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# Evaluation of Drought Tolerance in Mid and Late Mature Corn Hybrids Using Stress Tolerance Indices

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**Abstract:** In order to study the effect of water stress exerted to seeds of corn hybrids in their various stages of growth on their yield and determining their level of tolerance, a split block experiment based on completely randomized block design with 3 replications was conducted in Agriculture and Natural Resources Research Center of Moghan, Ultan, Parsabad, Ardabil province, Iran. The experimental factors included 4 irrigational regimes (normal irrigation and cease of irrigation in vegetative, flowering and seed filling stages) and 7 commercial corn hybrids. Drought tolerance indices including stress susceptibility index, tolerance index, mean production, geometric mean of production, stress tolerance index and harmonic average were estimated based on seeds yields of the genotypes studied under water stress and non-stress conditions. It was found that in addition to the significant correlation between each of indices and seed yield, there were also statistically significant correlations between these indices under stress and non-stress conditions. Furthermore, as stress tolerance index could separate the group A from other groups, it was selected as the most appropriate index for selection of stress tolerant genotypes. Therefore, only stress tolerance index and yields under stress and non-stress conditions were applied to design three-dimensional figures and observed that the genotypes SC647 and SC704 were the most tolerant cultivars.

**Key words:** Corn, water stress, drought tolerance, stress tolerance indices, yield

## INTRODUCTION

The yield of agronomical crops is influenced by environmental conditions, genetic structure and their interactions. Although, all biotic and abiotic stresses could be considered as important factors for yield reduction (Entz and Fowler, 1990), but water stress is the major factor limits corn production in arid and semi-arid districts. Even short-lasting water stress during growth of corn plant can reduce Leaf Growth Rate (LGR) and decrease Leaf Area Index (LAI) and Radiation Use Efficiency (RUE) in the next stages (Sorvar and Ali, 1999). Water stress can lead to the closed stomata and consequently decrease carbon dioxide absorption, photosynthesis and dry matter production (Shiri *et al*., 2010).

Eghball and Maranville (1993) reported root length and water use efficiency reduction and decreased rate or failure in ovule fertilization as the consequence of water stress during corn plant pollination that led to significant decreases in number of seeds on cobs. Osborne *et al.* (2002) indicated that water stress in the vegetative stage, florescence and seed filling of corn plants could reduce seed yield 25, 50 and 21%, respectively. Wassome *et al.* (2000) investigated the impact of irrigation volume in 3 different growth and development stages and concluded that corn plants are highly susceptible to water shortage during their flowering stage. A slightly water stress at this stage would prevent the appearance of flower primordia and reduce seed number.

Water shortage during florescence also postpones tasseling and silking, increases Anthesis Silking Interval (ASI) and causes partial or no pollination and pollen reception. Additionally, the emerged silks may dry soon as the result of water shortage and high temperatures, which consequently will affect the reception of pollens, their subsequent germination, elongation and penetration into the stigma and inside the ovules. Fertilization may not occur well and this can reduce the seed number on the cobs.

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Bolanos *et al.* (1993) found that the ASI increased to 4.6 days in stress treatment in flowering stage and to 8.3 days in severe stress treatment before and after florescence compared to 2.2 days in control. The occurrence of stress during seed filling period reduced final seed weight.

Plants can increase their resistance to water stress through various mechanisms such as leaf area reduction, stomata closing, thicker cuticles, more root growth, increased rates of producing some proteins, maintaining photosynthetic rates at high levels, respiration reduction and regulation of osmotic conditions (Levitt, 1980). Plant drought resistance depends on soil humidity rate and plant genotype, so that the potential yield of a genotype may be more than another genotype in a given rate of soil humidity. Therefore, there are complex mechanisms and reactions that maintain successful growth and development of plants under water shortage conditions (Rostami and Samdi, 1991). Seed yield is the most frequently applied index used for identification of cultivars convenient to the stress environments. However, seed yield is not always the only useful and/or the simplest selective characteristic (Shiri *et al.*, 2010).

Richards (1996) believed that the yield-based selection of genotypes in both stress and non-stress environments can lead to the selection of high yield genotypes under stress conditions since, the response of selection under non-stress conditions is maximal and hereditability of the yield under these conditions is high.

