Electronic Journal of Plant Breeding, 7(3): 595-601 (September 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00076.4

Research Article

Combining ability studies for grain yield and its components in pearl millet (*Pennisetum glaucum* [L.] R. Br.)

B.C. Patel*, M.P. Patel and J.A. Patel
Regional Research Station, Anand Agricultural University, Anand-388 110 India
Email: bcpatel@aau.in

(Received:28 Aug 2015; Accepted:25 Jul 2016)

Abstract

Sixty hybrids of Pearl millet were produced by crossing six male sterile lines with ten diverse inbred lines were studied for combining ability effects. The analysis of variance revealed significant difference between parents for all the characters studied. The estimates of combining ability variances suggested the importance of both additive and non-additive gene action in the control of most of the characters.The mean degree of dominance $(\sigma^2_D / \sigma^2_A)^{0.5}$ was found greater than unity for characters *viz*., productive tillers per plant, grain yield per plant, 1000 grain weight and earhead length, indicating the over dominance.The CGMS line JMSA-9904 was found as good general combiners for days to 50 % flowering, days to maturity and earhead length. The CGMS lines ICMA-98444 and ICMA-20041 were found to be good general combiner for productive tillers per plant and earhead girth but poor combiners for days to 50 % flowering. ICMA-97111 was average combiners for all the charcters. Three parents *viz.*, J-2340, J-2507 and J-2490 were good general combiner for grain yield. Among the sixty hybrids, 14 hybrids showed the best performance with significantly positive *sca* effect for grain yield. The cross ICMA-97111 x 236SB had significant and positive *sca* effects for grain yield per plant, earhead girth and days to maturity.

Key words

Pearl millet, combining ability, *gca*, *sca*, line x tester analysis.

Introduction

Among the cereals, Pearl millet (*Pennisetum glaucum* [L.] R. Br.)is one of the most important food crops of India. In India, it is commonly known as *bajra* or *bajri,* and is mainly grown in Rajasthan, Maharashtra, Gujarat, Haryana, Utter Pradesh, Karnataka and Tamil Nadu. Pearl millet occupies an area of 8.69 million hectares with a production of 10.05 million tones and productivity of 1156 kg/ha in the country. While, in Gujarat it is grown in 1.07 million hectares with a production of 1.23 million tones and productivity of 1250 kg/ha. (Anon., 2012).

Knowledge of relative magnitude of general and specific combining ability is helpful in selection of suitable inbreds for a successful breeding programme. This information enables the breeders to evaluate and classify selected parental material for their utility in breeding high yielding F_1 hybrids in crop like Pearl millet, where hybrids are being cultivated on commercial scale. Further, the study also helps to know the genetic diversity among the parents and their efficiency to produce better recombinant and the nature and extent of average degree of dominance controlling the inheritance of yield and its components (Kunjir and Patil, 1986). The combining ability studies have been therefore, undertaken to study the genetic structure in relation to productive potential. In Gujarat, pearl millet is grown as a summer as well *kharif* crop, in low fertility soils of north Gujarat as rain fed crop and also in high fertility regimes of middle Gujarat under assured irrigation. By stimulating environmental conditions existing in different pearl millet growing regions of Gujarat, and evaluating different hybrid combinations in these environments, it is possible to draw plausible conclusions regarding the performance of hybrids, which will be suitable under varied environmental conditions.

Materials and methods

The experimental material for this study consisted of 60 hybrids produced by crossing six male sterile lines (JMSA-9904, ICMA-97111, ICMA-98444, JMSA-20041, ICMA-96222 and ICMA-04999) with 10 diverse inbreds (J-2507, J-2490, 236 SB, J-2433, J-2526, J-2340, AIB-2, AIB-11, AIB-20 and AIB-23) in a line x tester mating fashion. The CGMS lines were received from Main Bajra Research Station, Junagadh Agricultural University, Jamnagar, whereas, inbred parents were used for restorers supplied by Jamnagar station and also from the lines maintained at Regional Research Station, Anand Agricultural University, Anand. The experimental material was grown in randomized complete block design, replicated thrice in July, 2011 at Regional Research Station, Anand Agricultural University, Anand. The genotypes were randomized separately among the parents as well as hybrids in each replication. Each experimental unit was represented by single row of 3.5 m length with 60 x 15 cm inter and intra row spacing. The recommended package of agronomical practices obligatory to raise good crop were followed. The observations were recorded on five randomly selected competitive plants from each replication for traits *viz.*, plant height (cm), total productive tillers per plant, earhead length (cm), earhead girth (cm), grain yield per plant (g), 1000 grains weight (g) and for days to 50 per cent flowering and days to maturity observation recorded on population basis. The combining ability analysis was done following method of Kempthorne (1957).

