Combining ability of pearl millet [*pennisetum glaucum* (l.) R. Br.] Hybrids involving diverse cgms lines and restorers

ABSTRACT

The experimental material comprised of five female lines, ten male lines of pearl millet, their 50 hybrids developed by line × tester design and one standard check hybrid (GHB 1231). They were evaluated in randomized block design with three replications at Main Pearl Millet Research Station, J.A.U., Jamnagar during *kharif* 2023 for studies of combining ability of pearl millet. The analysis of variance for combining ability revealed that mean squares due to females and males were significant for all the characters under studied. The result indicates that significant contribution of both female and male toward total variation. The mean squares due to females × males were significant for all the 12 characters under studied except days to maturity. The variance ratio of gca and sca showed that the non-additive gene action was pre-dominant for the expression of all traits studied except days to 50% flowering and days to maturity. Among the parents two female parents *viz*., $ICMA_1$ 95444 and $JMSA_5$ 20212 and five male parents like J-2597, J-2569, J-2580, J-2637 and J-2641 were found good general combiners for grain yield per plant. The gca effect of parents indicated that $ICMA_1$ 95444 was found good general combiner for all the characters under studied. The highest positive sca effect was manifested by cross $ICMA_1$ 94555 × J-2580 (20.53) for grain yield per plant followed by $JMSA_5$ 20212 × J-2562 (14.58) and $ICMA_1$ 95444 × J-2372 (13.15).

Key words: Pearl millet, gene action, combining ability, Hybrid Performance

INTRODUCTION

"Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a key member of the Poaceae (Gramineae) family and the *Pennisetum* genus. Commonly known as bajra, bajri, cattail millet, spiked millet, and bulrush millet, this crop is highly cross-pollinated and features protogynous flowering with wind-borne pollination" [6,7]. "These traits facilitate hybrid development and the commercial benefits of heterosis. In India, pearl millet is a major staple food, ranking fourth in acreage after rice, wheat, and sorghum, and it is the sixth most important cereal globally. Believed to have originated in tropical Western Africa around 4000 years ago, pearl millet is diploid, with a chromosome number of 2n=2x=14. The selection of appropriate parents for hybridization programme can be made on the basis of their ability to transmit desirable performance to their progenies" [8-10]. The combining ability analysis helps in the evaluation of inbreds in terms of their genetic value, and in the selection of suitable parents for hybridization. It also helps in the identification of superior cross combinations which may be utilized for commercial exploitation of heterosis.

MATERIALS AND METHODS

The experimental material comprised of five CGMS (Female) lines viz., $ICMA_1$ 94555, $ICMA_1$ 95444, $ICMA_1$ 11222, $ICMA_1$ 20209, $JMSA_5$ 20212; ten restorer (male) lines of pearl millet viz., J-2372, J-2496, J-2562, J-2597, J-2569, J-2580, J-2634, J-2637, J-2639, J-2641 and their 50 F_1s hybrids developed by line × tester design and one standard check hybrid (GHB 1231). They were evaluated in randomized block design (RBD) with three replications at Main Pearl Millet Research Station, J.A.U., Jamnagar during *kharif* 2023. Row to row and plant to plant spacing was of 60 cm × 15 cm. "The observations were recorded on five randomly selected plants expect the plot basis from parents and crosses for 12 characters *viz.*, days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant, grain yield per plant, threshing index and harvest index. Mean data were used for statistical analysis. The total variation among F_1 hybrids was partitioned further into variance due to females, males and their interaction effects, which were used for combining ability analysis" (Kempthorne, 1957).

RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed that mean squares due to females and males were significant for all the characters under study. The result indicates that significant contribution of both female and male toward total variation. The mean squares due to females × males were significant for all the 12 characters under study except days to maturity. Thus, non-additive genetic variance was predominant in the inheritance of various traits. When, females × males interaction component was significant, the mean squares due to females and males were further tested against their respective interaction mean squares. "The mean squares due to females were also found significant for all the characters under studied except for days to maturity, plant height and earhead diameter when tested against mean squares due to females × males interaction. Similarly, the mean squares due to males were also found significant for days to 50 % flowering when tested against mean squares due to females × males interaction" [8]. The variance ratio of gca and sca showed that the non-additive components were pre-dominant for the expression of all the characters under study except days to 50% flowering and days to maturity.

