Annals of Arid Zone 51(1): 35-41, 2012

Interrelationship and Heritability of Yield and its Components in Chickpea Crosses Differing for Harvest Index

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Received: September 2010

Abstract: The study was undertaken on heritability, association and path analysis for seed yield and its components in three F_2 populations of chickpea. Parents involved in the cross combinations with varying level of harvest index expressed fairly wide range of variation for other characters too. High heritability (>60%) coupled with high genetic advance (>20%) were observed for plant height, primary branches per plant, pods per plant and seeds per plant. Seed yield per plant showed significant positive correlation with seeds and pods per plant, total biomass per plant and 100-seed weight. Associations were strong and positive among the days to flowering, flowering period and days to maturity, but they were not correlated with seed yield per plant. Path analysis indicated that seeds per plant had maximum direct effect on seed yield followed by 100-seed weight. Pods per plant and total biomass per plant contributed substantially to seed yield *via* seeds per plant. Therefore, it was concluded that seed yield in chickpea may be improved by selecting for more seeds and pods per plant with higher biomass yield. To break down the undesirable linkages between two important yield components like total biomass per plant and harvest index as indicated by negative correlation between them and to recover the suitable recombinants, biparental mating is suggested.

Key words: *Cicer arietinum*, yield components, heritability, correlation, path analysis.

Chickpea is the fifth most important food legume crop in the world. Being rich in protein, it is playing a significant role in human diet. In India, it accounts for an area of 7.49 million hectares with annual production of 6.33 million tones and productivity of 845 kg ha^{-1} (Anon, 2007). Our national average of chickpea yield is very low as compared to its potential, and yield obtained by other countries (Anon, 2007). One of the reasons for this low yield is the nonavailability of genotypes with high yield potential and adaptability to wide environmental conditions.

In chickpea breeding program, the enhancement of genetic potential for seed yield is of paramount important objective. Although a great success in chickpea yield improvement through selection from germplasm has been achieved, there is considerable scope to further increase the yield by hybridization and selection. Earlier studies had established that great variation existed in chickpea germplasm (Pundir *et al*., 1988; Verma *et al*., 2008). Several researchers also estimated correlation and path coefficients in chickpea germplasm lines/ breeding lines/cultivars (Singh *et al*., 1999; Arora *et al*., 2003; Sidramappa *et al*., 2008a). The present study reports the results obtained on variability and interrelationships among yield and yield component traits in segregating populations resulting from three chickpea crosses.

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Materials and Methods

Three chickpea crosses were made involving five parents. The characteristic features of the parental lines used in crossing program are presented in Table 1. The crosses were made in the combination of high x low, high x intermediate and low x low harvest index parents as JCP 27 x CSJ 103 (1 x 2), JCP 27 x IPC 2000-52 (1 x 3) and GJG 0106 x Phule G 96006 (4 x 5), respectively, hereafter referred to as cross 1 x 2, 1 x 3 and 4 x 5. Each F_1 hybrid was sown in rabi-2005 for advancement of generation. The F_2 generations along with their parents were grown in randomized block design with three replications at the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh, during rabi-2006 under irrigated condition. Plot was of five rows for each F_2 population and single row for each parent. Rows were 4 m long and 45 cm apart.

Table 1. Characteristic features of five parents and mean, range and genotypic variance in F_2 population of three chickpea crosses

