Gene action and combining ability estimates using cytoplasmic-genic male sterile lines to develop pigeonpea hybrids for rainfed condition

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Abstract- Pigeonpea is the major source of vegetable protein in Indian diet. About 72.5 percent area and 62.5 production of world's pigeonpea is in India.Pigeonpea is the only food legume where cytoplasmic-genic male sterility is being exploited for commercial use of hybrids. The discovery of stable CMS system and breeding of commercial hybrids in pigeonpea has become a landmark in increasing the productivity of this crop. Keeping in view the combining ability estimates were worked out through Line x Tester analysis of 10 hybrids developed by crossing 2 lines (Males) with five cytoplasmic male sterile (CMS) lines (Females) to know the genetic architecture of yield attributes- Days to maturity, branches plant[1], pods plant[1], seed yield, wilt resistance and pollen fertility. Analysis of variance revealed significant differences among genotypes, crosses, lines, testers and Line x tester interactions for most of the traits. Preponderance of non-additive gene action was realized by higher values of specific combining ability compared to general combining ability. The average degree of dominance were more than unity (>1) and predictability ratio was less than unity (<1) for all the traits, signifying non-additive gene action resulted from dominance, over dominance, epistasis and various other interactions. Hence, heterosis breeding is effective for increasing yield potential of hybrids in pigeonpea.The proportional contribution of testers was observed to be lower than that of line x tester interactions, thus highest estimates of SCA variances. The estimates of GCA effects indicated male parent ICPL 87119 was good general combiner for days to maturity and pollen fertility and among the female parent ICP 2043 was good general combiner. Cross combinations ICP 2043 x ICP 87119, ICP 2048 x ICP 20108, ICP 2078 x ICP 87119 and ICP 2092 x ICP 20108 were found to be good specific combinations for seed yield plant1 and other desirable traits.

Index Terms- Cytoplasmic-genic male sterility (CMS); General combining ability (GCA); Specific combining ability (SCA); heterosis, epistasis

I. Introduction

Pigeonpea is an important food legume crop for Indiaand is cultivated on 4.04 m ha (IIPR, 2013) mainly at subsistence level as rainfed intercrop since hundreds of years.Among pulses, pigeonpea *dal* is a staple food across the country and plays an important role in national economic and nutritional security. Many varieties have been evolved with good resistance to Fusarium wilt and high yielding ability. Cytoplasmic-genic male sterility has been used since long time to improve the yield level of pigeonpea. The discovery of stable CMS system (Saxena et al. 2005) and breeding of commercial hybrids in pigeonpea are a landmark achievement. This new hybrid pigeonpea breeding technology is capable of substantially increasing the productivity of pigeonpea(Saxena and Nadarajan 2010). It is believed that the hybrid plants are naturally programmed to produce vigorous plants and greater yield and stability expressed due interactions among a favourable alleles. Pigeonpea hybrids show hybrid vigour right from the early seedling stage. In comparison to pure lines, the hybrids have been reported to have18 % longer radical and 15 % greater seedling growth indices (Bharathi and Saxena, 2012; Thakre et al., 2012). According to Saxena et al. (1992) the vigour of the hybrid plants is carried forward throughout its growth period and in comparison to pure lines they produce more shoot and root mass. Commercial hybrid of pigeonpea for large scale cultivation is now available (Saxena et al, 2013) with successful seed production technology of hybrid seed production (Saxena et al, 2011). Utilization of this hybrid technology in pigeonpea improvement will have impact in Indian pulse production(Tikle et al, 2015). The present investigation was conducted to study the combining ability of some cytoplasmic male sterile lines with possible restorers to exploit hybrid vigour for yield traits in pigeonpea.

II. Material and Methods

Five CMS lines as female lines (ICP 2043, ICP 2047, ICP 2048, ICP 2078 and ICP 2092) procured from ICRISAT were crossed with two testers (ICPL 87119 (Asha) and ICP 20108) in the year 2013-14 to make 10 hybrid combinations. The 5 lines (B lines) ,and 2 testers were grown together with their 10 hybrids in Randomized Complete Block Design of 3 replications in the year 2014-15. Each replication had four rows of 4 meter row length. Ten competitive plants at the time of flowering were tagged to record the observations on yield related traits- days to maturity, branches per plant, pods per plan and seed yield/ha was recorded on plot basis. Pollen fertility was recorded in males (Testers) and crosses by cytological studies. Microscopic observations of staining by 1% Acetocarmine solution was used to observe the fertile pollen grains. Two rows consisting of 40 plants of each genotype (lines, testers and crosses) were planted in wilt sick plot to record the wilt incidence in them. The wilt incidence was recorded in percent damage. Line x Tester analysis was carried out using SPAR II program formulated by Indian Agricultural Statistics Research Institute, New Delhi.

