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RESEARCH ARTICLE

Gene action studies in pearl millet (*Pennisetum glaucum* L.)

■ **S. B. Borgaonkar, J. E. Jahagirdar, H. V. Kalpande and D. K. Patil**

SUMMARY

The present investigation on "Studies on heterosis for yield and its components in pearl millet (*Pennisetum glaucum* L.)" was conducted during *Kharif*-2020, at Department of Agriculture Botany, Vasantrao Naik Krishi Vidyapeeth, Parbhani, National Agricultural Research Project, Aurangabad and College of Agriculture, Golegaon. The experimental material included in the present study comprised of five females (lines) and twelve restorers (testers) and sixty crosses. The experimental material was evaluated for twelve characters *viz*., days to 50% flowering, days to maturity, earhead length (cm), earhead girth (cm), number of nodes per plant, plant height (cm), total number of tillers per plant, number of effective tillers per plant, Fe content (ppm), Zn content (ppm), grain yield per plant (g) and grain yield per hectare (kg). The range of heterobeltiosis was from -33.13 % to 78.20 %. In case of heterobeltiosis, twenty-two crosses showed positive significant heterobeltiosis for grain yield per plant. The cross 02888 X 15006R displayed highly significant standard heterosis over AHB 1200 (43.45 %), AHB 1666 (72.14 %) and Dhanshakti (68.53 %). The standard heterosis for grain yield per plant ranged from -36.31 % to 72.14 %. The other crosses having highly significant and positive standard heterosis were 99111A X 15713R (41.07 %, 69.29 % and 65.73 % over standard check AHB 1200, AHB 1666 and Dhanshakti), 99111A X 15020R (39.29 %, 67.14 % and 63.64 % over standard check AHB 1200, AHB 1666 and Dhanshakti), 02333A X 15183R (36.31 %, 63.57 % and 60.14 % over standard check AHB 1200, AHB 1666 and Dhanshakti) and 02333A X 15351R (37.50 %, 65.00 % and 61.54 % over standard check AHB 1200, AHB 1666 and Dhanshakti).

Key Words : Heterosis, Heterobeltiosis, Standard heterosis

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Pearl millet [*Pennisetum glaucum* (L.)] is a monocot species belonging to the family *Poaceae* and sub family *Panicoideae*, having relatively small diploid genome (2n = 2x = 14). Pearl millet is well-adapted to growing areas characterized by drought, low soil fertility, and high temperatures. It performs well in soils having high salinity or low pH. On account of its tolerance of difficult growing conditions, it can be grown in areas where other cereal crops such as sorghum and maize cannot even survive. Pearl millet is being grown in arid

and semi arid regions of the world including West Africa, India and Pakistan with the rainfall ranging from 150-700 mm. It thrives well in regions with seasonal rainfall in 150-700 mm range. Pearl millet is an important crop in dryland agriculture in India. The grain contains high protein, a balanced amino acid profile, high levels of iron, zinc and insoluble dietary fibre. Millets are the cereal crops generally small-seeded and known for high nutritive value. India is a major pearl millet producing country with 43.3 per cent of the world's area and 42 per cent of world's production. It is mainly cultivated in the states of Rajasthan, Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, Uttar Pradesh and Tamil Nadu on a total area of 7.41 million hectares with the production of 10.3 million tones and national average productivity of 1391 kg/ha. While in Maharashtra, it is grown on an area of 6.37 lakh hectares with an annual production of 8.16 lakh tonnes. The state average productivity is 1282 kg/ha (Anonymous, 2021). During the past three decades, single-cross F_1 hybrids based on cytoplasmic-nuclear male sterility (CMS) system have contributed significantly in increasing pearl millet productivity in India. So far very limited research work has been carried out on these lines. Considering the importance of the crop and the above facts, there is need to generate information on heterosis stability analysis for yield and yield contributing traits. The information about heterotic pattern of the current breeding material generated in *Kharif* 2019 and evaluated in *Kharif* 2020 to create new hybrids with grain yield potential.

MATERIAL AND METHODS

The present investigation on "Studies on heterosis, combining ability and stability analysis for yield and its components in pearl millet [*Pennisetum glaucum* (L.)]" was conducted during *Kharif*-2020, at three locations *viz*., Department of Agricultural Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (L_1), National Agricultural Research Project, Aurangabad (L_2) and College of Agriculture, Golegaon (L_3). The experimental material included in the present study comprised of five females (lines) and twelve restorers (testers) which are mated in a Line X Tester design to obtain sixty crosses. The males (Restorer lines) and females (male sterile lines) were bagged before anthesis. This will be followed by hand pollination of collected pollen grains from desired restorers and dusted on selected female line to obtain hybrid seed production. Five male sterile lines (lines) and twelve restorers (testers) were crossed in L x T mating design to obtain sufficient quantity seeds for obtaining the cross seeds, parents were grown at Department of Agricultural Botany to generate 60 F_1 hybrids. These 60 F_1 hybrids along with 12 restorers and 5 B lines with three standard checks were grown in randomized block design during *Kharif* 2020 season. The observations were recorded on twelve characters *viz*., days to 50% flowering, days to maturity, earhead length (cm), earhead girth(cm), number of nodes per plant, plant height(cm), total number of tillers per plant, number of effective tillers per plant, Fe content (ppm), Zn content (ppm), grain yield per plant (g) and grain yield per hectare (kg). Heterosis is the superiority of F_1 hybrid over both the parents in terms of yield or some other characters and is expressed as per cent. In the present investigation heterosis has been estimated over mid parent (Average/Relative heterosis) and better parent (heterobeltiosis) as per Fonesca and Patterson (1968). Analysis of variance for Randomized Block Design was performed by using method given by Panse and Sukhatme (1989). Heterosis was studied over mid parent, better parent and checks AHB 1200, AHB 1666 and Dhanshakti.

