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Combining ability of new male sterile lines of diverse sources in pearl millet for yield and forage components

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Abstract

Investigation was carried out to study the combining ability of different (three lines of A_1 system and one each from A_2, A_3, A_4, A_5, A_{egp}) cytoplasms of alloplasmic isonuclear lines of Pearl Millet. The analysis of variance for the design of experiment revealed that significant genetic variability was present among crosses for all the characters studied. The estimates of general combining ability effects revealed that lines $81A_{egp}$ and $81A_4$ representing A_{egp} and A_4 cytoplasmic systems combined better for grain yield and most of its contributing traits. The lines of A_1 systems *viz*., $81A_1$ for plant height and $843A_1$ for earliness were good general combiners. Testers H77/29-2, INB 526 and INB 427 were top general combiners for grain yield and majority of its component traits. The estimates of sca effects revealed that hybrids $81A_4$ X INB 526,$81A_4$ X G73-107,$81A_4$ X INB1250,$81A_{egp}$ X INB 87/74,$81A_{egp}$ X H77/29-2 and $81A_{egp}$ X H90/4-5, were identified as desirable crosses for grain yield and majority of its component traits. They produced significant and desirable sca effects for most of the traits studied, indicating potential for exploiting hybrid vigour using diverse cytoplasm lines in breeding programmes.

Keywords: Male sterile lines, GCA, sca, pearl millet

Introduction

Pearl Millet [*Pennisitum glaucum* (L.) R.Br.] is the most important cereal in the hot and arid regions of Indian and African sub continents of the world. Though it is being cultivated on sandy, rocky, too acidic, too dry and infertile soils but it has great yield potential and could also produce more forage than either sorghum or maize when grown in favourable environments. It is an important food, feed and fodder (dual purpose) crop. It is widely cultivated in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana (Anonymous, 2013) [1].

Pearl Millet is highly nutritive, staple food and the primary source of calories for millions of people who are inhabitants of world's driest regions. It is a richer source of protein, fat, iron, calcium, magnesium, phosphorus and total carotenoids than some of the other important cereals (Singh and Nainawatee 1999) [6].

In Pearl Millet male sterile lines are the backbone of hybrid development programme. Grain yield of commercial hybrids largely depends on the genetic makeup of cytoplasmic-genic male sterile lines and pollinators. Pear Millet hybrid breeding programme was initiated with the availability of first male sterile line Tift 23A (Burton, 1958) [3]. The use of cytoplasmic-genic male sterility in Pearl Millet paved the way for grain yield augmentation with development and release of first grain hybrid "HB-1" by Athwal (1965) [2] using Tift 23A male sterile line and BIL-3B, restorer. The diversification of CMS lines across sources is helpful in hybrid breeding programme. An understanding of the combining ability and gene action is a prerequisite for any successful plant breeding programme. Phenotypic elimination of lines is effective for many traits that influence the commercial acceptance of hybrids. But it is very difficult to eliminate a poor combining line on the basis of phenotypic expression and hence the combining ability analysis of newly developed CMS line in hybrid breeding programme is essential. Different studies have shown that cytoplasm exhibits pronounced effect on combining ability (Young and Virmani, 1990) [7]. Therefore, the present investigation was undertaken to assess the combining ability for yield and contributing traits, to determine the nature and magnitude of gene action in a line x tester mating design involving alloplasmic iso - nuclear lines of Pearl Millet.

Materials and Methods

The material for the present study consisted of eight male sterile lines representing six systems of male sterility *viz*., three male sterile lines from A_1system (MS $81A_1$, MS $842A_1$ and MS

843A_1) and one each from A2 (MS81A2),A3 (MS 81A3),A4 (MS 81A4),A5 (MS 81A5) and Aegp (MS 81Aegp)systems and ten restorers *viz*., H 90 / 4-5,H 77/833-2,H 77/371,H 78/711, H 77/29-2, G 73-107, INB 87/74, INB 427,INB 526 and INB 1250.

The eight male sterile lines were crossed with ten restorers in a line x tester fashion at the research farm of CCS, HAU, Hisar. The eighty Pearl Millet hybrids, thus produced were grown in two environments E1- CCS, HAU, Research farm, RRS, Bawal and E2- CCS, HAU, Research farm, Hisar. The experiment was raised in simple lattice design with two replications in each of the environments. Each entry was accommodated at 0.45m with 20cm intra row spacing. All the recommended agronomic practices for each of the environments were followed to raise a good crop. Data was recorded on five competitive plants selected randomly from each replication for ten characters *viz*., grain yield (g/plant),dry fodder yield(g/plant),biological yield (g/plant), plant height(cm),days to 50% flowering, ear length(cm),ear girth(cm),ear weight(cm),1000 grain weight (g) and harvest index(%).Harvest index was calculated in percentage by the formula given by Donald (1962). Combining ability analysis of variance was performed according to Kempthorne (1958).