Fernandez (1992) classified genotypes into 4 classes based on their yields under stress and non stress conditions including: A genotypes of high yields under both conditions, B those with acceptable yields merely under non stress conditions, C those with acceptable yields merely under stress conditions and D genotypes with low yields under both conditions. According to Fernandez, the most suitable index for selection of drought-resistant genotypes was the one that could distinguish class A from other classes, as the yield stability of genotypes in this class is higher.

Fischer and Maurer (1978) suggested Stress Susceptibility Index (SSI) for yield stability measurement that apprehended the changes in both potential and actual yields in variable environments. The SSI can be calculated based on the equation:

$$SSI = [1-(Y_s/Y_p)]/SI$$

where, $Y_p$ is the yield of a genotype under favorable conditions, $Y_s$ is the yield of same genotype under stress conditions and SI is stress severity index which varies between 0 and 1 and can be calculated by the equation:

$$SI = 1-(\bar{Y}_S)/(\bar{Y}_P)^2$$

where, $\bar{Y}_P$ and $\bar{Y}_S$ are the average seed yields of that genotype under stress and non stress conditions, respectively. The stress severity was calculated for treatments, in vegetative growth, florescence and seed-filling stages using the above-mentioned equation.

Rosielle and Hamblin (1981) offered Tolerance Index (TI) as an criterion for determination of yield difference under stress ($Y_s$) and no-stress ($Y_p$) conditions and Mean Productivity (MP) as an estimation of average $Y_s$ and $Y_p$ yields calculated as follows:

$$TOL = (Y_P - Y_S)$$

$$MP = (Y_P + Y_S)/2$$

The selection for stress-tolerance is accompanied with the least difference between $Y_p$ and $Y_s$. On the other hand, a high TOL indicates higher susceptibility of the genotypes to drought stress. Therefore, to select the favorite genotypes, a lower TOL rate is considered as a suitable criterion (Rosielle and Hamblin, 1981). Selection based on Mean Productivity (MP) index under stress and no-stress conditions is accompanied with a higher numerical rate for the index. Stress Tolerance Index (STI) was applied by Fernandez (1992) to discriminate the high yield genotypes under stress conditions:

$$STI = (Y_P).(Y_S)/(\bar{Y}_P)^2$$

Also, the Geometric Mean Productivity (GMP) introduced by Fernandez (1992) calculated through the following equation:

$$GMP = \sqrt{Y_P.Y_S}$$

The harmonic mean (HAR) can be obtained through the following equation as applied by Baheri *et al.* (2003):

$$HAR = 2(Y_P - Y_S)/(Y_P + Y_S)$$

The purpose of this research was to determine water stress tolerance of several corn genotypes and to this end, stress tolerance indices were applied to estimate their yields under the conditions with and without stress, so that the most appropriate stress tolerance index or indices together with the superior genotype could be introduced.

## MATERIALS AND METHODS

The present investigation was carried out during 2007 growing season in Moghan Agriculture and Natural Resource Research Center, Ardabil Province, latitudes of 39°, 40'-42' and longitudes of 47°, 31-33', at the altitudes of 45 to 50 m above sea level. Based on statistical climatologic data from Pars Abad Synoptic Meteorological Station, the district is of mild semi-arid climate with mild winters and warm summers. The maximal (31.4°C) and the minimal (1.4°C) temperatures have been reported in August and January, respectively and an average of 389.5 mm annual rainfall.

The experiment was set up as a split block based on completely randomized block design with three replications. The main factor was irrigational regime with 4 levels: (1) full irrigation based on plant water requirement and regional custom; (2) irrigation cessation in vegetative stage (cease of irrigation after emergence until the appearance of crown flower and restart irrigation afterward); (3) cease of irrigation in florescence stage (since the appearance of crown flower until the end of pollination and restart irrigation afterward; (4) cease of irrigation during seed filling period (irrigate until the end of pollination and cease irrigations till the end of growth season). The irrigational regimes were considered as vertical stripes (main plots). The second factor was corn genotype with 7 late- and mid-mature corn genotypes (SC 704, SC 724, SC 647, SC 720, SC 700, SC 703 and TWC 600) considered as horizontal stripes (sub plots).

The tillage practices were plowing, disking, leveler, furrowing, fertilizing and plotting. Each experimental plot included 4 lines of 75 cm distant from each other and 5.76 m in length. In each plot 32 seeds were sown by hand in 18 cm distances (75,000 plants per hectare). In order to avoid border effects, two lateral lines and also the plants in the 25 cm border stripes were omitted and only two central lines of each plot were harvested. The rates of water entered in and flown out from each plot were measured using a W.S.C. flume.

