THE EVALUATION OF WATER STRESS IN MAIZE (*ZEA MAYS* L.) USING SELECTION INDICES

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ABSTRACT

Drought is one of the major problems that affect crops, including maize, in the Romanian region of Oltenia. As a result, the identification of maize hybrids with high yielding potential and drought tolerance are important breeding objectives. In order to identify such maize hybrids 20 Romanian maize hybrids were studied in yield trials at the Agricultural Research and Development Station (ARDS) of Şimnic, during three years (2003-2005) at different water availability conditions (irrigated and non-irrigated) in randomized blocks, with three replications. In order to evaluate the drought tolerance/susceptibility, six indices of selection were used: mean productivity (MP), geometric mean productivity (GMP), stress tolerance (TOL), stress susceptibility index (SSI), stress tolerance index (STI) and harmonic mean (HAR). The best indices for both conditions (irrigated and non-irrigated) proved to be MP, GMP, STI and HAR. The TOL and SSI were good predictors for non-irrigation conditions only. The tolerance of the researched hybrids depended on the severity of the water stress. The following hybrids were the most tolerant at severity water stress (SI = 0.78): Neptun, Oana, Ileana, Rapsodia, Campion and Cocor.

Key words: maize hybrids, selection indices, tolerance, water stress, *Zea mays* L.

INTRODUCTION

Within Oltenia region, maize occupies the first place among the field crops. The climatic regime of this zone is continental temperate, with a plain specific, with sub Mediterranean influence. The average values of temperatures are between 10.0 and 11.8°C and the rainfall reaches 500-550 mm. Because in this zone drought is rather frequent, only two years of ten are favorable for maize (Urechean et al., 2008). Taking this into account, the main objectives of maize breeding for this zone, besides yielding capacity, are yield stability and drought tolerance.

The goal of this study was to evaluate the effects of the water stress on the yield of 20 Romanian maize hybrids grown in Oltenia and to compare the efficiency of six selection indices in identifying the tolerant hybrids. Stress indices based on loss of yield under stress conditions in comparison to normal conditions have been used for screening stress tolerant genotypes (Mitra, 2001).

Many indices for stress tolerance evaluation have been proposed. Rosielle and Hamblin (1981) proposed the stress tolerance index (TOL) and defined it as the difference between the yield obtained in no-stress conditions (Yp) and the one obtained in stress conditions (Ys), and the mean productivity (MP), that was defined as the average between Yp and Ys. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI). The genotypes with high values of TOL and SSI are susceptible to stress and this is why selection for tolerance has to be made on the basis of the lowest values of these indices. Golabadi et al. (2006) showed that the selection based on these two indices favors the genotypes with low yields in no-stress conditions and high yields in stress conditions.

Fernandez (1992), introduced a new index of selection, called stress tolerance index (STI) that can be used in order to identify the genotypes with high and stable yields both in stress and no-stress conditions. Other estimations for stress tolerance, based on yields, are GMP and HAR (Fernandez,

1992; Kristin et al., 1997; Ramirez and Kelly, 1998; Baheri et al., 2003).

Higher values of MP, GMP, HAR and STI indicate better drought tolerance (Fernandez, 1992; Golobadi et al., 2006; Sio-Se Mardeh et al., 2006). These indices of selection have been used for evaluation of drought tolerance in maize by Khalili et al. (2004), Moghaddam and Hadizadeh (2002), Jafari et al. (2009), Shirinzadeh et al. (2010), Golbashy et al. (2010). Fernandez (1992) classified the genotypes based on their performances, in four groups: group A – genotypes with good results, similar for both conditions (stress and non-stress); group B – genotypes with good results only in no-stress conditions; group C – genotypes with good results only in stress conditions; group D – genotypes with low results in both conditions.

