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COMBINING ABILITY AND HETEROSIS FOR SOME YIELD TRAITS AND PROTEIN CONTENT IN PEARLMILLET

ANIL KUMAR, I. S. YADAV* AND R. K. ARYA

Department of Genetics and Plant Breeding
CCS Haryana Agricultural University,
Hisar-125 004 (Haryana), India
**(e-mail : ishwar.yadav@gmail.com)*

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SUMMARY

The present investigation was carried out in Department of Genetics and Plant Breeding, CCS HAU, Hisar during **kharif** season to identify good general combiners and good specific cross combinations and to estimate the extent of heterosis in pearlmillet. The material for present study was developed by crossing 10 male sterile lines viz., HAMS9A, HAMS13A, HAMS14A, HAMS18A, HAMS22A, ICMA89111, ICMA94222, ICMA94555, ICMA95222 and ICMA95555 with five diverse pollinators/testers viz., CSSC46-2, G73-107, H90/4-5, H77/833-2 and 1307 in line x tester fashion. All the 50 crosses along with the check HHB94 were grown in randomized block design with three replications. Data were recorded on five competitive plants for grain yield (g)/plant, dry fodder yield (g)/plant, days to 50 per cent flowering, plant height (cm), ear length (cm), effective tillers (no.)/plant, ear girth (cm), ear weight (g), total biological yield (g)/plant, harvest index (%),1000-grain weight (g) and protein content (%). Among the testers, CSSC46-2 and G73-107 expressed highly significant and positive gca effects for grain yield and also for most of its components. On the other hand, H77/833-2 and 1307 were the good general combiners for protein content. It revealed that the crosses ICMA95222 x CSSC46-2, ICMA94555 x G73-107, HAMS13A x CSSC46-2 and ICMA94222 x G73-107 possessed significantly higher yield and most of its contributing traits. These crosses not only exhibited high sca effects but also expressed high *per se* performance for grain yield and its component traits. Out of these only four, namely, ICMA95222 x CSSC46-2 (92.05%), ICMA94555 x G73-107 (77.76%), HMS13A x CSSC46-2 (66.76%) and HMS9A x CSSC46-2 (55.52%) showed more than 50 per cent heterosis over check HHB94. Standard heterosis over check HHB94 for protein content was exhibited by only two crosses HMS9A x 1307 and HMS18A x H77/833-2. These crosses can be further used for the improvement of nutritional quality.

Key words : Pearlmillet, grain yield, fodder yield and protein content, gca and sca effects

Pearlmillet (*Pennisetum glaucum* (L.) R. Br.) is one of the major cereal crops of the arid and semi-arid regions of Africa and Asia and provides staple food for millions of people in these regions (Arya and Yadav, 2009). It is a multipurpose cereal grown for grain, stover and green fodder. It shall continue to play a prominent role in the integrated agricultural and livestock economy of the country particularly in rainfed areas due to its drought hardiness and tolerance to high temperature. It has the virtue of having exceptionally highest productivity per day both for grain as well as fodder. In the limiting environments, pearlmillet is the only successful cereal and a major source of nutrition for the poor farming community. With its ability to adapt to diverse agro-ecological conditions, it may have unique position in the world agriculture. It also responds well to improved moisture and soil fertility conditions. In terms of annual production, pearlmillet is the seventh most important cereal crop in the world, following wheat, rice, maize, barley, oat and sorghum.

The ultimate aim of breeders is the development of high yielding hybrids. The quick and efficient method for evaluation of new gremplasm for their performance in crosses is required. The line x tester method suggested by Kempthorne (1957) is the most effective technique for the study of combining ability. It helps in evaluating large number of genotypes for their general and specific combining ability. It assumes greater importance when one of the parents is male sterile line. In most of the previous studies the results are contradictory, because in case of pearlmillet the results on inheritance pattern and combining ability depend on the material used. Therefore, keeping the above points in view, present investigation was carried out to identify good general combiners and good specific cross combinations and to estimate the extent of heterosis in pearlmillet.

