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Gene action and combining ability estimates for yield and other quantitative traits in chickpea (*Cicer arietinum*)

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ABSTRACT

A diallel set of 6 parents and their 15 F_1 hybrids were analyzed to understand the nature and magnitude of gene action and to identify the best combiners for yield and its component traits of chickpea (*Cicer arietinum* L.) The gca and sca components showed the predominance of additive gene action in governing days to flowering, days to poding, plant height, number of pods, number of seeds/pod, plant biomass, harvest index, grain yield and 100-seed weight and non-additive gene action for number of branches. Estimates of gca effects showed that the parent 'GL 98010' was the best general combiner, followed by 'GL 96010' and 'GL 90168'. Thus the ascochyta blight resistant parents 'GL 96010', 'GL 98010' and 'GL 90168' should be involved in the hybridization programmes for making yield breakthrough in chickpea. The cross combination 'GL 98010'×'GL 90168' showed significant and desirable sca effects for most of the traits including grain yield.

Key words: Chickpea, Combining ability, Gene action, Quantitative traits, Yield and yield components

Chickpea is an important pulse crop of winter (*rabi*) season in India. India grows chickpea on about 7.67 million ha and producing 5.97 million tonnes of grains with productivity of 728 kg/ha (IIPR 2007). India alone contributes about 65% of the global acerage and first in production of chickpea in the world. Even then, India is importing about 0.5 million tonnes of chickpea every year. This is because the production and productivity of chickpea are hovering about these figures for the last several years. Thus, efforts are needed to strengthen the genetic yield potential of chickpea varieties. Being grain yield a complex trait and is a product of a number of component traits, it is a great task to enhance the grain yield potential of new genotypes. These traits are polygenically inherited and require thorough understanding of the gene action involved in their inheritance. Diallel analysis is one of the approaches to know the nature and magnitude of gene action and also to assess the nicking ability of the parents. Further, the selection of suitable parents which could combine well and yield good segregants is also an important prerequisite for genetic improvement of chickpea. Thus, the combining ability analysis provides useful information for selecting high order parents for effective breeding strategy, besides elucidating the nature and magnitude of gene action involved in the inheritance of these characters. Therefore, a diallel set of six parents involving two widely adapted released cultivars and four ascochyta blight resistant lines was studied for gene action and combining ability estimates.

MATERIALS AND METHODS

Material for the present study involved six parents, viz 'GG 1267', 'GL 90168', 'GL 96010' and 'GL 98010', advance breeding lines resistant to ascochyta blight and released cultivars, viz 'GL 769' and 'C 214' susceptible to ascochyta blight. These parents were sown in the crop season 2004–05 at Research Farm, Punjab Agricultural University, Ludhiana and were crossed in a diallel fashion to generate F_1 hybrids of 15 crosses. In the following crop season 2005–06, the six parents along with the F_1 hybrids of all the 15 crosses were sown in a randomized complete block design with 3 replications. Row-to-row and plant-to-plant spacings were kept 50 cm and 25 cm, respectively. Observations on five randomly selected plants for each treatment were recorded on the characters influencing yield, viz days to flowering, days to poding, plant height, number of branches, number of pods, seeds/pod, plant biomass, harvest index, grain yield and 100-seed weight to assess combining ability and gene action. The combining ability analysis was done

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following Method 2, Model 1 of Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences existed among the chickpea genotypes and their F_1 hybrids for grain yield and its component traits at genotypic level (Table 1). Further combining ability analysis was followed. The analysis of variance for general combining ability (gca) and specific combining ability (sca) variances, σ^2 A and σ^2 D and their ratios for grain yield and its components are given in Table 2. The gca reflects the average performance of a genotype in hybrid combination and is primarily a measure of additive genetic variance. The sca is detected whenever a specific hybrid combination performs better (or worse) than would be expected based on the average performance of their parental lines and is a result of dominance and other non-additive gene action. The gca as well as sca component was highly significant for all the traits. However, high magnitude of gca effects for days to flowering, days to poding, plant height, number of pods, number of seeds/pod, plant biomass, harvest index, grain yield and 100-seed weight were observed which indicated that additive gene action governed these traits. The predominance of additive gene action for days to flowering and days to poding was also reported by Kumar *et al.* (1999), for plant height and harvest index (Gupta *et al.* 2007a, 2007b) and 100-seed weight (Gupta *et al.* 2007b). These traits with higher magnitude of additive gene action can be easily improved through line selection which would favour the increased expression of the traits. The trait, number of branches showed the high magnitude of sca component.