Parents/Crosses	Days to flowering	Flowering period	Days to maturity	Plant height (cm)	Primary branches/ plant	Pods/ plant	Seeds/ plant	100-seed weight (g)	Total biomass/ plant (g)	Harvest index (%)	Seed yield/ plant(g)
Parents											
JCP 27(1)	50.87	41.53	114.80	29.80	8.60	40.06	51.57	15.41	18.49	43.05	7.98
CSJ 103(2)	64.60	34.60	119.53	29.20	8.73	41.06	49.73	12.33	25.13	24.70	6.13
IPC 2000-52(3)	47.80	37.80	107.60	25.33	6.60	28.13	38.47	12.04	13.67	34.03	4.64
GJG 0106(4)	46.07	35.73	104.47	29.53	7.60	19.60	28.67	11.15	14.33	22.45	3.21
Phule G 96006(5)	42.47	32.47	97.93	26.73	6.27	21.00	29.27	10.14	15.47	19.26	2.98
Crosses											
1x2											
Mean	63.07	25.40	112.27	27.40	8.80	37.18	49.42	12.94	20.79	30.64	6.35
Range	62.2-63.8	23.20-27.40	110.2-113.4	26.20-28.80	8.4-9.2	34.72-41.01	45.92-54.44	12.66-13.24	20.48-21.18	28.88-32.26	5.83-6.87
Genotypic variance	6.00	4.98	26.48	16.67	7.71	31.05	28.38	2.40	8.72	19.86	0.31
1x3											
Mean	58.60	27.80	110.40	33.11	10.54	38.65	56.52	8.70	17.82	28.27	4.92
Range	57.2-59.4	25.80-29.40	109.2-111.4	31.40-34.80	9.4-11.53	37.89-38.88	56.21-56.80	8.62-8.86	17.85-18.07	27.70-29.21	4.84-5.01
Genotypic variance	5.29	11.21	6.79	14.28	5.49	20.94	49.38	0.41	3.26	16.05	0.70
4x5											
Mean	44.88	35.74	104.87	32.48	7.61	27.52	40.93	12.10	16.60	30.70	4.95
Range	44.0-45.4	34.20-37.81	103.0-106.2	31.2-33.8	6.8-8.2	27.0-27.8	40.3-41.4	11.9-12.4	16.0-17.0	30.37-31.24	4.8-5.0
Genotypic variance	16.83	12.38	12.23	21.28	6.82	14.06	14.00	0.42	6.31	28.36	0.21

1 x 2 = JCP 27 x CSJ 103, 1 x 3 = JCP 27 x IPC 2000-52 and 4 x 5 = GJG 0106 x Phule G 96006

Forty seeds were hand sown in a row. All the recommended agronomic practices were followed to raise the good crop.

Data collection in F_2s and parents were on individual plant basis. Seventy five plants from each F_2 and five plants from each parent were selected randomly and tagged before flowering were used for recording the data on eleven agronomic characters. Total biomass plant^{-1} of each well sun-dried plant harvested just above the ground level at maturity was recorded. After threshing, the produce obtained from each plant was cleaned and weighed to record grain yield plant^{-1}. Harvest index (HI) was calculated for each plant as the ratio of economic yield to total biomass and expressed as percentage. Since the each plant produce was not sufficient to draw sample of 100 seeds, the 100-seed weight was estimated as grain yield plant^{-1} (g) divided by number of seeds plant^{-1} and multiplied by hundred. Height of individual plant was measured in cm, while days to flowering, flowering period, days to maturity as well as primary branches, pods and seeds per plant were recorded on individual plant basis in terms of absolute values/numbers.

Analysis of variance was carried out to study the variation among the populations for examined traits. Broad-sense heritability (h^2) of each trait in each cross was calculated using the relationships as follows (Mahmud and Kramer, 1951):

$$h^2 = \sigma^2F_2 - (\sigma^2P_1 + \sigma^2P_2)/2/\sigma^2F_2$$

where, σ^2F_2 = the variance of any F_2 population; σ^2P_1 = the variance of female parent; σ^2P_2 = the variance of male parent

Total variation (σ^2F_2) of each generation was used as phenotypic variation for estimation of genotypic variation of the generation. Estimate of environmental variance (σ^2E) for any cross was calculated as $(\sigma^2P_1 + \sigma^2P_2)/2$. Genotypic coefficient of variation and genetic advance as percentage of mean was worked out according to Allard (1960). Simple correlation and path coefficient analysis was carried out as per the procedures described by Singh and Chaudhary (1977).

Results and Discussion

The mean performance of parental lines for some yield attributing characters presented in Table 1 indicated that HI values ranged from 19.26 to 43.05%. The parent JCP 27 expressed 43.05% HI and considered as high HI parent, whereas IPC 2000-52 with 34.03% HI was considered as medium harvest index parent. The remaining parents, i.e., CSJ 103 with 24.70%, GJG 0106 with 22.45% and Phule G 96006 with 19.26% of HI, were considered as low HI parents. The crosses showed a fairly wide range of variation for other characters too and that are supposed to have a large influence on HI. The close examination of the data revealed that JCP 27 expressed the highest HI with the highest seed yield per plant and

Table 2. Heritability and genetic advance as percentage of mean for yield and its components in three crosses of chickpea

