



**AN INVESTIGATION OF YIELD AND INDICES OF DROUGHT TOLERANCE IN
SUNFLOWER GENOTYPES**

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ABSTRACT

To investigate the effects of drought stress on agronomic traits and to determine the best genotype of drought tolerance, the yield and indices of drought tolerance were examined in an experiment with a random complete block design in three replications from 2011 to 2012 under draught stress and no stress conditions at the Agricultural Research Station of Birjand University. The examined materials included Farrukh hybrids, Azargol, SHF8190 and open pollinated varieties of Progress, Zaria, Armavirosky and Arena. The examined traits included one thousand seed weight, economic yield, the distance of the highest point of stalk from the ground, the distance between the head and the ground, leaf length, leaf width, petiole length, diameter of the upper part of stem, diameter of the lower part of stem, leaf number, head diameter, and the plant height. Percentage of trait changes showed that draught stress has a negative impact on most of the examined traits. Meanwhile, the highest reduction was related to the yield and one thousand seed weight and the lowest reduction was related to the head diameter, the distance between the head and the ground, leaf length, leaf width and the number of leaves. The results of correlation analysis between the indices and the yield showed that STI, GMP, MP, and Harm indices were desirable and the selection on the basis of them can identify resistant genotypes. Therefore, Zaria and SHF8190 genotypes were identified as desirable genotypes. The results of principal component analysis showed that the first two components explain about 99.94% of the changes in the data, so Biplot analysis was done based on two above factors. Biplot analysis also

approved these genotypes. Besides, cluster analysis based on indices categorized genotypes into three categories.

Keywords: Biplot, stress, cluster, component.

INTRODUCTION AND OBJECTIVES

Sunflower as a source of edible oil is economically important (Ashraf and Mehmood, 1990). Sunflower ranks fourth among oilseed plants in terms of cultivation in the world. The cultivated area of this plant is 68 thousand hectares in Iran and 26 million hectares in the world. The average yield is 1.12 seed ton/ha in Iran and 1.54 seed ton/ha in the world (FAO, 2013). Draught is the main factor limiting plant growth and its' yield in many parts of the world (Manivannan et al., 2007). Yield losses due to water stress depend on factors such as the type of crop, growth stage, stress severity, and drought tolerance to the plant genotype (Ahmad et al., 2009). Sunflower grows in areas prone to a variety of environmental stresses such as drought, flooding, heat or poor soil with high salinity. Avoiding periods of high evaporation, changing Sunflower planting date, and choosing high early strength were provided as means to improve Sunflower yield in areas with limited water (Chimenti et al., 2002). Sunflower yield highly depends on water availability, especially in the process of seed germination and flowering. The amount and

distribution of water has significant effects on seed yield and oil (Iqbal et al., 2005). Water stress during vegetative development reduces height of peduncle, stem diameter, number of nodes, number of leaves and the leaf area (Agele, 2003). Under water stress, the increase in ratio of root to shoot is obvious (Sobrado and Turner, 1986) which leads to a reduction in biomass. Reduction of biomass results in less light /heat and it reduces the photosynthetic activity. Thus, the absorption of photosynthesis products is reduced during the reproductive stage and so the head diameter, number of rows in the head, and the number of seeds in the head are reduced as well (Zaharia et al., 2005). The amount of this reduction is associated with stress severity (Rauf and Sadaqat, 2007). Water stress during vegetative stage reduces the plant yield to 15-25 percent (Reddy et al., 2003).

Susceptibility to drought in sunflower is high just a short time before observing the head, until the full coloring of the seeds or the time to reduce green coloring behind the head. The most susceptibility to moisture stress is during pollination stage (Kalhori et al.,