If we discuss about general combining of male parents, J-2597 found good combiner for grain yield was also recorded good gca effect in favorable direction for plant height, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant and threshing index. Likewise, parent J-2569 was noted to have greater potential to transmit useful genes for grain yield per plant, days to 50% flowering, number of effective tillers per plant, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant and threshing index. Similarly, male parent J-2580 exhibited good combiner for grain yield as well as dry earhead weight per plant. "Male parent J-2637 exhibited good combiner for grain yield was also recorded good gca effect in favorable direction for days to 50% flowering and dry earhead weight per plant. Thus, the parents were good general combiners for grain yield per plant also showed good general combining ability for one or more component traits. Thus, the parents, in addition to being good general combiners for grain yield per plant, showed good general combining abilities for one or more component traits" which is in concurrence with results of Badurkar *et al.* (2018), Kumawat *et al.* (2019) and Madane *et al.* (2023) in pearl millet.

The estimates of sca effect revealed that none of the cross was consistently superior for all the traits. Out of 50 crosses studied, 18 cross combinations exhibited significant and positive sca effect for grain yield per plant. The highest sca effect for grain yield per plant was manifested by $ICMA_1$ 94555 × J-2580, which also exhibited significant sca effect in desired direction for earhead diameter, dry earhead weight per plant, 1000-grain weight, threshing index and harvest index. This cross was involved poor × good general combining parents for grain yield per plant, second rank in *per se* performance and standard heterosis for grain yield per plant.

The second highest sca effect in desired direction was recorded by cross, $JMSA_5$ 20212 × J-2562 involved good × poor general combiners parents for grain yield per plant, which also exhibited significant sca effect in desired direction for number of effective tillers per plant, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant and threshing index. This cross was also manifested third rank in heterobeltiosis, *per se* performance and standard heterosis for grain yield per plant.

Likewise, third highest significant sca effect in desired direction for grain yield per plant was recorded by cross ICMA1 95444 × J-2372 combined good and poor general combiners for grain yield per plant. The sca effect of grain yield per plant in this cross combination was also accompanied by sca effect for yield attributing traits *viz.*, plant height, number of effective tillers per plant, earhead length, earhead diameter, dry earhead weight per plant, 1000-grain weight, dry fodder yield per plant, threshing index and harvest index.

The gca effect of the parents and sca effect of their crosses in the present study indicated that the crosses between two poor general combiners were not always the worst for their sca effect. The sca effect of certain crosses in the undesirable direction could be due to the failure of desirable alleles of the parents to co-operate. As a result, a cross from good general combiner parents may exhibit poor sca effect. A perusal of table 3 revealed that there was some degree of correspondence sca effect of crosses as well as estimates of heterosis. The superiority of average × average, average × poor and poor × poor combinations for most of the characters may be due to the presence of genetic diversity among the parents and there could be some complementation indicating importance of non-additive effect.

However, Chaudhary *et al.* (1974) stated that high sca effect would not necessarily mean a high performance by the cross and the estimation of sca effect seemed to be superfluous, as no additional information was obtained by doing so. Therefore, it is suggested that the selection of parents for further breeding programme should be based on gca effect and due consideration should be given to mean value of the cross combination while selecting crosses for specific combining ability effect

CONCLUSION

In the present study the mean squares due to females × males were significant for all the 12 characters under study except days to maturity. The non-additive genetic variance was important in the inheritance of various traits. The variance ratio of gca and sca showed that the non-additive gene action was pre-dominant for the expression of all traits studied except days to 50% flowering and days to maturity. The gca effect of parents indicated that $ICMA_1$ 95444 was found good general combiner for all the characters under study. From ongoing discussion, it could be concluded that the best three promising crosses namely $JMSA_5$ 20212 × J-2637, $ICMA_1$ 94555 × J-2580 and $JMSA_5$ 20212 × J-2562 exhibited significant sca effect in desired direction for grain yield per plant and some components traits. Therefore, these three best crosses could be further evaluated over years and locations to exploit for commercial cultivation through heterosis breeding or utilized in future breeding programme to obtain desirable transgressive segregants and to identify high yielding superior inbreds.

