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THE EVALUATION OF MAIZE HYBRIDS USING OF TOLERANCE INDICES TO HEAT AND DROUGHT STRESSES

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Abstract

Dryness and high temperature are very important intentions in reducing the growth and production of plants. For this purpose, three maize hybrids were examined for tolerance to heat and drought tension. In this regard, a split-split plot experiment was carried out in a randomized block design with three replications in the north of Khuzestan province (Shahid Beheshti Province, Iran) during two years of 2017-2018. The main factor was thermal stress (date of cultivation in three levels of first of July, twelfth of July, ninth of August), sub factor including drought tension at three levels (irrigation after 70, 90, 120 mm from the evaporation pan) and sub-subtraction factor Includes three hybrids, H1 (704), H2 (701), and H3 (AS71). Tolerance index, arithmetic mean, geometric mean, drought or heat stress index, Stress sensitivity index, tolerance indices were used to evaluate the tolerance to heat and dryness of hybrids. The results of Drought tolerance indices showed that hybrid H1 had more drought tolerance than other hybrids. Also, examination of heat tolerance indices showed that H1 hybrids had higher grain yield and hence more heat tolerance among other hybrids. Therefore, it can be concluded that hybrids H1 had higher grain yield under drought tension and heat conditions in terms of tolerance to heat and drought indices.

Key words : Corn hybrid, tolerance Indices of heat and drought tension, grain yield.

Introduction

Maize (*Zea mays* L.) is one of the most important harvest plants and it is used as food, forage and industrial usages, and in terms of global production after wheat one can rank it as the first one (Amini *et al.,* 2011: Sun *et al.,* 2018). Being friendliness to warmth, bearing a carbon tetracycline pathway, an efficiency in water usage as compared to other cereals, are among the features that have made the corn more attractive to researchers. On the other hand, in the case of 4 carbs plants, corn is most sensitive to environmental tensions (Emam and Niknejad, 1995: Bezrutczyk *et al.,* 2018; Li *et al.,* 2016). The heat and drought tension are two factors limiting crop production (Hall 1992; Xu *et al.,* 2016). The most important factor limiting the yield of crops is the lack of enough water in the world (Beck and Turner, 1976). Since most of Iran's lands are located in dry areas, drought tolerance in crops stands a particular importance. Drought tension is one of the most important factors limiting the yield of corn. The amount of water required for maize is between 6 and 12 thousand cubic meters per hectare depending on environmental conditions and food (Golbashi *et al.,* 2011, Ren *et al.,* 2019).

Reducing yield in plants under drought tension depends on several factors such as plant development stage, severity and duration of water shortage and hybrid sensitivity (Frederick *et al.,* 1989; Chaturvedi *et al.,* 2019). In the study of the effect of drought tension on corn is was observed in addition to yield, the quality characteristics of corn were affected by tension, so that the amount of protein increased and starch decreased (Farley *et al.,* 1998; Fahad *et al.,* 2017). Damage threshold of reproductive organs and disruption of corn pollination is all done by the temperature of 42°C (Barzegari, 2009).

Dale and Daleys, 1983, found that when the corn grain was filled with more than 32^0C for five consecutive days, seed production in different parts of the United States decreased by 10-50%.

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The most suitable temperature ranges for optimum growth and achieving the yield potential of maize is 25-30°C (Khan *et al.,* 2002; Rafiq *et al.,* 2016) According to Houghton *et al.,* 1996, if temperature rise with relative humidity decreases, there will be harmful effects on corn pollen grains and at 30-35°C and low relative humidity, about 30% Pollen loses fertility after being released surrounded by a period of one to two hours. Overall, the response of crops and their evaluation of optimal performance in a variety of environmental conditions depend on their ability to use environmental conditions. This is possible through the adjustment of the yield components and the collaboration between the genotype and the environment in case of desirable and unfavorable conditions at each stage of plant growth (Antez and Flower, 1990; Paucar-Menacho *et al.,* 2017).

