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Evaluation of heterosis and inbreeding depression for grain yield and It's attributing characters in pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract
The present investigation was carried out using 83 genotypes consisting of 12 parental lines, 35 hybrids resulting from Line × Tester mating design, their 35 F2's and a standard check (GHB 558). Hybrids exhibited significant moderate to high heterosis over mid parent, better parent and standard check in desired direction for all the traits except standard heterosis in days to flowering. The significant economic heterosis in desirable direction was observed in high heterotic hybrids of a grain yield per plant. Out of this hybrids, two hybrids *viz.*, ICMA 92333 × 15388 R and ICMA 05888 × 15403 R were possess significant economic heterosis for component characters like number of effective tiller per plant, ear head girth, ear head length, dry fodder yield per plant and test weight and also exhibited significant and positive inbreeding depression for those traits, which indicating that the maximum contribution of this character towards grain yield heterosis. The hybrid ICMA 91777 × 15041 R was exhibited significant inbreeding depression for all the traits except dry fodder yield per plant. None of the cross showed significant and positive high heterosis with low inbreeding depression in desirable direction in all traits except days to maturity.

Keywords: Heterobeltiosis, inbreeding depression, line x tester mating design, pearlmillet, *per se* performance, relative heterosis, standard heterosis

Introduction
Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is world's sixth and India's third important cereal food grain crop after rice and wheat. Pearl millet is a cereal crop that thrives in the arid and semi-arid tropical regions of Asia and Africa. Pearl millet excels all other cereals due to these features of C4 plant with high photosynthetic efficiency and high dry matter production capacity. It is well adapted to grow under most adverse agro-climatic conditions characterized by drought, low soil fertility and high temperatures. It is an annual tillering, cross pollinated, diploid (2n = 14) belong to family *poaceae,* sub-family *panicoideae*, tribe-*paniceae* and genus *pennisetum* is believed to be originated to Western Africa. India is the largest pearl millet growing country contributing 42 percent of production in the world. To bring millets into main stream for exploiting the nutritional rich properties and promoting their cultivation, Government of India has declared year 2018 as the "Year of Millets".
Heterosis has been exploited for increasing the yield in several crops. The knowledge of heterosis helps in identifying best combiners, either to exploit heterosis or to accumulate fixable genes through selection. The heterosis reveals the type of gene action involved and it helps in the selection of suitable breeding methodology and parameters, which are employed for crop improvement programme.
Inbreeding reduces the mean phenotypic value of various fitness-related traits and the phenomenon is known as inbreeding depression (Stebbins, 1958 and Wright, 1977) [8, 11]. Heterosis resulting from crosses between strains or between different races or varieties is theoretically known as the reverse of inbreeding depression and forms an important means of genetic improvements. In general, inbreeding depression and heterosis are associated with changes in heterozygosity and homozygosity for several reasons. First, homozygotes may have reduced fitness value for traits which are controlled by directionally dominant alleles and second, increasing homozygosity increases the chances of the expression of deleterious recessive alleles. The relationship between the amount of inbreeding depression and heterosis as defined in the present study is in accordance with the theory that the phenomenon of heterosis is the reverse of inbreeding depression indicating that the traits, which have decreased by inbreeding can be recovered by crossing (Falconer, 1989) [2].

Materials and Methods

The crossing programme was carried out using seven CMS lines as females *viz.* ICMA 05888, ICMA 92333, ICMA 91777, ICMA 04999, ICMA 10777, ICMA 01555 and ICMA 09555 and five testers as males *viz.* 15388 R, 15041 R, 15403 R, 15001 R and 15061 R during *kharif* 2017 in a Line x Tester mating design at Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. Seeds of 35 experimental crosses (F1) were obtained and all 35 F1's were selfed for the development of F2's in *summer* 2018. A set of 83 genotypes comprising of 12 parents (7 female and 5 male parents), 35 F1 and their 35 F2's with a standard check GHB 558 were sown in Randomized Block Design (RBD) with two replications in *kharif* 2018 for evaluation of different eleven characters.

