Genetic variability and interrelationships among agronomic traits in chickpea (*Cicer arietinum* L.) genotypes

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ABSTRACT

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To determine the association between genetic parameters and traits in chickpea (*Cicer arietinum* L.) genotypes, a field experiment was conducted with 17 chickpea genotypes using a randomized complete block design with four replications at the Ilam Agricultural and Natural Resources Research Center in the 2004 growing season. Genetic parameters including genetic, environmental and phenotypic variances; coefficients of variation; heritability; genetic advances; correlation coefficients and path coefficients were estimated, and cluster analysis was performed. Heritability values were greater for number of days to 50% maturity (98.43%), number of days to 50% flowering (98.19%), plant height (58.87%), number of secondary branches (45.81%), number of primary branches (42.03%) and number of seeds per plant (35.42%), indicating that these traits are controlled mainly by additive genes and that selection of such traits may be effective for improving seed yield. Number of seeds per plant and 100-seed weight had a positive direct effect on seed yield. Number of seeds per plant, number of secondary branches, 100-seed weight, number of pods per plant, number of primary branches and plant height also had positive and highly significant phenotypic correlations with seed yield. Stepwise regression analysis indicated that number of seeds per plant and 100-seed weight explained 96% of total yield variation. It can be concluded that seed yield in chickpea can be improved by selecting an ideotype having greater number of secondary and primary branches, as well as higher number of pods per plant, number of seeds per plant and 100-seed weight.

Key words: chickpea, heritability, variance components, path coefficient analysis, cluster analysis

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is Iran's most important food legume crop, comprising nearly 64**%** of the area grown to food legumes in the country. Iran's chickpea area represents 5**.**1**%** of the world's total chickpea area and produces 2**.**75**%** of global chickpea production (Sabaghpour *et al*., 2003). Chickpea is grown on 700,000 ha in Iran, which ranks fourth in the world following India, Turkey and Pakistan. However, chickpea productivity in Iran is less than half of the world average. In Iran, 95% of chickpea (665,000 ha) is grown in rainfed areas (Sabaghpour *et al*., 2006) **.**Chickpea, with 17-24**%** protein, 41-50**.**8% carbohydrates and high content of other nutrients, is one of the most important food legumes in the world **(**Kay, 1979; Witcombe and Erskine, 1984).

Khan *et al.* (2006) studied the genetic variability, heritability, genetic advances and correlations in 13 chickpea cultivars. They reported that genotypic coefficient of variation was relatively low for days to flowering, days to maturity and plant height, but was high for number of pods per plant, 100-seed weight and seed yield, indicating low environmental influence on these characters**.** Singh (2007) observed that seed yield had highly significant positive correlations with dry weight per plant, number of pods per plant, harvest index and number of secondary branches. He proposed that these traits be used as criteria for selecting high yielding cultivars in chickpea breeding programs**.**

Genetic variation for traits is important in breeding programs and for selecting desirable genotypes. On the other hand, an analysis of the correlation between seed yield and yield components is essential for determining selection criteria; however, path coefficient analysis may help to determine the direct effect of traits and their indirect effects on other traits (Yücel *et al*., 2006).

Arshad *et al***.** **(**2002) stated that low heritability(%) coupled with low and moderate genetic advancement has been observed for primary and secondary branches, respectively. Additionally, they indicated that these traits were largely influenced by environment**.** Noor *et al***.** **(**2003**)** found that days to flowering, number of secondary branches, and 100-seed weight exhibited high heritability**.** Both correlation and path analyses indicated that pod number per plant and 100-seed weight were potential contributors to grain yield through direct effects. They reported that days to flowering, 100-seed weight, and seed yield per plant showed higher heritability, whereas significant and positive correlation was observed between seed yield and pod number per plant**.** Pod number per plant had a positive direct effect on yield per plant (Uddin *et al***.**, 1990)**.**

The main purpose of this study was to estimate the total genotypic variability, correlations, and to determine some selection criteria for improving yield in winter-sown chickpea in Ilam, Iran**.**

MATERIALS AND METHODS

Seventeen winter-sown chickpea genotypes, developed by the Dryland Agricultural Research Institute of Iran and the International Center for Agricultural Research in Dry Areas (ICARDA), were grown in the 2004 cropping season in the Ilam Agricultural and Natural Resources Research Center of Iran. The experimental design was randomized complete blocks with four replications. Plots consisted of four rows, 4 m in length, with 30 cm row spacing and 10 cm between plants**.** Data on seed yield and other traits were taken and recorded from the two middle rows in each plot. Observations on number of days to 50% flowering, number of days to 50% maturity, number of pods per plant, number of seeds per plant, number of primary branches, number of secondary branches, 100-seed weight, plant height and seed yield were also made and recorded.

