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HETEROSIS STUDIES IN DIVERSE CYTOPLASMIC MALE STERILITY SOURCES OF PEARL MILLET [*PENNISETUM GLAUCUM* (L.) R. BR.]

S. M. Rafiq*, B. Sunil Kumar and U. Prasada Rao[1]

Department of Plant Breeding, Annamalai University, Annamalainagar – 608 002 (Tamil Nadu) India.
[1]Head R & D Nuziveedu Seeds, Hyderabad – 500 100 (Telangana), India.

Abstract

Among the available sources of cytoplasmic male sterility only the A_1 source has so far been exploited for developing commercial hybrids in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. In the present study, heterosis over mid parent, better parent and standard check estimated in lines belonging to A_1, A_4 and A_5 cytoplasms for nine yield attributing traits. Heterosis was observed in all sources of cytoplasm for days to 50% flowering, days to maturity, plant height, no. of productive tillers per plant, panicle length, panicle girth, panicle weight, 1000-grain weight and grain yield per plant.

Key words : Heterosis, heterobeltiosis and yield contributing traits, pearl millet.

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] a cross pollinating, diploid (2n = 2x = 14) is the most drought tolerant warm season cereal crop grown as a staple food grain and source of feed and fodder on about 26 million hectares in Asia, Africa and Latin America. It is grown primarily under very hot and dry conditions in soils of low fertility and water-holding capacity where other crops fail completely. In India, pearl millet is the most widely cultivated cereal after rice and wheat. It is grown on more than 9.3 m. ha with production of 9.5 m. tones and productivity of 1,044 kg/ha (http://www.agricoop.nic.in). The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana, which account for nearly 90 per cent of the acreage under pearl millet. The grain production has increased from 3.5 to 9.5 m tones with 47.9% increase in production due to adoption of high-yielding cultivars and suitable agro-production technologies.

Pearl millet provides the main source of nutritious staple food grain, high-energy feed grain (for milch and draft animals, as well as for poultry, fish and other mono-gastric livestock) and green and dry fodder for ruminant livestock. It is also grown as a forage crop in south-eastern USA, Australia and Brazil. With substantial increase in pearl millet production in India especially during last three decades, additional pearl millet grain is being diverted to cattle feed in northern India, poultry feed in southern India and also in beverage industries. Though there are no base line surveys available, it is estimated that 40-50% of pearl millet grain is being diverted to be used in feed and other industries.

Exploitation of hybrid vigour is one of the most efficient means of elevating the productivity potential, particularly in cross pollinated crops. It is well established that the pearl millet hybrids perform better than open pollinated cultivars. High levels of heterosis for grain yield have been indicated in pearl millet (Rawat & Tyagi, 1989 and Ugale *et al*., 1989). The performance of a larger number of hybrids based on CMS lines under a wide range of agro-ecological conditions in India was demonstrated by Rachie *et al*. (1967). These hybrids were found to be superior to the parental lines as well as open-pollinated varieties and some of the best hybrids out yielded the controls by margins ranging from 75-200%. Cytoplasmic male sterility (CMS) is considered an efficient tool in pearl millet breeding. A_1, A_2, A_3 (Burton and Athwal, 1967), A_4 (Hanna, 1989), A_5 (Rai, 1995), violaceum (Marchais and Pernes, 1985) and Ex- Borne (Aken'Ova, 1985) are seven different CMS sources in pearl millet. Of these the A_1, A_2, A_3, Av, A_4 and A_5 are distinctly different CMS systems. All most all the single cross F_1 hybrids cultivated

****Author for correspondence*** : E-mail : smrafiq123@gmail.com

in India and USA are based on the A_1 CMS system and have contributed significantly in increasing productivity of pearl millet in India (Dave, 1987 and Talukdar *et al*., 1997). Although, other sources of CMS such as A_2, A_3, and A_4 were discovered, the A_1 source continues to be the most exploited source in commercial hybrid breeding (Yadav, 1994). Based on the history of hybrid development in India, it is evident that some popular hybrids, most importantly, HB 3, HB 4, BJ 104 and MBH 110, all were based on A_1 CMS system (Dave, 1987 and Govila, 1998) and had to be withdrawn from farmers' fields because of susceptibility to the downy mildew. A critical appraisal revealed that failure of these hybrids was mainly due to lack of diversity in the parental lines, as all the hybrids were first based on Tift 23 A_1 and then on 5141A_1 (Govila, 2001). Thus, a clear need is felt for diversification of the cytoplasmic bases of hybrids to reduce the potential hazards of vulnerability and also to provide opportunities for greater exploitation of hybrid vigour (Delorme *et al*., 1997).

