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HETEROSIS AND COMBINING ABILITY IN RELATION TO CYTOPLASMIC DIVERSITY IN PEARL MILLET

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ABSTRACT

In pearl millet (*Pennisetum glaucum*) several sources of cytoplasmic male-sterility (CMS) are available. This investigation was undertaken to study the combining ability of alloplasmic isonuclear lines and to quantify the magnitude of heterosis in hybrids based on different CMS sources. Such information is ultimately helpful in determining the relative chances of success with any CMS source. The lines with A3 and A4 cytoplasms were significantly better general combiner for grain yield than the lines retaining either A1 male-sterile or fertile cytoplasm. Pollinators IPC 1173, IPC 1600, IPC 1546 and IPC 390 proved their utility for breeding high yielding hybrids. None of the pollinators proved to be good combiner simultaneously for all traits. Magnitude of heterosis varied considerably within the hybrids retaining particular cytoplasm. Heterosis was negative for days to flower and of the similar magnitude in the hybrids grouped by their cytoplasmic source. Manifestation of cytoplasmic effects was higher for heterosis for grain yield and plant height than heterosis for days to flower and panicle length. The usefulness of A4 CMS source is discussed, in the light of results obtained here and those already available, in pearl millet hybrid breeding programmes.

Key Words : *Pennisetum glaucum* - cytoplasmic male-sterility - male-sterility-inducing cytoplasm - general combining ability

In pearl millet (*Pennisetum glaucum* (L.) R. Br.) the highly stable A1 system of cytoplasmic male-sterility (CMS) is the principal source of male-sterility for hybrid seed production, though some other sources have also been reported. They are A2, A3 [1], A4 [2], A5 [3], violaceum [4] and Ex-Bornu [5]. Among these A4 seems highly promising because of being the most stable [2]. Isonuclear lines have been established in the background of A1, A2, A3 and A4 CMS systems providing the opportunity for studying the cytoplasmic effects in the common nuclear genetic background. These male-sterility-inducing cytoplasms were similar or slightly better than the fertile cytoplasm in their effects for grain yield and other yield contributing traits [6].

In any hybrid breeding programme based on several CMS sources, the information on the combining ability of alloplasmic lines and the relative magnitude of heterosis in cytoplasmically diverse hybrids is helpful in determining the relative chances of success with any source. There are indications that cytoplasm exhibits pronounced effects on heterosis and combining ability [7, 8]. This investigation was undertaken to study the combining ability of alloplasmic isonuclear lines of pearl millet. The second objective was to quantify the magnitude and direction of heterosis in hybrids carrying different cytoplasms.

MATERIALS AND METHODS

In this study, five isonuclear lines were used which included male fertile 81B containing normal cytoplasm and four male-steriles, 81A1, 81A2, 81A3 and 81A4. The four male-sterile lines were developed by at least six successive backcrossing of the nuclear genome of 81B into the background of A1, A2, A3 and A4 male-sterility-inducing cytoplasms. 81B maintains the sterility of all the four male-sterile lines.

All five isonuclear lines were crossed to 12 genetically diverse pollinators. The 60 hybrids produced, thereof, along with the parental lines were grown at Jodhpur as rainfed in a randomized block design with three replications. Each entry was grown in 4m long four row plots. The rows were spaced 60 cm apart and a plant-to-plant distance of 20 cm was maintained within rows. The experiment received a fertilizer dose of 40 Kg N and 20 Kg P_2O_5/ha. The central two rows were used for recording the data to avoid border effects.

Days to flowering was recorded as the point at which stigma emerged in the main panicles of 50% plants in a plot. Grain yield (Kg/ha) was recorded on plot basis. Plant height (cm) and main panicle length (cm) were recorded on five competitive plants, randomly selected in each plot at maturity. Data were analyzed following the line × tester design [9] to obtain the combining ability estimates. Heterosis in hybrid [F1] was estimated over mid-parent (MP) as [(F1-MP)/MP] × 100.

RESULTS AND DISCUSSION

Mean squares due to hybrids and parents were highly significant for all traits (data not presented) indicating sufficient genetic variation in parental lines and hybrids for all characters. Highly significant mean squares due to single d.f. contrast 'parents vs hybrids' showed presence of heterosis in hybrids for all traits. Mean squares due to lines were significant for grain yield only while those due to pollinators were significant for other traits too. These results indicated diversity among pollinators for grain yield and other traits, and among lines only for grain yield.

General combining ability (GCA) effects for grain yield were significant and positive in A3 and A4 cytoplasms, nonsignificant for A2 and significant and negative for A1 (Table 1). The lines with A3 and A4 cytoplasms were significantly better combiner for grain yield than the lines retaining normal and A1 male-sterile cytoplasm. This suggests the superiority of A3 and A4 cytoplasms over A1 for producing higher yielding hybrids. The line 81A2, on the other hand, proved to be average combiner for grain yield. These results showed the good differences in the combining ability of lines retaining different male-sterile cytoplasms. This finding is consistent with the observation of Virk and Brar [10] and Yadav [8] who reported that the combining ability of pearl millet lines is strongly influenced by the type of cytoplasm they carried. Significant effect of cytoplasm on the combining ability has also been demonstrated in rice [7].

