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Study on heterosis for grain yield components and nutritional traits in pearl millet (*Pennisetum glaucum* (L.) R. Br.)

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Abstract
A total of fifty four hybrids were developed using six male sterile lines and nine restorer lines to study the heterotic potential of the synthesized hybrids. The hybrids and parents were evaluated for thirteen characters which includes eight biometric and five quality traits *viz*., days to fifty per cent flowering, plant height, number of productive tillers/plant, earhead length, earhead girth, test weight, single head grain weight, single plant yield, crude protein, crude fiber, beta carotene, iron and zinc. Out of fifty four hybrids evaluated, mean performance and standard heterosis revealed that the hybrids *viz*., ICMA 92777 x RIL 68, ICMA 92888 x RIL 81, ICMA 94222 x RIL 53, ICMA 94222 x RIL 81 and ICMA 02777 x RIL 53 were found to be promising for yield contributing and nutritional characters.

Keywords: Heterosis, *per se*, bio fortification, pearl mille

Introduction
Pearl millet is the fifth most important grain crop in India next to rice, wheat, maize and sorghum. Pearl millet is well adapted to growing areas characterized by drought, low soil fertility, and high temperature. It performs well in soils with high salinity or low pH. Because of its tolerance to difficult growing conditions, it can be grown in areas where other cereal crops, such as maize or wheat, would not survive. Globally vitamin A deficiency is rampant and a total of 250 million preschool-age children and accounts for about 70 per cent of the childhood deaths for this nutrient. Supplementation, food fortification, and diet diversification have been used to try and address vitamin A deficiency (Chandler *et al.*, 2013) [7]. Increasing the concentration of provitamin A, iron, zinc and other quality traits in the edible portions of staple crops through plant breeding, termed bio fortification. This approach has the potential to be highly sustainable and cost effective when bio fortified crops are continuously consumed and grown year after year at recurrent costs lower than the initial costs of varietal development (Bouis and Welch, 2010) [2]. The phenomenon of heterosis has proved to be the outstanding genetic tool in enhancing the yield of cross-pollinated species in general and pearl millet in particular. With the ease of use of CGMS system in pearl millet, exploitation of hybrid vigor on a commercial scale has become realistic and economical. In India, a factual breakthrough in pearl millet production has come with development and release of hybrids for commercial cultivation. In heterosis breeding program, it is essential to study and evaluate available useful promising diverse potential lines in their hybrid combinations for yield and yield components. Recognition of a potential hybrid combination through the magnitude and direction of heterotic behavior is of paramount importance.

Materials and Methods
The trial was carried out in randomized block design (RBD) with three replications under the prevailing environmental conditions at department of millets, TNAU, Coimbatore which lies between 11° North latitude and 77° East longitude during Summer,17.The hybrids and parents were represented by 3 rows of 5 m length with 45 cm between rows and 15 cm between plants. Till the harvesting, all the recommended inputs and cultural practices including fertilizer, irrigation, hoeing and pest control were followed. Heterosis study was carried out for thirteen characters which includes eight biometric and five quality traits *viz*., days to fifty per cent flowering, plant height, number of productive tillers/plant, earhead length, earhead girth, test weight, single head grain weight, single plant yield, crude protein, crude fiber, beta carotene, iron and zinc. The observation was recorded for nutritional traits *viz*., protein content (N x 6.25) using microkjeldahl method (Jackson 1973). Crude protein and crude fiber content were estimated at the Department of Forage crops, Centre for Plant Breeding and Genetics.

The zinc and iron contents were determined by using Atomic Absorption Spectrophotometer (Humphries 1956) [5] at the department of Environmental Sciences, TNAU, Coimbatore. Beta carotene estimation was done using the protocol standardized by Sathya *et al*. (2014) [12]. All the statistical analysis was done by using TNAUSTAT statistical software.

Results and Discussion

A hybrid is commercially valuable only when it exhibits significantly high heterosis over its better parent and/or over the best locally adopted variety or hybrid. The heterosis per cent estimated over standard variety TNAU cumbu hybrid CO 9 for all the thirteen characters are briefly discussed here under.

