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Diallel Analysis for Grain Yield and Component Traits in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.] under Semi-arid Condition of Gujarat

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ABSTRACT

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The present investigation on combining ability studies was undertaken in 10 x 10 diallel set, excluding reciprocals, for grain yield and its 14 component traits in pearl millet. Both general combining ability (GCA) and specific combining ability (SCA) variances were highly significant for all the characters in all the three environments. The predictability ratio of GCA and SCA revealed preponderance of non additive genetic components for threshing index, harvest index, starch content, earhead weight and grain yield, while, both were equally important for plant height, ear head length, 1000 grain weight and protein content. Among the parent, J-2290, J-2340, RH-RBI-458 and SB-170-06 were found to be uniformly best parent across the environments for grain yield per plant and could be used in hybridization programme to exploit their GCA effects for grain yield and attributing traits. The crosses viz., J-2444 x J-2290, J-2290 x SB-170-6, J-2444 x RH-RBI-458, J-2340 x J-2290 and J-2290 x D-23 were the most promising having good SCA, coupled with high *per se* performance and heterobeltiosis for grain yield and its components. Analyses of crosses revealed majority of the superior crosses were involved good x good, good x poor and poor x poor general combiners.

Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is an annual tillering diploid (2n=14) and the most important member of the genus *Pennisetum* belonging to the tribe Paniceae (sub family- Panicoideae) and family Poaceae. It is commonly known as pearl, cat tail, spiked or bulrush millet and is believed to be originated in Africa, where the greatest diversity exists. It is the sixth most important cereal crop in the world, following wheat, rice,

maize, barley and sorghum. India and Africa together account for 93.2% of the total pearl millet production of the world. India is the largest producer of pearl millet both in terms of area (7.12 million ha) and production (8.06 million t) with an average productivity of 1132 kg/ha and (Annon, 2017).

Development of Tift-23-A male sterile source by Burton (1965) opened new vistas for the exploitation of heterosis in pearl millet and witnessed a major breakthrough in total

production and productivity of pearl millet in India after the release of first commercial hybrid HB-3. Later on, by the use of other male sterile lines viz. MS 5141A, MS 5054A which were developed from 23-A, remarkable break-through was made resulting in a spectacular jump in pearl millet productivity and production. In heterosis breeding programme, it is of paramount importance to evaluate available, useful and promising diverse parental lines and their cross combinations for grain yield its attributes and quality characters. The assessment of magnitude and direction of heterotic behavior also assume a great significance. Although, there has been an enormous achievement in pearl millet in respect of increasing the yield potential but a plateau has already been reached and that requires precise and directed efforts to overcome it.

The performance of the parents may not always necessarily give an indication of the probable performance of the progeny. Thus, the choice of right type of parents to be incorporated in the hybridization program is a crucial step for a breeder to achieve the desired genotype. The use of parents of known superior genetic potential ensures much better success. The foremost step in development of hybrids is the identification and assessment of the parental combinations with respect to their general and specific combining abilities and gene actions involved in the inheritance of yield and its component characters which are of utmost importance for a successful hybridization programme.

Thus, the current investigation was carried out to study the nature and magnitude of heterosis for grain yield and its components, estimation of general and specific combining ability effects in respect of restorers and hybrids, respectively, estimation of the nature of gene action involved in the inheritance of yield and its attributes and characterization of promising

parents and appropriate crosses for grain yield and its components for further breeding programme.

Materials and Methods

Ten genetically diverse restorer lines (table 1) were crossed in all possible combinations, excluding reciprocals, to make a diallel set during Summer 2006 at Main Millet Research Station, Junagadh Agricultural University, Jamnagar (Gujarat). Thus, the forty-five crosses and their 10 parents along with hybrid GHB-558, released for general cultivation in the region, included as standard check formed the experimental materials for the present study. Each entry was accommodated in a single row plot of 5.0 m length spaced at 60 cm apart with plant-to-plant spacing of 30 cm. All the recommended agronomic practices and plant protection measures were followed to raise the healthy crop. Observations were recorded on five randomly selected competitive plants for each entry, in each replication for 14 characters (Table 2). The general combining ability (GCA) and specific combining ability (SCA) variances and effects were worked out according to Model II, Model I of Griffing (1956).

