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RESEARCH ARTICLE

Evaluation of heterosis in pearl millet under rainfed condition

B. K. DAVDA, K. K. DHEDHI AND C. J. DANGARIA

SUMMARY

Eight CMS lines were crossed with 10 male parents in a line x tester design to study the extent of heterosis in pearl millet under rainfed condition. Heterosis was observed in both directions for most of the characters. The high standard heterosis was obtained for grain yield, harvest index, days to 50 per cent flowering, days to maturity and length of protogyny; medium level of heterosis was found for plant height and threshing index, and low for number of nodes per plant. The highest positive heterobeltiosis and standard heterosis for grain yield per plant was 262.15 and 41.05 per cent, respectively. The heterosis in grain yield might be contributed by the traits like number of nodes per plant, plant height, days to maturity and harvest index. Early hybrids *viz.,* ICMA-98333 x IPC-1518, JMSA-2005 x IPC-1501 and ICMA-00777 x IPC-1518 were the best heterotic hybrids for grain yield and its three or more component traits. Hence, these early maturing high yielding hybrids can be utilized further for commercial exploitation of hybrid vigour especially in rainfed area.

Key Words **:** Grain yield, Heterosis, *Pennisetum glaucum*, Line x tester, Rainfed condition

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Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is predominantly grown as the dual purpose crop, grain as well as fodder in marginal lands under erratic and poor rainfed conditions, and is amazingly tolerant to adverse environmental conditions. The phenomenon of heterosis is proved to be the most important genetic tool in enhancing the yield of self as well as cross pollinated crop species in general and pearl millet in particular. The exploitation of heterosis on commercial scale in pearl millet is regarded as one of the major breakthroughs in the improvement of its productivity. Development of Tift-23A male sterile source by Burton (1965) opened new vistas for the exploitation of heterosis on commercial scale in pearl millet. In genetic improvement, selection of better parents is one of the important steps for development of superior hybrids. The information on magnitude of heterosis, combining ability and gene action for grain yield and its components involved in inheritance is more helpful in selecting appropriate parents and desirable cross combinations for commercial exploitation of hybrid vigour. The present study was, therefore, undertaken to determine the extent of heterosis in pearl millet and to identify heterotic hybrids under rainfed condition.

MEMBERS OF THE RESEARCH FORUM

Author to be contacted :
K. K. DHEDHI, Pearl millet Research Station, Junagadh Agricultural University, JAMNAGAR (GUJARAT) INDIA
E-mail: kkdhedhi@rediffmail.com

Address of the co-authors:
B. K. DAVDA AND C. J. DANGARIA, Pearl millet Research Station, Junagadh Agricultural University, JAMNAGAR (GUJARAT) INDIA

MATERIALS AND METHODS

Eight male sterile lines *viz.,* JMSA-2005, Pb-214A, JMSA-20021, Pb-409A, ICMA-98333, ICMA-00777, ICMA-98777 and ICMA-99111 were crossed with 10 diverse restorer lines *viz.,* J-2340, J-2290, J-2439, J-2454, IPC-655, $IPCA_4R$-873, IPC-1518, $IPCA_5R$-873, IPC-1501 and H-77/833-2 in a line x tester mating design during summer-2002. The resultant 80 cross combinations alongwith fertile counter parts of eight male sterile lines, 10 pollinators and the standard check, GHB-558 were grown in a randomized block design with three replications during *Kharif*-2002 at Pearl millet Research Station, Junagadh Agricultural University, Jamnagar (Gujarat), India. Each entry was represented by a single row of 5.0 m length spaced at 60 cm x 15 cm. All the recommended cultural practices were followed for raising the good crop. Observations were recorded on ten randomly selected competitive plants for each entry, in each replication for various characters (Table 1). The extent of heterosis over better parent (heterobeltiosis as per Fonseca and Patterson, (1968) and the standard check, GHB-558 (standard heterosis) was worked out for each character.