To determine the relationships between examined traits and seed yield per plant, correlation coefficients were calculated using the STATISTICA program**.** The path coefficient analysis was performed by examining seed yield per plant as a dependent variable. Phenotypic correlations were determined and factor analysis was performed using STATISTICA software. Cluster analysis was performed to determine the genetic distances between genotypes, and a cluster diagram was constructed following Ward's method using genotypic means.

Total genetic, phenotypic, and environmental variances, plus broad-sense heritability and genetic advances were calculated following Singh and Chaudhary (1979).

Variance components were estimated using expectations as below:

$$EV = MSE$$
$$GV = (MSG - MSE) / r$$
$$PV = (EV + GV) / r$$

where EV, GV and PV are variance components for error, genotype and phenotype, respectively, and MSE and MSG are the observed values of the mean squares for error and genotype, respectively. Broad sense heritability estimates were calculated on entry basis using the following relationship:

$$h_i^2 = GV / PV$$

The genotypic coefficient of variation (GCV), environmental coefficient of variation (ECV) and phenotypic coefficient of variation (PCV) were calculated using the formulas:

$$GCV = \sqrt{GV} / \bar{U} \times 100$$
$$ECV = \sqrt{EV} / \bar{U} \times 100$$
$$PCV = \sqrt{PV} / \bar{U} \times 100$$

where $\bar{U}$ is the mean value of the particular trait of interest.

Genetic advance was calculated following Singh and Chaudhary (1979):

$$G.A. = k.\ h_i^2.\ \sqrt{VP}$$

where G.A.=genetic advance, and k: constant = 2.06 at 5% selection intensity.

RESULTS AND DISCUSSION

Highly significant differences were observed among genotypes for all traits except number of pods per plant (Table 1)**.** This considerable variability provides a good opportunity for improving traits of interest in chickpea breeding programs. The highest phenotypic coefficients of variation were recorded for number of pods per plant, seed yield, number of secondary branches and number of seeds per plant**.** The highest estimates for genetic coefficients of variation were observed for number of secondary branches, seed yield, and number of seeds per plant, which indicates the presence of exploitable genetic variability for these traits. Heritability estimates were greater for such traits as number of days to 50% flowering, number of days to 50% maturity, plant height, number of secondary branches, number of primary branches and number of seeds per plant. Hence, it is assumed that phenotypes of number of days to 50% flowering and number of days to 50% maturity are largely determined by their genotypes.

The genetic advance **(**5**%** selection intensity**)** was highest for number of secondary branches, number of seeds per plant and seed yield, and lowest for number of days to 50% flowering and number of days to 50% maturity (Table). This implies that progress on improving seed yield could be achieved through simple selection of the number of secondary branches and number of seeds per plant. Heritability alone is not a very useful measure but, together with genetic advance, it is valuable (Johanson *et al*., 1955; Arshad *et al*., 2004). For number of days to 50% flowering and number of days to 50% maturity, high

Table 1. Means and analysis of variance for seed yield and its components in 17 chickpea genotypes