The observations were recorded on five randomly selected competitive plants of each genotype in each replication for various characters *i.e* plant height (cm), number of effective tiller per plant, ear head length (cm), ear head girth (mm), grain yield per plant (g), dry fodder yield per plant (g), harvest index (%), test weight (g) and protein content (%). While the observation of days to flowering (DF) was recorded on the basis of 50% plants of each genotype flowered and the observation of days to maturity (DM) was recorded on the basis of 80% plants of each genotype matured. The protein content (PC) was estimated in percentage by using NIR spectroscopy technique. The replication wise mean values were used in statistical analysis. The data were subjected to analysis of variance as per the procedure suggested by Panse and Sukhatme (1985) [6].

Heterosis was estimated as percent increase or decrease in the mean value of F1 hybrid over mid parent *i.e.*, relative heterosis (Briggle 1963), over better parent *i.e.*, heterobeltiosis (Fonseca and Patterson 1968) and over standard check *i.e.*, standard heterosis (Meredith and Bridge 1972) for each character. Inbreeding depression was estimated as percent increase or decrease in the mean value of F2 with reference to F1 hybrid for each character (Wright 1922) [10].

Results and Discussion

The analysis of variance depicting mean squares for various characters are presented in Table 1. The mean squares due to genotypes (Parents, Hybrids, F2's and a standard check GHB 558) were highly significant for all the characters.

The comparison of Hybrids *vs.* F2's was highly significant for most of the traits except days to flowering, days to maturity, plant height and harvest index. Further, partitioning of the genotypes into parents, hybrids and parents *vs.* hybrids revealed that the parents exhibited significant differences for all the characters except grain yield, whereas hybrids exhibited significant differences for all the characters. This indicated the existence of appreciable amount of genetic variability in the experimental material of the present study.

Furthermore, the splitting of parents into females and males revealed that the females, were significant for all the characters except grain yield. While males were significant for all the characters except for plant height and grain yield. The females *vs.* males comparison was significant for most of the characters except number of effective tiller per plant, ear head length, ear head girth and grain yield. This suggested that the contribution of females and males to hybrid might be different due to differential performance of females and males for these characters.

In practical plant breeding, the heterosis measured over better parent is more realistic and is of more practical importance. However, the commercial usefulness of a hybrid would primarily depend on its performance in comparison with the best commercial variety/hybrid of the concerned crop species. Hence in the present study, heterosis has been estimated over the mid parent, better parent and standard check. Thus, the aim of heterosis analysis in the present study was to find out the best combination of parent giving high degree of heterobeltiosis and standard heterosis and its exploitation to get better transgressive segregants and characterization of parents for their prospects for further use in breeding programme of pearlmillet.

In the present investigation hybrids were exhibited significant moderate to high heterosis over mid parent, better parent and standard check in desired direction for all the traits (Reshma *et al.* 2017) [7] except standard heterosis in days to flowering (Table 2). The significant economic heterosis in desirable direction was observed in high heterotic hybrids of a grain yield per plant. Out of this hybrids, two hybrids *viz.*, ICMA 92333 × 15388 R and ICMA 05888 × 15403 R were possess significant economic heterosis for component characters like number of effective tiller per plant, ear head girth, ear head length, dry fodder yield per plant and test weight (Vetriventhan *et al.* 2008) [9] and also exhibited significant and positive inbreeding depression for those traits, which indicating that the maximum contribution of this character towards grain yield heterosis. Hybrids *viz.*, ICMA 92333 × 15388 R, ICMA 05888 × 15403 R, ICMA 91777 × 15388 R and ICMA 91777 × 15041 R were found most promising heterotic hybrids for grain yield per plant with useful and significant heterosis over mid parent (MP), better parent (BP) and standard check (SC) for component characters showing desirable heterosis were depicted in Table 3.

