FERTILITY RESTORATION CAPACITY OF HIGH COMBINING POLLINATORS IN PEARL MILLET

R. Appadurai, U. S. Natarajan* and T. S. Raveendran

Tamil Nadu Agricultural University, Coimbatore, 641 003, India

'Tift. 23A', the seed parent of the pearl millet (*Pennisetum americanum* (L.) *Leeke*) hybrids 'HB. 1' to 'HB. 5' is highly susceptible to downy mildew. Efforts made by the breeders at the Indian Agricultural Research Institute, New Delhi to replace this male-sterile line with a downy mildew resistant one resulted in the release of 'MS. 5141A' which is currently being used extensively in hybrid programmes. Investigations were made at the Tamil Nadu Agricultural University to assess the combining ability of 'MS. 5141A' *vis-a-vis* that of 'Tift. $23D_2A$' (an isogenic dwarf of Tift. 23A) and of 40 other inbreds and to test the pollen production in the hybrids.

Materials and Methods

Forty inbreds of diverse origin (Table 2) as males were crossed to 'Tift. $23D_2A$' and 'MS. 5141 A' as females to produce 80 F_1 hybrids. These F_1s were compared in a randomised block design with three replications during *kharif* 1976. The entries were sown in single rows of 3 m length with a spacing of 45 cm between rows. The crop was thinned to leave about 20 seedlings per row so that the spacing between plants was 15 cm. At maturity stage five plants in each row were selected at random and observations on plant height, number of productive tillers, panicle length and number of grains per cm^2 were recorded. Grain yield per plant was calculated after harvest. A line × tester analysis for general and specific combining ability was made using the mean values of five observations, following the sire × dam mating design of Kempthorne (1957).

A duplicate set of the material was raised separately in 3 m rows in two replications to study fertility restoration capacity of the inbreds. Individual plants were examined for anther dehiscence and pollen production and the percentage of fertile plants calculated.

Results and Discussion

The results of the analysis of variance are given in Table 1. Partitioning the hybrid sum of squares showed that variance due to males as well as females were highly significant for all the characters studied. The interaction component was significant in the case of plant height, panicle length and grain yield only. The SCA variance was predominant over GCA variance in the case of plant height, tillers, panicle length and grain yield indicating that dominant gene action was more important for the expression of these characters in the material studied. In the case of grain density, however, additive gene action was found to be predominant as evidenced by greater GCA variance.

*Present address: Sugarcane Breeding Institute, Coimbatore 641 007.

TABLE 1

Analysis of variance for various characters

Source	df	Mean squares				
		Plant height	Tillers	Panicle length	No. of grains/ cm^2	Grain yield
Males	39	562.51**	3.78**	35.00**	62.34**	141.44**
Females	1	291.06**	17.60**	27.74**	260.62**	183.75**
Males × Females	39	281.19**	0.24	11.12**	13.68	119.02**
Error	158	130.39	1.25	5.94	10.60	50.74
GCA		2.31	0.13	10.32	2.35	0.69
SCA		50.27	0.56	1.73	1.09	22.76
GCA : SCA		1:22	1:4	1:15.4	1:0.46	1·33

**Significant at P=0.01

The mean values of hybrids for various characters are given in Table 2. 'Tift. $23D_2A$ × J. $126D_2B$' was the shortest hybrid. The highest mean value for tillering was obtained in the hybrid 'Tift. 23A × PT. 734/5'. For panicle length the two hybrids produced by 'J. $126D_2B$' in both the male-steriles were outstanding. The highest value for number of grains per cm^2 was recorded by the two hybrids involving 'PT 1939' as the male parent. The best grain yielders were 'MS. 5141A × PT 1939', 'Tift. $23D_2A$ × PT. 1921' and 'MS. 5141A × PT. 1600'.

The significant general combiners in the sense that they could produce superior hybrids with both the male sterile lines for various characters are given in Table 3. Of the two females, 'MS. 5141A' was found to be better in general combining ability for number of grains per cm^2. With regard to the other characters including grain yield, there was no difference in the combining ability between these two male-sterile lines. This is at variance with the findings of Pokhriyal *et al.* (1976) that 'MS. 5141A' was a better combiner than 'Tift. 23A' for panicle length and grain yield. However, they reported no difference in combining ability between these two lines for plant height and number of tillers as has been the finding in the present investigation also.

Among the pollen parents 'PT. 1921', 'PT. 1600' and 'PT. 1939' were high combiners for yield. The other inbreds worth mentioning as general combiners were 'J. $126D_2B$' and 'PT. 1610' for dwarfness, 'PT. 734/5' for tillering, 'J. $126D_2B$' for panicle length and 'PT 1939' and 'PT. 732/2' for number of grains per cm^2.

