HETEROSIS AND COMBINING ABILITY IN PEARL MILLET

C. S. Tyagi, R. S. Paroda, N. D. Arora and K. P. Singh

Department of Plant Breeding, Haryana Agricultural University, Hissar (India)

(Accepted: 24–iii–75)

Despite the high yielding ability of pearl millet hybrids, it has been felt in recent years that the varietal programme must also be undertaken simultaneously as the hybrids involving susceptible male sterile line Tift 23 A, are invariably attacked by diseases like downy mildew and ergot. Selection of suitable inbreds with good general combining ability would be of specific advantage in breeding of varieties. Accordingly, the present investigation was undertaken to study heterosis as well as combining ability for grain yield and its component characters in pearl-millet (*Pennisetum typhoides* (Burm f.) Stapf & C. E. Hubb.).

Materials and Methods

Selection of the ten inbreds used in the present study was mainly based on the extent of variability present among them for various yield and yield contributing characters. In addition, these inbreds, except for H–48, H–52 and H–126 showed infection score below 6% for downy mildew in field conditions during 1970 and 1971. H–48, H–52 and H–126 were almost at par with HB–1 in disease rating as all these showed disease score of more than 13% in both the years. A 10 × 10 diallel, excluding reciprocals, was made. The parents, 45 F_1's, 45 F_2's and the two promising checks (HB–1 and S–530) were sown in a randomised block design with four replications. The parents and the F_1's were sown in one row plots of 5 metres spaced 45 cm. apart, and the F_2's in two row plots each. Five plants in parents and F_1's and 20 plants in F_2 were selected at random for recording data. Combining ability analysis was carried out according to both Method 2, Model I and Method 4, Model I of Griffing (1956). Method 4, Model I was used particularly in order to have unbiased estimates as advocated by Griffing (1956) and Hayes and Paroda (1974) and to see the impact of deleting parental generations on the estimates of combining ability.

Results and Discussion

The mean squares due to combining ability variances using both the generations are given separately for Method 2, Model I and Method 4, Model I in Table 1. The variances due to general as well as specific combining ability were highly significant for all the six characters studied. In the fixed effect model, a GCA : SCA ratio greater than two indicated the preponderance of additive genetic variance both in the F_1 as well as in the F_2 generations. The ratio was invariably high in case of Method 4, Model I, which takes into account the data of only the crosses. Earlier, Hayes and Paroda (1973) have established that the exclusion of the parental generation from the diallel gave unbiased estimates of the combining ability variances, whereas both GCA and SCA effects remained almost unaltered.

The GCA effects of the parents are given in Table 2. In general, inbreds H-19 and H-403 showed better combining ability for most of the characters

TABLE 1

Analysis of variance for combining ability in the F_1 and F_2 generations using both Method 2, Model I (X_1) and Method 4, Model I (X_2)

Source	Generations		D.F.	Mean Squares: Days to ear emergence	Ear number	Ear length (cm)	Ear diametre (cm)	500-grain weight (gm)	Grain yield (gm)
General combining ability	F_1	X_1	9	63·87**	21·63**	187·55**	0·39**	0·53**	6317·52**
		X_2	9	110·29**	17·31**	163·76**	0·36**	0·45**	9739·06**
	F_2	X_1	9	59·36**	18·54**	148·52**	0·25**	0·53**	2927·99**
		X_2	9	53·66**	13·89**	108·55**	0·21**	0·45**	4296·33**
Specific combining ability	F_1	X_1	45	13·25**	7·61**	7·91**	0·02**	0·17**	2600·90**
		X_2	45	9·46**	5·54**	3·64**	0·01**	0·06**	1252·71**
-	F_2	X_1	45	16·09**	5·03**	38·92**	0·02**	0·11**	1036·81**
		X_2	45	13·08**	3·05**	3·78**	0·17**	0·01**	585·29**
Error	F_1	X_1	162	0·64	0·43	1·54	0·01	0·01	30·19
		X_2	162	0·64	0·43	1·54	0·01	0·01	30·19
	F_2	X_1	162	1·42	0·33	0·40	0·01	0·01	29·05
		X_2	162	1·42	0·33	0·39	0·01	0·01	29·05
GCA : SCA Ratio	F_1	X_1		4·82	2·84	23·71	19·50	3·11	2·42
		X_2		11·65	3·12	44·98	36·00	7·50	7·77
	F_2	X_1		3·69	3·69	3·81	12·50	4·82	2·83
		X_2		4·11	4·56	28·71	12·35	45·00	7·34

**Significant at 1% level.

TABLE 2

Estimates of general combining ability effects and the mean performance (in parenthesis) of parents for six characters using both the F_1 and F_2 generations