MATERIALS AND METHODS

The present investigation was carried out in Department of Genetics and Plant Breeding, CCSHAU, Hisar during **kharif** season. The material for present study was developed by crossing 10 male sterile lines viz., HAMS9A, HAMS13A, HAMS14A, HAMS18A, HAMS22A, ICMA89111, ICMA94222, ICMA94555, ICMA95222 and ICMA95555 with five diverse pollinators/testers viz., CSSC46-2, G73-107, H90/4-5, H77/833-2 and 1307 in line x tester fashion. All the 50 crosses along with the check HHB94 were grown in randomized block design in three replications. Data were recorded on five competitive plants for grain yield, dry fodder yield (g)/plant days to 50 per cent flowering, plant height (cm), ear length (cm), effective tillers (no.)/ plant, ear girth (cm), ear weight (g), total biological yield (g)/plant, harvest index (%),1000-grain weight (g) and protein content (%). The data were subjected to line x tester analysis as suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance revealed the presence of considerable amount of genetic variability in the material under investigation (Table 1).The line x tester analysis was followed by Kempthorne (1957). The results on computation of general predictability ratio based on Baker (1978) revealed that in the present material both additive as well as non-additive type of gene effects played an important role for expression of all the characters. However, the additive component was higher in magnitude for majority of traits, except for days to 50 per cent flowering, total tillers, biological yield and protein content where the non-additive component was higher in magnitude.

A close look on the information made evident that it is difficult to generalize the nature of gene effects for the various quantitative characters. For the characters, namely, ear weight, grain yield and harvest index which are largely controlled by additive gene action, the selection schemes involving family selection and recurrent selection for gca using a broad base test would be quite effective. On the other hand for days to 50 per cent flowering, total tillers, effective tillers, biological yield and protein content where there is predominance of non-additive gene action, recurrent selection for specific combining ability would be quite effective. For plant height, ear length, ear girth and dry fodder yield both additive and non-additive gene effects were important. In such situation some variations of RRS have been suggested (Yadav *et al*., 2000).

General Combining Ability Effects

The gca effect (Table 2) revealed that line HMS9A emerged as the best general combiner for almost all the characters. Lines HAMS13A, ICMA94555, ICMA95222, ICMA95222 and ICMA95555 were the good general combiners for grain yield and most of it components. However, HAMS9A, HAMS18A, ICMA89111 and ICMA95555 were the good general combiners for protein content. Among the testers, CSSC46-2 and G73-107 expressed highly significant and positive gca effects for grain yield and also for most of its components. On the other hand, H77/833-2 and 1307 were the good general combiners for protein content.

On the basis of gca effects, it would be concluded that among lines HAMS9A, HAMS13A, ICMA94555, ICMA95222, ICMA95555, CSSC46-2 and G73-107 among testers may be listed as the most promising material. This material could be further exploited in the breeding programme for developing superior hybrids or to develop a base population. The base population thus developed could be further improved by following suitable recurrent selection with the objectives of synthetic/composite and /or as a source of variability for variability extracting superior inbreds to develop superior hybrids. It may be noticed that some of the hybrids based on above material viz., ICMA95222 x CSSC46-2, ICMA94222 x G73-107, HAMS13A x CSSC46-2, HAMS9A x CSSC46-2 and ICMA95555 x CSSC46-2 outyielded the check by a significant margin of 92.05, 77.76, 66.67, 55.52 and 46.00 per cent, respectively. Above results have been supported by Yadav *et al.* (2011).

Specific Combining Ability Effects

A perusal of the Table 3 revealed that the crosses ICMA95222 x CSSC46-2, ICMA94555 x G73-107,

