RESEARCH ON DROUGHT TOLERANCE OF MAIZE HYBRIDS USING SPECIFIC INDICES

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ABSTRACT

The reaction of maize genotypes to drought stress is evaluated using some specific indicators (SSI- stress susceptibility index, TOL-tolerance index, STI-stress tolerance index). Known that Simnic area is a drought year six maize genotypes grown in three different planting times and densities have been evaluated for their response to drought stress using specific indicators. Grain yield was an important criterion for assessing drought tolerance of the hybrids evaluated. In 2010 drought stress appeared in July to September, period that coincides with flowering, silk and grain filling. Differences in stress tolerance index values were quite close, suggesting that this index is not influenced by sowing time. In light of drought tolerance specific indices under three planting times and densities only Kitty and Kamelias were the most drought tolerant hybrids.

INTRODUCTION

Among all natural stress factors which plants are subjected, drought affects 26% of the arable land of Earth, thus limiting more plants distribution and their productivity in both natural and agricultural systems (Hanson and Hitz, 1982). Maximum sensitivity of maize to drought enroll in 2-22 days after silk when the number of grains may decrease with 45%, 1000-kernels weight decreased also with 51% when the drought appeared to 12-16 days after silk leading to yield losses especially when the stress period appear from head emergence to grain filling (Denmead and Show, 1960, Claassen and Show, 1970, Grant et al., 1989, NeSmith and Richie, 1992, Heisey and Edmeades, 1998, Engelen-Eigles et al., 2001, Burzo and Dobrescu Aurelia, 2011). When drought occurs during this period of high sensitivity low grain yield is greatly correlated with the number of grains/plant (r = 0,90** and ASI – anthesis silking interval = -0,60**) (Balaños and Edmeades, 1996). This is one of the reasons why researchers have focused on this critical period to get drought tolerance in order to stabilize the number of grains/plant and to increase yield. Beside classical breeding methods that require time to obtain genotypes with tolerance to drought stress and technological methods to decrease drought effects, actually a huge attention is focused to obtain transgenic plants with high tolerance to this stress factor (Vasal et al., 1997, Seki and Kamel, 2003, Vinocur and Altman, 2005, Byun et al., 2007, Zhang and Shih, 2007). Regardless of how are obtained these genotypes assessment of drought effects is performed using some specific indicators (Rasielle and Hamblin, 1971, Fischer and Maurer, 1978, Fernandez, 1992). Thus, the aim of this study was to evaluate the tolerance to drought stress of six hybrids grown in three different planting times and densities in the climatic conditions of Simnic area.

MATERIAL AND METHODS

During 2010 year six maize hybrids grown on three times (the 15^{th} April, the 1^{st} May and the 15^{th} May) and planting density (40000pl/ha, 50000pl/ha and 60000pl/ha) have been tested in different climatic conditions in order to evaluate their response to drought stress. The material was represented by six maize hybrids (F 475, Kamelias, Danubian, KWS 2376, Rapsodia, Kitty) tested using a split plot design with two factors (Factor A – planting density, Factor B – maize hybrid) in three replications. The size of each plot was 25 m^2. Plots were fertilized at sowing time with 200 kg/ha complex fertilizer NPK 20-20-0 basal applied and 150 kg/ha ammonium nitrate top-dressed during vegetation period. Weeds were controlled in each experimental year using herbicides. To evaluate the reaction of the maize hybrids to drought stress were used specific indices: stress susceptibility index (SSI) (Fischer and Maurer, 1978), tolerance index (TOL) (Rosielle and Hamblin, 1981) and stress tolerance index (STI) (Fernandez, 1992). Also, grain yield was an important criterion for assessing drought tolerance of the hybrids evaluated.

RESULTS AND DISCUSSION

Generally, in rained conditions precipitations are variable and cannot be predicted, therefore a "successful" maize cultivar tolerant to drought stress must be able to withstand some variation in rainfall year to year and to record stable yields. The differences in grain yield between hybrids increased with the intensity of drought stress (Betrán et al., 2003). Drought affects maize grain yield to some degree at almost all grown stages, but the crop is the most susceptible during flowering (Denmead and Show, 1960, Claassen and Show, 1970, Grant et al., 1989) because its female florets develop virtually at the same time and are usually borne on a single ear on a single stem. Although there are often reasonable quantities of plant reserves formed well before flowering and stored in the stem, the developing maize ear has very little capacity to mobilize and attract them in its first two weeks of life. Often in Simnic area drought stress occurs during the most sensitive crop stages leading finally to yield decreased or even to crop compromising. In 2010 drought stress appeared in July to September, period that coincides with flowering, silk and grain filling. In the conditions of 0,26 drought intensity (moderately strong) stress susceptibility index ranged between 0,11-0,95 (for the 15th April planting time), 0,70-1,74 (for the 1st May) and 0,86-1,46 (for the 15th May) (Table 1).

