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Combining ability effects in CMS based pigeonpea (*Cajanus cajan* (L.) Millsp) hybrids

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Abstract
A total number of 54 genotypes (5 lines, 8 testers, 40 hybrids and 1 standard check) were evaluated in a randomized block design with two replications during *Kharif* 2018 to study the general and specific combining ability effects for yield and yield contributing characters at Agriculture Research Station, Badnapur. Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Five competitive plants were selected randomly from each row in each replication for recording the observations. High magnitude of variances due to lines and testers against line x tester interaction for the characters indicated the presence of variability. The estimates of components of variance for GCA were higher in magnitude than SCA variances except for pollen fertility and primary branches per plant indicating presence of additive gene action. The estimates of GCA effects revealed that BSMR 736 B, BDN 2004-4 B, BDNHR 1 and BDNHR 35-8 were the good general combiners for grain yield per plant and most of the yield contributing characters. The lines BDN 2004-3 B and tester BDNHR 21-1-1 and BDNHR 36-7 have registered significant negative GCA effect for days to 50 per cent flowering and days to maturity. Among all crosses, BSMR 736 A x BDNHR 22-1-1 manifested maximum positive SCA effect followed by BDN 2004-4 A x BDNHR 35-8 and BDN 2004-2A x BDNHR 24-1-1-1 for grain yield per plant. On the basis of *per se* performance and general combining ability parents, BSMR 736 B, BDN 2004-4 B, BDNHR 1 and BDNHR 35-8 were identified for their use in potential breeding programmes. Two crosses BSMR 736 A x BDNHR 22-1-1 and BDN 2004-3 A x BDNHR 35-8 showing high per se performance, significant desirable SCA effects for grain yield per pant, days to maturity and pollen fertility.

Keywords: Pigeaonpea, general combining ability, specific combining ability, CGMS

Introduction

Pigeonpea *Cajanus cajan* (L.) Millsp. (2n=22) is an important legume (pulse) crop of tropical and subtropical regions of Asia and Africa. It occupies an important place among rainfed resource poor farmers with many benefits at low cost. In India, pigeonpea is grown in an area of 4.45 million hectares with a production of 4.18 million tones [1]. The Indian sub-continent alone contributes nearly 92 per cent of the total pigeonpea production in the world. Although India leads the world both in area and production its productivity is too low (937 kg/ha). So the Indian Government annually imports about 0.5 to 0.6 m. tons of pigeonpea mainly from Myanmar and southern and eastern Africa to meet the growing domestic needs as it is the largest consumer too [2].

The progress in the genetic improvement of yield potential has been limited and the improved cultivars failed enhance the productivity of the crop. Therefore, an alternative breeding approach such as hybrid technology was attempted in pigeonpea to enhance the yield. In 1974, a source of genetic male-sterility (GMS) was identified. As a consequence, a genetic male-sterility based pigeonpea hybrid ICPH 8 was released in 1991 in India [3]. This hybrid, however, could not be commercialized due to its high seed cost and difficulties in maintaining the genetic purity. Due to the limitation of large-SCAle hybrid seed production in GMS-based hybrids, the development of cytoplasmic male-sterility (CMS) became imperative. A_2 and A_4 systems derived from crosses involving wild relatives of pigeonpea and cultivated types have shown promise because of their stability under various agro-climatic conditions and availability of good maintainers and fertility restorers [2]. However, environmental effect greatly influence the combining ability estimates. Combining ability analysis provides guideline to plant breeder in choosing parents for hybridization to isolate desirable recombination from segregating population and to identify the potential crosses for exploitation of heterosis. It would also help to define the pattern of gene effects in the expression of quantitative traits [4].

Selection of parents on the basis of their phenotypic performance alone is not a sound procedure since phenotypicaly superior lines may yield poor recombination. It is therefore, essential that parents should be chosen on the basis of their genetic value [5]. In view of above consideration, the present study has been planned on combining ability, heterosis in CGMS based pigeonpea hybrids.