Analysis of variance exhibited significant differences among the studied traits which revealed that sufficient variability was observed among the hybrids (Table 1). The per se performance revealed that, minimum and maximum number of days taken among the hybrids for 50% flowering was ICMA 02777 x RIL 19 (38.67 days) and ICMA 93111 x RIL 81 (63.00 days) respectively. Twenty four hybrids registered significantly less number of days to 50% flowering than the grand mean of 48.50. The hybrids ICMA 02777 x RIL 19 (67.67 cm) and ICMA 93111 x RIL 53 (188.33 cm) were the shortest and tallest in height among the hybrids and twenty five were found to be significantly taller. In the case of productive tillers it varied from ICMA 02777 x RIL 75 (2.00) to (5.33) ICMA 92888 x RIL 75 among hybrids. Twenty five out of 54 hybrids significantly expressed more tillers over the grand mean of 3.60. The range for ear head length was between 14.93 cm (ICMA 92888 x RIL 19) and 35.33 cm (ICMA 93111 x RIL 135). Twenty four hybrids showed significantly longer earhead as compared to grand mean of 24.43 cm. Test weight range was expressed by ICMA 93111 x RIL 81 (5.80 g) and ICMA 02777 x RIL 116 (16.00 g) respectively.

Crude protein content exhibited a variation from 5.75 g/100 g (ICMA 94222 x RIL 182) to 14.85 g/100 g (ICMA 94222 x RIL 19) and twenty two hybrids showed significantly higher protein content compared to grand mean (10.40 g/100 g). ICMA 02777 x RIL 53 outshine for the trait beta carotene and crude protein with eight yield attributing traits. Hybrid ICMA 92888 x RIL 75 scored maximum content of 36.67 mg/100g for iron and 15.97 mg/100g (ICMA 92777 x RIL 49) for zinc content among the hybrids. Nineteen and twenty hybrids expressed significant amount of iron and zinc content over the grand mean respectively. Among the hybrids, ICMA 93111 x RIL 81 (16.03 g) and ICMA 93111 x RIL 53 (169.30 g) recorded the minimum and maximum grain yield/plant respectively. A total of eighteen hybrids registered significant grain yield/plant than the mean (79.67 g). (Table 2)

With regard to mean performance, the hybrids ICMA 92777 x RIL 68, ICMA 92888 x RIL 81, ICMA 93111 x RIL 68, ICMA 94222 x RIL 19, ICMA 94222 x RIL 53, ICMA 94222 x RIL 81 and ICMA 02777 x RIL 53 showed superior mean performance for a total of more than nine different traits each. Among them, ICMA 92888 x RIL 81 had high *per se* for traits of yield *viz.*, days to 50 % flowering, plant height, number of productive tillers, earhead length, earhead girth, test weight, single head grain weight, beta carotene content, iron content, zinc content and single plant yield. The hybrid ICMA 92777 x RIL 68 excelled in mean performance for yield contributing traits *viz*., days to 50 % flowering, plant height, number of productive tillers, earhead length, test weight, single head grain weight and single plant yield and nutritional traits *viz*., crude protein, beta carotene, iron content and zinc content.

In case of standard heterosis, the hybrid ICMA 92777 x RIL 68 excelled high values for a maximum of 11 yield contributing and nutritional traits *viz*., days to 50 per cent flowering, number of productive tillers, earhead length, test weight, single head grain weight, crude protein, crude fiber, betacarotene, iron and zinc content. The cross ICMA 94222 x RIL 53 also scored for maximum standard heterosis for eleven traits except number of productive tillers and earhead girth. The findings were coinciding with the results of Chittora and Patel (2017) [3], Maryam (2015) [8] in pearl millet for productive tillers. The hybrids, ICMA 92888 x RIL 81, ICMA 94222 x RIL 81 and ICMA 02777 x RIL 53 were observed significantly maximum heterosis for more than seven yield contributing and nutritional traits. Therefore these hybrids could be selected based on standard heterosis per cent for improvement in yield and nutritional quality (Table 3).