III. RESULTS AND DISCUSSION

The analysis of variance showed significant differences among the parents and hybrids for all the yield related characters studied (Table 1). For wilt resistance, only female (lines) parents showed significant differences, the crosses did not differ significantly. The partitioning of mean sum of squares revealed that variance due females x males interactions were highly significant for all the characters except wilt %..

Table 1: Analysis of variance for yield traits in pigeonpea

Sources of variation	d. f.	Days to maturity	Branches/ plant	Pods/ plant	Seed yield (kg/ha)	Wilt %	Pollen Fertility %
Replication	2	0.914	10.3**	7.8	764.2	0.210	0.430
Genotypes	16	168.5**	106.3**	13321**	148396.4**	37.6*	5881**
Parents	6	243.0**	7.6*	111*	19051.6**	71.9**	6576**
Crosses	9	109.4**	20.8**	7950**	210193.9**	6.5	10.6**
P. vs. Crosses	1	253.8**	1467**	140925**	368287.8**	111.7**	54552**
Females (Lines)	4	97.3	12.6	7126	352601*	10.6*	--
Males (Testers)	1	112.1	45.6	104.5	1228.8	3.5	7.3
Line x Tester	4	120.8**	22.8**	10735.9**	120027.8**	3.0	2.47**
Error	21	2.04	0.504	16.1	731.1	5.485	0.302

Higher magnitude of SCA than GCA variances, more than unity (>1) values of average degree of dominance and lesser than unity (<1) predictability ratio were observed for all the characters, indicated the preponderance of overdominancein the characters studied (Table 2). Pandey et al (2014) also reported overdominance of gene action in pigeonpea hybrids using CMS lines of late maturing pigeonpea lines. Higher magnitude of dominance variance ((σ^2D) than additive variance (σ^2A)signifies the presence of non-additive gene action for these traits. Jahagirdar,2003;Banu et al 2006 and Vaghela et al 2009 also reported the importance of both type of gene effects with predominance of non-additive gene action in yield and yield contributing traits. High estimates of heritability in narrow sense was recorded for pods per plant (60.73) suggested that direct selection would be effective for pods per plant to improve in seed yield.

Table 2: Estimates of components of genetic variance, degree of dominance and heritability

Characters	GCA (Variance)	SCA (Variance)	Average degree of dominance	Predictability ratio	Additive variance (σ^2A)	Dominance variance (σ^2D)	Heritability (h^2n)%)
Days to maturity	-0.529	37.2085	8.387	0.01	2.12	148.83	7.99
Branches/ plant	-0.0953	9.0535	9.747	0.01	0.38	36.21	12.93
Pods/ plant	-128.55	2280.24	4.212	0.06	514.20	9120.96	60.73
Wilt %	0.1573	-0.2797	1.333	0.56	0.63	-1.12	14.02
Pollen Fertility %	0.3749	2.3141	2.484	0.16	1.50	9.26	66.99
Seed yield (kg/ha)	4161.51	43043.76	3.216	0.10	16646.04	172175.04	21.11

The general combining ability revealed that among the lines, ICP 2047 and ICP 2092 and among the testers ICP 20108 had significant negative (desirable) GCA values for days to maturity. For branches per plant ICP 2043, ICP 2047 among the lines and ICP 20108 among testers were the best general combiners. For pods per plant ICP 2043 and ICP 2092 lines (females) and ICP 20108 (male) were better general combiners. Significant positive GCA values were observed for seed yield by the line ICP 2043 only while the tester ICP 20108 had better GCA effects as tester. (Table 3). For wilt resistance, none of the parents had significant GCAs. For pollen fertility ICP 2043 and ICP 2047 female lines and tester ICP 87119 were found good general combiners to exhibit better pollen fertility.

Table 3: General combining ability (GCA) effects for yield attributes in Pigeonpea

Parents	Days to maturity	Branches/ plant	Pods/ plant	Seed yield (kg/ha)	Wilt %	Pollen Fertility %
Lines						
ICP 2043	1.20*	1.26*	47.66*	409.6*	0.64	1.49*
ICP 2047	-6.30**	0.76*	-1.33	-70.3*	1.09	1.57*
ICP 2048	3.20**	-2.33*	-36.50*	-236.3*	-2.29	0.57*
ICP 2078	3.36**	-2.40*	-28.33*	-27.7	0.09	-1.00*
ICP 2092	-1.46**	0.60	18.50*	-75.3*	0.46	-2.64*
Testers						
ICP 87119	1.93*	-1.23	-1.86	-6.4	0.34	0.49**
ICP 20108	-1.93*	1.23*	1.86*	6.4	-0.34	-0.49**
SE'(g) Lines	0.48	0.29	1.63	11.0	0.95	0.22
SE'(g_i-g_j) Lines	0.82	0.41	2.31	6.98	1.35	0.34
SE' (g)Testers	0.36	1.18	1.03	15.61	0.60	0.14
SE'(g_i-g_j) Testers	0.52	0.25	1.46	9.87	0.85	0.20
No. of parents with desirable effects	3	3	3	2	0	3

