Estimation of Heterosis for Yield and Quality Traits in Pearl millet [*Pennisetum glaucum* (L.) R. Br.]

ABSTRACT

In this research thirty-three hybrids of pearl millet were developed in line x tester mating design using three CMS lines as females and eleven restorer lines as males during summer, 2022 and evolution of 33 hybrids and three checks in terms of heterosis during kharif, 2022 at Research farm of AICRP on Pearl Millet, Mandor (Jodhpur) Rajasthan. For all the traits Significant differences were found among various genotypes, parents and parent's *vs* hybrids. The hybrids ICMA 04999 × MIR 915, ICMA 94555 × MIR 1252 and ICMA 04999 × MIR 710 were used for grain yield per plant and hybrids ICMA 94555 × MIR 1252, ICMA 96333 × MIR 710 and ICMA 96333 × MIR 705-1 were advisable for fodder yield per plant. For zinc content, three hybrids like ICMA 94555 × MIR 606, ICMA 94555 × MIR 1106 and ICMA 94555 × MIR 1259 showed positive standard heterosis. Five topmost hybrids, namely ICMA 04999 × MIR 915, ICMA 94555 × MIR 1252, ICMA 96333 × MIR 710, ICMA 96333 × MIR 1253 and ICMA 04999 × MIR 525-2 were advantageous for grain yield per plant and fodder yield per plant because they had high *per se* performance and positive standard heterosis for both traits and also showed positive heterobeltiosis and standard heterosis for other traits. Therefore, these hybrids are of considerable practical importance which were proved to be superior over best standard

check.

Keywords: Heterosis, Fodder yield, grain yield, Line x Tester, Pearl millet

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is known as Bajra, Cat-tail and Bulrush millet. It is a major coarse grain cereal of dry land agriculture. It can grow in a wide range of ecological conditions like drought stress, high temperature and low fertility soils (Nambiar *et al*., 2011). It has been originated from Africa and belongs to the family poaceae (gramineae), sub family *Panicoideae*, genus *Pennisetum*. It is an annual, cross pollinated, diploid (2n=2x=14) C_4 plant species with protogynous flowering pattern and high photosynthetic efficiency. Pearl millet ranks sixth among the important cereal crop in the world next to rice, wheat, maize, barley and sorghum (Satyavathi *et al*., 2021). India covers an acreage of 7.57 million hectare contributing 10.86 million tonnes of production with the productivity of 1436 kg/ha (Anonymous 2020-21). Rajasthan covers an area of 4.32 million hectare, having production of about 4.53 million tonnes with the productivity of 1049 kg/ha (Anonymous 2020-21). Pearl millet is nutritionally superior than wheat, rice, maize and sorghum, so it is called as the power house of nutrition. It contains carbohydrates (60-78%), proteins (11.6%), lipids (5%), dietary fiber (1.2g/100g) with micronutrients like iron (2.80%), calcium (42mg), phosphorus (296mg), vitamins and mineral components including antioxidant such as ferulic acid and coumaric acid (Chapke *et al.,* 2018). Its alkaline properties retain even after being cooked and it is gluten free also, so it's perfect for acidity suffering people and gluten allergy (celiac disease). Heterosis refers to an increase in fitness and vigour of F_1 over parental values, which was first time reported by Koelreuter (1766) and the term coined by Shull (1914). Heterosis

breeding is essential for efficient hybrid breeding in pearl millet. Development of Tift-23A male sterile source by Burton (1965) opened new aspect for the utilization of heterosis on commercial scale.

