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Environment x combining ability and pollen fertility studies in pigeonpea [*Cajanus cajan* (L.) Millspaugh]

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Abstract:

The present investigation was carried out to derive information on combining ability for yield and yield contributing and cytological characters to study influence of environment on these factors. A line x tester mating design was used to develop 32 F_1 hybrids using 4 CGMS lines and 8 testers were planted in all the three environments with two replications.The analysis of variance (ANOVA) for line x tester mating scheme indicated significant differences among the parents and hybrids for all the characters under study. The significant variances for parents versus hybrids indicated occurrence of substantial heterotic response in almost all the characters over all. The MSS due to locations x hybrids were highly significant for all the characters except days to 50% flowering, days to maturity, plant height (cm), number of primary branches plant^{-1} , number of secondary branches plant^{-1}. Locations x lines were highly significant for days to 50% flowering, number of pods plant^{-1}, number of seeds pod $^{-1}$. The MSS due to locations x lines x testers were significant for number of seeds pod^{-1}, test weight (g) , grain yield plant^{-1} (g), harvest index (%) and pollen fertility (%). (Table 1)

Keywords: *Cajanus cajan*, combining ability × environment, environment, combining ability, pollen fertility.

Introduction:

In a systematic breeding program, the choice of suitable parents for hybridization depends upon the general combining ability (GCA) of the parents whereas, specific combining ability (SCA) gives an idea for the performance of a specific hybrid exhibiting the dominance and epitasis Combining ability analysis helps to choose suitable parents for hybridization and provides valuable information regarding cross combinations to be exploited commercially. The environment plays an important role in the expression of a trait and greatly influences combining ability estimates and thus the study in single environment may not provide reliable information. Therefore, present study was undertaken to estimates combining ability for seed yield and other traits in pigeonpea over three different environments.

MATERIALS AND METHOD

A line x tester mating design was used to develop 32 F_1 hybrids using four CGMS lines ICPA-2043, ICPA-2047, ICPA-2092 with A_4 cytoplasm, derived from *C.cajanifolius* (Saxena *et al.* 2005b) developed at ICRISAT and BSMR-736A with A_2 cytoplasm, derived from *C.scarabaeoides* (Tikka *et al.*, 1997; Saxena and Kumar , 2003) from Agricultural Research Station, Badnapur ,V.N.M.A.U., Parbhani. The tester materials comprised of 2 genotypes (ICPR-2671, ICPL-20181) obtained from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru (Andhra Pradesh), 5 genotypes (BSMR-79, BSMR-175, BSMR-316, BSMR-528 and BSMR-253) from Agricultural Research Station, Badnapur, V.N.M.A.U., Parbhani. RVSA-0722 selected from local germplasm. All these materials were evaluated at three selected environments viz., Parbhani (E_1), Nanded (E_2), and Badnapur (E_3). All the 32 cross combinations were made during *Kharif* 2012 in a line (4) x tester (8) mating design and sufficient number of hand pollinated seeds were produced during 2012 rainy season at the Department of Agricultural Botany, Vasantrao Naik Marathwada Agricultural University, Parbhani. The 32 F_1s and parents in all the three environments were planted with two replications. The inter and intra row spacing was kept at 90 cm and 30 cm, respectively.. Observations on five randomly selected competitive plants in all the environments were recorded for days to 50% flowering, days to maturity, plant height (cm), number of primary branches plant^{-1}, number of secondary branches plant^{-1}, number of pods plant^{-1}, number of seeds pod $^{-1}$, test weight (g), grain yield plant^{-1} (g), harvest index (%) and pollen fertility(%). The analysis was carried out for L X T mating design as suggested by Kempthorne (1957). Statistical analysis was performed using SAS software available at ICRISAT, Patancheru.

