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Application of drought stress indices for the selection of appropriate fertilizer treatments in forage corn crop

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Abstract

In order to investigate drought indices used to identify the appropriate fertilizer treatments in forage corn, hybrid Maxima (*Zea mays var maxima*) separate experiments were conducted during 2011 and 2012 in Arak. The experiment was a split-split plot in a randomized complete block design with four replications. Irrigation treatments consisted of two irrigation levels (I_0) and deficit irrigation (I_1) as the main factor, Nitroxin in three levels: 0, 0.5 and 1 ml per 30 kg seed and nitrogen levels of 0, 125 and 250 kg per hectare, which was considered as a minor factor. The results shown that STI, GMP and MP most appropriate indicators was applied to determine the best fertilizer treatments, to achieve the highest production yield in both normal irrigation and stress conditions. The maximum yield under both traditional irrigation and drought conditions achieved of the treatment combination of 1 ml per 30 kg seed Nitroxin with 250 kg Nitrogen per hectare (No_2N_2), this treatment was selected as the most favorable treatment combination.

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Introduction

Scarcity of water is one of the most important factors limiting for crop production in arid and semi-arid areas of tension in the growing stages. Water stress occurs when the actual amount of water intake on factors such as drought, high temperature and salinity, which is lower than losses. Effects of water stress on growth and yield of corn depending on the time of tension, stress, and developmental stage of the plant's genotype. the report of some researchers water stress before flowering stage, flowering and yield of maize after flowering, decrease yield, 25, 50 and 21 percent respectively (Osborne *et al.,* 2004). A team of researchers evaluated the effect of drought stress on yield and yield components in late 8 genotypes of serotinous maize in stress and non stress conditions in vegetative and reproductive stages. The results showed that GMP and STI indices based on high performance hybrids in both stress and non-stress environments and using SSI criteria hybrid high performances with average yield are selected in terms of stresses (Khalili *et al.,* 2004). Some researchers examined response of maize hybrids and their parental lines to drought using different stress tolerance indices. The results showed that the calculated indices SSI, STI, TOL and MP, STI index more benefits for the selection of genotypes was normal and stress conditions (Moghaddam and Hadizadeh, 2002). The report stated that was conducted an experiment to verify the terminal drought tolerance in promising winter and facultative wheat genotypes using stress susceptibility and tolerance indices (Shafazadeh *et al.,* 2004). The results showed that arithmetic mean rating for genotypes the MP, GMP and STI were similar and also existed a significant positive correlation between these indices with grain yield in both conditions of normal and drought stress. Therefore concluded that these three indicators are suitable for evaluating drought tolerance genotypes.

One of the researchers conducted experiments on stress indicators for the evaluation of breeding lines of bean and Reported that the reactions of genotypes to functional parameters were different significantly and concluded that the best indicator of STI to select tolerant genotypes with high yield (Fernandez, 1992). Some researchers by applying GMP and SSI indicators to assess common bean genotypes (*Phaseolus vulgaris L.*) stated that GMP Index introduced as an index to identify tolerant genotypes (Schneider *et al.,* 1997). The SSI used criteria for the identification and selection of drought tolerant genotypes in wheat and large variation observed among genotypes in terms of this indicator (Clark and Colleagues, 1992). Some researchers using SSI criteria for assessing drought tolerance genotypes of sunflower (*Helianthus annuus*) much genetic variation were reported for drought tolerance in plants (Fereres *et al.,* 1986).

In a study to identify resistant lines based on quantitative indices of drought resistance in 20 wheat cultivars in irrigated and dry farming conditions showed that MP and TOL indices are most appropriate for screening lines (Farshadfar *et al.,* 1994). Acosta-Gallegos and Adams (1991) GMP were suitable index for evaluating bean genotypes. some researchers to determine the reaction of 18 varieties of legume species in relation to drought stress susceptibility index, were classified cultivars into two groups: drought resistant (31> SSI) and drought-sensitive (44 <SSI) (Grzesiak *et al.,* 1996).