It is significant to understand the physiological processes involved in tension-induced injuries and adaptation mechanisms and plants adaptation to environmental tensions. Therefore, the present study was conducted to evaluate the tension tolerance of heat and dryness of maize hybrids in northern of Khuzestan.

Materials and Methods

This experiment was conducted through split plot (split plot design) in the base of the design Completely randomized block with three replications in northern of Khuzestan in the region of Dezful, Shahid Beheshti, in the latitude of 32° 21 'N, longitude 48° 15' East with 102 meters above sea level in the summer of the year 2017 and 2018 were executed. The main factor included heat stress (cultivating date) at three levels (July 1st, July 21th and November 9th); sub plots included drought stress at three levels (irrigation after 70 millimeters of drainage from a pot, evaporated or non-stressed, 90 millimeters of evaporation or medium stress, 120 mm of evaporation or intense stress) and sub factor included three hybrids 704, Karun 701, and AS71. The average annual rainfall is about 350 millimeters, the maximum temperature is 53 degrees Celsius and the minimum temperature is 12 degrees Celsius, and in some years it rarely reaches zero degrees. Atmospheric overflows are often in the fall-winter rains and rarely in spring. Meteorological information during the growth period of corn is given in table 1.

Hybrid maize

Production of own maize seed by smallholder farmers Hybrid varieties are made by planting two varieties in the same field, allowing only the male parent to produce pollen, and harvesting the seed only from the female parent. This is controlled crossing of two different parents. Hybrid seed corn production involves the crossing of two (2) inbred lines, hybridization. The two inbreds that are used in the process are referred to as male (the plant responsible for producing pollen) and female (the plant which produces the hybrid seed).

The preparation of the land was done in early of June in two years 2017 and 2018, and then it was created with atmospheric Faroer and stacks at intervals of 75 cm. Planting was done manually with plant spacing in a row of 16 centimeters. Each experimental unit (plots) consisted of 6 rows of planting lengths of 6 meters. The test plots were separated by two non-line plots.5 meter was considered between the blocks. Prior to testing, the soil was sampled for determination of nutrients and physical properties of soil (Table 2).

The amount and type of fertilizer were based on the soil test results. The amount of 100 kg of nitrogen fertilizer (urea), and over 50 kg of triple super phosphate and 50 kg of potassium sulfate at the time of preparation of the culture medium added to the land. 250 and 100 kg of fertilizer Nitrogen (urea) was added to soil as a roadway with cultivating operation and irrigation, respectively. The stresses were applied after the third irrigation for hybrids. Weed control operations were carried out at a rate of 1.5 liters per hectare with the Maister herbicide.

Grain yield measurements with a moisture content of 14% of a 4 m^2 area were measured by harvesting5 random samples from harvested balances. In each stage, irrigation stress and heat stress, indices related to drought tolerance and heat tolerance were calculated.

The method of calculating the indices was as follows:

$$TOL = YP - YS \quad MP = \frac{YP + YS}{2}$$

$$GMP = \sqrt{YP \times YS} \qquad STI = \frac{YP \times YS}{(\overline{YP})^2}$$

$$SSI = \frac{1 - \frac{YS}{YP}}{SI} \qquad ST = 1 - \left[\frac{\overline{YS}}{\overline{YP}}\right]$$

In these formulas, TOL = Tolerance index, MP = arithmetic Mean, GMP = Geometric mean, STI = Drought or heat stress index, SSI = Stress sensitivity index, YP = Genotype function in non-stressed medium, YS = Genotype function in The medium with stress, Y âP = The average yield of all genotypes in a stress-free environment, Y ?S = The average yield of all genotypes in a stressed environment, SI = Stress intensity.

Results and discussion

1. Drought tolerance indices

The results of SSI sensitivity index in 2017 indicate

Table 1: Meteorological data during plant development throughout two years 2017 and 2018.