Results and Discussion

The variance components due to lines x testers and MSS due to hybrids were significant for all the characters. The variance components due to lines were significant only for pollen fertility (%). The MSS due to testers were significant for eight characters, except days to maturity, number of secondary branches plant^{-1}, number of pods plant^{-1}, number of seed pod $^{-1}$ and harvest index (%). The MSS due to locations x hybrids were highly significant for all the characters except days to 50% flowering, plant height (cm), number of primary branches plant^{-1}, number of secondary branches plant^{-1}, fertility of plants (%) and pollen size (µm). Locations x lines were highly significant for days to 50% flowering and number of pods plant^{-1}. The MSS due to locations x lines x testers were significant for number of seeds pod $^{-1}$, test weight (g) , grain yield plant^{-1} (g), harvest index (%) and pollen fertility (%). (Table 1). The Female parent ICPA – 2047 and male parents ICPL –20181 (20.04), ICPR- 2671 (17.80) and BSMR – 175 (16.56) exhibited significant and positive GCA effects for plant height. The canopy development depends on the number of primary and secondary branches plant^{-1} in turn it determinate the yield. The female parent ICPA – 2043(0.87) and male parents ICPL-20181(1.91), BSMR-175 (1.69) and ICPR-2671 (1.61) were good general combiners and possessed favourable genetic architecture for number of primary branches plant^{-1}. The pooled data showed that BSMR-175 (7.77) had highest significant and positive GCA effect followed by ICPL-20181 (6.95) and ICPR-2671 (4.83) for number of secondary branches plant^{-1}. It was observed that the parents having high *per se* performance also showed high GCA effects. (Yadav *et al*. 2008). The estimates of GCA effects over pooled data analysis revealed that the female parent ICPA – 2047 (11.10) and the male parent ICPR – 2671 (38.11) recorded the highest significant and positive GCA effects followed by BSMR – 79 (26.22) and ICPL – 20181 (21.40) for number of pods plant^{-1}. It was observed that the parents which showed high GCA effects were associated with medium to high *per se* performance. These parents appeared promising for use in breeding programme for high seed yield. The parents ICPA-2043, ICPL-20181, BSMR-253 (0.08)] recorded the highest significant GCA effect for number of seeds pod^{-1}. Female parents BSMR-736 A (0.37), ICPA – 2092 (0.07) and the male parents BSMR – 316 (0.73) followed by BSMR – 253 (0.64) and BSMR – 175 (0.44) recorded by highest significant and positive GCA effect for 100 seed weight. (Singh and Srivastava, 2001) and (Dalvi, 2007) reported that good general combiners for 100-seed weight were the parents of the high heterotic hybrids. For grain yield plant^{-1} female parents ICPA – 2092 and ICPA-2047 and the male parents ICPR-2671, ICPL-20181 and BSMR – 175 exhibited significant and positive GCA effects for grain yield plant-1. Similar finding have been reported by (Yadav *et al*., 2008) and (Phad *et al*., 2009). Female parents ICPA – 2092 (1.28) and BSMR-736A (1.15) and the male parents ICPL – 20181 and BSMR – 175 (2.2 (2.80) recorded the highest GCA effect for harvest index (%) (Table 2). *Per se* performance of the ICPL-20181 and BSMR-175 were also high (Fig 1B). (Pandey and Singh, 2002) and (Jahagirdar *et al*. 2003) reported similar results for per cent harvest index of pigeonpea. The highly significant and positive SCA effects in hybrids were recorded by BSMR-736A X BSMR-79 (39.87) and ICPA-2047 X RVSA-0722 (27.28) for plant height. It was observed that the high SCA effects in above cross combinations were from low x poor, high x high, poor x low GCA effects of parents respectively. The *per se* performance of high x low, low x low and high x low combinations involved in above hybrids. (Baskaran and Muthiah , 2007) revealed that the high SCA effects of high x low combinations indicating the operation of additive x dominance gene effects and hence could be used in heterosis breeding in pigeonpea. The highest significant and positive SCA effects for number of primary branches plant^{-1} and number of secondary branches plant^{-1} regulated by ICPA-2043 X ICPR-2671 (2.84), BSMR-736A X BSMR-79 (2.66) and ICPA-2047 X BSMR-175 (2.30). The high x low combinations indicated the operation of additive x dominance gene effects and hence could be used in heterosis breeding. Hybrids ICPA-2047 X BSMR-175 (89.57), BSMR-736A X BSMR-528 (50.59) and ICPA-2043 X RVSA-0722 (44.78) showed the highest significant and positive SCA effects on pooled basis for number of pods plant^{-1}. High x high, low x high, high x low general combiners were present in above cross combination respectively. Also high SCA effects showing hybrids for number of pods plant $^{-1}$ had medium x high, high x low and high x average performing parents. significant and positive SCA effects were present in hybrids ICPA-2043 x BSMR-253 (0.41), ICPA-2047 X RVSA-0722 (0.35) and ICPA-2092 X BSMR-79 (0.34) for number of seeds pod-1. The highest significant and positive SCA effects were registered by ICPA-2043 X BSMR-528 (1.55), BSMR-736A X ICPL-20181 and ICPA-2043 X BSMR-175 (0.91 for test weight. Most of the hybrids showing significant and positive SCA effects combined with one good and one poor and such hybrids could produce desirable transgressive segregants if the additive genetic system present in the good combiners and the complementary epistatic effects in the F_1s act in the same direction to maximize the desirable plant attributes. Higher estimates of SCA effects were usually recorded in those hybrids which involved high and significant *per se* performance and heterosis. In the present study the hybrids BSMR-736A x BSMR-79 (20.28), ICPA-2047 x BSMR-175 (13.67) and ICPA-2043 X ICPR-2671 (11.44) showed the highest significant and positive specific combining ability (SCA) effects for grain yield plant^{-1}(Table 3). Same hybrids ICPA-2047 X BSMR-175 and ICPA-2043 X ICPR-2671 had superior *per se* performance (Fig 1A). The high SCA effects in hybrids were due to low x high, high x low and low x high general combiners which gave significant SCA effects thereby indicating the involvement of non-allelic interactions. (Vannirajan *et al.*, 1999) reported that some of the cross combinations having parents with high x low and low x high general combining ability (GCA) effects also produced significant SCA effects. The analysis of pooled data showed that highly significant and positive SCA effects were present in hybrids ICPA – 2043 x ICPR – 2671, ICPA – 2092 x BSMR – 528 and ICPA – 2043 x ICPL – 20181 for harvest index (%).