MATERIAL AND METHODS

The data were obtained in field yield trials performed at ARDS Simnic in 2003, 2004 and 2005 in irrigated and non-irrigated conditions. The grain yield was calculated at standard moisture and used as Yp (for irrigated) and Ys (for non-irrigated conditions). The six indices of water stress tolerance were calculated for each hybrid and every year, using the following formulas:

1. Mean productivity (MP) (Rosielle and Hamblin, 1981):
   $$MP = (Ys + Yp)/2$$
2. Geometric mean productivity (GMP) (Fernandez, 1992):
   $$GMP = (\sqrt{Ys \cdot Yp})$$
3. Tolerance index (TOL) (Rosielle and Hamblin, 1981):
   $$TOL = (Yp - Ys)$$
4. Stress susceptibility index (SSI) (Fischer and Maurer, 1987):
   $$SSI = 1 - (Ys/Yp)/SI, \text{ where (SI), the}$$
   intensity stress, can vary from 0 to 1 and is calculated as: $SI = 1 - (Ysi/Ypi)$
5. Stress tolerance index (STI) (Fernandez, 1992):
   $$STI = (Yp) \times (Ys)/(Ypi)^2$$
6. Harmonic mean (HAR) (Kristin et al., 1997):
   $$HAR = 2 (Yp \times Ys)/(Yp + Ys),$$

where, Yp = yield of a genotype in irrigated condition Ys = yield of a genotype in non-irrigated condition, Ypi = mean yield in irrigated condition, Ysi = mean yield in non-irrigated condition

The relations between yield (Yp and Ys) and the six selection indices were analyzed using simple correlation coefficients (r) (Săulescu and Săulescu, 1967).

Hybrids with values higher than the mean for each of the drought tolerance indices were selected, and the suitability of each index was estimated based on the correspondence of the selected hybrids with the hybrids that were above the average both in irrigated (Yp) and water stress conditions (Ys), as suggested by Fernandez (1992).

RESULTS AND DISCUSSION

The values of the yields obtained under irrigation (Yp) and non-irrigated conditions (Ys), as well water stress tolerance indices for the researched hybrids during three years of trials are presented in tables 1, 4 and 7.

During 2003, in severe drought conditions (SI = 0.78) (Table 1) the grain yield varied from 7.39 t/ha (Saturn) to 11.47 t/ha (Campion) in irrigation conditions and from 0.92 t/ha (Rapid) to 2.61 t/ha (Neptun) in non-irrigated conditions. The average yield under irrigation was 8.81 t/ha while in non-irrigated conditions was of 1.94 t/ha, with a decrease of 78%.

The selection of hybrids on the Yp and Ys values and the stress tolerance indices is presented in the table 2.

Using the approach of Fernandez, six hybrids were placed in group A (Campion, Neptun, Ileana, Rapsodia, Cocor, Oana) because their yields were higher than the mean in both conditions, four hybrids were placed in group B (Andreea, Olimp, Paltin, Şoim) because they gave higher yields only in irrigated conditions, five hybrids were placed in group C (Oituz, Granit, Olt, F376, Faur) because they gave higher yields only in non-irrigated conditions and five hybrids were placed in group D (Saturn, Opal, F322, Panciu, Rapid) because they gave lower yields in both conditions.

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Table 1. The estimation of stress tolerance in studied hybrids at ARDS Şimnic under severe drought conditions
(SI = 0.78) in 2003

Hybrid	Y_P	Y_S	MP	GMP	TOL	SSI	STI	HAR
Saturn	7.39	1.70	4.55	3.54	5.69	0.99	0.16	2.76
Oana	8.84	2.57	5.68	4.71	6.33	0.92	0.29	3.91
Olimp	8.99	1.90	5.45	4.13	7.09	1.01	0.22	3.14
Oituz	8.61	2.01	5.31	4.16	6.60	0.98	0.22	3.26
Neptun	9.83	2.61	6.22	5.06	7.22	0.94	0.33	4.12
Andreea	9.67	1.81	5.74	4.18	7.86	1.04	0.23	3.05
Ileana	9.36	2.15	5.76	4.49	7.21	0.99	0.26	3.50
Opal	7.91	1.65	4.78	3.61	6.26	1.01	0.18	2.73
Paltin	9.00	1.49	5.25	3.66	7.51	1.07	0.17	2.56
F322	7.73	1.23	4.48	3.08	6.50	1.08	0.12	2.12
Rapid	8.28	0.92	4.60	2.76	7.36	1.14	0.10	1.66
Şoim	8.84	1.25	5.05	3.32	7.59	1.10	0.14	2.19
Panciu	8.45	1.55	5.00	3.62	6.90	1.05	0.17	2.62
Granit	8.63	2.58	5.61	4.72	6.05	0.90	0.29	3.97
Olt	8.64	2.24	5.44	4.40	6.40	0.95	0.25	3.56
Rapsodia	9.21	2.17	5.69	4.47	7.04	0.98	0.26	3.51
F376	8.32	2.45	5.39	4.51	5.87	0.90	0.26	3.79
Faur	8.08	2.18	5.13	4.20	5.90	0.94	0.23	3.43
Campion	11.47	2.19	6.83	5.01	9.28	1.04	0.32	3.68
Cocor	9.01	2.11	5.56	4.36	6.90	0.98	0.25	3.42
Mean	8.81	1.94	5.38	4.10	6.88	1.00	0.22	3.15

