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

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**ABSTRACT**


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

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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:

\[
h^2 = GV / PV
\]

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):

\[
G.A. = k \cdot h^2 \cdot \sqrt{PV}
\]

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
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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, determining these traits. Crop improvement for these traits is indicated that additive gene effects are important in per plant, coupled with high genetic advance, variation and additive gene effects (Noor 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 secondary branches, 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>
<thead>
<tr>
<th>Traits</th>
<th>GV 1</th>
<th>EV 2</th>
<th>PV 3</th>
<th>GCV 4</th>
<th>PCV 5</th>
<th>ECV 6</th>
<th>hi 2</th>
<th>G.A. 7</th>
<th>G.A. (%) 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pods per plant</td>
<td>3.00</td>
<td>3.27</td>
<td>1.37</td>
<td>19.25</td>
<td>37.25</td>
<td>19.96</td>
<td>26.85</td>
<td>65.07</td>
<td>0.85</td>
</tr>
<tr>
<td>Number of seeds per plant</td>
<td>4.78</td>
<td>8.71</td>
<td>13.49</td>
<td>29.56</td>
<td>49.67</td>
<td>39.91</td>
<td>35.42</td>
<td>26.68</td>
<td>36.20</td>
</tr>
<tr>
<td>Number of primary branches</td>
<td>0.15</td>
<td>0.20</td>
<td>0.35</td>
<td>16.12</td>
<td>24.87</td>
<td>18.94</td>
<td>42.03</td>
<td>0.51</td>
<td>21.5</td>
</tr>
<tr>
<td>Number of secondary branches</td>
<td>1.22</td>
<td>1.44</td>
<td>2.66</td>
<td>35.97</td>
<td>53.14</td>
<td>39.12</td>
<td>45.81</td>
<td>1.54</td>
<td>50.15</td>
</tr>
<tr>
<td>100-seed weight</td>
<td>8.28</td>
<td>23.03</td>
<td>31.31</td>
<td>10.51</td>
<td>20.44</td>
<td>17.54</td>
<td>26.43</td>
<td>3.05</td>
<td>11.13</td>
</tr>
<tr>
<td>Number of days to 50% flowering</td>
<td>11.37</td>
<td>0.21</td>
<td>11.58</td>
<td>4.05</td>
<td>4.08</td>
<td>0.55</td>
<td>98.19</td>
<td>6.88</td>
<td>8.26</td>
</tr>
<tr>
<td>Number of days to 50% maturity</td>
<td>23.24</td>
<td>0.67</td>
<td>23.61</td>
<td>3.85</td>
<td>3.88</td>
<td>0.49</td>
<td>98.43</td>
<td>9.85</td>
<td>7.88</td>
</tr>
<tr>
<td>Plant height</td>
<td>11.62</td>
<td>8.12</td>
<td>19.74</td>
<td>11.13</td>
<td>14.51</td>
<td>9.31</td>
<td>58.87</td>
<td>5.39</td>
<td>17.60</td>
</tr>
<tr>
<td>Seed yield per plant</td>
<td>0.38</td>
<td>0.91</td>
<td>1.29</td>
<td>29.81</td>
<td>54.81</td>
<td>45.99</td>
<td>29.59</td>
<td>0.69</td>
<td>33.41</td>
</tr>
</tbody>
</table>

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 (hi²), Genetic Advance (5% selection intensity) (G.A.) and Genetic Advance in percentage of mean(G.A.%), respectively.

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

Table 1. Means and analysis of variance for seed yield and its components in 17 chickpea genotypes
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 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 are shown in Table 3. Seed yield was considered the 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.

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

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

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

Table 4: Summary of stepwise regression analysis for grain yield

<table>
<thead>
<tr>
<th>Steps</th>
<th>Entered variable</th>
<th>Adj $R^2$</th>
<th>b</th>
<th>SE</th>
<th>T value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of seeds per plant</td>
<td>0.892</td>
<td>0.272</td>
<td>0.008</td>
<td>35.607</td>
</tr>
<tr>
<td>2</td>
<td>100-seed weight</td>
<td>0.960</td>
<td>0.055</td>
<td>0.005</td>
<td>10.678*</td>
</tr>
<tr>
<td>Intercept</td>
<td>-1.440</td>
<td>0.143</td>
<td>-10.678*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

****: significant at the 1% probability level.

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

<table>
<thead>
<tr>
<th>Traits</th>
<th>Direct effect</th>
<th>Indirect effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pods per plant (1)</td>
<td>-0.034</td>
<td>0.111</td>
</tr>
<tr>
<td>Number of seeds per plant (2)</td>
<td>-0.912</td>
<td>-0.015</td>
</tr>
<tr>
<td>Number of primary branches (3)</td>
<td>-0.019</td>
<td>-0.005</td>
</tr>
<tr>
<td>Number of secondary branches (4)</td>
<td>0.003</td>
<td>0.505</td>
</tr>
<tr>
<td>100-seed weight (5)</td>
<td>0.263</td>
<td>-0.007</td>
</tr>
<tr>
<td>Plant height (6)</td>
<td>-0.003</td>
<td>0.197</td>
</tr>
<tr>
<td>Number of days to 50% flowering (7)</td>
<td>-0.012</td>
<td>0.004</td>
</tr>
<tr>
<td>Number of days to 50% maturity (8)</td>
<td>-0.032</td>
<td>0.015</td>
</tr>
</tbody>
</table>

†: Trait number.
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.

REFERENCES