The aim of this experiment was to evaluate the use of different drought stress indicators to determine the most appropriate treatment combination, including different levels of nitrogen and Nitroxn in a hybrid corn fed hybrid of Maxima to achieve the greatest amount of yield produced environmental conditions prevailing was in both irrigated and drought stress at Arak.

Material and methods

The present experiment was conducted during 2011 and 2012 at a farm in Arak (Markazi Province-Iran) with 49° and 48' eastern longitude and 34° and 3' northern latitude. This region latitude's is 1635 meter above sea level. Soil texture was Clay-Loamy and pH was 7.1. The plant in this experiment was corn, hybrid

Maxima (*Zea mays cv Maxima*). Experimental treatments were considered including irrigation in two levels of I_0 and I_1 that were normal and deficit irrigation respectively as the main factor, Nitroxin in three-levels of No_0, No_1 and No_2 including zero, 0.5, and 1 ml per 30 kg of seed consumption respectively and nitrogen in three-levels of N_0, N_1 and N_2 including zero, 125 and 250 kg per ha, respectively as sub factors. The experiment was conducted the split-split plot in a randomized complete block design. The farmland was plowed in mid-April and was prepared by furrower. The number of rows in each plot determined 4 rows and length of each row 6 meter and spacing of seed on row was 19 cm. The seeds were mixed with Nitroxin before planting in the shade. The seeds were planted manually. Before the first irrigation was distributed one-fifth of the nitrogen by urea 46%. The other four stages of fertilization were in stages of three-leaf, six-leaf, before the advent tassel and post-pollination. The amounts of phosphorus fertilizer were calculating and used to basis of 100 Kg phosphorous (P_2O_5) per acre by source of triple superphosphate according to soil test results.

Method applied deficit irrigation

Since the establishment of full- the activation time of 4 hours for optimum irrigation sprinklers, it was necessary to develop deep roots in the area (Based on irrigated farm's design) it's time declined to consult the experts Irrigation 2.5 hours. Volume of irrigation water used on the farm at any stage of conventional irrigation and drought stress was calculated for each section. To ensure the least amount of moisture by the roots at low water wt% moisture measurement method in accordance with Equation (1) was used after carrying out the necessary calculations were compared in table 1.

Formula 1:

$$\text{Weight percent moisture} = \frac{W_2 - W_1}{W_2} \times 100$$

In this formula; W_2= Wet soil weight and W_1= Dry soil weight after leaving the oven

Sampling

Midfielder forage maturities of each plot separately the components of conventional irrigation and water stress was weighing forage and an area of 2 square meters per iteration. Then the average fodder yield calculated in similar experimental treatments.

Software and the formula used

For calculation correlation of coefficients between traits was used in the software SPSS. To determine the relative resistance to drought and tested hybrid combination of various treatments of the Stress Susceptibility Index (SSI), tolerance to the stress (STI), Geometric Mean Production (GMP), Tolerance (TOL) and Mean production (MP) in accordance with the following formula was used:

Formula 2: Stress Susceptibility Index[1]

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

Formula 3: Stress Tolerance Index[1] $STI = \frac{(Y_P)(Y_S)}{(\bar{Y}_P)^2}$

Formula 4: Geometric Mean Production[2]

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

Formula 5: Tolerance[1] $TOL = Y_P - Y_S$

Formula 6: Mean Production[1] $MP = \frac{Y_P + Y_S}{2}$

Results and discussion

Stress Susceptibility Index (SSI)