Result and discussion

The analysis of variance for combining ability (Table-1) revealed that mean square due to lines and testers were significant for all the characters indicating existence of sufficient amount of variability among materials studied except productive tillers per plant. The interactions between male and female were also significant for all the characters except plant height and earhead girth. The above results suggested that the parents used in this study were diverse and significant difference exists between them. Such variations in parents have also been reported earlier by Rathore *et al*. (2004) and Patel *et al*. (2014).

The analysis of variance for combining ability (Table 1) revealed that the variance due to general combining ability (GCA) and specific combining ability (SCA) were highly significant for most of the characters indicating that both additive and non-additive gene action were involved in expression of these traits. Almost similar trends of involvement of both additive and non-additive gene actions have been earlier reported by Azhaguvel *et al*. (1996). While, non-significance of σ^2gca for number of productive tillers per plant revealed importance of only non-additive genetic variance and the findings confirmed with the results of Janardhana and Reddi (1982) and Jethava *et al*. (2011). Similarly, σ^2sca was non-significant for plant height and earhead girth suggesting only importance of additive gene action. The results are in conformity with the findings of Dhuppe *et al.* (2006), Dangariya *et al*. (2009) and Patel *et al*. (2014).

The mean degree of dominance $(\sigma^2_D / \sigma^2_A)^{0.5}$ was found greater than unity for characters namely productive tillers per plant, grain yield per plant, 1000 grain weight and earhead length, indicating the over dominance behavior of interacting alleles. Similar results were also observed by Rathore *et al*. (2004) and Patel *et al.* (2012). The complete dominance was observed for days to maturity as value is equal to one and for the rest of characters said value was less than one indicating partial dominance. Since over dominance gene action is involved for inheritance of grain yield, heterosis breeding would be most effective approach to improve the character. Pearl millet is cross pollinated crop; hence heterosis can be utilized for development of hybrids.

In a crop improvement programme, much of the success depends upon isolation of valuable genes combinations as determined in the form of lines with a good combining ability. The combining ability analysis is a powerful tool to discriminate good as well as poor combiners and to choose appropriate parental material in breeding programme. The concept of general and specific combining ability as a measure of gene action was proposed by Sprague and Tatum (1942). The general combining ability is an average performance of a line in hybrid combinations, and can be recognized as a measure of additive gene action and specific combining ability is the deviation in a performance of a hybrid from expected value on the basis of general combining ability effect of lines involved, and can be regarded as a measure of non-additive gene action. The predominance of non- additive action in the expression of several of the yield component characters suggest that it can be exploited through the production of hybrids. However, for the development of high yielding varieties general combining ability was more important (Phul *et al.*, 1973).

The results of estimates of *gca* effects for patents and *per se* performance are presented in Table 2. The line JMSA-9904 was the good combiner for days to 50 per cent flowering, days to maturity and earhead length. ICMA-96222 was good general combiner for days to 50 % flowering and plant height. ICMA-98444 and JMSA-20041 was good combiner for earhead girth and productive tillers per plant but poor combiners for days to 50 per cent flowering. ICMA-97111 was average combiner for days to 50 per cent flowering, days to maturity, plant height, earhead length and earhead girth. Most of the parents had relatively high degree of correspondence between *per se* performance and their *gca* effects for majority of characters, which could be because of performance of gene showing additivity and pseudo-additivity gene effect. Therefore, in selecting of parents for hybridization work for development of specific type of hybrids, equal importance should be given to their *per se* per formance along with *gca* effects.

Among the male parents, the gca effects for grain yield ranged from -0.31 to 6.52. Three parents *viz*., J-2340, J-2507 and J-2490 were good general combiner for grain yield. Male parent J-2340 had the highest positive effect for earhead girth and grain yield per plant. Five parents (AIB-2, 236 SB, J-2433, AIB-20 and AIB-11) were good general combiner for days to 50% flowering which suggests that this line could be successfully used in developing early and high yielding combinations. J-2526, AIB-11, J-2340 and AIB-2 were good general combiner for 1000 grain weight and these parents could be used for bold seeded hybrid. The parents 236 SB, J-2433 and AIB-20 were also good general combiner for days to maturity but poor combiner for seed yield per plant. The combining ability studies also revealed that among male parents the genotypes J-2340, J-2507 and J-2490 for grain yield, the testers J-2340 for earhead girth and J-2526, AIB-11, J-2340 and AIB-2 for 1000 grain weight had significant positive *gca* effects. These genotypes can be exploited through hybridization.

