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Heterosis for grain yield and quality characters in pearl millet (*Pennisetum glaucum* (L.) Br.)

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ABSTRACT

In present study Line x tester analysis was carried out to estimate all three types of heterosis (heterobeltiosis, averageand standard heterosis) for identification of superior cross combinations of pearl millet [Pennisetum glaucum (L.) R. Br.].Crosses attempted between 10 testers and four male sterile lines during summer, 2019. Forty hybrids along with four male sterile lines, 10 testers and check MPMH 17 were grown at Research farm of AICRP on pearl millet, Mandor (Jodhpur) Rajasthan during kharif, 2019 and evaluated for thirteen characters. Analysis of variance revealed that sufficient genetic variability present among parents and hybrids for all the studied characters. The results indicated presence of significantly high heterosis in desirable direction for all the characters except grain yield per plant and harvest index (standard heterosis) and protein and iron content (heterobeltiosis). The hybrids, ICMA 94111 × RIB 37-40 S/17 and ICMA 96666 × RIB 16300 showed positive standard heterosis for grain yield per plant with desirable negative standard heterosis for days to 50 % flowering. The hybrid, ICMA 97111 × RIB 17 S/109 showed significant positive standard heterosis for plant height, panicle diameter, test weight and stover yield per plant over check MPMH 17.Hybrids, ICMA 96666 x RIB 16300 and ICMA 94111 x RIB 37-40 S/17 also had higher level of iron content and hybrid ICMA 96666 x RIB 16300 additionally had higher protein content.

Keywords: Pearl millet, heterosis, male sterile line, tester.

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an important cereal crop in arid and semi-arid region of the world.It is a diploid species having chromosomes number 2n=14 belongs to family Poaceae (Gramineae). In India, pearl millet is regarded as one of major source of dietary energy for poor farmers and consumers. It is also an excellent forage crop because of its lower hydrocyanic acid content than sorghum. The grain contains 8.5 to 15 % protein, 5.03 to 6.0 % fat, 1.05 to1.7 % crude fiber and 65 to 70 % carbohydrates. As a food crop, pearl millet grain possesses the highest amount of calories per 100 gram which is mainly supplied by carbohydrates, fats, and protein. Its grains have high densities of two most important micro-nutrients viz. iron 18 to 135 ppm and zinc 22 to 92 ppm (Rai *et al.*, 2012). For which widespread deficiency in human population had been reported worldwide, including India. Because of its cultivation largely in rainfed production systems, pearl millet growth is constrained several abiotic stress. Drought is the primary abiotic constraint and is caused by low and erratic distribution of rainfall. Hence, development of pearl millet cultivars suitable for rainfed and unpredictable low-rainfall situations has been priority area in crop management. Therefore, there is need to identify good parents and superior cross combinations for development of promising hybrids suited to various climatic conditions of the country. Heterosis breeding is the foremost breeding method for improvement in cross pollinated crops. Heterosis studies also help in rejecting a large number of crosses in F_1 generation itself and selecting only those having high yield potential. The identification of parental combinations that provide high heterosis for grain yield is the most important factor in hybrid development (Zhao *et al.*, 2015). Heterosis breeding provides an opportunity for utilization of available variability and generates new variability that is important for development of climate resilient hybrid varieties.

MATERIAL AND METHODS

Experimental material was developed through crosses between 4 lines (Male sterile lines) *viz.*, ICMA 94111, ICMA 96666, ICMA 97111and ICMA 97444 and10 testers (Restorer

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lines) *viz*.,RI 3135-18, RIB 494, RIB 17 S/109, RIB 16 S/111, RIB 16300, RIB 16296, RIB 17-20 S/17, RIB 33-36 S/17, RIB 37-40 S/17 and RIB 13-16 S/17in Line × Tester design during summer 2019. Subsequently, the resulting 40 F_1 crosses along with parents (lines and testers) and standard check (MPMH17) were evaluated at AICRP on pearl millet, Mandor (Jodhpur) Rajasthan during *kharif,* 2019. The sowing time of experimental material was done on 19 July 2019. Recommended cultural practices were adopted in order to raise a healthy crop. The observations were recorded on individual plant basis on five randomly selected plants from each replication for 13 characters *viz*; days to 50% flowering, days to maturity, plant height (cm), number of productive tillers per plant, panicle length (cm), panicle diameter (cm), 1000-grain weight (g), grain yield per plant (g), stover yield per plant (g), harvest index (%), protein content (%) (Nitrogen content was determined by the Kjeldahl method using a KEL PLUS distillation unit (Pelican Equipment, Chennai, India). The crude protein content of the sample was calculated as 6.25 times its nitrogen content and expressed as percentage.), iron content (ppm) and zinc content (ppm) (The iron and zinc estimation were done by using Atomic Absorption Spectrophotometer by following the method proposed by Jackson (1973). Heterosis was estimated for 40 hybrids for 13 characters using the formulae given by Fonseca and Patterson (1968) and Standard heterosis according to Meredith and Bridge (1972).

