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Component and Combining Ability Analyses in a 8 × 8 Diallel of Pearl millet (*Pennisetum typhoides* S. & H.)

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In a 8×8 complete diallel, involving five Indian and three exotic inbreds, characters, namely, ear length, ear girth and yield/plant revealed overdominance, whereas partial dominance conditioned effective tillers/plant. Variance due to GCA and SCA indicated that both additive as well as nonadditive gene actions were important, however, nonadditive gene action was predominant for ear length, ear girth and yield/plant. Wide range of reciprocal effect was noticed for ear length, ear girth and yield/plant, and thus, due caution should be given at the time of selecting the pollinator and recipients in hybrid seed production. The GCA effect of the parents, SCA effect of the crosses and heterosis percentage over better parent were inter-related. Mostly, the cross combinations involving one Indian and the other exotic inbred, exhibited high degree of heterosis. Reciprocal recurrent selection was recommended to improve the pearl millet population.

Generally it is assumed that the expression of a trait is controlled by the nuclear genes rather than the maternal cytoplasm. However, Nanda and Gupta (1967), in pearl millet, Anand and Murty (1975) in linseed, Nagur and Murthy (1970) in sorghum and Singh and Asnani (1979) in maize reported considerable influence of the maternal cytoplasm. The present inves-[illegible]igation was undertaken to assess the [illegible]f maternal cytoplasm, if any, [illegible]bining ability and heterosis [illegible] 8 full diallel of pearl millet.

[illegible]IAL AND METHODS

Eight inbreds, *viz.*, J-82, J-275, J-319, J-459, J-1934 (Indian), ZNS, MDB-72 and ExBenue (exotic) were selected on the basis of high degree of phenotypic diversity for the various quantitative characters and were intercrossed to obtain all possible hybrid combinations (diallel), including the reciprocals during *Kharif* 1975. The diallel progenies, 56 F_1's along with the 8 parents, were sown in a randomized block design with three replications during *Kharif* 1976. Observations were recorded for effective tillers/plant, ear length ear girth and grain yield/plant.

Plot means were used for statistical analysis. The genetic components of variation were calculated by the method proposed by Hayman (1954). The combining ability analysis was done following Method I and Model I of Griffing (1956).

RESULTS AND DISCUSSION

The t^2 estimate was nonsignificant for all the traits (Table I), thus, the

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assumptions of the diallel analysis was fulfilled. However, the presence of epistasis was revealed in case of grain yield/plant as the regression coefficient 'b' deviated significantly from unity. Further, the assumption of on reciprocal effect was not satisfied for ear length, ear girth and yield/plant (Table II).

Component Analysis

The estimates of genetic components of variation and proportions are presented in Table I. The additive genetic variance $\hat{D}$ was significant for all the traits, except yield/plant. The dominance components ($\hat{H}_1$, $\hat{H}_2$ and $\hat{h}^2$) were significant for ear length, ear girth and yield/plant but nonsigificant for effective tillers/plant. Estimates of dominance components, in general, were higher than additive components suggesting that dominance genetic variances were more important than additive variance in the inheritance of the traits except in effective tillers/plant. Among the dominance components, $\hat{H}_1$ was greater than $\hat{H}_2$, indicating that positive and negative alleles at the loci governing the traits were not equal in proportion in the parents. The component $\hat{F}$ which is a measure of covariance between additive and dominance effects, was nonsignificant for all the traits.

Proportions of genetic components

Characters ear length, ear girth and yield/plant exhibited overdominance $\left[(\hat{H}_1 / \hat{D})^{0.5} > 1 \right]$ whereas, partial dominance was revealed for effective tillers per plant. Singh *et al.* (1979) reported similar observations with the exception that effective tillers/plant was under the influence of overdominance. Appadurai and Subramanian (1975) also reported overdominance for plant height, panicle length and grain yield. The ratio $\hat{H}_2/4\hat{H}_1$ was almost close to 0.25 for all the traits, execpt effective tillers/plant thereby suggesting the symmetrical distribution of positive and negative genes among the parents. Presence of excess of dominant alleles, as revealed by the proportion K_D/K_R, was suggested for all the traits; being the highest for effective tillers/plant. The proportion h^2/H_2, ranged from 1.76 to 2.74, indicating that at least two pairs of genes showing dominance were present among the eight parents for the traits studied.

The correlation coefficient (r) between parental measurement and parental order of dominance was significantly negative for ear girth, indicating an excess of positive genes in dominance. Whereas, equal proportion of positive and negative genes towards dominance was suggested for the remaining traits.

Heritability in narrow sense indicated higher proportion of nonadditive genetive variance compared to the additic variance as the heritability estimates for different traits were moderate to low, being the highest for ear girth (47.93 %) and the lowest for grain yield (15.61 %).