The magnitude of inbreeding depression was moderate to high varied from cross to cross indicating influence of genetic constitution of cross. Magnitude of Inbreeding depression over F1 for different characters expressed as percentage in pearl millet mentioned in Table 4. For grain yield per plant, inbreeding depression ranged from -10.54 (ICMA 01555 × 15388 R) to 49.27 per cent (ICMA 91777 × 15388 R). Among 35 F2, eighteen F2 exhibited significant positive inbreeding depression for grain yield per plant. The cross, ICMA 91777 × 15388 R (49.27%) exhibited highest inbreeding depression followed by ICMA 01555 × 15061 R (44.89%) and ICMA 05888 × 15403 R (40.64%). The cross, ICMA 01555 × 15388 R (-10.54%) exhibited lowest inbreeding depression for grain yield per plant. These findings were in agreement with the reports of Jog *et al.* (2016) [4].

The cross, ICMA 05888 × 15403 R (33.33%) exhibited highest inbreeding depression followed by ICMA 92333 × 15403 R (32.43%) and ICMA 04999 × 15041 R%). The cross ICMA 10777 × 15061 R (-40.00%) exhibited lowest inbreeding depression for number of effective tiller per plant. In case of ear head length, ICMA 91777 × 15388 R (46.83%) exhibited highest inbreeding depression followed by ICMA 10777 × 15388 R (43.17%) and ICMA 92333 × 15388 R (36.71%). The cross, ICMA 10777 × 15001 R (-29.94%) exhibited lowest inbreeding depression for these character.

In relation to ear head girth, ICMA 09555 × 15041 R (30.42%) exhibited highest inbreeding depression followed by ICMA 09555 × 15388 R (29.20%) and ICMA 10777 × 15041 R (24.90%). The cross, ICMA 01555 × 15403 R (-37.50%)

exhibited lowest inbreeding depression for ear head girth. These findings were also in agreement with the reports of Jog *et al.* (2016) [4].

The inbreeding depression ranged from -27.09 (ICMA 09555 × 15388 R) to 53.82 per cent (ICMA 01555 × 15061 R). The cross ICMA 01555 × 15061 R (53.82%) exhibited highest inbreeding depression followed by ICMA 09555 × 15041 R (52.53%) and ICMA 92333 × 15388 R (49.54%). Out of 35 F2, 14 F2 exhibited significant positive inbreeding depression and ICMA 09555 × 15388 R (-27.09%) exhibited lowest inbreeding depression for dry fodder yield per plant.

The hybrid ICMA 91777 × 15041 R was exhibited significant inbreeding depression for all the traits except dry fodder yield per plant. None of the cross showed significant and positive high heterosis with low inbreeding depression in desirable direction in all traits except days to maturity.

Table 1: Analysis of variance (mean squares) for parents and hybrids for grain yield and its components characters in pearl millet

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	No. of effective tiller per plant	Ear head length (cm)	Ear head girth (mm)	Grain yield per plant (g)	Dry fodder yield per plant (g)	Harvest index (%)	Test weight (g)	Protein content (%)
Replication	1	3.47	2.66	53.46	0.02	0.01	2.53	0.05	3.72	3.22	0.08	0.02
Genotype	82	35.93**	52.40**	2583.48**	0.59**	31.17**	36.36**	48.75**	310.57**	104.10**	3.09**	0.03**
Parents	11	49.43**	51.95**	4337.29**	0.57**	17.56**	40.72**	9.99	191.79**	113.51**	4.24**	2.56**
Female	6	33.33**	61.45**	593.43**	0.25**	17.65**	55.72**	14.19	109.49**	83.21**	5.00**	2.09**
Male	4	36.90**	34.25**	145.26	1.21**	21.40**	28.24**	5.99	259.60**	151.72**	3.55**	3.27**
Female *vs.* male	1	196.23**	65.74**	43568.64**	0.01	1.65	0.58	0.73	414.32**	142.51**	2.39**	2.56**
Parents *vs.* Hybrids	1	18.82*	4.44	27968.75**	0.24**	88.58**	190.25**	82.58**	400.99**	28.21*	1.08**	0.22
Hybrids	34	46.25**	55.33**	2436.70**	0.64**	26.72**	46.84**	36.47**	378.25**	115.19**	3.25**	2.17**
F2	34	21.18**	51.88**	1488.63**	0.49**	33.78**	19.48**	47.93**	258.16**	95.35**	2.01**	0.82**
Hybrids *vs.* F2	1	3.43	26.41	2239.55	1.06*	146.13**	90.51**	484.08**	799.02**	2.07	13.37**	14.58**
Error	82	5.93	4.39	150.43	0.02	1.8	1.53	7.68	12.39	7.48	0.08	0.01

and ** indicates significant at P = 0.05 and P = 0.01 levels, respectively.