Since the differences in the combining ability could arise as a result of cytoplasm-nuclear interactions [8], male parents should also be considered in evaluation. The pollinators IPC 1173, IPC 1600, IPC 1546 and IPC 390 exhibited significant and positive GCA effects for grain yield (Table 1) and thus proved their superiority for breeding high yielding pearl millet hybrids. Since in most of the pearl millet growing areas early maturing genotypes escape the moisture stress towards the end of the growing season, pollinators IPC 1600, IPC 107 and IPC 324 contributing earliness in their hybrids were good to average combiner for grain yield. On the other hand, IPC 1500 and IPC 94 that contributed lateness in their hybrids proved to be poor combiners for grain yield. A few other pollinators showed their utility for specific traits like IPC 1500, IPC 390 and IPC 1546 for increased plant height and IPC 107 and IPC 1170 for longer panicles. But none of the pollinators proved to be good combiner for all traits simultaneously. This emphasized the need of ranking traits and using the diverse seed parents for complimenting the pollinator parent of hybrids.

There was a wide range in the magnitude of heterosis among crosses for all traits (Table 2). All the hybrids exhibited significant heterosis for grain yield and plant height. For days to flower and panicle length also 75-85% crosses showed significant heterosis. The direction of heterosis, however, varied among traits. Only for days to flower the heterosis was negative and for other traits it was positive. Mean heterosis was highest for grain yield. Manifestation of heterosis for other traits was not that high indicating that most heterotic trait was grain yield. Earlier, heterosis in pearl millet has been reported in numerous studies for several productivity related traits [11, 12]. The heterosis estimates obtained here in hybrids retaining different male-sterility-inducing cytoplasms are within the range of these reports.

Table 1. General combining ability effects of pearl millet alloplasmic isonuclear lines and pollinators for four traits

Parent	Days to flower	Plant height	Panicle length	Grain yield
Lines				
81A1	–0.09	–1.82	0.06	–0.91*
81A2	0.49	–0.71	–0.38	0.03
81A3	0.29	1.85	–0.02	1.19**
81A4	–0.57	2.24	0.28	1.14**
81B	–0.12	–1.57	0.06	–1.46**
S.E. ±	0.22	1.60	0.38	0.36
Pollinators				
IPC 1173	–0.26	–5.34*	1.00	3.09**
IPC 1600	–1.99**	–7.80**	–1.00	2.18**
IPC 1500	4.01**	28.19**	–1.80**	–1.50**
IPC 107	–0.99*	4.19	3.67**	0.15
IPC 324	–0.92*	–6.88**	0.40	0.48
IPC 1546	0.74	8.99**	0.07	2.62**
IPC 1518	0.81	–7.68**	1.00	–0.75
IPC 1170	–1.06	1.32	2.53**	–0.59
IPC 94	1.34**	–0.54	–1.47*	–2.57**
IPC 1329	0.21	–10.48**	–1.93**	–2.01**
IPC 390	–1.12	10.86**	–1.33*	1.85**
IPC 1365	–0.79	–14.81**	–1.13	–2.95**
S.E. ±	0.45	2.47	0.59	0.56

*, ** significant at P = 0.05 and 0.01, respectively

Heterosis values for days to flower were consistently negative and of similar magnitude in the hybrids grouped by their cytoplasmic source. The negative heterosis for days to flower supports the repeated finding that heterosis for earliness in pearl millet is a general phenomenon [11]. The results obtained here suggest that heterosis for earliness is equally expressed in hybrids irrespective of their cytoplasmic source. Mean heterosis in hybrids grouped by cytoplasm type appeared to be of similar magnitude for panicle length also. But for plant height and grain yield the differences in hybrids grouped by their cytoplasmic source were relatively more pronounced. These results indicate that manifestation of cytoplasmic effects on heterosis was different for various traits. The considerable variation in expression of heterosis in hybrids based on various cytoplasm, particularly for grain yield, suggests that there exists ample opportunity to exploit these differences in pearl millet hybrid breeding to raise the productivity at higher levels than existing.

Table 2. Mean and range in heterosis (%) in pearl millet hybrids carrying different cytoplasms

Character		Line				
		81A1	81A2	81A3	81A4	81B
Days to flower	Mean	–6.6	–5.3	–7.0	–8.0	–6.7
	Maximum	1.0	1.5	3.6	–2.7	1.7
	Minimum	–12.9	–10.2	–11.6	–11.4	–10.9
Plant height	Mean	52.7	61.1	63.0	64.9	59.1
	Maximum	62.6	68.7	77.2	79.4	75.3
	Minimum	39.9	50.4	49.0	50.9	46.2
Panicle length	Mean	20.4	19.1	21.8	24.5	20.3
	Maximum	32.2	29.8	34.4	31.5	29.4
	Minimum	3.4	10.9	10.3	17.6	8.8
Grain yield	Mean	109.0	92.4	115.0	124.6	125.3
	Maximum	184.3	135.0	160.3	179.2	150.9
	Minimum	37.1	40.3	73.1	91.4	91.8

From among the hybrids based on various male-sterility-inducing cytoplasms A4 hybrids had maximum heterosis for grain yield followed by A3 hybrids indicating a distinct advantage of these cytoplasms over other sources. The combining ability analysis also supports this. However, other equally important consideration in the use of any CMS source at commercial scale is its stability. Elaborate studies conducted across wide range of environments have established that A3 source is highly unstable [13] and is thus commercial unviable. Thus, inspite of its discovery three decades ago no commercial hybrid based on this source has been released in India. On the other hand A4 source has been shown to be highly stable. Thus the results of this study on combining ability and heterosis and those on the stability [2, 13] suggest that A4 CMS source should provide a good opportunity to diversify the cytoplasmic base of pearl millet hybrids.

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