2002). Water stress during flowering stage causes ovarian and embryo abortion, sterility of pollen, reduction in leaf area index, the number of seeds per head, one thousand seed weight and the number of fertile seeds per head (Baldini and Vannozzi, 1999). Water stress also has negative effects on physical traits such as seed size, weight and content of the plant skin (Connor and Hall, 1997). Water stress during flowering reduces the yield over 50% (Reddy et al., 2003). The lowest head diameter is related to irrigation cut at flowering stage (Kalhori et al., 2002). Many indices have been suggested in order to choose plants based on the yield. These indices involve the plant yield under two stress and non-stress conditions (Fernandez, 1992). Fisher and Maurer (1978) suggested the stress susceptibility index (SSI). The smaller SSI, the higher drought stress is found. Selection regarding SSI index, results in selection of genotypes with lower yield under normal conditions, but the high yield under the stress condition. Rosielle and Hambelen (1981) proposed Tolerance Index (TOL) and mean productivity (MP) index. The smaller index of tolerance, the less is susceptibility to the genotype drought which is desirable. Selection based on this index leads to selecting genotypes which have low yield under no stress condition, but high

potential yield under stress conditions. The average index of fertility is also responsible for the selection of genotypes with high yield under favorable conditions, but low yield under unfavorable conditions. Not all these indices are able to distinguish genotypes with high yield under stress and non-stress conditions from genotypes with high yield under stress conditions. Fernandez (1992) presented stress tolerance index (STI) which is able to identify genotypes with high yield in both stress and non stress conditions from other genotypes. A higher value of STI index for one genotype shows high stress tolerance and potentially higher yield of that genotype. He presented another useful index namely geometric mean productivity (GMP). In assessing tolerance to drought stress in sunflower hybrids, STI, GMP and MP indices are suitable (Daneshian and Jonoubi, 2008). Razi and Assad (1998) stated that STI index moves the selection toward choosing sunflowers' varieties with optimal yield which is drought-resistant. Sunflower cultivation during the last twenty years has increased because of its resistance to drought in the areas with draught tensions and one way to cope with drought tension is to modify tolerant plants (Koocheki et al., 2005). Sunflower is able to withstand lack of water and it is potentially able to become an

important product in the semi-arid environments which necessitates identifying and developing drought-resistant genetic resources, so the expansion of the cultivated area becomes possible (Ashraf and Mehmood, 1990). Sunflower is a product with low to moderate susceptibility to drought. Development of genotypes with increased drought tolerance is the most successful and economically reasonable strategy to overcome water stress (Mwale et al., 2003). This study aimed to investigate the effects of draught stress on morphological and quantitative traits of sunflower, to assess drought stress tolerance, to determine the best index of resistance to drought and to introduce the best genotypes resistant to draught regarding the yield, indices of drought resistance and by drawing Biplot along with selecting the best criteria.

MATERIALS AND METHODS

A. Plant materials

Seven genotypes of sunflower including; hybrids of Farrukh, Azargol and SHF8190 and open pollinated varieties of Progress, Zaria, Armavirsky and Arena were chosen in two random complete block design with three replications, once through normal irrigation and another time with limited irrigation (stress) and then they were compared at Agricultural Research Station of

Birjand University in Amirabad campus. Seedbed preparation included autumn plowing, spring disc, leveling and preparing the bed. Seeds of each genotype were planted in four rows along the two meters. The distance between the plants was considered 20 cm and between the rows it was 60 cm. The first irrigation was done in 4.05.2012 and it was considered as the planting date. The desired stress was based on the cumulative evaporation from A class evaporation pan. Before implementation of stress, every two parts (normal and stress) were irrigated by 100 mm from A class evaporation pan. The stress started by flowering and evaporation was done in the normal irrigation condition by 100 mm and in the stress condition by 200 mm. 20 days before irrigation; both environments were cut and at the time of getting brown color and the harvest was done behind the head. The measured traits were: 1. TKW: 1000 seed weight in grams, 2. economic yield (g) the average weight of seeds obtained from ten plants, 3. the distance of the highest point of stalk from the ground (cm): average distance of highest point of stalk at the bending point of shoot to the ground, 4. the distance between the head and the ground (cm): average distance of the head to the ground in ten plants per cm, 5. the leaf length (cm): the

average of ten leaf length, 6. leaf width (cm): average width of 10 leaves, 7. petiole length (cm): the average length of ten leaf petiole, 8. the diameter of the higher stem (cm): average diameter of ten stems, 9. the lower stem diameter (cm): the diameter of the bottom of ten stems, 10. the number of leaves: counting the number of leaves in ten plants, 11. the head diameter (cm): the average diameter of 10 heads and 12. the plant height (cm): average height of ten plants.