TABLE 1
Analysis of variance for combining ability for different characters

Source of variation	d. f.	Mean sum of squares					
		Days to 50% flowering	Plant height (cm)	Ear length (cm)	Effective tillers (No./plant)	Ear girth (cm)	Ear weight (g)
Replicates	2	1.39	18.91	0.75	0.47	0.13	19.89
Hybrids	49	25.09**	1037.42**	26.20**	1.79**	3.10**	2027.96**
Lines	9	69.54**	2599.32**	37.83**	2.55	9.41**	12638.05**
Testers	4	13.13	2354.69**	113.63**	1.05	3.95**	7011.05**
Lines x Testers	36	15.31**	500.59**	13.58**	1.68	1.43**	1321.76**
Error	98	0.93	14.34	0.30	0.17	0.05	7.60
Source of variation	**d. f.**	**Dry fodder yield (g/plant)**	**Grain yield (g/plant)**	**Total biological yield (g/plant)**	**Harvest index (%)**	**1000-grain weight (g)**	**Protein content (%)**
Replicates	2	36.09	16.25	88.25	2.17	0.41	0.15
Hybrids	49	4504.53**	950.57**	12101.65**	132.66**	7.06**	5.42**
Lines	9	18885.62**	11821.84**	119346.00**	655.54**	27.20**	9.48**
Testers	4	12034.42**	2941.09**	38102.80**	5.39	1.61	3.32
Lines x Testers	36	2572.60**	571.59**	7401.54**	16.06	2.63	4.64**
Error	98	16.74	6.36	30.73	3.29	0.16	0.08

**Significant at P=0.01.

TABLE 2
General combining ability effects for different characters

Genotype	Days to 50% flowering	Plant height (cm)	Ear length (cm)	Effective tillers (No./plant)	Ear girth (cm)	Ear weight (g)	Dry fodder yield (g)/plant	Grain yield (g)/plant	Total biological yield (g)/plant	Harvest index (%)	1000-grain weight (g)	Protein content (%)
Lines												
1. HMS9A	-1.80*	4.45*	1.70*	0.19	-0.47*	6.03*	7.82*	5.87*	13.16*	4.73*	1.67*	0.26*
2. HMS13A	0.75	15.65*	-0.38	0.23	0.29*	7.23*	6.95*	28.67*	36.96*	2.51*	2.22*	-0.73*
3. HMS14A	0.42	-7.81*	0.84*	-0.66*	0.39*	-14.69*	-10.04*	-29.72*	-44.70*	3.88*	0.45*	-1.18*
4. HMS18A	-4.38*	-17.81*	-0.78*	-0.20	-1.37*	-23.00*	-19.24*	-43.86*	-66.50	2.37*	-1.39*	1.01*
5. HMS22A	-2.18*	-12.01	-1.94*	0.21	-0.86*	-15.83*	-12.51*	-8.26*	-23.43*	0.87*	-1.99*	0.49*
6. ICMA89111	0.95*	0.85	-0.20	0.32	-0.14	2.50*	-4.71*	-6.12*	-2.96*	1.73*	-1.42*	0.26*
7. ICMA94222	0.22	-17.14*	-3.08*	0.33	0.62*	3.23*	0.28	-10.92*	-7.03*	4.26*	0.07	-1.08*
8. ICMA94555	3.48*	2.58	1.29*	-0.08	1.07*	17.03*	11.88*	27.27*	37.96*	4.22*	0.19	-0.15
9. ICMA95444	1.55*	17.25*	1.38*	0.39*	-0.42*	7.23*	10.28*	10.87*	28.76*	-11.35*	-0.32	0.07
10. ICMA95555	0.35	13.45*	1.18*	-0.72	0.89*	10.83*	9.28*	16.20*	27.76*	-13.24*	0.51*	1.05*
S. Em±	0.35	1.38	0.20	0.15	0.08	1.01	0.92	1.49	2.02	0.66	0.14	0.10
Testers												
11. CSSC46-2	0.02	8.55*	2.14*	-0.16	0.31*	18.83*	10.72*	24.87*	44.70*	0.05	-0.16	-0.10
12. G73-107	0.15	8.02*	1.26*	0.32*	0.01	11.23*	8.25*	17.04*	28.60*	-0.12	-0.05	-0.35*
13. H90/4-5	0.62	-1.91	-1.40*	-0.08	0.36*	-3.20*	-0.81	-10.42*	-12.63*	0.47	0.14	-0.23*
14. H77/833-2	-1.11	-13.04*	-2.58*	-0.04	-0.51*	-7.00*	-4.41*	-8.99*	-18.83*	0.24	-0.24	0.30*
15. 1307	0.32	-1.61	0.56*	-0.03	-0.16*	-19.86*	-13.74*	-22.49*	-41.83*	-0.64	0.32*	0.39*
S. Em±	0.24	0.97	0.14	0.10	0.05	0.71	0.65	1.05	1.43	0.46	0.10	0.07