SSI, TOL, MP, GMP, STI and HAR indices were calculated for each irrigation regime after determination of seed yields under conditions with and without stress. The correlations among the indices in each of the irrigational regimes were also analyzed. Data were analyzed using MSTATC software and three-dimensional graphs for each irrigational and each genotype were drawn in the limits of A, B, C and D using STATGRAPH software.

## RESULTS AND DISCUSSION

The rates of $Y_p$, $Y_s$, as well as other drought tolerance indices for the studied cultivars are shown in Table 1-3. The maximal rate of the stress severity indicated as SI and incorporated in stress susceptibility index formula can be 1.00. In our experiments, the rates of SIs for stress treatments in vegetative, florescence and seed filling stages were 0.27, 0.51 and 0.39, respectively (Table 1-3). The less numerical rate of SSI would mean less stress susceptibility and more water stress tolerance of a genotype. In other words, the closer quantitative rate of $Y_s$ to $Y_p$ means less susceptibility of a given genotype to drought. It was demonstrated that the hybrids SC720 and SC724 had the least SSI rates (0.431 and 0.675,

Table 1: Stress tolerance indices of grain yields (t ha$^{-1}$) for maize hybrids under normal irrigation and water stress conditions in vegetative stage (SI = 0.27)

| Hybrids | $Y_P$ (t ha$^{-1}$) | $Y_{S1}$ (t ha$^{-1}$) | SSI | TOL | MP | GMP | STI | HAR |
|---|---|---|---|---|---|---|---|---|
| SC703 | 12.317 | 8.92 | 1.038 | 3.397 | 10.618 | 10.482 | 0.754 | 10.348 |
| SC700 | 12.204 | 7.869 | 1.327 | 4.348 | 10.03 | 9.792 | 0.658 | 9.558 |
| SC720 | 11.323 | 10.025 | 0.431 | 1.298 | 10.674 | 10.654 | 0.779 | 10.633 |
| SC647 | 12.434 | 6.285 | 1.861 | 6.149 | 9.359 | 8.84 | 0.536 | 8.351 |
| SC724 | 11.299 | 9.272 | 0.675 | 2.027 | 10.285 | 10.235 | 0.719 | 10.186 |
| TWC600 | 11.251 | 8.878 | 0.794 | 2.327 | 10.065 | 9.994 | 0.685 | 9.924 |
| SC704 | 13.683 | 10.384 | 0.907 | 3.301 | 12.035 | 11.921 | 0.975 | 11.806 |
| Mean | 12.073 | 8.865 | 1.006 | 3.263 | 10.438 | 10.274 | 0.729 | 10.115 |

$Y_P$: Potential yield, $Y_S$: Yield under stress, SSI: Stress susceptibility index, TOL: Tolerance, MP: Mean productivity, GMP: Geometric mean productivity, STI: Stress tolerance index, HAR: Harmonic mean

Table 2: Stress tolerance indices of grain yield (t ha$^{-1}$) for maize hybrids under normal irrigation and water stress conditions in florescence stage (SI = 0.51)

| Hybrids | $Y_P$ (t ha$^{-1}$) | $Y_{S2}$ (t ha$^{-1}$) | SSI | TOL | MP | GMP | STI | HAR |
|---|---|---|---|---|---|---|---|---|
| SC703 | 12.317 | 3.763 | 1.350 | 8.554 | 8.040 | 6.808 | 0.318 | 5.763 |
| SC700 | 12.204 | 4.722 | 1.191 | 7.482 | 8.463 | 7.591 | 0.395 | 6.809 |
| SC720 | 11.323 | 4.987 | 1.087 | 6.336 | 8.155 | 7.515 | 0.387 | 6.925 |
| SC647 | 12.434 | 8.318 | 0.643 | 4.116 | 10.376 | 10.170 | 0.710 | 9.966 |
| SC724 | 11.299 | 5.754 | 0.953 | 5.545 | 8.526 | 8.063 | 0.446 | 7.617 |
| TWC600 | 11.251 | 5.26 | 1.034 | 5.991 | 8.256 | 7.693 | 0.406 | 7.169 |
| SC704 | 13.685 | 8.254 | 0.771 | 5.431 | 10.969 | 10.628 | 0.775 | 10.297 |
| Mean | 12.073 | 5.856 | 1.004 | 6.207 | 8.969 | 8.352 | 0.491 | 7.792 |

