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RESPONSE OF SOME CORN HYBRIDS TO DROUGHT STRESS

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Abstract

Corn (Zea mays. L), the most widespread agricultural crop in Romania, is frequently affected by drought. In order to investigate and quantify the effect of drought stress (hydric and thermal stress) on grain yield at seven hybrids of corn, an experiment was conducted in a randomized block with three replications during 2017 and 2018 at ARDS Simnic. Year 2017 was considered a dry year (with water and thermal deficiency), and 2018 a year favorable to corn (without stress). Six stress tolerance indices, including mean productivity (MP), geometric mean productivity (GMP), Yield Index (YI), Yield stability index (YSI), stress susceptibility (SSI) and stress tolerance index (STI) were used. The ANOVA test showed significant differences between the two culture conditions for the production. All hybrids experimented under favorable crop conditions (without stress) have achieved higher yields (7.37-10.16 tons/ha) and under drought conditions had a lower yield of 38% (4.32-6.16 tons/ha). The grain yield under drought conditions (stress) (Ys) was having significant positive correlation with GMP, YI, YSI and significant negative correlation with SSI. The yield under favorable field conditions (no-stress) (Yp) had a strong positive correlation only with MP index The verification of drought-tolerant crops using this rankings method indicated the hybrids HSF 158-14, HSF 734-13 and F376 as the most tolerant of drought.

Key words: *drought, corn, stress tolerance index.*

INTRODUCTION

The Oltenia area is often affected by drought and heat that strongly influence plant development and yield (Bonea & Urechean, 2015; Bonea, 2016).
Decrease of grain yield in corn due to drought, depends on genotype, stage of plant development at the moment of drought installation, intensity and duration of drought etc. Mi et al. (2018) showed that the drought manifested in the corn reproductive stage led to a reduction in grain yield of 41.6-46.6% and the drought installed in the vegetative stage at a reduction of 18.6-26.2%.
Bonea and Urechean (2017) reported that the drought during blooming phase has determined a significant reduction of the grain yield with 60.5%.
Although it is believed that the intensity of physiological processes decreases after reaching the physiological maturity, it seems that the august rainfall has a decisive role in defining production capacity, both in dry years and in favorable years (Urechean et al., 2010).
To reduce these negative effects, it is important to identify and use drought-tolerant hybrids in the culture.
Using plant genotypes adaptable to drought stress is an optimal strategy in sustainable agriculture (Asgarinia et al., 2017). According to Shiri et al. (2010) direct selection of drought tolerant hybrids by yield only has low selection effectively because of environmental influences sometimes are greater than genetic influence.
Therefore, the researchers proposed various techniques for assessing genetic differences between hybrids on their drought tolerance, such as stress tolerance indices based on a mathematical relation between stress and optimum conditions (Bouslama & Schapaugh, 1984; Fernandez, 1992; Fischer & Maurer, 1978; Gavuzzi et al., 1997; Rosielle & Hamblin, 1981).
The present study was conducted to identify corn hybrids with drought tolerance by using different selection indices and the ranking method. In order to investigate and quantify the effect of drought stress (hydric and thermal stress) on grain yield using different tolerance indices and rankings method.

MATERIALS AND METHODS

Seven Romanian corn hybrids were studied for production performance under two different environmental conditions, namely in 2017 and 2018, respectively.

The years of the investigation as regards weather conditions, were characterized as follows: 2017 was considered a dry year and 2018 was considered a favorable to corn.

Both experiences were placed in a randomized block (latin rectangle) with three replications at ARDS Simnic, Craiova.

Sowing was made on 10.04.2017 and 24.04.2018 respectively. The plant sown in the previous year was wheat.

Plowing was done in autumn and in spring preparing the suitable soil for germination was done with the disc and the combiner.

Fertilization was done with 250 kg/ha ($N_{20}P_{20}K_0$) complex fertilizers before sowing and in vegetation (phase 8-10 leaves) with ammonium nitrate 250 kg/ha.

The herbicide was made with DUAL GOLD 960-1.5 l/ha immediately after sowing and with EQUIP 1.5 l/ha + BUCTRIL 1.0 l/ha in vegetation (phase 6-8 leaves).

Two mechanical and two manuals weeding were applied.