TABLE 3
Specific combining ability effects for different characters

Genotype	Days to 50% flowering	Plant height (cm)	Ear length (cm)	Effective tillers (No./plant)	Ear girth (cm)	Ear weight (g)	Dry fodder yield (g)/plant	Grain yield (g)/plant	Total biological yield (g)/plant	Harvest index (%)	1000-grain weight (g)	Protein content (%)
1.	4×11	6×13	10×11	4×11	3×13	8×12	9×11	2×11	8×12	9×11	1×15	4×14
	(-4.48)	(29.51)	(3.90)	(1.56)	1.41	51.16	28.48	47.99	102.40	5.27	2.03	2.58
2.	1×12	1×15	9×11	8×12	4×12	2×11	8×12	8×12	2×11	8×14	4×11	1×15
	(-3.48)	(22.28)	(2.91)	1.29	1.41	32.36	20.34	44.56	8.30	3.51	1.48	2.54
3.	4×15	9×13	6×11	9×11	4×11	9×11	2×11	5×14	9×11	5×15	4×12	4×13
	(-3.12)	(20.11)	(2.89)	0.96	0.90	30.36	15.81	44.12	70.50	3.18	1.10	1.84
4.	5×15	5×12	4×14	8×12	5×15	7×11	7×12	9×11	5×14	2×14	10×13	5×13
	(-2.32)	(15.44)	(2.50)	0.96	0.87	22.36	12.94	41.12	62.12	3.07	1.08	1.66
5.	10×15	7×11	2×15	1×13	6×11	9×14	2×14	6×15	7×12	5×13	3×15	7×12
	(-2.18)	(15.04)	(2.15)	0.88	0.77	19.20	12.28	32.49	43.40	2.49	0.70	1.26
6.	6×13	2×15	1×13	7×12	10×11	7×12	6×13	3×13	3×13	6×12	10×11	2×11
	(-2.08)	(13.41)	(2.14)	0.84	0.72	18.96	12.01	29.02	42.30	2.21	0.65	1.25
7.	4×13	2×11	3×12	5×14	10×14	5×14	3×13	7×12	9×14	6×13	6×13	6×12
	(-1.75)	(12.24)	(2.10)	0.82	0.72	15.26	11.34	24.76	42.00	2.21	0.63	1.19
8.	9×15	8×14	4×15	6×12	8×14	5×13	7×11	2×15	7×11	3×15	8×12	8×12
	(-1.72)	(11.24)	(2.02)	0.65	0.71	14.46	10.48	23.69	41.30	1.97	0.63	1.15
9.	7×14	4×12	8×12	1×12	2×13	1×13	5×14	1×13	1×13	6×11	9×12	5×11
	(-1.62)	(10.24)	(1.48)	0.58	0.68	13.60	10.41	23.42	38.43	1.82	0.63	0.94
10.	7×12	10×13	6×13	9×14	1×11	3×13	1×11	4×13	6×15	10×11	5×11	10×13
	(-1.11)	(6.91)	(1.24)	0.54	0.46	13.60	7.94	23.16	37.76	1.69	0.62	0.86

TABLE 4

Per se performance of top 10 hybrids selected on basis of grain yield

S. No.	Hybrids	Days to 50% flowering	Plant height (cm)	Ear length (cm)	Total tillers	Effective tillers (No./plant)	Ear girth (cm)	Ear weight (g)	Dry fodder yield (g)/plant	Grain yield (g)/plant	Total biological yield (g)/plant	Harvest index (%)	1000-grain weight (g)	Protein content (%)
1.	9 x 11	53.00	233.33	23.20	5.50	4.30	8.02	59.33	40.33	82.66	138.66	29.08	7.98	10.03
2.	8 x 12	52.33	197.33	27.70	5.30	4.30	9.17	63.67	37.33	83.33	147.00	25.40	10.27	10.96
3.	2 x 11	50.00	237.00	26.60	4.50	4.46	7.57	56.67	35.00	87.55	145.33	24.07	11.30	10.73
4.	1 x 11	48.00	201.00	26.30	3.13	2.30	8.20	50.00	32.67	66.77	116.77	27.97	9.33	10.62
5.	7 x 11	52.33	207.00	22.50	2.90	2.30	8.83	52.00	31.00	65.00	117.00	26.49	9.37	8.63
6.	7 x 12	48.67	191.33	22.80	5.00	4.60	8.60	48.33	31.00	64.00	112.33	27.59	9.52	10.15
7.	10 x 11	51.00	224.33	30.90	2.70	2.40	9.83	50.33	30.33	68.66	119.00	25.77	10.20	10.38
8.	1 x 12	45.33	219.00	26.80	4.80	4.20	7.70	43.33	29.55	63.88	107.22	27.56	10.31	9.45
9.	2 x 14	49.00	196.00	21.40	3.80	3.20	7.62	40.33	28.77	59.33	99.66	28.87	10.63	9.57
10.	1 x 13	50.00	182.00	26.10	4.60	4.10	7.68	42.67	28.33	60.00	103.66	27.31	10.45	8.52
11.	HHB97	49.33	222.33	23.40	3.20	2.80	7.64	30.33	21.00	44.66	75.00	28.00	8.45	12.48