RESULTS AND DISCUSSION

The prime objective in any crop breeding programme is identification of superior parents from available gene pool. The variability is created through hybridization for selection of parents which are utilized to exploit heterosis through heterosis breeding. The heterosis study is useful for finding highly heterotic hybrid for grain yield. The environment plays important role in the expression of characters as it greatly influences the performance of parents as well as crosses for yield and yield contributing characters. Therefore, evaluation of genotypes in a single environment may not provide real expression of parents as well as crosses for yield and yield contributing traits. The line × tester analysis method given by Kempthorne (1957) is one of the powerful tool to estimate the general combining ability effects of parents. It helps in selecting desirable parents to be utilized in heterosis breeding programme. In the present study, considerable heterosis was observed in most of the crosses for yield and its component characters. The degree and magnitude of heterosis varied from cross to cross for all the characters studied.

Days to flowering :

The cross 00111A X 15351R (-31.65%) exhibited highly significant and negative relative heterosis for days to 50% flowering (Table 1). Fifty-two crosses exhibited negative significant relative heterosis for days to flowering. The cross 00111A X 15351R exhibited highly significant and negative heterobeltiosis (-33.10%), standard heterosis over AHB 1200 (-12.04%) and AHB 1666 (-4.68%) followed by cross 02333A X 15006R over standard check AHB 1200 (-12.04%) and AHB 1666 (-4.68%). Whereas the cross combination 02888A X 15006R (-10.49%) and 02888A X 15351R (-7.72%) recorded negative significant standard heterosis over check AHB 1200. Similar results were quoted by Lakshamana *et al.* (2010), Bachkar *et al.* (2014) and Ashok *et al.* (2016).

Days to maturity :

The cross 00111A X 15713R (-18.05%) exhibited highly significant and negative relative heterosis for days to maturity. The range of relative heterosis was -18.05% to 13.02% (00444A X 15020R). Thirty-six crosses exhibited negative significant relative heterosis for days to maturity. The cross 00444A X 15351R exhibited highly significant and negative heterobeltiosis (-20.33%) at pooled over locations. The sum total of twelve and two crosses showed significant and negative heterosis over standard check AHB 1200 and AHB 1666, respectively over locations. The crosses 99111A X 15020R (-10.00 %), 00444A X 15351R (-9.06 %) and 02333A X 15006R (-5.47%) exhibited highly significant and negative standard heterosis over check AHB 1200. The results are in agreement with the results of Chotaliya *et al.* (2009), Vagadiya *et al.* (2010) and Bachkar *et al.* (2014).

Plant height :

The value for relative heterosis ranged from was -15.20 % to 29.87% (02333A X 15020R). The cross combination 02333 X 15020R exhibited highly significant and positive heterobeltiosis (26.25 %). The cross 00111A X 15392R displayed highest standard heterosis plant height over check AHB 1200 (16.37 %), AHB 1666 (13.28 %) and Dhanshakti (6.89 %), respectively. The crosses which recorded significant and positive heterosis for plant height at pooled over environments were 02333A X 15392R (15.89 %, 12.81 %, 6.45 % over standard

Table 1: Pooled relative heterosis, heterobeltiosis and standard heterosis for various traits in pearl millet

