Multivariate regression and path coefficient analysis of seed and oil yield in spring safflower (*Carthamus tinctorius* L.) cultivars

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**Key words**
- Spring safflower
- in direct selection
- genetic improvement
- step-wise regression
- path analysis

**ABSTRACT**

Assessment of the seed and oil yield components is very efficient in genetic improvement of these traits via indirect selection in safflower cultivars. Because of that, fifteen spring safflower cultivars were sown at normal condition in a randomized complete block design with three replications in the research field of Islamic Azad University, Isfahan (Khorasgan) Branch. Correlation analysis showed positive and significant relation of 1000-seed weight, no. seed/capitulum, no. seed/plant, oil yield, biological yield, plant height and days to physiological maturity with seed yield while 1000-seed weight, no. seed/capitulum, no. seed/plant, seed yield, seed oil percent, plant height, harvest index, days to flowering, days to physiological maturity and grain filling rate with oil yield. Regression analysis revealed importance of 100-seed weight, plant height and no. seed/plant for seed yield that verified 75% of variation exist in this trait. Amongst, 1000-seed weight and plant height had the highest direct effect on seed yield. These traits have genetic potential to introduce as the best indirect selection criteria to improve seed yield in safflower cultivars especially from preliminary generations. Regression and path analysis for oil yield showed importance of 1000-seed weight and grain filling rate for enhancement of oil yield in this oil crop.

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**Introduction**

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop with 35-40% oil content. It has been used as a source of edible oil and dying since ancient times. It has a well-defined tap root that generally penetrates up to a depth of 2-3 m. This deep-rooting characteristic allows the plant to absorb moisture and nutrients from different volumes of soil (Kaya et al., 2003). Identification of the traits that affect seed and oil yield in safflower (*Carthamus tinctorius* L.) is very important in genetic improvement of these attributes. Especially, seed yield is a polygenic trait that direct selection isn’t effective for this especially in early generations. Therefore, indirect selection via traits having higher heritability and correlated strongly with seed and oil yield has more genetic efficiency than direct selection in genetic improvement of these traits (Falconer, 1998).

Correlation coefficient analysis help researchers to distinguish significant relationship between traits. Step-wise regression can reduce effect of non-important traits in regression model; in this way, traits accounted for considerable variations of dependent variable could be determined (Acharya et al., 1994; Agrama, 1996). Path analyses that presented by Li (1956) have been extensively used in field crops. Path analysis is used to determine the amount of direct and indirect effects of the variables on the dependent variable (Farshadfar, 2000; Li, 1956).

Salamati (2010) and Ulukan et al. (2003) reported positive and significant relationships between biological yield with plant height, pod number plant\(^{-1}\) and grain number pod\(^{-1}\) in faba bean genotypes. The total coefficient of determination was found as 63.6% in the regression model for biological yield as dependent variable. Direct effects of plant height, pod number plant\(^{-1}\) and grain number pod\(^{-1}\) upon biological yield were positive. These traits determined as selection criteria for genetic improvement of biological yield.

Zheng et al. (1993) and Arslan (2007) emphasized on indirect selection via higher capitulum number plant\(^{-1}\) and 1000-seed weight and lower number of branches along with thin seed pericarp for improvement of seed and oil yield in safflower. Bratulin (1993) reported positive and significant relation between seed yield and capitulum number plant\(^{-1}\) and 1000-seed weight in safflower genotypes. Cassato et al. (1997) observed positive and significant correlation of capitulum number plant\(^{-1}\) with seed yield in safflower.
This study was undertaken in order to determine the dependence relationship between seed and oil yield with agronomic traits in spring safflower cultivars under Isfahan province condition and to identify the best indirect selection criteria for genetic improvement of these traits.

Materials and Methods

Fifteen spring safflower cultivars namely; Isfahan landrace, Kuseh landrace, Arak-2811, Nebraska-10, Semnan landrace, Lordegan landrace, Bushehr landrace, Shiraz landrace, Kerman landrace, U.S.10, S149, C111, S3110, A.C. sterling and Gila were planted at the beginning of March 2012 at the research field of Islamic Azad University, Isfahan (Khorasgan) Branch in a randomized complete block design (RCBD) with three replications.

The plots comprising three rows were 3 m long and 0.5 m apart. Distance between plants within rows was 5 cm. Therefore, plant density was 400,000 plants ha\(^{-1}\). In spring 2012 the trial was irrigated based normally. Total amount of precipitation in agronomic season was 130 mm.

Measurement for 14 traits days to 50% flowering, days to physiological maturity, grain filling duration, grain filling rate (g day\(^{-1}\)), plant height (cm), capitulum number/plant, seed number/capitulum, 1000-seed weight (g), seed number/plant, biological yield (g), harvest index (%), seed yield/plant (g), seed oil percent (%) and oil yield/plant (g) were done on 10 normal plants were randomly selected from the two middle rows of each plot.

Grain filling duration was considered as days from flowering until physiological maturity and grain filling rate was calculated according to equation. Seed oil percent was measured by NMR instrument in research laboratory of Karaj Jihad Agriculture institute.

Relationships between traits were investigated using simple correlation coefficient analysis. Step-wise regression was achieved for determination of the best model, which accounted for variation exist in plant seed and oil yield as dependent variables in separate analysis. Direct and indirect effects of traits entered to regression model were determined using path coefficient analysis. In this study path analysis was carried out based on method given by Dewey and Lu (1959). Analysis of data was conducted by using SAS\(_2\) and Path\(_2\) softwares.