RESULT AND DISCUSSION

Analysis of variance (Table 1) revealed highly significant differences among parents and F_1 crosses for all 13 characters indicating existence of considerable genetic variability in the study material. The results indicated presence of significantly high heterosis in desirable direction for all the characters except grain yield per plant, number of productive tillers per plant and harvest index (positive standard heterosis) and protein content and iron content (positive heterobeltiosis), where the estimates of heterosis was numerically at par with standard check MPMH 17 (Table 2).Terms “positive” and “negative” heterosis indicated the trait value is increased or decreased as compared to the mean of the parents or to the better parent or best check, MPMH 17. Relative heterosis has less or no significance for plant breeders, so only heterobeltiosis and economic heterosis have been discussed. Development of high yielding genotypes but despite that earliness (negative heterosis for number of days to 50% flowering and days to maturity) is also a major breeding objective for pearl millet breeding. On the basis of estimates of better parent, mid parent and economic heterosis, top 3 best hybrids for 13 traits are presented in Table 2.

In pearl millet, earliness is desirable, therefore hybrids possessing negative heterotic effects were considered to be superior for days to 50 % flowering and days to maturity. The heterobeltiosisis varied from -9.93% (ICMA 94111× RIB 17 S/109) to 14.68% (ICMA 97444× RIB 37-40 S/17).Hybrid, ICMA 94111 × RIB 17 S/109 (-9.93 %), showed significant negative heterobeltiosisand was earlier in flowering than their respective early parents. The standard heterosis varied from -24.64% (ICMA 96666 × RIB 37-40 S/17) to -2.90% (ICMA 96666 × RIB 17 S/109). Hybrid ICMA 96666 × RIB 37-40 S/17 recorded maximum standard heterosis (-24.64%) followed by hybrid ICMA 94111 × RIB 37-40 S/17 (-21.74%) (Table 2). Similar findings were observed by Kapadia *et al.* (2016). For days to maturity also earliness is required and crosses with negative heterosis are desirable. Maximum significant negative heterobeltiosis was recorded by hybrid ICMA 94111 × RIB 17 S/109 (-8.23%). Hybrids, ICMA 96666 × RIB 37-40 S/17 (-8.68 %) and ICMA 94111 × RIB 3135-18 (-6.39 %) recorded maximum negative standard heterosis(Table 2).Similar findings were reported by Pawar *et al.* (2015).Tallness is desirable in pearl millet, the hybrids possessing positive heterotic effects were therefore considered to be superior.The highest positive significant heterobeltiosis was recorded by hybrid ICMA 96666 × RIB 16296 (51.38 %).The standard heterosis for plant height ranged from -4.60% (ICMA 97111 × RIB 37-40 S/17) to 14.77% (ICMA 96666 × RIB 13-16 S/17). Highest positive significant standard heterosis was recorded by hybrid ICMA 96666 × RIB 13-16 S/17(14.77 %) followed by hybrid ICMA 97111× RIB 17 S/109 (14.39 %) (Table 2). The current findings are in close association with results observed by Kapadia *et al.* (2016).

Higher number of productive tillers per plant is considered as a desirable trait.

Table 1: Analysis of variance (MSS) for grain yield and its component characters in pearl millet