Suitability of the many different sources of cytoplasm for development of successful pearl millet hybrids is also challenging as it requires stable male sterile female parents, maintainers for sterility and restorers for fertility restoration along with yield superiority. Hence, the present study was undertaken with the objective of estimating the heterosis in diverse cytoplasmic male sterile sources (A_1, A_4 and A_5) of pearl millet.

Materials and Methods

The material for the present study comprises of three female parents from diverse cytoplasmic male sterility sources (A_1, A_4 and A_5) obtained from International Crops Research Institute for Semi Arid Tropics (ICRISAT), Patancheru and 50 elite restorers developed in house Pearl millet breeding programme of Nuziveedu seed, Hyderabad. The three female parents ICMA99444 (A_1 cytoplasm), ICMA05666 (A_4 cytoplasm) and ICMA07999 (A_5 cytoplasm) and the 50 restorers of NB525, NB526, NB527, NB528, NB530, NB 580, NB590, NB595, NB600, NB611, NB612, NB614, NB616, NB619, NB624, NB627, NB645, NB647, NB648, NB652, NB653, NB654, NB656, NB657, NB667, NB670, NB693, NB714, NB717, NB718, NB720, NB732, NB733, NB734, NB737, NB747, NB782, NB785, NB788, NB789, NB797, NB799, NB803, NB805, NB809, NB812, NB815, NB816, NB826, NB827 along with one standard hybrid check (86M64) were sown at research and development farm, Nuziveedu seeds, Hyderabad. The crosses were developed by LxT mating design following Kempthorne (1957) method in *Kharif* and *Rabi*, 2014. The experiment (150 hybrids with one standard hybrid check -86M64) was conducted in the *kharif*, 2015, at R & D farm of Nuziveedu seeds, Hyderabad in RBD with three replications. Each hybrid was accommodated in 4m one row with a row spacing of 50 cm and plant to plant spacing of 15 cm. Uniform and recommended cultural practices were followed to raise agronomically well managed crop. The observations were recorded on five randomly selected competitive plants from each replication for 9 traits *viz*., days to 50 per cent flowering, days to maturity, plant height (cm), number of productive tillers, panicle length (cm), panicle girth (cm), panicle weight, 100 grains weight (g) and grain yield per plant (g). The expression of heterosis in 150 hybrids involving three lines and fifty testers was measured in terms of relative heterosis in relation to mid parents, heterobeltiosis in relation to better parent and standard heterosis in comparison with 86M64, the hybrid as the standard.

Results and Discussion

The analysis of variance for 53 parents (3 diverse cytoplasmic male sterile lines and 50 testers and 150 F_1 crosses) for the 9 characters related to grain yield and showed significant differences (table 1). The analysis of variance revealed presence of high amount of variability for all the characters. This is in the lines of expectation as the parental material comprised different cytoplasms like A_1, A_4 and A_5 and hence in the hybrids as well. Similar results were reported by Rai *et al*. (2006) and Tara Satyavathi *et al*. (2009).

Heterosis

Heterosis breeding has been recognized as the most suitable breeding methodology for augmenting yield in pearl millet. Selection of suitable parents and assessment of degree of heterosis in the resulting crosses forms an important step (Manga *et al*., 2004). The expression of heterosis in the cultivar crosses clearly indicates the agronomic potential of the hybrids (Ouendeba *et al*., 1993).

The number of heterotic crosses, range of heterosis and the best three crosses over mid parent *i.e*. heterosis, better parent *i.e*. heterobeltiosis and standard check *i.e*. standard heterosis for the nine yield and yield contributing traits are presented in table 2.