B. Statistical methods

Analysis of variance was used for statistical analysis. Combined analysis of two normal and stress environments was considered as two locations. Then, the percentage of stress changes was calculated. To calculate the percentage of stress changes, equation (1) $C = \frac{(CP - CD)}{CP} \times 100$ was used where C is percentage of changes and CP and CD are respectively the trait average under stress and non-stress conditions. To determine the genotypes' tolerance or susceptibility to draught, six indices of SSI, MP, Harm, GMP, TOL, and STI were used and based on the obtained values; the comparison of genotypes' average was conducted through Duncan method. Using correlation analysis between the yield and calculated indices, the best related index was identified regarding

the yield. The calculation formula for each index is as below: 2) SI or stress severity:

$$SI = (1 - \frac{\bar{Y}_S}{\bar{Y}_P})$$

$$SSI = \frac{1 - (YS/YP)}{SI}$$

$$MP = \frac{YP + YS}{2}$$

$$GMP = \sqrt{(YS)(SP)}$$

$$Tol = YP - YS$$

$$STI = \frac{(YP)(YS)}{(\bar{Y}_P)^2}$$

3) stress susceptibility index= 4) the arithmetic mean: 5) geometric mean: 6) tolerance index: 7) Stress tolerance index= 8) Harmonic mean: = $\frac{2(YP.YS)}{YP+YS}$. In these formula, the values of YS and YP showed potential yield of each genotype under stress and non-stress conditions, and \bar{Y}_P and \bar{Y}_S values showed average yield of all genotypes under stress and non stress conditions.

By using Biplot technique in an effective and strong method, genotypes with high yield in both stress and non-stress conditions were detected from other genotypes. The calculated indices along with two yield variables under stress and non-stress conditions were interred into principal component analysis, and then two first components which justified the highest variances were measured for all genotypes.

In the next stage, the second component was plotted on the first component. The two components were shown in two perpendicular axes and genotypes were

determined based on these two components in the above diagram by points (Fisher and Maurer, 1978). Clustering analysis was done by using minimum variance method for grouping the genotypes based on the indices. Data analysis was done through SPSS, Excel and Stat graph.

RESULTS AND DISCUSSION

Combined analysis of variance and analysis of stress-induced changes

The results of combined analysis of variance (Table 1) showed that the genotypes were significantly different in all traits except in leaf length. The result showed that different genotypes were different in both environments regarding the measured traits. The effect of environment or condition (normal and stress) was not significant in all traits except in yield, 1000 seed weight and the head diameter; in other words, normal and stress conditions affect only the yield, 1000 seed weight and the head diameter. Regarding the above results, it can be stated that the imposed stress at the mentioned level affect only yield parameters while parameters related to the morphology of leaves and stem were not affected by the stress.

The effect of X genotype was significant only for 1000 seed weight, and this result

showed that 1000 seed weight of different genotypes reacts differently in different environments. Other traits showed the same reactions in both environments. To determine the stress effect, the percentage of changes caused by draught stress was determined on the traits which are shown in Table 2. The greatest damages due to drought stress were related to 1000 seed weight and yield. Karam et al. (2007) and Kamel and Khiavi (2003) also concluded that irrigation cut and drought stress in the aggregate process has a negative impact on the seed weight, yield and its components. However, other researchers also reported decrease in seed weight and yield loss due to drought stress (Ravishankar et al., 1990; Jafarzade and Poostini, 1997; Reddy et al., 2003; Iqbal et al., 2005; Baldini and Vannozzi, 1999). Traits such the diameter of the bottom and top of the stem, petiole length, plant height and distance of the highest point of stalk from the ground decreased less when it is compared with the yield and weight of seeds. Agele (2003) believed that decrease in the main stem height and diameter due to water stress caused during vegetative development.