MATERIALS AND METHODS

Thirty-three hybrids were developed through line x tester mating design using three CMS lines as females *viz.*, ICMA 04999, ICMA 94555 and ICMA 96333 and eleven restorer lines as males *viz.*, MIR 606, MIR 612, MIR 705-1, MIR 710, MIR 915, MIR 1106, MIR 1259, MIR 1252, MIR 1253, MIR 519-2 and MIR 525-2 during summer, 2022 and these hybrids, parents and three standard checks were evaluated during kharif, 2022 at Research farm of AICRP on Pearl Millet, Mandor (Jodhpur) Rajasthan. Thirty three hybrids, their corresponding parent and three standard checks *viz.*, HHB 67, MPMH-17 and MPMH-21 were recorded on five randomly selected plants in each replication for different characters *i.e.*, plant height (cm), number of effective tillers per plant, panicle length (cm), panicle diameter (cm), seed yield per plant(g), fodder yield per plant(g), 1000 grain weight(g), harvest index (%), iron content (ppm) and zinc content (ppm). Significance of difference among the genotypes for the characters studied, as suggested by Panse and Sukhatme (1978). The manifestation of heterosis in 33 hybrids and their parents was measured in terms of mid parent, better parent and standard heterosis in comparison with standard check HHB 67 (Imp.), MPMH 17 (Mandor Pearl millet Hybrid-17) and MPMH 21 (Mandor Pearl millet Hybrid-21).

RESULTS AND DISCUSSION

Analysis of variance (Supp.table-1) revealed that the mean sum of squares due to genotypes were significant for all the characters, which indicated sufficient genetic

variability present among the various genotypes for the different traits. For all the traits, the parents and the parents *vs* hybrids mean square value were significant. This suggested that the material that was used in this study expressed a significant amount of genetic variability and heterosis. The analysis of variance for thirty-three hybrids formed by crossing line x tester revealed that they also showed significant results for all the traits except for plant height and days to 50% flowering.

The primary criterion used to select better hybrids was mean performance value which indicated their real value. (Supp.table-2) gives the mean performance of parents and their hybrids for different traits like grain yield per plant, fodder yield per plant, iron and zinc content. Eighteen hybrids for grain yield per plant and six hybrids for fodder yield per plant were recorded as significantly superior to the best standard check.

Any breeding program, the main goal is to improve the yield. Therefore, the plant breeders are particularly interested in this trait. Thirty-three hybrids showed positive significant heterosis over better parent and mid parent. Seventeen hybrids displayed positive significant heterosis over the standard check. The range for heterobeltiosis falls within 65.40% (ICMA 96333 × MIR 606) to 701.28% (ICMA 04999 × MIR 915), average heterosis between 133.33% (ICMA 96333 × MIR 606) to 880.39% (ICMA 04999 × MIR 915) and standard heterosis between -36.21% (ICMA 94555 × MIR 1259) to 115.52% (ICMA 04999 × MIR 915), respectively (Table-1). These results are in close agreement with earlier findings of Patel *et al*. (2016), Bhasker *et al*. (2017) and Patil *et al*. (2021).

The magnitude of heterosis over better parent, mid parent and hybrid check for fodder yield per plant ranged from 0.00% (ICMA 94555 × MIR 1253) to 211.11% (ICMA 96333 × MIR 1253), 7.79% (ICMA 94555 × MIR 1253) to 268.42% (ICMA 96333 × MIR

1253) and -38.10% (ICMA 04999 × MIR 606) to 57.14% (ICMA 94555 × MIR 1252), respectively. Out of thirty-three crosses, twenty-nine, thirty-two and six crosses showed significant positive heterosis over better parent, mid parent and standard check, respectively for fodder yield per plant (Table-1). These results are in confirmation with Patel *et al*. (2016), Bhasker *et al*. (2017) and Pareek *et al*. (2020).

Quality traits like zinc content of the five hybrids *viz.*, ICMA 04999 × MIR 519-2 (0.20), ICMA 94555 × MIR 705-1 (7.04), ICMA 94555 × MIR 606 (30.27), ICMA 94555 × MIR 710 (16.52) and ICMA 96333 × MIR 1106 (8.04) showed positive heterobeltiosis and three hybrids *viz.*, ICMA 94555 × MIR 606 (3.88), ICMA 94555 × MIR 1106 (1.38) and ICMA 94555 × MIR 1259 (1.12) showed positive standard heterosis. For iron content none of the hybrids depicted positive standard heterosis and one hybrid ICMA 04999 × MIR 705-1(20.49) exhibited positive heterobeltiosis (Table-1). The results are in close proximity of partial agreement to Ladumor *et al*. (2018), Jeeterwal *et al*. (2017) and Barathi *et al*. (2022).