Genotypes	Number of pods per plant	Number of seeds per plant	Number of primary branches	Number of secondary branches	100-seed weight (g)	Number of days to 50% flowering	Number of days to 50% maturity	Plant height (cm)	Seed yield (g)
FLIP 97-211	9.2	5.2	2.2	1.3	29	86	123	26.3	1.48
FLIP 97-113	10.4	3.8	1.8	1.7	24	85	120	27.5	1.07
FLIP 97-85	11.8	5.3	2.1	2.9	29	82	135	30.5	1.56
FLIP 97-78	10.1	3.4	1.8	1.4	33	87	120	27.8	1.21
FLIP 97-41	5.9	5.9	2.0	1.9	32	86	126	28.5	1.89
FLIP 97-30	10.1	10.2	2.4	3.5	23	84	129	27.5	2.50
FLIP 97-102	7.3	6.4	2.7	2.6	23	84	130	30.5	1.50
FLIP 97-79	9.2	8.5	2.3	3.8	32	80	126	31.5	2.70
X95TH1	5.9	5.6	2.3	2.8	30	82	127	24.8	1.76
X95TH154	6.6	8.6	2.2	2.8	29	86	130	35.5	2.53
FLIP 97-43	9.4	8.8	2.8	3.2	25	75	132	29.0	2.20
FLIP 97-95	5.9	5.8	2.1	3.4	25	84	121	39.0	1.49
FLIP 97-114	10.7	9.7	2.4	4.1	27	84	118	33.3	2.59
X94TH45K10	12.9	10.9	2.4	4.9	28	78	120	32.0	3.30
X95TH5K10	12.9	13.1	3.3	4.3	31	87	123	35.8	4.02
X45TH150K10	8.1	8.4	3.4	5.9	19	87	125	30.8	1.71
Arman	6.8	6.5	2.4	2.2	28	80	121	30.5	1.81
Mean	9.0	7.4	2.4	3.1	27	83	125	30.6	2.07
Mean Square(V)	22.27^{ns}	27.82^{**}	0.78^{*}	6.31^{*}	56.13**	45.67^{**}	93.34^{**}	54.59^{**}	2.44^{**}
Mean Square (R)	198.19^{**}	24.48^{*}	0.87^{**}	3.40^{ns}	16.13ns	0.51^{ns}	0.45^{ns}	19.00^{ns}	1.71^{ns}
Mean Square (E)	34.27	8.71	0.20	1.44	23.03	0.21	0.37	8.12	0.91
LSD (p<0.05)	8.65	4.36	0.66	1.77	7.09	0.68	0.90	4.21	1.41

*** and **: Significant at the 5% and 1% probability levels, respectively.**
ns: Not significant.

Table 2. Genetic parameters for different agronomic traits in 17 chickpea genotypes

Traits	GV_1	EV_2	PV_3	GCV_4	PCV_5	ECV_6	hi^2_7	$G.A_8$	G.A. $(\%)_9$
Number of pods per plant	3.00	34.27	37.27	19.25	67.85	65.07	8.05	1.01	11.25
Number of seeds per plant	4.78	8.71	13.49	29.56	49.67	39.91	35.42	2.68	36.20
Number of primary branches	0.15	0.20	0.35	16.12	24.87	18.94	42.03	0.51	21.5
Number of secondary branches	1.22	1.44	2.66	35.97	53.14	39.12	45.81	1.54	50.15
100-seed weight	8.28	23.03	31.31	10.51	20.44	17.54	26.43	3.05	11.13
Number of days to 50% flowering	11.37	0.21	11.58	4.05	4.08	0.55	98.19	6.88	8.26
Number of days to 50% maturity	23.24	0.37	23.61	3.85	3.88	0.49	98.43	9.85	7.88
Plant height	11.62	8.12	19.74	11.13	14.51	9.31	58.87	5.39	17.60
Seed yield per plant	0.38	0.91	1.29	29.81	54.81	45.99	29.59	0.69	33.41

1, 2,,...., 9 are abbreviations for: Genotype Variance (GV), Error Variance (EV), Phenotype Variance (PV), Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV), Environmental Coefficient of Variation (ECV), Heritability (hi^2), Genetic Advance (5% selection intensity) (G.A.) and Genetic Advance in percentage of mean(GA%), respectively.

heritability was associated with low genetic advance, indicating the influence of dominant and epistatic gene effects on these traits**.** High heritability for number of secondary branches and number of seeds per plant, coupled with high genetic advance, indicated that additive gene effects are important in determining these traits. Crop improvement for these traits is assumed to be possible by simple selection, due to high heritability coupled with high genotypic variation and additive gene effects (Noor *et al***.**, 2003).

