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RESEARCH PAPER

Combining ability studies through diallel analysis in pearl millet [*Pennisetum glaucum* (L.) R.Br.]

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Abstract : Combining ability was studied in 8x8 diallel set, including reciprocals, for grain yield and its 11 component traits in pearl millet. Both GCA and SCA variances were highly significant for all the characters. The ratio of GCA and SCA revealed preponderance of non- additive gene action in expression of all the characters *viz*., grain yield per plant, days to flowering, days to maturity, number of effective tillers per plant, ear head length, ear head girth, ear head weight, plant height, number grains per square cm, 1000-grain weight, dry fodder yield per plant and harvest index. The parents like J-2467, J-2511 and J-2405 could be used in hybridization programme to exploit their GCA effects for grain yield and some important attributing traits. Inbred J-2405 was also found to be good source of genes for earliness. The crosses *viz*., J-2454 x J-2467, J-2454 x J-2511, J-2290 x J-2480 and J-2290 x J-2511 were the most promising having good SCA, coupled with high *per se* performance and heterobeltiosis for grain yield and some of its components. Analyses of crosses revealed majority of the superior crosses were involved poor x good or average x poor or average x good and few cases good x good general combiners. The development of new inbred lines with high *per se* performance and good combining ability, through appropriate breeding methodology is suggested.

Key Words : Combining ability, Pearl millet, Diallel analysis, Grain yield

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INTRODUCTION

Efforts to develop pearl millet inbreds have greatly increased since the discovery of cytoplasmic-nuclear male sterility (Burton, 1958) and the development of single cross forage and grain hybrids. Pearl millet inbreds are used to breed synthetics, maintainer or B-lines and / restorer (R-lines). Restorer lines are used as pollinators to produce commercial hybrids. They should (1) have good general combining ability (GCA), but also high specific combining ability (SCA), (2) completely restorer male fertility in grain hybrid, (3) confer stable fertility restoration, (4) have similar or less days to flowering as A-line, (5) produce large amounts of pollen, and (6) confer desirable agronomic traits to the hybrid (Andrews, 1987). Selection of parents and crosses for development of new inbreds is most critical. Among the various genetic designs, diallel-mating design is very useful for evaluation of crosses and parents for study of heterosis, combining ability and gene action. Combining ability studies regarded useful to select best combining parents, which upon crossing would produce more desirable segregates. Such studies also elucidate the nature and magnitude of gene actions involved in the inheritance of grain yield and its components, which will decide the breeding programme to be followed in segregating generations. Good combining ability of improved inbreds is essential because inbreds are usually used to produce hybrids and synthetics. Both GCA and SCA are important, depending on the use of the inbred and traits of interest (Gartan *et al.*, 1988). Accordingly, the present study was undertaken to have an idea on the nature of gene action involved in the inheritance of quantitative traits

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and to identify appropriate parents and crosses for development of new inbred lines in pearl millet.

MATERIAL AND METHODS

Eight genetically diverse inbreds of pearl millet *viz.*, J-2290, J-2340, J-2405, J-2454, J-2467, J-2480, J-2511 and H-77/833-2 were crossed in all possible combinations including reciprocals during summer 2009 to generate a diallel set. Eight parents' along with their 56 F_1s were evaluated for grain yield and 11 yield components in a Randomized Block Design with three replications at Pearl millet Research Station, Junagadh Agricultural University, Jamnagar (Gujarat), India, during *Kharif*-2009. Each entry was sown in single row of 5.0 m length having 60 x 15 cm crop geometry. All the recommended cultural practices were adopted to raise good crop of pearl millet. Observations were recorded on five randomly selected competitive plants for each entry, in each replication for 12 characters (Table 1). Days to flowering and days to maturity were noted on the basis of whole plot. The general combining ability (GCA) and specific combining ability (SCA) variances and effects were worked out according to Method I, Model 1 of Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance for combining ability (Table 1) showed that general combining ability and specific combining ability variances were highly significant for all the characters. The results suggested the importance of both additive and non additive genetic components in the inheritance of all the characters. Similar result was reported by Dhuppe *et al.* (2006). However, GCA : SCA variance ratio indicated the predominance of non-additive genetic variance in the expression of all the characters under study. The results are in accordance with the reports of earlier workers Bhanderi *et al.* (2007), Vaghasiya *et al.* (2008), Chotaliya *et al.* (2010), Vagadiya *et al.* (2010) and Jethva *et al.* (2011).