Pollen fertility (%) is an important character to evaluate the restoration of fertility and amount of viable pollens produced by particular hybrid which is basic need for the successful production of high yielding CMS based hybrids of pigeonpea. At Parbhani female parents BSMR 736A (76.50%) and ICPL – 20181(75.50 %) exhibited highest pollen fertility. Parents BSMR–736A (72.50 %) and ICPA – 2047 (71.50%) show highest pollen fertility among the parents at Nanded. At Badnapur parents ICPA – 2092 (76.50 %) and ICPL – 20181(76.00 %) showed highest pollen fertility among the parents. Hybrids ICPA – 2043 X ICPL – 20181, ICPA – 2092 X BSMR – 175 and ICPA – 2092X ICPL – 20181 exhibited 100% pollen fertility across three locations. The analysis of pooled data revealed that parents ICPL – 20181 (74.16%) and ICPA – 2047 (72.83 %) showed highest pollen fertility. Hybrids ICPA – 2043 x ICPL – 20181, ICPA – 2092 x BSMR – 175 and ICPA – 2092 x BSMR – 528 exhibited 100% pollen fertility. Parents ICPR-2671, BSMR-175 and ICPL-20181 were found to be good general combiners for pollen fertility. ICPA-2047 x BSMR-175 show high positive SCA effects for pollen fertility (%) (Fig 2 A&B).

Conclusion

In the present investigation , the parents ICPR-2671, BSMR-175 and ICPL-20181 were found to be good general combiners for pollen fertility. These parents should be extensively used in improvement programme so that useful combination for higher pollen fertility (%) with other yield component can be obtained which is necessary for achieving the high yield level. hybrids BSMR-736A x BSMR-79, ICPA-2047 x BSMR-175 and ICPA-2043 X ICPR-2671 showed the highest significant and positive SCA for grain yield plant^{-1} and pollen fertility. Most of the crosses of which involved one good combiner and one medium or negative combiner. Desirable transgressive segregants could be produced from such crosses if the additive gene effects of the good parent and the complementary epistasis effects in the resulting F_1s act in the favourable direction. (Venkateswarlu and Singh, 1982)

Table 1: ANOVA for combining ability of yield and yield contributing and cytological characters in pigeonpea, over locations, 2013 rainy season.