RESULTS AND DISCUSSION

Pearl millet is grown in erratic conditions of rainfall in marginal lands. Early flowering and maturity is desirable in pearl millet for escaping the drought conditions. Hence, negative heterosis is useful for days to 50 per cent flowering, and days to maturity. In the present study, the degree of heterosis varied from cross to cross for all the characters studied. Heterosis for days to 50 per cent flowering ranged from -15.79 to 6.17 per cent and -17.24 to 6.32 per cent over better parent and standard check, respectively (Table 1). Out of 80 crosses studied, 28 and 34 exhibited significantly negative heterobeltiosis and standard heterosis, respectively. In respect to days to maturity, range of heterosis varied from -14.13 to 6.32 per cent and -13.24 to 1.47 per cent over better parent and standard check, respectively. The most of cross combinations manifested earliness for heterobeltiosis and standard heterosis. Of these, 17 and 44 crosses rendered significant heterosis in desired direction over better parent and standard check, respectively. A large number of crosses manifested significantly negative heterobeltiosis and standard heterosis for days to 50 per cent flowering and days to maturity, pinpointing thereby the existence of dominant genes for earliness. The high yielding hybrids *viz.,* ICMA-98333 x IPC-1518, JMSA-2005 x IPC-1501 and ICMA-00777 x IPC-1518 depicted significant standard heterosis in desired direction for days to maturity (Table 2). Gandhi *et al.* (1999) also reported desirable negative heterosis for days to flowering and days to maturity.

A short length of protogyny is desirable, because success of the commercial hybrid depends on good seed setting as one of the essential indices. Hence, this trait is important in imparting the synchrony between male and female parts, which is a must for successful fertilization, seed setting and ultimately grain yield realization. Therefore, negative heterosis in length of protogyny is desirable. The extent of heterosis over better parent was -18.18 to 43.66 per cent and over standard check -23.42 to 17.25 per cent for this trait. None of the cross combinations was found to be significantly superior for desirable heterosis over better parent. While, six crosses exhibited significant negative standard heterosis for length of protogyny. The cross combination JMSA-20021 x IPC-1501displyed the highest magnitude of heterosis in desirable direction consistently in both types of heterosis, though it was not significant with regards to heterobeltiosis. A large number of nodes are considered as a positive character, because the plant height is a desirable character in pearl millet. The heterobeltiosis and standard heterosis ranged form -14.15 to 37.35 per cent and -29.00 to 7.36 per cent for number of nodes per plant, respectively. None of the crosses showed significant positive standard heterosis, while, the nature of heterosis in all the significant 19 crosses was positive in case of better parental heterosis that clearly indicated the prevalence of dominance. Borkhataria (1999) have also reported the positive and significant heterosis for number of nodes per plant.

Plant height is regarded as a favourable character due to important role of stem as a source in supplementing assimilates during grain development (Joshi *et al.,* 2003). For heterobeltiosis and standard heterosis, the range lied between -15.08 to 45.09 per cent and -30.56 to 23.82 per cent for plant height, respectively. Out of 80 crosses studied, forty and five rendered significant positive heterosis over better parent and standard check, respectively. The high magnitude of heterosis and a large number of crosses exhibiting significant positive heterobeltiosis in plant height indicated predominantly the presence of over dominance. The present findings corroborate the findings of Singh and Sagar (2001), who also reported presence of over dominance. Significant positive heterosis in plant height has also been observed by Gandhi *et al.* (1999), Yadav (1999) and Sheoran *et al.* (2000). It is interesting to note that the hybrid ICMA-98333 x IPC-1518 had second rank in heterobeltiosis for plant height, also possessed the first rank in both types of heterosis for grain yield. The cross combination ICMA-00777 x IPC-1518 occupying third rank in heterobeltiosis both for number of nodes per plant and plant height, also had third rank in standard heterosis for grain yield, indicating the importance of both these traits towards the grain yield.

In case of harvest index, the range of heterosis was -14.31 to 44.62 per cent in heterobeltiosis and -15.04 to 33.18 per cent in standard heterosis. Most of the crosses displayed positive heterobeltiosis and standard heterosis. Of these, 27 and 12 rendered positive significant heterosis over better parent and standard check, respectively. The high degree of heterosis and a large number of crosses exhibiting positive heterosis revealed the presence of dominant alleles for harvest index. It is apparent that the cross combination ICMA-98333 x J-2290 had second rank in standard heterosis for harvest index, also occupied fifth rank in heterosis over standard check in grain yield (Table 2). This indicated the importance of harvest index in the expression of grain yield especially under rainfed condition. The predominant role of harvest index with respect to grain yield in pearl millet under rainfed condition has been reported by Joshi *et al.* (2005). Further, Nijhawan and Yadav (1993) and Deore *et al.*(1997) have also reported positive heterosis for harvest index. With regards to threshing index, the extent of heterobeltiosis and standard heterosis varied from -24.09 to 34.69 per cent and -23.83 to 14.06 per cent, respectively. Out of 80 crosses studied, thirty and four displayed significant positive heterobeltiosis and standard