Table 1. Combined analysis of variance for different traits in sunflower

| SOV | DF | Distance between ground and head | Distance between ground and highest point of the stalk | Leaf length | Leaf width | Petiole length |
|------------------------|----|----------------------------------|--|--------------------|-------------------|--------------------|
| Environment | 1 | 56.8 ^{ns} | 121.9 ^{ns} | 5.8 ^{ns} | 0.1 ^{ns} | 1.0 ^{ns} |
| Error (a) | 4 | 684.6 | 455.4 | 6.9 | 5.5 | 8.3 |
| Genotype | 6 | 1631.4* | 1075.0** | 28.2 ^{ns} | 48.2** | 36.6** |
| Genotype * Environment | 6 | 679.7 ^{ns} | 123.3 ^{ns} | 23.4 ^{ns} | 9.9 ^{ns} | 10.4 ^{ns} |
| Error (b) | 24 | 502.5 | 128.8 | 19.7 | 6.4 | 6.6 |

Continued Table 1. Combined analysis of variance for different traits in sunflower

| SOV | DF | MS,s | | | | | | |
|------------------------|----|-------------------|-----------------------|-------------------|-----------------------|------------------|---------------------|-------------------|
| | | Top stem diameter | Bottom stalk diameter | Leaf number | Yield | 1000 seed weight | Plant height | Head diameter |
| Environment | 1 | 4.9 ^{ns} | 13.0 ^{ns} | 1.2 ^{ns} | 101575.3** | 1184** | 181.4 ^{ns} | 35.0* |
| Error (a) | 4 | 18.1 | 17.0 | 15.7 | 6023.0 | 2.4 | 596.0 | 7.2 |
| Genotype | 6 | 21.1** | 53.3** | 58** | 36045.1* | 528.9** | 2262.4** | 18.3** |
| Genotype * Environment | 6 | 1.5 ^{ns} | 3.7 ^{ns} | 9.5 ^{ns} | 27323.0 ^{ns} | 89.4** | 247.8 ^{ns} | 6.4 ^{ns} |
| Error (b) | 24 | 4.8 | 7.3 | 6.9 | 12563.2 | 3.0 | 158.0 | 4.9 |

Some traits such as distance between ground and head, leaf length, leaf width, leaf number and the head diameter increased due to the stress. Increase of distance between ground and the head next to the head weight reduction in the stress environment makes sense, in other words, by reducing the yield and weight of the seed, the head weight decreases which caused that the stem from the bending point toward the ground bends lower. The results of these tests in terms of increasing the head diameter, leaf length, leaf width, and the number of leaves is somewhat against the reports. This is because there can be less fertilized seeds per head. In other words, the imposed stress in early flowering,

and the fertile seeds per head declined, but after this stage and with the cold weather in Birjand and by mitigating the stress effects, the photosynthetic materials which are surplus were used to increase the number of new leaves, leaf length, leaf width and the head diameter. The investigation by Kalhori et al. (2002) and Zaharia et al. (2005) showed that drought stress reduced the head diameter and the number of seeds per head. Agele (2003) and Karam et al. (2007) also reported that reducing the number of leaves, leaf area, and leaf area index have been caused due to drought stress during vegetative and flowering stages in sunflower.

Table2. The change percentage induced of drought stress on traits in sunflower genotypes

| Traits | Mean trait in | Mean trait in stress | % Traits |
|--------|---------------|----------------------|----------|
|--------|---------------|----------------------|----------|

| | normal condition | condition | changes |
|---|------------------|-----------|---------|
| Distance between ground and highest point of the stalk (cm) | 136.82 | 134.49 | 1.70 |
| Distance between ground and head(cm)(cm) | 116.24 | 119.64 | -2.93 |
| Leaf length (cm) | 18.97 | 19.71 | -3.94 |
| Leaf width (cm) | 17.34 | 17.48 | -0.78 |
| Petiole length (cm) | 11.37 | 11.05 | 2.80 |
| Top stalk diameter (cm) | 14.98 | 14.30 | 4.59 |
| Bottom stalk diameter (cm) | 21.74 | 20.62 | 5.14 |
| Leaf number (gr) | 25.45 | 25.79 | -1.33 |
| Yield (gr) | 897.01 | 781.82 | 11.18 |
| 1000-seed weight (gr) | 81.05 | 70.43 | 13.11 |
| Plant height (cm) | 159.51 | 155.35 | 2.61 |
| Head diameter (cm) | 18.71 | 20.53 | -9.77 |