Yp – grain yield under irrigated conditions, Ys – grain yield under non-irrigated conditions; MP – mean productivity;
GMP – geometric mean productivity; TOL – stress tolerance; SSI – stress susceptibility index; STI – stress tolerance index,
HAR – harmonic mean.

Table 2. Maize hybrids selected on the basis of stress tolerance indices in severe drought conditions
(SI = 0.78) during 2003 at ARDS Şimnic

Indices	Hybrids selected
Yp	Campion, Neptun, Andreea, Ileana, Rapsodia, Cocor, Paltin, Olimp, Oana, Şoim,
Ys	Neptun, Granit, Oana, F378, Olt, Campion, Faur, Rapsodia, Ileana, Cocor, Oituz
MP	Campion, Neptun, Ileana, Andreea, Rapsodia, Oana, Granit, Cocor, Olimp, Olt, F376
GMP	Neptun, Campion, Granit, Oana, F376, Ileana, Rapsodia, Olt, Cocor, Faur, Andreea, Oituz, Olimp
TOL	Saturn, F376, Faur, Granit, Opal, Oana, Olt, F322, Oituz
SSI	Granit, F376, Oana, Neptun, Faur, Olt, Rapsodia, Cocor, Oituz, Ileana, Saturn
STI	Neptun, Campion, Oana, Granit, F376, Rapsodia, Ileana, Olt, Cocor, Andreea, Faur
HAR	Neptun, Granit, Oana, F376, Campion, Olt, Rapsodia, Ileana, Faur, Cocor, Oituz

On the basis of MP index, six hybrids from group A, two hybrids from group B and three from group C were selected. Out of the hybrids selected using GMP index, six hybrids were placed in group A, two hybrids in group B and five hybrids in group C.

Using TOL index, a single hybrid from the group A, five hybrids from group C and three hybrids from group D were selected. The hybrids selected on the basis of SSI index, included five hybrids from group A, five hybrids from group C and one hybrid from group D. On the basis of STI index six hybrids from group A, four hybrids in group C and one hybrid in group B were selected, and by using HAR index six hybrids included in

group A and five hybrids from group B were selected.

According to Fernandez (1992), the best criterion of selection is the one capable to distinguish genotypes from group A apart of genotypes from other groups (B, C, D). As a result, the selection capacity of MP, GMP, STI and HAR to separate all hybrids from group A apart of the other hybrids makes them the best predictors of high yields with both water conditions, including the drought tolerance. The SSI index was a less good predictor for group A hybrids, yet both SSI and TOL indices were better predictors of higher yielders for non-irrigated conditions (group C). Similar results were obtained by Jafari et al. (2009) and by Golabadi et al. (2006).

In order to identify the best selection criterion for water stress tolerance simple correlation coefficients (r) between Yp, Ys and the six selection indices were calculated (Tables 3, 6 and 9).

In severe drought conditions (SI = 0.78), the strongest correlations were recorded between Ys and (MP, GMP, SSI, STI and HAR) (r = 0.692**, r = 0.950**, r = -0.923^{00}, r = 0.943**, respectively r = 0.995**). These associations demonstrate that the selection of hybrids based on MP, GMP, STI and HAR could improve the yields in non-irrigated conditions and less in irrigated conditions.

Other strong positive correlations were recorded between GMP and (MP, STI and HAR) (r = 0.879**, r = 0.996**, respectively r = 0.973**) and strong negative correlations were recorded between SSI and (GMP, STI and HAR) (r = -0.763^{00}, r = -0.745^{00}, respectively r = -0.889^{00}).

Table 3. Correlation coefficients between tolerance indices and grain yield (Yp, Ys)
in severe drought conditions (SI = 0.78)

Indices	Yp	Ys	MP	GMP	TOL	SSI	STI	HAR
Yp	-	0.047	0.236	0.129	0.268	0.046	0,137	0.063
Ys		-	0.692**	0.950**	-0.196	-0.923^{00}	0.943**	0.995**
MP			-	0.879**	0.570**	-0.368	0.888**	0.749**
GMP				-	0.113	-0.763^{00}	0.996**	0.973**
TOL					-	0.551*	0.134	-0.114
SSI						-	-0.745^{00}	-0.889^{00}
STI							-	0.966**
HAR								-

* significant at 5% probability level;
** significant at 1% probability level.

