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# Diversity of drought tolerance and seed yield in sunflower (*Helianthus annuus* L.) hybrids

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**Abstract**

Randomized complete block design with four replications in two drought and non-drought environments was used for this study. Drought resistance indices were calculated based on seed yield in stress and non-stress conditions. The results showed that GMP and STI were the best drought resistance indices so had the positive and significant correlation with Yp and Ys. Three dimensional graph showed that RFG5*AF80, G-543 and Farokh were the drought resistant hybrids. These hybrids had the highest amount of Yp, Ys, GMP and STI that revealed the highest yield potential as well as drought tolerance in these genotypes. Because of that these hybrids have promised potential to cultivate in drought prone environments. Regression analysis revealed that the traits grain filling rate, grain filling duration and water use efficiency accounted for 97.0% of total variation exist in seed yield. Path coefficient analysis demonstrated the highest and positive direct effect of grain filling rate and grain filling duration on seed yield in sunflower hybrids. Water use efficiency had low direct effect while high indirect effects via grain filling duration on seed yield. Therefore, the study revealed the importance of total grain filling rate and grain filling duration as indirect selection criteria for genetic improvement of seed yield in sunflower breeding programs especially in early generations. On the other hand, indirect effects of water use efficiency through grain filling duration on seed yield have promising result in selection programs.

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## Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops that widely grown on many parts of the world. Sunflower seed contains high oil content ranging from 35-48% with some types yielding up to 50%, 20-27% protein and high percentage of poly-unsaturated fatty acids (60%) including oleic acid (16.0%) and linoleic acid (72.5%), which control cholesterol in blood (Ghafoor and Ahmad, 2005). The abundant food value of oily sunflower seeds as the richest sources of vegetable oil and protein production in nature has drawn the attention of most developed industrial countries to produce these plants. Sunflower as one of the major sources of vegetable oil is of special importance throughout the world (Arshi and Jafari, 1992).

Drought usually is the most important abiotic stress that affects crop production. Hence, selection for drought resistance and production of tolerant cultivars with high yield potential is the main objective of breeding programs. Many researchers (Quarrie *et al*., 1999; Richards, 1996) believed that tolerance to drought stress must be done via genetic improvement of physiological traits. Harvest index and biological yield introduced as the most important traits in this connection (Quarrie *et al*., 1999). In small-grained cereals increase in harvest index may causes yield improvement, without increase in plant water use (Richards, 1996; Quarrie *et al*., 1999). Indirect selection in early generations through traits correlated with seed yield is one of the most important strategies in plant breeding.

The objective of any plant breeder includes selection from a natural population or artificially developed for one or several characters (Hladni *et al*., 2006). Success in plant breeding primarily depends on the magnitude of variation present for yield and yield components and the nature of association among them. The estimates of genotypic and phenotypic correlations among the characters are useful in planning the selection strategies. Path coefficient analysis is helpful in partitioning the correlation coefficients into its direct and indirect effects, so that the relative contribution of each component character to the end product yield could be assessed. Various kinds of associations have been reported in sunflower. The length of developmental phases before and after flowering were independent of morphological characters (Arshad *et al*., 2004) while seed weight was reported to be positively associated with duration of vegetative phase.

Golparvar and Hejazi (2012) found the relationship between seed yield and many characters, including yield components, of sunflower. Furthermore, among yield components, seed size was the most important yield-related character (Hladni *et al*., 2006). Therefore, selection based on yield components may increase seed yield of sunflower. Moreover, path coefficient analysis may be used to partition the correlation coefficients into direct and indirect effects to clarify the relationship between different characters with the seed yield.

The results obtained by Teklewold *et al*. (2006) showed that the head diameter had the highest direct effect on seed yield and also the seed filling percentage and plant height had the highest indirect effect on seed yield through head diameter.

Earlier in sunflower, Punia and Gill (1994), Shankar *et al*. (2006) and Farratullah *et al*. (2006) applied path coefficient by partitioning the genotypic correlations into direct and indirect effects of the traits. Moreover, other researchers (Arshad *et al*., 2004; Ghafoor and Ahmad, 2005; Golparvar and Hejazi, 2012) have used these techniques along with diversity study for investigating genetic parameters.

Hence, it would be necessary to know diversity existence for drought tolerance and seed yield and kind of relationship among morphological and yield. The present study was taken up to study diversity for drought tolerance as well as seed yield in order to make some general inferences.

## Materials and methods

*Research site*

The research was carried out at Agricultural Research Station, Isfahan during agronomic year of 2013. This station is located 45 km northeast of Isfahan (32 53' N, 51 38' E and 1620 meter above sea level) in Mahyar region. This location is an arid and warm area (according to the Koppen climate classification) characterized by warm and dry summers. The long-term (30 years) mean annual rainfall and temperature of area was 120 mm and 16 centigrade degrees, respectively.

