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Research Article

Heterosis studies in pearl millet from diallel analysis

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Abstract : Eight diverse inbreds were crossed in a diallel fashion, including reciprocals, to study the extent of heterosis and to identify superior new inbreds with good combining ability in pearl millet. The magnitude of heterosis varied from cross to cross for all the characters studied. The high magnitude of standard heterosis was observed for grain yield per plant, number of effective tillers per plant, ear head weight and harvest index; while moderate to low heterosis over standard check hybrid (GHB-744) was found for rest of the traits under study. The highest positive heterosis for grain yield per plant over better parent and standard check was observed to be 77.82 and 42.91 per cent, respectively. The cause of heterosis in grain yield might be due to heterosis in its component traits, mainly, ear head weight and harvest index. The crosses *viz*., J-2454 x J-2467, J-2454 x J-2511 and J-2340 x J-2511 displayed high *per se* performance, high positive and significant standard heterosis, heterobeltiosis alongwith high SCA and involved atleast one good combiner parent. Therefore, these crosses may be segregates the favourable segregants in later generations for selection of superior inbred lines in pearl millet.

Key Words : Heterosis, *Pennisetum glaucum*, Diallel, Grain yield

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INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the most drought tolerant warm-season cereal crop predominantly grown as a staple food grain and source of feed and fodder. It provides nutritionally superior and staple food for millions of people living in harsh environments characterized by erratic rainfall and nutrient-poor soil. In fact, pearl millet is the only suitable and efficient crop for arid and semiarid conditions because of its efficient utilization of soil moisture and higher level of heat tolerance than sorghum and maize (Harinarayana *et al.,* 1999). Pearl millet is a highly cross-pollinated crop with protogynous flowering and wind borne pollination mechanism, which fulfils one of the essential biological requirements for hybrid development. The quantum jump (from 303 kg to 850 kg/ ha) in the productivity of pearl millet was possible mainly through development of hybrids by the utilization of cytoplasmic genetic male sterility system. Burton (1965) was the first to develop cytoplasmic male sterile line Tift 23A.This opened up a new field for hybrid seed production in pearl millet. In India first pearl millet hybrid HB-1 was released in 1965 and subsequently number of promising hybrids have been developed and released for general cultivation. However, the availability of suitable restorer is a limiting factor in the development of hybrids. Though the A4 and A5 sources were found to be highly stable, their utility is restricted due to non-availability of suitable restorers (Rai *et al.*, 2006). Hence, it is necessary to develop new inbred (restorer) lines and isolate the good combining inbreds for commercial exploitation of heterosis in pearl millet. Therefore, selection of parents and crosses for development of new inbred lines is most critical. Hence,

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the present investigation was undertaken to determine the extent of heterosis and to identify superior inbred lines in pearl millet.

EXPERIMENTAL METHODS

Eight genetically diverse inbreds of pearl millet *viz*., J-2290, J-2340, J-2405, J-2454, J-2467, J-2480, J-2511 and H-77/833-2 were crossed in all possible combinations (including reciprocals) during summer-2009. The resultant diallel set of fifty six cross combinations along with their eight parents and one standard check hybrid (GHB-744) were sown on 13th July during *Kharif* 2009, in a randomized block design replicated thrice at Main Millet Research Station, Junagadh Agricultural University, Jamnagar (Gujarat), India. Each entry was represented by single row plot of 5.0 m length. Border rows were planted at the extreme of each replication. Inter and intra row distance of 60 and 15 cm. was kept, respectively. The recommended agronomic practices and plant protection measures whenever necessary were adopted for raising the good crop. Observations were recorded on five randomly selected competitive plants for each entry, in each replication for 12 characters (Table 1). Days to flowering and days to maturity were noted on the basis of whole plot. The heterosis as percentage deviation from the better parent (heterobeltiosis) and the standard check, GHB-744 (standard heterosis) for each character were worked out as per the standard procedure given by Fonseca and Patterson (1968) and Meredith and Bridge (1972), respectively.