Results and Discussion

Pearl millet is a highly cross-pollinated crop with the advantages of huge genetic variability, protogyny and availability of efficient cytoplasmic genetic male sterility system. These characteristics offer great possibilities of crop improvement through hybridization. Development of Tift-23-A male sterile source by Burton (1965) opened new vistas for the exploitation of heterosis in pearl millet. Later on, by the use of other male sterile lines viz. MS 5141A, MS 5054A which were developed from 23-A, a remarkable break-through was made resulting in a spectacular jump in pearl millet productivity

and production. Although commercial exploitation of hybridization in pearl millet has resulted in a substantial improvement in the productivity but there is still a need to surpass the plateau encountered in the grain yield. Attempts to improve its nutritive value have been rather limited. Therefore, concerted efforts are required to bring about simultaneous improvement in grain yield and quality of this crop.

The present investigation was, therefore, undertaken to get the first hand information pertaining to the magnitude of heterosis and combining ability in different environments with respect to grain yield, its contributing traits and some quality parameters utilizing a half diallel design involving ten diverse restorers. The analysis of variance for combining ability in individual environment (Table 2) and pooled analysis of variance for combining ability (Table 3) showed that general combining ability and specific combining ability variances were highly significant for all the characters in all three individual environments as well as pooled over the environments, suggesting the importance of both additive and non additive components of genetic variance in the expression of yield, its component and quality traits. Similar results were observed by Jeeterwal *et al.*, (2017). Comstock *et al.*, (1949) have suggested the use of reciprocal recurrent selection for effective use of both additive and non-additive gene effects.

In the present study, the computation of predictability ratio (Table 2) based on pooled analysis revealed preponderance of non additive genetic components for threshing index, harvest index, starch content, earhead weight and grain yield. The higher magnitude of additive component envisaged for earhead girth while in the expression of rest of the characters both additive as well as non-additive gene effects played prominent role with a little higher proportion of later one. In

case of earhead girth the general predictability ratio was closure to unity in all the individual environments revealing thereby the preponderance of additive genetic system in the inheritance of that character. While, in case of threshing index, harvest index, starch content, earhead weight and grain yield the predictability ratio of GCA and SCA variance revealed the preponderance of non-additive genetic variance in the expression of these characters. While, in case of days to 50 per cent flowering, days to maturity, number of effective tillers per plant in E1 and E2 and fodder yield in E1 and E3 and protein content and plant height in E2 the preponderance of non-additive gene action was evident. However, equal importance of both additive and non-additive gene effects was observed in the genetic control of plant height (except in E2), ear head length, 1000 grain weight and protein content (except in E2). These results were in conformity with the findings reported by Bhanderi *et al.*, (2007), Ansodariya *et al.*, (2006), Dhuppe *et al.*, (2006), Chotaliya (2005), Rasal and Patil (2003) and Karale *et al.*, (1998), and for 1000 grain weight by Ansodariya *et al.*, (2006) and Pethani and Kapoor (1995).

The general combining ability effects for parents (Table 4) 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. For days to 50% flowering and days to maturity, H-77/833-2 was found to be good general combiner in all three individual environments as well as on pooled basis as this exhibited highest significant gca effects in desirable direction (negative) for days to 50 % flowering. This indicated that this parent possessed genes for early flowering. The parents H-77/833-2 and J-108 were also found better for starch and protein content in addition to early flowering and maturity. They can be best exploited in breeding to improve earliness and quality parameters.

Other promising parents for earliness on pooled basis were J-2454 and J-108, they can be best exploited for improvements in earliness, number of effectives tiller and quality of grain in pearl millet. The parent J-108 performed similar trend specifically in E₃ environment. It was found to be good general combiner for early flowering, days to maturity, number of effective tillers per plant, protein content and starch content but poor combiner for grain yield. However, with respect to *per se* performance in grain yield it surpassed the entire environment with very high margin. It is most suitable for development of early maturing hybrids with improved starch and protein contents for summer season.