The six stress tolerance indices: MP, GMP, YI, YSI, SSI and STI have been calculated on the basis of grain yield obtained in two conditions: without stress (Yp) and drought stress (Ys) using the following formulas:

Mean productivity (MP) (Rosielle & Hamblin, 1981), the genotypes with high value of this index will be more desirable:

$$MP = \frac{Y_S + Y_P}{2}$$

Geometric mean productivity (GMP) (Fernandez, 1992), the genotypes with high GMP value will be more desirable:

$$GMP = \sqrt{(Y_S)(Y_P)}$$

Yield Index (YI)) (Gavuzzi et al., 1997), the genotypes with high value of this index will be suitable for drought stress condition:

$$YI = \frac{Y_S}{\bar{\bar{Y}}_P}$$

Yield stability index; YSI (Bouslama & Schapaugh, 1984), the genotypes with high YSI values can be regarded as stable genotypes under drought and non-stress conditions:

$$YSI = \frac{Y_S}{Y_P}$$

Stress susceptibility index (SSI) (Fischer & Maurer, 1978), the genotypes with SSI < 1 are more resistant to drought stress conditions:

$$SSI = \frac{1-(\frac{Y_S}{Y_P})}{SI} \quad , SI = 1-(\frac{\bar{Y}_S}{\bar{\bar{Y}}_P})$$

Where SI = intensity of stress

Stress tolerance index (STI) (Fernandez, 1992), the genotypes with high STI values will be tolerant to drought stress:

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

For the evaluation of tolerant genotypes by the rankings method, was used the formula proposed by Farshadfar and Elyasi (2012):

Rank sum (RS) = Rank mean + Standard deviation of rank (SDR)

The data on the grain yield have been computed by variance analysis using ANOVA program for both environmental condition.

The phenotypical correlation between studied traits as well as the correlation between yields in both environmental conditions (Yp and Ys) and the six indices of stress tolerance have been interpreted by using simple correlation coefficients (r).

RESULTS AND DISCUSSIONS

ANOVA results showed that there were significant differences between hybrids for grain yield in both environmental conditions (p = 0.05) (Table 1).

All hybrids experimented under favorable crop conditions (without stress) have achieved higher yields (7.37-10.16 tons/ha) and under drought conditions had a lower yield of 38% (4.32-6.16 tons/ha).

Hybrids HSF 158-14 and HSF 153-14 achieved the highest yield under drought conditions and hybrids HSF 734-13 and F376 had the highest yield under without drought conditions (Table 2).

Photo 1. Corn during blooming phase

Photo 2. Corn at physiological maturity

The calculation of stress tolerance indices (Table 3) is not always eloquent and sufficient to identify stress tolerance hybrids. For example, based on MP and GMP, the most tolerant hybrid was HSF 734-13; based on YI and STI the most tolerant was the HSF 158-14 hybrid, and on the basis of YSI and SSI the most tolerant hybrid was HSF 154-14.

In a previous paper Bonea and Urechean (2011) confirm that using all tolerance indices there cannot be selected genotypes with similar tolerance.

Therefore, to determine the best indices in establishing stress tolerance, correlation coefficients were calculated between YP, Ys and the six indices used in this study (Table 4).

Numerous researchers (Kumar et al., 2015; Urechean & Bonea, 2017) believe that analyzing these correlations is a much better criterion for assessing drought tolerance of genotypes.

Table 1. Analysis of variance for grain yield under non-stress (Yp) and stress (Ys) conditions

Source of variations	Degree of freedom	Ys (MS)	YP (MS)
Genotype	6	1.213*	1.446*
Error	7	0.054	0.046

MS = mean square; * = significant at p=0.05

Table 2. Mean comparisons of grain yield under non-stress (Yp) and stress (Ys) conditions

Hybrid	Drought condition (Ys) tons/ha	Non-stress condition (Yp) tons/ha
F376	5.36	9.45*
F423	5.56	8.03^{0}
Oituz	4.32^{0}	8.46
Iezer	4.48^{0}	8.08
HSF 734-13	5.52	10.16*
HSF 153-14	5.91*	7.37^{0}
HSF 158-14	6.16*	8.48
Mean (CT)	5.33	8.57
LSD5%	0.45	0.41
% reduction	**38%**	

*, ^{0} = significant positive and negative, respectively at p = 0.05

Grain yield under without drought conditions (Yp) has significantly positive correlated only with the MP index (r = 0.80*).

Yield under drought stress (Ys) recorded a significant positive correlation with: GMP (r = 0.75*), YI (r = 1.00**); YSI (r = 0.75*) and a significant negative correlation with SSI (r = -0.77^{0}).

Similar results have been reported by Ghobadi et al. (2012) in bread wheat genotypes under post anthesis drought stress. These was observed the highest correlation positive (r = 1.00**) between Ys and YI and the significant negative correlations between Ys and SSI (r = -0.47*).

Ceceareli et al. (1987) reported that there was a negatively significant correlation between grain yield cereal under drought stress condition (Ys) and SSI.

Other significant positive correlations were recorded between MP and GMP (r = 0.98**), STI (r = 0.98**), between GMP and YI (r = 0.75*), STI (r = 1.00**); between YI and YSI (r = 0.78*), STI (r = 0.74*).