Crude protein was found to have the minimum maximum -50.56 and 28.40 per cent of heterosis over standard parent fourteen cross combinations were found to have significant and positive standard heterosis per cent respectively. The minimum and maximum per cent of heterosis for Beta-carotene over standard parent was recorded by the hybrids -66.67 and 488.62 per cent respectively. Almost 24 hybrids expressed significantly positive heterosis per cent over standard parents. The hybrids, ICMA 92777 x RIL 68, ICMA 92888 x RIL 81, ICMA 93111 x RIL 68, ICMA 93222 x RIL 53, ICMA 93222 x RIL 81, ICMA 94222 x RIL 53 and ICMA 02777 x RIL 53 were excelled for high beta carotene content. Highly significant and positive standard heterosis for iron content was observed in the hybrids *viz*., ICMA 92777 x RIL 49 (59.12 %), ICMA 92777 x RIL 68 (95.23 %), ICMA 92888 x RIL 81 (45.41 %), ICMA 93111 x RIL 68 (73.62 %), ICMA 94222 x RIL 81 (54.41 %), ICMA 94222 x RIL 116 (63.81 %) and ICMA 02777 x RIL 75 (87.18 %) Whereas in the case of zinc content the standard heterosis existed between -40.25 and 111.99 per cent. Significant and positive heterosis per cent over standard parent were recorded in twenty three crosses. The hybrids *viz*., ICMA 92888 x RIL 49, ICMA 93111 x RIL 68, ICMA 93111 x RIL 116, ICMA 93222 x RIL 49, ICMA 93222 x RIL 53, ICMA 94222 x RIL 19, ICMA 94222 x RIL 53, ICMA 94222 x RIL 75 and ICMA 94222 x RIL 116 were recorded high standard heterosis percentage for zinc content. Similar findings were observed by Velu *et al.*, 2011b [13], Rai *et al.*, 2012 [10] and Govindaraj *et al.*, 2013 [4].

Table 1: ANOVA for Line x tester

Source	df	MSS												
		Days to 50 per cent flowering	Plant height (cm)	No. of productive tillers	Earhead length (cm)	Earhead girth (cm)	Test Weight (g)	Single head grain weight (g)	Crude protein (g/100g)	Crude fibre (g/100g)	Beta carotene content (µg/g)	Iron (mg/100g)	Zinc (mg/100g)	Grain yield / plant (g)
Lines	5	37.29**	11869.17**	3.34**	452.42**	11.32**	35.74**	611.43**	41.20**	7.47**	0.47*	43.15**	40.15**	5806.88**
Testers	8	104.89**	1579.11**	2.28**	13.72**	3.69**	25.92**	129.53**	14.04**	1.45**	2.35**	109.04**	21.76**	3099.79
L X T	40	82.21**	2478.38**	1.77**	46.93**	4.03**	15.73**	132.83**	17.18**	2.64**	0.48*	60.51**	15.76**	3744.68**
Error	106	1.26	49.96	0.29	4.44	0.50	0.23	8.18	0.14	0.12	0.01	5.34	1.08	54.04

Table 2: *Per se* performance of hybrids for various quantitative and qualitative traits