Simple correlation coefficients between examined traits in chickpea genotypes are given in Table 3**.** Seed yield is a complex trait that receives the interactive effects of many other plant traits, which are in turn influenced by their genetic structures and the environment where the plant is grown. Thus the direct evaluation and improvement of seed yield itself may be misleading due to the influence of the environmental component**.** Therefore, it is essential to analyze the data for the relative contribution of various components to yield performance. The simple correlation is an important tool for this purpose**.** Positive significant relationships were found between seed yield and number of seeds per plant, number of secondary branches, 100-seed weight, number of pods per plant, number of primary branches and plant height. These results suggest that any positive increase in such traits will improve the seed yield of chickpea, and are in agreement with the findings of Raval and Dobariya (2003), Toker (2004), Obaidullah *et al***.** (2006), Saleem *et al*. (2002), Toker and Cagirgan (2004), Yücel *et al*. (2006), Farshadfar *et al*. (2008), Amjad *et al*. (2009) and Zali *et al*. (2009).

Number of secondary branches was positively correlated with number of pods per plant, number of seeds per plant and number of primary branches. Thus an increase in number of secondary branches would increase number of pods per plant, number of seeds per plant and seed yield, but with negative

Table 3: Correlation coefficients between different agronomic traits in chickpea genotypes

Traits	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of pods per plant (1)	1.000							
Number of seeds per plant (2)	0.450**	1.000						
Number of primary branches (3)	0.162ns	0.554**	1.000					
Number of secondary branches (4)	0.215 ns	0.591**	0.518**	1.000				
100-seed weight (5)	0.202 ns	0.216 ns	-0.187 ns	-0.097 ns	1.000			
Number of days to 50% flowering (6)	-0.043 ns	-0.130 ns	-0.006 ns	-0.129 ns	0.008 ns	1.000		
Number of days to 50% maturity (7)	-0.050 ns	0.014 ns	0.102 ns	-0.005 ns	-0.066 ns	-0.231 ns	1.000	
Plant height (8)	0.122 ns	0.424**	0.175 ns	0.391*	0.125 ns	0.064 ns	-0.124 ns	1.000
Seed yield per plant (9)	0.429**	0.945**	0.429**	0.500**	0.458**	-0.120 ns	-0.034 ns	0.414**

*** and ****: **Significant at the 5 and 1% probability level, respectively.**
ns: Not significant.

effect on 100-seed weight. Similar results were reported by Malik *et al*. (2009) and Yücel and Anlarsal (2008). The main objective of chickpea breeders is to achieve an increase in chickpea seed yield. Seed yield and its components are polygenic traits that are also strongly influenced by the environment and other factors known and yet to be identified (Yücel *et al*., 2006). Hence, to improve seed yield, emphasis should be given to developing chickpea genotypes with higher number of seeds per plant and higher 100-seed weight**.**

The results of stepwise regression analysis are shown in Table 4. Seed yield was considered a dependent variable, while other traits were considered independent variables. Number of seeds per plant was entered in the model first and explained 89% of variation; then 100-seed weight was entered into the model.

Direct and indirect effects in path coefficient analysis revealed that number of seeds per plant and

Table 4. Summary of stepwise regression analysis for grain yield

Steps	Entered variable	Adj .R^2	b_i	SE	T value
1	Number of seeds per plant	0.892	0.272	0.008	35.607**
2	100-seed weight	0.960	0.055	0.005	10.678**
	Intercept		-1.440	0.143	-10.678**
	Suggested model	$\hat{Y} = -1.440 + 0.272X_{12} + 0.0554X_{15}$			

: **significant at the 1% probability level.

100-seed weight had positive direct effects on seed yield (Table 5). Compared with simple correlations, path analysis demonstrated that number of seeds per plant and 100-seed weight were major contributors to seed yield. Similar findings were reported by Amjad *et al*. (2009) and Yücel *et al*. (2006). These results suggest that these traits could be used as selection criteria in chickpea breeding programs and exploited more efficiently for chickpea improvement. Results of the path analysis revealed that number of pods per plant, number of secondary branches, number of primary branches and plant height had great indirect effects on seed yield through number of seeds per plant. Thus improving these traits may increase seed yield. Path analysis of seed yield also indicated that number of seeds per plant exerted the greatest direct effect. This trait's major contributions to seed yield could therefore be used to improve seed yield in chickpea breeding programs.