Table 1

Stress Susceptibility Index (SSI) values for 2010 year

Hybrid	40000			50000			60000		
	Yn	Ys	SSI	Yn	Ys	SSI	Yn	Ys	SSI
The 15th April									
F475	66.9	53.0	0.79	76.0	58.0	0.91	69.6	59.3	0.57
Kamelias	64.1	58.0	0.37	73.4	63.4	0.52	62.2	65.4	0.20
Danubian	60.6	58.8	0.11	71.0	57.7	0.72	59.9	53.7	0.22
KWS2376	62.9	53.5	0.57	76.9	58.9	0.90	76.3	59.2	0.56
Rapsodia	64.5	61.8	0.16	77.1	62.9	0.71	74.4	61.5	0.67
Kitty	74.2	63.3	0.57	84.0	63.2	0.95	76.7	66.2	0.58
The 1st May									
F475	71.7	47.5	1.30	81.6	55.1	1.25	72.3	49.6	1.21
Kamelias	74.0	60.5	0.70	77.6	59.2	0.91	86.1	55.2	1.38
Danubian	74.3	45.4	1.50	68.5	47.2	1.20	75.0	41.1	1.74
KWS2376	74.7	50.5	1.25	75.2	55.6	1.00	80.2	47.1	1.59
Rapsodia	78.2	49.3	1.42	72.8	57.9	0.79	78.8	52.2	1.30
Kitty	82.6	53.3	1.36	75.5	61.5	0.71	89.8	50.8	1.67
The 15th May									
F475	67.6	41.9	1.46	69.8	50.1	1.09	69.0	50.7	1.02
Kamelias	70.6	50.9	1.07	73.9	57.3	0.86	80.9	57.8	1.10
Danubian	63.9	45.2	1.13	69.9	51.0	1.04	67.0	49.8	0.99
KWS2376	68.8	45.8	1.26	84.1	56.8	1.25	79.2	52.5	1.30
Rapsodia	67.9	43.6	1.38	75.6	54.6	1.07	76.8	53.4	1.17
Kitty	74.4	49.7	1.28	79.8	56.4	1.13	77.9	59.4	0.91

Yn mean = 73,6; Ys mean = 54,4; drought intensity = 0,26

There results suggest that normal and delayed sowing time influenced drought tolerance of maize hybrids as evidenced by yield differences recorded. When maize hybrids were sown on 15th April, Danubian at planting density of 40000 pl/ha recorded the lowest SSI (0,11) meaning that is a drought tolerant cultivar in the conditions of a lower plants number/ha, while the highest SSI was recorded by Kitty at planting density of 50000pl/ha suggesting that it was most affected by drought stress. Among all maize hybrids sown at the 1st May and 40000pl/ha the most tolerant to drought stress was Kamelias which recorded 74 q/ha grain yield and SSI 0,70. The same hybrid was noticed also as having a good stress tolerance for 50000 pl/ha with 77,6 q/ha grain yield and SSI 0,91. For delayed sowing time most tested hybrids recorded a SSI up to 1, excepting Kamelias, Danubian and Kitty. Under three planting times and densities only Kamelias and Kitty were the most drought tolerant hybrids.

Tolerance index values ranged between 1,8-20,8 q/ha (for the 15th April sowing time), 13,5-39 q/ha (for the 1st May sowing time) and 16,6-39 q/ha (for the 15th May sowing time) (Table 2).

Table 2

Tolerance Index (TOL) values for 2010 year

Hybrid	40000			50000			60000		
	Yn	Ys	TOL	Yn	Ys	TOL	Yn	Ys	TOL
The 15th April									
F475	66.9	53.0	13.6	76.0	58.0	18.0	69.6	59.3	10.3
Kamelias	64.1	58.0	6.1	73.4	63.4	2.10	62.2	65.4	-3.2
Danubian	60.6	58.8	1.8	71.0	57.7	13.3	59.9	53.7	3.2
KWS2376	62.9	53.5	9.4	76.9	58.9	18.0	76.3	59.2	17.1
Rapsodia	64.5	61.8	2.7	77.1	62.9	14.3	74.4	61.5	12.9
Kitty	74.2	63.3	10.9	84.0	63.2	20.8	76.7	66.2	10.5
The 1st May									
F475	71.7	47.5	24.2	81.6	55.1	26.5	72.3	49.6	22.7
Kamelias	74.0	60.5	13.5	77.6	59.2	18.4	86.1	55.2	30.9
Danubian	74.3	45.4	28.9	68.5	47.2	21.3	75.0	41.1	33.9
KWS2376	74.7	50.5	24.2	75.2	55.6	13.6	80.2	47.1	33.1
Rapsodia	78.2	49.3	28.9	72.8	57.9	14.9	78.8	52.2	26.6
Kitty	82.6	53.3	29.3	75.5	61.5	14.0	89.8	50.8	39.0
The 15th May									
F475	67.6	41.9	25.7	69.8	50.1	19.7	69.0	50.7	22.7
Kamelias	70.6	50.9	19.7	73.9	57.3	16.6	80.9	57.8	30.9
Danubian	63.9	45.2	18.7	69.9	51.0	18.9	67.0	49.8	33.9
KWS2376	68.8	45.8	23.0	84.1	56.8	27.3	79.2	52.5	33.1
Rapsodia	67.9	43.6	24.3	75.6	54.6	21.0	76.8	53.4	26.6
Kitty	74.4	49.7	24.7	79.8	56.4	23.4	77.9	59.4	39.0