During 2004 (Table 4), with a relatively severe water stress (SI = 0.57) the grain yield varied from 8.06 t/ha (Olt) to 11.91 t/ha (Neptun) in irrigation conditions and from 3.23 t/ha (Andreea) to 4.64 t/ha (Rapid) in non-irrigated conditions.

The average yield was of 9.38 t/ha for Yp and 3.99 t/ha for Ys, indicating a decrease of 57% in water stress conditions.

The hybrids selected (higher values than the mean) according to Yp, Ys and drought tolerance indices are presented in the table 5.

According to Fernandez' model, nine hybrids were placed in group A (Oituz, Rapid, Panciu, Ileana, Şoim, Opal, Paltin, Faur, F322), no hybrid in group B, four hybrids in group C (Oana, Olt, Rapsodia, F376) and seven hybrids were placed in group D (Saturn, Olimp, Neptun, Andreea, Granit, Campion, Cocor).

Among the hybrids selected on MP and GMP basis, nine hybrids were placed in group A, and one hybrid in group C (Table 5). On the basis of TOL index there two hybrids in group A, four hybrids in group C and six hybrids within group D were selected. Based on SSI, two hybrids in group A, four hybrids in group C and one hybrid in group D were selected. Using STI nine hybrids from group A and one hybrid

from group C were selected, while on the basis of HAR index nine hybrids included in group A and two hybrids from group C were selected.

Table 4. The estimation of stress tolerance in studied hybrids at ARDS Şimnic
under relatively severe drought (SI = 0.57) in 2004

Hybrid	Y_P	Y_S	MP	GMP	TOL	SSI	STI	HAR
Saturn	8.33	3.54	5.94	5.43	4.79	1.01	0.34	4.97
Oana	8.15	4.34	6.25	5.95	3.81	0.82	0.40	5.66
Olimp	9.14	3.45	6.29	5.62	5.69	1.09	0.36	5.01
Oituz	11.91	4.40	8.16	7.24	7.51	1.11	0.60	6.43
Neptun	8.75	3.42	6.09	5.47	5.33	1.07	0.34	4.92
Andreea	8.51	3.23	5.92	5.27	5.38	1.10	0.32	4.70
Ileana	10.41	4.01	7.21	6.46	6.40	1.08	0.47	5.79
Opal	9.90	4.00	6.95	6.29	5.90	1.05	0.45	5.70
Paltin	9.64	4.50	7.07	6.59	5.14	0.94	0.49	6.14
F322	9.49	4.58	7.04	6.59	4.91	0.91	0.49	6.18
Rapid	11.11	4.64	7.88	7.18	6.47	1.02	0.59	6.55
Şoim	10.00	4.24	7.12	6.51	5.76	1.01	0.48	5.96
Panciu	10.81	4.00	7.41	6.58	6.81	1.11	0.49	5.84
Granit	8.27	3.43	5.85	5.33	4.84	1.03	0.32	4.85
Olt	8.06	4.10	6.08	5.75	3.96	0.86	0.38	5.45
Rapsodia	9.19	4.00	6.60	6.06	5.19	0.99	0.42	5.57
F376	9.36	4.30	6.83	6.34	5.06	0.95	0.46	5.89
Faur	9.56	4.05	6.81	6.22	5.51	1.01	0.44	5.69
Campion	8.25	3.82	6.04	5.61	4.43	0.94	0.36	5.22
Cocor	8.73	3.65	6.19	5.64	5.08	1.02	0.36	5.15
Mean	9.38	3.99	6.69	6.11	5.40	1.01	0.43	5.58

Yp – grain yield under irrigated conditions, Ys – grain yield under non-irrigated conditions; MP – mean productivity; GMP – geometric mean productivity; TOL – stress tolerance; SSI – stress susceptibility index; STI- stress tolerance index, HAR –harmonic mean.