On the basis of specific combining ability four crosses emerged with negative (desirable) SCA for days to maturity. Most promising are ICP 2043 x ICP 87119, ICP 2092 x ICP 20108 and ICP 2047 x ICP 20108. For branches per plant ICP 2043 x ICP 20108, ICP 2078 x ICP 87119 and ICP 2047 x ICP 87119 are the best crosses. Out of four crosses, the crosses involving ICP 87119 as tester had significant positive SCA values for pods per plant. Five crosses emerged with positive SCA values, out of which four crosses- ICP 2078 x ICP 87119, ICP 2048 x ICP 20108, ICP 2092 x ICP 20108 and ICP 2043 x ICP 87119 involving two lines and two different testers have significant SCA values. Regarding pollen fertility three crosses- ICP 2043 x ICP 20108, ICP 2048 x ICP 87119, ICP 2078 x ICP 20108 involving three different female lines had significant positive SCA values (Table 4).

Table 4: Specific combining ability (SCA) effects for yield attributes in Pigeonpea

Crosses	Days to maturity	Branches/ plant	Pods/ plant	Seed yield (kg/ha)	Wilt %	Pollen Fertility %
ICP 2043 x ICP 87119	-5.26**	-3.26**	-72.80**	49.73**	-0.39	-0.56
ICP 2043 x ICP 20108	5.26**	3.26**	72.80**	-49.73**	0.39	0.56**
ICP 2047 x ICP 87119	3.90**	1.23**	19.20**	24.4	0.89	-0.27
ICP 2047 x ICP 20108	-3.90**	-1.23**	-19.20**	-24.4	-0.89	0.27
ICP 2048 x ICP 87119	-1.60	0.23	22.70**	-151.3**	-0.72	0.92**
ICP 2048 x ICP 20108	1.60	-0.23	-22.70**	151.3**	0.72	-0.92**
ICP 2078 x ICP 87119	-2.43**	1.73**	31.20**	198.4**	-0.40	-0.49
ICP 2078 x ICP 20108	2.43**	-1.73**	-31.20**	-198.4**	0.40	0.49*
ICP 2092 x ICP 87119	5.4**	0.06	-0.30	-121.3**	0.62	0.40
ICP 2092 x ICP 20108	-5.4**	-0.06	0.30	121.3**	-0.62	-0.40
SE'S_{ij}	0.82	0.41	2.31	15.61	1.35	0.31
Sij - Skl	1.16	0.58	3.27	22.07	1.91	0.45
No. of crosses with desirable SCA effects	4	3	4	5	0	3

The range of heterosis and highly heterotic crosses with significant SCA effects for different characters were computed to identify the superior cross combinations for their use in heterosis breeding (Table 5). The manifestation of relative heterosis indicated the overdominance for yield and yield related traits.The maximum heterotic effects for branches per plant (108,141%), pods per plant (127%),seed yield (37, 42%). The hybrid ICP 2043 x ICP 87119 expressed highest heterotic effect of 42.1, followed by the hybrid ICP 2043 x ICP 20108(36.9%) could be utilized in heterosis breeding programs.it is evident that both additive and non-additive gene effects were important with predominance of non-additive gene effects in inheritance of seed yield and its components.

Table 5: Range of heterosis and best heterotic crosses for six characters in pigeonpea

Character	Range of heterosis	Best heterotic crosses (Over standard check (ICP 87119)	SCA effect	GCA effect	
				Female	Male
Days to maturity	-8.64-1.39	ICP 2047 x ICP 20108	-3.90**	-6.30**	-1.93*
Branches/plant	66.7-141.7	ICP 2043 x ICP 20108	3.26**	1.26*	1.23*
Pods/plant	24.4-127.0	ICP 2043 x ICP 20108	72.80**	47.66*	1.86*
Wilt %	-39.83-25.11	ICP 2048 x ICP 87119	-0.72	-2.29	0.34
Pollen Fertility %	-5.34-0.27	ICP 2048 x ICP 87119	0.92**	0.57*	0.49**
Seed yield (kg/ha)	-9.1-42.1	ICP 2043 x ICP 87119 (42.1%)	49.73**	409.6**	-6.4
		ICP 2043 x ICP 20108(36.9%)	-49.73**	409.6**	6.4

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