Results and Discussion

The analysis of variance for combining ability (Table1) revealed that the mean sum of squares due to lines, testers and lines x testers, were highly significant when tested against the error mean sum of squares for all the characters in both the environments. This showed that sufficient amount of genetic variability existed among lines and testers for majority of the characters. However, the mean sum squares for lines and testers when tested against the interaction (lines x testers) mean sum of squares revealed that the mean sum of squares due to lines for dry fodder yield (E2), biological yield (E2) and harvest index (E1) and testers for harvest index were non-significant. This revealed that lines and esters did not differ significantly for these traits in different environments. Further, the magnitude of mean sum of squres due to lines was invariably higher as compared to those of testers. This indicated that large portion of the genetic variability of the crosses was accounted by differences among lines.

The estimates of general combining ability effects of lines and testers are presented in table 2.The perusal of the summarized gca effects revealed that general combining ability effects for grain yield and most of its contributing characters namely, dry fodder yield, biological yield, ear weight and harvest index were significant and positive for Aegp and A4 cytoplasm and significant and negative for A2 cytoplasm. This suggested the superiority of Aegp and A4 cytoplasm over the other sources for producing, in general, high yielding hybrids. Further, an examination of GCA effects within A1 source revealed that male sterile line 842A1 appeared to be good general combiner for grain yield, dry fodder yield, biological yield, ear girth, 1000 grain weight and days to 50% flowering. MS843A1 exhibited the similar results except for grain, dry fodder and biological yield.81A1 was good general combiner for plant height and harvest index. These results showed that good differences in the combining ability of lines with different male sterile cytoplasms. Lakhman *et al*. (2010) [5] also reported that A4 cytoplasm was the best general combiner for grain yield and other component traits followed by A1 and A5 cytoplasm.

The testers INB526, H77/29-2, INB 427 and H78/711 exhibited significant and positive gca effects for grain yield and for majority of its component traits in both the environments and thus proved the superiority for breeding programmes aimed at development of hybrids or synthetics combining high yield.

In general the cross combinations with high sca effects differed from character to character and also across the environments. Kumar (2017) also reported similar observations. A list of few selected cross selected on the basis of sca performance for various characters is presented in Table 3.The hybrids 81A4 x INB526,81Aegp x H77/29-2, 81Aegp x INB87/74 and 81A3 x INB 87/74 expressed high sca effects for yield and its component traits.

Table 1: Analysis of variance for combining ability in Pearl Millet

Source of Variation	d. f.	Grain Yield		Dry fodder Yield		Biological Yield		Ear Girth		Ear Weight		1000 Grain Weight		Plant Height		Days to 50% Flowering		Ear Length		Harvest Index	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Replication	1	11.18	0.049	644	114.58	911.54	158.6	0.002	0.337	26.08	3.57	0.03	0.662	61.75	412.16	28.05	15.62	1.15	0.014	8.73	3.21
Hybrids	79	80.33**	126.01**	578.19**	494.97**	1163.78**	873.84**	1.42**	1.07**	191.66**	164.09**	1.93**	2.79**	434.32**	329.63**	12.75**	20.52**	14.35**	16.2**	14.17**	21.18**
Lines	7	246.71**	292.6**	250.31**	875.48	4657.53**	1121.2	7.39**	3.91**	468.52**	330.22*	4.85**	7.59**	2797.37**	747.77**	55.32**	95.82**	29.28**	47.63**	20.21	78.06**
Testers	9	122.57*	134.46	614.82	679.84	1403.26	1401.8	2.24**	2.34**	276.48	196.43	3.6**	7.62**	756.48**	785.66**	29.77**	51.76**	51.71**	40.08**	21.71	6.85
Lines X Testers	63	55.81**	106.3**	359.07**	426.29**	741.37**	770.95**	0.63**	0.579**	148.78**	141.01**	1.37**	1.57**	125.74**	218.03**	5.59**	7.7**	7.36**	9.3**	12.42**	16.9**
Error	79	2.61	5.12	14.76	25.12	24.23	38.06	0.059	0.203	4.84	7.92	0.31	0.161	25.21	16.62	1.81	3.54	1.19	2.53	0.975	1.51

** Significant at 1%

* Significant at 5%

Table 2: Estimates of general combining ability effects of lines and testers for different characters in two environments