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Table 1: Analysis of variance for combining ability and variance components for different characters in pearl millet

Source	d.f.	Days to 50 % Flowering	Days to maturity	Plant height (cm)	No. of effective tillers/plant	Earhead length (cm)	Earhead diameter (cm)
Replications	2	0.5	12.66	126.78	0.04	0.31	0.02
Females	4	376.88**++	322.98**	1527.53**	2.37**++	164.76**+	0.82**
Males	9	35.01**++	31.85**	613.07**	0.15**	50.01**	0.13**
Females × Males	36	6.92**	14.16	977.04**	0.22**	44.49**	0.33**
Error	98	3.18	10.63	48.03	0.02	2.69	0.01
σ^2f		12.46	10.41	49.32	0.08	5.40	0.03
σ^2m		2.12	1.41	37.67	0.01	3.15	0.01
σ^2fm		1.25	1.18	309.67	0.07	13.94	0.11
σ^2gca		9.01	7.41	45.43	0.06	4.66	0.02
σ^2sca		1.25	1.18	309.67	0.07	13.94	0.11
σ^2 gca/σ^2 sca		7.22	6.31	0.15	0.82	0.33	0.19

Table 1: Cont…

Source	d.f.	Dry earhead weight (g)/plant	1000-grain weight (g)	Dry fodder yield (g)/plant	Grain yield (g)/ plant	Threshing index (%)	Harvest index (%)
Replications	2	1.58	1.46	21.21	0.95	0.63	4.75
Females	4	1872.88**++	7.36**+	3655.27**++	1365.62**++	229.66**+	130.26**+
Males	9	128.79**	1.43**	494.64**	92.95**	74.29**	48.18**
Females × Males	36	347.90**	1.94**	849.72**	240.38**	63.36**	42.65**
Error	98	5.87	0.0001	32.16	3.41	3.57	2.08
σ^2f		62.23	0.25	120.77	45.41	7.54	4.27
σ^2m		8.19	0.10	30.83	5.97	4.71	3.07
σ^2fm		114.01	0.65	272.52	78.99	19.93	13.52
σ^2gca		44.22	0.20	90.79	32.26	6.60	3.87
σ^2sca		114.01	0.65	272.52	78.99	19.93	13.52
σ^2 gca/σ^2 sca		0.39	0.30	0.33	0.41	0.33	0.29

*, ** Significant at 5% and 1% levels, respectively, when tested against error mean square.

+, ++ Significant at 5% and 1% levels, respectively, when tested against females × males interaction mean

Table 2: Estimates of general combining ability effect of parents for different characters in pearl millet

Sr. No.	Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers/plant	Earhead length (cm)	Earhead diameter (cm)
				Females			
1	$ICMA_1$ 94555	-2.45**	-1.75**	-8.95**	-0.02	-1.20**	-0.03
2	$ICMA_1$ 95444	-4.52**	-4.61**	7.55**	0.26**	1.87**	0.11**
3	$ICMA_1$ 11222	0.08	0.25	-6.10**	-0.34**	-2.92**	-0.15**
4	$JMSA_1$ 20209	3.58**	2.95**	2.97*	-0.20**	-0.60*	-0.15**
5	$JMSA_5$ 20212	3.31**	3.15**	4.54**	0.31**	2.86**	0.22**
	S.Em. ±	**0.31**	**0.54**	**1.29**	**0.02**	**0.29**	**0.02**
				Males			
1	J-2372	-1.75**	-1.28	6.10**	0.04	-2.32**	-0.05*
2	J-2496	1.11*	1.25	10.10**	-0.15**	-0.31	-0.01
3	J-2562	-1.09*	-0.41	-11.77**	-0.15**	0.48	0.08**
4	J-2597	2.91**	2.72**	4.52*	0.001	2.31**	0.08**
5	J-2569	-1.22**	-0.68	2.54	0.19**	1.21**	0.06*
6	J-2580	1.11*	0.79	-0.99	0.05	-3.18**	-0.04
7	J-2634	-0.02	-0.01	1.52	-0.06	-1.42**	-0.21**
8	J-2637	-1.75**	-1.35	-4.18*	0.01	0.70	0.03
9	J-2639	1.05*	1.05	-6.34**	0.06*	0.36	-0.04
10	J-2641	-0.35	-2.08**	-1.51	0.001	2.17**	0.09**
	S.Em. ±	**0.44**	**0.76**	**1.82**	**0.03**	**0.41**	**0.03**