Combining ability analysis

The analysis of variance for combining ability is presented in Table II. The mean squares for both GCA and SCA were significant for all the traits except SCA variance for effective tillers/plant. Significant reciprocal effects of the traits studied, were recorded for all but effective tillers per plant. Mahadevappa (1968) also observed significant reciprocal effects for the four characters of the present study. Contrary to above findings Badwal (1970) reported absence of reciprocal differences in pearl millet. The variance ratio $\hat{\sigma}^2_g / \hat{\sigma}^2_s$ was less than unity for all the characters except effective tillers/plant. Therefore, nonadditive gene actions were predominantly important for the traits namely, ear length, ear girth and yield/plant whereas effective tillers per plant were controlled mainly by additive gene effects. Hence, the inheritance of the traits revealed by the two analyses, component and combining ability was in close parity.

The estimates of GCA effects along with the *per se* performance of the parents are presented in Table III. Parents J-275 and MDB-72 exhibited significantly desirable GCA effects for grain yield. Whereas, J-319, J-459 and J-1934 were found to be poor general combiners. Inbreds J-275 and MDB-72 were also the best general combiners for yield among the Indian and exotic inbreds, respectively, which differed in the GCA effects of yield components. Parent J-275 recorded positive and significant GCA effects for effective tillers per plant but failed to show desirable GCA effects for ear length and ear girth. On the other hand, MDB-72 exhibited desirable GCA effects for ear length and ear girth. However, other two exotic inbreds, ZNS and ExBenue, did not follow the relationship as revealed in case of MDB-72. The GCA effects were correlated with the *per se* performance for all the traits, except yield/plant, in general.

The estimates of SCA effects heterosis percentage over better parent, and mean performance of the seven best crosses selected on the basis of SCA effects for grain yield are presented in Table IV. The above estimates were not carried out for effective tillers per plant as the SCA variance was nonsignificant. The cross combinations J-82 × J-275, J-82 × ZNS, J-275 × ZNS, J-319 × J-459, J-459 × ExBenue, MDB-72 × ExBenue and MDB-72 × J-1934 exhibited significant positive SCA effects for grain yield, being the highest for J-275 × ZNS. These crosses also showed high SCA effects for ear length and ear girth. The highest SCA effects for ear length and ear girth were recorded for the cross combinations J-459 × ExBenue and ExBenue ×

J-1934, respectively. The greatest reciprocal effect was observed in case of cross J-319 × MDB-72 for grain yield whereas, cross J-319 × J-459 exhibited the highest for both ear length and girth. High mean performance was, in general, interrelated with high SCA effect.

As regards the heterosis, most of the crosses were significant and positive for the three traits. The highest heterosis for yield/plant was recorded for the cross J-275 × ZNS. For ear length, cross J-82 × ZNS exhibited the highest heterosis. The reciprocal hybrids showed a good amount of heterosis and a large variations against the corresponding F_1's. The maximum heterosis for grain yield among the reciprocal hybirds was observed for the cross ZNS × J-275 whereas, for ear length and ear girth, it was for hybird J-459 × J-319. The results of the present findings suggest that a breeder should cautions in selecting the parents as pollinator and recipient for the production of hybird pearl millet. Similar observations were made by Nagur and Murthy (1970) and Chauhan and Singh (1974) in sorghum, an often cross pollinated crop.

An examination of the mean values of hybrids revealed that mostly high heterosis was related to high *per se* performance as well as SCA effects. In addition, the crosses which scored maximum SCA effects and heterosis involved at least one good general combiner, in general. As expected, crosses having high SCA effects with greater degree of heterosis involved one Indian and the other exotic inbred most often.

Thus from the different analyses it was indicated that both additive as well as nonadditive gene actions were important in the inheritance of the traits studied. A reciprocal recurrent selection procedure seems to be most appropriate breeding scheme since intermating among the selects becomes imperative in order to exploit fully the additive and nonadditive gene effects. Selections may be practiced on the basis of high GCA and SCA effects Even *per se* performance may help in chosing the the parents and crosses. Inbreds J-275 and MDB-72 and crosses like J-275 × ZNS, J-459 × ExBenue may be utilized in the crossing programmes.

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TABLE I Estimates of genetic components of variation and proportions for four characters in pearl millet

Estimates	Effective tillers/plant	Ear length	Ear girth	Yield/plant
Components of variance				
$\hat{D}$	0.287**	22.910**	0.080**	3.045
	±0.049	±5.891	±0.008	±14.207
$\hat{H}_1$	0.043	52.240**	0.111**	157.308**
	±0.113	±13.542	±0.019	±32.661
$\hat{H}_2$	0.018	53.810**	0.098**	130.206**
	±0.098	±11.781	±0.016	±28.415
$\hat{h}_2$	−0.032	144.987**	0.269**	272.182**
	±0.066	±7.901	±0.011	±19.056
$\hat{F}$	0.139	6.234	0.035	13.570
	±0.116	±13.919	±0.019	±33.571
$\hat{E}$	0.238**	0.346	0.003	12.230*
	±0.016	±1.964	±0.003	±4.736
Proportions				
$(\hat{H}_1/\hat{D})^{0.5}$	0.387	1.594	1.179	7.187
$\hat{H}_2/4\hat{H}_1$	0.107	0.231	0.221	0.207
K_D/K_R	4.351	1.187	1.456	1.898
$\hat{h}^2/\hat{H}_2$	−1.765	2.695	2.741	2.091
Correlation coefficient 'r'	0.059	−0.641	−0.949**	−0.640
Heritability (narrow sense)	25.060	30.028	47.929	15.610
t^2	0.384	0.014	1.469	0.975
'b'	0.985	0.699	1.115	0.094
	±0.229	±0.273	±0.181	±0.274

* Significant at P = 0.05;
** Significant at P = 0.01.