Character	1 x 2		1 x 3		4 x 5	
	Heritability (%)	GA as (%) mean	Heritability (%)	GA as (%) mean	Heritability (%)	GA as (%) mean
Days to flowering	56.61	8.72	56.83	8.26	93.23	34.34
Flowering period	56.01	17.94	82.85	36.93	89.00	31.71
Days to maturity	72.21	21.60	53.83	5.63	81.56	10.67
Plant height (cm)	83.37	55.70	72.93	39.49	89.38	59.98
Primary branches/plant	89.45	80.19	70.64	47.70	82.35	82.07
Pods/plant	88.86	76.47	73.40	49.60	85.84	46.77
Seeds/plant	88.36	52.58	92.04	79.98	65.82	31.32
100-seed weight (g)	38.59	1.70	53.14	4.34	45.50	3.14
Total biomass/plant (g)	55.50	38.42	29.17	16.73	42.48	34.81
Harvest index (%)	48.40	15.55	83.77	51.99	83.20	84.58
Seed yield/plant (g)	58.88	4.53	70.30	13.07	49.87	3.93

1 x 2 = JCP 27 x CSJ 103, 1 x 3 = JCP 27 x IPC 2000-52 and 4 x 5 = GJG 0106 x Phule G 96006

Table 3 Simple correlation coefficient for seed yield and its components in three chickpea crosses

Character	Cross	Flowering period	Days to maturity	Plant height (cm)	Primary branches/ plant	Pods/ plant	Seeds/ plant	100-seed weight (g)	Total biomass/ plant (g)	Harvest index (%)	Seed yield/ plant (g)
Days to flowering	1 x 2	0.77**	0.86**	-0.01	0.11	0.12	-0.02	0.01	0.07	-0.08	-0.01
	1 x 3	0.60**	0.86**	-0.02	0.08	0.04	0.08	0.18*	0.04	0.09	0.17*
	4 x 5	0.78**	0.94**	0.08	0.12	0.02	-0.03	0.23**	0.01	0.03	0.07
Flowering period	1 x 2		0.93**	0.03	0.02	0.19**	0.06	0.14*	0.08	0.04	0.11
	1 x 3		0.86**	0.09	-0.01	-0.01	0.04	0.28**	0.01	0.15*	0.20**
	4 x 5		0.84**	0.20**	0.21**	0.04	0.06	0.07	0.01	0.08	0.09
Days to maturity	1 x 2			0.06	0.04	0.13	0.03	0.13	0.07	0.02	0.08
	1 x 3			0.01	0.03	-0.01	0.05	0.24**	0.00	0.14*	0.18*
	4 x 5			0.12	0.09	0.01	-0.03	0.20**	0.00	0.04	0.06
Plant height (cm)	1 x 2				0.14*	-0.03	-0.01	-0.05	0.03	-0.06	-0.03
	1 x 3				0.41**	0.47**	0.32**	0.15*	0.41**	-0.26**	0.35**
	4 x 5				0.01	0.10	0.10	0.06	0.00	0.12	0.13
Primary branches/plant	1 x 2					0.07	0.11	-0.01	0.27**	-0.20**	0.09
	1 x 3					0.27**	0.24**	0.07	0.28**	-0.16*	0.25**
	4 x 5					0.43**	0.37**	-0.04	0.40**	-0.19**	0.33**
Pods/plant	1 x 2						0.67**	0.17*	0.38**	0.28**	0.60**
	1 x 3						0.55**	0.15*	0.57**	-0.31**	0.53**
	4 x 5						0.71**	0.03	0.60**	-0.17*	0.68**
Seeds/plant	1 x 2							0.24**	0.58**	0.41**	0.90**
	1 x 3							-0.03	0.63**	-0.12	0.82**
	4 x 5							-0.10	0.70**	-0.11	0.88**
100-seed weight (g)	1 x 2								0.36**	0.35**	0.64**
	1 x 3								0.27**	0.10	0.54**
	4 x 5								0.11	0.21**	0.37**
Total biomass/ plant (g)	1 x 2									-0.37**	0.63**
	1 x 3									-0.73**	0.68**
	4 x 5									-0.69**	0.70**
Harvest index (%)	1 x 2										0.48**
	1 x 3										-0.04
	4 x 5										-0.01

*, ** significant at 5% and 1% level, respectively 1 x 2 = JCP 27 x CSJ 103, 1 x 3 = JCP 27 x IPC 2000-52 and 4 x 5 = GJG 0106 x Phule G 96006

Table 4 Direct (bold) and indirect effect of ten component characters on seed yield per plant in three chickpea crosses