Materials and Methods

Material for present study comprised of total 40 CGMS based F1 hybrids developed by crossing 5 female and 8 male parents in Line X Tester mating design. 54 genotypes (5 lines, 8 testers, 40 hybrids and 1 standard check) were sown in a randomized block design with two replications during *Kharif* 2018 at Agriculture Research station, Badnapur. The crop was given a uniform basal dose of 25 kg N and 50 kg P_2O_5/ha. Cultural practices like weeding and plant protection measures were followed as and when required. Crop was irrigated once during vegetative growing stage because of long dry spell and the rest of the time it was rainfed. Observations for eleven yield and yield contributing traits were recorded on five randomly selected plants from each row in each replication. For testing the pollen fertility in the hybrids 2 per cent aceto-carmine solutions was used to stain and differentiate the fertile and sterile pollen grains. Per cent pollen fertility of hybrids was calculated as percent of mean of all the observations from a hybrid. Mean data of genotypes (excluding standard check) was analyzed as per line x tester mating design [6] to estimate general and specific combining ability while mean data of 54 genotypes (including standard check) was used for the estimation of standard heterosis.

Results and Discussion

The analysis of variance (Line x tester) due to different sources for eleven characters is summarized in Table 1 indicated variation among the genotypes was highly significant for all the characters. The differences due to crosses and lines were significant for all the characters except for pod length in case of crosses and days to 50 per cent flowering and number of pods per plant in case of lines. High magnitude of variance due to lines against line x tester interaction for these traits indicated the presence of considerable variability among female lines. The analysis of variance due to testers was significant for the characters plant height, days to 50 % flowering, days to maturity and number of seeds per pod. The analysis of variance due to line x tester were significant for all the characters except plant height, number of seeds per pod, pod length and grain yield per plant indicating importance of SCA variance and non additive gene action. Similar results were reported earlier [7].

General Combining Ability

The mean squares of GCA effect were significant for all characters except pollen fertility and number of primary branches per plant (Table 2). similarly mean square of SCA effect were significant for all the characters except plant height, number of primary branches per plant, number of seeds per pod and pod length. This indicated the presence of significant differences between males and females for these traits. However the estimates of components of variance for GCA were higher in magnitude than SCA variances for days to plant height, days to 50% flowering, days to maturity, no of pods per plant, no. of seeds per plant, pod length, 100 seed weight, number of secondary branches per plant and grain yield/plant indicating preponderance of additive gene action. Predominance of additive gene effects for the yield and yield contributing characters reported by [8]. High SCA effects for number of primary branches and pollen fertility showed presence of non additive gene action. Non additive gene effects were reported for number of branches per plant governed by [9].

General combining ability (GCA) effect for parents is presented in Table (3) revealed among lines BDN 2004-4 B (12.74**) and BSMR 736 B (4.26*) and among testers BDNHR 1 (7.42**) and BDNHR 35-8 (6.44**) had significant desirable GCA effect for grain yield per plant. The negative GCA effect desirable in days to 50 per cent flowering and days to maturity was observed in BDN 2004-3 B (-2.26** & -4.97**) among lines and BDNHR 24-1-1-1 (-4.58** & -1.80*) among testers. Hence selection of these parents in hybridization programme would result in early maturing hybrids. Desirable negative GCA effects for days to maturity was also observed in BDN 2004-1, BSMR 736 B, BDNHR 36-7 and BDNHR 35-8. Among CMS lines BSMR 736 B and BDN 2004-4 B had desirable GCA effect for grain yield per plant, number of primary & secondary branches per plant, pollen fertility and number of pods per plant. While among testers BDNHR 35-8 had shown good GCA effects for pollen fertility, number of pods per plant and grain yield per plant. However BDNHR 1 though exhibits good GCA effects for grian yield per plant, 100 seed weight and number of secondary branches, showed significantly negative GCA effect for pollen fertility hence would not be effective in developing stable hybrid.

In most of the parents high GCA effects were associated with high *per se* mean for yield and yield components. It is important to mention here that the parents which showed good GCA effects for grain yield per plant also indicated significantly positive GCA effects for number of pods per plant. The results are in corroborance with the findings [10-13].