Table 5. Maize hybrids selected on the basis of stress tolerance indices in relatively severe drought conditions
(SI = 0.57) during 2004 at ARDS Şimnic

Indices	Hybrids selected
Yp	Oituz, Rapid, Panciu, Ileana, Şoim, Opal, Paltin, Faur, F322
Ys	Rapid, F322, Paltin, Oituz, Oana, F376, Şoim, Olt, Faur, Ileana, Opal, Panciu, Rapsodia
MP	Oituz, Rapid, Panciu, Ileana, Şoim, Paltin, F322, Opal, F376, Faur
GMP	Oituz, Rapid, Paltin, F322, Panciu, Şoim, Ileana, F376, Opal, Faur
TOL	Oana, Olt, Campion, Saturn, Granit, F322, F376, Cocor, Paltin, Rapsodia, Neptun, Andreea
SSI	Oana, Olt, F322, Paltin, Campion, F376, Rapsodia
STI	Oituz, Rapid, Paltin, F322, Panciu, Şoim, Ileana, F376, Opal, Faur
HAR	Rapid, Oituz, F322, Paltin, Şoim, F376, Panciu, Ileana, Opal, Faur,Oana

As a results, in the conditions of this year, the best predictors of the grain yield for both conditions (irrigated, non-irrigated) proved to be MP, GMP, STI and HAR. These indices succeeded in identifying all nine hybrids from group A, while TOL and SSI indices were good predictors only for group C hybrids.

With relatively severe water stress conditions (SI = 0.57) strong correlations

between Yp and (MP, GMP, TOL, SSI, STI and HAR) were established (Table 6) and between Ys and (MP, GMP, STI and HAR). As a result, the selection on the basis of MP, GMP, STI and HAR should provide positive results for both water availability conditions.

Table 6. Correlation coefficients between tolerance indices and grain yield (Yp, Ys) in relatively severe drought conditions (SI = 0.57)

Indices	Yp	Ys	MP	GMP	TOL	SSI	STI	HAR
Yp	-	0.535*	0.964**	0.889**	0.921**	0.504*	0.898**	0.768**
Ys		-	0.782**	0.887**	0.241	-0.430	0.876**	0.962**
MP			-	0.981**	0.783**	0.215	0.982**	0.921**
GMP				-	0.660**	0.058	0.997**	0.976**
TOL					-	0.761**	0.674**	0.495*
SSI						-	0.082	-0.156
STI							-	0.968**
HAR								-

* significant at 5% probability level;
** significant at 1% probability level.

Table 7. The estimation of stress tolerance in studied hybrids at ARDS Şimnic under mild drought (SI = 0.14) in 2005

Hybrid	Y_P	Y_S	MP	GMP	TOL	SSI	STI	HAR
Saturn	10.17	7,61	8.89	8.80	2.56	1.80	0.66	9.17
Oana	11.28	9.99	10.64	10.61	1.29	0.82	0.97	10.60
Olimp	11.67	9.89	10.78	10.74	1.78	1.09	0.99	10.71
Oituz	13.22	11.63	12.43	12.40	1.59	0.86	1.32	12.37
Neptun	12.36	9.26	10.81	10.69	3.10	1.79	0.98	10.60
Andreea	10.90	8.48	9.69	9.61	2.42	1.59	0.79	9.54
Ileana	11.13	8.65	9.89	9.81	2.48	1.59	0.83	9.73
Opal	13.67	11.85	12.76	12.72	1.82	0.95	1.39	12.70
Paltin	12.84	12.05	12.45	12.44	0.79	0.44	1.33	12.43
F322	11.38	10.67	11.03	11.02	0.71	0.45	1.04	11.01
Rapid	13.62	11.70	12.66	12.62	1.92	1.01	1.37	12.59
Şoim	12.28	12.15	12.22	12.21	0.13	0.08	1.28	12.21
Panciu	12.88	12.19	12.54	12.53	0.69	0.38	1.35	12.53
Granit	10.32	10.27	10.30	10.29	0.05	0.03	0.91	10.32
Olt	14.36	11.97	13.17	13.11	2.39	1.19	1.48	13.06
Rapsodia	14.00	11.40	12.70	12,63	2.60	1.33	1.37	12.57
F376	15.00	11.05	13.03	12.87	3.95	1.88	1.42	12.73
Faur	11.79	11.13	11.46	11.46	0.66	0.40	1.13	11.45
Campion	13.02	11.93	12.48	12.46	1.09	0.60	1.33	12.45
Cocor	13.96	12.06	13.01	12.97	1.90	0.97	1.45	12.94
Mean	12.49	10.79	11.65	11.60	1.70	0.96	1.17	11.58

Yp – grain yield under irrigated conditions, Ys – grain yield under non-irrigated conditions; MP – mean productivity; GMP – geometric mean productivity; TOL – stress tolerance; SSI – stress susceptibility index; STI – stress tolerance index, HAR – harmonic mean.