Mean sum of square												
Source of variation	**D.F.**	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**Number of primary branches plant^{-1}**	**Number of Secondary branches plant^{-1}**	**Number of pods plant^{-1}**	**Number of seeds pod^{-1}**	**Test weight (g)**	**Grain Yield plant $^{-1}$ (g)**	**Harvest index (%)**	**Pollen fertility (%)**
Replicates	1	26.09	23.04	155.80	0.68	4.32	2732.55	0.66	0.65	28.935	6.99	2.64
Varieties	43	178.65**	220.05**	3025.77**	19.81**	353.72**	15309.45**	0.36**	4.10**	2282.048**	78.18**	2295.95**
Parents	11	11.45**	71.79**	1470.35**	1.20*	65.58**	907.54**	0.285**	2.30**	45.960**	45.21**	871.43**
Parents (Line)	3	19.48*	22.55**	2561.52**	3.01**	53.24**	1364.83**	0.38**	6.11**	29.415*	78.14**	2.70
Parents (Testers)	7	9.33*	25.38**	1086.75**	0.47	76.46**	713..43**	0.22**	0.88**	7.22	34.14**	873.76**
Parents (L vs T)	1	2.25	544.44**	882.09**	0.88	26.43**	894.40	0.44**	0.79**	366.72**	23.94**	3461.36**
Parents vs Crosses	1	15.96	32.24**	6514.90**	16.89**	222.37**	273984.50**	0.97**	13.10**	69803.27**	135.14**	800.74**
Crosses	31	243.22**	278.71**	3465.14**	26.50**	460.20**	12075.50**	0.37**	4.45**	897.39**	88.04**	2849.65**
Line Effect	3	190.89	262.54	5108.79	35.18	400.98	5804.85	0.20	4.15	425.04	109.63	4494.34*
Tester Effect	7	692.64**	479.90	7223.65**	53.07*	738.53	21831.62	0.17	8.56*	2139.68**	96.51	7695.32**
Line * Tester Eff.	21	100.89**	213.96**	1977.50**	16.41**	375.88**	9719.27**	0.46**	3.12**	550.77**	82.13**	999.48**
Location x Crosses	62	2.87	17.65	128.57	0.33	1.89	489.26**	0.04**	0.08*	30.77**	4.83**	28.41**
Location x Line effect	6	8.02**	20.97	272.59	0.50	2.30	2396.70**	0.16**	0.06	43.09	2.98	37.89
Location x Tester effect	14	2.99	16.87	151.80	0.30	2.86	295.83	0.02	0.06	41.14	4.65	20.10
Location x Line x Tester	42	2.09	17.44	100.25	0.32	1.51	281.24	0.03*	0.09*	25.55**	5.15**	29.82**
Error	43	4.26	2.95	96.24	0.55	0.90	239.84	0.09	0.05	8.55	1.67	11.40
6^2Gca		9.37	4.32	113.24	0.76	5.35	84.27	-0.009	0.09	19.86	0.61	141.56
6^2Sca		16.46	32.75	312.87	2.68	62.39	1573.00	0.07	0.50	87.53	12.83	161.61
6^2Gca/6^2Sca		0.56	0.13	0.36	0.28	0.08	0.05	-0.12	0.18	0.22	0.04	0.87

*, &** =Significant at 5 % and 1 % level respectively

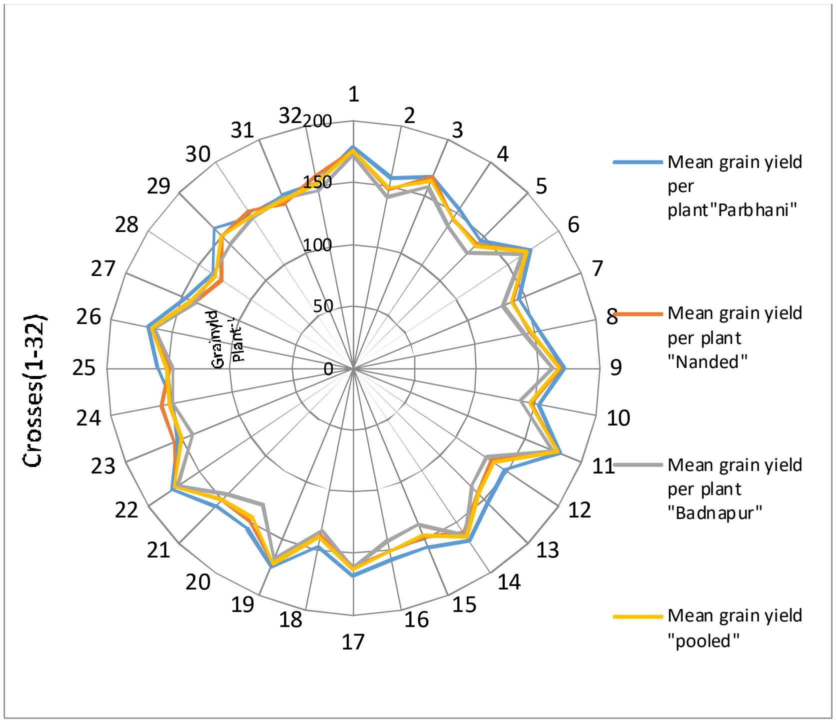
Table 2: General combining ability effects for yield and yield contributing characters for lines and testers in pigeonpea.