The consideration of *per se* performance of parents in combination with *gca* effects was found to provide a better criteria for choice of superior parents in hybridization programme. Along with considerable *per se* performance,

parent *viz.*, J-2290, J-2340, RH-RBI-458 and SB-170-06 displayed significant and positive *gca* effects for grain yield per plant. They also exhibited desirable and significant *gca* effects for component traits like plant height, earhead girth, earhead length, earhead weight, fodder yield, harvest index and test weight. Such type of parents could be utilized for the improvement of grain yield. Thus, while selecting the parents for hybridization programme, *per se* performance of the parents should be given due consideration with their *GCA* effects. If a character is uni-directionally controlled by a set of alleles and additive effects are important, the choice of parents on the basis of the *per se* performance may be more effective. Madhusudhana and Govila (2001), Mohan *et al.*, (2002) and Manga and Dubey (2004) have also suggested that parental selection can be done on the basis of *per se* performance, which supported the present findings.

Table.1 List of parents with pedigree and developing center

Sr. No.	Name of parents	Pedigree	Developing center
1	J-108	N-28-15-2-S-43	J. A. U. Jamnagar
2	J-2290	ICB-429-5-4-2-1	J. A. U. Jamnagar
3	J-2340	Selection from (F 298 x F ₄ F _C -1498)-3-13-2-1-B	J. A. U. Jamnagar
4	J-2405	{(4880-HHVBLN x J-2290)}-3-1-B(Blk)	J. A. U. Jamnagar
5	J-2444	IPS-D-61	J. A. U. Jamnagar
6	J-2454	DAT-51 (RIB-3135-18)	J. A. U. Jamnagar
7	SB-170-06	MC94C ₂ -S ₁ -3-1-1-2-3-2	J. A. U. Jamnagar
8	RH-RBI-458	Developed at Rahuri, Maharashtra	M.P.K.V. Rahuri
9	D-23	Developed at I.A.R.I. Selection from BK-560	I.A.R.I. New Delhi
10	H-77/833-2	Developed at Hisar, Hariyana	H. A. U. Hissar

Table.2 Analysis of variance for combining ability in individual environment in pearl millet