Table 1 Analysis of variance for different traits in chickpea

Source of variation	df	Mean square									
		Days to flowering	Days to poding	Plant height	No. of branches	No. of pods	Seeds/ pod	Plant biomass	Harvest index	Grain yield	100-seed weight
Replicates	2	0.86**	0.91	9.9**	0.16	9.1**	0.0015	32.08**	3.6*	1.20**	0.2
Treatments	20	75.62**	98.1**	100.51**	1.83**	42.7**	0.017**	105.03**	63.2**	13.71**	16.7**
Error	40	0.16	0.37	2.70	0.56	2.31	0.00096	5.2	0.0001	0.22	0.2

**P=0.01, *P=0.05

Table 2 Analysis of variance for combining ability for different characters in chickpea

Source of variation	df	Mean square									
		Days to flowering	Days to poding	Plant height	No. of branches	No. of pods	No. of seeds/ pod	Plant biomass	Harvest index	Grain yield	100-seed weight
GCA	5	82.8**	93.2**	111.45**	0.09**	29.91**	0.0096**	57.3**	0.0072**	11.0**	17.36**
SCA	15	6.01**	12.53**	7.53**	0.52**	9.00**	0.0045**	27.6**	0.0060**	2.43**	1.64**
Error	40	0.532	0.12	0.90	0.19	0.77	0.00032	1.73	0.000035	0.75	0.065
σ^2A		20.68	23.27	27.62	0.18	7.3	0.0023	13.9	0.014	2.73	4.32
σ^2D		5.96	12.41	6.63	0.33	8.23	0.0042	25.9	0.006	2.35	1.58
σ^2A/σ^2D		3.47	1.88	4.16	0.54	0.88	0.55	0.54	2.33	1.16	2.73

**P=0.01

Table 3 Estimates of GCA for different characters for six parents

Parent	Days to flowering	Days to poding	Plant height	No. of branches	No. of pods	No. of seeds/ pod	Plant biomass	Harvest index	Grain yield	100-seed weight
'GL769'	–0.49**	–1.28**	–3.38**	–0.24**	1.69**	0.03**	3.07**	–0.02**	–0.04	–0.80**
'C214 '	–2.83**	–1.59**	–1.72**	0.02	0.93**	0.03**	0.01	0.02**	–0.99**	–1.28**
'GG 1267'	2.95**	2.64**	6.84**	0.01	–0.94**	–0.01	–1.14**	–0.03**	–1.38**	–1.67**
'GL 90168'	–2.73**	–2.68**	–2.46**	–0.49**	–2.98**	–0.06**	–4.59**	0.03**	–0.25**	1.21**
'GL 96010'	4.91**	5.68**	–0.67	0.41**	1.21**	0.02**	1.85**	0.01**	0.87**	0.52**
'GL 98010'	–1.82**	–2.78**	1.39	0.31**	1.95**	–0.02**	0.80**	0.04**	1.78	2.01**
SE (g_i)	0.074	0.013	0.4	0.06	0.013	0.0075	0.2	0.0024	0.04	0.034
SE (g_i-g_j)	0.115	0.031	0.2	0.9	0.03	0.004	0.3	0.003	0.06	0.06

**P=0.01

Table 4 Crosses with high *per se* performance and significant sca effects for grain yield and its components in *desi* chickpea