$Y_P$: Potential Yield, $Y_S$: Yield under stress, SSI: Stress susceptibility index, TOL: Tolerance, MP: Mean productivity, GMP: Geometric mean productivity, STI: Stress tolerance index, HAR: Harmonic mean

Table 3: Stress tolerance indices of grain yield (t ha$^{-1}$) for maize hybrids under normal irrigation and water stress conditions in seed filling stage (SI = 0.39)

| Hybrids | $Y_P$ (t ha$^{-1}$) | $Y_{S3}$ (t ha$^{-1}$) | SSI | TOL | MP | GMP | STI | HAR |
|---|---|---|---|---|---|---|---|---|
| SC703 | 12.317 | 3.763 | 1.259 | 6.176 | 9.229 | 8.697 | 0.519 | 8.196 |
| SC700 | 12.204 | 4.722 | 1.011 | 4.916 | 9.746 | 9.431 | 0.61 | 9.126 |
| SC720 | 11.323 | 4.987 | 0.94 | 4.238 | 9.204 | 8.957 | 0.55 | 8.716 |
| SC647 | 12.434 | 8.318 | 0.946 | 4.683 | 10.092 | 9.817 | 0.661 | 9.549 |
| SC724 | 11.299 | 5.754 | 0.822 | 3.699 | 9.45 | 9.267 | 0.589 | 9.088 |
| TWC600 | 11.251 | 5.26 | 1.168 | 5.235 | 8.634 | 8.227 | 0.464 | 7.84 |
| SC704 | 13.685 | 8.254 | 0.864 | 4.709 | 11.166 | 10.949 | 0.822 | 10.84 |
| Mean | 12.073 | 7.265 | 1.022 | 4.761 | 9.645 | 9.335 | 0.602 | 9.05 |

$Y_P$: Potential yield, $Y_S$: Yield under stress, SSI: Stress susceptibility index, TOL: Tolerance, MP: Mean productivity, GMP: Geometric mean productivity, STI: Stress tolerance index, HAR: Harmonic mean

respectively) and were the most tolerant hybrids under irrigation cessation conditions in growth stage. These hybrids had their yields lower than the average yield under non-stress conditions and located in the class C based on Fernandez model. At this stage, SC647 and SC700 with SSI rates of 1.831 and 1.337 were discerned as the most susceptible hybrids.

With the water cease treatment in florescence stage, the hybrids SC647, SC704 and SC724 had the SSI rates of 0.643, 0.771 and 0.953, respectively. The comparison of the yields from these hybrids with the average yields under stress and non-stress conditions, indicate less yield difference compared with other hybrids under similar conditions. At this stage, the hybrids SC647 and SC704 were classified in class A, while SC724 was placed in class D. The most susceptible hybrids in florescence stage were SC720, SC703 and SC700, respectively with SSI rates of 1.087, 1.350 and 1.191 (Table 2).

In seed filling stage, the hybrids SC724 and SC704 with SSI rates of 0.822 and 0.864, respectively were the most stress tolerant hybrids. Based on Fernandez model, these hybrids were classified in classes C and A, respectively. The most susceptible hybrids at this stage were SC703, TWC600 and SC700 with SSI rates of 1.259, 1.168 and 1.011, respectively (Table 3).

Evaluation of hybrids using TOL showed higher rates of TOL infer to more changes in hybrids yield under stress and non-stress conditions. Considering TOL index, a hybrid would be more tolerant if it has got less TOL. Therefore, selection for tolerance would be accompanied with minimal difference between $Y_s$ and $Y_p$. Using TOL demonstrated that hybrids SC720, SC724, TWC600 had TOL rates equal to 1.298, 2.027 and 2.327, respectively and were the most tolerant hybrids in growth stage and classified in class C. These hybrids produced lower yields than the average under normal irrigation conditions. Among the above-mentioned hybrids, hybrid SC720 showed less yield changes under both conditions and was the most tolerant hybrid. The hybrids SC647 and SC700 with TOL rates of 6.149 and 4.709 at this stage were less tolerant and produced yields higher than the average under normal conditions (Table 1).

In the stage of florescence, the hybrids SC647, SC724, TWC600 and SC704 were the most tolerant hybrids. The hybrids SC703 and SC700 were the most drought susceptible at this stage. In seed filling stage, the hybrid SC724 was also the most tolerant and SC703 the most susceptible hybrid (Table 3).