Sr. No.	Crosses	Days to 50% flowering					Days to maturity				
		RH	HB	AHB 1200	AHB 1666	Dhanshakti	RH	HB	AHB 1200	AHB 1666	Dhanshakti
1.	00111A X 15183 R	-14.62**	-2.59**	0.00	8.36**	14.08**	-8.87**	-10.98**	-2.08	1.37	4.01*
2.	00111A X 15351 R	-31.65**	-33.10**	-12.04**	-4.68*	0.35	-14.31**	-15.87**	-3.96**	-0.59	2.00
3.	00111A X 15713 R	-24.91**	-27.21**	-8.33**	-0.67	4.58*	-18.05**	-18.26**	-9.62**	-6.45**	-4.01*
4.	02333A X 15006 R	-6.40**	-11.21**	-12.04**	-4.68*	0.35	0.40	-3.84*	-5.47**	-2.15	0.40
5.	02333A X 15183 R	-10.71**	-14.53**	-7.41**	0.33	5.63*	-4.36**	-7.37**	-2.83	0.59	3.21*
6.	02333A X 15351 R	-14.66**	-23.35**	-1.85	6.35**	11.97**	-2.84*	-9.59**	3.21*	6.84**	9.62**
7.	02888A X 15006 R	-14.58**	-25.83**	-10.49**	-3.01	2.11	-2.56	-11.07**	-3.02*	0.39	3.01
8.	02888A X 15351 R	-26.81**	-29.81**	-7.72**	0.00	5.28*	-14.62	-16.53**	-4.72**	-1.37	1.20
9.	02888A X 15706 R	-8.28**	-10.74**	7.72**	16.72**	22.89**	-5.82**	-6.23**	2.26	5.86**	8.62**
10.	02888A X 15934 R	-24.97**	-29.60**	-3.09	5.02*	10.56**	-9.67**	-10.66**	-0.38	3.13*	5.81**
11.	00444A X 15006 R	1.54	0.00	-8.33**	-0.67	4.58*	4.55**	3.05	-4.53**	-1.17	1.40
12.	00444A X 15351 R	-18.95**	-31.22**	-9.57**	-2.01	3.17	-12.04**	-20.33**	-9.06**	-5.86**	-3.41*
13.	00444A X 15392 R	13.66**	6.47**	11.73**	21.07**	27.46	6.26**	0.73	4.15**	7.81**	10.62**
14.	00444A X 17592 R	-7.16**	-19.20**	0.00	8.36**	14.08**	-3.84**	-11.07**	-3.02*	0.39	3.01
15.	99111A X 15020 R	-12.86**	-20.57**	-5.86**	2.01	7.39**	-9.83**	-14.52**	-10.00**	-6.84**	-4.41**
16.	99111A X 15183 R	3.95**	-0.52	17.90**	27.76**	34.51**	6.10**	5.91**	11.51**	15.43**	18.44**
17.	99111A X 15392 R	6.63**	0.52	19.14**	29.10**	35.92**	5.06**	4.12**	9.62**	13.48**	16.43**
	S.E.±	0.89	1.03	1.03	1.03	1.03	1.15	1.32	1.32	1.32	1.32
	C.D. (P=0.05)	1.77	2.05	2.05	2.05	2.05	2.27	2.62	2.62	2.62	2.62

* and ** indicate significane of values at P=0.05 and 0.01, respectively

Table 1 : Continued...

Table 1 : Pooled relative heterosis, heterobeltiosis and standard heterosis for various traits in pearl millet

Sr. No.	Crosses	Plant height					Number of effective tillers per plant				
		RH	HB	AHB 1200	AHB 1666	Dhan-shakti	RH	HB	AHB 1200	AHB 1666	Dhan-shakti
1.	00111A X 15183 R	3.53	-2.44	-2.73	-5.31 *	-10.65 **	21.59 **	9.18 **	-2.73	5.42 *	7.00 **
2.	00111A X 15351 R	2.94	0.00	5.75 **	2.94	-2.86	32.07 **	23.98 **	10.45 **	19.70 **	21.50 **
3.	00111A X 15713 R	2.08	-1.19	5.26 *	2.47	-3.31	38.12 **	27.55 **	13.64 **	23.15 **	25.00 **
4.	02333A X 15006 R	16.45 **	-1.69	13.16 **	10.15 **	3.94 *	6.25 **	-4.80 *	8.18 **	17.24 **	19.00 **
5.	02333A X 15183 R	23.40 **	17.13 **	3.31	0.57	-5.10 *	28.81 **	15.15 **	3.64	12.32 **	14.00 **
6.	02333A X 15351 R	8.54 **	-5.07 *	0.39	-2.28	-7.79 **	27.03 **	18.69 **	6.82 **	15.76 **	17.50 **
7.	02888A X 15006 R	-0.14	-8.13 **	5.75 **	2.94	-2.86	33.18 **	18.80 **	35.00 **	46.31 **	48.50 **
8.	02888A X 15351 R	-0.91	-5.16 *	0.29	-2.37	-7.88 **	45.65 **	36.73 **	21.82 **	32.02 **	34.00 **
9.	02888A X 15706 R	1.19	-3.98 *	3.41	0.66	-5.01 *	49.46 **	41.84 **	26.36 **	36.95 **	39.00 **
10.	02888A X 15934 R	7.92 **	6.03 **	6.24 **	3.42	-2.42	24.01 **	14.16 **	20.91 **	31.03 **	33.00 **
11.	00444A X 15006 R	-7.00 **	-15.07 **	-2.24	-4.84 *	-10.21 **	16.36 **	2.40	16.36 **	26.11 **	28.00 **
12.	00444A X 15351 R	10.72 **	5.16 *	11.21 **	8.25 **	2.15	38.67 **	32.11 **	14.09 **	23.65 **	25.50 **
13.	00444A X 15392 R	-10.87 **	-15.31 **	-10.53 **	-12.90 **	-17.82 **	41.94 **	38.95 **	20.00 **	30.05 **	32.00 **
14.	00444A X 17592 R	-1.90	-4.20	-4.39 *	-6.93 **	-12.18 **	41.08 **	37.37 **	18.64 **	28.57 **	30.50 **
15.	99111A X 15020 R	16.46 **	7.00 **	7.21 **	4.36 *	-1.52	54.24 **	46.77 **	24.09 **	34.48 **	36.50 **
16.	99111A X 15183 R	22.40 **	15.08 **	15.30 **	12.24 **	5.91 **	51.23 **	57.05 **	11.36 **	20.69 **	22.50 **
17.	99111A X 15713 R	5.70 **	2.56	9.26 **	6.36 **	0.36	65.27 **	66.27 **	25.45 **	35.96 **	38.00 **
	S.E.±	3.21	3.71	3.71	3.71	3.71	0.63	0.73	0.73	0.73	0.73
	C.D. (P=0.05)	6.34	7.32	7.32	7.32	7.32	1.25	1.45	1.45	1.45	1.45