Character	Crosses with high *per se* performance and significant sca effects	Sca effects	*Per se* performance	Gca effects of parents
Days to flowering	'GG1267'× 'GL96010'	–4.17**	101.80	L×L
	'GL769'×'GL98010'	–2.87**	92.83	M×M
	'GL769'×'GL90168'	–1.83**	93.06	M×H
	'C214'×'GL90168'	–0.90**	91.66	H×H
	'C214'×'GL769'	–0.60**	94.20	H×M
Days to poding	'GL98010'×'GL90168'	–6.66**	103.53	H×H
	'GG1267'×'GL96010'	–2.97**	121.00	L×L
	'C214'×'GL769'	–1.85**	110.93	M×M
	'GL769'×'GL98010'	–0.86**	110.73	M×H
Plant height	'GL98010'×'GL90168'	–2.61**	41.40	L×H
	'GL90168'×'GL96010'	–1.48**	40.46	L×H
	'C214'×'GL769'	–0.63**	39.33	M×H
	'C214'×'GL90168'	–0.03**	40.86	M×H
	'C214'×'GL96010'	–0.02**	42.66	M×M
No. of branches	'C214'×'GG1267'	1.18**	16.46	M×M
	'C214'×'GL96010'	0.85**	16.53	M×M
	'GL98010'×'GL90168'	0.73**	15.80	H×L
	'GL90168'×'GL96010'	0.70**	15.86	L×H
	'GL769'×'GL96010'	0.65**	16.06	L×H
No. of pods	'GL98010'×'GL90168'	4.66**	58.73	H×L
	'C214'×'GL96010'	3.35**	58.73	M×M
	'C214'×'GG1267'	3.07**	58.93	H×L
	'GL98010'×'GL96010'	2.07**	60.33	H×M
	'C214'×'GL98010'	2.07**	58.20	M×H
No. of seeds/pod	'GL98010'×'GL90168'	0.12*	1.44	L×L
	'C214'×'GL769'	0.07*	1.53	H×H
	'C214'×'GG1267'	0.07*	1.49	H×L
	'GL98010'×'GL96010'	0.06*	1.46	L×H
	'GL769'×'GL96010'	0.04*	1.48	H×H
Plant biomass	'GL98010'×'GL90168'	9.71**	46.73	M×L
	'C214'×'GL769'	6.18**	50.06	L×H
	'GL98010'×'GL96010'	5.88**	49.33	M×M
	'GL769'×'GG1267'	3.12**	45.86	H×L
	'C214'×'GG1267'	3.05**	42.73	L×L
Harvest index	'GG1267'×'GL98010'	0.03**	0.35	L×H
	'GG1267'×'GL90168'	0.03**	0.34	L×H
	'GL769'×'GL96010'	0.03**	0.32	L×M
	'GL769'×'GL90168'	0.02**	0.33	L×H
	'C214'×'GL98010'	0.02**	0.34	M×H
Grain yield	'GL769'×'GL96010'	2.04**	15.57	L×M
	'GL98010'×'GL90168'	1.71**	15.95	H×L
	'GG1267'×'GL90168'	1.69**	12.73	L×L
	'GG1267'×'GL98010'	1.36**	14.47	L×H
	'GL98010'×'GL96010'	1.08**	16.44	H×M
100-seed weight	'GG1267'×'GL90168'	1.95**	17.86	L×M
	'GG1267'×'GL98010'	1.79**	18.50	L×H
	'GL769' 'GL96010'	1.70**	17.80	L×M
	'C214'×'GL98010'	1.06**	18.16	L×H
	'GL769' 'GL90168'	0.96**	17.75	L×M

*P=0.05, **P=0.01, L, M and H: Low, medium and high general combiners

So, selection for this trait should be delayed to few generations when the effect of dominance is minimized. Gupta *et al.* (2007a) also reported the importance of non-additive gene action for number of branches in chickpea. The ratio $\sigma^2 A/\sigma^2 D$ indicated the equal importance of additive and non-additive gene action in governing the number of branches, number of pods, number of seeds/pod and plant biomass. Thus, for these traits population improvement programme should be taken for the development of superior lines. Importance of both additive and non-additive gene action in governing number of pods/plant was also reported by Gupta *et al.* (2007b), whereas for plant biomass was reported by Bhardwaj and Sandhu (2007) and Gupta *et al.* (2007b). Singh *et al.* (1992) reported equal importance of both the gene effects for number of seeds/pod.