A perusal of the general combining ability effects for parents (Table 2) revealed that none of the parents was good general combiners for all the characters, but good combining ability for multiple characters could be noticed in some parents. Similar results were reported by Dhuppe *et al.* (2006), Vaghasiya *et al.* (2008), Chotaliya *et al*. (2010), Vagadiya *et al.* (2010) and Jethva *et al.* (2011). Among the parents, J-2467 ranked first in respect to good general combining ability for grain yield per plant. They also registered good general combining ability effects for other attributes *viz.*, ear head weight, number of grains per square cm and harvest index. Similarly, J-2511 was found to be good source of genes for increasing the grain yield per plant, ear head length, ear head weight, plant height, number of grains per square cm, 1000-grain weight and harvest index. Whereas, early parent J-2405 recorded significant GCA effects in desired direction for grain yield per plant as well as for days to flowering, days to maturity, ear head weight, number of grains per square cm, dry fodder yield per plant and harvest index. The inbred J-2290 was average general combiner for grain yield per plant. This parent was also appeared to be good general combiner for ear head weight, 1000-grain weight and harvest index. The parent J-2340 turned out to be a good general combiner for number of effective tillers per plant and number of grains per square cm and average combiner for grain yield. J-2454 had a good source of genes for increasing ear head length and plant height. Besides, J-2480 identified as a good general combiner for 1000-grain weight and dry fodder yield per plant. While, H-77/833-2 displayed significant and positive GCA effects for number of effective tillers per plant, ear head length, plant height, 1000-grain weight and dry fodder yield per plant. These good combiner parents may be used in crop breeding programme aimed at improvement of the respective characters. Further, consideration of *per se* performance in combination with combining ability estimates was reported to provide a better criteria for the choice of superior parents in hybridization programme (Rao, 1972). Results of the present study also revealed that a close relationship between *per se* performance and GCA effects for grain yield and some of its components. The inbreds J-2467, J-2511 and J-2405 exhibiting significant and desirable GCA effects for grain yield per plant had also recorded high *per se* performance for the trait. It is also observed that the

Table 1 : Analysis of variance for diallel Model-1, Method-I for grain yield and its component traits in pearl millet

Source	d.f.	Grain yield/ plant (g)	Days to flowering	Days to maturity	No. of effective tillers/ plant	Ear head length (cm)	Ear head girth (cm)	ear head weight (g)	Plant height (cm)	No. of grains per square cm	1000 grain weight (g)	Fodder yield/ plant (g)	Harvest index (%)
GCA	7	133.18**	11.43**	9.06**	1.20**	5.56**	0.09**	221.38**	276.56**	5.19**	2.74**	67.54**	30.79**
SCA	28	160.72**	20.51**	22.86**	0.79**	4.78**	0.24**	403.45**	224.36**	3.80**	1.33**	102.99**	60.47**
Reciprocal	28	130.87**	5.99**	8.32**	0.78**	6.41**	0.23**	290.32**	290.27**	5.66**	1.32**	94.00**	34.42**
Error	126	2.01	1.78	2.55	0.17	0.49	0.08	2.95	14.13	0.18	0.23	4.10	1.02
σ^2 gca:σ^2 sca	-	0.05	0.03	0.02	0.10	0.07	0.00	0.03	0.07	0.08	0.14	0.04	0.03

* and ** significance of values at P=0.05 and 0.01, respectively

parents showed significant and positive GCA effects for grain yield, of their majority crosses had also registered significant and desired SCA effects for grain yield per plant and some of its component traits. The results corroborate with the findings of Dhuppe *et al.* (2006), Vaghasiya *et al.* (2008) and Chotaliya *et al*. (2010). Hence, these parents can be helpful in further pearl millet breeding programme to improve yield potentiality. It is manifested that the parents were good general combiners for grain yield, possessed significant and desired GCA effects for many yield components. The results are akin with reports of Dhuppe *et al.* (2006), Chotaliya *et al.* (2010) and Jethva *et al.* (2011).

Estimates of SCA effects revealed that none of the cross combination was found to be consistently significant SCA effects in desired direction for all the characters. Among 56 crosses, 24 exhibited significant and positive SCA effects for grain yield per plant. Of which, ten best specific crosses were identified as desirable crosses for grain yield per plant (Table 3). These ten crosses also displayed significant and desirable SCA effects for some of the yield components. The cross J-2454 x J-2467was recorded significant and positive SCA effect for grain yields. This cross was also displayed significant and in desired direction SCA effects for other eight contributing traits *viz*., days to flowering, days to maturity, number of effective tillers per plant, ear head weight, number of grains per square cm, 1000-grain weight, dry fodder yield per plant and harvest index. Similarly, cross J-2454 x J-2511 depicted significant and positive SCA effects for grain yield, ear head weight and harvest index. The cross combination J-2290 x J-2480 displayed significant and in desired direction SCA effects for grain yield and other seven contributing traits *viz*., days to flowering, days to maturity, number of effective tillers per plant, ear head weight, number of grains per square cm, 1000-grain weight and harvest index.