Specific Combining Ability

Specific combining ability effect is the index to determine usefulness of a particular combination in the exploitation of heterosis. The estimation of SCA effects of the hybrids are presented in table 4.

Among all crosses, BSMR 736 A x BDNHR 22-1-1 (15.42**) manifested maximum positive SCA effect followed by BDN 2004-4 A x BDNHR 35-8 (14.52**) and BDN 2004-2A x BDNHR 24-1-1-1 (12.38*) for grain yield per plant. Parents involved in these crosses have high × low, high x high and low × low GCA effects. These results are in agreement with the findings of [8, 14] for grain yield per plant. All the parents involved in first two hybrids ie. BSMR 736 A, BDNHR 22-1-1, BDN 2004-4 A and BDNHR 35-8 showed good per se performance and GCA effects for pollen fertility and grain yield. Therefore these hybrids would be highly economical on commercial basis.

Significant negative SCA effects both for days to 50 per cent flowering and days to maturity are desirable to produce early maturing hybrids. three hybrids *viz*., BDN 2004-1 A x BDNHR 22-1-1, BSMR 736 A x BDNHR 22-1-1 and BDN 2004-3 A x BDNHR 35-8 showed significant negative SCA effect for both the traits. These results are in agreement with the earlier results reported [15, 10, 16].

Twenty one crosses showed significant positive SCA effect for pollen fertility. Maximum significant positive SCA effect was shown by BDN 2004-2 A x BDNHR 36-6 followed by

BDN 2004-1 A x BDNHR 1. However parents showing good GCA effects and per se mean performance for pollen fertility were reported to have negative SCA effects.

Significant positive SCA effect for No. of secondary branches per plant was exhibited by BDN 2004-4 A X (3.93**). Cross BSMR 736 A X BDNHR 22-1-1 reported significant positive SCA effect for number of pods per plant, grain yield and days to flowering and days to maturity. Present observations are in close agreement with the earlier reports of [13, 16].

None of the crosses, exhibited significant positive SCA effect for the trait number of seeds per pod, pod length, number of primary branches and plant height. Eight crosses showed significant positive SCA effect for 100 Seed weight. Maximum significant positive SCA effect was registered by the cross BDN 2004-2 A x BDNHR 36-7 followed by BDN 2004-2 A x BDNHR 35-8. These results are in agreement with [17]. From the present study it can be clearly indicated that there is no particular relationship between positive significant SCA effects of crosses with GCA effects of their parents. SCA effects may be the positive or negative effect of inter allelic interaction. This was in agreement with the findings of [13, 18].

On the basis of *per se* performance and general combining ability parents, BSMR 736 B, BDN 2004-4 B, BDNHR 1 and BDNHR 35-8 were identified for their use in potential breeding programmes. Two crosses BSMR 736 A x BDNHR 22-1-1 and BDN 2004-3 A x BDNHR 35-8 showing high per se performance, significant desirable SCA effects for grain yield per pant, days to maturity and pollen fertility may be exploited in near future after studying its stability across the environments.

Table 1: ANOVA for Line x Tester analysis

Sources of Variation	d. f.	Mean sum of squares										
		Plant height (cm)	Days to 50 % flowering	Pollen fertility (%)	Days to maturity	No. of primary branches per plant	No. of secondary branches per plant	No. of pods per plant	No. of seeds per pod	Pod length (cm)	100 seed weight (g)	Grain yield per plant (g)
Replications	1	380.89	12.01	7.65	1.51	2.59	1.68	1035.36	0.03	0.19	0.31	133.54
Crosses	39	235.47*	44.78**	1029.33**	158.99**	3.26**	15.71**	3984.89*	1.03**	0.17	6.86**	285.52**
Parents (Line)	4	1023.12**	30.20	2941.87*	510.45**	15.25**	54.85**	24653.48	9.36**	0.64**	55.56**	1454.39**
Parents (Tester)	7	361.97**	118.01*	916.11	382.01**	2.24	22.20	1551.99	0.17*	0.20	1.39	264.94
Line x Tester	28	91.33	28.55**	784.42**	53.03**	1.80*	8.50*	1640.45**	0.063	0.09	1.28**	123.68
Error	39	111.45	5.52	6.74	10.71	0.98	4.43	459.20	0.063	0.16	0.12	72.80