TABLE II Analysis of variance for combining ability four characters in pearl millet

Source	d. f.	Mean some of Sqares			
		Effective tillers/plant	Ear length	Ear girth	Yield/plant
GCA	7	0.93**	84.76**	0.23**	78.59**
SCA	28	0.25	21.25**	0.05**	77.31**
Reciprocals	28	0.35	5.07**	0.03**	36.33*
Error	126	0.23	0.35	0.003	12.23
$\hat{\sigma}^2 g/\hat{\sigma}^2 s$		8.40	0.240	0.407	0.004

* Significant at P = 0.05;
** Significant at P = 0.01.

TABLE III Estimates of GCA effects *per se* performance (in parenthesis) of the eight parents for four characters in pearl millet

Parents	Effective tillers/plant	Ear length	Ear girth	Yield/plant
J-82	—0.12 (2.16)	—1.46** (21.68)	0.12** (2.03)	—0.87 (26.17)
J-275	0.47** (3.10)	—1.71** (22.35)	—0.12** (1.75)	3.81** (18.43)
J-319	—0.07 (2.27)	—2.10** (22.20)	—0.13** (1.49)	—2.10* (21.84)
J-459	—0.29** (1.25)	0.17 (23.00)	0.07** 1.84)	—1.62* (15.91)
ZNS	0.14 (3.63)	—0.36** (20.30)	—0.06** (1.78)	0.47 (17.41)
MDB-72	—0.21 (1.97)	3.38** (31.76)	0.11** (2.21)	2.29** (18.96)
ExBenu	—0.02 (2.11)	3.67** (33.08)	0.13** (2.22)	0.54 (25.62)
J-1934	0.09 (2.27)	—1.59** (24.73)	—0.13** (1.48)	—2.52** (17.32)
S.E. (gi)	±0.11	±0.14	±0.01	±0.82

* Significant at P = 0.05;
** Significant at P = 0.01.

TABLE IV Estimates of SCA effects, heterosis percentage over better parent and mean performance of the seven best crosses selected on the basis of SCA effects of grain yield

Crosses	Yield/plant SCA	Yield/plant % Heterosis F_1 direct	Yield/plant % Heterosis F_1 reciprocal	Ear length SCA	Ear length % Heterosis F_1 direct	Ear length % Heterosis F_1 reciprocal	Ear girth SCA	Ear girth % Heterosis F_1 direct	Ear girth % Heterosis F_1 reciprocal
J-82 × J-275	7.70**	50.24** (39.32)	49.17** (39.04)	1.09**	28.05** (28.62)	29.41** (29.04)	0.14** ——	5.43 (2.14)	16.61** (2.36)
J-82 × ZNS	7.52** ——	10.30 (28.87)	62.21** (42.46)	1.87** ——	48.19** (32.13)	37.38** (29.79)	0.07*	14.31** (2.32)	7.56* (2.18)
J-275 × ZNS	10.80** ——	167.95** (49.37)	105.40** (37.86)	1.18**	31.06** (29.30)	37.52** (30.74)	−0.03 ——	11.96** (2.00)	0.56 (1.79)
J-319 × J-459	6.46** ——	70.28 (37.19)	16.13 (25.36)	0.22 ——	14.65** (26.37)	39.30** 32.04)	0.01 ——	−0.72 (1.82)	25.04 (2.30)
J-459 × ExBenue	10.40**	48.81** (38.13)	46.73** (37.59)	10.25** ——	42.41** (47.11)	29.75** (42.92)	0.04 ——	17.59 (2.61)	−4.96 (2.11)
MDB-72 × ExBenue	5.89**	40.50* (36.00)	50.31** (38.51)	−5.15** ——	—4.67* (31.53)	3.07 (34.09)	−0.16** ——	—3.76 (2.13)	1.95 (2.26)
MDB-72 × J-1934	5.94**	62.18** (30.75)	99.10** (37.75)	1.73** ——	7.40** (34.11)	9.50** (34.78)	0.09 ——	−5.87* (2.08)	3.31 (2.29)
S. E. (Sij)	±2.18	±4.02		±0.37	±0.71		±0.03	±0.06	

* Significant at P = 0.05;
** Significant at P = 0.01.

Underline values indicate significant reciprocal effect.