Rain (mm)		Relative humidity		Temperature ° C						Month
Rain	Rain	humid	Relative	(mean)		(Min)		(Max)		
2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	
0	00	35.6	31	36.43	36.3	26.26	26.4	45.02	46.1	March
0	0	32.8	34	37.06	37.4	27.60	28.6	46.51	46.3	August
0	1.5	37.8	37	33.56	34.9	24.16	26.6	42.96	43.2	September
0	0.5	42.42	50	27.12	29.4	17.76	21.5	36.44	37.3	October
0	71.4	55.78	61	22.26	20.5	14.41	15.1	30.08	29.9	November

Table 2: Physical and chemical properties of soil.

Amount	Soil properties
0.088	Total nitrogen (%)
178	Absorbable k(mg.kg^{-1})
9.9	Absorbable p (mg,$^{[kg]\uparrow(-1)}$)
0.88	Organic matter (%)
7.47	(PH)
1.19	EC (ds.$^{m\uparrow(-1)}$)
Silty Loam	Soil texture

that the lower numerical value of this index indicates more tolerance of hybrid to stress (Moghadam and Hadi-Zadeh, 2002). In mild stress, hybrid H2 (701 Karun) was more tolerant. In severe stress, hybrid H1 (digit 704) has an SSI of 0.05 and represents the greater tolerance of this hybrid to severe drought stress. But for this indicator, in 2012, in mild stress, H3 hybrid (AS71) and in severe drought stress, H3 hybrid was more predisposed to drought tolerance (Tables 1, 2, 3, 4).

In the SSI index, in addition to the performance of the lines in stress conditions, the variation or damage to the lines due to stress is also considered. This means that if any line has a higher performance in both stressed and non-stressed conditions but shows a large change percentage, it will not be detected as a tolerant line. In other words, by using this index, sensitive and tolerant genotypes can be identified regardless of their potential for yield (Naderi *et al.,* 2004). In mild stress, hybrid H2 (701 Karun) was more tolerant. In severe stress, hybrid H1 (digit 704) has an SSI of 0.05 and represents the greater tolerance to severe drought stress. But for this indicator, in 2012, in mild stress, H3 hybrid (AS71) and in severe drought stress, hybrid H3 had more drought tolerance (Tables 1, 2, 3, 4).

The results of STI indices in 2017 and 2018 indicate that hybrid H1 has a higher tolerance index in mild and severe stress. Naderi *et al.,* 1999, stated that this index is reliable when the genotype has a high yield under stress conditions. Also, according to Sadeq-Zadeh Ahari, 2006, Khalilzadeh and Karbalaei Khiyavi, 2002 and Fernandez, 1992, the best indicator for selection of cultivars is the stress tolerance index, because it is capable of distinguishing in both conditions without stress and yield stress, Tables (1, 2, 3, 4).

The results of the TOL Tolerance Index in 2017, in the mild stress, H2 hybrids, showed a lower index and tolerance to drought in severe stress. In 2012, hybrid H3 (AS71) had a lower index and drought tolerance in mild and severe drought stress (1, 2, 3, 4).

Geometric mean GMP index in 2017 and 2018 indicate that the hybrid

H1 (cultivar 704) had more tolerance and higher index values in mild and severe drought stress. Fernandez, (1992), believes that the stress tolerance indices and the geometric mean of productivity, with regard to high and significant correlations between them and grain yield under stress and non-stress conditions, are the most appropriate indices of selection of suitable genotypes which is highly recommended (Tables 1, 2, 3, 4). The results of the average productivity index or MP average in 1394 and 1395 indicate that there was a higher level of intense stress in the hybrid H1 (704), and the high value of this index indicates more hybrid tolerance to drought status. Tables (1, 2, 3, 4). The use of the mean productivity index, which indicates that its high numerical values are relative tolerance to stress, often leads to the selection of high yielding cultivars in normal conditions and low tolerance to stress conditions (Rosenley & Hamilton, 1984). Although Ahmadzadeh, 1997, introduced the mean productivity index as a suitable measure for selecting high yielding and drought tolerance of corn, Siyo Se Mard *et al.,* 2006 reported that the average time of productivity index for selection of genotypes under stress conditions has high efficiency when intensity of the stress is not severe and the difference in performance under stress and non-stress conditions is not high.