None of the hybrid combinations showed specific combining ability for panicle length, grains per cm^2 and grain yield. Two hybrid combi-

TABLE 2

Mean values of hybrids for various characters

	Plant height (cm)		Productive tillers/plant		Panicle length (cm)		Grains/cm²		Grain yield (g/plant)		Fertility restoration (%)	
	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A
J. $16D_2B$	98·3	142·1	3·8	4·3	24·4	23·6	14	15	20·8	30·4	0	0
PT. 1510	135·2	142·4	3·6	3·2	18·1	23·4	26	25	18·1	30·1	—	40
PT. 1522	148·1	130·1	3·4	2·7	17·4	18·9	24	26	32·1	22·9	0	0
PT. 1531	156·0	153·8	3·7	4·2	19·9	13·8	22	21	20·0	23·6	0	0
PT. 1577	140·4	141·8	4·3	3·6	18·0	19·9	19	19	24·1	18·4	100	100
PT. 1600	155·6	157·0	3·6	3·4	19·7	19·0	22	31	30·9	40·1	17	76
PT. 1610	125·4	127·4	4·4	2·8	17·5	18·4	27	27	17·4	16·5	100	100
PT. 1921	150·7	145·7	3·8	3·3	20·0	20·8	21	25	44·6	33·8	100	100
PT. 732/2	128·5	142·9	3·8	4·3	14·3	13·3	27	29	17·3	31·8	100	100
PT. 734/4	144·3	156·0	4·9	5·3	19·6	19·8	21	21	24·5	26·0	0	0
PT. 734/5	154·8	142·8	9·1	3·7	14·3	21·2	14	23	14·7	26·7	0	0
PT. 1695	135·6	136·4	2·8	3·0	19·0	20·5	25	28	11·7	23·2	88	—
IP. 241	140·1	130·0	3·7	3·9	24·3	19·0	20	24	22·7	27·8	90	50
PT. 1722	171·2	161·5	4·8	3·6	15·0	14·8	25	28	35·7	29·9	0	0
PT. 1922	132·8	147·6	4·3	3·0	18·2	19·7	22	19	32·8	22·3	100	100
PT. 1923	135·5	148·2	7·8	3·5	16·0	23·3	22	21	37·4	23·3	—	85
PT. 1924	137·9	148·3	5·9	5·2	14·7	19·4	25	25	30·6	25·1	100	72
PT. 1925	132·3	168·9	5·4	5·0	18·6	16·4	20	19	19·1	28·6	100	—
PT. 1926	154·8	144·4	5·4	4·1	18·6	17·9	23	21	27·3	22·4	—	50
PT. 1927	140·2	155·1	4·2	3·3	16·2	21·3	20	27	29·6	19·2	100	100
PT. 1928	151·7	129·2	4·1	4·2	23·9	21·3	23	27	29·3	17·2	36	52
PT. 1929	133·3	145·3	3·5	3·3	18·8	20·1	20	25	23·6	23·5	38	63
PT. 1930	154·7	147·2	4·1	3·7	18·5	20·2	20	25	23·5	24·4	75	33
PT. 1931	149·7	159·3	4·3	2·3	21·8	21·4	19	24	24·5	15·9	0	0
PT. 1932	167·9	167·4	4·1	4·0	21·4	21·1	19	21	19·4	22·0	65	64
PT. 1933	150·6	137·4	3·5	4·5	15·6	18·7	21	25	20·9	27·6	27	42
PT. 1934	149·3	152·5	4·1	4·1	17·4	17·9	23	23	25·2	21·5	38	74
PT. 1935	133·2	135·0	3·8	3·9	18·0	20·2	25	23	22·6	24·9	73	67
PT. 1936	145·6	152·9	3·0	3·2	19·3	17·9	26	25	23·2	16·6	59	50

(—) Population was not sufficient for sowing.

TABLE 2—(*Contd.*)

	Plant height (cm)		Productive tillers/plant		Panicle length (cm)		Grains/cm²		Grain yield (g/plant)		Fertility restoration (%)	
	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A	Tift. $23D_2A$	MS. 5141A
PT. 1937	152·4	143·9	2·5	2·3	20·8	19·2	24	28	25·2	22·6	66	73
PT 1930	138·4	149·6	3·0	3·8	18·3	19·0	24	•25	22·2	36·9	22	21
PT. 1939	143·4	155·2	3·9	5·7	15·8	15·6	30	31	22·6	46·1	—	26
IP. 863	148·7	141·8	4·2	4·3	19·3	19·9	23	22	19·6	23·5	61	67
IP. 897	167·4	152·6	4·7	3·5	11·6	10·2	27	26	19·1	23·8	66	75
IP. 1388	139·4	143·4	3·3	3·0	17·7	18·6	19	25	26·4	38·8	0	0
PT. 1509	159·4	162·6	5·6	3·4	15·6	15·5	24	31	22·0	25·6	100	100
PT. 1513	150·2	157·1	4·6	3·8	14·9	18·2	17	17	17·4	21·1	0	0
PT. 1886	140·7	134·0	4·3	4·0	19·1	19·6	17	22	16·4	30·7	0	0
MS. 6112	133·7	147·7	3·8	3·0	19·0	18·8	21	25	25·2	24·4	82	84
MS. 6317	157·3	134·2	4·1	4·1	21·7	21·5	22	23	19·9	19·8	0	0
SE	6·6		0·5		1·4		1·9		4·1			
CD	18·3		1·4		3·9		5·2		11·4			

(—) Population was not sufficient for sowing.