Sr. No.	Parents	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of primary branches plant $^{-1}$	Number of secondary branches plant $^{-1}$	Number of pods plant $^{-1}$	Number of seeds pod $^{-1}$	Test weight (g)	Grain yield plant $^{-1}$ (g)	Harvest index (%)
Female parents											
1.	ICPA-2043	-1.07**	-0.56*	-4.39**	0.87**	2.34**	2.93	0.08**	-0.29**	0.21	-1.89**
2.	ICPA-2047	-1.01**	-0.14	15.02**	0.11	0.74**	11.10**	-0.04	-0.16**	1.03**	-0.54**
3.	ICPA-2092	-0.90**	-2.45**	-2.32	0.18	1.12**	1.10	0.01	0.07*	2.88**	1.28**
4.	BSMR-736A	2.99**	3.16**	-8.29**	-1.17**	-4.21**	-15.15**	-0.05**	0.37**	-4.13**	1.15**
Male parents											
5.	ICPR-2671	-5.84**	-1.60**	17.80**	1.61**	4.83**	38.11**	-0.007	-0.54**	11.10**	0.81**
6.	BSMR-79	4.69**	2.35**	-2.65	-0.33	-1.97**	26.22**	-0.06*	-0.99**	-3.09**	-2.45**
7.	BSMR-175	-6.09**	-7.35**	16.56**	1.69**	7.77**	14.15**	-0.03	0.44**	10.63**	2.22**
8.	BSMR-316	3.15**	2.22**	-12.53**	-1.11**	-4.50**	-47.20**	0.01	0.73**	-12.45**	-1.65**
9.	RVSA-0722	3.78**	3.89**	3.94*	-1.55**	-3.87**	-1.43	-0.15**	-0.05	-7.07**	-0.80**
10.	ICPL-20181	-7.38**	-6.02**	20.04**	1.91**	6.95**	21.40**	0.08**	-0.24**	10.70**	2.80**
11.	BSMR-528	4.24**	2.89**	-20.52**	-1.33**	-5.52**	-22.00**	0.07*	0.01	-7.14**	1.07**
12.	BSMR-253	3.44**	3.60**	-22.64**	-0.89**	-3.67**	-29.23**	0.08**	0.64**	-2.67**	-2.01**
	SE + Gi (line)	0.43	0.36	1.80	0.17	0.17	2.17	0.02	0.04	0.38	0.28
	SE ± Gj (tester)	0.61	0.52	2.54	0.25	0.24	3.08	0.04	0.06	0.54	0.40