Results and Discussion

Correlation analysis showed the significant and positive relationship exist between seed yield/plant and traits 1000-seed weight, no. seed/capitulum, no. seed/plant, oil yield, biological yield, plant height and days to physiological maturity. On the other hand, oil yield/plant correlated positively and significantly with 1000-seed weight, no. seed/capitulum, no. seed/plant, seed yield, seed oil percent, plant height, harvest index, days to flowering, days to physiological maturity and grain filling rate. Mozaffari and Asadi (2006) and Omidi-Tabrizi (2002) also reported similar findings in their studies on spring safflower cultivars.

### Table 1. Step-wise regression for seed yield/plant (dependent variable) in safflower cultivars

<table>
<thead>
<tr>
<th>Variable</th>
<th>b</th>
<th>R(^2)%</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000-seed weight</td>
<td>0.307</td>
<td>53.3</td>
<td>0.000</td>
</tr>
<tr>
<td>Plant height</td>
<td>0.103</td>
<td>69.4</td>
<td>0.000</td>
</tr>
<tr>
<td>No. seed/plant</td>
<td>0.060</td>
<td>75.0</td>
<td>0.040</td>
</tr>
<tr>
<td>Intercept</td>
<td>-14.420</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Path analysis for seed yield/plant in safflower cultivars

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>Sum of effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 1000-seed weight</td>
<td>0.479</td>
<td>0.181</td>
<td>0.069</td>
<td>0.730</td>
</tr>
<tr>
<td>(2) Plant height</td>
<td>0.200</td>
<td>0.433</td>
<td>0.036</td>
<td>0.671</td>
</tr>
<tr>
<td>(3) No. seed/plant</td>
<td>0.102</td>
<td>0.048</td>
<td>0.324</td>
<td>0.474</td>
</tr>
<tr>
<td>Residual effects</td>
<td>0.456</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3. Step-wise regression for oil yield/plant (dependent variable) in safflower cultivars

<table>
<thead>
<tr>
<th>Variable</th>
<th>b</th>
<th>R(^2)%</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000-seed weight</td>
<td>0.260</td>
<td>52</td>
<td>0.022</td>
</tr>
<tr>
<td>Grain filling rate</td>
<td>1.622</td>
<td>64.5</td>
<td>0.000</td>
</tr>
<tr>
<td>Grain filling duration</td>
<td>0.037</td>
<td>76.3</td>
<td>0.003</td>
</tr>
<tr>
<td>Days to physiological maturity</td>
<td>0.026</td>
<td>79.9</td>
<td>0.011</td>
</tr>
<tr>
<td>Intercept</td>
<td>-3.475</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. Path analysis for oil yield/plant in safflower cultivars

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>Sum of effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 1000-seed weight</td>
<td>2.382</td>
<td>0.032</td>
<td>-0.052</td>
<td>-1.580</td>
<td>0.721</td>
</tr>
<tr>
<td>(2) Grain filling rate</td>
<td>-0.065</td>
<td>1.174</td>
<td>0.428</td>
<td>-0.021</td>
<td>0.662</td>
</tr>
<tr>
<td>(3) Grain filling duration</td>
<td>0.802</td>
<td>-0.024</td>
<td>-1.188</td>
<td>1.101</td>
<td>-0.008</td>
</tr>
<tr>
<td>(4) Days to physiological maturity</td>
<td>-1.504</td>
<td>0.001</td>
<td>-0.523</td>
<td>2.502</td>
<td>0.047</td>
</tr>
<tr>
<td>Residual effects</td>
<td>0.362</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Step-wise regression analysis for seed yield/plant as dependent variable and the other traits as independent revealed that 1000-seed weight, plant height and seed number/plant are the most important seed yield/plant components (Table 1). These traits accounted for 75% of total variation exist in seed yield/plant trait.

Path analysis was achieved using these traits that entered to regression model. Results given from path analysis showed direct and positive effects of these traits on seed yield/plant (Table 2). However, 1000-seed weight and plant height had the highest direct effect on seed yield/plant as well as correlation with this trait. Efficacy of these traits as indirect selection criteria is higher than no seed/plant. Arslan (2007), Kaya et al (2003) and Mozaffari and Asadi (2006) also emphasized on the traits 1000-seed weight, seed number plant\(^1\) and seed number capitulum\(^1\) as the best selection criteria for improvement of seed yield/plant in safflower genotypes that is in agreement with the results of present study.

Step-wise regression for oil yield/plant as dependent variable and the other traits as independent assigned that 1000-seed weight, grain filling rate, grain filling duration and days to physiological maturity had positive and significant regression coefficient and accounted for 79.9% of total variation exist in oil yield/plant (Table 3). Path analysis showed that all traits entered to regression model except grain filling duration had direct and positive effects on oil yield/plant. Although, 1000-seed weight and grain filling rate were introduced as the best indirect selection criteria for genetic improvement of oil yield/plant in spring safflower cultivars (Table 4).

Kaya et al (2003) and Omid Tabrizi (2002) studied spring safflower cultivars under drought stress and determined traits biological yield, capitulum number plant\(^1\), number of branches and seed number capitulum\(^1\) as the most important components of oil yield/plant. Uluka et al (2003), Arslan (2007) and Mozaffari and Asadi (2006) also reported similar results.

In conclusion, indirect selection in preliminary generations through traits having the highest direct effect on dependent variables is one of the best breeding strategies. These traits usually determine by means of statistical procedure like correlation, step-wise regression and path analysis. In the present study, traits 1000-seed weight and plant height were determined as the best indirect selection criteria to improve seed yield/plant in safflower cultivars. On the other hand, 1000-seed weight and grain filling rate had the highest efficacy to enhance oil yield/plant especially from early segregating generations.

References