Table-1 Estimation of heterosis for grain yield per plant, fodder yield per plant, iron and zinc content in pearl millet

S.NO	Traits	Heterosis	Heterosis Range (%)	S.Ed.±	No. of desired hybrids
1	Grain yield per plant (g)				
		BP	65.40(ICMA 96333 × MIR 606) – 701.28(ICMA 04999 × MIR 915)	3.05	33
		MP	133.33(ICMA 96333 × MIR 606) - 880.39(ICMA 04999 × MIR 915)	2.64	33
		SC	-36.21(ICMA 94555 × MIR 1259) - 115.52(ICMA 04999 × MIR 915)	3.05	17

2	Fodder yield per plant (g)				
		BP	0.00(ICMA 94555 × MIR 1253)-211.11(ICMA 96333 × MIR 1253)	5.69	29
		MP	7.79(ICMA 94555 × MIR 1253) -268.42(ICMA 96333 × MIR 1253)	4.93	32
		SC	38.10(ICMA 04999 × MIR 606) -57.14(ICMA 94555 × MIR 1252)	5.69	6
3	Iron content (ppm)				
		BP	-46.55% (ICMA 04999 × MIR 1252)-20.49% (ICMA 04999 × MIR 705-1)	5.69	1
		MP	-38.27% (ICMA 96333 × MIR 1252)-23.36% (ICMA 04999 × MIR 519-2)	4.93	4
		SC	-61.93% (ICMA 96333 × MIR 122)--24.53% (ICMA 94555 × MIR 1259)	5.69	-
4	Zinc content (ppm)				
		BP	-40.28% (ICMA 96333 × MIR 915)-30.27% (ICMA 94555 × MIR 606)	1.87	2
		MP	-30.18% (ICMA 04999 × MIR 915)-51.10% (ICMA 94555 × MIR 606)	1.62	6
		SC	-36.21% (ICMA 04999 × MIR 525-2)-3.88% (ICMA 96333 × MIR 705-1)	1.87	-

A comparative study of the top three prospective hybrids with high *per se* performance for grain yield per plant, their respective standard heterosis and heterobeltiosis indicated that none of the hybrid combinations depicted positive and significant heterobeltiosis and standard heterosis for all the characters studied (Table-2). The cross combination of ICMA 04999 × MIR 915 exhibited high *per se* performance (83.33) and standard heterosis (115.52) and also showed significant and desired heterobeltiosis (701.28) for grain yield per plant. Furthermore, this cross combination showed positive and significant heterobeltiosis for number of effective tillers per plant, panicle length and diameter, 1000-

grain weight, fodder yield per plant and harvest index as well as positive standard heterosis for number of effective tillers per plant, 1000-grain weight, fodder yield per plant and harvest index. It also shows significant standard heterosis for number of effective tillers per plant and harvest index. The second-best hybrid ICMA 94555 × MIR 1252 showed significant desirable heterobeltiosis (320.37), standard heterosis (56.55) and mean performance (60.53) and also showed positive and significant heterobeltiosis for number of effective tillers per plant, panicle length and diameter, 1000-grain weight, fodder yield per plant, harvest index, and standard heterosis for number of effective tillers per plant, 1000-grain weight and fodder yield per plant. For the number of effective tillers per plant and fodder yield per plant this hybrid also showed significant standard heterosis. The cross combination ICMA 04999 × MIR 710 exhibited desirable heterobeltiosis (469.23), standard heterosis (53.10) and mean performance (59.20). The cross ICMA 04999 × MIR 710 also showed positive and significant heterobeltiosis for number of effective tillers per plant, panicle length and diameter, 1000-grain weight, fodder yield per plant and harvest index as well as standard heterosis for number of effective tillers per plant, 1000-grain weight and harvest index and significant standard heterosis for harvest index.

For fodder yield per plant, the hybrid ICMA 94555 × MIR 1252 showed maximum *per se* performance (110.00), standard heterosis (57.14) and also displayed positive heterobeltiosis for grain yield per plant, number of effective tillers per plant, panicle length and panicle diameter, 1000-grain weight and harvest index and significant heterobeltiosis for all these characters except for panicle diameter. Further, this hybrid depicted positive standard heterosis for grain yield per plant, number of effective tillers per plant and 1000-grain weight and significant standard heterosis for grain yield per plant and number of