EXPERIMENTAL RESULTS AND ANALYSIS

The use of cytoplasmic genetic male sterility system has made it practically feasible to exploit heterosis on a commercial basis in pearl millet. The nature and magnitude of heterosis help in identifying superior cross combinations for their exploitation to obtain better transgressive segregants. In the commercial exploitation of hybrid vigour, excess of F_1 over standard check (hybrid) is of significance. Hence, in the present study, the extent of heterosis over standard check hybrid (GHB-744) for grain yield and 11 other component traits is discussed as under.

A perusal of Table 1 revealed that the degree and direction of heterosis varied enormously for grain yield and its attributing characters. Overall, the magnitudes of heterotic effects were high for grain yield per plant, number of effective tillers per plant, ear head weight and harvest index; whereas, days to flowering, days to maturity, ear head length and 1000-grain weight displayed moderate standard heterosis. Ear head girth, plant height, number of grains per square cm and dry fodder yield per plant exhibited the least heterotic values. Pearl millet being grown in erratic conditions of rainfall, the earliness in flowering and maturity are desirable in pearl millet for escaping the drought conditions. Hence, negative heterosis is useful for days to flowering and days to maturity. Heterosis over standard check (GHB-744) for days to flowering and days to maturity ranged from -13.85 to 10.25 per cent and -10.93 to 5.86 per cent, respectively. Out of 56 crosses studied, 11 and 13 crosses exhibited significant heterosis over standard check in desired direction for days to flowering and days to maturity, respectively. All the three top ranking standard heterotic crosses for days to flowering and days to maturity involved at least one early parent. Thus, they can be considered as the desirable parents having favourable alleles for earliness and to transmit to its progeny in desirable direction. A large number of crosses manifested significantly negative standard heterosis for earliness, suggesting thereby the existence of dominant genes for earliness. Similar results of heterosis for earliness in pearl millet were also observed by Vagadiya *et al*. (2010) and Manga and Dubey (2004).

In case of number of effective tillers per plant, the extent of heterosis over standard check ranged -46.19 to 77.14 per cent. The cross combination J-2340 x H-77/833-2 (77.14 %) recorded the highest positive standard heterosis followed by J-2480 x J-2340 (30.95 %) and H-77/833-2 x J-2480 (30.95%) for this trait. All these three best heterotic crosses possessed atleast one good *per se* performing parent for number of effective tillers per plant. The high magnitude of positive and significant standard heterosis in this trait indicated predominantly the presence of over dominance. The present findings corroborate the findings of Davda *et al.* (2008), Manga and Dubey (2004), Singh *et al.* (2004) and Singh and Sagar (2001) have also reported positive heterosis for number of effective tillers per plant.

With regards to ear head length, the standard heterosis ranged from -39.26 to 16.45 per cent. Out of 56 crosses, seven exhibited significant positive heterosis over standard check. Positive and significant heterosis for this trait had also been noticed by Davda *et al.* (2008), Manga and Dubey (2004), Singh *et al.* (2004), Sheoran *et al.* (2000) and Gandhi *et al.* (1999). Ear head girth is the major component of the ear head dimension, which is directly reflecting the grain yield. The range of standard heterosis varied from -31.79 to 5.46 per cent for ear head girth. None of the cross showed significant and positive standard heterosis for this trait. Heterosis for ear head girth in pearl millet as observed low in the present study was also reported by Davda *et al.* (2008) and Manga and Dubey (2004).

In case of ear head weight, the range of standard heterosis was -65.21 to 45.94 per cent. Out of total of 56

