.45	2.64	0.81	-	0.81
Narrow sense heritability (%)	11.67	69.03	8.56	10.23	35.96	35.76

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

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Table 3 Estimates of general combining ability (GCA) effect of parents for various characters in pearl millet

Parents	Plant height	Number of effective tillers per plant	Average earhead length	Average ear head girth	Average earhead weight	Average grain weight per earhead	Grain yield per plant	Test weight	Dry fodder yield per plant	Harvest index	Total Protein content
AIB-3	-1.49	-0.03	1.83 **	0.04	-0.29	-0.13	-0.64	-0.03	-0.08	0.03	-0.01
AIB-4	0.63	-0.02	0.20	-0.21 **	1.06	0.29	1.75	0.18	-13.22 **	4.13 **	0.00
AIB-6	3.28 *	-0.19	0.18	-0.26 **	0.50	0.65	-2.59 *	0.09	-6.00 **	-0.56	0.40 **
AIB-9	0.24	0.07	0.52	-0.54 **	-1.28	0.00	-0.20	-0.06	8.98 **	-3.04 **	-0.23 **
AIB-13	3.35 *	-0.16	0.77 **	-0.09	1.03	0.67	-0.81	0.03	-5.94 **	0.52	-0.13 **
AIB-19	-6.25 **	-0.02	-2.39 **	0.42 **	-2.64 **	-2.19 **	-2.86 *	-0.45 **	1.64	-2.00 *	-0.03
AIB-21	5.35 **	0.02	-0.39	0.50 **	2.61 **	1.21 *	2.03	0.04	13.40 **	-3.27 **	0.12 *
AIB-26	0.54	0.08	-1.67 **	0.11 *	-1.13	-0.97 *	-0.23	-0.03	2.26	-0.67	-0.02
AIB-29	-7.74 **	0.12	2.42 **	-0.31 **	0.83	0.67	0.86	0.01	-7.00 **	2.11 *	0.25 **
AIB-34	2.09	0.15	-1.48 **	0.13 *	-0.70	-0.01	2.71 *	0.21	5.97 **	2.75 **	-0.36 **
Range of GCA effects	-7.74 to 5.35	-0.19 to 0.15	-2.39 to 2.42	-0.54 to 0.50	-2.64 to 2.61	-2.19 to 1.21	-2.86 to 2.71	-0.45 to 0.21	-13.22 to 13.40	-3.27 to 4.13	-0.36 to 0.40
S.E (gi) ±	1.31	0.23	0.28	0.05	0.78	0.47	1.27	0.11	2.07	0.97	0.05
S.E. (gi-gj) ±	1.96	0.11	0.42	0.08	1.16	0.71	1.89	0.16	3.09	1.44	0.07
CD 5 %	3.88	0.22	0.84	0.16	2.29	1.40	3.76	0.32	6.13	2.86	0.15

*,** Significant at 5 % and 1 % levels, respectively.

Table: 4 Top three crosses with respect to their *per se* performance, heterobeltiosis (HB), standard heterosis (SH) and *sca* effect for various characters of pearl millet