Based on MP index, among studied hybrids, SC704, SC720 and SC703 had yields of 12.035, 10.674 and 10.618, respectively and were more tolerant under stress conditions in growth stage. Among these hybrids, SC704 and SC703 were grouped in class A because their yields were higher than the average under both stress and non stress conditions, while SC720 was in class C and had a yield lower than average under normal conditions. At this stage, the hybrids SC647, SC700, TWC600 were the most drought susceptible hybrids, respectively (Table 1). The hybrids SC704 and SC647 had higher MP rates than other genotypes under water stress conditions in florescence stage. These hybrids produced higher yields than average and were placed in class A (Table 2). In seed filling stage, the hybrids SC704 and SC647 were selected as the most tolerant hybrids considering their mean yields. These hybrids had higher yields than average under both stress and non-stress conditions and the rates of their yields changes were less. At this stage, the hybrids TWC600 and SC720 with MP values of 8.634 and 9.204 were the most susceptible cultivars, respectively (Table 3).

Considering yields of the hybrids (Table 1-3) and calculating their related STI index, under water cease conditions in growth stage, the hybrids SC704 and SC703 were grouped in class A, while the hybrids SC647 and SC700 were placed in class B and the hybrids SC600, SC724 and SC720 were discerned as class C. Under water stress conditions in florescence stage, the hybrids SC704 and SC647 were placed in class A, SC700 and SC703 in class B and SC600, SC724 and SC720 in class D. The hybrids in class A had yields higher than the average under both conditions. Thus, the higher STI values in all three stages belong to the hybrid SC704.

The results from the analysis of simple correlation coefficients between drought tolerance indices and seed yields under each of water stress conditions (Table 4-6)

Table 4: Correlation coefficients between yield potential, yield under water stress at the vegetative stage and water tolerance indices ($Y_P$, $Y_{S1}$, SSI, TOL, MP, GMP, STI and HAR)

| Treats | $Y_P$ | $Y_{S1}$ | SSI | TOL | MP | GMP | STI | HAR |
|---|---|---|---|---|---|---|---|---|
| $Y_P$ | 1 | 0.0277ns | 0.4267ns | 0.5233ns | 0.5584ns | 0.4243ns | 0.4659ns | 0.3212ns |
| $Y_{S1}$ | - | 1 | -0.8920ns | -0.8373* | 0.8446* | 0.9162** | 0.8971** | 0.9534** |
| SSI | - | - | 1 | 0.9936** | -0.5116ns | -0.6362ns | -0.6007ns | -0.7158ns |
| TOL | - | - | - | 1 | 0.4146ns | -0.5490ns | -0.5108ns | -0.6371ns |
| MP | - | - | - | - | 1 | 0.9887** | 0.9941** | 0.9636** |
| GMP | - | - | - | - | - | 1 | 0.9984** | 0.9935** |
| STI | - | - | - | - | - | - | 1 | 0.9862** |
| HAR | - | - | - | - | - | - | - | 0.1 |

*and **: significant at 5 and 1% probability levels, respectively, ns: Non- significant

Table 5: Correlation coefficients between yield potential, yield under water stress at the florescence stage and water tolerance indices ($Y_P$, $Y_{S2}$, SSI, TOL, MP, GMP, STI and HAR)

| Treats | $Y_P$ | $Y_{S2}$ | SSI | TOL | MP | GMP | STI | HAR |
|---|---|---|---|---|---|---|---|---|
| $Y_P$ | 1 | 0.5758ns | 0.1563ns | -0.0879ns | 0.7941* | 0.6835ns | 0.7119ns | 0.6141ns |
| $Y_{S2}$ | - | 1 | 0.4156ns | -0.8669** | 0.9531** | 0.9890** | 0.9829** | 0.9972** |
| SSI | - | - | 1 | 0.5994ns | -0.2502ns | -0.3473ns | -0.3285ns | -0.9510** |
| TOL | - | - | - | 1 | -0.6753ns | -0.7862* | -0.7615* | -0.8384* |
| MP | - | - | - | - | 1 | 0.9858** | 0.9918** | 0.9663** |
| GMP | - | - | - | - | - | 1 | 0.9989** | 0.9958** |
| STI | - | - | - | - | - | - | 1 | 0.9909** |
| HAR | - | - | - | - | - | - | - | 1 |

*and **: significant at 5 and 1% probability levels, respectively, ns: Non- significant