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

Sr. No.	Characters	Best *per se* performing parents	Range of standard heterosis (%)	Heterosis over standard check cross (GHB-744) (SC)		
				Best crosses	Heterosis	N*
1.	Days to flowering	J-2405	-13.85	J-2405 x H-77/833-2	-18.85**	11
		J-2454	to	J-2290 x J-2405	-12.65**	
		H-77/833-2	10.25	J-2405 x J-2290	-12.65**	
2.	Days to maturity	H-77/833-2	-10.93	J-2511 x J-2454	-10.93**	13
		J-2405	to	J-2405 x H-77/833-2	-10.15**	
		J-2454	5.86	J-2480 x J-2405	-8.98**	
3.	No. of effective tillers per plant	J-2290	-46.19	J-2340 x H-77/833-2	77.14**	3
		J-2340	to	J-2480 x J-2340	30.95*	
		H-77/833-2	77.14	H-77/833-2 x J-2480	30.95*	
4.	Ear head length (cm)	J-2290	-39.26	J-2290 x J-2511	16.45**	7
		J-2467	to	J-2467 x J-2511	15.76**	
		J-2454	16.45	J-2480 x H-77/833-2	15.57**	
5.	Ear head girth (cm)	J-2290	-31.79	J-2340 x J-2454	5.46	0
		H-77/833-2	to	-	-	
		J-2454	5.46	-	-	
6.	Ear head weight (g)	J-2467	-65.21	J-2480 x J-2290	45.94**	10
		J-2340	to	J-2454 x J-2467	43.43**	
		J-2405	45.94	J-2454 x J-2511	37.84**	
7.	Plant height (cm)	H-77/833-2	-43.26	J-2511 x J-2405	17.55**	3
		J-2454	to	J-2454 x J-2290	9.83**	
		J-2467	17.55	J-2290 x J2405	9.05*	
8.	No. of grains per square cm.	J-2467	-52.44	J-2480 x J-2290	4.37	0
		J-2340	to	-	-	
		J-2511	4.37	-	-	
9.	1000-grains weight (g)	J-2405	-35.21	J-2480 x J-2511	20.55**	2
		J-2467	to	J-2290 x J-2480	18.50**	
		J-2480	20.55	-	-	
10.	Dry fodder yield per plant (g)	J-2340	-53.17	H-77/833-2 x J-2511	10.77**	1
		J-2480	to	-	-	
		J-2405	10.77	-	-	
11.	Harvest index (%)	J-2467	-58.67	J-2340 x J-2511	37.09**	16
		J-2405	to	J-2467 x J-2480	36.16**	
		J-2340	37.10	J-2454 x J-2405	34.05**	
12.	Grain yield per plant (g)	J-2467	-78.26	J-2454 x J-2467	42.91**	5
		J-2340	to	J-2454 x J-2511	30.91**	
		J-2405	42.91	H-77/833-2 x J-2405	25.86**	

* and ** indicate significance of values at P=0.05 and 0.01, respectively *N =No. of crosses showing significant desirable heterosis

Table 2 : Five top standard heterotic crosses along with their *per se* performance, GCA and SCA effects for grain yield per plant and significant desirable standard heterosis for other traits in pearl millet

Sr. No.	Crosses	Grain yield/ plant (g)	Heterosis (%) over			SCA	GCA effects of parents		Significant and desirable heterosis over standard check in other traits
			MP	BP	SC		P_1	P_2	
1.	J-2454 x J-2467	69.07	53.42**	5.92	42.91**	9.69**	Poor	Good	EW, HI
2.	J-2454 x J-2511	63.27	109.47**	77.82**	30.88**	9.66**	Poor	Good	EW, HI
3.	H-77/833-2 x J-2405	60.83	39.82**	22.49**	25.83**	-16.25**	Poor	Good	DF, DM, EW, HI
4.	J-2340 x J-2511	59.77	37.21**	15.97**	23.73**	6.01**	Average	Good	EW, HI
5.	J-2290 x J-2467	55.40	15.20**	-15.04**	14.68**	2.24*	Average	Good	EW, HI

* and ** indicate significance of values at P=0.05 and 0.01, respectively MP=Mid parent, BP= Beller parent, SC=Standard check, DF = Days to flowering, DM = Days to maturity, EW = Ear head weight, HI = Harvest index.

crosses under study, ten showed significant positive standard heterosis for this trait. A large number of crosses exhibiting significant positive standard heterosis with very high magnitude revealed the prevalence of dominance and over dominance. The results are in close correspondence with the findings of Davda *et al.* (2008), Manga and Dubey (2004) and Singh and Sagar (2001). 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). The range of standard heterosis for plant height lied between -43.26 to 17.55 per cent. Only three crosses rendered significant positive heterosis over standard check for this trait. The number of positively significant heterotic crosses and magnitude of heterosis were low with respect to this character, indicating preponderance of partial dominance. Significant positive heterosis in plant height had also been reported by Sheoran *et al.* (2000) and Gandhi *et al.* (1999). The standard heterosis ranged from -52.44 to 4.37 per cent for numbers of grains per square cm. None of cross showed positive and significant heterosis over standard check for this trait.