In 2005 (Table 7) in mild water stress conditions (SI = 0.14), the yield in irrigated conditions varied from 10.17 t/ha (Saturn) to 15.00 t/ha (F376) and in non-irrigated conditions, from 7.61 t/ha (Saturn) to 12.19 t/ha (Panciu). The average yield in irrigated conditions was 12.49 t/ha and in non-irrigated conditions, 10.79 t/ha, indicating a decrease of 14%. The hybrids selected on the basis of Yp, Ys and the selection indices (with higher values than the mean) are presented in the table 8.

In the given water conditions, using the approach of Fernandez, ten hybrids were placed in group A (F376, Olt, Rapsodia, Cocor, Opal, Rapid, Oituz, Campion, Panciu, Paltin), no hybrid in group B, two hybrids in group C (Șoim and Faur) and eight hybrids in group D (Saturn, Oana, Olimp, Neptun, Andreea, Ileana, F322, Granit).

Among the hybrids selected on the basis of MP and GMP (Table 8), all ten hybrids were placed in group A, and one hybrid in group C. On the basis of TOL index four hybrids from group A, two hybrids from group C and three hybrids from group D were selected, and on the basis of SSI five hybrids from group A, two hybrids from group C and three hybrids group D were selected. Using STI and HAR all ten hybrids included in group A and one from group C were selected.

Under mild water stress conditions, MP, GMP, STI and HAR were the best predictors of group A, while TOL and SSI were the best predictors for group C hybrids.

Under mild water stress strong positive correlations between Ys and Yp, as well as between them and (MP, GMP, STI and HAR) (Table 9), means that the selection on the basis of these indices should give positive results for both water conditions. The negative correlation between Ys and (TOL, SSI) shows that the selection for high yields in non-irrigated conditions should be made on the basis of the lowest values of these indices.

Very strong correlations (close to 1.00) between MP and GMP, between GMP and STI as well as between STI and HAR suggest that these indices contain the same information, and their use conducts to similar results.

Table 8. Maize hybrids selected on the basis of stress tolerance indices in mild drought conditions
(SI = 0.14) during 2005 at ARDS Șimnic

Indices	Hybrids selected
Yp	F376, Olt, Rapsodia, Cocor, Opal, Rapid, Oituz, Campion, Panciu, Paltin
Ys	Panciu, Șoim, Cocor, Paltin, Olt, Campion, Opal, Rapid, Oituz, Rapsodia, Faur, F376
MP	Olt, F376, Cocor, Opal, Rapsodia, Rapid, Panciu, Campion, Paltin, Oituz, Șoim,
GMP	Olt, Cocor, F376, Opal, Rapsodia, Rapid, Panciu, Campion, Paltin, Oituz, Șoim,
TOL	Granit, Șoim, Faur, Panciu, F322, Paltin, Campion, Oana, Oituz
SSI	Granit, Șoim, Panciu, Faur, Paltin, F322, Campion, Oana, Oituz, Opal
STI	Olt, Cocor, F376, Opal, Rapsodia, Rapid, Panciu, Campion, Paltin, Oituz, Șoim,
HAR	Olt, Cocor, F376, Opal, Rapid, Rapsodia, Panciu, Campion, Paltin, Oituz, Șoim

Table 9. Correlation coefficients between tolerance indices and grain yield (Yp, Ys)
in mild drought conditions (SI = 0.14)

Indices	Yp	Ys	MP	GMP	TOL	SSI	STI	HAR
Yp	-	0.728**	0.928**	0.916**	0.358	0.132	0.924**	0.908**
Ys		-	0.930**	0.941**	-0.378	-0.577[00]	0.932**	0.944**
MP			-	0.999**	-0.013	-0.242	0.998**	0.996**
GMP				-	-0.043	-0.270	0.998**	0.007
TOL					-	0.966**	-0.022	-0.059
SSI						-	-0.247	-0.281
STI							-	0.998**
HAR								-

* significant at 5% probability level;
** significant at 1% probability level.