A perusal of Table 3 revealed that there was some

Table 2 : Estimates of general combining ability effects of parents for grain yield and its component traits in pearl millet

Parent	Grain yield/ plant (g)	Days to flowering	Days to maturity	No. of effective tillers/ plant	Ear head length (cm)	Ear head girth (cm)	Ear head weight (g)	Plant height (cm)	No. of grains per square cm	1000 grain weight (g)	Fodder yield/ plant (g)	Harvest index (%)
J-2290	0.07	-0.40	0.44	0.07	-0.04	0.09	2.47**	-2.23*	-0.04	0.25*	-0.38	0.53*
J-2340	-0.19	0.17	0.83*	0.46**	-0.99**	-0.02	-1.30**	-7.70**	0.61**	-0.12	-2.06**	0.30
J-2405	2.20**	-1.67**	-1.64**	0.09	-0.37*	0.09	2.63**	0.10	0.73**	-0.02	0.97*	0.95**
J-2454	-1.16**	-0.17	-0.10	-0.18	0.72**	-0.03	-1.98**	3.00**	-0.90**	-0.23*	-3.00**	-0.03
J-2467	3.98**	0.10	0.18	-0.21*	-0.17	0.06	3.73**	1.13	0.29**	-0.10	-1.01*	1.75**
J-2480	-5.19**	1.33**	0.51	-0.39**	-0.32	-0.10	-6.88**	-2.93**	-0.57**	0.27*	1.39**	-2.31**
J-2511	2.30**	0.13	-0.32	-0.10	0.51**	0.03	3.50**	3.78**	0.20*	0.68**	0.69	0.67**
H-77/ 833-2	-2.01**	0.47	0.10	0.24*	0.64**	-0.10	-2.18 **	4.87**	-0.30**	0.72**	3.42**	-1.84**
S.E. ±	0.33	0.31	0.38	0.09	0.16	0.06	0.40	0.87	0.10	0.11	0.47	0.23

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 3 : Ten top crosses showing significant positive SCA along with their *per se* performance, GCA, heterobeltiosis for grain yield and their performance in other traits in pearl millet

Sr. No.	Cross	SCA effects	Grain yield/ plant (g)	GCA status of parents P_1	GCA status of parents P_2	Heterobeltiosis (%)	Component traits showing useful and significant SCA effects
1.	J-2467 x J-2454	17.21**	34.63	Good	Poor	-46.89**	EL, EW, NGS, HI
2.	J-2511 x J-2454	13.11**	37.03	Good	Poor	2.08	EL, EW, PH, TW, HI
3.	J-2511 x J-2340	12.30**	35.17	Good	Average	-31.76**	EW, HI
4.	J-2454 x J-2467	9.69**	69.07	Poor	Good	5.92	DF, DM, ET, EW, NGS, TW, FY, HI
5.	J-2454 x J-2511	9.66**	63.27	Poor	Good	77.82**	EW, HI
6.	J-2290 x J-2480	9.14**	43.10	Average	Poor	39.17**	DF, DM, ET, EW, NGS, TW, HI
7.	J-2511 x J-2467	7.08**	36.03	Good	Good	-44.75**	DF, ET, EL, EW, PH, TW, HI
8.	J-2467 x J-2340	6.88**	22.73	Good	Average	-65.14**	EW, PH, TW, FY, HI
9.	H-77/833-2 x J-2290	6.68**	25.83	Poor	Average	-30.84**	DM, ET, EW, NGS, HI
10.	J-2290 x J-2511	6.49**	47.90	Average	Good	34.63**	EW, PH, FY, HI

*, ** = Significant at 5% and 1% levels, respectively. DF=Days to flowering, DM=Days to maturity, ET=No. of effective tillers /plant, EL=Ear head length, EG=Ear head girth, EW=Ear head weight, PH=Plant height, NGS=No. of grains/square cm, TW= 1000 grain weight, FY=Fodder yield/plant and HI=Harvest index.

degree of correspondence between SCA effect, mean performance and heterobeltiosis. But there was no linearity found between SCA effects, heterobeltiosis and mean performance that means a cross showing the highest SCA effect may not show the highest heterobeltiosis or mean performance. Although heterobeltiosis, per se performance and SCA effects expressed an association to some extent, so far selecting the promising cross combination all the three criterions to be consideration. The high *per se* performance, high heterotic status, high SCA estimates and involvement of poor x good combiner parents in crosses J-2454 x J-2467 and J-2454 x J-2511 indicated involvement of predominantly non-additive gene effects with significant additive effects in the expressing grain yield and its attributes. These types of crosses can yield desirable transgressive segregants in further generations. The cross J-2290 x J-2511recorded significant and positive SCA effects, along with high *per se* performance, high estimates of heterobeltiosis and involved average x good combiner parents, indicated involvement of predominantly both non-additive and additive gene effects in the expression of grain yield and its attributes. Such crosses can generate desirable transgressive segregants in further generations, if additive effect of one parent and complimentary epistasis effects of the other parent act in the same direction. The cross J-2290 x J-2480 had high *per se* performance, sixth rank in SCA effects as well as fourth position in better parental heterosis and involved average x poor GCA status. This implies that mostly additive and additive x additive interaction may be involved in the expression of grain yield and its attributes. Such crosses can be effectively handled through conventional pedigree method for the development of high yielding inbred lines. Thus, the exploitation of these crosses *viz*., J-2454 x J-2467, J-2454 x J-2511, J-2290 x J-2511 and J-2290 x J-2480 for the development of new inbred lines with high *per se* performance and good combining ability, through appropriate breeding methodology is suggested.

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