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 1 : Continued...

Table 1: Pooled relative heterosis, heterobeltiosis and standard heterosis for various traits in pearl millet

Sr. No.	Crosses	Earhead length					Earhead girth				
		RH	HB	AHB 1200	AHB 1666	Dhanshakti	RH	HB	AHB 1200	AHB 1666	Dhanshakti
1.	00111A X 15183 R	-3.30	-8.33 *	-12.58 **	0.76	-5.04	-6.48	-15.97 **	-8.02	2.56	3.55
2.	00111A X 15351 R	18.44 **	15.97 **	10.60 **	27.48 **	20.14 **	10.85 **	-1.05	8.31	20.77 **	21.94 **
3.	00111A X 15713 R	15.89 **	10.76 **	15.89 **	33.59 **	25.90 **	-3.85	-11.78 **	-3.44	7.67	8.71
4.	02333A X 15006 R	19.42 **	18.57 **	9.93 **	26.72 **	19.42 **	12.42 **	12.06 *	1.15	12.78 *	13.87 **
5.	02333A X 15183 R	30.11 **	25.00 **	15.89 **	33.59 **	25.90 **	19.67 **	16.83 **	5.44	17.57 **	18.71 **
6.	02333A X 15351 R	20.14 **	19.29 **	10.60 **	27.48 **	20.14 **	20.59 **	17.89 **	5.73	17.89 **	19.03 **
7.	02888A X 15006 R	33.59 **	25.36 **	14.57 **	32.06 **	24.46 **	23.87 **	23.67 **	6.30	18.53 **	19.68 **
8.	02888A X 15351 R	32.82 **	24.64 **	13.91 **	31.30 **	23.74 **	2.56	-1.54	-8.31	2.24	3.23
9.	02888A X 15706 R	0.37	-8.78 **	-10.60 **	3.05	-2.88	21.67 **	16.98 **	8.60	21.09 **	22.26 **
10.	02888A X 15934 R	26.12 **	14.97 **	11.92 **	29.01 **	21.58 **	19.68 **	19.49 **	7.16	19.49 **	20.65 **
11.	00444A X 15006 R	18.90 **	13.07 **	14.57 **	32.06 **	24.46 **	22.22 **	19.87 **	7.16	19.49 **	20.65 **
12.	00444A X 15351 R	18.21 **	12.42 **	13.91 **	31.30 **	23.74 **	-10.66 *	-13.73 **	-17.19 **	-7.67	-6.77
13.	00444A X 15392 R	-16.22 **	-18.95 **	-17.88 **	-5.34	-10.79 **	0.31	-1.54	-8.60	1.92	2.90
14.	00444A X 17592 R	-19.34 **	-19.61 **	-18.54 **	-6.11	-11.51 **	7.64	5.73	-2.15	9.11	10.16
15.	99111A X 15020 R	21.32 **	17.86 **	9.27 **	25.95 **	18.71 **	1.83	-1.08	-8.45	2.08	3.06
16.	99111A X 15183 R	1.92	0.76	-11.92 **	1.53	-4.32	-6.08	-7.76	-11.46 *	-1.28	-0.32
17.	99111A X 15713 R	20.00 **	10.13 **	15.23 **	32.82 **	25.18 **	9.66 *	8.98	0.86	12.46 *	13.55 *
	S.E.±	0.71	0.82	0.82	0.82	0.82	0.47	0.54	0.54	0.54	0.54
	C.D. (P=0.05)	1.40	1.62	1.62	1.62	1.62	0.94	1.07	1.07	1.07	1.07

* and** indicate significance of values at P=0.05 and 0.01, respectively

Table 1 Continued..