According to results of this experiment in both years of the project, the treatment combination of 125 kg nitrogen per hectare, without Nitroxin (No_0N_1) revealed the lowest number of stress susceptibility index (Tables 2 and 3). Therefore in terms of this indicator was selected as the best treatment combination that causes the least sensitivity of forage maize (hybrid Maxima) is attributed to the onset of drought conditions. Despite the recent conclusion treatment (No_0N_1) the yield of fodder in both situations optimal irrigation field and applied drought stress among the nine cases treated ranked in eighth

tables 2 and 3. While treatments of 1 liter Nitroxin with 250 kg nitrogen per hectare (No_2N_2) and consumption of 1 liter Nitroxin with 125 kg N per hectare (No_2N_1) in both conditions of optimum irrigation and drought stress, compared with other treatments, had first and second Ranked respectively. Therefore, we conclude that this index is not able to differentiate the treatment combination of drought tolerant than those who are low yield potential, based on the selection index (SSI) leads to the selection of tolerant treatment with low yield potential. There wasn't correlation between SSI with yield in both performances of experiment (Tables 4 and 5). Abolhasani and Saeidi (2006) conducted an experiment to evaluate drought tolerance of Safflower lines based on tolerance and sensitivity indices to water stress, and they said that genotype to had the lowest SSI index showed lower yield compared to many other genotype. Fernandez (1992) stated that the choice based on SSI genotypic selection, leads to which a lower performance in terms of stress, but in stress conditions, will have higher yield relatively. According to a team of researchers, if a line has a higher yield in both stress and non-stress conditions but to show the percentage of change is not recognized as tolerant line (Choukan *et al.,* 2006).

Table 1. Comparison between soil moisture weight percent in conventional irrigation and stress field in different depths.

Soil depth (cm)	Weight percent moisture (irrigated fragments)	Weight percent moisture (drought fragments)
10	0.25	0.19
20	0.33	0.26
30	0.24	0.21

Table 2. Treatments applied to assess various indicators of drought resistance in crop field conditions in 2011.

E.T	Yp		Ys		SSI		STI		GMP		TOL		MP	
	Amo	Ra	Amo	Ra	Amo	Ra	Amo	Ra	Amo	Ra	Amo	Ra	Amo	Ra
No_0N_0	56.6	9	48.8	9	0.78	2	0.46	9	52.5	9	7.8	2	52.7	9
No_0N_1	62.63	8	56.32	8	0.55	1	0.59	8	59.4	8	6.31	1	59.47	8
No_0N_2	79.06	5	63.48	5	1.11	5	0.84	5	70.8	5	15.58	5	71.27	5
No_1N_0	70.1	7	58.05	7	1	4	0.68	7	63.8	7	12.05	4	64.07	7
No_1N_1	72.78	6	61.63	6	0.89	3	0.75	6	67	6	11.15	3	67.2	6
No_1N_2	85.55	3	66.5	3	1.28	7	0.95	3	75.4	3	19.05	7	76.02	3
No_2N_0	80.66	4	63.59	4	1.17	6	0.86	4	71.6	4	17.07	6	72.12	4
No_2N_1	92.1	2	73.77	2	1.11	5	1.14	2	82.4	2	18.33	8	82.93	2
No_2N_2	95.81	1	76.46	1	1.11	5	1.23	1	85.6	1	19.35	9	86.13	1

In this table, E.T: Experimental Treatments, Amo: Amount, Ra: Rank, No: reagent levels of Nitroxin and N: represent the levels of nitrogen, Y_p: yield of variety in normal irrigation, Y_s: yield of variety in drought stress, SSI: Stress Susceptibility Index, STI: stress tolerance index, GMP: Geometric Mean Production, TOL: Tolerance, MP: Mean Production.

Stress Tolerance Index (STI)

In the two-years of trial use of 1 liter Nitroxin treated with 250 kg N per ha (No_2N_2) induced tolerance in the highest value of corn, in drought-stress conditions the hybrid Maxima and Subsequent treatments (No_2N_1) and (No_1N_2) were in second and third place (Tables 2 and 3). In addition, this treatment caused the greatest amount of forage yield in both conditions were optimum irrigation and drought stress. Also, between the STI index with forage yield there was a significant positive correlation with yield both favorable and drought stress (Tables 4 and 5). So according to this index, treatment of (No_2N_2) is selected as more favorable treatment. The lowest

index was related to the control and had the final ranking. Many research results show that the stress tolerance index (STI) is more favorable compared with other stress indicators. Vaisi malamiri *et al* (2010) the STI, introduced as leading indicators for the selection of drought tolerant genotypes they said that can be selected using the components of drought tolerant genotypes with high yield. Some researchers have reported that stress tolerance index are successful in both normal and stress conditions for select genotypes and have higher performance than the other indices (Shoaa hoseini *et al.,* 2008).