Heterosis may be desirable both in the positive and negative direction. For days to 50% flowering, the cross ICMA05666 × NB590 belonging to A_4 cytoplasm showed -18.21% of heterosis over mid parent, -7.91% heterobeltiosis over better parent and -20.98% standard heterosis over check 86M64. In case of days to maturity,

Table 1 : ANOVA for the pearl millet genotypes involved in the study.

Source of Variations	df	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of productive tillers/plant	Panicle length (cm)	Panicle girth (cm)	Panicle weight (g)	1000 grain weight (g)	Grain yield per plant (g)
Replicates	2	4.42**	15.45**	23.86**	1.05**	7.36**	4.42**	18.99**	0.24	28.55**
Treatments	202	68.00**	69.82**	2813.86**	1.06**	37.17**	0.57**	507.90**	7.50**	340.73**
Parents	52	78.40**	78.07**	1075.33**	1.90**	19.78**	0.60**	170.70**	6.77**	93.05**
Line	2	3.00**	2.12**	573.38**	0.86**	10.80**	0.13*	96.33**	0.49	64.67**
Testers	49	64.96**	64.58**	1070.84**	1.65**	19.81**	0.63**	174.94**	6.97**	86.67**
Line vs Testers	1	887.42**	890.86**	2299.30**	16.31**	36.13**	0.03	111.80**	9.42**	462.33**
Parents vs Crosses	1	5950.81**	6253.14**	369740.18**	0.29	1291.91**	9.34**	40667.02**	413.06**	23532.62**
Crosses	149	24.89**	25.44**	958.01**	0.77**	34.82**	0.50**	356.06**	5.04**	271.51**
Error	404	0.3	0.16	0.60	0.82	0.54	0.30	0.17	1.03	3.0

'*' significant at 5% and '**' significant at 1%

the cross ICMA05666 x NB619 belong to A_4 cytoplasm recorded -12.69% heterosis. The cross ICMA05666 × NB590 belonging to A_4 cytoplasm showed -12.42% heterosis over mid parent, -5.70 over better parent and -13.99% standard heterosis over standard check 86M64. The negative heterosis denotes earliness and is a desirable mechanism of drought avoidance and disease escape under the short moisture availability period in the arid regions.

The cross ICMA99444 × NB670 belonging to A_1 cytoplasm exhibited significant heterosis (90.14%) and heterobeltiosis (83.25%) and the cross ICMA07999 × NB527 belonging to A_5 cytoplasm showed standard heterosis of 41.28% for plant height.

For number of productive tillers, the cross ICMA05666 × NB737 belonging to A_4 cytoplasm, recorded heterosis 38.46% and standard heterosis 101.39% over the standard check 86M64.

For panicle length, the cross ICMA07999 × NB614 belonging to A_5 cytoplasm showed heterosis (67.80%), heterobeltiosis (60.71%) and 55.01% for standard heterosis. The cross ICMA07999 × NB815 belonging to A_5 cytoplasm showed significant 65.28% heterosis, 55.97% heterobeltiosis and 52.50% standard heterosis for panicle girth.

The cross ICMA05666 × NB612 belonging to A_4 cytoplasm showed significant 79.97% heterosis, 76.79% heterobeltiosis and 57.28% standard heterosis for panicle weight.

For 1000 grain weight the cross ICMA07999 × NB527 belonging to A_5 cytoplasm recorded 50.00% heterosis, the cross ICMA05666 × NB619 belonging to A_4 cytoplasm showed 31.31% for heterobeltiosis and 46.28% over standard heterosis (86M64).