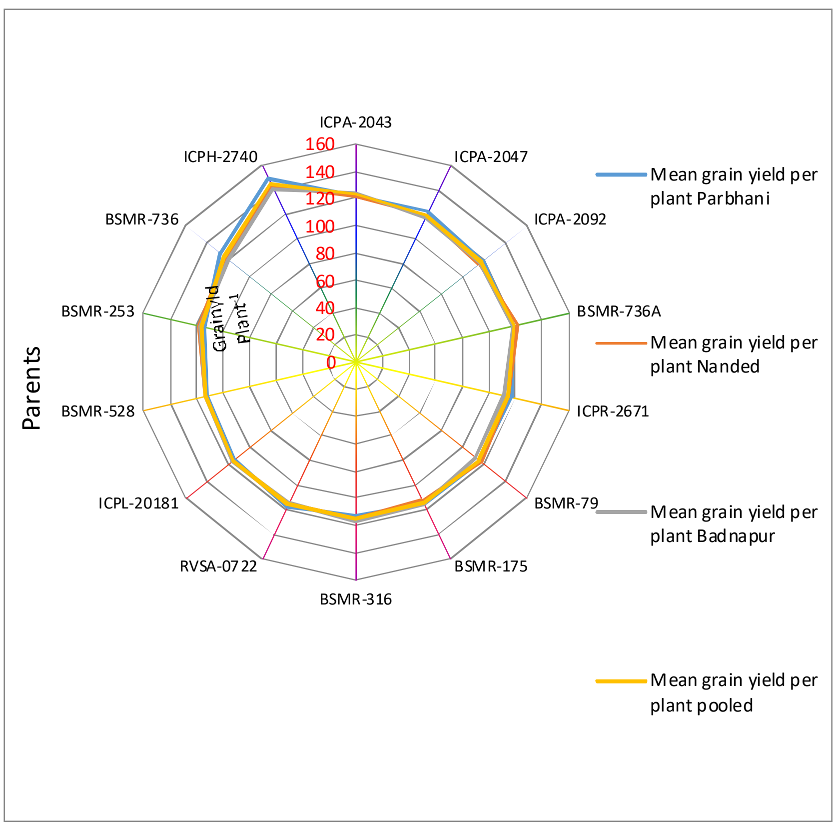
*,&**=Significant at 5% and 1% level respectively

Table 3: Specific combining ability (SCA) effects for yield and yield contributing characters in pigeonpea hybrids.

Sr. No.	Crosses	Days to 50 % floweri ng	Days to maturi ty	Plant heigh t (cm)	Number of primary branch es	Number of seconda ry branche	Numb er of pods plant^{-1}	Numb er of seeds pod^{-1}	Test weig ht (g)	Grain yield plant^{-1} (g)	Harve st index (%)
	Crosses										
1.	ICPA-	-4.09**	-6.77**	4.41	2.84**	14.80**	1.44	0.14*	0.23*	11.44*	6.74**
2.	ICPA-	1.19	1.93*	-	-1.43**	0.61	34.48	-0.46**	0.14	-2.16	0.03
3.	ICPA-	1.15	10.47**	-4.68	-1.58**	-12.46**	-	0.27**	0.91*	0.22	-9.25
4.	ICPA-	-0.76	-1.60*	5.35	0.60	-1.35**	1.66	0.19**	-	4.70**	-0.85
5.	ICPA-	2.11*	0.89	-	-0.58	-3.98**	44.78*	-0.52**	-	-	-4.34**
6.	ICPA-	-3.21**	-2.35**	22.74	1.41**	7.34**	11.58	0.06	-	4.77**	4.24**
7.	ICPA-	1.82*	-1.27	-	-0.43	-2.33**	5.67	-0.11*	-	-	-3.92**
8.	ICPA-	1.78*	-1.31	23.96	-0.82*	-2.60**	-49.67	0.41**	0.58*	-	-1.66**
9.	ICPA-	-1.49	-0.18	6.57	-0.46	-5.80**	16.53*	-0.09	-0.16	1.02	-5.92**
10	ICPA-	-0.03	0.52	-	-0.48	-2.57**	-11.01	-0.11*	0.26*	-	-1.56**
11	ICPA-	-3.57**	-9.10**	15.89	2.30**	15.45**	89.57*	-0.31**	-	13.67*	1.78**
12	ICPA-	2.51**	2.81**	-	0.06	0.28	-5.76	-0.16**	0.22*	-	0.12
13	ICPA-	1.71	1.14	27.28	-0.16	0.18	-	0.35**	-	-	1.27*
