Electronic Journal of Plant Breeding, 9(4): 1396-1402 (Dec 2018) DOI: 10.5958/0975-928X.2018.00174.6
ISSN 0975-928X

Research Article

Combining ability and gene action for grain yield and its attributing traits in pearl millet (*Pennisetum glaucum* [L.] R. Br.)

B. C. Patel* M. P. Patel[1] and J. A. Patel[2]
***** College of Agriculture, Anand Agricultural University, Vaso-387 380 India
[1] Regional Research Station, Anand Agricultural University, Anand-388 110 India
[2] Regional Research Station, Anand Agricultural University, Anand-388 110 India
***E-Mail**: bcpatel@aau.in

(Received: 22 Nov 2017; Revised: 17 Sep 2018; Accepted: 20 Oct 2018)

Abstract
Sixty hybrids of Pearl millet were developed by crossing six male sterile lines with ten diverse inbred lines and studied for its combining ability effects. The analysis of variance revealed significant difference between parents for all the characters under study. The estimates of combining ability variances indicated that the importance of both additive and non-additive gene action in the control of most of the characters under study. The mean degree of dominance $(\sigma^2_D / \sigma^2_A)^{0.5}$ was found greater than unity for characters days to maturity, grain yield per plant, stover yield per plant and protein content, indicating the over dominance.The CGMS line ICMA-98444 was found as good general combiners for days to maturity, plant height, earhead length and earhead girth. The CGMS line JMSA-9904 were found good general combiner for days to 50 % flowering and earhead length but poor combiners for plant height, earhead girth and stover yield per plant. Three inbreds J-2433, AIB-23 and J-2490 were good general combiner for earhead girth, while J-2526 and AIB-11 was good general combiner for earhead length. Among the sixty hybrids, 12 hybrids showed the best performance with significantly positive sca effect for grain yield. The cross ICMA-04999 x J-2526 had significant and positive sca effects for grain yield per plant and stover yield par plant.

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 7.12 million hectares with a production in tune of 9.05 million tones and productivity of 1272 kg/ha in the country. While, in Gujarat it is grown in 0.46 million hectares with a production of 0.73 million tones and productivity of 1602 kg/ha. (Anon. 2015). 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 used for hybrid development (Burton, 1965), which permitted development of hybrids in India. Afterward, development of several new cytoplasmic genetic male sterility sources has 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 necessary to study and evaluate available promising diverse parental lines for their hybrid nicking ability and knowledge of relative magnitude of general and specific combining ability for selection of suitable inbreds. This information enables the breeders to evaluate and classify selected parental material for their utility in breeding high yielding F_1 hybrids, 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 rainfed 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. In Gujarat only hybrids are gown by the farmers, hence present investigation was carried out to find out best hybrids suitable to Gujarat conditions.

Material 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 ten 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 design. 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 February, 2013 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), stover yield per plant, protein content, 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).

Results 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 except productive tillers per plant and protein content for line and protein content for tester indicating existence of sufficient amount of variability among materials studied. The interactions between male and female were also significant for all the characters except plant height. The above results suggested that the parents used in this study were diverse and significant difference exist 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 (Av.) were significant and higher than specific combining ability for days to flowering, days to maturity, ear head length, and ear head girth suggesting predominant role of additive genetic action, whereas variance component of specific combining ability (SCA) were considerably higher for the characters days to maturity, productive tillers per plant, grain yield and stover yield, protein content and 1000 grain wt show predominance of non additive gene action for these characters. An almost similar trend of involvement of non additive gene actions has been earlier reported by Joshi *et al.* (2001), Rathore *et al.* (2004), Dangariya *et al.*(2009), Jagendra and Sharma (2014), Patel *et al*, (2014), Rafiq *et al* (2016) and Solanki *et al* (2017). Similarly, σ^2sca were non-significant for plant height, suggesting only importance of additive gene action. The results are incorporated with 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 protein content, stover yield per plant, grain yield per plant and day to maturity indicating the over dominance behavior of interacting alleles. Similar results were also observed by Rathore *et. al*. (2004) and Patel *et. al.* (2014). Rest of characters said value less than one indicating partial dominance. Since over dominance gene action is involved for inheritance of grain yield, therefore, 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 superior 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. σ^2 gca (line) and σ^2 gca (tester) was found non- significant for productive tillers per plant, grain yield per plant, 1000 grain weight and protein content, while σ^2 gca (tester) was found non- significant for days to 50 % flowering and days to maturity, hence gca effects was not mentioned. The CGMS line ICMA-98444 was found as good general combiners for days to maturity, plant height, earhead length and earhead girth. The CGMS line JMSA-9904 were found good general combiner for days to 50 % flowering and earhead length but poor combiners for plant height, earhead girth and stover yield per plant. 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* performance along with gca effects.