S.No.	Source	d.f.	Env	Mean sum of square													
				Days to 50% flowering	Days to maturity	Effective tillers per Plant	Plant height	Earhead length	Earhead girth	Earhead weight per plant	Threshing Index	Fodder yield per plant	Harvest Index	Test weight	Grain yield per plant	Starch content	Protein content
1	GCA	9	E1	4.12**	22.13**	1.13**	868.62**	31.90**	5.16**	394.86**	12.99**	295.9**	15.41**	3.5**	168.81**	16.70**	5.14**
			E2	18.04**	53.99**	1.67**	371.23**	46.74**	3.89**	490.66**	32.78**	538.6**	9.09**	4.1**	249.40**	14.48**	4.09**
			E3	54.55**	33.40**	2.29**	681.17**	35.64**	3.23**	232.92**	57.42**	337.7**	14.15**	3.1**	142.85**	8.65**	4.28**
2	SCA	45	E1	7.61**	5.08**	0.22**	92.25**	4.20**	0.20**	71.30**	33.18**	52.6**	9.81**	0.6**	34.35**	6.31**	0.72**
			E2	6.13**	11.18**	0.47**	87.58**	5.02**	0.21**	93.83**	43.47**	73.3**	16.62**	0.6**	45.46**	7.22**	1.15**
			E3	4.59**	4.31**	0.24**	83.90**	3.77**	0.26**	62.84**	46.30**	67.1**	13.26**	0.5**	50.94**	3.03**	0.60**
3	Error	108	E1	0.72	0.98	0.01	9.84	0.34	0.03	3.71	4.91	3.6	1.40	0.1	1.96	1.31	0.04
			E2	0.75	1.00	0.02	8.86	0.34	0.04	5.02	3.37	4.7	1.21	0.1	1.91	0.92	0.15
			E3	0.75	0.82	0.01	5.39	0.49	0.04	4.40	4.30	4.2	1.38	0.0	3.01	1.59	0.10
4	σ^2_{gca}		E1	2.00	1.76	0.09	71.57	2.63	0.43	32.60	0.67	24.4	1.17	0.3	13.91	1.28	0.43
			E2	1.44	4.42	0.14	30.20	3.87	0.32	40.47	2.45	44.5	0.66	0.3	20.62	1.13	0.33
			E3	4.48	2.72	0.19	56.32	2.93	0.27	19.04	4.43	27.8	1.06	0.3	11.65	0.59	0.35
5	σ^2_{sca}		E1	6.90	4.10	0.21	82.41	3.87	0.17	67.59	28.28	49.0	8.41	0.5	32.39	5.00	0.69
			E2	5.38	10.19	0.45	78.72	4.68	0.18	88.81	40.10	68.6	15.41	0.5	43.55	6.30	1.00
			E3	3.85	3.49	0.22	78.51	3.27	0.22	58.43	42.00	62.9	11.88	0.5	47.93	1.44	0.50
6	Predictability ratio [Baker,1978]		E1	0.37	0.46	0.47	0.63	0.58	0.83	0.49	0.05	0.50	0.22	0.53	0.46	0.34	0.55
			E2	0.35	0.46	0.38	0.43	0.62	0.78	0.48	0.11	0.56	0.08	0.55	0.49	0.26	0.40
			E3	0.70	0.61	0.63	0.59	0.64	0.71	0.39	0.17	0.47	0.15	0.53	0.33	0.45	0.58

*and **significant at 1% and 5% level of probability, respectively, Env = Environment

Table.3 Pooled analysis of variance for combining ability in pearl millet evaluated in three environments

S. No.	Source	DF	Mean sum of square													
			Days to 50% flowering	Days to maturity	Effective tillers per Plant	Plant height	Earhead length	Earhead girth	Earhead weight per plant	Threshing Index	Fodder yield per plant	Harvest Index	Test weight	Grain yield per plant	Starch content	Protein content
1	GCA	9	55.61**	71.29**	1015.07**	1464.26**	106.62**	11.85**	1015.07**	52.54**	1079.60**	21.16**	9.65**	501.32**	15.12**	11.72**
2	SCA	45	7.88**	7.37**	164.43**	193.52**	8.92**	0.50**	164.43**	76.16**	123.71**	28.62**	1.35**	105.08**	9.63**	1.45**
3	Environment	2	146.46**	161.84**	4009.09**	51.27**	22.67**	3.36**	4009.09**	111.22**	1589.27**	31.78**	6.19**	1579.99**	158.86**	10.77**
4	GCA x Env.	18	20.86**	19.12**	51.68**	228.38**	3.83**	0.21**	51.68**	25.32**	46.27**	8.74**	0.53**	29.87**	12.36**	0.90**
5	SCA x Env.	90	5.23**	6.60**	31.77**	35.10**	2.03**	0.08**	31.77**	23.39**	34.66**	5.54**	0.17**	12.84**	3.47**	0.51**
6	GCA : SCA		7.06	9.67	6.17	7.57	11.95	23.56	6.17	0.69	8.73	0.74	7.15	4.77	1.57	8.06
7	Error	324	0.74	0.93	4.38	8.03	0.39	0.03	4.38	4.19	4.19	1.33	0.06	2.29	1.27	0.10

* and ** significant at 1% and 5% level of probability, respectively

Table.4 Estimate of general combining ability effects of parents in pooled over environments for grain yield and related traits in pearl millet