CONCLUSIONS

By using all six selection indices there can not be selected genotypes with similar tolerance and this is why it is better that selection to be made on the basis of combinations of these indices. The tolerance of the studied hybrids depends on the severity of the water stress.

The best predictors of the grain yields in irrigation and non-irrigated conditions proved to be MP, GMP, STI and HAR. They succeeded in identifying all hybrids from group A (according to Fernandez).

On the basis of these indices the following hybrids: Neptun, Oana, Ileana, Rapsodia, Campion, Cocor were selected for severe water stress (SI = 0.78), the hybrids: Oituz, Rapid, Panciu, Şoim, Ileana, Opal, Paltin, Faur, F322 – for relatively severe water stress (SI = 0.57) and the hybrids: F376, Olt, Rapsodia, Cocor, Opal, Rapid, Oituz, Campion, Panciu, Paltin – for mild water stress (SI = 0.14).

The efficacy of TOL and SSI index highly depended on the severity of water stress, yet they are good predictors only for group C hybrids.

REFERENCES

Baheri, S.F., Javanshir, A., Kazemi H.A. and Aharizad, S., 2003. *Evaluation of different drought tolerance indices in some spring barley genotypes.* Journal Agricultural Sci., 13: 95-100.

Fernandez G.C.J., 1992. *Effective selection criteria for assessing plant stress tolerance.* In: Kuo, C.G. (ed), Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water stress. AVRDC Publication, Tainan, Taiwan: 259-270.

Fischer, R.A., Maurer, R., 1978. *Drought resistance in spring wheat cultivars.* Part 1: *Grain yield response.* Australian Journal of Agricultural Research, 29: 897-912.

Golboshy, M., Ebrahimi, M., Khorasani, S.K. and Choukan, R., 2010. *Evaluation of drought tolerance of some corn (Zea mays. L) hybrids in Iran.* African Journal of Agricultural Research, 5 (19): 2714-2719.

Golabadi, M., Arzani, A., Maibody, S.A.M., 2006. *Assessment of drought tolerance in segregating populations in durum wheat.* African Journal Agric. Res., 5: 162-171.

Jafari, A., Paknejad, F., Jami Al-Ahmadi,M., 2009. *Evaluation of selection indices for drought toler-ance of corn (Zea mays L.) hybrids.* International Journal of Plant Production, 3 (4): 33-38.

Khalili, M., Kazemi, M., Moghaddam, A., Shakiba, M., 2004. *Evaluation of drought tolerance indices at different growth stages of late-maturing corn genotypes.* Proceedings of the 8th Iranian Congress of Crop Sci. and Breed., Rasht, Iran: 298.

Kristin, A.S., Senra, R.R., Perez, F.I., Enriques, B.C., Gallegos, J.A.A., Vallego, P.R., Wassimi, N. and Kelley, J.D., 1997. *Improving common bean performance under drought stress.* Crop Sci., 37: 43-50.

Mitra, J., 2001. *Genetics and genetic improvement of drought resistance in crop plants.* Curr. Sci., 80: 758-762.

Moghaddam, A., Hadizadeh, M.H., 2002. *Response of corn hybrids and their parental lines to drought usingdifferent stress tolerant indices.* Iranian Journal Seed and Seedling, 18: 255-272.

Ramirez, V.P. and Kelly, J.D., 1998. *Traits related to drought resistance in common bean.* Euphytica, 99: 127-136.

Rosielle, A.A., Hamblin, J., 1981. *Theoretical aspects of selection for yield in stress and non-stress environment.* Crop Sci., 21: 943-946.

Săulescu, N.A., Săulescu, N.N., 1967. *Câmpul de experienţă.* Editura Agro-Silvică, Bucureşti.

Shirinzadeh, A., Zorghami, R., Azghandi, A.V., Shiri, M.R. and Mirabdulbaghi, M., 2010. *Evaluation of drought tolerance in Mid and Late mature corn hybrids using stress tolerance index.* Asian Journal of Plant Sciences, 9 (2): 67-73.

Sio-Se Mardeh, A., Ahmadi, A., Poustini, K., Mohammadi, V., 2006. *Evaluation of drought resistance indices under various environmental conditions.* Field Crop Res., 98: 222-229.

Urechean, Viorica, Bonea, Dorina, Constantinescu, Emilia, 2008. *The influence of the hidric stress on the capacity of growth and development at the sunflower.* Buletin USAMV-Cluj-Napoca, 65: 123-128.