Parents	Estimated general combining ability effects for											
	Days to ear emergence		Ear number		Ear length (cms)		Ear diameter (cms)		500-grain weight (gms)		Grain yield (gms)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
H–19	4·08** (56)	4·56** (56)	–1·81** (3)	–1·44** (5)	9·96** (37·45)	7·88** (32·95)	0·05 (1·96)	0·06 (2·00)	0·32** (4·76)	0·37** (4·11)	51·73** (37·44)	31·08** (114·53)
H–30	–0·59 (47)	–0·22 (50)	2·81** (14)	2·41** (9)	–0·19 (22·50)	0·35 (25·41)	–0·22** (1·50)	–0·22** (1·71)	–0·12** (3·64)	0·16** (3·97)	–25·85** (43·36)	–17·12** (56·11)
H–48	–1·24** (46)	–2·19** (48)	0·59* (14)	0·89** (7)	–1·14** (23·03)	–1·38** (23·28)	–0·23** (1·59)	–0·18** (1·74)	–0·15** (3·45)	–0·12** (3·65)	–8·36** (51·84)	–2·26 (73·09)
H–52	0·04 (50)	0·58 (51)	0·35 (6)	0·33 (7)	2·00** (32·75)	2·22** (26·62)	–0·17** (1·66)	–0·09** (1·85)	–0·16** (3·99)	–0·17** (3·54)	–11·55** (75·53)	–2·42 (70·54)
H–80	–2·95** (46)	–3·30** (47)	–1·53** (4)	–1·29** (5)	–2·75** (20·10)	–3·07** (21·55)	0·25** (2·24)	0·21** (2·14)	0·01 (4·13)	–0·01 (3·72)	–20·98** (26·22)	–20·05** (54·26)
H–91	2·69** (54)	0·95 (51)	–0·17 (8)	–0·56* (6)	2·14** (29·30)	2·52** (27·23)	–0·06 (1·89)	–0·06 (1·85)	0·34** (3·94)	–0·31** (4·12)	–13·04** (76·13)	–8·59** (63·06)
H–126	–1·01** (48)	–0·09 (50)	0·41 (6)	0·03 (6)	–3·54** (19·85)	–2·45** (22·31)	–0·13** (1·70)	–0·09** (1·84)	–0·11** (3·59)	–0·14** (3·61)	1·03 (40·98)	–3·39 (72·81)
H–224	2·49** (59)	1·96** (52)	–0·22 (6)	–0·13 (6)	–2·24** (19·95)	–1·91** (23·01)	0·13** (1·98)	0·11** (2·05)	0·04 (3·76)	–0·01 (3·76)	–5·56* (49·82)	–5·66** (69·21)
H–375	–1·59** (47)	–0·73 (50)	–0·19** (6)	–0·87** (5)	–0·67 (21·70)	0·05 (25·11)	0·20** (2·02)	0·13** (2·07)	–0·14** (3·09)	–0·22** (3·57)	14·64** (81·01)	14·83** (90·68)
H–403	–1·92** (53)	–1·52** (49)	0·76** (5)	0·63** (7)	–3·58** (16·10)	–4·21** (20·67)	0·18** (2·02)	0·13** (2·06)	–0·29** (3·02)	–0·17** (3·63)	17·94** (15·26)	13·62** (92·11)
C.D. at 5% (gi-gj)	0·64	0·96	0·53	0·45	0·99	0·49	0·09	0·08	0·06	0·02	4·40	4·21
CORRELATIONS												
GCA and parent mean	0·8216**	0·7532**	0·7355**	0·8056**	0·9305**	0·9513**	0·9512**	0·9983**	0·8081**	0·6653**	0·3771	0·1675*
GCA and array mean	0·9843**	0·9916**	0·9622**	0·9523**	0·9915**	0·9997**	0·9998**	0·9512**	0·7223**	0·9667**	0·9981**	0·9960**

***Significant at the 5% and **Significant at the 1% level.**

TABLE

Mean performance, heterosis over better parent and s.c.a. effects of four best hybrids

Crosses/checks	Characters							
	Days to ear emergence			Ear number			Ear length	
	Mean	Heterosis	S.C.A.	Mean	Heterosis	S.C.A.	Mean	Heterosis
H-19 × H-403	45	-15·81	-5·92	9	69·40	2·18	40·50	8·14
H-19 × H-126	47	-0·94	-4·19	8	39·24	1·61	33·15	-11·48
H-19 × H-30	49	2·98	-3·10	7	-49·59	6·62	40·00	6·81
H-80 × H-224	47	1·23	-1·31	6	16·78	0·21	25·35	26·11
HB-1	45			8			24·15	
S-530	51			5			32·30	

studied. H-80 was particularly good combiner for characters like earliness and ear diameter. Accordingly, exploitation of these inbreds is advocated. The trend in the F_2 was quite similar to that observed in the F_1. Thus, F_2 generation could effectively be used for estimating the GCA effects. Recent reports in cereals by Niehaus and Pickett (1966), Paroda and Joshi (1970) and Saini (1974) have also advocated the use of F_2 generation. Both parental means as well as array means were found to be correlated with the GCA effects. However, the magnitude of the latter was invariably high in case of all the characters, whereas the former showed positive but non-significant correlation in some cases. Thus, use of array means to judge the GCA effects appeared to be useful particularly when it is likely to save considerable time (Hayes and Paroda, 1973 in barley and Solanki, Paroda and Chaudhury, 1974 in oats).