For grain yield, high heterosis was observed in ICMA05666 × NB827 (102.21%) belonging to A_4 cytoplasm. Same hybrid (ICMA05666 × NB827) exhibited more heterosis (28.57%) for number of productive tillers per plant. The hybrid ICMA05666 × NB527 belonging to A_4 cytoplasm recorded significant high heterosis (101.44%) for grain yield also exhibited high heterosis (73.44%) for panicle weight. The cross ICMA05666 × NB624 belong to A_4 cytoplasm recorded significant high heterosis (92.31%), heterobeltiosis (76.82%) for grain yield also recorded high heterosis (79.32%), hererobeltiosis (78.14%) for panicle weight. The cross ICMA05666 × NB527 belonging to A_4 cytoplasm and the cross ICMA99444 × NB526 belong to A_1 cytoplasm showed 67.37% and 54.91% standard heterosis (over check 86M64), respectively. Panicle weight and grain yield per plant exhibited highest heterotic values, which were in confermation with Vetriventhan *et al*. (2008), Dangaria *et al*. (2009) and Alidad Amiribezadi *et al*. (2012).

The general expectation of the pearl millet farmers is mainly focused on level of superiority of newly released hybrids than the local hybrids, which are grown widely. So, there is a compulsive need for the breeder to evaluate the newly developed

Table 2 : Heterosis over mid parent (heterosis) better parent (Heterobeltiosis) and standard check (standard heterosis) for the best three crosses belonging to A_1, A_4 and A_5 cytoplasmic sources of male sterility in pearl millet for various yield attributing traits.

Character	Heterosis over	Range of heterosis		Crosses	Heterosis %	Cytoplasm
		Minimum	Maximum			
Days to 50% flowering	Midparent	7.50	-20.11	ICMA 05666 × NB619	-20.11	A_4
				ICMA 05666 × NB590	-18.21	A_4
				ICMA05666 × NB718	-18.01	A_4
	Best Parent	25.35	-7.91	ICMA 05666 × NB590	-7.91	A_4
				ICMA05666 × NB718	-5.03	A_4
				ICMA99444 × NB826	-4.13	A_1
	Check	9.07	-20.98	ICMA 05666 × NB590	-20.98	A_4
				ICMA05666 × NB718	-17.28	A_4
				ICMA05666 × NB789	-9.45	A_4
Days to maturity	Midparent	4.42	-12.69	ICMA05666 × NB 619	-12.69	A_4
				ICMA 05666 × NB590	-12.42	A_4
				ICMA05666 × NB718	-11.82	A_4
	Best Parent	16.02	-5.70	ICMA 05666 × NB590	-5.70	A_4
				ICMA05666 × NB718	-3.51	A_4
				ICMA05666 × NB670	-2.63	A_4
	Check	7.20	-13.99	ICMA 05666 × NB590	-13.99	A_4
				ICMA05666 × NB718	-12.00	A_4
				ICMA05666 × NB670	-11.20	A_4
Plant height (cm)	Midparent	9.75	90.14	ICMA99444 × NB670	90.14	A_1
				ICMA07999 × NB527	89.67	A_5
				ICMA05666 × NB611	82.47	A_4
	Best Parent	-3.97	83.25	ICMA99444 × NB670	83.25	A_1
				ICMA05666 × NB611	81.43	A_4
				ICMA07999 × NB527	76.35	A_5
	Check	-14.45	41.28	ICMA07999 × NB527	41.28	A_5
				ICMA99444 × NB527	38.27	A_1
				ICMA07999 × NB528	38.08	A_5
No. of productive tillers/plant	Midparent	-56.25	38.46	ICMA05666 × NB737	38.46	A_4
				ICMA05666 × NB600	33.33	A_4
				ICMA05666 × NB827	28.57	A_4
	Best Parent	-66.67	-10.00	ICMA05666 × NB737	-10.00	A_4
				ICMA05666 × NB600	-10.00	A_4
				ICMA05666 × NB827	-10.00	A_4
	Check	-32.74	101.79	ICMA05666 × NB737	101.79	A_4
				ICMA05666 × NB600	101.79	A_4
				ICMA05666 × NB827	101.79	A_4

Table 2 continued...