Table 2: Top three ranking parent and hybrids with respect to *per se* performance, heterosis over better parent and standard check (GHB 558) and Inbreeding depression in pearl millet

Sr. No.	Characters	Best performing parent (*per se* performing)	Best performing hybrids (*per se* performing)	Status of parents	Hybrids (%) over		Inbreeding Depression
					Better parent	Standard check	
1	Days to flowering	ICMA-91777	ICMA-01555 × 15403-R/ ICMA-01555 × 15001-R	G × G / G × G	-7.29 / -5.21	0.00 / 2.25	-28.74**/-5.75
		ICMA-04999	ICMA-10777 × 15061-R/ ICMA-04999 × 15403-R	A × A / G × G	-7.29	0.00	-14.61**/-10.11*
		ICMA-01555/15061-R	CMA-04999 × 15001-R	G × G	0.00	2.25	-5.56
2	Days to maturity	ICMA-91777	ICMA-05888 × 15403-R	G × A	-7.48	-13.38	-8.82**
		ICMA- 05888	ICMA-01555 × 15041-R/ ICMA-09555 × 15388-R	G × G / G × P	9.56	-5.10	-11.43**/-8.57**
		15061-R	ICMA-01555 × 15001-R/ ICMA-01555 × 15061-R	G × P/ G × G	-2.01	7.01	-21.99**/-4.96*
3	Plant height (cm)	ICMA-92333	ICMA-01555 × 15061-R	G × G	-49.28	-54.70	5.18
		ICMA-10777	ICMA-05888 × 15041-R	A × P	-59.64	-64.80	2.37
		ICMA-05888	ICMA-05888 × 15001-R	A × G	-51.68	-52.02	-49.59**
4	No. of effective tiller per plant	15001-R	ICMA-10777 × 15388-R/ ICMA-91777 × 15061-R	P × A / P × A	33.33	69.23	10.53*/-15.79*
		ICMA-92333	ICMA-05888 × 15061-R/ ICMA-92333 × 15403-R	G × A / G × G	37.04	42.31	29.73**/32.43**
		15388-R	ICMA-01555 × 15388-R/ ICMA-01555 × 15041-R	A × A / A × G	3.45	15.38	-5.71/-11.43**
5	Earhead length (cm)	15388-R	ICMA-91777 × 15388-R	G × G	12.83	15.38	46.83**
		ICMA-92333	ICMA-01555 × 15388-R	G × G	25.21	32.58	4.56
		ICMA-01555	ICMA-91777 × 15041-R	G × A	22.81	9.50	21.28**
6	Earhead girth (mm)	ICMA-92333	ICMA-05888 × 15403-R/ ICMA-09555 × 15388-R	G × G / G × G	28.57	22.59	23.97**/29.20**
		15041-R	ICMA-05888 × 15001-R	G × P	-6.64	-6.64	23.79**
		15388-R	ICMA-92333 × 15403-R	G × G	13.77	4.32	22.05**

and ** indicates significant at P = 0.05 and P = 0.01 levels, respectively.

Table 2: Continue…..