Genotype correlation analysis and identification of the most resistant genotype to the drought by using indices

The results of the correlation between yield and drought resistance index (Table 3) showed that the indices such as STI, GMP, MP, Harm are positively correlated with yield under normal and stress conditions. Therefore, they are the best known indices to identify genotypes with high yield in two normal and stress environments. Accordingly, the genotypes that had high levels of these indices were identified as the most resistant genotypes. TOL and SSI indices showed a significant positive correlation with yield under no stress condition and they showed a significant negative correlation with yield under stress condition. Since the genotypes with lower values of this index are known as the possible indices, therefore selection based on these indices leads to the selection of genotypes with high yield under stress

condition which showed low yield under no stress condition. Therefore, TOL and SSI indices cannot be useful in identifying resistant genotypes and so they are not desirable indices to identify desirable genotypes under two conditions in sunflower. Since STI, GMP, MP, and Harm are highly correlated with yield in both stress and normal conditions, so, according to Fernandez's theory (Fernandez, 1992) they were introduced as the best indices. Daneshian and Jonoubi (2008) assessed the tolerance to drought stress in sunflower hybrids which approved STI, MP and GMP. Razi and Assad (1998) considered STI index favorable to introduce genotypes resistant to drought with high yield of sunflower. Chookan et al. (2008) in studying the drought tolerance in corn hybrids, introduced STI, GMP, MP and Harm indices. Thus, there was no significant correlation between the yield under two environments which can be due to the

genotypes that had high yield in normal condition and low yield in stress condition

while the typical genotype is Armavirosky.

Table 3. Correlation analysis of yield and drought resistance indices in sunflower genotypes

| Index | YP | YS | SSI | TOL | MP | STI | GMP | Harm |
|-------|-------|--------|-------|------|-------|-------|-------|------|
| YP | 1 | | | | | | | |
| YS | -.08 | 1 | | | | | | |
| SSI | .71** | -.75** | 1 | | | | | |
| TOL | .80** | -.66** | .98** | 1 | | | | |
| MP | .77** | .58** | 0.10 | 0.23 | 1 | | | |
| STI | .75** | .59** | 0.09 | 0.22 | .99** | 1 | | |
| GMP | .74** | .61** | 0.07 | 0.20 | .99** | .99** | 1 | |
| Harm | .71** | .63** | 0.04 | 0.16 | .98** | .99** | .99** | 1 |

The yield with different indices was presented in Table 4. Since indices like STI, GMP, MP, and Harm are favorable, thus, the selection according to them can identify resistant genotypes. Armavirosky genotype has the highest yield in normal conditions, but it doesn't have a higher yield when it is compared with other genotypes under stress condition. Considering STI, GMP, MP, and Harm indices, it is clear that they are higher than other genotypes, but SSI and TOL are high as well which indicates their susceptibility to the draught. This is because of the negative correlation of these indices with the yield under stress condition. Hence, in case of Armavirosky genotype, the considered indices are not effective. Therefore, Armavirosky genotype is not a proper one under stress condition. Selecting based on SSI and TOL indices lead to selection of high yield genotypes under stress condition. Due to undesirable high

values of SSI and TOL and low values of STI, GMP, MP, and Harm, Farrukh and Progress genotypes were not desirable. Regarding drought tolerance, Zaria, SHF8190, Arena, and Azargol genotypes showed a better yield than other genotypes in both environments. This is due to high values of STI, GMP, MP, and Harm along with low values of SSI and TOL. Generally, taking all indices into account, in addition to considering the yield under two environments, Zaria and line SHF8190 genotypes acted favorably in both conditions rather than other genotypes (Without taking into account the significant differences of them regarding their higher values) and Zaria genotype was also more resistant to drought stress and STI, GMP, MP, Harm were higher than SHF8190 line. Therefore, under Birjand condition, Zaria genotype is better than others. However, in the present condition the worst genotype was Farrukh.