Hybrids	Days to 50 % flowering	Plant height (cm)	No. of productive tillers / plant	Earhead length (cm)	Earhead girth (cm)	Test weight (g)	Single head grain weight (g)	Crude protein (g/100g)	Crude fibre (g/100g)	Beta carotene content (µg/g)	Iron (mg/100g)	Zinc (mg/100g)	Single plant yield (g)
ICMA 92777 x RIL 19	47.67*	91.67	4.00*	15.83	8.90	7.93	10.57	11.06*	1.383	0.298	14.96	4.11	42.73
ICMA 92777 x RIL 49	42.33*	90.33	3.67*	14.93	9.07	7.47	9.27	8.76	0.433	0.275	20.81*	15.97*	35.67
ICMA 92777 x RIL 53	48.67	103.33	4.33*	18.77	9.70	8.70	15.53	11.31*	0.860	0.843*	15.83*	7.90	67.40
ICMA 92777 x RIL 68	42.33*	182.67*	4.33*	26.13*	9.23	10.47*	30.40*	14.78*	1.533	1.292*	26.69*	14.98*	140.00*
ICMA 92777 x RIL 75	50.67	90.00	4.33*	17.50	8.47	7.27	15.40	14.85*	0.427	0.280	7.23	6.55	60.43
ICMA 92777 x RIL 81	38.67*	67.67	4.33*	20.50	7.53	7.20	12.00	12.05*	0.987	0.403	10.07	7.48	51.83
ICMA 92777 x RIL 116	47.67*	73.00	3.33	17.97	9.63	7.63	13.20	11.09*	1.033	0.268	14.64	10.17*	46.80
ICMA 92777 x RIL 135	49.67	75.00	3.00	18.47	8.00	6.50	11.50	8.87	2.683*	0.244	9.26	8.30	36.33
ICMA 92777 x RIL 182	59.33	84.00	2.67	19.27	9.53	7.37	14.50	13.71*	1.950	0.217	9.18	9.69*	38.20
ICMA 92888 x RIL 19	46.00*	75.00	4.00*	18.40	9.17	11.73*	25.70*	13.14*	2.193*	0.185	16.20*	7.48	99.33*
ICMA 92888 x RIL 49	46.67*	90.33	3.67*	20.43	10.43*	8.53	22.86	9.53	1.467	0.382	17.28*	9.67*	82.73*
ICMA 92888 x RIL 53	51.00	168.67*	3.33	22.77	8.80	7.17	16.13	9.15	0.793	0.951*	7.55	5.75	52.69
ICMA 92888 x RIL 68	47.67*	102.33	3.67*	24.47*	10.60*	8.70	16.43	8.03	1.387	0.153	9.38	9.15	59.90
ICMA 92888 x RIL 75	53.33	112.00	4.00*	17.17	10.03	8.37	20.03	7.26	1.287	0.152	14.22	9.40*	78.27
ICMA 92888 x RIL 81	44.67*	188.33*	5.33*	24.70*	14.47*	14.30*	31.90*	8.12	1.230	1.756*	36.67*	12.52*	169.30*
ICMA 92888 x RIL 116	50.33	112.33	4.00*	20.43	11.23*	6.13	13.63	10.33	1.047	0.158	8.76	8.42	54.40
ICMA 92888 x RIL 135	49.33	159.33	3.33	21.33	7.70	6.73	18.10	7.73	2.960*	0.194	9.07	4.49	57.73
ICMA 92888 x RIL 182	46.33*	115.00	2.67	25.33*	11.23*	7.57	21.23	14.79*	1.367	0.172	8.79	5.86	53.67
ICMA 93111 x RIL 19	45.67*	126.33	2.67	18.17	10.07	6.37	13.70	14.45*	1.970*	0.609	12.61	6.34	35.30
ICMA 93111 x RIL 49	49.67	178.00*	3.00	23.33	9.90	7.60	24.22	14.15*	1.000	0.272	18.23*	10.17*	72.67
ICMA 93111 x RIL 53	55.33	109.00	3.33	18.47	8.80	6.97	16.38	12.78*	1.347	0.777*	13.66	9.66*	51.60
ICMA 93111 x RIL 68	56.67	124.33	4.00*	25.10*	9.83	11.53*	30.60*	12.81*	1.160	1.383*	26.04*	11.87*	122.40*
ICMA 93111 x RIL 75	56.33	91.33	4.33*	16.57	8.93	6.40	11.34	13.90*	1.977*	0.433	6.64	6.53	48.47
ICMA 93111 x RIL 81	47.67*	173.00*	3.00	30.67*	13.17*	6.83	11.97	6.41	1.780	1.226*	9.34	7.33	35.90
ICMA 93111 x RIL 116	45.33*	167.00*	2.67	21.87	11.07*	7.20	17.87	6.05	1.610	0.506	12.58	11.32*	46.80
ICMA 93111 x RIL 135	55.33	105.67	5.33*	16.50	9.10	10.13*	22.13	6.64	1.047	0.267	7.53	8.28	112.83*
ICMA 93111 x RIL 182	42.67*	90.33	4.33*	17.23	8.50	6.47	13.73	6.92	1.327	0.364	9.33	4.63	60.30
ICMA 93222 x RIL 19	45.00*	168.00*	3.33	29.97*	11.53*	7.17	24.97*	9.53	1.293	0.148	16.09*	6.49	81.63*
ICMA 93222 x RIL 49	39.67*	142.67*	3.33	24.67*	10.37*	7.70	21.43	8.97	3.247*	0.656	15.84*	11.93*	70.43
ICMA 93222 x RIL 53	44.33*	168.67*	2.00	23.83	10.63*	6.73	25.73*	7.13	2.293*	1.320*	11.19	12.71*	49.20
ICMA 93222 x RIL 68	56.33	116.67	2.33	28.60*	10.50*	6.73	28.80*	8.93	2.480*	0.735*	13.22	7.40	66.17
ICMA 93222 x RIL 75	48.67	165.67*	4.00*	23.73	10.53*	6.60	16.60	10.17	4.973*	0.556	14.27	9.45*	69.50
ICMA 93222 x RIL 81	63.00	147.67*	2.67	27.83*	11.77*	5.80	6.01	7.95	2.547*	1.327*	9.21	6.15	16.03
ICMA 93222 x RIL 116	46.00*	176.00*	2.33	25.83*	10.83*	6.97	22.07	10.67*	2.247*	0.555	18.87*	6.28	54.67