Significant negative correlations were recorded between YI and SSI (r = -0,77^{0}) and between YSI and SSI (r = -1.00^{00}). Similar results have been reported by Sayyah et al. (2011) in bread wheat genotypes under post-anthesis drought stress.

According to Mitra (2001) some suitable indices must have a significant correlation with grain yield under both the conditions.

Because, in our study, have not been identified indices of drought tolerance that correlate significantly with the production obtained in both environmental conditions, the rankings method was used (Table 5).

The same situation was observed by Sio-Se Mardeh et al. (2006) and Bonea and Urechean (2017) in severe drought conditions.

According to Farshadfar and Elyasi (2012) the genotypes with the lowest RS (sum of the ranks) value are the most stable.

In our case, hybrids HSF 158-14, HSF 734-13 and F376 which recorded the lowest value for the sum of the ranks (RS), were identified as the most tolerant drought tolerant.

Numerous researchers have used a rankings method for the quantitative evaluation of all corn drought tolerance indices (Farshadfar & Sutka, 2002; Bonea et al., 2018).

Table 3. Drought tolerance indices (at SI = 0.38)

Indices / Hybrid	Yp	YS	MP	GMP	YI	YSI	SSI	STI
F376	9.45	5.36	7.40	7.11	1	0.56	1.15	0.68
F423	8.03	5.56	6.79	6.68	1.04	0.69	0.81	0.6
Oituz	8.46	4.32	6.39	6.04	0.81	0.51	1.28	0.49
Iezer	5.08	4.48	6.28	6.02	0.84	0.55	1.18	0,49
HSF 734-13	10.16	5.52	7.84	7.48	1.03	0.54	1.21	0.76
HSF 153-14	7.37	5.91	6.64	6.59	1.1	0.8	0.52	0.59
HSF 158-14	8.48	6.16	7.32	7.22	1.15	0.72	0.73	0.71

Yp = yield in non-stress condition; Ys = yield in stress condition; MP = Mean Productivity; GMP = Geometric Mean Productivity; YI =Yield Index; YSI=Yield stability index; SSI = Stress susceptibility index STI = Stress tolerance index; SI = intensity of stress

Table 4. Correlation coefficients between drought tolerance indices

	Yp	Ys	MP	GMP	YI	YSI	SSI	STI
Yp	-	-0.01	0.80*	0.65	-0.01	-0.63	0.64	0.66
Ys			0.59	0.75*	1.00**	0.78*	-0.77^{0}	0.74
MP				0.98**	0.59	-0.05	0.06	0.98**
GMP					0.75*	0.17	-0.16	1.00**
YI						0.78*	-0.77^{0}	0.74*
YSI							-1.00^{00}	0.16
SSI								-0.15
STI								

Yp = yield in non-stress condition; Ys = yield in stress condition; MP = Mean Productivity; GMP = Geometric Mean Productivity; YI =Yield Index; YSI=Yield stability index; SSI = Stress susceptibility index STI = Stress tolerance index; $^{*;0}$ and $^{**;00}$ - significant at 0.05 and 0.01 level of probability, respectively

Table 5. Ranking, average, standard deviation (SDR) and sum of rankings (SR) of tolerance indices

Hybrids / Indices	F376	F423	Oituz	Iezer	HSF 734-13	HSF 154-14	HSF 158-14
Yp	2	6	4	5	1	7	3
Ys	5	3	7	6	4	2	1
MP	2	4	6	7	1	5	3
GMP	3	4	6	7	1	5	2
YI	5	3	7	6	4	2	1
YSI	4	3	7	5	6	1	2
SSI	4	3	7	5	6	1	2
STI	3	4	6	7	2	5	1
Aveage	3.50	3.75	6.25	6.00	3.13	3.50	1.88
SDR	0.42	0.37	0.37	0.33	0.77	0.80	0.29
RS	3.92	4.12	6.62	6.33	3.90	4.30	2.17

CONCLUSIONS

The ANOVA test showed significant differences between the two culture conditions for the production.

All hybrids experimented under favorable crop conditions (without stress) have achieved higher yields (7.37-10.16 tons/ha) and under drought conditions had a lower yield of 38% (4.32-6.16 tons/ha).

The grain yield under drought conditions (*stress*) (Ys) was having significant positive correlation with GMP, YI, YSI and significant negative correlation with SSI.

The yield under favorable field conditions (no-stress) (Yp) had a strong positive correlation only with MP index.

The verification of drought-tolerant crops using this rankings method indicated the hybrids HSF 158-14, HSF 734-13 and F376 as the most tolerant of drought.

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