*Sunflower hybrids*

In this research, fifteen sunflower hybrids as treatments were evaluated in the layout randomized complete block design with four replications in two separate drought and non-drought environments. Each plot consisted of four 6-m rows with spacing 75 cm between rows and 25 cm between hills. Each hill was planted with 3-4 seeds and thinned to one seedling per hill 12 days after germination. Fertilizer formula 15–15–15 (N, $P_2O_5$ and $K_2O_5$) was applied at the rate of 40 kg $rai^{-1}$ at planting and 25 days after germination. Weed control was done manually at 25 days after germination to give a free weed condition. Diseases and insects were controlled by regular applications of fungicides and insecticides. Overhead sprinkler irrigation was applied once a week as there was no rain in the planting season.

*Studied traits*

The traits such as days to budding, days to flowering, days to 70% flowering, days to full flowering, days to ripening, plant height, head diameter, number of seeds per head, 1000-seed weight, seed yield, oil percentage, oil yield, water use efficiency, grain filling rate and grain filling duration were measured. Drought resistance indices were calculated based on the formulas suggested by Fernandez (1992).

*Statistical analysis*

Mean values were subjected to different statistical and biometrical analysis. Phenotypic correlation coefficients were estimated according to Pearson's method. Step-wise regression was conducted to determine the most important components of seed yield. Increasingly, a path coefficient analysis was done according to method proposed by Dewey and Lu (1959) in order to evaluate the direct and indirect effects of the traits entered to the regression model on seed yield. The data analysis was achieved by using $SAS_{9.02}$ and $path_2$ software.

## Results

Analysis of variance showed significant differences among sunflower hybrids for all the drought resistance indices except Yp (Table 1). Mean comparison revealed the highest Yp, Ys, GMP and STI in RFG5*AF80, G-543 and Farokh hybrids (Table 2). These hybrids have genetically potential to introduce as the drought tolerant in breeding programs as well as cultivate in water-limited regions. Three dimensional graphical display (Fig. 1) showed the efficiency of mean comparison to segregate tolerant and susceptible hybrids. A region in graph (Fig. 1) indicate the highest yield potential and tolerant genotypes. Fernandez (1992) discussed dispersion of the genotypes in four regions A, B, C and D. B region dictated on the genotypes having the highest yield potential but the highest susceptibility to stress. These genotypes are suitable for irrigated environments. D region show that RF22×AF81 and RF74×AF80 hybrids have the lowest seed yield potential and the highest susceptibility (Fig. 1). Golparvar and Hejazi (2012) and Sowmya *et al.* (2010) reported the similar results to identify the best selection indices for breeding drought tolerance in sunflower.

Phenotypic correlation analysis indicated that traits water use efficiency, biological yield, oil yield and grain filling rate have positive and highly significant relationship with seed yield. Further, days to full flowering and head diameter showed a negative relation with seed yield. The correlation of other traits with seed yield weren't significant. Oil percentage showed negative and significant interrelationship with seed yield in sunflower hybrids. Oil yield revealed positive and significant correlation with the traits seed yield, biological yield and water use efficiency while negative with grain filling rate.

The regression analysis of seed yield as dependant variable according to step-wise method demonstrated that just traits such as grain filling rate, grain filling duration and water use efficiency entered to regression model and totally justified 99.5% of total variation exist in seed yield (Table 3). At last, the following regression model was obtained for indicating the relationship between the seed yield and these traits as independent variables:

Seed yield = 1124.32+ 25.16 grain filling rate + 103.04 grain filling duration + 29.17 water use efficiency.

**Table 1.** Analysis of variance for drought resistance indices in sunflower hybrids.

| S.V | d.f | Mean of squares | | | |
|---|---|---|---|---|---|
| | | Yp | Ys | GMP | STI |
| Block | 3 | 12965 | 9036 | 6362 | 0.001 |
| Cultivars | 4 | 148202 | 109364** | 123797** | 0.017** |
| Error | 12 | 14189 | 12080 | 6843 | 0.001 |

**Significant at 1% probability level.

The path analysis for seed yield was conducted based on traits; grain filling rate, grain filling duration and water use efficiency which had a meaningful correlation with seed yield (Table 4). Among these traits, grain filling rate had the highest and positive direct effect on seed yield. Therefore, selection for the highest amounts of this trait can improve the seed yield in sunflower hybrids. These results are inconsistent with the results given by Kaya *et al.* (2007) and Golparvar and Hejazi (2012).

**Table 2.** Mean comparison among sunflower hybrids for drought resistance indices.

| Sunflower hybrids | Yp | Ys | GMP | STI |
|---|---|---|---|---|
| (1)RF22×AF81 | 3567 b | 1901 bc | 2604 b | 0.46 b |
| (2)RF74×AF80 | 3672 b | 1770 c | 2548 b | 0.44 b |
| (3)RF65×AF80 | 3985 a | 2029 ab | 2842 a | 0.55 a |
| (4)G-543 | 3934 a | 2152 a | 2909 a | 0.58 a |
| (5)FAROKH | 3969 a | 2151 a | 2921 a | 0.58 a |

In each column, means with the same letter(s), have non-significant difference.