S. No.	Genotypes	Grain Yield		Dry fodder Yield		Biological Yield		Ear Girth		Ear Weight		1000 Grain Weight		Plant Height		Days to 50% Flowering		Ear Length		Harvest Index	
Lines		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1	$81A_1$	1.60*	-5.24*	-0.29	-2.51	1.61	-8.32*	-0.51*	-0.17	1.93*	-5.81*	-0.13	0.14	6.76*	12.52*	-0.68	-3.06*	0.31	0.43	0.70*	-1.77*
2	$81A_2$	-1.47*	-3.40*	-0.78	-3.25*	-2.26	-6.01*	-0.06	-0.48*	-1.64*	-2.76*	-0.47*	-1.01*	7.39*	-7.99*	-1.38*	-0.01	0.67	-0.56	-0.40	-1.07*
3	$81A_3$	0.44	2.69*	3.61*	-10.10*	4.70*	-8.08*	-0.28*	-0.24	1.1	2.00*	0.01	-0.22	3.99*	-3.87*	-0.13	0.83	0.64	0.63	-0.42	3.04*
4	$81A_4$	1.84*	2.35*	-0.06	-2.16	-0.14	1.49	-0.37*	-0.05	-0.06	3.65*	-0.02	-0.34*	15.07*	1.5	1.41*	2.63*	1.32*	1.43*	0.82*	1.10*
5	$81A_5$	-0.61	0.62	13.23*	-4.02*	13.20*	-2.56	-0.31*	-0.02	-0.008	1.45	-0.63*	-0.18	-6.08*	-0.79	0.46	0.78	0.65	1.63*	-2.16*	0.80*
6	$81A_{egp}$	4.46*	2.62*	4.80*	6.76*	12.40*	8.35*	-0.30*	-0.35*	7.62*	1.67	-0.18	-0.05	1.65	-0.84	3.16*	2.33*	0.13	0.8	0.71*	0.14
7	$842A_1$	1.24*	4.81*	4.79*	6.33*	5.68*	11.31*	1.22*	0.78*	0.91	4.97*	0.74*	0.93*	-2.55	3.07*	-0.88*	0.31	-1.68*	-1.56*	0.21	1.03*
8	$843A_1$	-7.49*	-4.47*	-25.31*	9.04*	-35.20*	3.84	0.64*	0.55*	-9.86*	-5.20*	0.68*	0.73*	-24.56*	-3.58*	-1.98	-3.21*	-2.06*	-2.81*	0.54	-3.28*
	S.E(d)	0.51	0.71	1.21	1.58	1.55	1.95	0.07	0.14	0.69	0.89	0.17	0.12	1.58	1.28	0.42*	0.59	0.34	0.5	0.31	0.38
Testers																					
9	H 90/4-5	1.12	-0.81	4.55*	1.98	5.94*	-0.27	-0.06	0.36*	1.41	-2.25*	-0.62*	-0.34*	-7.44*	-8.55*	-2.08*	-0.02	-3.84*	-3.15*	-0.11	-0.29
10	H 77/833-2	-1.55*	1.64*	-3.11*	1.45	-5.31*	3.67	-0.45*	-0.50*	-2.17*	2.21*	-0.18	0.002	-11.75*	-9.71*	-2.70*	-3.52*	-1.55*	-1.15*	-0.06	0.25
11	H 77/371	-2.29*	-6.74*	-11.24*	-11.30*	-15.23*	-19.74*	-0.53*	-0.64*	-3.97*	-8.43*	-0.07	0.5	-5.09*	-9.52*	0.01	-1.15	0.16	-1.05	0.89*	-0.68
12	H 78/711	2.42*	0.17	5.17*	-0.91	5.42*	-0.9	0.51*	0.35*	0.26	0.004	-0.25	-0.62*	3.44	6.75*	0.41	0.28	0.67	2.25*	0.55	0.15
13	H 77/29-2	2.64*	0.88	6.18*	-3.16	12.50*	-3.62	0.26*	0.02	6.36*	-0.46	0.22	-0.11	3.94*	2.97*	-0.01	-1.65*	-0.27	-1.05	-0.36	1.16*
14	G 73-107	-3.05*	1.64*	-7.35*	9.99*	-12.54*	12.76*	-0.13	0.34*	-5.17*	2.76*	-0.13	0.25	0.92	3.5	0.35	0.03	0.04	0.5	0.24	-0.69
15	INB 87/74	-3.99*	2.63*	2.37	8.85*	-0.46	11.44*	-0.12	-0.34*	-2.81*	2.58*	1.04*	1.64*	6.17*	1.83	1.23*	1.22	2.46*	0.62	-2.55*	-0.49
16	INB 427	2.15*	-3.01*	7.48*	-6.84*	10.40*	-7.93*	0.60*	0.35*	2.94*	-1.08	0.43*	-0.69*	10.23*	6.29*	1.29*	0.78	2.21*	0.62	-0.41	-0.5
17	INB 526	3.90*	2.46*	-2.04	-2.53	4.20*	0.93	-0.15*	0.13	6.27*	3.47*	-0.43*	-0.49*	-4.39*	-1.96	1.23*	3.10*	-0.32	1.22*	2.03*	0.91*
18	INB 1250	-1.36*	1.12	-2.01	2.45	-4.91*	3.66	0.07	-0.08	-3.13*	1.20	0.01	-0.12	3.95*	8.37*	0.29	0.91	0.52	1.19*	-0.21	0.18
	S.E(d)	0.57	0.8	1.35	1.77	1.74	2.18	0.08	0.15	0.77	0.99	0.19	0.14	1.77	1.44	0.49	0.66	0.38	0.56	0.34	0.43