Table 4. Mean comparison of yield and drought resistance indices in sunflower genotypes

| Genotype | Harm | GMP | STI | MP | TOL | SSI | YS | YP |
|----------|------|-----|-----|----|-----|-----|----|----|
|----------|------|-----|-----|----|-----|-----|----|----|

| | | | | | | | | |
|--------------|---------------------|---------------------|--------------------|---------------------|----------------------|-------------------|--------------------|---------------------|
| Farrukh | 720.3 ^b | 720.8 ^b | 0.67 ^b | 721.3 ^b | 52.32 ^b | 0.62 ^a | 695.1 ^a | 747.4 ^b |
| SHF8190 line | 837.5 ^{ab} | 837.6 ^{ab} | 0.91 ^{ab} | 837.6 ^{ab} | 6.34 ^b | 0.07 ^a | 834.4 ^a | 840.7 ^b |
| Progress | 792.6 ^{ab} | 794.9 ^{ab} | 0.82 ^{ab} | 797.2 ^b | 121.26 ^{ab} | 1.26 ^a | 736.6 ^a | 857.8 ^b |
| Zaria | 857.3 ^{ab} | 857.4 ^{ab} | 0.95 ^{ab} | 857.4 ^{ab} | 17.37 ^b | 0.18 ^a | 848.7 ^a | 866.1 ^b |
| Armavirosky | 899.5 ^a | 919.7 ^a | 1.09 ^a | 940.4 ^a | 391.7 ^a | 3.08 ^a | 744.5 ^a | 1136.2 ^a |
| Azargol | 836.3 ^{ab} | 837.1 ^{ab} | 0.90 ^{ab} | 837.8 ^{ab} | 70.33 ^b | 0.72 ^a | 802.7 ^a | 873.0 ^b |
| Arena | 820.1 ^{ab} | 820.2 ^{ab} | 0.87 ^{ab} | 820.4 ^{ab} | 29.2 ^b | 0.31 ^a | 805.8 ^a | 834.9 ^b |

Biplot analysis and genotypes cluster analysis

Eigenvalues, variance, variance cumulative percentage and eigenvectors were presented in Table 5 for six indices of drought tolerance. Two first components explained about 99.94% of the changes in the data.

Table 5. Eigenvalue, variance, cumulative variance percentage and eigenvectors for drought stress indices in sunflower

| Harm | STI | GMP | SSI | TOL | MP | YS | YP | %Cumulative variance | Variance | Eigen value | Vector |
|-------|-------|------|------|------|-------|-------|------|----------------------|----------|-------------|--------|
| 0/99 | 0/98 | 0/97 | 0/96 | 0/39 | 0/31 | 0/63 | 0/74 | 72/28 | 72/28 | 5/78 | 1 |
| 0/10 | 0/20 | 0/24 | 0/29 | 0/92 | 0/95 | -0/77 | 0.67 | 99/94 | 27/65 | 2/21 | 2 |
| -0/03 | -0/04 | 0/02 | 0/01 | 0/03 | -0/03 | -0/02 | 0/03 | 99/99 | 0/06 | 0/004 | 3 |
| 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 100 | 0/00 | 0/00 | 4 |
| 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 100 | 0/00 | 0/00 | 5 |
| 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 100 | 0/00 | 0/00 | 6 |
| 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 100 | 0/00 | 0/00 | 7 |
| 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 0/00 | 100 | 0/00 | 0/00 | 8 |

The first component explains 72.28% of changes in total data and it shows a high correlation with STI, GMP, Harm and MP indices. Since the high values of these indices are desirable, and regarding the positive correlation of the first component with these indices, if the highest value is chosen, genotypes showed a high yield in no stress condition and if they showed a relatively high yield in stress condition, so it's called yield potential and stress tolerance. On the other hand, the second component allocates 27.65% of the changes to itself and it has a high positive correlation

Using these two components and ignoring others lead to loss of a few changes and so interpretation of the results based on the first and second components showed a high yield. Therefore, drawing Biplot was based on two factors above.