Table 3. Treatments applied to assess various indicators of drought resistance in crop field conditions in 2012.

E.T	Yp		Ys		SSI		STI		GMP		TOL		MP	
	Amo	Ra	Amo	Ra	Amo	Ra	Amo	Ra	Amo	Ra	Amo	Ra	Amo	Ra
No_0N_0	57.54	9	46.68	9	1.05	5	0.45	9	51.8	9	10.86	3	52.11	9
No_0N_1	62.58	8	56.57	8	0.55	1	0.6	8	59.5	8	6.01	1	59.57	8
No_0N_2	77.81	5	64.6	4	0.94	3	0.84	5	70.9	5	13.21	4	71.2	5
No_1N_0	72.34	6	58	7	1.11	6	0.7	7	64.7	7	14.34	5	65.17	7
No_1N_1	71.82	7	62.23	6	0.72	2	0.74	6	66.8	6	9.59	2	67.02	6
No_1N_2	85	3	69.18	3	1.05	5	0.98	3	76.7	3	15.82	6	77.09	3
No_2N_0	81.11	4	63.35	5	1.22	7	0.85	4	71.7	4	17.76	8	72.23	4
No_2N_1	92.63	2	75.97	2	1	4	1.17	2	83.8	2	16.66	7	84.3	2
No_2N_2	96.41	1	77.02	1	1.11	6	1.24	1	86.1	1	19.39	9	86.71	1

In this table, E.T: Experimental Treatments, Amo: Amount, Ra: Rank, No: reagent levels of Nitroxin and N: represent the levels of nitrogen, Y_p: yield of variety in normal irrigation, Y_s: yield of variety in drought stress, SSI: Stress Susceptibility Index, STI: stress tolerance index, GMP: Geometric Mean Production, TOL: Tolerance, MP: Mean Production.

Table 4. Correlation coefficients between traits tested in 2011.

E.T	Y_P	Y_S	SSI	STI	GMP	TOL	MP
YP	1						
YS	0.98**	1					
SSI	0.78*	0.65	1				
STI	0.99**	0.99**	0.7*	1			
GMP	0.99**	0.99**	0.73*	0.99**	1		
TOL	0.95**	0.87**	0.93**	0.9**	0..91**	1	
MP	0.99**	0.99**	0.73*	0.99**	1.00**	0.92**	1

E.T: Experimental Treatments , *,** and number of without symbol: Significant at the 5% level, significant at the 5% level and non-significant at the 5% level respectively.

Geometric Mean Production (GMP)

The results of experiments conducted in both years showed that consumption of one liter Nitroxin treated with 250 kg N (No_2N_2) makes creating the highest geometric mean index of manufacturing (GMP) in forage maize (hybrid Maxima) and was the first rank. The treatments of (No_2N_1) and (No_1N_2) also were ranked second and third respectively. The lowest amount of GMP was assigned to the control treatment (Tables 2 and 3). All experimental treatments were the same rank in terms of both components of stress tolerance index (STI) and the geometric mean index for manufacturing (GMP) and there was a direct correlation between the two indexes. In other words, the treatment (No_2N_2) has resulted most of the geometric mean product (GMP) has led to the largest numeric value of stress tolerance index (STI) Indicates that the incidence of induced resistance in maize under drought stress.

There was a significant positive correlation between (GMP) with yield in both conditions in this

experiment (Tables 4 and 5). So seems the GMP to be a good indicator for the selection of treated more favorably. One of the researchers reported that the three indices STI, GMP and MP have a high positive correlation for selecting drought tolerant genotypes of Kabuli chickpea yield in both stress and non-stress environments (Frayedi, 2004). According to some scholars reported that there was a significant positive correlation between sorghum grain yield under drought stress indices GMP, STI and the highest correlation between the performance indicators is obtained GMP in stress conditions (Narooyi rad *et al.,* 2009).