effective tillers per plant. It was followed by another hybrid ICMA 96333 × MIR 710, that showed per se performance (96.67), standard heterosis (38.10) and also showed positive and significant heterobeltiosis for number of effective tillers per plant, panicle length and panicle diameter, 1000-grain weight, grain yield per plant, harvest index, and positive standard heterosis for grain yield per plant and 1000-grain weight and significant standard heterosis for grain yield per plant, which was lower than the hybrid ICMA 94555 × MIR 1252. The hybrid ICMA 96333 × MIR 705-1 depicted *per se* performance (95.33), standard heterosis (36.19) and showed positive and significant heterobeltiosis for the number of effective tillers per plant, panicle length and diameter, 1000-grain weight and grain yield per plant. Further, this hybrid exhibited positive standard heterosis for the number of effective tillers per plant and 1000-grain weight and significant standard heterosis for number of effective tillers per plant (Table-2).

Table-2 Top three prospective hybrids with high *per se* performance for grain yield per plant and fodder yield per plant and their respective standard heterosis, heterobeltiosis and positive heterotic effects for other traits

Traits	*Per se* performance	Better parent heterosis	Standard heterosis	Positive heterosis for other traits over better parent	Positive heterosis for other traits over standard check
Grain yield per plant (Hybrids)					
ICMA 04999 × MIR 915	83.33	701.28 **	115.52	ETI, PL, PD, TW, FYP, HI	ETI, TW, FYP, HI
ICMA 94555 × MIR 1252	60.53**	320.37 **	56.55**	ETI, PL, PD, TW, FYP, HI	ETI, TW, FYP

ICMA 04999 × MIR 710	59.20**	469.23 **	53.10**	ETI, PL, PD, TW, FYP, HI	ETI, TW, HI
Fodder yield per plant (Hybrids)					
ICMA 94555 × MIR 1252	110.00	98.80	57.14	ETI, PL, PD, TW, GYP, HI	ETI, TW, GYP
ICMA 96333× MIR 710	96.67	104.23	38.10	ETI, PL, PD, TW, GYP, HI	TW, GYP
ICMA 96333 × MIR 705-1	95.33	146.55	36.19	ETI, PL, PD, TW, GYP	ETI, TW

Fig-1 Positive standard heterosis for grain yield per plant and fodder yield per plant

For grain yield per plant and fodder yield per plant, all the top five hybrids like ICMA 04999 × MIR 915, ICMA 94555 × MIR 1252, I, ICMA 96333 × MIR 710, ICMA 96333 × MIR 1253 and ICMA 04999 × MIR 525-2 showed positive heterobeltiosis for the number of effective tillers per plant, panicle length and diameter, 1000-grain weight, grain yield per plant, fodder yield per plant and harvest index. Further, the hybrid ICMA 04999 × MIR 915 depicted positive standard heterosis for the number of effective tillers per plant, 1000-grain weight, grain yield per plant, fodder yield per plant and harvest index. Two hybrids, *viz.*, ICMA 94555 × MIR 1252 and ICMA 96333 × MIR 1253 showed positive standard heterosis for the number of effective tillers per plant, 1000-grain weight, grain yield per plant and fodder yield per plant. The hybrid ICMA 96333 × MIR 710 for 1000-grain weight, grain yield per plant and fodder yield per plant and for the number of effective tillers per plant, grain yield per plant, fodder yield per plant and harvest index, the

hybrid ICMA 04999 × MIR 525-2 exhibited positive standard heterosis (Table-3).

Table-3 Top five hybrids for both (grain and fodder yield per plant) with *per se* performance their respective standard heterosis and positive heterotic effects for other traits

Hybrids	*Per se* performance (GYP)	*Per se* performance (FYP)	Standard heterosis (GYP)	Standard heterosis (FYP)	Positive heterosis for other traits over better parent	Positive heterosis for other traits over standard check
ICMA 04999 × MIR 915	83.33	78.67	115.52 **	12.38	ETI, PL, PD, TW, GYP, FYP, HI	ETI, TW, GYP, FYP, HI
ICMA 94555 × MIR 1252	60.53	110.00	56.55**	57.14**	ETI, PL, PD, TW, GYP, FYP, HI	ETI, TW, GYP, FYP
ICMA 96333 × MIR 710	57.33	96.67	48.28**	38.10**	ETI, PL, PD, TW, GYP, FYP, HI	TW, GYP, FYP
ICMA 96333 × MIR 1253	55.73	93.33	44.14**	33.33**	ETI, PL, PD, TW, GYP, FYP, HI	ETI, TW, GYP, FYP
ICMA 04999 × MIR 525-2	58.60	75.33	51.55**	7.62	ETI, PL, PD, TW, GYP, FYP, HI	ETI, GYP, FYP, HI