Character	Cross	Days to flowering	Flowering period	Days to maturity	Plant height (cm)	Primary branches/ plant	Pods/ plant	Seeds/ plant	100-seed weight (g)	Total biomass/ plant (g)	Harvest index (%)	Correlation with seed yield/ plant(g)
Days to flowering	1 x 2	**-0.001**	-0.004	0.003	0.000	0.001	-0.001	-0.018	0.006	0.004	-0.004	-0.01
	1 x 3	**-0.005**	-0.003	0.008	0.000	0.000	-0.001	0.068	0.101	0.001	0.002	0.17*
	4 x 5	**-0.008**	0.004	0.003	0.000	0.000	-0.001	-0.028	0.104	0.001	-0.003	0.07
Flowering period	1 x 2	-0.001	**-0.005**	0.004	0.000	0.000	-0.001	0.047	0.058	0.005	0.002	0.11
	1 x 3	-0.003	**-0.006**	0.008	0.000	0.000	0.000	0.036	0.158	0.000	0.003	0.20**
	4 x 5	-0.006	**0.006**	-0.003	0.002	0.002	0.000	0.054	0.032	0.001	0.002	0.09
Days to maturity	1 x 2	-0.001	-0.005	**0.004**	0.000	0.000	-0.001	0.023	0.053	0.004	0.001	0.08
	1 x 3	-0.004	-0.005	**0.010**	0.000	0.000	0.000	0.040	0.132	0.000	0.003	0.18*
	4 x 5	-0.007	0.005	**-0.003**	0.001	0.001	0.000	-0.030	0.092	0.000	0.001	0.06
Plant height (cm)	1 x 2	0.000	0.000	0.000	**0.001**	0.001	0.000	-0.001	-0.019	0.002	-0.003	-0.03
	1 x 3	0.000	-0.001	0.000	**0.002**	0.002	-0.007	0.266	0.081	0.014	-0.005	0.35**
	4 x 5	-0.001	0.001	0.000	**0.009**	0.000	0.001	0.090	0.029	0.000	0.003	0.13
Primary branches/ plant	1 x 2	0.000	0.000	0.000	0.000	**0.007**	0.000	0.078	-0.003	0.018	-0.010	0.09
	1 x 3	0.000	0.000	0.000	0.001	**0.004**	-0.004	0.202	0.041	0.009	-0.003	0.25**
	4 x 5	-0.001	0.001	0.000	0.000	**0.009**	0.003	0.329	-0.019	0.017	-0.005	0.33**
Pods/plant	1 x 2	0.000	-0.001	0.001	0.000	0.001	**-0.004**	0.493	0.072	0.025	0.015	0.60**
	1 x 3	0.000	0.000	0.000	0.001	0.001	**-0.015**	0.452	0.082	0.019	-0.006	0.53**
	4 x 5	0.000	0.000	0.000	0.001	0.004	**0.007**	0.636	0.015	0.025	-0.005	0.68**
Seeds/plant	1 x 2	0.000	0.000	0.000	0.000	0.001	-0.003	**0.739**	0.102	0.038	0.022	0.90**
	1 x 3	0.000	0.000	0.001	0.001	0.001	-0.008	**0.826**	-0.018	0.021	-0.002	0.82**
	4 x 5	0.000	0.000	0.000	0.001	0.003	0.005	**0.892**	-0.044	0.029	-0.003	0.88**
100-seed weight (g)	1 x 2	0.000	-0.001	0.001	0.000	0.000	-0.001	0.178	**0.422**	0.024	0.018	0.64**
	1 x 3	-0.001	-0.002	0.002	0.000	0.000	-0.002	-0.026	**0.559**	0.009	0.002	0.54**
	4 x 5	-0.002	0.000	-0.001	0.001	0.000	0.000	-0.088	**0.453**	0.004	0.006	0.37**
Total biomass/ plant (g)	1 x 2	0.000	0.000	0.000	0.000	0.002	-0.002	0.431	0.152	**0.065**	-0.019	0.63**
	1 x 3	0.000	0.000	0.000	0.001	0.001	-0.009	0.523	0.148	**0.034**	-0.014	0.68**
	4 x 5	0.000	0.000	0.000	0.000	0.004	0.004	0.625	0.048	**0.041**	-0.018	0.70**
Harvest index (%)	1 x 2	0.000	0.000	0.000	0.000	-0.001	-0.001	0.306	0.0.146	-0.024	**0.052**	0.48**
	1 x 3	0.000	-0.001	0.001	-0.001	-0.001	0.005	-0.097	0.058	-0.025	**0.019**	-0.04
	4 x 5	0.000	0.000	0.000	0.001	-0.002	-0.001	-0.100	0.097	-0.29	**0.027**	-0.01