Table 1 : Three best *per se* performing parents and three top ranking heterotic crosses alongwith range of heterosis and number of crosses showing significant heterosis in desired direction for various characters in pearl millet

Sr. No.	Characters	Best *per se* performing parents	Range of heterosis (%) BP	Range of heterosis (%) SC	Heterosis over better parent (BP) Best crosses	Heterosis	N*	Heterosis over standard check (SC) (GHB 558) Best crosses	Heterosis	N*
1.	Days to 50 %	ICMA 00777	15.79 to	17.24	ICMA 98333 x J 2454	15.79	28	ICMA 98333 x J 2454	17.24	34
	flowering	H 77/833-2	6.17	to	JMSA 2005 x J 2439	13.90		ICMA 00777 x IPC 655	13.22	
		J 2340		6.32	Pb 214A x IPC 1518	13.51		ICMA 00777 x IPCA$_4$R 873	13.22	
2.	Days to	Pb 409A	14.13 to	13.24	Pb 214A x J 2454	14.13	17	JMSA 2005 x J 2454	13.24	44
	maturity	JMSA 2005	6.32	to	Pb 214A x IPCA$_4$R 873	8.24		Pb 214A x J 2454	12.87	
		ICMA 00777		1.47	ICMA 98333 x J 2454	8.02		Pb 409A x IPC 1501	12.87	
3.	Length of	IPC 655	18.18 to	23.42	JMSA 20021 x IPC 1501	18.18	0	JMSA 20021 x IPC 1501	23.32	6
	protogyny	J 2340	43.66	to	ICMA 99111 x H 77/833-2	12.36		ICMA 00777 x J 2454	23.32	
		JMSA 2005		17.25	ICMA 00777 x IPCA$_4$R 873	11.96		JMSA 20021 x J 2454	22.36	
4.	No. of nodes	J 2439	14.15 to	29.00	ICMA 99111 x H 77/ 833-2	37.35	19	ICMA 99111 x IPC 1501	7.36	0
	per plant	IPCA$_5$R 873	37.35	to	ICMA 00777 x J 2340	32.14		ICMA 98777 x J 2290	7.36	
		J 2290		7.36	ICMA 00777 x IPC 1518	26.29		ICMA 99111 x J 2340	6.93	
5.	Plant height	IPCA$_5$R 873	15.08 to	30.56	JMSA 20021 x J 2340	45.09	40	ICMA 99111 x IPCA$_5$R 873	23.82	5
	(cm)	J 2439	45.09	to	ICMA 98333 x IPC 1518	34.94		Pb 214A x IPCA$_5$R 873	14.38	
		J 2290		23.82	ICMA 00777 x IPC 1518	30.13		Pb 214A x J 2290	10.11	
6.	Harvest index	J 2340	14.31 to	15.04	JMSA 20021 x IPCA$_5$R 873	44.62	27	ICMA 98777 x J 2454	33.18	12
	(%)	H 77/833-2	44.62	to	JMSA 20021 x IPCA$_4$R 873	38.97		ICMA 98333 x J 2290	15.32	
		ICMA 00777		33.18	ICMA 98333 x J 2454	38.68		JMSA 20021 x IPCA$_5$R 873	14.86	
7.	Threshing	ICMA 98333	24.09 to	23.83	ICMA 98777 x J 2454	34.69	30	ICMA 98777 x J 2454	14.06	4
	index (%)	ICMA 99111	34.69	to	ICMA 98777 x IPCA$_4$R 873	26.33		ICMA 99111 x IPC 655	10.01	
		IPC 1501		14.06	JMSA 20021 x IPC 1518	19.03		ICMA 98777 x IPCA$_4$R 873	8.88	
8.	Grain yield	J 2290	34.00 to	55.77	ICMA 98333 x IPC 1518	262.15	41	ICMA 98333 x IPC 1518	41.05	7
	per plant (g)	ICMA 99111	262.15	to	JMSA 20021 x IPC 1518	109.95		JMSA 2005 x IPC 1501	29.68	
		IPCA$_5$R 873		41.05	ICMA 98333 x IPC 1501	101.55		ICMA 00777 x IPC 1518	29.31	

*N - Number of crosses showing significant desirable heterosis

Table 2 : Promising hybrids along with their *per se* performance, heterosis, [illegible] SCA effects for grain yield and significant desirable heterosis for other traits in pearl millet