with SSI and TOL and high and negative correlation with YS (Figure 1), so, that is called susceptibility to the stress. Since the low value of these indices are considered, regarding the positive correlation of the second component with these indices, if its value is lowered, genotypes tolerant to the stress with high yield at stress environment have been chosen. Thus, regarding the abovementioned, the desired part of Biplot is low and it moves toward the right side (Figure 1). Since Zaria and line SHF8190 genotypes are among the selected genotypes through the best indices, and they were

located at the favorable part of bi-plot that was in the lower right, so they were introduced as genotypes with high yield potential in both stress and no stress environments. Armavirosky genotype with the highest yield in no stress environment and the lowest yield in stress environment was located at the upper right part of Biplot. So, the top and right area leads to the selection of genotypes with high yield in normal and stress susceptible environment. Farrukh genotype with the lowest yield in no

stress condition and stress in the left part and on top of bi-plot are related to genotypes with low yield under normal and stress conditions and it is not desirable. Progress, Arena and Azargol are located in the middle of Biplot and in case of the yield they are in two environments in the middle level. The distribution of genotypes for resistance to drought stress indicates genetic variation in some studied genotypes for this trait which provides a suitable way for its improvement.

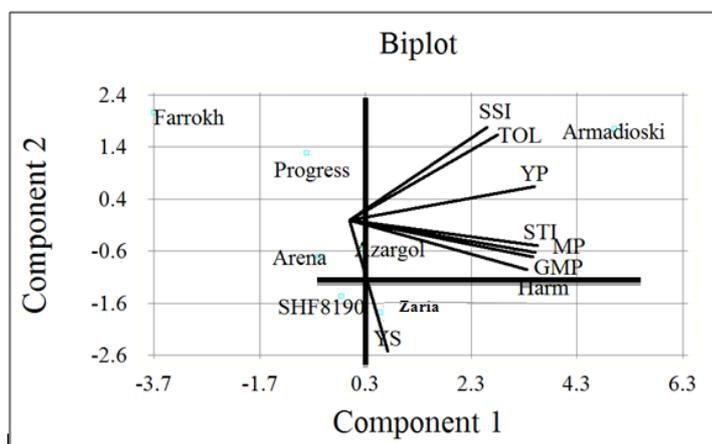


Figure 1-Biplot analysis for yield and drought stress indices and determination of the best resistant genotype in sunflower

The results of cluster analysis were shown in Figure 2. Thus, the genotypes were evaluated in three categories. The first category was related to Farrukh genotype with lower yield in both normal and stress conditions. The second category was related to Armavirosky genotype with high yield in normal condition and low yield in stress condition. The rest of the genotypes were in

the third category and its yield under both conditions was high and relatively desirable. In this category, Progress genotype with a higher difference with others was categorized in one category with a relatively high yield under normal condition and low yield under stress condition. The results of cluster analysis approved Biplot results.

In general, it can be concluded that in this study STI, GMP, Harm and MP indices were able to separate the genotypes. Thus, STI, GMP, Harm and MP were recognized as the best indices. According to these indices, and regarding the yield under normal and stress conditions, Zaria and line

SHF8190 genotypes acted better than others in Birjand conditions. So these genotypes are recommended in Birjand conditions and of course the stability tests of these genotypes are needed for more precise recommendations.

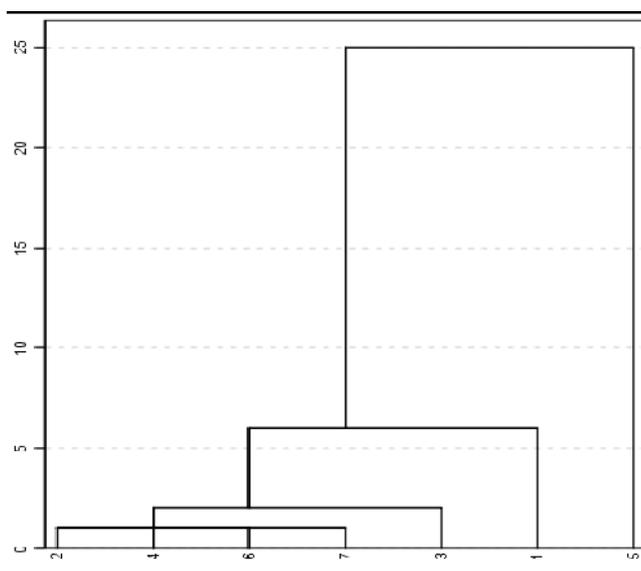


Figure 2. Cluster analysis using yield and drought tolerance indices in different genotypes of sunflower

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