Table 1: Pooled relative heterosis, heterobeltiosis and standard heterosis for various traits in pearl millet

Sr. No.	Crosses	Fe content					Zn content				
		RH	HB	AHB 1200	AHB 1666	Dhanshakti	RH	HB	AHB 1200	AHB 1666	Dhanshakti
1.	00111A X 15183 R	-27.95 **	-35.54 **	-38.66 **	-18.36 **	-37.19 **	-36.72 **	-42.33 **	-31.38 **	-26.08**	-38.63 **
2.	00111A X 15351 R	37.17 **	30.37 **	24.05 **	35.11 **	27.02 **	-5.16 **	-19.46 **	-4.18 *	3.22	-14.30 **
3.	00111A X 15713 R	10.30 **	1.37	-3.54 **	28.38 **	-1.23	8.51 **	-3.05	15.34 **	24.23*	3.16
4.	02333A X 15006 R	17.60 **	10.25 **	7.75 **	43.41 **	10.33 **	-2.17	-4.81 **	8.30 **	16.64*	-3.14
5.	02333A X 15183 R	10.48 **	3.75 *	-11.27 **	18.09 **	-9.15 **	-15.67 **	-19.48 **	-13.34 **	-6.67	-22.50 **
6.	02333A X 15351 R	47.89 **	47.71 **	26.63 **	38.53 **	29.66 **	50.72 **	33.54 **	43.72 **	54.81**	28.53 **
7.	02888A X 15006 R	35.84 **	31.50 **	28.52 **	41.05 **	31.60 **	-5.04 **	-8.48 **	4.13 *	12.16	-6.87 **
8.	02888A X 15351 R	-13.98 **	-16.69 **	-23.78 **	1.45	-21.95 **	-16.91 **	-25.74 **	-21.64 **	-15.60*	-29.92 **
9.	02888A X 15706 R	-28.19 **	-42.25 **	-47.17 **	-29.68 **	-45.90 **	-34.11 **	-43.70 **	-40.59 **	-36.01	-46.87 **
10.	02888A X 15934 R	3.01 *	-10.57 **	-18.18 **	8.90 **	-16.22 **	-22.14 **	-25.74 **	-21.64 **	-15.58*	-29.92 **
11.	00444A X 15006 R	-28.60 **	-34.77 **	-14.54 **	13.74 **	-12.50 **	3.87 *	-18.38 **	-7.14 **	0.02	-16.95 **
12.	00444A X 15351 R	-27.06 **	-31.01 **	26.54 **	37.85 **	29.57 **	47.52 **	31.49 **	9.24 **	17.68*	-2.30
13.	00444A X 15392 R	8.96 **	-6.83 **	-45.94 **	-28.05 **	-44.65 **	26.04 **	24.88 **	-18.80 **	-12.54	-27.38 **
14.	00444A X 17592 R	-21.88 **	-35.65 **	-25.42 **	-0.74	-23.63 **	12.37 **	-6.96 **	-7.78 **	-0.65	-17.52 **
15.	99111A X 15020 R	-34.00 **	-34.08 **	21.29 **	31.43 **	24.19 **	51.81 **	19.24 **	43.38 **	54.42**	28.23 **
16.	99111A X 15183 R	9.53 **	-1.28	-50.37 **	-33.94 **	-49.18 **	-27.63 **	-38.44 **	-39.74 **	-35.08**	-46.11 **
17.	99111A X 15392 R	-3.88 *	-16.41 **	-25.33 **	-0.62	-23.55 **	29.61 **	25.06 **	-14.16 **	-7.54	-23.23 **
	S.E.±	0.95	1.10	1.10	1.10	1.10	0.78	0.90	0.90	0.90	0.90
	C.D. (P=0.05)	1.88	2.17	2.17	2.17	2.17	1.54	1.78	1.78	1.78	1.78

* and ** indicate significane of values at P=0.05 and 0.01, respectively

Table No. 1 Continued...

Table 1 : Relative heterosis, heterobeltiosis and standard heterosis for various traits in pearl millet

Sr. No.	Crosses	Number of nodes per plant					Grain yield per plant				
		RH	HB	AHB 1200	AHB 1666	Dhanshakti	RH	HB	AHB 1200	AHB 1666	Dhanshakti
1.	00111A X 15183 R	-10.37 **	-21.94 **	-19.87 **	-19.87 **	-21.94 **	31.10 **	24.84 **	16.67 **	40.00 **	37.06 **
2.	00111A X 15351 R	12.03 **	9.94 **	17.22 **	17.22 **	14.19 **	45.69 **	45.22 **	35.71 **	62.86 **	59.44 **
3.	00111A X 15713 R	14.56 **	14.19 **	17.22 **	17.22 **	14.19 **	56.55 **	44.59 **	35.12 **	62.14 **	58.74 **
4.	02333A X 15006 R	45.65 **	16.18 **	33.11 **	33.11 **	29.68 **	44.62 **	42.81 **	36.01 **	63.21 **	59.79 **
5.	02333A X 15183 R	65.91 **	36.02 **	45.03 **	45.03 **	41.29 **	51.66 **	43.13 **	36.31 **	63.57 **	60.14 **
6.	02333A X 15351 R	17.18 **	10.40 **	26.49 **	26.49 **	23.23 **	46.20 **	44.38 **	37.50 **	65.00 **	61.54 **
7.	02888A X 15006 R	-2.55	-4.97 **	1.32	1.32	-1.29	70.32 **	54.49 **	43.45 **	72.14 **	68.53 **
8.	02888A X 15351 R	-23.27 **	-26.06 **	-19.21 **	-19.21 **	-21.29 **	59.01 **	44.23 **	33.93 **	60.71 **	57.34 **
9.	02888A X 15706 R	18.40 **	11.56 **	27.81 **	27.81 **	24.52 **	55.38 **	51.88 **	20.24 **	44.29 **	41.26 **
10.	02888A X 15934 R	-3.05 *	-8.09 **	5.30 **	5.30 **	2.58	46.02 **	30.25 **	25.60 **	50.71 **	47.55 **
11.	00444A X 15006 R	3.16 *	1.24	7.95 **	7.95 **	5.16 **	22.54 **	21.38 **	14.88 *	37.86 **	34.97 **
12.	00444A X 15351 R	8.24 **	-0.54	21.85 **	21.85 **	18.71 **	44.44 **	43.08 **	35.42 **	62.50 **	59.09 **
13.	00444A X 15392 R	24.83 **	16.77 **	19.87 **	19.87 **	16.77 **	32.64 **	20.13 **	13.69 *	36.43 **	33.57 **
14.	00444A X 17592 R	6.80 **	-7.10 **	3.97 *	3.97 *	1.29	35.44 **	21.38 **	14.88 *	37.86 **	34.97 **
15.	99111A X 15020 R	20.42 **	1.18	13.25 **	13.25 **	10.32 **	80.69 **	70.80 **	39.29 **	67.14 **	63.64 **
16.	99111A X 15183 R	-25.99 **	-29.19 **	-13.25 **	-13.25 **	-15.48 **	47.73 **	37.32 **	16.07 **	39.29 **	36.36 **
17.	99111A X 15392 R	-0.31	-4.73 **	6.62 **	6.62 **	3.87 *	56.97 **	52.71 **	17.26 **	40.71 **	37.76 **
	S.E.±	0.13	0.16	0.16	0.16	0.16	1.41	1.63	1.63	1.63	1.63
	C.D.(P=0.05)						2.79	3.22	3.22	3.22	3.22