*, ** Significant at 5% and 1% levels, respectively

Table 2: Cont…

Sr. No.	Parents	Dry earhead weight (g)/plant	1000-grain weight (g)	Dry fodder yield (g)/plant	Grain yield (g)/plant	Threshing index (%)	Harvest index (%)
				Females			
1	$ICMA_1$ 94555	-0.74	-0.30**	-5.70**	-0.69*	0.46	1.66**
2	$ICMA_1$ 95444	8.71**	0.62**	12.81**	7.49**	3.19**	1.58**
3	$ICMA_1$ 11222	-6.87**	-0.51**	-9.67**	-6.08**	-3.25**	-1.35**
4	$JMSA_1$ 20209	-8.47**	-0.24**	-8.57**	-7.01**	-2.38**	-3.01**
5	$JMSA_5$ 20212	7.37**	0.43**	11.13**	6.28**	1.99**	1.12**
	S.Em. ±	**0.43**	**0.17**	**0.98**	**0.32**	**0.35**	**0.26**
				Males			
1	J-2372	-1.63**	-0.27**	-3.82**	-2.34**	-4.50**	-1.22**
2	J-2496	-0.22	-0.35**	-0.14	0.23	1.39**	0.70
3	J-2562	-2.98**	-0.40**	-2.81*	-2.28**	0.03	-0.68
4	J-2597	2.66**	0.40**	8.78**	2.48**	1.82**	-0.75*
5	J-2569	3.70**	0.43**	10.21**	3.35**	1.78**	-0.56
6	J-2580	2.05**	-0.27**	-2.62	0.98*	-1.96**	0.67
7	J-2634	-4.92**	0.16	-1.52	-4.26**	-1.74**	-3.39**
8	J-2637	2.35**	0.01	1.56	1.90**	-0.23	0.48
9	J-2639	-2.79**	0.09	-9.00**	-1.61**	2.96**	3.40**
10	J-2641	1.76**	0.22**	-0.65	1.56**	0.46	1.36**
	S.Em. ±	**0.06**	**0.08**	**1.39**	**0.46**	**0.49**	**0.37**

*, ** Significant at 5% and 1% levels, respectively

Table 3: Five best specific cross combinations of sca effect for grain yield per plant along with their desirable sca effect of component characters including gca effect of their parents in pearl millet

Crosses	sca effect for grain yield/ plant	gca effect for grain yield/plant		Heterosis (%) over		Significant desirable sca effect for component traits
		Female	Male	Better parent	Standard check (GHB-1231)	
ICMA$_1$ 94555 × J-2580	20.53**	-0.69* (P)	0.98* (G)	48.33**	81.49**	6,7,8,10,11
JMSA$_5$ 20212 × J-2562	14.58**	6.28** (G)	-2.28** (P)	71.87**	72.35**	4,5,6,7,8,9,10
ICMA$_1$ 95444 × J-2372	13.15**	7.49** (G)	-2.34** (P)	97.86**	71.21**	3,4,5,6,7,8,9,10,11
JMSA$_5$ 20212 × J-2637	13.01**	6.28** (G)	1.90** (G)	82.46**	82.97**	1,4,5,6,7,8,9,10
JMSA$_1$ 20209 × J-2639	12.43**	-7.01** (P)	-1.61** (P)	44.97**	12.05*	3,5,6,7,8,9,10,11

Where, *, ** significant at 5 % and 1 % levels, respectively.

1= Days to 50% flowering; 2= Days to maturity; 3= Plant height (cm); 4= No. of effective tillers/plant; 5= Earhead length (cm); 6= Earhead diameter (cm); 7= Dry earhead weight (g)/plant; 8= 1000-grain weight (g); 9= Dry fodder yield (g)/plant; 10= Threshing index (%) and 11= Harvest index (%)