Sr. No.	Characters	Best performing parent (*per se* performing)	Best performing hybrids (*per se* performing)	Status of parents	Hybrids (%) over		Inbreeding Depression
					Better parent	Standard check	
7	Grain yield per plant (g)	ICMA-91777	ICMA-92333 × 15388-R	A × G	48.91	30.58	36.92**
		ICMA-10777	ICMA-05888 × 15403-R	A × A	48.37	24.03	40.64**
		15061-R	ICMA-91777 × 15388-R	G × G	24.22	19.11	49.27**
8	Dry fodder yield per plant (g)	15403-R	ICMA-92333 × 15388-R	G × A	123.06	169.68	49.54**
		ICMA-05888	ICMA-01555 × 15403-R	G × A	44.18	161.66	24.78**
		15041-R	ICMA-09555 × 15061-R	G × G	103.64	86.45	28.69**
9	Harvest index (%)	15061-R	ICMA-91777 × 15001-R	G × A	-28.09	-21.88	1.21
		ICMA-91777	ICMA-91777 × 15061-R	G × P	-18.78	-11.76	0.13
		ICMA-10777	ICMA-91777 × 15388-R	G × A	-4.86	-2.76	4.97
10	Test weight (g)	ICMA-92333	ICMA-92333 × 15388-R	G × G	6.56	36.84	35.77**
		15001-R	ICMA-91777 × 15041-R	G × A	6.60	18.95	26.29**
		15388-R	ICMA-91777 × 15388-R	G × G	16.93	30.53	12.18**
11	Protein Content (%)	15061-R	ICMA-09555 × 15403-R	G × G	13.82	19.90	24.49**
		ICMA-09555	ICMA-10777 × 15061-R	G × G	12.69	29.74	20.80**
		15041-R	ICMA-04999 × 15403-R	P × G	5.55	5.55	27.55**

and ** indicates significant at P = 0.05 and P = 0.01 levels, respectively

Table 3: A comparative study of most promising heterotic hybrids for grain yield per plant with useful component characters in pearl millet

Sr No.	Hybrids	Heterosis for grain yield over			Useful and significant heterosis over MP for component characters	Useful and significant heterosis over BP for component characters	Useful and significant heterosis over SC for component characters
		MP	BP	SC			
1	ICMA 92333 × 15388 R	56.98**	48.91**	30.58**	DF, DM, TW	DF, PH, TW	DF, DM, ETPP, EL, EG, DFPP, TW
2	ICMA 05888 × 15403 R	53.38**	48.37**	24.03**	DF, DM, EL, EG, HI, TW	DF, DM, EL, EG, HI, TW	DF, DM, ETPP, EL, EG, DFPP, TW
3	ICMA 91777 × 15388 R	31.85**	26.21**	21.02**	DM, EL, EG, HI, TW, PC	DF, DM, EL, TW, PC	DF, DM, EL, TW, PC
4	ICMA 91777 × 15041 R	26.74**	24.22**	19.11*	DF, EL, EG, HI, TW, PC	DF, DM, EL, EG, TW	DF, DM, EL, EG, TW, PC

DF : Days to flowering
DM : Days to maturity
PH : Plant height
ETPP : Effective tillers per plant
EL : Earhead length
EG : Ear head girth
HI : Harvest index
TW : Test weight
PC : Protein content
DFPP : Dry fodder per plant

and ** indicates significant at P = 0.05 and P = 0.01 levels, respectively

Table 4: Magnitude of Inbreeding depression over F1 for different characters expressed as percentage in pearl millet