Fig-2 Top five hybrids standard heterosis for grain yield per plant and fodder yield per plant

ABBREVIATIONS:

DF = Days to 50% flowering, **DM** = Days to maturity, **ETI** =Effective tillers per plant, **PL** = Panicle length, **PD** = Panicle diameter, **TW** = 1000-grain weight, **GYP** = Grain yield per plant,

FYP = Fodder yield per plant and **HI** = Harvest Index

CONCLUSION

The mean sum of squares due to genotypes, parents and parent's *vs* hybrids were significant for all the characters, which indicated sufficient amount of genetic variability. Among 33 hybrids, three hybrids like ICMA 04999 × MIR 915, ICMA 94555 × MIR 1252 and ICMA 04999 × MIR 710 were desirable for grain yield per plant and hybrids ICMA 94555 × MIR 1252, ICMA 96333× MIR 710 and ICMA 96333 × MIR 705-1 used for fodder yield per plant. All these hybrids were high per se performance for both characters and positive heterotic effect for other contributing traits. Three hybrids showed positive standard heterosis for zinc content. The hybrids *viz.*, ICMA 04999 × MIR 915, ICMA 94555 × MIR 1252, ICMA 96333 × MIR 710, ICMA 96333 × MIR 1253 and ICMA 04999 × MIR 525-2 had high per se performance and positive standard heterosis for grain yield per plant and fodder yield per plant and also showed positive heterobeltiosis and standard heterosis for other traits. Therefore, these five superior hybrids may be exploited commercially for getting benefits of heterosis for grain yield with fodder yield and its component traits in pearl millet.

ACKNOWLEDGMENT

I am very thankful to major advisor Dr. Vikas Khandelwal, Senior Scientist, AICRP on Pearl Millet, all advisory committee members for their kind cooperation and members of AICRP on Pearl Millet, Jodhpur provides me proper suggestions and facilities for my research work.

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Supp. table 1 Analysis of variance (M.S.S.) for seed yield and its component traits in pearl millet

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Number of effective tillers per plant	Plant height (cm)	Panicle length (cm)	Panicle diameter (cm)	1000-grain weight (g)	Seed yield per plant (g)	Fo pe
Replication	2	2.43	1.15	0.06	327.80	4.32	0.05	0.90	16.96	
Genotype	46	17.46**	18.20**	1.50**	1069.96**	23.70**	0.33**	8.29**	1079.28**	1
Parents	13	29.71**	15.15**	0.14**	424.15**	4.93**	0.14**	3.32**	20.59*	
Males (Lines)	10	17.61*	15.07**	0.17**	547.62**	5.24**	0.14**	3.35**	18.81	
Females (Testers)	2	87.44**	14.33**	0.01	5.08	1.99	0.20**	0.48	0.87	
Female *vs* Males	1	35.23*	17.55*	0.12	27.49	7.72*	0.02	8.66**	77.81**	
Parents *vs* Crosses	1	230.26**	201.16**	45.32**	40375.97**	736.21**	10.27**	217.71**	36140.55**	3
Crosses	32	5.83	13.72**	0.68**	104.01	9.06**	0.09**	3.77**	413.71**	
Line effect	10	6.16	25.67*	0.40	83.24	7.43	0.12	4.21	409.81	
Tester effect	2	0.21	0.67	0.42	38.94	3.47	0.01	0.32	245.07	
Line *vs* Tester effect	20	6.23	9.05**	0.85**	120.90	10.43**	0.09**	3.89**	432.52**	
Error	92	7.21	2.54	0.04	116.26	1.81	0.02	0.45	10.56	
Total	140	10.51	7.66	0.52	432.64	9.03	0.12	3.03	361.80	