14	ICPA-	0.38	5.22**	-4.47	-1.06**	-7.97**	-4.32	0.07	-	-0.64	-3.24**
15	ICPA-	0.59	-1.18	-6.31	-0.21	0.23	-57.98	0.27**	1.55*	0.44	3.33**
16	ICPA-	-0.11	0.77	-9.32*	0.01	0.18	-1.29	-0.02	-0.16	-0.72	4.20**
17	ICPA-	-1.09	3.12**	12.54	-0.46	-6.04**	10.30	-0.24**	0.21*	-	-1.23*
18	ICPA-	1.86*	4.66**	-9.23*	-0.74*	-3.98**	-	0.34**	-0.17	-	1.79**
19	ICPA-	-4.84**	-9.12**	-2.90	1.59**	7.08**	-11.08	0.08	0.36*	4.13**	-1.19*
20	ICPA-	2.40**	2.12**	2.71	-1.11**	-2.13**	2.43	-0.12*	0.62*	2.52*	-1.91**
21	ICPA-	2.61**	1.62*	-1.28	-0.67	-0.76*	-9.55	0.08	0.27*	2.44*	1.28*
22	ICPA-	-3.55**	-9.79**	-6.21	1.89**	9.89**	38.55*	-0.05	-	7.26**	0.92
23	ICPA-	0.49	3.45**	14.47	-0.49	-2.11	1.72	0.02	-0.04	1.36	5.21**
24	ICPA-	2.11*	3.91**	-	0.01	-1.93**	20.50*	-0.10	-	-1.28	-4.88**
25	BSMR-	6.67**	3.83**	-	-1.91**	-2.95**	-	0.19**	-	-	0.40
26	BSMR-	-3.03**	-7.12**	39.87	2.66**	5.95**	29.40*	0.23**	-	20.28*	-0.26
27	BSMR-	7.26**	7.75**	-8.31*	-2.31**	-10.07**	-	-0.03	-	-	-0.34
28	BSMR-	-4.15**	-3.33**	10.85	0.44	3.20**	1.67	0.09	-	-2.44*	2.64**
29	BSMR-	-6.44**	-3.66**	-4.41	1.43**	4.56**	-9.49	0.07	0.83*	8.73**	1.77**
30	BSMR-	6.38**	6.91**	-	-2.24**	-9.26**	-45.81	-0.08	1.21*	-	-1.93**
31	BSMR-	-2.90**	-1.00	2.12	1.14**	4.21**	50.59*	-0.18**	-	5.79**	-4.62**
32	BSMR-	-3.78**	-3.37**	-4.53	0.79*	4.36**	30.45*	-0.28	0.21*	6.04**	2.34**
	S.E.±	1.22	1.04	5.09	0.50	0.48	6.16	0.08	0.12	1.09	0.80