Sr. No.	Hybrids	Days to flowering	Days to maturity	Plant height	No. of effective tillers per plant	Earhead length	Earhead girth
1	ICMA-05888 × 15388-R	21.85**	4.08	19.42**	6.67	-6.69	5.91*
2	ICMA-05888 × 15041-R	16.52**	2.58	2.37	13.79**	17.54**	5.60
3	ICMA-05888 × 15403-R	10.34**	-8.82**	16.27*	33.33**	15.88**	23.97**
4	ICMA-05888 × 15001-R	13.68**	14.10**	-49.59**	24.19**	5.41	23.79**
5	ICMA-05888 × 15061-R	15.32**	14.63**	10.38	29.73**	-1.20	4.92
6	ICMA-92333 × 15388-R	-1.98	17.65**	18.04**	29.41**	36.71**	15.17**
7	ICMA-92333 × 15041-R	10.91**	-0.66	1.74	-6.00	-0.45	12.34**
8	ICMA-92333 × 15403-R	-20.22**	4.91*	1.37	32.43**	32.50**	22.05**
9	ICMA-92333 × 15001-R	3.81	-2.47	-91.15**	4.84	7.25	20.89**
10	ICMA-92333 × 15061-R	0.00	8.81**	-21.08*	-20.00**	-0.45	3.20
11	ICMA-91777 × 15388-R	1.03	16.28**	12.93*	26.92**	46.83**	-2.30
12	ICMA-91777 × 15041-R	-6.80*	-5.37*	39.72**	13.04*	21.28**	17.58**
13	ICMA-91777 × 15403-R	-3.19	9.14**	13.07*	-7.14	-1.24	-3.03
14	ICMA-91777 × 15001-R	-20.00**	16.47**	24.17**	-3.33	3.75	-4.60
15	ICMA-91777 × 15061-R	-6.12	3.64	11.99	-15.79*	-6.17	15.47**
16	ICMA-04999 × 15388-R	-8.08*	12.50**	22.05**	9.68*	12.54**	-8.69*
17	ICMA-04999 × 15041-R	-26.37**	3.70	18.19**	31.82**	12.22*	20.67**
18	ICMA-04999 × 15403-R	-10.11*	0.62	16.21*	9.37*	20.93**	-1.94
19	ICMA-04999 × 15001-R	-5.56	13.37**	14.81*	-15.91**	2.75	-9.82**
20	ICMA-04999 × 15061-R	-6.00	-16.44**	23.71**	21.67**	29.56**	-26.00**
21	ICMA-10777 × 15388-R	-0.99	8.33**	14.98*	10.53*	43.17**	0.69
22	ICMA-10777 × 15041-R	3.51	3.13	42.29**	10.71*	31.09**	24.90**
23	ICMA-10777 × 15403-R	-6.59	-8.92**	-2.64	-25.00**	24.06**	13.90**

24	ICMA-10777 × 15001-R	-5.88	6.49**	-84.80**	-19.23**	-29.94**	-6.18
25	ICMA-10777 × 15061-R	-14.61**	-7.28**	-30.74**	-40.00**	13.02*	-5.57
26	ICMA-01555 × 15388-R	5.94	4.73*	-2.40	-5.71	4.56	-0.17
27	ICMA-01555 × 15041-R	-1.04	-11.43**	-1.63	-11.43**	-8.43	-8.36*
28	ICMA-01555 × 15403-R	-28.74**	-17.33**	-18.68*	12.96**	6.57	-37.50**
29	ICMA-01555 × 15001-R	-5.75	-21.99**	-7.83	4.76	7.87	-14.09**
30	ICMA-01555 × 15061-R	5.61	-4.96*	5.18	26.67**	28.32**	-17.07**
31	ICMA-09555 × 15388-R	8.91*	-8.57**	5.85	-19.57**	7.34	29.20**
32	ICMA-09555 × 15041-R	13.76**	-8.00**	33.60**	4.17	0.37	30.42**
33	ICMA-09555 × 15403-R	10.62**	-3.25	-3.73	22.86**	13.38*	24.76**
34	ICMA-09555 × 15001-R	-16.13**	-0.63	29.67**	6.25	-18.18**	2.62
35	ICMA-09555 × 15061-R	-12.09**	-2.05	8.24	29.69**	8.87	23.09**
S.Em.±		1.66	1.55	10.73	0.12	1.19	0.95
Range		-28.74 to 21.85	-21.99 to 17.65	-91.15 to 42.29	-40.00 to 33.33	-29.94 to 46.83	-37.50 to 30.42
Significant heterosis		19	24	22	26	18	23
No. of +ve significant		9	13	16	18	16	16
No. of -ve significant		10	11	6	8	2	7

* and ** indicates significant at P = 0.05 and P = 0.01 levels, respectively

Table 4: Continue….