Table 5. Correlation coefficients between traits tested in 2012.

E.T	YP	YS	SSI	STI	GMP	TOL	MP
YP	1						
YS	0.97**	1					
SSI	0.46	0.23	1				
STI	0.99**	0.99**	0.36	1			
GMP	0.99**	0.99**	0.35	0.99**	1		
TOL	0.84**	0.69*	0.86**	0.78*	0.78*	1	
MP	0.99**	0.99**	0.36	0.99**	1.00**	0.79*	1

E.T: Experimental Treatments , *,** and number of without symbol: Significant at the 5% level, significant at the 5% level and non- significant at the 5% level respectively.

Tolerance (TOL)

According to results of this experiment every two years the implementation of testing, treatment of 125 kg Nitrogen, without Nitroxin (No_0N_1) Most of the established tolerance towards drought and received first place (Tables 2 and 3). The lowest tolerance to drought stress was obtained by treating the use of 1 liter Nitroxin coupled with 250 kg of nitrogen (No_2N_2) and it combines elements of TOL treatments took place in the final ranking. Since the tolerance index (TOL) is obtained by subtracting the average yield under drought stress of average yield under optimum irrigation lowest numerical value obtained by subtracting the two conditions led to treatment (No_0N_1) is introduced as a superior treatment. While the yield obtained from the use of this treatment in the two-years trial both favorable and drought stress conditions in comparison with (No_2N_2) decreased Respectively 53.1 and 35.1 percent in the first year and the 52.9 and 36.7 percent in the second year. Therefore, it is concluded that the application of the selection indices is desirable TOL treatments will result in greater performance stability but did not succeed in selecting treatments that have application in both stress and non-stress would result in a good performance.

Some researchers reported that low TOL does not necessarily mean high yield under stress, but a line performance may be little in stress condition and is also associated with fewer declines in stress condition which makes TOL be small (Moghaddam and Hadizadeh, 2000). According report of some researchers TOL indices has been successful in the selection of genotypes with high yield in stress condition but it did not succeed in select genotypes that are both favorable and drought stress conditions are favorable performance (Choukan *et al.,* 2006). Another group of researchers concluded that the low value of TOL, is suitable criterion for the identification of high yielding varieties and drought tolerance, because varieties with low yielding aren't favorable cultivars in both normal and stress conditions, and much less than TOL (Vaisi malamiri *et al.,* 2010).

Mean Production (MP)

Due to the high amount of numerical index indicates the relative tolerance to drought stress treatments (No_2N_2) took place in the first rank. Subsequent treatments (No_2N_1) and (No_1N_2) were received second and third place respectively**.** Because the control treatment resulted in the lowest average forage

production and stress conditions tested were ranked in the final (ninth) place (Tables 2 and 3). Since the average index of production (MP) has been able to identify treatments that are both favorable and drought stress caused a higher yield of forage and, as was observed between the MP index yield optimum irrigation and drought conditions in both positive and significant correlation (Tables 4 and 5) So it can be considered as a good indicator. According report of some researchers reported that MP index is suitable as an index for identifying drought tolerant genotypes of chickpea (Souri *et al.,* 2005). According to some researchers selection based on MP lead to the selection of genotypes with high yield potential (Abolhasani and Saeedi, 2006).

Conclusion

Among the indicators of SSI, STI, GMP, TOL and MP to choose the best treatment combination, with the aim of achieving the maximum amount of forage maize yield under irrigation conditions applied field or stress, most desirable parameters are indicators of STI, GMP and MP. The remarkable point of this experiment is that the ratings assigned to the same treatment in all three indices. Despite of that indices of SSI and TOL represent a superior treatment, but as in both conventional irrigation and drought stress, resulted in lower performance indicators are not considered desirable.

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