* Significant at 5%

Table 3: Estimates of specific combining ability effects (in parenthesis) of top five crosses for quantitative characters in two environments

s	Grain Yield		Dry fodder Yield		Biological Yield		Ear Girth		Ear Weight		1000 Grain Weight		Plant Height		Days to 50% Flowering		Ear Length		Harvest Index	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1	7x12 (11.69*)	4x17 (18.76*)	7x11 (25.88*)	4x14 (32.06*)	4x17 (43.69*)	6x15 (50.68*)	8x16 (2.13*)	4x14 (1.14*)	4x17 (22.93*)	6x15 (19.06*)	8x11 (1.88*)	6x17 (2.38*)	4x9 (14.06*)	8x10 (29.33*)	2x10 (-4.49*)	8x16 (-4.85*)	4x14 (7.41*)	4x14 (6.47*)	8x14 (6.29*)	3x13 (5.82*)
2	8x14 (10.46*)	6x15 (18.57*)	2x17 (22.51*)	6x15 (31.61*)	3x17 (41.64*)	4x17 (37.04*)	7x12 (1.59*)	7x18 (0.93*)	3x17 (21.26*)	8x10 (16.36*)	2x12 (1.71*)	8x11 (1.48*)	6x13 (12.79*)	2x17 (20.43*)	3x10 (-4.49*)	1x13 (-3.75*)	5x16 (4.63*)	5x17 (4.80*)	1x10 (5.33*)	8x10 (5.33*)
3	3x17 (9.31*)	8x10 (16.17*)	4x17 (20.74*)	5x16 (28.01*)	7x11 (26.46*)	4x14 (36.92*)	7x13 (1.09*)	6x9 (0.92*)	6x14 (15.14*)	1x16 (15.87*)	7x12 (1.49*)	8x10 (1.46*)	3x14 (11.77*)	6x9 (18.12*)	3x9 (-4.36*)	8x14 (-2.96)	6x9 (3.30*)	7x17 (4.50*)	6x15 (3.79*)	5x15 (5.10*)
4	4x16 (9.21*)	3x13 (12.20*)	2x10 (20.59*)	8x13 (23.76*)	6x14 (26.04*)	5x16 (31.52*)	7x18 (0.88*)	8x16 (0.82*)	1x18 (13.53*)	4x17 (15.20*)	8x10 (1.35*)	2x12 (1.41*)	4x14 (11.55*)	7x11 (16.93*)	7x9 (-3.61*)	4x11 (-2.95)	3x11 (3.04*)	3x18 (3.33*)	3x16 (3.70*)	7x11 (4.518)
5	6x14 (9.00*)	7x12 (8.84*)	3x17 (20.36*)	7x18 (23.35*)	2x17 (25.51*)	3x17 (29.48*)	6x15 (0.76*)	8x11 (0.77*)	4x16 (12.06*)	3x13 (13.63*)	4x15 (1.30*)	8x14 (1.38*)	4x16 (11.39*)	4x14 (14.46*)	6x15 (-2.48)	4x18 (-2.51)	2x12 (2.64*)	8x11 (3.28*)	7x17 (3.63*)	8x9 (3.81*)

* Significant at 5%

Based on the results obtained in the present study it may be concluded that hybrids based on Aegp and A4 system were superior to those of other cytoplasmic sources. The sufficient amount of non-additive genetic variance could be exploited either by direct use of hybrids namely 81A4 x INB526, 81A4x G73-107,81A4 x INB427, 81Aegp x H77/29-2 and 81Aegp x INB87/74 after evaluating them at time and space or the parents involved in these crosses could also be used in the development of base population by allowing inter mating among them for few generations to ensure adequate recombinations. Such population may serve as a source of parent material for use in developing superior hybrids / synthetics.

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