HAMS13A x CSSC46-2 and ICMA94222 x G73-107 possessed significantly higher yield and most of its contributing traits. These crosses not only exhibited high sca effects but also expressed high *per se* performance for grain yield and its component traits (Table 4).

The above results were further supplemented by the high significant and positive rank correlation between *per se* performance and sca effects (Table 5). However, these crosses may be further evaluated at time and space to confirm their superiority before they are exploited as commercial hybrids. For judicious decision, one has to consider both *per se* performance and sca effect as these are complementary to each other. Considering them alone may be misleading as observed for crosses 3 x 13 and 5 x 14 have higher rank on the basis of sca effects but were lower in rank on the basis of *per se* performance. Likewise on the basis of *per se* performance crosses 10 x 11 and 1 x 12 scored to be non-significant. However, as the rank correlation between *per se* performance and sca effects for all the characters studied was positive and highly significant, therefore, for preliminary screening of the material, *per se* performance alone could give a broader idea to select or reject a cross/hybrid.

Parents, namely, ICMA95222, ICMA94555, HMS13A, ICMA94222, CSSC46-2 and G73-107 involving in the above crosses may also be picked up and inter-mated to develop a base population to exploit the sufficient amount of non-additive genetic variance. The base population thus developed may be further improved following the recurrent selection for sca effects. The cross combinations HMS18A x H77/833-2, HMS9A x 1307, HMS18A x H90/4-5 and HMS22A x H90/4-5 expressed highly positive significant sca effects for protein content. These crosses can be utilized to develop nutritionally superior hybrids or the parent involved can be used to develop base population with higher protein content. Similar findings were also reported by Yadav *et al.* (2012).

Heterosis

The superiority of F_1 hybrid over the commercial varieties/hybrids has been reported and being exploited in pearlmillet since the release of the first commercial hybrid in 1965. Through calculation of heterosis over mid parent value, though, has genetic basis, is of no use in practical plant breeding. The heterosis over better parent (heterobeltiosis) and commercial best variety or hybrid (standard heterosis) has practical values. The former has no relevance in crop like pearlmillet, therefore, in the present investigation standard heterosis over best check HHB94 was estimated.

A critical examination of the results (Table 6) revealed that crosses HMS18A x CSSC46-2, HMS18A x H90/4-5, HMS18A x H77/833-2, HMS18A x 1307, HMS22A x CSSC46-2, HMS22A x G73-107, HMS22A x H77/833-2, HMS22A x 1307 and ICMA94222 X H77/833-2 were found to exhibit high negative heterosis over the check HHB94 by a significant margin of -16.88, -10.13, -6.08, -13.50, -4.05, -7.41 and -4.05 per cent, respectively, for early maturity. These crosses would be of great importance in isolating the hybrids especially for rainfed conditions because these hybrids would not be affected by the drought in late season. Report of Thete *et al.* (1986) and Chavan and Nerkar (1994) for days to 50 per cent flowering is in full agreement with the above finding.