The *per se* performance of hybrids was higher than parents in desired direction for all the characters except plant height, which suggested the possibility for existence of heterotic effects. In respect to *per se* performance of parents, among the CGMS lines, lines ICMA-97111, ICMA-96222 and JMSA-20041, and among the males, inbreds AIB-2 and 236 SB were found to be superior for grain yield per plant and for most of the yield contributing characters. Among the hybrids, hybrids ICMA-04999 x J-2490, ICMA-97111 x J-2340 and ICMA-97111 x 236SB had high *per se* performance for grain yield per plant.

The information regarding *sca* is presented in Table 3. The magnitude of *sca* effects for different characters was in both the directions. In general, the crosses which show high desirable *sca* effects also had a high *per se* performance. The top three crosses had atleast one parent as good general combiners for all the characters except 1000 grain weight. The crosses which show higher *sca* effects for different characters does not had G x G combination of parents. It may be G x A, A x P, A x A *etc*., Therefore, while selecting the parents for hybridization programme due weightage given to average or poor combiners.Those crosses having both good general combiner parents need to be advanced for desired transgressive segregants and/or to develop new CGMS lines and restorers in addition to exploitation of heterosis, as their heterotic effects could be because of pseudo-additive interalleliec interaction. Whereas, crosses those having atleast one parent as average or poor general combiner could be exploited for heterosis breeding as their seed parents are CGMS lines. The CGMS lines having desired gene effects for various attributes could be inter mated with uses of their maintainer lines, and desirable CGMS recombinants could be identified from the segregating populations.

Among the sixty hybrids, 14 hybrids *viz*., (ICMA-04999 x J-2490, ICMA-97111 x 236 SB, ICMA-97111 x J-2340, JMSA-20041 x AIB-23, ICMA-98444 x J-2507, JMSA-20041 x AIB-20, JMSA-20041 x AIB-11, ICMA-96222 x J-2507, JMSA-9904 x J-2340, JMSA-9904 x AIB-20, ICMA-98444 x J-2526, ICMA-96222 x J-2526, ICMA-97111 x AIB-2 and JMSA-9904 x AIB-23 showed the best performance with significantly positive *sca* effect for grain yield. The genotypes with high *gca* effects for many characters did not always produce combinations with high *sca* effects. None of the hybrids recorded significant positive effect for all the characters under studied. From the top three ranking crosses, the cross ICMA-97111 x 236SB had significant and positive SCA effects for grain yield per plant, earhead girth and days to maturity.

References

Anonymous. 2012. All-India area, production and yield of bajra from 1950-51 to 2009-2010 along with percentage coverage under irrigation. State wise yield of bajra. Directorate of economics and statistics, Department of Agriculture and Cooperation, 1999-2000 to 2009-10 as per Final Forecast Reports.Website < http:// www.agricoop.nic.in >

Azhaguvel, P., Jayaraman, N. and Nirmala, V.S. 1998. Combining ability analysis in pearl millet for yield components. *Ann. Agric. Res.*, **19**(4): 429-432.

Dangariya, C.J., Chotalia, J.M., Savaliya, J.J., Davda, B.K. and Pansuriya, A.G. 2009. Combining ability analysis in pearl millet [*Pennisetum glaucum*(L.) R. Br.]. *Agricultural Science Digest*, **29**(4): 287-290.

Dhuppe, M.V., Chavan, A.A., Phad, D.S. and Chandankar, G.D. 2006. Combining ability studies in pearl millet.*J. Maharashtra Agril. Uni.*, **31**(2): 146-148.

Gill K, S., Phulp.S. and Jindia, L.N. 1974. Line x Tester analysis of combining ability in pearl millet. *Punjab Agricultural University Journal of Research, Ludhiana*, **11**(4): 345-349

Janardhana Rao, P. and Reddi, V. 1982. Studies on combining ability in pearl millet (*Pennisetum americanum* (L) K Schum). *Madras Agric. J.*, **69**(8):507-512.

Jethva, A.S., Raval, L., Madriya, R.B., Mehta, D.R. and Mandavia, C. 2011. Combining ability over environments for grain yield and its related traits in pearl millet. *Crop improve.*, **38**(1): 92-96.

Kempthorne, O. 1957.*An introduction to Genetic statistics*, John wiley and sons. Inc. New York. pp.545.

Kunjir, A.N. and Patil, R.B. 1986. Line x Tester analysis for combining ability in Pearl Millet. *Journal of Maharastra Agricultural University,* **11**(1): 29-32.