(A)



(B)

Figure 1 (A) Rader showing mean performance of crosses for grain yield plant^{-1} over the environments (B) Rader showing mean performance of parents for grain yield plant-1 over the environments.

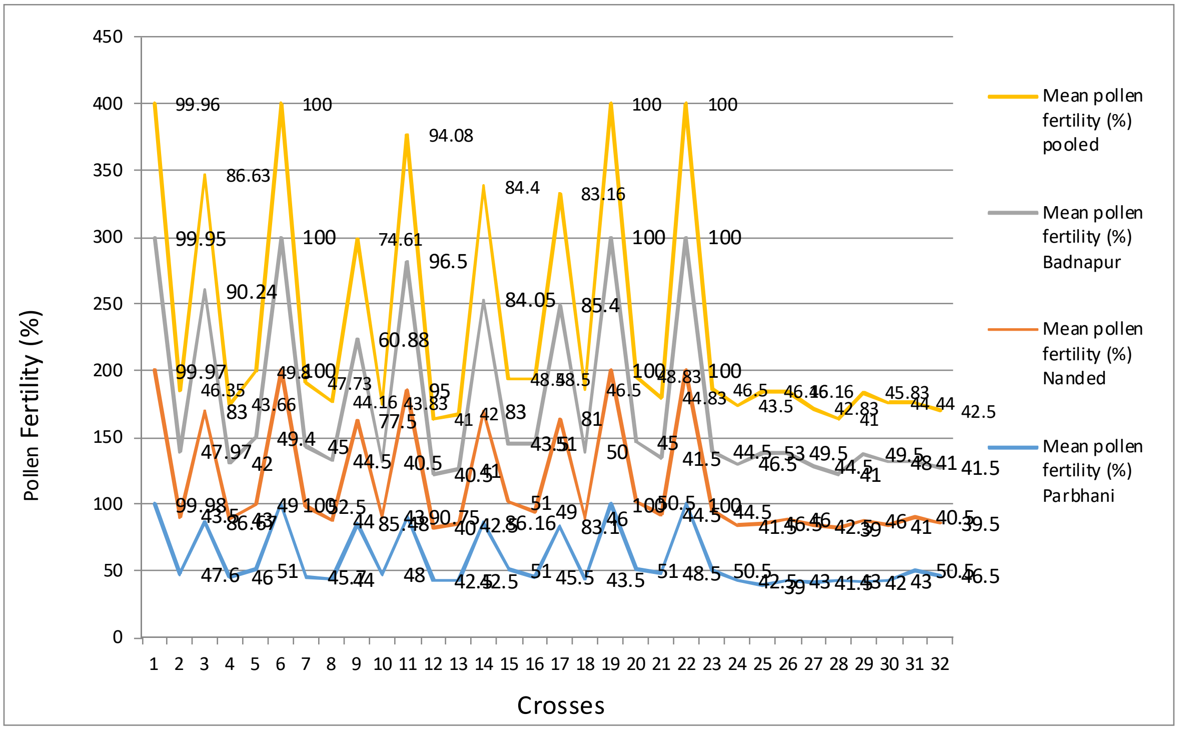


Figure 2. (A) Graph showing mean performance of crosses for pollen fertility (%) over the environments.

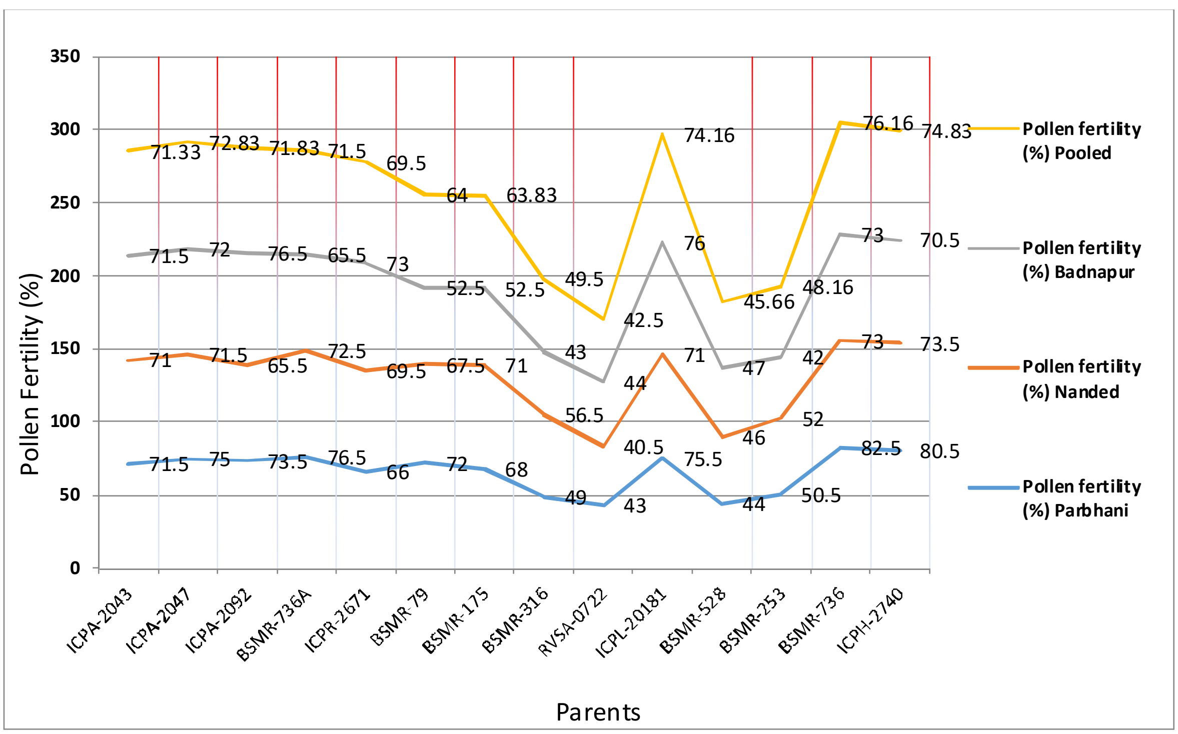


Figure 2. (B) Graph showing mean performance of parents for pollen fertility (%) over the environments.

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