Sr. No.	Crosses	Grain yield Mean	Grain yield Heterosis over (%) BP	Grain yield Heterosis over (%) SC	Grain yield SCA	Days to maturity Mean	Days to maturity Heterosis over (%) BP	Days to maturity Heterosis over (%) SC	Traits showing significant heterosis in desirable direction BP	Traits showing significant heterosis in desirable direction SC
1.	ICMA 98333 x IPC 1518	51.67	262.15**	41.05**	14.52**	87	0.38	4.05*	ND, [illegible]	PH, DM, [illegible]
2.	JMSA 2005 x IPC 1501	41.50	88.24**	29.68**	13.40**	85	0.79	7.36**	DF, ND, PH, HI, TI	DM, HI, TI
3.	ICMA 00777 x IPC 1518	41.31	96.54**	29.31**	11.40**	82	5.04*	9.93**	DM, ND, HI	DM
4.	ICMA 98777 x J 2290	46.23	39.96**	26.22**	6.51**	92	4.96*	1.10	ND, PH, HI, TI	
5.	ICMA 98333 x J 2290	45.97	39.15**	25.49**	0.02	90	3.44	0.37	HI	HI
6.	JMSA 20002 x J 2290	44.67	35.22**	21.94*	4.39*	89	0.45	1.87	DF, HI	DF
7.	ICMA 00777 x J 2290	43.40	31.38**	18.48*	4.93	88	1.55	3.68		HI

* and ** indicate significance of values at P=0.05 and 0.01, respectively, DF : Days to 50 per cent flowering, ND : Number of nodes per plant, PH : Plant height, DM : Days to maturity, HI : Harvest index, TI : Threshing index

heterosis for this trait, respectively. The cross combination ICMA-98777 x J-2454 registered the highest values of heterosis over better parent and the standard check. Most of the crosses revealed significant heterosis in the positive direction focusing thereby the preponderance of dominant gene effect. The hybrid ICMA-98333 x IPC-1518 possessed third rank in heterobeltiosis for threshing index also had first rank in both types of heterosis for grain yield.

Grain yield represents the prime character of economic importance in pearl millet. A large number of crosses exhibited positive better parental heterosis with very high magnitude. In all, 41 crosses displayed significantly positive heterobeltiosis for grain yield per plant. The extent of heterosis ranged from -34.00 (ICMA-99111 x IPC-1518) to 262.15 per cent (ICMA-98333 x IPC 1518) over better parent and -55.77 (ICMA-00777 x IPC-655) to 41.05 per cent (ICMA-98333 x IPC-1518) over standard check. The identification and utilization of heterotic and useful crosses are very important in hybrid breeding approach in order to make commercial cultivation of hybrid beneficial. Among the 80 crosses studied, seven promising hybrids were significantly superior to standard check, GHB-558, in respect of grain yield per plant (Table 2). Of these, ICMA-98333 x IPC-1518 had the highest *per se* performance, ranking first in both types of heterosis for grain yield and also exhibited significantly high heterotic effects in desired direction for other component traits *viz.,* days to maturity, number of nodes per plant, plant height and harvest index. Similarly, the hybrid JMSA-2005 x IPC-1501 stood second in *per se* performance and standard heterosis, alongwith significantly high heterobeltiosis for grain yield per plant. This cross combination also depicted significant heterotic effects in desired direction for earliness, number of nodes per plant, plant height, harvest index and threshing index. Another high yielding hybrid ICMA-00777 x IPC-1518 had third rank in standard heterosis, coupled with significantly high heterobeltiosis for grain yield and it also registered significantly desirable heterotic effects for days to maturity, number of nodes per plant and harvest index. All these three hybrids also exhibited significant positive SCA effects for grain yield per plant, indicating the involvement of non-additive gene action in the heterotic response of the hybrids. Present findings are consistent with earlier results of Ramamoorthi and Jehangir (1995), Karale *et al.* (1997), Azhaguvel *et al.* (1998), Borkhataria (1999), Gandhi *et al.* (1999), Yadav *et al.* (2000), Sheoran *et al.* (2000) and Singh and Sagar (2001) who also reported very high magnitude of heterosis for grain yield in pearl millet.

Therefore, the early maturing high yielding hybrids *viz.,* ICMA-98333 x IPC-1518, JMSA-2005 x IPC-1501 and ICMA-00777 x IPC-1518 exhibited significantly high heterobeltiosis and standard heterosis, coupled with good SCA effects for grain yield. They also registered high heterosis for many yield attributing traits in desired direction. Hence, these early maturing high yielding hybrids can be utilized further for commercial exploitation of hybrid vigour especially in rainfed area.

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