Patel, T.K. 2014. Studies on heterotic effects, gene effects and stability parameters for grain yield, its components and quality characters in pearl millet (*Pennisetumglaucum* [L.] R. Br.), an unpublished Ph.D. thesis submitted to Anand Agricultural University, Anand.

Phul. P.S., Nanda, G.S. and Gupta, S.R. 1973. Combining ability in pearl millet. *Indian Journal of Genet.,* **33** (3): 334-339.

Rathore, V.S, Singhania, D.L. and Jakhar, M.L. 2004. Combining ability of diverse restorers of pearl millet [*Pennisetum glaucum*(L.) R. Br.] for grain yield and its components. *Indian J. Genet.*, **64**(3): 239-240.

Patel, S.M., Patel, M.P., Patel, B.C. and Patel, J.A. 2014. Combining ability and gene action for grain yield and agronomic traits in pearl millet restorer lines. *Elect. J. Plant Breed.*, **5**(3): 394-401

Electronic Journal of Plant Breeding, 7(3): 595-601 (September 2016)
ISSN 0975-928X

Sprague, G.F. and Tatum, L.A. 1942. General verses specific combining ability in single crosses of corn. *J. Amer. Soc. Agron*., **34**: 923-932.

Electronic Journal of Plant Breeding, 7(3): 595-601 (September 2016)
ISSN 0975-928X

Table 1. Analysis of variance for combining ability for component characters in Pearl millet

Source	d.f.	Days to 50 % flowering	Days to Maturity	Plant height	Productive tillers per plant	Ear head length	Ear head girth	Grain yield	1000 grain weight
Line	5	16.16**	15.97**	779.59**	0.64**	31.21**	8.26**	110.95**	14.76**
Tester	9	32.45**	8.04**	1208.38**	0.17	6.54**	1.28**	301.07**	7.79**
Line x tester	45	4.86**	4.43**	231.64	0.30**	6.78**	0.50	138.06**	3.95**
Error	118	1.95	2.53	227.60	0.12	1.80	0.37	21.09	0.11
$\sigma^2_{gca\ (lines)}$		0.38*	0.38**	18.26*	0.01	0.81**	0.26**	-0.90	0.36
$\sigma^2_{gca\ (testers)}$		1.53**	0.20	54.26**	-0.01	-0.01	0.04*	9.06*	0.21**
σ^2gca (Av.)		0.81**	0.32**	17.15*	0.001	0.50**	0.18**	2.83**	0.31**
σ^2sca		0.97**	0.63**	1.35	0.06**	1.66**	0.04	38.99**	1.28**
σ^2_A		1.62	0.63	63.53	0.01	1.01	0.36	5.66	0.61
σ^2_D		0.97	0.63	1.35	0.06	1.66	0.04	38.99	1.28
$(\sigma^2_D / \sigma^2_A)^{0.5}$		0.77	1.00	0.14	2.50	1.28	0.33	2.62	1.45

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

Table 2. Estimation of general combining ability effect and *per se* performance of parents