ICMA 93222 x RIL 135	55.67	128.83	3.00	29.67*	10.93*	7.30	22.43	13.31*	1.457	0.499	7.17	6.71	62.30
ICMA 93222 x RIL 182	55.67	123.00	3.00	26.83*	10.23*	7.57	31.80*	11.92*	1.800	0.821*	12.50	8.76	109.10*
ICMA 94222 x RIL 19	40.00*	151.67*	4.00*	24.67*	10.87*	13.40*	34.93*	10.76*	2.627*	0.551	17.91*	14.98*	141.60*
ICMA 94222 x RIL 49	56.00	106.00	2.33	27.83*	10.97*	6.30	14.77	11.98*	1.783	0.299	16.97*	10.94*	32.77
ICMA 94222 x RIL 53	40.33*	188.00*	4.67*	25.97*	10.07	14.60*	34.17*	14.66*	3.557*	2.179*	36.41*	15.12*	158.90*
ICMA 94222 x RIL 68	51.00	153.67*	3.00	24.77*	9.40	8.07	26.30*	10.89*	1.407	0.327	8.51	9.05	72.67
ICMA 94222 x RIL 75	52.67	170.67*	3.67*	34.50*	9.50	8.97*	28.20*	9.78	1.230	0.892*	16.03*	13.44*	102.00*
ICMA 94222 x RIL 81	45.67*	135.00*	4.67*	27.17*	8.97	16.00*	33.20*	9.54	5.673*	0.694*	20.20*	8.61	153.93*
ICMA 94222 x RIL 116	49.67	147.67*	2.33	34.83*	9.97	7.57	22.83*	9.86	1.627	0.783*	21.43*	13.32*	51.80
ICMA 94222 x RIL 135	46.33*	153.67*	2.33	31.77*	10.10	7.80	29.67*	8.11	2.580*	0.972*	12.80	5.45	67.80
ICMA 94222 x RIL 182	57.00	146.33*	2.33	35.33*	9.40	6.90	26.67*	9.14	1.313	0.135	8.16	8.39	61.33
ICMA 02777 x RIL 19	46.00*	150.33*	3.33	27.67*	9.33	8.90	28.53*	7.92	2.913*	0.600	14.11	6.55	94.50*
ICMA 02777 x RIL 49	51.33	156.00*	2.67	28.33*	9.43	10.60*	39.23*	8.49	1.027	0.354	18.04*	6.60	102.77*
ICMA 02777 x RIL 53	45.67*	166.67*	5.00*	31.83*	9.43	14.80*	32.53*	10.74*	1.660	2.412*	10.72	5.36	158.63*
ICMA 02777 x RIL 68	51.67	81.23	3.33	22.17	10.57*	14.20*	24.80*	6.44	2.547*	0.374	7.86	7.08	89.50*
ICMA 02777 x RIL 75	48.67	136.00*	3.00	24.00	11.40*	6.60	21.27	7.06	1.280	0.544	22.88*	8.13	60.13
ICMA 02777 x RIL 81	50.67	95.67	4.33*	19.13	9.83	7.80	17.83	8.97	1.117	0.328	14.13	6.86	80.07*
ICMA 02777 x RIL 116	51.33	74.00	3.67*	18.83	10.50*	6.93	16.63	8.86	0.900	0.473	8.60	8.22	57.57
ICMA 02777 x RIL 135	51.00	155.00*	3.33	27.33*	11.83*	8.37	26.30*	5.83	1.800	0.191	15.11	6.42	86.80*
ICMA 02777 x RIL 182	51.33	76.63	4.00*	19.37	9.50	7.20	19.07	5.75	1.400	0.238	10.36	10.53*	73.80
TNAU Cumbu hybrid CO 9 (Check)	46.00	174.33	3.67	22.20	11.40	7.97	23.67	11.56	1.27	0.36	14.08	7.71	114.90
Mean	49.22	128.28	3.49	23.68	10.03	8.46	21.43	10.04	1.797	0.612	14.28	8.80	74.80
SE	0.71	4.92	0.11	0.71	0.17	0.34	1.05	0.36	0.13	0.07	0.89	0.40	4.87
Total	48.50	133.21	3.60	24.39	10.20	8.80	22.47	10.40	1.93	0.68	15.17	9.19	79.67