TABLE 3

General combiners and combining ability effects

Plant height (cm)		Productive tillers/plant		Panicle length (cm)		No. of grains/cm^2		Grain yield/plant (g)	
Parents	Effect	Parents	Effect	Parents	Effect	Parents	Effect	Parents	Effect
				Males					
PT. 1932	21·95**	PT. 734/5	2·37**	J. 126D_2B	5·32**	PT. 1939	7·6**	PT. 1921	14·3**
PT. 1722	20·65**	PT. 1923	1·67**	PT. 1928	3·98**	PT. 732/2	5·1**	PT. 1600	10·6**
PT. 1509	15·25**	PT. 1924	1·50**	IP. 241	3·02*	PT. 1509	4·7*	PT. 1939	9·5*
IP. 897	14·25**	PT. 1937	−1·63**	PT. 1931	2·98*	J. 126D_2B	−8·21**		
J. 126D_2B	−25·55**			MS. 6317	2·95*	PT. 734/5	−5·0**		
PT. 1610	*−19·35***					PT. 1577	−4·2*		
				Females		PT. 1513	−6·3**		
Nil	—	Nil	—	Nil	—	MS. 5141A	1·04*	Nil	—
						Tift. 23D_2A	−1·04*		

*Significant at $P=0 \cdot 05$; **Significant at $P=0 \cdot 01$.

nations (Tift. $23D_2A \times$ J. $126D_2B$ and MS. 5141A $\times$ J. $126D_2B$) for dwarfness and one (Tift. $23D_2A \times$ PT. 734/5) for tillering were found to be specific combiners. It could be seen that both the specific combiners for dwarfness involve 'J. $126D_2B$' which is a general combiner for that character. This inbred, which is a sterility maintainer in A_1 cytoplasm is known for its downy mildew resistance, dwarf plant habit, long panicles and bold grains. Hence, 'J. $126D_2B$' can serve as an useful material for improvement of other maintainers like 'Tift. $23D_2B$' and 'MS. 5141B' through recombination breeding without losing the dwarfness in the progeny.

In heterosis breeding involving cytoplasmic-genic male-sterile system, information on fertility restoration capacity of the tested inbreds is vital for further breeding. The 40 inbreds used as male parents were classified as restorers, non-restorers and partial restorers based on the data on pollen fertility in the hybrids (Table 2). There were eight restorers, 11 non-restorers and 21 partial restorers. Partial restoration may either be due to weak restorer genes or to the absence of complete homozygosity for the genes in the inbreds concerned. Of the inbreds identified as good general combiners for various characters 'PT. 1921', 'PT. 1610' and 'PT. 732/2' were full restorers while 'J. $126D_2B$' and 'PT. 734/5 were complete non-restorers. Because of high combining ability present in these lines, they can be used as parents in a breeding programme for improving the existing restorers and non-restorers respectively, apart from using them directly as parents for hybrids. The other two high combining inbreds 'PT. 1600' and 'PT. 1939', were partial restorers. Selfing followed by selection for fertility restoration or otherwise has to be practised in these lines if they are to be made useful in a breeding programme.

The present study has established that 'MS. 5141 A' is as good a general combiner for yield and other attributes as 'Tift. $23D_2A$'. In fact, 'MS. 5141A' has been found to be a better combiner for number of grains per cm^2. Thus 'MS. 5141A', the downy mildew resistant male-sterile line, has proved itself as a suitable replacement for 'Tift. $23D_2A$' which is highly susceptible to downy mildew.

Summary

In a top-cross analysis for combining ability in pearl millet with Tift. $23D_2A$ and MS. 5141A as females and 40 other inbreds of diverse origin as males, no difference in general combining ability was found between the females for yield, plant height, number of productive tillers and panicle length. MS.5141A was found to be a better combiner for number of grains per cm^2. Among the males, general combiners that could produce superior hybrids with both the male-sterile parents were found for all the five characters studied. PT. 1921, PT. 1600 and PT. 1939 were the general combiners for yield. With the exception of three hybrids, specific combining ability was not generally observed in the present study. The results confirm that MS. 5141A, the downy

mildew resistant male-sterile line, is a suitable replacement for the downy mildew susceptible Tift. $23D_2A$.

The male parents were classified as restorers, non-restorers and partial restorers and the usefulness of these inbreds falling under high combining category is outlined.

REFERENCES

Kempthorne, O. (1957). *An Introduction to Genetical Statistics.* John Wiley and Sons, Inc., New York.

Pokhriyal, S. C., K. V. Unnikrishnan, Balzor Singh, Ram Dass and R. R. Patil. (1976). Combining ability of downy mildew resistant lines in pearl millet. *Indian J. Genet.*, **36**: 403–9.