Parents	Days to 50 % flowering		Days to Maturity		Plant height (cm)		Productive tillers per plant		Earhead length (cm)		Earhead girth (cm)		Grain yield per plant (g)		1000 grain weight (g)	
Females	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**
JMSA-9904	47.0	-0.63**	81.7	-1.30**	184.3	-2.89	2.0	-0.08	19.1	0.56**	7.9	-0.29**	11.1	-	10.246	-
ICMA-97111	46.3	0.17	81.0	-0.10	166.3	3.30	2.0	0.03	17.8	-0.16	9.7	0.14	18.2	-	7.111	-
ICMA-98444	50.7	0.80**	81.7	0.27	91.3	6.09**	2.5	0.21**	11.3	0.21	8.8	0.85**	10.7	-	8.249	-
JMSA-20041	50.7	0.30*	82.7	0.10	127.9	3.82	2.7	0.12*	11.9	-1.81**	9.1	0.28**	17.1	-	6.541	-
ICMA-96222	51.0	-1.13**	82.0	0.93**	106.0	-6.82**	2.3	-0.12*	14.6	-0.05	7.2	-0.48**	17.4	-	7.103	-
ICMA-04999	48.7	0.50*	82.3	0.10	117.8	-3.50	1.9	-0.17**	15.9	1.25**	7.6	-0.50**	13.5	-	5.786	-
S.E. (g_i)		0.21		0.24		2.23		0.05		0.20		0.09		-		-
S.E. (g_i -g_j)		0.36		0.41		3.89		0.09		0.35		0.16		-		-
CD @ 5%		0.71		0.80		7.62		0.18		0.69		0.31		-		-
Males																
J-2507	48.7	3.33**	83.0	-	229.3	15.53**	2.6	-	20.9	-	8.5	-0.18	25.0	5.68**	9.650	0.02
J-2490	47.3	0.67*	80.7	-	198.2	0.57	2.7	-	18.5	-	9.2	0.17	27.3	4.32**	7.455	-1.04**
236 SB	50.3	-0.94*	80.0	-	187.0	-10.3**	2.2	-	18.9	-	9.7	-0.18	42.0	-3.61**	7.593	0.01
J-2433	50.0	-0.61*	81.3	-	195.3	-9.32**	2.2	-	20.3	-	11.1	0.22	35.7	-4.78**	10.059	-0.63**
J-2526	50.0	0.17	81.0	-	151.4	6.58*	1.7	-	19.9	-	7.2	-0.09	17.9	-0.31	6.966	0.85**
J-2340	47.7	-0.44	80.7	-	206.7	3.03	2.4	-	19.3	-	11.5	0.58**	24.6	6.52**	9.932	0.56**
AIB-2	47.0	-1.50**	81.3	-	199.9	-5.46	3.2	-	20.9	-	9.8	-0.15	43.7	-1.06	9.375	0.52**
AIB-11	49.0	-0.56*	83.3	-	187.0	-1.38	2.7	-	18.5	-	9.5	-0.29*	34.1	-0.60	8.746	0.57**
AIB-20	46.0	-0.61*	80.3	-	198.4	-6.13*	2.3	-	20.2	-	9.9	-0.18	33.5	-3.64**	9.177	-0.89**
AIB-23	46.0	0.50	82.0	-	203.4	6.89*	2.5	-	20.6	-	8.6	0.12	24.7	-2.52**	9.034	0.02
S.E.(g_i)		0.28		-		3.00		-		-		0.12		0.91		0.07
S.E.(g_i -g_j)		0.46		-		5.02		-		-		0.20		1.53		0.11
CD @ 5%		0.90		-		9.84		-		-		0.39		3.00		0.22

*,** Significant at 5 % and 1 % level, respectively

Table 3. Estimation of specific combining ability effects and *per se* performance of pearl millet hybrids

Characters	Range of SCA effects	Range of crosses for their *per se* performance	Top ranking three crosses	*Per se* performance	SCA effect of crosses	GCA effect of parents involved with across	Number of crosses with significant +ve and –ve SCA effects	
							+ve	-ve
Days to 50 % flowering	-2.67 to 3.20	40.3 to 49.0	ICMA-04999 X J-2490 JMSA-9904 X J-2507 ICMA-04999 X AIB-23	40.0 43.0 41.7	-2.60** -2.20** -1.83**	G X P G X P P X A	5	4
Days to Maturity	-2.31 to 2.60	75.00 to 81.70	JMSA 9904 X J-2490 ICMA-97111 X 236SB ICMA-04999 X J-2340	75.0 76.3 78.0	-2.31** -1.96** -1.66**	G X A A X A A X A	4	6
Plant height (cm)	-19.55 to 16.34	170.4 to 225.0	ICMA-96222 X AIB-20 JMSA-9904 X J-2433 JMSA-20041 X 236SB	170.4 174.9 198.9	-19.55** -15.42** -13.13**	G X G A X G A X G	2	3
Productive tillers per plant	-0.60 to 0.77	1.9 to 3.6	JMSA-20041 X J2340 JMSA-20041 X J-2507 ICMA 04999 X 236SB	3.6 3.3 2.9	0.77** 0.70** 0.58**	G X A G X A P X A	10	6
Earhead length (cm)	-2.12 to 4.27	15.7 to 24.3	ICMA-98444 X 236SB ICMA-04999 X J-2433 ICMA-98444 X J-2507	23.8 24.3 23.7	4.27** 3.43** 3.10**	G X A G X A G X A	6	7
Earhead girth (cm)	-0.93 to 0.73	8.4 to 11.3	ICMA-04999 X J-2526 ICMA-97111 X 236SB JMSA-20041 X J-2490	9.8 9.6 10.7	0.73** 0.66** 0.59**	P X A P X A G X A	5	4
Grain yield per plant (g)	-12.22 to 15.40	22.9 to 58.2	ICMA-04999 X J-2490 ICMA-97111 X 236SB ICMA-97111 X J2340	58.2 44.7 53.7	15.46** 12.44** 10.88**	A X G A X P A X G	14	15
1000 grain weight (g)	-2.34 to 2.09	6.104 to 12.012	ICMA 98444 X J-2433 JMSA-9904 X J-2490 ICMA-96222 X AIB-23	11.763 8.889 10.547	2.09** 1.78** 1.56**	A X A A X P A X P	22	20