For the 15th April sowing time as planting density increases TOL values grow, excepting Kamelias and Danubian for a planting density of 60000 pl/ha. When maize was sown at the 1th May all hybrids at all densities showed TOL values up to 13,5 q/ha. The highest TOL value was recorded by Kitty (39 q/ha) for a planting density of 60000 pl/ha. This hybrid recorded also the highest TOL value for the same planting density when sowing time was done at the 15th May. All maize hybrids sown at the 15th May for all densities recorded TOL up to 16,6 q/ha.

Overall TOL values below 5 q/ha recorded Danubian (1,8 q/ha) and Rapsodia (2,7 q/ha) for a planting density of 40000 pl/ha and Kamelias (-3,2 q/ha) and Danubian (3,2 q/ha) for a planting density of 60000 pl/ha.

Similar results for maize inbred lines and hybrids were reported by Ahmandzadeh (1997) and Khodarahmpour et al. (2011) and also for other crops (Clarke et al., 1992, Ramirez and Kelly, 1998).

Differences in stress tolerance index values were quite close, suggesting that this index is not influenced by sowing time (Table 3). For the first two sowing time at a density of 60000 pl/ha Danubian recorded the lowest value of STI, but is not correlated with a higher yield in normal year. Generally, Kitty has been the most productive of all sowing times and densities recording high STI values due to lower yield obtained under drought conditions. STI vas the best index to identify superior genotypes in drought stress conditions as previously show other authors for different crops (Fernandez, 1992, Pourdad, 2008, Khodarahmpour and Hamidi, 2011, Khodarahmpour et al. ,2011).

Table 3

Stress Tolerance Index (STI) values for 2010 year

Hybrid	40000			50000			60000		
	Yn	Ys	STI	Yn	Ys	STI	Yn	Ys	STI
The 15th April									
F475	66.9	53.0	0.65	76.0	58.0	0.81	69.6	59.3	0.76
Kamelias	64.1	58.0	0.69	73.4	63.4	0.86	62.2	65.4	0.75
Danubian	60.6	58.8	0.66	71.0	57.7	0.76	59.9	53.7	0.56
KWS2376	62.9	53.5	0.62	76.9	58.9	0.84	76.3	59.2	0.83
Rapsodia	64.5	61.8	0,74	77.1	62.9	0.89	74.4	61.5	0.84
Kitty	74.2	63.3	0.87	84.0	63.2	0.98	76.7	66.2	0.94
The 1st May									
F475	71.7	47.5	0.63	81.6	55.1	0.83	72.3	49.6	0.66
Kamelias	74.0	60.5	0.83	77.6	59.2	0.85	86.1	55.2	0.88
Danubian	74.3	45.4	0.62	68.5	47.2	0.60	75.0	41.1	0.57
KWS2376	74.7	50.5	0.70	75.2	55.6	0.77	80.2	47.1	0.70
Rapsodia	78.2	49.3	0.71	72.8	57.9	0.78	78.8	52.2	0.76
Kitty	82.6	53.3	0.81	75.5	61.5	0.86	89.8	50.8	0.84
The 15th May									
F475	67.6	41.9	0.52	69.8	50.1	0.65	69.0	50.7	0.65
Kamelias	70.6	50.9	0.66	73.9	57.3	0.78	80.9	57.8	0.86
Danubian	63.9	45.2	0.53	69.9	51.0	0.66	67.0	49.8	0.62
KWS2376	68.8	45.8	0.58	84.1	56.8	0.88	79.2	52.5	0.77
Rapsodia	67.9	43.6	0.55	75.6	54.6	0.76	76.8	53.4	0.76
Kitty	74.4	49.7	0.68	79.8	56.4	0.83	77.9	59.4	0.86
$(Yn\ mediu)^2$	5416,96								

The results showed that the ability of crop cultivars to perform reasonably well in variable rainfall and water stress environments is an important trait for yield stability under drought stress conditions.

CONCLUSIONS

Often in Simnic area drought stress occurs during the most sensitive crop stages leading finally to yield decreased or even to crop compromising. In 2010 drought stress appeared in July to September, period that coincides with flowering, silk and grain filling. In the conditions of 0,26 drought intensity (moderately strong) stress susceptibility index ranged between 0,11-0,95 (for the 15th April planting time), 0,70-1,74 (for the 1st May) and 0,86-1,46 (for the 15th May). Tolerance index values ranged between 1,8-20,8 q/ha (for the 15th April sowing time), 13,5-39 q/ha (for the 1st May sowing time) and 16,6-39 q/ha (for the 15th May sowing time). Differences in stress tolerance index values were quite close, suggesting that this index is not influenced by sowing time. In light of drought tolerance specific indices under three planting times and densities only Kitty and Kamelias were the most drought tolerant hybrids.

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