Source of variation	DF	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of Productive tillers/plant	Panicle length (cm)	Panicle diameter (cm)	Test weight (g)	Grain yield per plant (g)	Stover yield per plant (g)	Harvest index (%)	Protein content (%)	Iron content (ppm)	Zinc content (ppm)
Replications	2	8.006	0.080	179.134	0.328	3.474	0.053	1.175	25.541	104.181	12.556	2.497	340.404	28.397
Genotypes	53	19.952**	16.072**	1575.664**	0.459**	19.615**	0.315**	7.283**	219.177**	532.409**	67.775**	5.661**	347.996**	213.382**
Parents	13	31.203**	34.383**	804.541**	0.788**	13.658**	0.401**	11.550**	47.493**	126.343*	103.070**	9.585**	709.903**	344.115**
Females	3	9.639*	8.222**	1196.003**	0.004	15.942**	0.086**	0.870	28.590	55.480	22.799	4.099*	273.811	270.853**
Males	9	37.319**	44.967**	726.086**	0.885**	11.237**	0.352**	13.359**	57.898**	126.202*	126.582**	12.032**	899.401**	399.339**
Females vs Males	1	40.860**	17.610**	336.252*	2.259**	28.600**	1.788**	27.311**	10.561	340.200*	132.273**	4.022	312.700	66.880*
Hybrids	39	12.972**	5.555**	256.379**	0.359**	10.297**	0.159**	4.480**	121.161**	285.073**	43.310**	4.489**	229.361*	175.229**
Parents vs Hybrids	1	145.889**	188.199**	63052.340**	0.080	460.489**	5.282**	61.123**	6273.665**	15457.370**	563.078**	0.353	269.958	1.821
Error	106	2.912	1.470	76.304	0.119	1.659	0.021	0.394	16.084	63.667	17.523	1.192	138.881	11.955

**, ** Significant at 5% and 1%, respectively*

Heterobeltiosis for number of productive tillers per plant ranged from -57.89% (ICMA 97111 × RIB 37-40 S/17) to 76.47% (ICMA 94111× RIB 16296).Hybrid ICMA 94111 × RIB 16296 (76.47 %) showed positive significant heterobeltiosis. However, hybrid ICMA 96666 × RIB 3135-18 (16.67) showed standard heterosis numerically at par with standard check MPMH 17 (Table 2). Similar results were reported in pearl millet by Jethva *et al.* (2012). For panicle length, the highest positive significant heterobeltiosis was recorded by hybrid ICMA 97444× RIB 37-40 S/17 (34.71 %) followed by ICMA 96666× RIB 16300 (25.16%). Standard heterosis for panicle length ranged from -22.01% (ICMA 94111× RIB 33-36 S/17) to 12.26% (ICMA 96666 × RIB 16300).Hybrid ICMA 96666 × RIB 16300 (12.26 %) showed maximum positive significant standard heterosis (Table 2). For panicle diameter, three hybrids, ICMA 94111 × RIB 17 S/109, ICMA 96666 × RIB 17 S/109, ICMA 97111 × RIB 17 S/109 (8.79 %) showed positive significant standard heterosisand also showed higher heterobeltiosis (10.00 %) (Table 2).Similar findings were reported by Jethva *et al.* (2012) and Kumar *et al.* (2017).

With respect to 1000-grain weight, the highest positive significant standard heterosis was recorded by hybrid ICMA 96666 × RIB 17 S/109 (66.04 %) followed by hybrid ICMA 97111 × RIB 17 S/109 (39.18 %) and hybrid ICMA 97444× RIB 3135-18 (11.45 %) showed positive significant heterobeltiosis (Table 2). The better parent heterosis for grain yield per plant ranged from -8.91% (ICMA 97444× RIB 16300) to 261.87% (ICMA 94111× RIB 37-40 S/17). For grain yield per plant the highest positive significant better parent heterosis was recorded by hybrid ICMA 94111× RIB 37-40 S/17 (261.87 %) followed by ICMA 94111 × RIB 16296

Table 2: Top 3 best performing hybrids based on the heterobeltiosis, average heterosis, and standard heterosis