The mean performance of the best four hybrids, estimates of hetreosis over better parent and the SCA effects are given for all the characters studied in Table 3. In a systematic breeding programme, criteria like parents with desirable characteristics and good general combining ability for yield and its components, high heterosis not only over the better parents but also over the best check and high estimates of SCA effects are obviously essential. It was interesting to find that crosses involving both good general combining parents as well as crosses involving one good and one poor combining parent had shown high SCA effects as well as high heterosis. Very few crosses exhibited high heterosis for more than one character. Also, limited heterosis was observed for characters like: ear length, ear diameter, grain weight and days to ear emergence. Characters like grain yield and ear numbers registered maximum heterosis as well as SCA effects. The best crosses for grain yield were H-19×H-403, H-19×H-126, H-19×H-30 and H-80×H-224 (Table 3). H-19×

3

as against the mean value of checks (HB1 and S. 530) used.

	Ear diametre			500 grain weight (gms)			Grain yield (gms)		
S.C.A.	Mean	Heterosis	S.C.A.	Mean	Heterosis	S.C.A.	Mean	Heterosis	S.C.A.
6·15	2·33	–15·34	0·11	4·32	–9·60	0·13	273·93	424·16	103·95
–1·23	1·97	0·51	0·06	4·28	–10·58	–0·09	260·31	535·21	107·24
2·25	1·90	–3·15	0·08	4·74	–0·77	0·15	192·89	344·85	66·70
2·37	2·44	8·92	0·07	4·47	8·20	0·26	188·85	279·0	115·00
	1·86			4·36			187·26		
	2·16			3·88			58·78		

H-403 appeared to be the best; in addition to being early as well as high yielding, it also appeared to be good in ear length as well as ear number. Heterosis over better parent was of the order of 424% and both the parents involved were good general combiners as well as resistant to downy mildew. As GCA was found to be high in case of yield as well as its components, it would be useful to exploit the fixable (additive) component of genetic variance for further improvement. Bi-parental cross approach in the F_2 generation of this cross using any of the North Carolina designs would, therefore, be most appropriate.

Summary

Combining ability studies, using Method 2 and Model I (P's and F_1's) and Method 4, Model I (only F_1's), were carried out for grain yield and its components in a 10×10 diallel set excluding reciprocals in pearl-millet. The estimates of both the combining ability variances (σ^2 gca and σ^2 sca) were highly significant for all the six characters studied. Boh the methods gave similar estimates of general combining ability and specific combining ability effects. The magnitude of GCA: SCA ratio in the F_1 and F_2 generations was low in Method 2 and high in Method 4. High GCA : SCA ratio revealed preponderance of additive genetic variance for all the grain characters studied. Significant association between array means and general combining ability effects suggested that the former could be used effectively in the selection of good combiners. Inbreds H-19 and H-403 showed better combining ability for most of the six characters studied. H-80 was particularly good combiner for characters like earliness and ear diameter. The best crosses for grain yield were

H-19 × H-403, H-19 × H-30, H-19 × H-126 and H-80 × H-224. Among these, the first two crosses involved good general combining parents. H-19 × H-403 also appeared to be a promising cross for characters like resistance to downy mildew, ear number, ear length, and earliness and thus, appeared to be the best among all. Its exploitation in varietal breeding programme, using bi-parental approach to accumulate more of additive genetic variance is, therefore, advocated.

REFERENCES

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing system. *Aust. J. biol. Sci.*, **9**: 463–93.

Hayes, J. D. and Paroda, R. S. (1974). Parental generation in relation to combining ability for ear emergence in spring barley. *Theoret. appl. Genet.*, **44**: 373–77.

Niehaus, M. H. and Pickett, R. C. (1966). Heterosis and combining ability in a diallel cross in *Sorghum vulgare* Pers. *Crop Sci.* **6**: 33–6.

Paroda, R. S. and Joshi, A. B. (1970). Genetic architecture of yield and components of yield in wheat. *Indian J. Genet.* **30**: 298–314.

Saini, M. L. (1974). Cytogenetical investigations in species and species hybrids of *Eu-Sorghums.* Ph.D. thesis, H. A. U., Hissar Unpublished.

Solanki, K. R., Paroda, R. S. and Chaudhary, B. S. (1974). Combining ability analysis in forage oats (Avena sativa L.) *H. A. U. J. Res.* **4**: 94–105.