In general, by studying the indices of drought tolerance, it could be concluded that the H1 hybrid had a sensitivity tolerance than the rest of the hybrids.

Heat tolerance indices

The result of the SSI stress susceptibility index in

Table 1: Estimation of Hybrid Sensitivity with Different Indices of Drought Tolerance (gentle Stress) D2 Year 2017.

Drought tolerance indices							
YP	**YS**	**SSI**	**STI**	**TOL**	**GMP**	**MP**	**Hybrid**
5.770	5.190	0.814	1.160	0.580	5.470	5.480	H1(704)
5.370	4.260	1.669	0.886	1.110	4.782	4.815	H2(701)
4.100	3.980	0.419	0.618	0.210	3.993	3.998	H3(AS71)

Table 2: Estimation of Hybrid Sensitivity with Different Indices of Drought Tolerance (Extreme Stress) D3 Year 2017.

Drought tolerance indices							
YP	**YS**	**SSI**	**STI**	**TOL**	**GMP**	**MP**	**Hybrid**
5.770	5.410	0.437	1.209	0.360	5.587	5.590	H1(704)
5.370	4.130	1.604	0.859	1.240	4.790	4.750	H2(701)
4.100	3.890	0.361	0.618	0.210	3.993	3.995	H3(AS71)

Table 3: Estimation of hybrid sensitivity to different indices of drought tolerance (mild stress) D2 of 2018.

Drought tolerance indices							
YP	**YS**	**SSI**	**STI**	**TOL**	**GMP**	**MP**	**Hybrid**
6.770	5.020	11.260	1.069	1.750	5.829	5.895	H1(704)
5.810	5.340	3.478	0.926	0.470	5.507	5.575	H2(701)
5.680	4.790	8.040	0.856	0.890	5.216	5.235	H3(AS71)

Table 4: Estimation of Hybrid Sensitivity with Different Indices of Drought Tolerance (Extreme Stress) D3 Year 2018.

Drought tolerance indices							
YP	**YS**	**SSI**	**STI**	**TOL**	**GMP**	**MP**	**Hybrid**
7.670	6.770	0.050	1.630	0.900	7.205	7.220	H1(704)
6.660	5.330	0.950	1.119	1.320	5.963	6.000	H2(701)
6.950	4.790	1.740	1.047	2.160	5.765	5.870	H3(AS71)

Table 5: The Estimation of hybrid sensitivity to heat tolerance index (mild stress) S2, 2017.

Heat tolerance indices							
YP	**YS**	**SSI**	**STI**	**TOL**	**GMP**	**MP**	**Hybrid**
7.710	6.990	0.265	0.860	0.720	7.341	7.350	H1(704)
8.600	4.540	1.336	0.623	4.060	6.248	6.570	H2(701)
7.430	3.820	1.372	0.452	3.610	5.327	5.620	H3(AS71)

2017, 2018 indicates that the H_1 hybrid had a lower index value in the first and second cultivation, indicating that the hybrid was more tolerant to heat than other types (Table 5, 6, 7, 8 and Fig 1). The result of the STI index indicates that the hybrid H_1 (704) had a higher index value in 2012 in mild and severe heat stress. But in 1959, in mild stress, the hybrid H_1, and in the intense stress of the H_2 hybrid have the higher temperature and the higher heat (Table 5, 6, 7, 8 and fig 1). The result of Toll Tolerance Index indicates that the hybrid H_1 during two years of 2017 and 2018 had a lower index value in mild and severe stresses, indicating a higher tolerance for this heat hybrid. Table 5, 6, 7, 8 and fig 1). The result of the GMP geometric index showed that in 1394, this index was higher for hybrid H_1 (704) in mild and severe heat stress. But in 1395, the index value of mild tension for the hybrid H_1 and for the high tensions of hybrids H_1 and H_2 achieved the highest score.