Among the male parents, three parents (236 SB, J-2340 and AIB-11) were good negative general combiner for plant height, which suggests that this line could be successfully used in developing dwarf types hybrids. The parents J-2490, J-2433 and AIB-23 were also good general combiner for earhead girth but poor and average combiner for earhead length. The combining ability studies also revealed that among male parents the genotypes J-2526 and AIB-11 for earhead length recorded significant positive gca effect. These genotypes can be exploited through hybridization. Patel *et al* (2014) and Solanki et al (2017) also reported similar results.

The *per se* performance of hybrids was higher than parents in desired direction for all the characters, which suggested the possibility for existence of heterotic effects. In respect to *per se* performance of parents, among the CGMS lines, lines ICMA-98444, JMSA-9904 and ICMA-97111, and among the males, inbreds J-2340, and 236SB were found to be superior for grain yield per plant and for most of the yield contributing characters. Among the hybrids, ICMA-04999 x J-2526, ICMA-97111 x J2433 and JMSA-20041 x J-2340 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 plant height, earhead length, earhead girth and stover yield per plant. 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, 12 hybrids viz; ICMA-04999 x J-2526 (25.51), JMSA-20041 x J-2340 (17.12), ICMA-97111 x J-2433 (15.67), ICMA-98444 x236SB (13.45), JMSA-9904 x AIB-20 (12.53), ICMA-97111 x J-2507 (12.43), JMSA-9904 x J-2490 (7.95), ICMA-04999 x AIB-20(7.04), JMSA-20041 x AIB-23 (6.63), ICMA-96222 x AIB-11 (6.06), JMSA-20041 x J-2507 (3.45) and ICMA-96222 x J-2507 (3.23) 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. From the top three ranking crosses, ICMA-04999 x J-2526 had significant and positive sca effects for grain yield per plant and stover yield par plant, therefore, this cross may be further exploited for hybrid variety and to get desirable segregants for restorer lines

References

Andrews, D.J. and Anand Kumar, K. (1992). Pearl millet for food, feed and forage. *Advan. in Agron.*, .**48**:89-139.

Anonymous. (2015). Website < http:// www.agricoop.nic.in > 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.

Burton, G.W. (1965). Pearl millet Tift 23A released. *Crops and Soil*, **17**: 19.

Burton, G.W. (1983). Breeding pearl millet. *Plant Breed. Rev.*, **1**: 162-182.

Dangariya, C. J., Chotalia, J. M., Savaliya, J. J., Davda, B. K. and Pansuriya, A. G. (2009). Combining ability analysis in pearl millet [*Pennisetumglaucum*(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.

Jagendra, S., & Sharma, R., (2014). Assessment of Combining Ability in pearl millet Using Line x Tester Analysis. *Advances in Crop Science and Technology*, 2, 4.

Joshi, H. J., Mehta, D. R.,Dhaduk, H. L. and Pethani, K. V. (2001).Combining ability of restorers in pearl millet.[*Pennisetumglaucum*(L). R. Br.].*Agril. Sci. Digest*, **213**: 161-163.

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, 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. *Electronic Journal of Plant Breeding*, 5(3): 394-401

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

Rafiq, S. M., Kumar, B. S., & Rao, U. P. (2016). Combining ability studies using diverse cytoplasm for grain yield and its components in Pearl millet [*Pennisetumglaucum* (L.) R. BR.]. *Plant Archives*, 16 (2), 588-593.

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

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.

Solanki, K. L., Bhinda, M. S., Gupta, P. C., Saini, H., & Saini, L. K. (2017). Combining Ability and Gene Action Studies for Grain Yield and Component Characters in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.] Under Arid Condition of Rajasthan. *International Journal of Pure and Applied Science*. 5 (4), 2121-2129.

Electronic Journal of Plant Breeding, 9(4): 1396-1402 (Dec 2018) DOI: 10.5958/0975-928X.2018.00174.6
ISSN 0975-928X