Table 6: Correlation coefficients between yield potential, yield under water stress at the grain filling stage and water tolerance indices ($Y_P$, $Y_{S3}$, SSI, TOL, MP, GMP, STI and HAR)

| Treats | $Y_P$ | $Y_{S3}$ | SSI | TOL | MP | GMP | STI | HAR |
|---|---|---|---|---|---|---|---|---|
| $Y_P$ | 1 | 0.6324ns | -0.1534ns | 0.1812ns | 0.8961** | 0.8369* | 0.8121* | 0.7596* |
| $Y_{S3}$ | - | 1 | -0.8733* | -0.6472ns | 0.9275** | 0.9655** | 0.9606** | 0.9840** |
| SSI | - | - | 1 | 0.9519** | -0.6289ns | -0.7169ns | -0.7037ns | -0.7725* |
| TOL | - | - | - | 1 | -0.3154ns | -0.4265ns | -0.4224ns | -0.5020ns |
| MP | - | - | - | - | 1 | 0.9928** | 0.9936** | 0.9788** |
| GMP | - | - | - | - | - | 1 | 0.9988** | 0.9962** |
| STI | - | - | - | - | - | - | 1 | 0.9946** |
| HAR | - | - | - | - | - | - | - | 1 |

*and **: significant at 5 and 1% probability levels, respectively, ns: Non- significant

indicated the positive and significant correlations between STI and seed yields under water stress conditions in growth, florescence and seed filling stages with r values of 0.89**, 0.98** and 0.96**, respectively. Therefore, the STI index is highly capable in selection of stress tolerant hybrids. In addition to the correlations between the indices MP, GMP, STI and HAR there were also high correlations among these indices.

Therefore, only STI index was applied to design three-dimensional graphs (Fig. 1a-c). According to the graphs, under stress conditions SC704 in growth stage, SC704 and SC647 in florescence stage and SC704 in seed filling stage were placed in class A. The hybrid SC704 had high yields under both stress and non-stress conditions and is therefore, the most tolerant hybrid under all three water stress stages.

It is feasible to classify the studied hybrids based on their seed yields under stress and non-stress conditions into four classes, A (with yields higher than average under both conditions), B (with yields higher than average under non-stress conditions), C (with yields higher than average under stress conditions) and D (with yields lower than average under both conditions). According to Fernandez (1992), the best criterion is the one that is capable to distinguish the class A from other classes.

Using SSI index ends to select the tolerant and low-yielding cultivars with less yield changes under both conditions. Referring to the yield rates of selected hybrids in each of the three stages (Table 1-3), it was illustrated that the SSI index is not successful in discrimination of A class genotypes from other classes. On the other hand, the comparison of SSI indices in three stages ended in paradoxical results with tolerant hybrids. For instance, in growth stage, SC647 was among the most susceptible cultivars, while the same hybrid shown as the most tolerant hybrid in florescence stage. In other words, based on Fernandez model, the hybrid SC647 is selected as a member of class D in growth stage, but it belonged to class A in florescence stage. Thus, it is better to use SSI index for the omission of susceptible cultivars and not for selection of stress tolerant cultivars. Moghaddam and Hadizadeh (2002) obtained similar results on this subject. It was illustrated that TOL has not been successful with