Residual effect: 1 x 2 =0.094, 1 x 3 =0.072 and 4 x 5 =0.071 ; 1 x 2 = JCP 27 x CSJ 103, 1 x 3 = JCP 27 x IPC 2000-52 and 4 x 5 = GJG 0106 x Phule G 96006

100-seed weight, however, the highest total biomass was registered by CSJ 103. Such variation for total biomass and HI depicted that yield improvement may be possible by increasing total biomass production with efficient partitioning of assimilates.

The estimates of mean, range and genotypic variance for eleven characters in F_2 population of three crosses (Table 1) showed that the F_2 plants of the cross 4 x 5 were earlier with longer flowering period and higher HI than those of remaining crosses. The F_2 mean manifestation of this cross for HI, pods and seeds plant^{-1}, 100-seed weight, total biomass and seed yield plant^{-1} was higher than that of its better parent for respective character, indicating the phenomenon of transgressive segregation. The F_2 plants of 1 x 3 also showed transgressive segregation in positive direction for seeds plant^{-1}and in negative direction for 100-seed weight and HI. High magnitude of genotypic variance was observed for pods and seeds plant^{-1} in the cross 1 x 3, but the cross 4 x 5 involving low x low HI parents showing greater estimate of genotypic variance for HI. Obviously, parents involved in cross combination with varying level of HI behaved differently in releasing variability for HI.

Estimates of heritability and genetic advance as percentage of mean (Table 2) indicated that high magnitude of heritability (>60%) together with high genetic advance (>20%) was observed for plant height, primary branches, pods and seeds plant^{-1} in all the crosses studied. This suggests that most likely the heritability is due to additive gene effects and selection for these traits may be effective. Earlier, Tripathi (1998) also reported similar results in chickpea. Total biomass, an important yield component in chickpea (Arora *et al*., 2003) showed moderate heritability alongwith high genetic advance in two (1 x 2 and 4 x 5) out of three crosses. Moderate heritability being exhibited due to influence of environment; however, high genetic gain is expected through selection in such cases (Tripathi, 1998). High heritability in one and moderate heritability in two crosses for seed yield plant^{-1} was accompanied by low genetic advance in all the crosses. This was indicative of non-additive gene effects and selection for such character may not be rewarding. Similar results supporting the findings of present study were also obtained by Sidramappa *et al.* (2008b).

Heritability estimates for seed yield was lower than other traits suggesting that selection of superior genotypes on the basis of yield *per se* would not be as effective as selection of its attributing traits, namely, plant height, primary branches, pods and seeds plant^{-1}. Therefore, the association of these components with grain yield and the interrelationships among the components assumes special importance as the basis for selecting high-yielding genotypes. Correlation coefficients worked out in the present study (Table 3) revealed that seed yield was correlated with number of seeds and pods plant^{-1}, and total biomass. Further, seeds and pods plant^{-1} and total biomass were significantly and positively correlated among themselves. Obviously, these characters should be given more weightage while fixing selection criteria in chickpea improvement programme. The results obtained by Arrora *et al.* (2003) strongly support the findings of present study. Association of high total biomass with low HI depicted inefficiency in conversion of biomass to economic yield, which may create problem in combining these important traits in one genotype. In such a situation, biparental mating is advisable to breakdown undesirable linkages and to recover suitable recombinants (Nagaraj *et al.*, 2002). Early flowering, short length of flowering period and early maturity were strongly correlated among themselves, but their associations with seed yield plant^{-1} were either very weak or non-significant. This indicates that selection for early types would not be so effective for enhancing seed yield in chickpea.

The indirect associations become complex and important as more number of variables is included in correlation studies. Hence path coefficient analysis has been found useful in finding out direct and indirect causes of correlation and permits a detailed analysis of forces acting to produce a given correlation. The values of direct and indirect effects presented in Table 4 indicated that seeds plant^{-1} had the highest positive direct effect on seed yield followed by 100-seed weight. Our results are in agreement with those reported by Arora *et al*. (2003). Moreover, seeds plant^{-1} was responsible for substantial indirect contribution through pods per plant and total biomass. These characters can serve as indicator characters for yield improvement in chickpea breeding.

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Printed in April 2013