Sr. No.	Hybrids	Grain yield per Plant	Dry fodder yield per plant	Harvest index	Test weight	Protein content
1	ICMA-05888 × 15388-R	-4.11	-22.36**	9.01	0.43	-17.24**
2	ICMA-05888 × 15041-R	15.83*	26.26**	-7.19	-5.73*	5.89
3	ICMA-05888 × 15403-R	40.64**	21.49*	12.69**	26.33**	4.67
4	ICMA-05888 × 15001-R	34.27**	32.68**	1.56	9.84**	13.21**
5	ICMA-05888 × 15061-R	32.95**	8.56	16.43**	-16.88**	11.67**
6	ICMA-92333 × 15388-R	36.92**	49.54**	-14.51*	35.77**	16.30**
7	ICMA-92333 × 15041-R	-3.09	-15.17	6.42	6.59*	26.12**
8	ICMA-92333 × 15403-R	16.54*	14.62	1.30	14.04**	-4.23
9	ICMA-92333 × 15001-R	20.15*	18.26*	0.95	8.33**	-11.13**
10	ICMA-92333 × 15061-R	-0.52	7.01	-4.25	-3.50	3.05
11	ICMA-91777 × 15388-R	49.27**	42.97**	4.97	12.18**	11.67**
12	ICMA-91777 × 15041-R	33.37**	13.26	11.60**	26.29**	21.58**
13	ICMA-91777 × 15403-R	-4.81	-5.76	0.08	12.71**	4.34
14	ICMA-91777 × 15001-R	-1.74	-4.82	1.21	10.95**	-0.91
15	ICMA-91777 × 15061-R	-2.97	-2.86	0.13	10.96**	3.12
16	ICMA-04999 × 15388-R	2.94	4.80	-1.00	18.68**	4.04
17	ICMA-04999 × 15041-R	10.62	2.64	3.78	17.24**	11.50**
18	ICMA-04999 × 15403-R	30.58**	3.70	14.30**	15.91**	27.55**
19	ICMA-04999 × 15001-R	-1.90	-17.92	7.43	9.35**	-12.52**
20	ICMA-04999 × 15061-R	7.79	-11.65	10.07*	6.54*	-1.71
21	ICMA-10777 × 15388-R	21.84**	43.14**	-15.85**	12.52**	18.68**
22	ICMA-10777 × 15041-R	-1.90	7.93	-5.79	20.00**	1.20
23	ICMA-10777 × 15403-R	31.49**	14.08	10.45*	12.89**	20.01**
24	ICMA-10777 × 15001-R	17.76*	34.80**	-13.67*	1.30	16.07**
25	ICMA-10777 × 15061-R	-6.97	2.94	-6.08	-7.11*	20.80**
26	ICMA-01555 × 15388-R	-10.54	-4.65	-3.27	-16.38**	9.29**
27	ICMA-01555 × 15041-R	-0.54	7.63	-5.87	-29.05**	13.44**
28	ICMA-01555 × 15403-R	14.87	24.78**	-8.73	4.88	-8.33*
29	ICMA-01555 × 15001-R	17.25*	47.93**	-29.39**	6.82*	11.60**
30	ICMA-01555 × 15061-R	44.89**	53.82**	-10.11	4.55	-0.55
31	ICMA-09555 × 15388-R	-10.06	-27.09*	7.24	-6.07*	26.70**
32	ICMA-09555 × 15041-R	23.74**	52.53**	-26.56**	8.15**	8.86**
33	ICMA-09555 × 15403-R	22.55**	37.26**	-12.46*	2.70	24.49**
34	ICMA-09555 × 15001-R	-5.00	1.50	-3.94	12.11**	9.78**
35	ICMA-09555 × 15061-R	23.11**	28.69**	-4.60	25.00**	10.79**
S.Em.±		2.49	3.17	2.23	0.26	0.27
Range		-10.54 to 49.27	-27.09 to 53.82	-29.39 to 16.43	-29.05 to 35.77	-17.24 to 27.55
Significant heterosis		18	16	12	29	24
No. of +ve significant		18	14	6	23	20
No. of -ve significant		0	2	6	6	4

* and ** indicates significant at P = 0.05 and P = 0.01 levels, respectively

Conclusion

A different type of heterosis has provided the most important genetic tools in improving seed yield of crop plants. Out of total 35 hybrids and 35 F2's, four hybrids *viz.*, ICMA 92333 × 15388 R, ICMA 05888 × 15403 R, ICMA 91777 × 15388 R and ICMA 91777 × 15041 R were found most promising heterotic hybrids for grain yield per plant with useful component characters depicted desirable heterosis and hybrid ICMA 91777 × 15041 R exhibited significant inbreeding depression for all the traits except dry fodder yield per plant. While none of the hybrid showed significant and positive high heterosis with low inbreeding depression in desirable direction in all traits except days to maturity.

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