*and ** indicate significance of values at P=0.05 and 0.01, respectively

check AHB 1200, AHB 1666 and Dhanshakti), 99111A X 15183R (15.30 %, 12.24 %, 5.91 % over standard check AHB 1200, AHB 1666 and Dhanshakti), and 99111A X 15223R (15.11 %, 12.05 %, 5.73 % over standard check AHB 1200, AHB 1666 and Dhanshakti). Similar findings were noted by Bachkar *et al.* (2014), Salgarkar *et al.* (2016) and Badhe *et al*. (2018).

Number of effective tillers per plant :

The cross combination 99111A X 15713R (65.27 %) exhibited highly significant and positive relative heterosis for number of effective tillers per plant. The cross 99111A X 15713R exhibited highly significant and positive heterobeltiosis (66.27%). The cross 02333A X 15006R displayed highly significant and positive standard heterosis (35.00%, 46.31%, 48.50% over standard check AHB 1200, AHB 1666 and Dhanshakti) followed by 00111A X 17715R (28.64%, 39.41%, 41.50% over standard check AHB 1200, AHB 1666 and Dhanshakti) and 02888A X 15706R (26.36%, 36.95%, 39.00% over standard check AHB 1200, AHB 1666 and Dhanshakti). The standard heterosis for number of effective tillers per plant ranged from -23.64% to 48.50%. The results are in accordance with the reports of Bachkar *et al.* (2014), Salgarkar *et al.* (2016) and Badhe *et al*. (2018).

Earhead length :

The cross 02888A X 15006R (33.59%) exhibited highly significant and positive relative heterosis for earhead length. The cross 02888 X 15006R exhibited highly significant and positive heterobeltiosis (25.36%). The standard heterosis for earhead length ranged from -38.41% to 33.59%. While, the crosses 02333A X 15183R and 00111A X 15713R displayed the highest standard heterosis over AHB 1200 (15.89%). The cross combination 02333A X 15183R recorded significant and positive standard heterosis over check AHB 1666 (33.59%). The crosses 02333A X 15183R and 00111A X 15713R recorded positive significant standard heterosis over check Dhanshakti (25.90%). Similar findings were reported by Jethva *et al.* (2012), Bachkar *et al.* (2014) and Badhe *et al*. (2018).

Earhead girth :

The cross combination 02888A X 15351R (23.87 %) exhibited highly significant and positive relative heterosis for earhead girth. The cross combination 002888 X 15351R exhibited highly significant and positive heterobeltiosis (23.67 %). While, the cross 00111A X 15351R displayed the highest standard heterosis over AHB 1666 (20.77 %). The cross combination 00111A X 15351R recorded significant and positive standard heterosis over check AHB 1200 (20.77%) and Dhanshakti (21.94 %). The standard heterosis for earhead length ranged from -26.07 % to 22.26 %. The crosses which recorded significant and positive heterosis for earhead girth over check AHB 1666 were 00444A X 15006R (19.49 %), 00444A X 15351R (19.49 %). Whereas, the cross 02888A X 15934R recorded highly significant standard heterosis over Dhanshakti (22.26 %). The results are in agreement with the results of Bachkar *et al.* (2014), Salgarkar *et al.*(2016) and Badhe *et al*. (2018).