Characters	Hybrids	Heterobeltiosis	Average heterosis	Standard heterosis
Days to 50 % flowering	ICMA 94111 × RIB 17 S/109	-9.93**	-10.25**	-7.79**
	ICMA 96666 × RIB 37-40 S/17	-4.59	-15.10**	-24.64**
	ICMA 94111 × RIB 37-40 S/17	-0.92	-13.60**	-21.74**
Days to maturity	ICMA 96666 × RIB 37-40 S/17	-0.50	-5.21**	-8.68**
	ICMA 94111 × RIB 17 S/109	-8.23**	-10.17**	-3.20*
	ICMA 94111 × RIB 3135-18	-5.96**	-8.69**	-6.39**
Plant height (cm)	ICMA 96666 × RIB 13-16 S/17	41.31**	49.79**	14.77**
	ICMA 97111 × RIB 17 S/109	30.61**	34.54**	14.39**
	ICMA 96666 × RIB 16296	51.38**	53.27**	11.78**
No. of productive tillers / plant	ICMA 94111 × RIB 16296	76.47**	87.50**	0.00
	ICMA 96666 × RIB 3135-18	6.06	42.86**	16.67
Panicle length (cm)	ICMA 96666 × RIB 16300	25.16**	25.94**	12.26**
	ICMA 97444 × RIB 37-40 S/17	34.71**	43.93**	-9.19*
Panicle diameter (cm)	ICMA 97111 × RIB 17 S/109	10.00**	13.14**	8.79*
	ICMA 96666 × RIB 17 S/109	10.00**	12.50**	8.79*
	ICMA 94111 × RIB 17 S/109	10.00**	16.74**	8.79*
1000-grain weight (g)	ICMA 97444 × RIB 3135-18	11.45**	30.83**	23.51**
	ICMA 96666 × RIB 17 S/109	7.49	23.44**	66.04**
	ICMA 97111 × RIB 17 S/109	-9.90*	5.37	39.18**
Grain yield per plant (g)	ICMA 96666 × RIB 16300	141.86**	198.56**	8.33
	ICMA 94111 × RIB 37-40 S/17	261.87**	299.31**	0.52
	ICMA 94111 × RIB 16296	218.75**	308.00**	-11.46
Stover yield per plant (g)	ICMA 94111 × RIB 37-40 S/17	152.90**	196.60**	37.40**
Harvest index (%)	ICMA 97444 × RIB 3135-18	22.75**	50.64**	-13.88
	ICMA 94111 × RIB 17 S/109	20.22**	21.18**	-0.54
Protein content (%)	ICMA 96666 × RIB 3135-18	10.07	15.91**	18.91**
	ICMA 94111 × RIB 16 S/111	4.24	4.73	14.77**
Iron content (ppm)	ICMA 96666 × RIB 17 S/109	8.20	23.37**	19.96**
Zinc content (ppm)	ICMA 97444 × RIB 16300	20.56**	52.55**	21.56**
	ICMA 97444 × RIB 37-40 S/17	3.00	20.43**	46.17**

*, ** Significant at 5% and 1%, respectively

(218.75 %). However, the hybrids, ICMA 96666× RIB 16300, and ICMA 94111 × RIB 37-40 S/17 showed non-significant positive standard heterosis (Table 2).The same result for heterobeltiosis has been earlier reported by Patel *et al.* (2016) and Bhasker *et al.*(2017).With respect to stover yield per plant the highest positive significant better parent heterosis (152.90 %) and standard heterosis (37.40 %) was recorded by ICMA 94111 × RIB 37-40 S/17 (Table 2).For harvest index, two hybrids,ICMA 97444 × RIB 3135-18 (22.75 %) and ICMA 94111 × RIB 17 S/109 (20.22 %) exhibitedhighly positive significant heterobeltiosis and average heterosis (Table 2). The economic heterosis for protein content ranged from -32.38% (ICMA 97111 × RIB 17 S/109) to 18.91% (ICMA 96666 × RIB3135-18).Hybrids ICMA 96666 × RIB 3135-18 (18.91 %) and ICMA 94111 × RIB 16 S/111 (14.77 %) displayed positive heterosis over the check for protein content and hybrid ICMA 96666 × RIB 17 S/109(19.96 %) exhibited significant positive economic heterosis for iron content. For zinc content, hybrid ICMA 97444× RIB 16300 (20.56 %) showed significant positive better parent heterosis and two hybrids, ICMA 97444 × RIB 37-40 S/17 (46.17 %) and ICMA 97444 × RIB 16300 (21.56 %) showed significant positive standard heterosis. The same result for standard heterosis has been earlier reported by Karvar *et al.* (2017), Sharma *et al.* (2019) and Warrier*et al.* (2020).

Based on the study it may be concluded that the hybrids namely ICMA 97444 × RIB 16300 and ICMA 97444 × RIB 37-40 S/17 exhibited positive standard heterosis for zinc content, whereas hybrids, ICMA 96666 × RIB 3135-18 and ICMA 94111 × RIB 16 S/111 exhibited positive standard heterosis for protein content with higher level of zinc and iron content as compared to standard check MPMH 17.These hybrids may be exploited for commercial cultivation to develop zinc rich hybrid with some compensation in yields to enrich malnutrition in poor people of the country. The hybrids, ICMA 94111 × RIB 37-40 S/17 and ICMA 96666 × RIB 16300 showed positive standard heterosis for grain yield per plant with desirable negative standard heterosis for days to 50 % flowering. The hybrid, ICMA 97111 × RIB 17 S/109 showed significant positive standard heterosis for plant height, panicle diameter, test weight and stover yield per plant. Hence, these hybrids may be exploited for commercial cultivation to have early maturing hybrids with higher grain and stover yield couple with higher iron and protein content suited to drier region of the country.

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