For grain yield contributing traits like ear length, ear girth, ear weight, 1000-grain weight and harvest index some crosses viz., ICMA94555 x G73-107, HMS9A x CSSC46-2, ICMA95555 x CSSC46-2 and HMS9A x H90/4-5 exhibited significant positive heterosis. These are the best heterotic combination for grain yield components. On the other hand for grain yield as many as 19 crosses expressed highly significant positive heterosis over the best check HHB94. Out of these only four crosses, namely, ICMA95222 x CSSC46-2 (92.05%), ICMA94555 x G73-107 (77.76%), HMS13A x CSSC46-2 (66.76%) and HMS9A x CSSC46-2 (55.52%) showed more than 50 per cent heterosis over

TABLE 5
Rank correlations between *per se* performance and sca effects

S. No.	Attributes	r-value
1.	Days to 50% flowering	0.54*
2.	Plant height	0.64*
3.	Ear length	0.56*
4.	Effective tillers	0.70*
5.	Ear girth	0.60*
6.	Ear weight	0.56*
7.	Grain yield	0.52*
8.	Dry fodder yield	0.61*
9.	biological yield	0.59*
10.	Harvest index	0.58*
11.	1000-grain weight	0.39*
12.	Protein content	0.76*

*Significant at P=0.05.

TABLE 6

Estimates of heterosis over standard check (HHB 94) of top 10 hybrids for different characters

S. No.	Hybrids	Days to 50% flowering	Plant height (cm)	Ear length (cm)	Total tillers	Effective tillers (No./plant)	Ear girth (cm)	Ear weight (g)	Dry fodder yield (g)/plant	Grain yield (g)/plant	Total biological yield (g)/plant	Harvest index (%)	1000-grain weight (g)	Protein content (%)
1.	1 x 11	-2.69	-9.59*	12.39*	-2.18	-17.85	7.32*	64.83*	55.52*	49.50*	55.70*	-0.11	10.42*	-8.10*
2.	1 x 12	8.10*	-1.49	14.52*	50.00*	50.00*	0.78	42.85*	40.71*	43.02*	42.96*	-1.57	22.07*	-13.54*
3.	1x 13	1.35	-18.13*	11.53*	43.75*	46.42	0.52	40.65*	29.32*	34.32*	38.22*	-2.46	23.63*	-17.99*
4.	2 x 11	1.35	6.59*	13.67*	40.62*	59.28*	-0.91	86.81*	66.67*	96.01*	93.77*	-14.03*	33.76*	-7.58*
5.	2 x 14	0.66	-11.84*	-8.54*	18.75*	14.28*	-0.26	32.96*	37.90*	32.83*	32.90*	3.12*	25.79*	-12.92*
6.	7 x 11	6.08*	-6.89*	-3.84*	-9.37	-17.85	15.57*	71.42*	47.62*	45.52*	56.00*	-5.39*	10.84*	-17.41*
7.	7 x 12	-1.33	-13.94*	-2.56	56.25*	64.28*	12.56*	59.34*	47.61*	43.28*	49.77*	-1.46	12.68*	-10.21*
8.	8 x 12	6.08*	-11.24*	18.37*	65.62*	53.57*	20.02*	109.89*	77.76*	86.56*	97.29*	-9.28*	21.51*	-6.54*
9.	9 x 11	7.43*	4.94*	28.63*	71.87*	53.57*	4.97*	84.61*	92.05*	85.07*	84.88*	3.86*	-5.50	-10.74*
10.	10 x 11	3.38*	0.89	32.05*	-15.62	-14.28	28.66*	65.93*	46.00*	53.73*	58.66*	-7.96*	204.71*	-9.15*
SE (d)		0.78	3.09	0.44	0.29	0.33	0.17	2.25	2.05	3.34	4.52	1.48	0.32	0.22

the best check HHB 94. The magnitude of heterosis in the above crosses may be due to the genetic diversity as reported by Upadhya and Murty (1971) along with cytoplasmic diversity present in the material. These crosses only exhibited not only high heterosis for grain yield but also showed high positive heterosis for most of its contributing traits. Thus, these may be evaluated at time and space before they are finally recommended for commercial exploitation. High magnitude of heterosis for a number of characters has been observed earlier by Chavan and Nerkar (1994).

Standard heterosis over check HHB94 for protein content was exhibited by only two crosses HMS9A x 1307 and HMS18A x H77/833-2. These crosses can be further used for the improvement of protein content. Higher heterosis for grain protein content has also been reported by Vaidya *et al*. (1983) and Pande *et al*. (1985).

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