Number of nodes per plant :

The cross combination 02333A X 15183R exhibited

Table 2 : Promising crosses in pearl millet across the environments

Crosses	Heterosis for grain yield per plant (%)			Significant heterosis for other traits in desirable direction
	AHB 1200	AHB 1666	Dhanshakti	
02888A x 15006R	43.45 **	72.14 **	68.53 **	Days to 50% flowering, days to maturity, earhead length, earhead girth, number nodes per plant, plant height, number of tillers per plant, effective tillers per plant, Fe content and Zn content
99111A x 15713R	41.07 **	69.29 **	65.73 **	Days to 50% flowering, days to maturity, earhead length, earhead girth, number nodes per plant, plant height, number of tillers per plant, effective tillers per plant, Fe content and Zn content
99111A x 15020R	39.29**	67.14**	63.64**	Days to 50% flowering, days to maturity, earhead length, number nodes per plant, plant height, number of tillers per plant, effective tillers per plant, Fe content and Zn content
02333A x 15351R	37.50 **	65.00 **	61.54 **	Days to 50% flowering, earhead length, earhead girth, number nodes per plant, number of tillers per plant, effective tillers per plant, Fe content and Zn content
00444A x 15351R	35.42 **	62.50**	59.09**	Days to 50% flowering, days to maturity, earhead length, earhead girth, number nodes per plant, plant height, number of tillers per plant, effective tillers per plant, Fe content and Zn content

* and ** indicate significance of values at P=0.05 and 0.01, respectively

highly significant and positive heterobeltiosis (36.52%). The range of heterobeltiosis was from -33.55 % to 36.02 %. While, the cross 02333A X 15392R displayed highest standard positive heterosis (50.33 %, 50.33 %, 46.45% over standard check AHB 1200, AHB 1666 and Dhanshakti) followed by 02333A X 15351R (45.03 %, 45.03 %, 41.29 % over standard check AHB 1200, AHB 1666 and Dhanshakti), 02333A X 15706R (42.38 %, 42.38 %, 38.71 % over standard check AHB 1200, AHB 1666 and Dhanshakti) and 00111A X 17715R (30.46 %, 30.46 %, 27.10 % over standard check AHB 1200, AHB 1666 and Dhanshakti). The standard heterosis for number of nodes per plant ranged from -34.84% to 50.33%. The findings are in accordance with the reports of Vagadiya *et al.* (2010).

Grain yield per plant :

The cross combination 99111A X 15713R (85.88%) exhibited highly significant and positive relative heterosis for seed yield per plant. The relative heterosis for grain yield per plant ranged from -25.17% to 85.88%. In case of heterobeltiosis, twenty-two crosses showed positive significant heterobeltiosis for grain yield per plant. The cross 02888 X 15006R displayed highly significant standard heterosis over AHB 1200 (43.45 %), AHB 1666 (72.14 %) and Dhanshakti (68.53 %). The standard heterosis for grain yield per plant ranged from -36.31 % to 72.14 %. The other crosses having highly significant and positive standard heterosis were 99111A X 15713R (41.07 %, 69.29 % and 65.73 % over standard check AHB 1200, AHB 1666 and Dhanshakti), 99111A X 15020R (39.29 %, 67.14 % and 63.64 % over standard check AHB 1200, AHB 1666 and Dhanshakti), 02333A X 15183R (36.31 %, 63.57 % and 60.14 % over standard check AHB 1200, AHB 1666 and Dhanshakti) and 02333A X 15351R (37.50 %, 65.00 % and 61.54 % over standard check AHB 1200, AHB 1666 and Dhanshakti). Similar results were reported by Bachkar *et al.,* (2014), Ashok *et al.* (2016), Salgarkar *et al.* (2016) and Badhe *et al*. (2018).

Fe content (ppm):

Micronutrient malnutrition resulting from dietary deficiency of one or more micronutrients has been recognized as a serious human health problem worldwide. Bio-fortification is conventional crop breeding to increase micro-nutrient levels. It helps to address deficiencies of key minerals like iron in human diet. The cross combination 00444A X 15223R (54.23 %) exhibited highly significant and positive relative heterosis for Fe content. The cross combination 02333A X 15351R exhibited highly significant and positive heterobeltiosis (47.71%). The cross 02888A X 15006R displayed highest standard heterosis over AHB 1200 (28.52%), AHB 1666 (41.05%) and Dhanshakti (31.60%) followed by 02333A X 15351R (26.63%, 38.53%, 29.66% over standard check AHB 1200, AHB 1666 and Dhanshakti), 00444A X 15351R (26.54%, 37.85 %, 29.57% over standard check AHB 1200, AHB 1666 and Dhanshakti). 00111A X 15351R (24.05%, 35.11%, 27.02% over standard check AHB 1200, AHB 1666 and Dhanshakti). The standard heterosis for Fe content ranged from -47.97% to 43.41%. The results are in accordance with the results of Govindraj (2011), Velu *et al.* (2011), Kanatti *et al.* (2014) and Badhe *et al.* (2018).