Estimates of gca effects (Table 3) revealed that the parents 'C 214' and 'GL 90168' were high general combiners for early flowering. The parents 'GL 98010' and 'GL 90168' were the high general combiners for early poding. 'GL 769' followed by 'GL 90168' were the high general combiners for short plant height. 'GL 96010' and 'GL 98010' were the high general combiners for number of branches, whereas 'GL 98010', 'GL 769' and 'GL 96010' were the high general combiners for number of pods. The parents 'GL 769', 'C 214' and 'GL 96010' were the high general combiners for number of seeds/pod. The parent 'GL 769' followed by GL 96010 were the high general combiners for plant biomass. The parents 'GL 98010' and 'GL 90168' were the high combiners for harvest index. 'GL 98010' was the high general combiner for grain yield, followed by 'GL 96010'. The parent 'GL 98010' was the high combiner for 100-seed weight, followed by GL 90168. The high gca effects are generally ascribed to additive gene effects or additive×additive interaction effects (Griffing 1956), hence the good general combiners can be used for the genetic amelioration of chickpea. The parents, namely, 'GL 98010', 'GL 96010' and 'GL 90168', had high gca effects for a number of desirable traits besides possessing resistance to ascochyta blight, should be used in breeding programme to recombine the favourable genes. The results of this study suggested that there is a scope for improving grain yield by involving these parents in the breeding programme.

The top five crosses with high and significant sca effects along with the *per se* performance for each character are given in Table 4. The gca effects of parents are also mentioned for each cross. The crosses showed significant and negative sca effects for days to flowering, days to poding and plant height, whereas significant and positive sca effects were present for grain yield, number of branches, number of pods, number of seeds/pod, plant biomass, harvest index and 100-seed weight, which indicated that parents involved in the crosses were good specific combiners for desirable traits. The cross 'GL 98010'×'GL 90168' recorded significant desirable sca effects for maximum number of traits, viz early poding, shorter plant height, number of branches, plant biomass, grain yield and 100-seed weight. Other promising cross was 'C 214'×'GL 769' which possessed desirable sca effects for days to flowering, days to poding, plant height, number of seeds/pod and plant biomass. The crosses 'GG 1267'×'GL 98010' and 'GG 1267'×'GL 90168' showed high and positive sca effects for harvest index, grain yield and 100-seed weight. The crosses 'GL 769'×'GL 96010' and 'GL 98010'×'GL 90168' exhibited high and positive sca effects for grain yield. The cross GL 98010×GL 96010 showed positive and high sca effects for number of pods, number of seeds/pod, plant biomass and grain yield. In the present study, most of the crosses with high sca effects involved the parents with high×low, medium×low or medium×medium general combining abilities and few were low×low general combiners. The crosses with high *per se* performance possessed high sca effects. Thus, even the parents with low/medium general combining abilities can lead to high sca effects in the crosses indicating, thereby the influence of non-additive interaction in these crosses. Generally, the significant desirable sca effects do not contribute much towards the improvement of self-pollinated crops like chickpea where commercial exploitation of heterosis is not feasible. Thus, in self-pollinated crops, the ultimate aim is to generate desirable transgressive segregants for developing potential homozygous lines through hybridization. The results of this study substantiate that the genotypes, like 'GL 98010', 'GL 96010' and 'GL 90168' which were good general combiners for different morphological traits, besides possessing resistance to ascochyta blight should be used to develop high-yielding chickpea lines.

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