Table 3: Standard parent heterosis over standard check (TNAU cumbu hybrid CO 9) for various traits

Hybrids	Days to 50 % flowering	Plant height (cm)	No. of productive tillers	Earhead length (cm)	Earhead girth (cm)	Test weight (g)	Single head grain weight (g)	Crude protein (g/100g)	Crude fibre (g/100g)	Beta carotene content(µg/g)	Iron (mg/100g)	Zinc (mg/100g)	Grain yield / plant (g)
ICMA 92777 x RIL 19	3.62	-47.42**	9.09	-28.68**	-21.47 **	-0.42	-55.35**	-4.30	8.64	-27.64	14.40	-40.25**	-62.81**
ICMA 92777 x RIL 49	-7.97**	-48.18**	-0.00	-32.73**	-20.00 **	-6.28	-60.85**	-24.16**	-65.97**	-32.52**	59.12**	12.66	-68.96**
ICMA 92777 x RIL 53	5.80**	-40.73**	18.18	-15.47*	-14.41 **	9.21	-34.37**	-2.13	-32.46**	105.69**	21.00	36.91**	-41.34**
ICMA 92777 x RIL 68	-7.97**	4.78	27.27*	17.72*	-18.53 **	31.38**	28.45**	27.88**	20.42**	215.45**	95.23**	31.04*	21.85**
ICMA 92777 x RIL 75	10.14**	-48.37**	18.18	-21.17**	-25.29 **	-8.79	-34.93**	28.40**	-66.49**	-31.71*	-44.75**	-4.70	-47.40**
ICMA 92777 x RIL 81	-15.94**	-61.19**	18.18	-7.66	-33.53 **	-9.62*	-49.30**	4.24**	-22.51**	-1.63	-22.99	8.87	-54.89**
ICMA 92777 x RIL 116	3.62	-58.13**	-9.09	-19.07*	-15.00 **	-4.18	-44.23**	-4.07*	-18.85*	-34.96*	11.93	47.96**	-59.27**
ICMA 92777 x RIL 135	7.97**	-56.98**	-18.18	-16.82*	-29.41 **	-18.41**	-51.41**	-23.27**	110.73**	-40.65*	-29.18*	20.76	-68.38**
ICMA 92777 x RIL 182	28.99**	-51.82**	-27.27*	-13.21	-15.88 **	-7.53	-38.73**	18.63**	53.14**	-47.15**	-29.82*	40.98**	-66.75**
ICMA 92888 x RIL 19	0.00	-56.98**	9.09	-17.12*	-19.12 **	47.28**	-8.59	13.67**	72.25**	-54.47**	-1.25	8.87	-13.55**
ICMA 92888 x RIL 49	1.45	-48.18**	-0.00	-7.96	-7.94	7.11	-3.41	-17.56**	15.18*	-6.50	32.08*	79.15**	-28.00**
ICMA 92888 x RIL 53	10.87**	-3.25	-9.09	2.55	-22.35 **	-10.04*	-31.85**	-20.82**	-37.70**	131.71**	-42.25**	-16.39	-54.14**
ICMA 92888 x RIL 68	3.62	-41.30**	-0.00	10.21	-6.47	9.21	-30.56**	-30.57**	8.90	-62.60**	-28.29*	33.12**	-47.87**
ICMA 92888 x RIL 75	15.94	-35.76**	9.09	-22.67**	-11.47 *	5.02	-15.35	-37.17**	1.05	-62.60**	8.69	36.76**	-31.88**
ICMA 92888 x RIL 81	-2.90	8.03*	45.45**	11.26	27.65 **	79.50**	34.79**	-29.73**	-3.40	328.46**	45.41**	-14.21	47.35**
ICMA 92888 x RIL 116	9.42**	-35.56**	9.09	-7.96	-0.88	-23.01**	-42.39**	-10.67**	-17.80*	-61.79**	-33.00*	22.50	-52.65**
ICMA 92888 x RIL 135	7.25**	-8.60*	-9.09	-3.90	-32.06 **	-15.48**	-23.52*	-33.10**	132.46**	-52.85**	-30.66*	-34.68**	-49.75**