This represents the high tolerance of this hybrid (H_1) to yield performance under thermal stress conditions (Table 5, 6, 7, 8 and fig 1) The result of mean productivity index MP shows that in 2012, in mild stress, hybrid in H1 and in severe stress, H1, and H2 hybrids had higher values. Also, in 2011, the H1 hybrid had higher MP values than other hybrids, indicating a higher heat tolerance than other hybrids (Table 5, 6, 7, 8) and Fig. 1).

Table 6: Estimation of the hybrids sensitivity to various heat tolerance indices (severe stress) S1 2017.

Heat tolerance indices							
YP	**YS**	**SSI**	**STI**	**TOL**	**GMP**	**MP**	**Hybrid**
7.710	1.680	0.892	0.206	6.030	2.598	4.695	H1(704)
8.610	0.620	1.058	0.850	7.980	2.309	4.610	H2(701)
7.430	0.630	1.044	0.074	6.800	2.163	4.030	H3(AS71)

Table 7: Estimation of Hybrid Sensitivity with Different Indices to Heat Tolerance (Smooth Stress) S2 2018.

Heat tolerance indices							
YP	**YS**	**SSI**	**STI**	**TOL**	**GMP**	**MP**	**Hybrid**
6.850	6.200	0.362	0.864	0.650	6.516	6.525	H1(704)
7.410	3.910	1.805	0.589	3.500	5.382	5.660	H2(701)
6.780	5.520	0.709	0.761	1.260	6.177	6.150	H3(AS71)

Table 8: Estimation of Hybrid Sensitivity with Different indices to Heat Tolerance (Extreme Stress) S1/ 2018.

Heat tolerance indices							
YP	**YS**	**SSI**	**STI**	**TOL**	**GMP**	**MP**	**Hybrid**
6.850	6.490	0.353	0.906	0.360	6.667	6.670	H1(704)
7.410	6.460	0.833	0.978	0.920	6.934	6.950	H2(701)
6.780	5.120	1.633	0.706	1.660	5.891	5.950	H3(AS71)

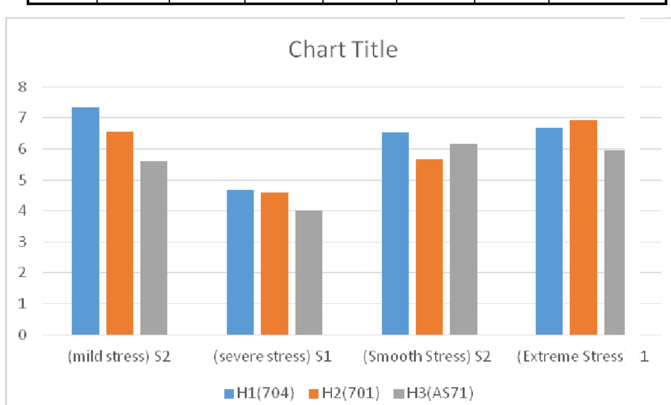

Fig. 1: Estimation of Hybrid Sensitivity with Different indices.

Conclusion

In general, the analysis of heat tolerance indices showed that H1 hybrids produced more seed yield per hectare among other similar hybrids, indicating a higher heat tolerance of this hybrid. In general, the response of agricultural crops and their assessment for optimal performance in a variety of environmental conditions depends on their ability to use environmental conditions. This is possible through the adjustment of the yield components and the collaboration between the genotype and the environment in case of desirable and unfavorable conditions at each stage of plant growth.

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