Table 2: ANOVA for combining ability analysis

Sources of Variation	d. f.	Mean sum of squares										
		Plant height (cm)	Days to 50 per cent flowering	Pollen fertility (%)	Days to maturity	No. of primary branches per plant	No. of secondary branches per plant	No. of pods per plant	No. of seeds per pod	Pod length (cm)	100 seed weight (g)	Grain yield per plant (g)
GCA	12	281.07*	108.33**	3.84	108.37**	1.67	11.35**	3724.45**	0.39**	1.33**	4.41**	254.31**
SCA	28	91.33	28.55**	784.42**	53.03**	1.80*	8.50*	1640.45**	0.063	0.09	1.28**	123.68**
Error	52	139.62	5.16	5.31	9.57	1.21	4.18	361.86	0.067	0.16	0.10	56.45

Table 3: General Combining Ability of Parents in Pigeonpea

Sr. No.	Parents	Plant height (cm)	Days to 50 per cent flowering	Pollen fertility	Days to maturity	No. of primary branches per plant	No. of secondary branches plant	No. of pods per plant	No. of seeds per pod	Pod length (cm)	100 Seed weight (g)	Grain yield per plant (g)
	Female parents (Lines)											
1.	BDN 2004-1 B	0.53	0.67	-5.11**	-2.47**	-0.35	-1.22*	1.02	0.54**	-0.02	-0.57**	-1.04
2.	BDN 2004-2 B	-4.99	1.23*	-21.65**	9.08**	-1.47**	-1.99**	-49.32**	-1.30**	-0.19	3.23**	-13.20**
3.	BDN 2004-3 B	-1.31	-2.26**	8.50**	-4.97**	0.10	-0.68	-23.29**	0.41**	0.31**	-0.20*	-2.76
4.	BDN 2004-4 B	-7.41*	-0.26	9.81**	1.71*	0.72*	2.18**	53.45**	-0.07	-0.13	-1.33**	12.74**
5.	BSMR 736 B	13.18**	0.61	8.45**	-3.35**	0.99**	1.72**	18.14**	0.41**	0.04	-1.12**	4.26*
	Male parents (Testers)											
6.	BDNHR 1	-5.11	0.31	-7.27**	0.08	-0.36	2.23**	2.67	-0.15	-0.16	0.36**	7.42**
7.	BDNHR 21-1-1	0.66	-4.58**	-1.80*	-1.01	-0.68	-0.87	-6.15	-0.01	-0.11	0.41**	-4.64
8.	BDNHR 22-1-1	-6.86	1.31	0.78	8.58**	-0.37	-1.03	-8.76	0.04	-0.14	0.31**	0.84
9.	BDNHR 24-1-1-1	-4.50	-1.28	9.29**	-7.11**	-0.22	-0.06	12.92*	0.16	0.09	-0.14	-0.49
10.	BDNHR 35-8	-1.90	0.31	10.63**	-2.51*	0.22	-0.12	20.86**	0.10	0.04	-0.14	6.44**
11.	BDNHR 36-1	10.90**	3.71**	-10.10**	1.68	0.27	-2.25**	-18.94**	-0.03	0.15	-0.07	-8.03**
12.	BDNHR 36-6	6.01	4.81**	-12.63**	8.28**	0.46	0.23	-0.78	-0.22*	-0.08	-0.01	-1.19
13.	BDNHR 36-7	0.80	-4.58**	11.10**	-8.01**	0.68	1.88**	-1.82	0.11	0.21	-0.72**	-0.35
	CD 5% GCA (Line)	5.97	1.14	1.16	1.56	0.55	1.03	9.61	0.13	0.20	0.16	3.79
	CD 5% GCA (Tester)	7.55	1.45	1.47	1.97	0.70	1.30	12.16	0.166	0.26	0.20	4.80