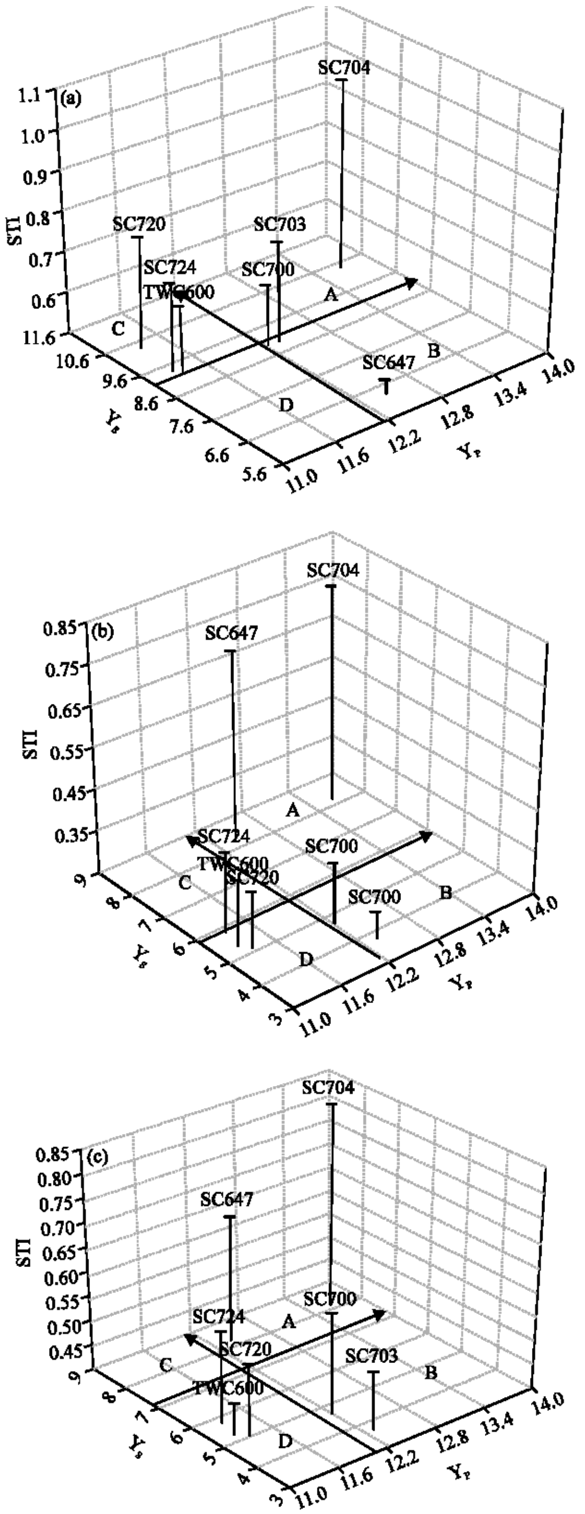


Fig. 1: Relationship between STI, $Y_P$ and $Y_S$ under stress in (a) vegetative, (b) florescence and (c) seed filling stages for different maize hybrids

selection of high-yielding genotypes under both conditions and has ended to low-yielding and tolerant hybrids. This index brought no success with discrimination of the class A from other classes. Jafari *et al.* (2009) also reported that TOL had succeeded in selecting genotypes with high yield under stress, but had failed to select genotypes with proper yield under both environments.

With an eye to the above-mentioned results and also to the positive significant correlations between SSI and TOL indices (r rates equal to 0.95*, 0.59* and 0.99* under water cease stress conditions in growth, florescence and seed filling stages, respectively), it can be concluded that these two indices are of equal potentials in discriminating of hybrid classes.

Totally, in all three stages of growth, florescence and seed filling studied, the hybrid SC704 was selected as the most water stress tolerant cultivar based on MP index. Therefore, MP ended to the selection of the cultivars of high yields under both stress and non-stress conditions. The results of this research are in agreement with those obtained by Ahamadzade (1997) and Moghaddam and Hadizadeh (2002), who declared that MP acts better than SSI and TOL indices in the selection of stress tolerant hybrids.

STI index was calculated based on geometric mean of yield under water stress and non water stress (Fernandez, 1992). The mathematical basis of this index is so that if the difference between two rates averaged is high, the geometrical mean will approach toward a smaller figure. Hence, this index is of high efficiency in the selection of stress tolerant hybrids. The higher rate of STI index infers to more drought stress tolerance of a genotype. Referring to the yield of this hybrid, it became clear that the index STI was completely successful in selection of high yielding cultivars under both conditions with and without stress and correlated well with yield under both conditions (Table 4-6). Based on this index, the hybrid SC647 in growth stage, the hybrid SC703 in florescence and the hybrid TWC600 seed filling were the most drought susceptible hybrids. It seems that these findings are in agreement with Sio-Se-Mardeh *et al.* (2006).

In this study, MP, GMP, STI and HAR indices (especially STI) were successful in selection of high yielding drought tolerant hybrids and are recommended as suitable indices. Jafari *et al.* (2009) in their studies on seed corn hybrids found that STI and GMP indices showed the highest correlation with grain yield under both optimal and stress conditions and can be used as the best indices for maize breeding programs to introduce drought tolerant hybrids.

Similar results were obtained by Baheri *et al.* (2003) who worked on barley and found MP, GMP, HAR and STI as preferred criteria in selection of drought tolerant genotypes. Similarly, Fernandez (1992) introduced the indices GMP and STI as superior criteria in selection of drought tolerant bean genotypes. Also, similar results have been obtained by Shiri *et al.* (2010) and Moghaddam and Hadizadeh (2002).


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