On the other hand, oil percentage and days to flowering have a negative correlation as well as direct and negative effect on seed yield. Thus, selection for the lowest amounts of this trait can increase the seed yield. In other words, it is possible that the choices of genotypes which enter the generative stage sooner and also terminate the flowering stage faster, causes the plant to escape preventing it from encountering the heat of end of the season. This mechanism leads to enhancement the yield in stress conditions of the end of season (Richards, 1996).

Furthermore, the lower number of seed per head in these conditions would be followed by the fewer hollow floret, increasing the seed yield. Meanwhile, just the head diameter has a direct negative effect on the seed yield. This negative effect is negligible and on the other hand, the indirect effects of this trait, especially via total number of seeds per head on seed yield are positive. In this case, choosing the dwarf plants through increasing the total number of seeds per head can lead to genetic improvement the seed yield.

**Table 3.** Step-wise regression for seed yield (dependent variable) in sunflower hybrids based on phenotypic correlation coefficients.

| Variable | $b_{(1)}$ | Partial $R^2$ | Model $R^2$ | F |
|---|---|---|---|---|
| Grain filling rate | 25.16 | 80.4 | 80.4 | ** |
| Grain filling duration | 103.04 | 14.5 | 94.9 | ** |
| Water use efficiency | 29.17 | 2.1 | 97.0 | ** |
| Intercept | 1124.32 | | | |

This is because of the better remobilization which occurs in dwarf sunflower cultivars and causes the seeds to be filled better. Although, for considering the traits such as the plant height as selection criteria more care must be taken. Because, if the plant is too much dwarft, it might lead to reduce the competition of plant to get light and other environmental parameters, thus the seed yield would diminish. Therefore, it is necessary that the best plant height is studied more carefully. Dagustu (2002) and Kaya *et al.* (2007) reported the similar findings in sunflower genotypes.

**Table 4.** Path analysis for seed yield in sunflower hybrids based on the traits entered to regression model.

| Variable | | (1) | (2) | (3) | Sum of effects |
|---|---|---|---|---|---|
| (1) | Grain filling rate | 0.980 | -0.030 | 0.020 | 0.961 |
| (2) | Grain filling duration | 0.162 | 0.009 | 0.273 | -0.110 |
| (3) | Water use efficiency | 0.801 | 0.062 | 0.730 | 0.020 |
| Residual effects | | -0.014 | | | |

Grain filling duration also showed the positive direct effect on seed yield while water use efficiency had very low direct effect on this (Table 2). Hence, grain filling duration after grain filling rate is one the best indirect selection criteria to improve seed yield. Although, water use efficiency affect on seed yield via grain filling duration. The findings given by Taghdiri *et al.* (2006) and Shankar *et al.* (2006) are inconsistent with this result.

## Discussion

In conclusion, the results dictated on efficacy of GMP and STI as the best indices to determine the tolerant genotypes in sunflower. Graphical display is the efficient tool to distinct the genotypes to different groups. Increasingly, indirect selection could be suggested in early generations via traits that have the highest direct effect on dependent variables. These traits usually determine by means of statistical procedure like correlation, regression and path analysis. In the light of results obtained in present study, it can be suggested that the traits grain filling rate and grain filling duration are the best indirect selection criteria to obtain the maximum seed yield in sunflower hybrids. Indirect selection for these traits in sunflower as a heterogamous and free polliniferous plant can result in more genetic gain than the direct selection for seed yield per se, because the heritability of these traits is more than seed yield and it can be measured easily, quickly and cost effectively.

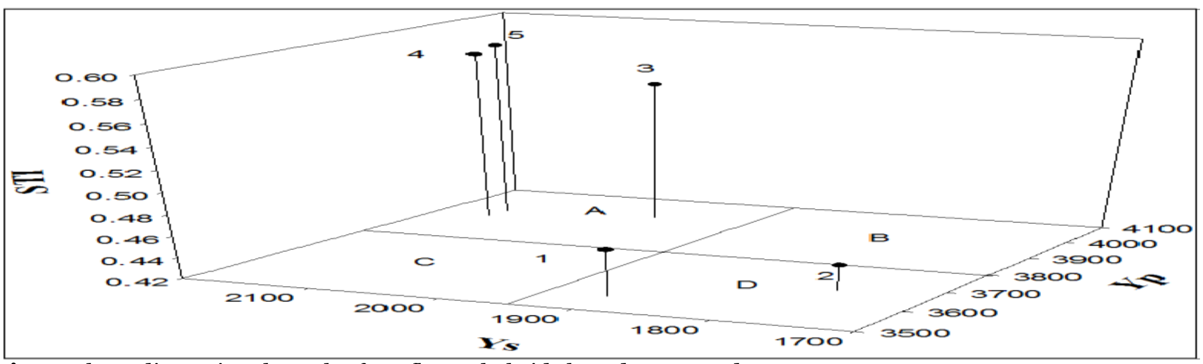

**Fig. 1.** Three dimensional graph of sunflower hybrids based on Yp and Ys.

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