Test weight being an important yield attributing character, use of high test weighted parental line in breeding programme may be most desirable. The range of standard heterosis was from -35.21 to 20.55 per cent. Out of 56 crosses, only two registered positive and significant standard heterosis for this trait. Vagadiya *et al*. (2010), Davda *et al.* (2008), Manga and Dubey (2004) and Singh *et al*. (2004) observed heterosis for this trait which confirmed the present findings. With respect to fodder yield, the range of standard heterosis varied from -53.17 to 10.77 per cent. Out of 49 significant crosses, only one manifested positive standard heterosis. Low heterosis for fodder yield was also reported by Davda *et al.* (2008) which confirmed the present result.

The role of partitioning of assimilates to the economic parts expressed, as harvest index is undisputed. The range of heterosis was -58.67 to 37.10 per cent in standard heterosis for harvest index. Of these, 16 rendered positive significant heterosis over standard check. Joshi *et al.* (2005) reported the predominant role of harvest index with respect to grain yield in pearl millet under rainfed condition. Further, Davda *et al.* (2008) and Manga and Dubey (2004) also reported positive heterosis for harvest index.

Grain yield is the character of economic importance for which considerable magnitude of heterosis was registered in a number of crosses. In all, 13 and 5 crosses manifested significant positive heterobeltiosis and standard heterosis, respectively. The magnitude of heterosis ranged from -55.15 (H-77/833-2 x J-2467) to 109.41 per cent (J-2454 x J-2511), -71.17 (J-2405 x J-2467) to 77.82 per cent (J-2454 x J-2511) and -78.26 (J-2405 x J-2467) to 42.91 per cent (J-2454 x J-2467) over mid, better parent and standard check, respectively.

Five top ranking crosses were identified for grain yield, based on *per se* performance from evaluation of 56 crosses (Table 2). The cross combination J-2454 x J-2467 had the highest *per se* performance, standard heterosis and high positive significant SCA effects and involved poor x good general combining parents. Similarly, the cross J-2454 x J-2511 had second rank in *per se* performance and standard heterosis, first rank in better parental heterosis as well as fifth position in SCA effects and involved poor x good GCA status. These indicated that involvement of predominantly non-additive gene effects with significant additive effects in the expressing grain yield and its attributes. These types of crosses can yield desirable transgressive segregants in further generations. The cross J-2340 x J-2511 displayed high *per se* performance, high estimates of standard heterosis, heterobeltiosis, high SCA and involved average x good GCA effects imply that involvement of predominantly both non-additive and additive gene effects in the expression of grain yield and its attributes. Such crosses can generate desirable transgressive segregants in later generations, if additive effect of one parent and complimentary epistatis effects of the other parent act in the same direction. It is interesting to note that the cross J-2454 x J-2467 had the highest standard heterosis in desired direction for grain yield also possessed the second rank in ear head weight. Similarly, another high heterotic cross *viz*., J-2454 x J-2511 for grain yield exhibited the third rank in ear head weight for standard heterosis. All the five high yielding crosses for grain yield exhibited significantly standard heterosis in desired direction for grain yield per plant, ear head weight and harvest index. The results indicated that the high heterotic effects of grain yield were mainly due to ear head weight and harvest index. Present findings are consistent with results of Vagadiya *et al*. (2010), Davda *et al.* (2008), Joshi *et al.* (2005), Manga and Dubey (2004), Singh *et al.* (2004), Singh and Sagar (2001) and Sheoran *et al.* (2000).

Therefore, all the three high *per se* performing crosses *viz*., J-2454 x J-2467, J-2454 x J-2511 and J-2340 x J-2511 exhibited significantly relative heterosis, standard heterosis, heterobeltiosis and SCA effects in desired direction for grain yield. They also registered significantly high heterosis in desired direction for some attributing traits. Hence, such crosses are likely to yield useful transgressive segregants in later generations for development of high yielding inbred lines in pearl millet.

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