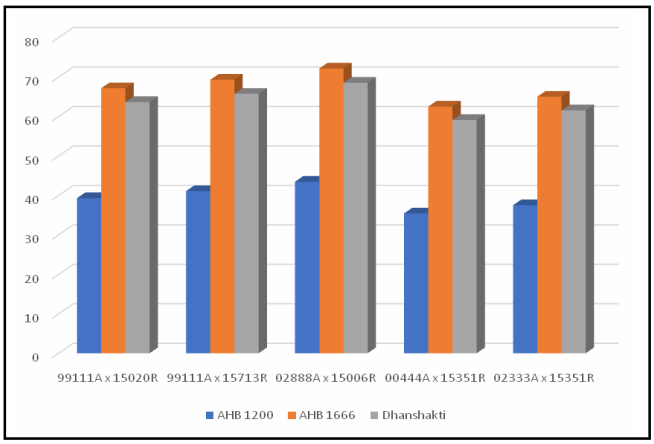

Fig 1 : Pooled heterosis of promising crosses for grain yield per plant

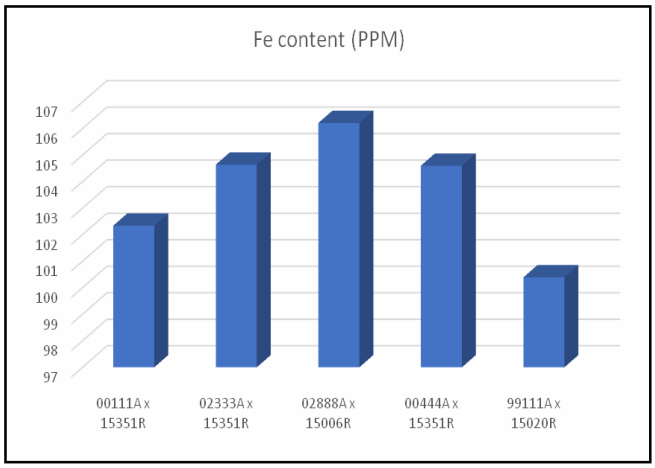

Fig 2 : Pooled heterosis of promising crosses for Fe content

Zn content (ppm):

Zinc is an essential nutrient which is important in proper growth, tissue repair, reproduction and better cellular immunity. It also plays a vital role in regulating the metabolism, as a component of metallo-protease enzymes fulfilling catalytic, structural, and regulatory functions, for the stabilization of membranes, and for various ionic cell functions. Bio-fortification is conventional crop breeding to increase micro- nutrient levels. It helps to address deficiencies of key minerals like iron and zinc in human diet. The cross combination 99111A X 15020R (51.81 %) exhibited highly significant and positive relative heterosis for Zn content. The cross combination 02333A X 15351R exhibited highly significant and positive heterobeltiosis (33.54 %) for Zn content. The range of heterobeltiosis was from -52.25 % to 33.54 %. In case of heterobeltiosis eight crosses showed positive significant heterobeltiosis for Fe content. The cross 02333A X 15351R displayed the highest standard heterosis over AHB 1200 (43.72 %), AHB 1666 (54.81 %) and Dhanshakti (28.53 %) followed by the cross 99111A X 15020 over AHB 1200 (43.38%), AHB 1666 (54.42 %) and Dhanshakti (28.23 %). The other crosses which displayed highly significant and positive heterosis for zinc content were 02333A X 15020R (27.18 %, 37.00 % and 13.75 % over standard check AHB 1200, AHB 1666 and Dhanshakti) and 00111A X 17592R (19.42 %, 28.62 % and 6.80 % over standard check AHB 1200, AHB 1666 and Dhanshakti). Similar results were reported by Govindraj (2011), Velu *et al.* (2011), Kanatti *et al.* (2014) and Badhe *et al.* (2018).

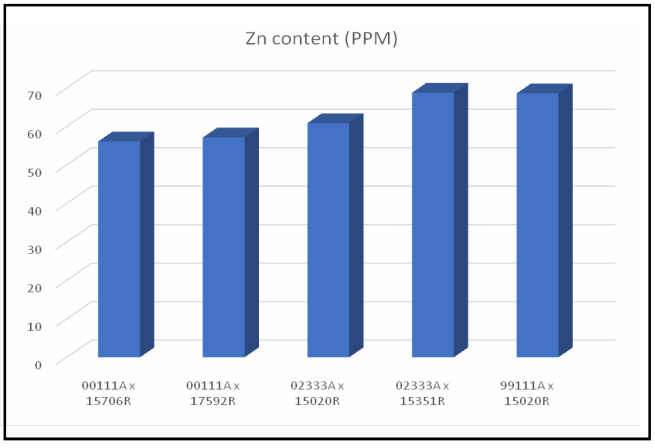

Fig 3: Pooled heterosis of promising crosses for Zn content

Conclusion :

The hybrids 02888A x 15006R, 99111A x 15020R and 99111A x 15183R were found highly heterotic over standard checks for grain yield per plant. The hybrids 02333A x 15351R, 00444A x 15351R and 99111A x 15020R were found highly heterotic for Fe content, whereas 99111A x 15020R, 02333A x 15351R and 02333A x 15020R had high Zn content. These hybrids could be further tested at locations and seasons before their release.

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