Table 1. Analysis of variance and combining ability analysis 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	Stover yield per plant	Protein content
Line	5	148.93**	34.42**	1394.60**	0.22	72.41**	1.87**	551.53**	1.33**	2945.68**	0.56
Tester	9	19.00**	5.16**	537.70**	0.31**	14.46**	2.10**	580.41**	1.25**	1190.49**	0.55
Line x tester	45	11.34**	10.00**	123.96	0.31**	5.80**	0.39*	316.26**	1.51**	1213.20**	0.69**
Error	118	0.72	2.24	100.96	0.12	2.51	0.24	59.81	0.090	187.05	0.29
$\sigma^2_{gca\ (lines)}$		4.59**	0.81**	42.35**	0.001	2.22**	0.05**	7.84	-0.01	57.75**	0.001
$\sigma^2_{gca\ (testers)}$		0.43	-0.27	22.99**	0.001	0.48**	0.10**	14.67	-0.01	-1.26	-0.01
σ^2gca (Av.)		3.03**	0.41**	35.09**	0.001	1.57**	0.07**	10.40**	-0.01	35.62**	-0.01
σ^2sca		3.54**	2.59**	7.67	0.07**	1.09**	0.05*	85.48**	0.47**	342.05**	0.13**
σ^2_A		6.05	0.82	70.18	0.001	3.14	0.13	20.81	-0.02	71.24	-0.01
σ^2_D		3.54	2.59	7.67	0.07	1.09	0.05	85.48	0.47	342.05	0.13
$(\sigma^2_D / \sigma^2_A)^{0.5}$		0.76	1.77	0.33	0.01	0.59	0.62	2.03	0.67	2.19	3.60

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

Electronic Journal of Plant Breeding, 9(4): 1396-1402 (Dec 2018) DOI: 10.5958/0975-928X.2018.00174.6
ISSN 0975-928X

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

Parents	Days to 50 % flowering		Days to Maturity		Plant height		Productive tillers per plant		Earhead length	
Females	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**
JMSA-9904	55.0	-0.61**	85.3	-0.39	127.8	5.65**	3.0	-	19.8	0.61*
ICMA-97111	56.0	2.13**	87.0	-0.22	143.5	6.11**	2.5	-	18.0	-1.09**
ICMA-98444	56.7	-0.27	93.3	-0.96**	88.5	-6.00**	2.8	-	14.2	0.83**
JMSA-20041	55.0	-4.01**	92.7	2.08**	106.0	-9.90**	3.4	-	12.1	-2.60**
ICMA-96222	55.7	1.29**	90.3	0.04	101.3	5.27**	3.1	-	13.5	0.63**
ICMA-04999	56.7	1.46**	89.7	-0.56	89.0	-1.14	2.9	-	18.1	1.63**
S.E. (g_i)	-	0.13	-	0.22		1.49	-	-	-	0.24
S.E. (g_i -g_j)	-	0.22	-	0.39		2.59	-	-	-	0.41
CD @ 5%	-	0.43	-	0.76		5.08	-	-	-	0.80
Males										
J-2507	52.0	-	88.7	-	195.5	7.56**	2.3	-	22.0	0.15
J-2490	53.0	-	91.3	-	189.8	9.72**	2.9	-	20.3	0.60
236 SB	50.3	-	88.3	-	168.5	-5.90**	3.2	-	17.3	-1.32**
J-2433	49.0	-	90.3	-	189.8	-1.31	2.9	-	20.1	-0.04
J-2526	49.7	-	92.0	-	159.3	-2.91	3.5	-	22.3	1.08**
J-2340	51.0	-	90.7	-	185.3	-4.22*	3.2	-	20.7	-1.05**
AIB-2	53.3	-	87.3	-	194.9	2.46	3.0	-	23.5	0.45
AIB-11	50.0	-	85.7	-	172.5	-6.18**	2.7	-	22.2	0.85**
AIB-20	49.0	-	86.3	-	190.4	-1.81	3.1	-	24.2	0.54
AIB-23	48.7	-	85.7	-	178.8	2.60	3.0	-	19.2	-1.27**
S.E.(g_i)	-	-	-	-	-	2.00	-	-	-	0.32
S.E.(g_i -g_j)	-	-	-	-	-	3.35	-	-	-	0.53
CD @ 5%	-	-	-	-	-	6.57	-	-	-	1.04

(Table Continue…)