*,**Significantat5%and1%,respective

Supp. table-2 Mean performance of parents and their hybrids

Parents	Grain yield per plant (g)	Stover yield per plant (g)	Iron content (ppm)	Zinc content (ppm)
Female parents				
ICMB 04999	11.53	22.00	28.73	35.07
ICMB 94555	10.40	24.00	37.13	37.63
ICMB 96333	10.20	29.33	25.53	21.20
Male parents				
MIR 606	8.00	26.67	18.17	22.33
MIR 612	8.00	37.33	35.77	33.10
MIR 705-1	9.00	26.00	42.17	42.77
MIR 710	14.40	55.33	26.10	30.30
MIR 915	15.80	38.67	33.73	34.90
MIR 1106	9.53	38.67	39.40	47.33
MIR 1259	8.93	26.00	36.27	33.60
MIR 1252	10.13	30.00	24.27	20.57
MIR 1253	7.53	20.67	36.20	32.67
MIR 519-2	6.60	47.33	40.53	33.60
MIR 525-2	7.53	28.80	29.93	30.83
Parents mean	9.82	32.2	6.44	32.56
Range	6.60- 15.80	20.67-55.33	5.47-7.43	20.57-47.33
Hybrids				
ICMA 04999 × MIR 606	36.87	43.33	33.00	28.07
ICMA 04999 × MIR 612	35.13	48.00	30.07	28.37
ICMA 04999 × MIR 705-1	44.93	50.00	36.07	32.47

ICMA 04999 × MIR 710	59.20	58.00	29.03	28.27
ICMA 04999 × MIR 915	83.33	78.67	25.27	24.87
ICMA 04999 × MIR 1106	34.67	58.67	29.23	33.83
ICMA 04999 × MIR 1259	34.60	52.00	31.93	25.40
ICMA 04999 × MIR 1252	41.87	64.67	21.67	25.83
ICMA 04999 × MIR 1253	42.67	75.33	27.33	29.40
ICMA 04999 × MIR 519-2	45.53	64.67	33.53	32.73
ICMA 04999 × MIR 525-2	58.60	75.33	31.60	24.67
ICMA 94555 × MIR 606	39.93	55.33	24.97	40.17
ICMA 94555 × MIR 612	54.07	50.00	32.00	32.13
ICMA 94555 × MIR 705-1	46.27	78.00	30.67	35.97
ICMA 94555 × MIR 710	35.33	69.33	28.67	38.57
ICMA 94555 × MIR 915	30.87	53.33	25.43	34.03
ICMA 94555 × MIR 1106	50.60	51.33	30.97	39.20
ICMA 94555 × MIR 1259	24.67	50.00	40.50	39.10
ICMA 94555 × MIR 1252	60.53	110.00	28.43	31.40
ICMA 94555 × MIR 1253	47.47	55.33	37.93	32.77
ICMA 94555 × MIR 519-2	51.80	76.67	25.57	26.57
ICMA 94555 × MIR 525-2	48.13	75.33	35.20	28.93
ICMA 96333 × MIR 606	26.13	55.33	34.30	31.23
ICMA 96333 × MIR 612	51.40	66.67	29.60	26.40
ICMA 96333 × MIR 705-1	34.73	95.33	29.23	31.33
ICMA 96333 × MIR 710	57.33	96.67	36.97	31.23
ICMA 96333 × MIR 915	45.33	70.00	27.00	28.27
ICMA 96333 × MIR 1106	37.33	56.67	33.73	36.30
ICMA 96333 × MIR 1259	42.27	75.33	31.63	32.77
ICMA 96333 × MIR 1252	44.67	83.33	20.43	26.63
ICMA 96333 × MIR 1253	55.73	93.33	23.83	30.90
ICMA 96333 × MIR 519-2	31.73	82.00	22.90	31.03
ICMA 96333 × MIR 525-2	45.87	73.33	23.37	24.97
Checks				
HHB 67	34.27	55.33	53.67	38.67
MPMH- 21	37.80	70.00	40.67	35.30
MPMH- 17	38.67	56.67	40.67	33.67
General mean	34.56	57.48	31.42	31.75
Hybrid range	24.66-83.33	43.33-110.00	20.43-40.50	24.67-40.16
C.V.%	9.14	11.72	8.93	8.93
S.Em. ±	1.82	3.89	1.64	1.64
C.D. (0.05)	5.12	10.91	4.60	4.60