* -Significant at 5 % level of significance

** -Significant at 1 % level of significance

Table 4: Specific combining ability of crosses in Pigeonpea

Sr. No.	Crosses		Days to 50 per cent flowering	Pollen fertility	Days to maturity	No. of primary branches per plant	No. of secondary branches per plant	No. of pods per plant	No. of seeds per pod	Pod length (cm)	100 Seed weight (g)	Grain yield per plant (g)
1.	BDN 2004-1 A x BDNHR 1	5.12	2.62	21.30**	0.47	1.27	1.18	29.03*	-0.23	-0.18	0.15	7.44
2.	BDN 2004-1 A x BDNHR 21-1-1	1.89	2.52	6.60**	5.07*	-0.40	0.74	9.30	0.12	-0.24	0.35	1.99
3.	BDN 2004-1 A x BDNHR 22-1-1	-8.12	-7.37**	-13.91**	-7.02**	-1.46	0.35	-34.98*	-0.07	-0.15	-0.28	-11.80*
4.	BDN 2004-1 A x BDNHR 24-1-1-1	-15.14	1.72	11.04**	2.67	-0.06	-0.81	19.18	0.15	0.41	-0.82**	4.78
5.	BDN 2004-1 A x BDNHR 35-8	5.81	1.62	8.58**	-3.92	0.39	0.24	-2.30	-0.08	0.12	0.13	0.33
6.	BDN 2004-1 A x BDNHR 36-1	-0.14	-0.27	13.23**	0.87	1.29	0.57	-35.25*	0.24	-0.21	0.31	-1.13
7.	BDN 2004-1 A x BDNHR 36-6	12.79	-1.87	-54.70**	4.27	-0.24	-1.71	-0.11	-0.16	-0.02	0.45	-6.72
8.	BDN 2004-1 A x BDNHR 36-7	-2.21	1.02	7.85**	-2.42	-0.76	-0.56	15.12	0.009	0.27	-0.31	5.10
9.	BDN 2004-2 A x BDNHR 1	3.05	-2.93	-45.31**	0.41	-0.85	-2.89	-54.11**	0.21	0.19	-0.02	-10.95*
10.	BDN 2004-2 A x BDNHR 21-1-1	0.30	2.46	10.46**	-3.98	0.41	3.61*	14.25	-0.12	-0.14	-0.59*	7.86
11.	BDN 2004-2 A x BDNHR 22-1-1	6.91	8.56**	19.00**	-1.58	0.75	0.52	-1.53	-0.07	-0.16	-1.002**	-0.18
12.	BDN 2004-2 A x BDNHR 24-1-1-1	3.48	-3.33*	11.97**	1.61	0.55	3.55*	50.68**	0.10	-0.03	0.61*	12.38*
13.	BDN 2004-2 A x BDNHR 35-8	0.34	-5.93**	11.91**	1.01	-1.13	-1.38	16.69	0.16	-0.10	1.39**	-2.55
14.	BDN 2004-2 A x BDNHR 36-1	-4.46	2.16	-41.64**	0.31	-0.93	-0.60	-8.30	-0.40*	0.08	-0.41	-3.30
15.	BDN 2004-2 A x BDNHR 36-6	-6.47	0.06	21.85**	-1.78	-0.02	-0.44	16.68	0.18	0.24	-1.61**	-0.15
16.	BDN 2004-2 A x BDNHR 36-7	-3.16	-1.03	11.75**	4.01	1.25	-2.39	-34.37*	-0.04	-0.08	1.62**	-3.10
17.	BDN 2004-3 A x BDNHR 1	-9.32	3.56*	11.28**	-4.02	-0.83	-1.00	23.70	0.14	0.36	-0.09	3.86
18.	BDN 2004-3 A x BDNHR 21-1-1	-1.51	-1.03	-5.35**	-1.92	-0.11	-2.99*	-34.42*	-0.04	0.06	0.42	-2.95
19.	BDN 2004-3 A x BDNHR 22-1-1	-0.37	-0.43	2.89	9.47**	0.77	-0.03	23.83	-0.09	0.07	0.59*	2.05
20.	BDN 2004-3 A x BDNHR 24-1-1-1	5.15	1.66	-8.46**	1.17	-0.37	-1.30	-31.34*	-0.21	-0.11	0.27	-8.47

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