ICMA 92888 x RIL 182	0.72	-34.03**	-27.27*	14.11	-0.88	-5.02	-10.28	27.94**	7.33	-57.72**	-32.82*	-14.74	-53.29**
ICMA 93111 x RIL 19	-0.72	-27.53**	-27.27*	-18.17*	-11.18 *	-20.08**	-42.11**	25.03**	54.71**	48.78**	-3.57	-7.81	-69.28**
ICMA 93111 x RIL 49	7.97**	2.10	-18.18	5.11	-12.65 **	-4.60	2.35	22.43**	-21.47**	-34.15**	39.37**	48.01**	-36.75**
ICMA 93111 x RIL 53	20.29**	-37.48**	-9.09	-16.82*	-22.35 **	-12.55*	-30.77**	10.52**	5.76	89.43**	4.41	36.66**	-55.09**
ICMA 93111 x RIL 68	23.19**	-28.68**	9.09	13.06	-13.24 **	44.77**	29.30**	10.78**	-8.90	237.40**	73.62**	72.65**	6.53
ICMA 93111 x RIL 75	22.46**	-47.61**	18.18	-25.38**	-21.18 **	-19.67**	-52.08**	20.24**	55.24**	5.69	-17.05	-4.95	-57.82**
ICMA 93111 x RIL 81	3.62	-0.76	-18.18	38.14**	16.18 **	-14.23**	-49.44**	-44.55**	39.79**	199.19**	-28.57*	6.69	-68.76**
ICMA 93111 x RIL 116	-1.45	-4.21	-27.27*	-1.50	-2.35	-9.62*	-24.51*	-47.66**	26.44**	23.58	21.69	64.74**	-59.27**
ICMA 93111 x RIL 135	20.29**	-39.39**	45.45**	-25.68**	-19.71 **	27.20**	-6.48	-42.56**	17.80*	-34.96*	-42.46**	20.47	-1.80
ICMA 93111 x RIL 182	-7.25**	-48.18**	18.18	-22.37**	-25.00 **	-18.83**	-41.97**	-40.11**	4.19	-11.38	-13.12	-32.69**	-47.52**
ICMA 93222 x RIL 19	-2.17	-3.63	-9.09	34.98**	1.76	-10.04*	5.49	-17.56**	1.57	-64.23**	22.99	-5.58	-28.95**
ICMA 93222 x RIL 49	-13.77**	-18.16**	-9.09	11.11	-8.53	-3.35	-9.4	-22.40**	154.97	60.16**	21.08	73.62**	-38.70**
ICMA 93222 x RIL 53	-3.62	-3.25	-45.45**	7.36	-6.18	-15.48**	8.73	-38.32**	80.10**	221.95**	-14.48	84.87**	-57.18**
ICMA 93222 x RIL 68	22.46**	-33.08**	-36.36**	28.86**	-7.35	-15.48**	21.69*	-22.72**	94.76**	79.67**	1.07	7.71	-42.41**
ICMA 93222 x RIL 75	5.80**	-4.97	9.09	6.91	-7.06	-17.15**	-29.86**	-12.02**	290.58**	35.77**	18.30	37.54**	-39.51**
ICMA 93222 x RIL 81	36.96**	-15.30**	-27.27*	25.38**	3.82	-27.20**	-74.61**	-31.23**	100.00**	223.58**	-34.99*	-10.48	-86.05**
ICMA 93222 x RIL 116	0.00	0.96	-36.36**	16.37*	-4.41	-12.55*	-6.76	-7.70**	76.44**	35.77*	44.27**	-8.68	-52.42**
ICMA 93222 x RIL 135	21.01**	-26.10**	-18.18	33.63**	-3.53	-8.37	-5.21	15.14**	14.40	21.95	-45.18**	40.74**	-45.78**
ICMA 93222 x RIL 182	21.21**	-29.45**	-18.18	20.87	-9.71 *	-5.02	34.37**	3.09	41.36**	100.00**	-4.41	-1.89	-5.05
ICMA 94222 x RIL 19	-13.04**	-13.00**	9.09	11.11	-4.12	68.20**	47.61**	-6.89**	106.28**	34.15*	36.90*	111.99**	23.24**
ICMA 94222 x RIL 49	21.74**	-39.20**	-36.36**	25.38**	-3.24	-20.92**	-37.61**	3.66*	40.05**	-26.83	29.74*	59.12**	-71.48**
ICMA 94222 x RIL 53	-12.32**	7.84*	27.27	16.97*	-11.18 *	83.26**	44.37**	26.82**	179.32**	431.71**	44.24**	83.17**	38.29**
ICMA 94222 x RIL 68	10.87**	-11.85**	-18.18	11.56	-17.06 **	1.26	11.13	-5.80**	10.47	-20.33	-28.01	31.72**	-36.76**
ICMA 94222 x RIL 75	14.49**	-2.10	-0.00	55.41**	-16.18 **	12.55*	19.15	-15.40**	-3.40	117.89**	22.55	95.59**	-11.23*