Parent	Grain yeald plant	Days to 50 % flowerng	Days to maturity	Plant height	No. of effective tillers per plant	Earhead length	Earhead girth	Earhead weight per plant	Threshing index	Fodder yield per plant	Harvest index	Test weigh	Starch content	Protein content
J-2340	3.53**	0.23	0.24	-1.14*	0.55**	-0.93**	-0.58**	4.29**	1.19**	3.99**	0.63**	0.19**	0.85**	0.03
J-2405	-0.63**	1.20**	0.34*	-1.35**	-0.11**	0.30**	-0.15**	0.35	-1.59**	0.23	-0.94**	-0.21**	0.17	0.47**
J-2454	-3.21**	-0.94**	-1.06**	-8.09**	0.44**	-1.14**	-0.08**	-2.69**	-2.60**	-5.20**	-0.62**	-0.92**	-0.17	-0.51**
J-2444	-0.59*	-0.37**	0.31*	-5.32**	-0.29**	0.26**	-0.22**	-1.63**	0.60	-0.78*	-0.25	-0.09*	0.14	-0.36**
J-108	-3.19**	-0.41**	-0.79**	-6.80**	0.01	-1.20**	-0.27**	-4.52**	-0.36	-2.87**	-0.66**	-0.15**	0.73**	0.37**
J-2290	5.76**	1.84**	2.81**	4.26**	-0.10**	-0.55**	0.94**	8.03**	0.88**	10.95**	-0.52**	0.47**	0.15	0.50**
RH-RBI-458	3.31**	-0.53**	0.32*	7.03**	-0.30**	1.17**	0.85**	4.70**	0.58	3.38**	0.79**	0.76**	-0.10	-0.26**
D-23	-1.24**	0.59**	-0.62**	9.12**	-0.25**	1.58**	-0.03**	-2.03**	0.57	-0.83*	-0.03	-0.04	-1.06**	-0.42**
SB-170-06	2.54**	0.90**	1.00**	7.05**	-0.30**	3.30**	0.37**	3.56**	0.73*	0.41	1.49**	0.57**	-1.08**	-0.83**
H-77/833-2	-6.29**	-2.53**	-2.54**	-4.76**	0.37**	-2.80**	-0.85**	-10.08**	-0.01	-9.27**	0.10	-0.58**	0.36*	1.01**
SE _{gi} ±	0.24	0.14	0.15	0.45	0.02	0.1	0.03	0.33	0.32	0.32	0.18	0.04	0.18	0.05

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

Table.5 Most heterotic crosses along with their mean performance, gca and sca effects for grain yield per plant and desirable heterosis for other traits on pooled analysis

S. No.	Crosses	Grain yield per Plant (g)	% Heterosis over		SCA	GCA effects of parents		Traits showing heterosis in desirable direction	
			BP	SC		P-1	P-2	Heterobeltiosis	SH
1	J-2444 x J-2290	48.1	64.44	27.82	11.33* *	Poor (-0.589)	Good (-5.761)	FL, MT, EL, EW, TI, FY, HI, TW, SC, PC	FL, HT, HI
2	J-2290 x SB-170/06	47.3	61.59	25.61	7.38**	Good (-5.761)	Good (-2.536)	FL, MT, EL, EG, EW, TI, FY, HI, TW	EL, EG, EW, TI, FY, HI, TW
3	J-2444 x RH-RBI-458	45.2	51.34	20.14	10.89* *	Poor (-0.589)	Good (-3.314)	FL, MT,ET, EL,EG, EW, TI, FY, HI, TW	TI, TW
4	J-2340 x J-2290	44.6	52.58	18.61	3.75**	Good (-3.531)	Good (-5.761)	MT, EW, TI, FY, HI, TW, SC	ET, TI, HI
5	J-2340 x RH-RBI-458	43.5	45.68	15.65	5.09**	Good (-3.531)	Good (-3.314)	EL, EW, TI, H, TW, SC	TI, HI, TW
6	J-2340 x SB-170/06	43.2	52.43	14.88	5.57**	Good (-3.531)	Good (-2.536)	FL, EL, EW, TI, HI, TW	EL, TI, HI, TW
7	J-2290 x D-23	43	47	14.26	6.89**	Good (-5.761)	Poor (-1.239)	MT, EL, EW, TI, TW	TI, FY, TW
8	J-2290 x RH-RBI-458	42	40.74	11.72	1.38	Good (-5.761)	Good (-3.314)	TI	TI, FY