Panicle length (cm)	Midparent	-13.76	67.80	ICMA07999 × NB614	67.80	A_5
				ICMA07999 × NB815	67.32	A_5
				ICMA07999 × NB624	62.35	A_5
	Best Parent	-18.64	62.48	ICMA07999 × NB815	62.48	A_5
				ICMA07999 × NB614	60.71	A_5
				ICMA07999 × NB624	58.61	A_5
	Check	-31.95	55.01	ICMA07999 × NB614	55.01	A_5
				ICMA07999 × NB815	52.28	A_5
				ICMA07999 × NB624	40.06	A_5
Panicle girth (cm)	Midparent	-32.68	65.28	ICMA07999 × NB815	65.28	A_5
				ICMA07999 × NB809	50.94	A_5
				ICMA07999 × NB657	48.61	A_5
	Best Parent	-41.89	55.97	ICMA07999 × NB815	55.97	A_5
				ICMA07999 × NB809	48.15	A_5
				ICMA07999 × NB527	44.44	A_5
	Check	-29.92	52.50	ICMA07999 × NB815	52.50	A_5
				ICMA07999 × NB826	43.49	A_5
				ICMA05666 × NB812	39.15	A_4
Panicle weight (cm)	Midparent	-11.38	79.97	ICMA05666 × NB612	79.97	A_4
				ICMA05666 × NB624	79.33	A_4
				ICMA0566 × NB527	73.44	A_4
	Best Parent	-16.74	78.15	ICMA05666 × NB624	78.15	A_4
				ICMA05666 × NB612	76.79	A_4
				ICMA05666 × NB527	71.57	A_4
	Check	-14.77	60.60	ICMA05666 × NB624	60.60	A_4
				ICMA05666 × NB647	59.07	A_4
				ICMA05666 × NB612	57.28	A_4
1000 grain weight (g)	Midparent	-17.24	50.00	ICMA07999 × NB527	50.00	A_5
				ICMA99444 × NB527	47.99	A_1
				ICMA99444 × NB654	45.45	A_1
	Best Parent	-22.99	31.31	ICMA05666 × NB619	31.31	A_4
				ICMA99444 × NB785	30.83	A_1
				ICMA07999 × NB526	29.04	A_5
	Check	-13.22	46.28	ICMA05666 × NB619	46.28	A_4
				ICMA99444 × NB627	44.84	A_1
				ICMA05666 × NB590	41.82	A_4
Grain yield (g)	Midparent	-15.67	102.21	ICMA05666 × NB827	102.21	A_4
				ICMA05666 × NB527	101.45	A_4
				ICMA05666 × NB624	92.33	A_4
	Best Parent	-24.75	92.30	ICMA05666 × NB827	92.30	A_4
				ICMA05666 × NB624	76.83	A_4
				ICMA05666 × NB527	75.65	A_4
	Check	-32.03	67.36	ICMA05666 × NB527	67.36	A_4
				ICMA05666 × NB647	61.67	A_4
				ICMA99444 × NB526	54.91	A_1

hybrids with such standard hybrids for yield or any other desirable characters. With this point of view, the hybrids generated in the present investigation were evaluated and selected on their standard heterosis values. The hybrid 86M64 was used as standard hybrid. The hybrid ICMA 05666 × NB827 belonging to A_4 cytoplasm expressed high heterotic value for number of productive tillers and grain yield per plant. The cross ICMA05666 × NB624 belonging to A_4 cytoplasm expressed significantly high standard heterosis for panicle weight and grain yield. The cross ICMA 05666 × NB527 belonging to A_4 cytoplasm and ICMA99444 × NB526 and belonging to A_1 cytoplasm were good for standard heterosis for grain yield. The cross ICMA05666 × NB647 belonging to A_4 cytoplasm was good for standard heterosis (over check 86M64) for panicle weight and grain yield.

The crosses ICMA05666 × NB624, ICMA05666 × NB647, ICMA99444 × NB526 were selected as best crosses, since they expressed high standard heterosis over standard hybrid (86M64) for grain yield.

Conclusion

The overall results of heterosis, heterobeltiosis and standard heterosis indicated that the parents involved in the crossing have contributed to the superior performance of the hybrid progenies. In the present study, the observed heterosis for different traits was contributed by the diverse nature of the female parents belonging to different cytoplasmic sources *i.e*. A_1, A_4 and A_5. The present study offers great scope for exploitation of the diverse cytoplasmic sources (A_4 & A_5) for development of high yielding superior performing hybrids of pearl millet on standard scale.

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