Characters	*Per se* performance	Heterobeltiosis	Standard heterosis	SCA effect
Plant height	AIB-19 x AIB-29	AIB-3 x AIB-4	AIB-19 x AIB-29	AIB-21 x AIB-26 (P x A)#
	AIB-6 x AIB-19	AIB-6 x AIB-19	AIB-6 x AIB-19	AIB-4 x AIB-34 (A x A)
	AIB- 3 x AIB-29	AIB-21 x AIB-26	AIB-3 x AIB-29	AIB-6 x AIB-19 (P x G)
Number of effective tillers per plant	AIB-9 x AIB-34	AIB-9 x AIB-34	AIB-9 x AIB-34	AIB-9 x AIB-34 (A x A)
	AIB-9 x AIB-29	AIB-19 x AIB-26	AIB-9 x AIB-29	AIB-9 x AIB-29 (A x A)
	AIB-19 x AIB-26	AIB-9 x AIB-29	AIB-19 x AIB-26	AIB-19 x AIB-26 (A x A)
Average earhead length	AIB-13 x AIB-29	AIB-6 x AIB-21	AIB-13 x AIB-29	AIB-6 x AIB-21 (A x A)
	AIB-6 x AIB-21	AIB-26 x AIB-34	AIB-6 x AIB-21	AIB-3 x AIB-19 (G x P)
	AIB-6 x AIB-29	AIB-19 x AIB-26	AIB-6 x AIB-29	AIB-6 x AIB-13 (A x G)
Average earhead girth	AIB-3 x AIB-19	AIB-26 x AIB-34	AIB-3 x AIB-19	AIB-3 x AIB-19 (A x G)
	AIB-6 x AIB-21	AIB-13 x AIB-34	AIB-6 x AIB-21	AIB-6 x AIB-21 (P x G)
	AIB- 4 x AIB-21	AIB-3 x AIB-19	AIB-4 x AIB-21	AIB-13 x AIB-34 (A x G)
Average earhead weight	AIB-6 x AIB-21	AIB-9 x AIB-34	AIB-6 x AIB-21	AIB-6 x AIB-21 (A x G)
	AIB-3 x AIB-21	AIB-19 x AIB-26	AIB-3 x AIB-21	AIB-19 x AIB-26 (P x A)
	AIB-13 x AIB-29	AIB-6 x AIB-21	AIB-13 x AIB-29	AIB-9 x AIB-34 (A x A)
Average grain weight per	AIB-6 x AIB-21	AIB-6 x AIB-21	AIB-6 x AIB-21	AIB-6 x AIB-21 (A x G)
	AIB-6 x AIB-29	AIB-6 x AIB-13	AIB-6 x AIB-29	AIB-6 x AIB-29 (A x A)
	AIB-13 x AIB-29	AIB-6 x AIB-29	AIB-13 x AIB-29	AIB-13 x AIB-29 (A x A)
Grain yield per plant	AIB- 9 x AIB-34	AIB-9 x AIB-34	AIB-9 x AIB-34	AIB-9 x AIB-34 (A x G)
	AIB-9 x AIB-29	AIB-9 x AIB-29	AIB-9 x AIB-29	AIB-9 x AIB-29 (A x A)
	AIB-4 x AIB-21	AIB-3 x AIB-26	AIB-4 x AIB-21	AIB-6 x AIB-21 (P x A)
Test weight	AIB-26 x AIB-29	AIB-3 x AIB-21	AIB-26 x AIB-29	AIB-19 x AIB-29 (P x A)
	AIB-3 x AIB-21	AIB-9 x AIB-13	AIB-3 x AIB-21	AIB-26 x AIB-29 (A x A)
	AIB-6 x AIB-13	AIB-3 x AIB-9	AIB-6 x AIB-13	AIB-3 x AIB-21 (A x A)
Dry fodder yield per plant	AIB-3 x AIB-34	AIB-19 x AIB-26	AIB-3 x AIB-34	AIB-3 x AIB-34 (A x G)
	AIB-19 x AIB-26	AIB-9 x AIB-34	AIB-19 x AIB-21	AIB-19 x AIB-26 (A x A)
	AIB-19 x AIB-21	AIB-9 x AIB-29	AIB-9 x AIB-34	AIB-6 x AIB-26 (P x A)
Harvest index	AIB-3 x AIB-4	AIB-3 x AIB-6	AIB-3 x AIB-4	AIB-3 x AIB-34 (A x G)
	AIB- 3 x AIB-6	AIB-3 x AIB-4	AIB-3 x AIB-6	AIB-3 x AIB-4 (A x G)
	AIB-4 x AIB-21	AIB-4 x AIB-21	AIB-4 x AIB-21	AIB-3 x AIB-9 (A x P)
Total protein content	AIB-21 x AIB-26	AIB-4 x AIB-13	AIB-21 x AIB-26	AIB-21 x AIB-26 (G x A)
	AIB-6 x AIB-19	AIB-4 x AIB-26	AIB-6 x AIB-19	AIB-19 x AIB-21 (A x G)
	AIB-19 x AIB-21	AIB-13 x AIB-34	AIB-19 x AIB-21	AIB-4 x AIB-3 (A x A)

 # combining ability of parents involved in the cross