Cluster analysis indicates the extent of genetic diversity that is of practical use in plant breeding (Sultana *et al*., 2006)**.** Chickpea genotypes used in this study were grouped in three clusters (I, II and III), comprised of 6, 6 and 5 genotypes, respectively (Fig. 1). Means of various traits for each character showed that genotypes with minimum number of secondary and primary branches were grouped in cluster I. Genotypes with maximum plant height, number of secondary branches, number of seeds per plant, number of pods per plant and seed yield were grouped in cluster II. Genotypes with minimum

Table 5. Partitioning of correlation coefficients for direct and indirect effects on seed yield

Traits	Direct effect	Indirect effect							
		(1)†	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of pods per plant (1)	-0.034		0.411	-0.003	0.001	0.053	-0.001	0.001	0.002
Number of seeds per plant (2)	0.912	-0.015		-0.011	0.002	0.057	-0.001	0.002	-0.000
Number of primary branches (3)	-0.019	-0.005	0.505		0.002	-0.049	-0.001	0.000	-0.003
Number of secondary branches (4)	0.003	-0.007	0.539	-0.010		-0.026	-0.001	0.002	0.000
100-seed weight (5)	0.263	-0.007	0.197	0.004	-0.001		-0.001	0.000	0.002
Plant height (6)	-0.003	-0.004	0.387	-0.003	0.001	0.033		-0.001	0.004
Number of days to 50% flowering (7)	-0.012	0.002	-0.118	0.001	-0.001	0.002	-0.000		0.007
Number of days to 50% maturity (8)	-0.032	0.002	0.013	-0.002	0.000	-0.017	0.001	0.003	

†: Trait number.

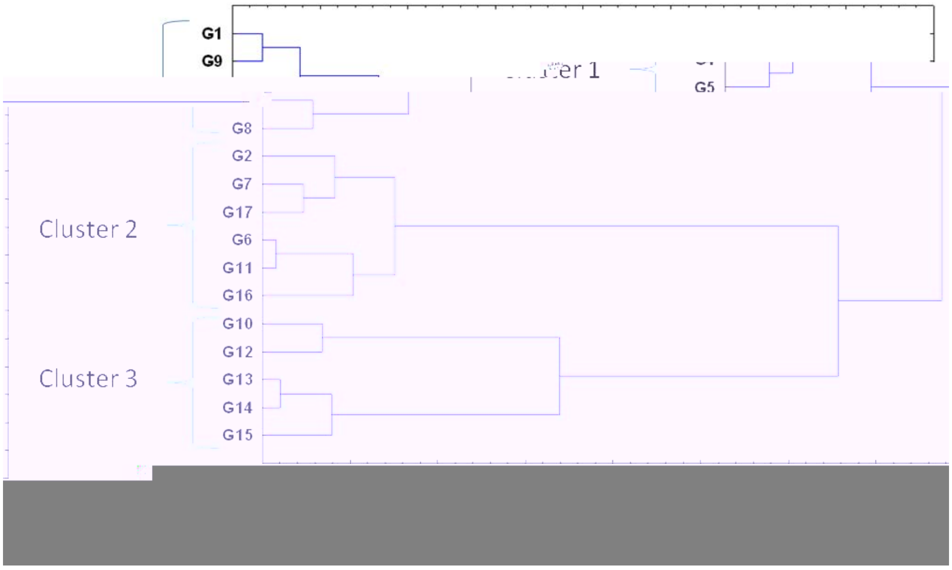

Fig. 1. Dendrogram of 17 chickpea genotypes based on information on agronomic traits

100-seed weight were classified in cluster III.

The cluster analysis supported the results of correlation coefficients, and both indicated that plant height, number of secondary branches, number of seeds per plant and number of pods per plant may be simultaneously improved and accumulated in a single genotype for seed yield improvement in chickpea. This is supported by the fact that all these four components were positively associated with seed yield and with each other. Furthermore, chickpea genotypes with high mean values for these traits as well as high seed yield were grouped in cluster II. It can be concluded that seed yield in chickpea can be improved by selecting for an ideotype having greater number of secondary and primary branches as well as higher number of pods per plant, number of seeds per plant and 100-seed weight.

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