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

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

Parents	Earhead girth		Grain yield per plant		1000 grain weight		Stover yield per plant		Protein content	
Females	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**	***Per Se***	**GCA**
JMSA-9904	9.2	-0.27*	36.8	-	8.056	-	54.5	-6.49**	9.98	-
ICMA-97111	9.6	0.07	36.0	-	8.423	-	55.7	2.67	10.74	-
ICMA-98444	9.5	0.38**	37.6	-	7.530	-	53.9	-7.53**	11.15	-
JMSA-20041	9.8	0.13*	20.5	-	8.222	-	38.3	-9.46**	10.19	-
ICMA-96222	8.9	-0.06	20.5	-	7.263	-	49.1	16.69**	9.93	-
ICMA-04999	8.7	-0.26*	17.9	-	7.562	-	33.3	4.12*	10.01	-
S.E. (g_i)	-	0.07	-	-	-	-	-	2.03	-	-
S.E. (g_i -g_j)	-	0.13	-	-	-	-	-	3.53	-	-
CD @ 5%	-	0.25	-	-	-	-	-	6.92	-	-
Males-										
J-2507	9.7	-0.28**	40.1	-	8.796	-	126.4	-	9.95	-
J-2490	11.1	0.39**	56.5	-	7.990	-	121.7	-	10.43	-
236 SB	10.9	-0.32**	62.4	-	10.117	-	128.9	-	10.76	-
J-2433	11.4	0.64**	54.1	-	10.692	-	109.5	-	10.87	-
J-2526	9.8	-0.26**	41.5	-	9.392	-	120.8	-	10.67	-
J-2340	11.9	0.03	69.9	-	9.996	-	135.0	-	10.02	-
AIB-2	9.8	-0.12	56.3	-	9.878	-	129.3	-	10.98	-
AIB-11	8.9	-0.30**	53.9	-	7.663	-	110.0	-	10.51	-
AIB-20	10.8	-0.12	55.5	-	9.999	-	112.9	-	10.17	-
AIB-23	9.9	0.35**	48.3	-	8.644	-	96.1	-	9.99	-
S.E.(g_i)	-	0.10	-	-	-	-	-	-	-	-
S.E.(g_i -g_j)	-	0.16	-	-	-	-	-	-	-	-
CD @ 5%	-	0.31	-	-	-	-	-	-	-	-

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

Electronic Journal of Plant Breeding, 9(4): 1396-1402 (Dec 2018) DOI: 10.5958/0975-928X.2018.00174.6
ISSN 0975-928X

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

Characters	Range of SCA effect	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 effect	
							+ve	-ve
Days to 50 % flowering	-3.39 to 6.09	42.0 to 54.3	ICMA-98444 x AIB-23	44.7	-3.39**	A x P	19	19
			ICMA-98444 x AIB-20	43.4	-3.34**	A x P		
			ICMA-04999 x AIB-23	46.7	-3.13**	P x P		
Days to Maturity	-3.58 to 4.23	82.0 to 91.0	JMSA-20041 x AIB-23	83.3	-3.58**	P x A	11	11
			JMSA-20041 x 236SB	83.0	-2.80**	P x P		
			JMSA-20041 x J-2433	83.7	-2.58**	P x P		
Plant height	-12.22 to 13.50	150.5 to 192.9	ICMA-97111 x J-2433	163.7	-12.22**	P x A	3	2
			JMSA-9904 x AIB-11	161.1	-9.43**	P x G		
			JMSA-9904 x AIB-23	187.0	8.47	P x A		
Productive tillers per plant	-0.86 to 0.53	1.9 to 3.9	JMSA-20041 x J-2340	3.3	0.53**	A x A	8	7
			JMSA-20041 x AIB-2	3.5	0.53**	A x P		
			JMSA-20041 x AIB-20	3.8	0.47**	P x P		
Earhead length	-0.31 to 3.38	17.7 to 27.8	JMSA-20041 x 236SB	21.7	3.38**	P x P	6	4
			ICMA-04999 x J-2490	27.8	3.29**	G x A		
			ICMA-96222 x AIB-23	24.2	2.50**	A x P		
Earhead girth	-0.73 to 0.99	9.1 to 11.8	ICMA-98444 x AIB-23	10.4	0.99**	G x G	4	3
			ICMA-04999 x AIB-20	10.4	0.62**	P x A		
			ICMA-97111 x AIB-20	10.1	0.60**	A x A		
Grain yield per plant	-21.40 to 25.51	34.4 to 79.2	ICMA-04999 x J-2526	79.2	25.51**	A x A	12	10
			JMSA-20041 x J-2340	65.7	17.12**	A x A		
			ICMA-97111 x J-2433	74.9	15.67**	A x P		
1000 grain weight	-1.60 to 1.38	7.243 to 10.192	JMSA-20041 x J-2526	10.164	1.38**	P x A	17	20
			ICMA-97111 x J-2507	10.192	1.15**	P x A		
			ICMA-04999 x J-2507	9.697	1.10**	P x A		
Stover yield per plant	-31.45 to 54.43	61.9 to 152.4	ICMA-98444 x 236SB	137.8	54.43**	P x A	13	17
			ICMA-04999 x J-2526	146.7	37.07**	G x A		
			ICMA-96222 x J-2490	152.4	31.48**	G x A		
Protein content	-0.99 to 0.97	9.85 to 11.75	ICMA-97111 x 236SB	11.65	0.97**	A x P	16	14
			JMSA-9904 x AIB-2	11.43	0.89**	A x A		
			ICMA-97111 x J-2507	11.31	0.73**	A x A		