ICMA 94222 x RIL 81	-0.72	-22.56**	27.27*	22.37**	-20.88 **	100.84**	40.28**	-17.47**	345.55**	69.11**	54.41**	25.22*	33.97**
ICMA 94222 x RIL 116	7.97**	-15.30**	-36.36**	56.91**	-12.06 **	-5.02	-3.52	-14.76**	27.75**	91.06**	63.81**	93.84**	-54.92**
ICMA 94222 x RIL 135	0.72	-11.85**	-36.36**	43.09**	-10.88 *	-2.09	25.35**	-29.90**	102.62**	137.40**	-2.17	-20.71	-40.99**
ICMA 94222 x RIL 182	23.91**	-16.06**	-36.36**	59.16**	-17.06 **	-13.39**	12.68	-20.96**	3.14	-66.67**	-37.61**	22.07	-46.62**
ICMA 02777 x RIL 19	0.00	-13.77	-9.09	24.62**	-17.65 **	11.72*	20.56*	-31.52**	128.80**	46.34**	7.85	-4.75	-17.75**
ICMA 02777 x RIL 49	11.59**	-10.52	-27.27*	27.63**	-16.76 **	33.05**	65.77**	-26.56**	-19.37**	-13.82	37.92**	-3.98	-10.56*
ICMA 02777 x RIL 53	-0.72	-4.40	36.36**	43.39**	-16.76 **	85.77**	37.46**	-7.09**	30.37**	488.62**	-17.79	-22.07	38.06**
ICMA 02777 x RIL 68	12.32**	-53.40**	-9.09	-0.15	-6.76	78.24**	4.79	-44.32**	100.00**	-8.94	-32.90*	3.01	-22.11**
ICMA 02777 x RIL 75	5.80**	-21.99**	-18.18	8.11	0.59	-17.15**	-10.14	-38.90**	0.52	32.52*	87.18**	18.33	-47.66**
ICMA 02777 x RIL 81	10.14**	-45.12**	18.18	13.81	-13.24 **	-2.09	-24.65*	-22.40**	-12.30	-19.51	4.03	-0.15	-30.32**
ICMA 02777 x RIL 116	11.59**	-57.55**	-0.00	-15.17*	-7.35	-12.97	-29.72**	-23.36**	-29.32**	15.45	-28.08*	19.54	-49.90**
ICMA 02777 x RIL 135	10.87**	-11.09**	-9.09	23.12**	4.41	5.02	11.13	-49.57**	41.36**	-53.66**	15.52	-6.55	-24.46**
ICMA 02777 x RIL 182	11.59**	-56.04**	9.09	-12.76	-16.18 **	-9.62*	-19.44*	-50.26**	9.95	-42.28**	-20.82	53.20**	-35.77**

Hybrids suitable for heterosis breeding should satisfy the two criteria *viz*., mean performance and standard heterosis. Hence the hybrids were analyzed under each criteria and combined to suggest them for heterosis breeding. For test weight the standard heterosis varied from -27.20 to 100.84 with four and thirteen hybrids showing significant and positive standard heterosis per cent. Concordant result for test weight was reported by Salagarkar and Wali (2016) [11] and Bachkar *et al.* (2014). Accordingly, the hybrid for single plant yield the hybrids ICMA 92777 x RIL 68 (21.85 %), ICMA 92888 x RIL 81 (47.35 %), ICMA 94222 x RIL 53 (23.24 %), ICMA 94222 x RIL 81 (33.97 %) and ICMA 02777 x RIL 53 (38.06 %) excelled for both *per se* as well as standard heterosis and the heterosis percentage varied from -86.05 to 47.35. These results were similar with the findings of Bachkar *et al.* (2014), Maryam (2015) [8], Patel *et al.* (2016) [09], Salagarkar and Wali (2016) [11] and Chittora and Patel (2017) [3] in pearl millet. Hence among the above mentioned hybrids could be concentrated for heterosis breeding programme for yield and nutritional traits.

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