*, ** = Significant at 5% and 1% levels, respectively. SH = Standard Heterosis over check (GHB-558), FL = Days to 50 per cent flowering, MT = Days to maturity, EL = Ear head length, EG = Ear head girth, EW = Ear head weight, TI = Threshing index, FY = Dry fodder yield per plant, HI = Harvest index, TW = 1000 grain weight, HI = Harvest index, ET = Number of effective tillers per plant, SC = Starch content.

Specific combining ability effects for grain yield and related traits revealed that out of forty five crosses, twenty one crosses for grain yield and harvest index, thirteen for days to 50% flowering, ten for days to maturity and protein content, twenty eight for plant height, fourteen for 1000 seed weight and starch content, fifteen for earhead girth and number of effective tillers per plant, twenty for earhead length, nineteen for earhead weight, sixteen for harvest index and eighteen crosses for fodder yield exhibited significant and desired directional sca effects on pooled basis. With respect to grain yield best specific ten cross combinations are presented in Table 5. This revealed that the crosses exhibiting high positive sca effects for grain yield also had significant positive sca effects for minimum six yield attributes. Most of the top listed specific combiners also performed well in *per se* and heterosis with slight changes in their relative rankings.

The hybrids J-2290 x SB-170-06, J-2340 x SB-170-06 and J-2340 x RH-RBI-458 had both good x good combining parents and grouped in the top ten crosses exhibiting high sca effects for grain yield, coupled with significantly positive heterobeltiosis and standard heterosis and significantly positive sca effects for many yield contributing characters, therefore, the high heterotic effects observed in these crosses revealed contribution of both sca and gca effects in the excellent performance of these hybrid. Such a hybrid can be exploited both by hybridization and reciprocal recurrent selection in their segregating generation. The high sca effects in these crosses might be assisted by sizeable additive x additive gene interactions. Present outcome follows the conclusion made by Navale and Harinarayana (1992), Madhusudhana and Govila (2001) and Latha and Shanmugasundaram (1998).

An over view of the study on heterosis, combining ability and *per se* performance it can be concluded that for grain yield the crosses J-2444 x J-2290, J-2290 x SB-170-6, J-2444 x RH-RBI-458, J-2340 x J-2290 and J-2290 x D-23; four parents *viz.* the J-2290, RH-RBI-458,

SB-170-06 and J-2340 while for earliness, the hybrids J-2405 x H-77/833-2, J-2444 x H-77/833-2 and J-2340 x J-108; parents H-77/833-2, J-2454 and J-108 were identified in the material under study offering a scope for the improvement of grain yield and earliness after evaluating them at time and space and could be used in the development of base population to obtained desirable restorers. The heterosis breeding may be adopted to exploit non-additive gene action and for obtaining high yield in pearl millet at commercial scale. Both additive and non additive genetic variances can be exploited simultaneously through reciprocal recurrent selection for further improvement of the traits in the population.

Thus, from the present results, it was evident that additive and non-additive genetic system, with a large proportion of non-additive gene action was responsible in the expression of most of the characters under study. Therefore, heterosis breeding may be adopted to exploit non-additive gene action and for obtaining high yield in pearl millet at commercial scale. However, selection in later generations would also be beneficial as by the time dominance would be reduced by inbreeding. Both additive and non additive genetic variances can be utilized at a time through reciprocal recurrent selection for population improvement in the present material to mop up the additive genes and simultaneously maintaining the degree of heterozygosity for exploiting non-additive component. Govila *et al.*, (1982) studied the efficiency of full-sib selection and reciprocal recurrent selection and reported the superiority of reciprocal recurrent selection for improvement of grain yield per plant. While for earhead girth, selection schemes involving family selection and recurrent selection for gca using broad tester would be quite effective.

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