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Original article

Determination of drought stress indices in corn (Case study: Behbahan)

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Extended abstract

Introduction

Drought stress is the most important factor limiting the growth and grain yield of maize (*Zea mays* L.). Drought stress is one of the most important abiotic stresses that can seriously reduce crop yields depending on the season and the time it occurs. In arid and semi-arid regions, the plant undergoes periods of dehydration during its growth and must be able to tolerate these periods to produce proper yield (Emam and Niknejad, 2004). Cooper et al. (2006) reported that the capacity and ability to produce different maize genotypes under drought stress varied according to their morphological and physiological characteristics. Corn at different stages of development requires different amounts of water. The effect of dehydration on maize plants is marked by certain symptoms. These symptoms are seen as decreasing plant height and root length, delay in plant growth, leaf area depletion, seed production and biomass (Cakir 2004). The results of correlations indicate a significant positive relationship between potential yield (without stress) with MP, GMP, STI, TOL and HARM indices. The most positive and significant correlation between indices was related to GMP and STI (0.99) (Alipour et al, 2014). Due to the importance of maize as one of the important cereals in Iran, using irrigation method can be adapted to water shortage during drought. The purpose of this study was to investigate the effect of drought stress through different irrigation intervals and identify superior cultivar based on stress indices.

Materials and Methods

In order to investigate the response of new maize cultivars to water stress, an experiment was conducted at Behbahan Agricultural Research Station with latitude 50°:14′ east and 30°:36′ north latitude as a split plot in a randomized complete block design with four replications. It was implemented in two years (2014 - 2015). Drought stress including irrigation after 100 and 200 mm evaporation from Class A pan in main plots and three maize cultivars (S.C. 704, PH3 and PH4) were compared in sub plots.

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Results

Comparison of mean water use efficiency in irrigation and cultivar interactions showed that 100 mm evaporation from Class A pan and V2 cultivar with yield of 1.299 kg maize per 1 m3 of water was in the first rank and position. The 100 mm evaporation treatment of Class A pan and cultivar V2 was ranked second with production of 1.155 kg of maize grain per cubic meter of water. Pearson correlation coefficient results showed that the highest correlation of grain yield with water use efficiency and 1000-grain weight were calculated as 0.8761 and 0.8478, respectively, indicating the effective role of 1000-grain weight in increasing maize yield. The highest values of SSI, STI, MP, TOL, GMP, HM and YI were for V2 and the lowest for V3. The lowest YSI index belonged to V2. In other words, the accuracy of the stress and non-stress treatments in V2 indicates that the above indexes are classified as ascending and descending, respectively. Therefore, higher values of SSI, STI, MP, TOL, GMP, HM and YI in each cultivar showed that the cultivar is resistant to drought stress or deficit irrigation. Therefore, the drought tolerant cultivar identification criterion can be high values of SSI, STI, MP, TOL, GMP, HM and YI. Thus, the values of the above indices and their use in selection of drought tolerant cultivars indicate an increase in grain yield under stress and non-stress conditions and can be recommended together to identify suitable cultivars for each condition.

Conclusion

Comparison of mean interaction effects between irrigation and cultivar in terms of water use efficiency showed that water use reduction in stress treatment decreased water yield in this treatment compared to non-stress treatment. The effect of reducing water use was even to the extent that it failed to cover the continuous decrease in yield in return for water consumption, and the treatment of 100 mm evaporation from Class A pan despite still consuming more water than the 200 mm evaporation treatment from Class A pan. Due to the increase in performance, water consumption was the most efficient. Positive and significant correlations of yield components with important traits of 1000-grain weight on one hand and highly significant correlation of 1000-grain weight with yields on the other hand indicate that the trend of increasing yield components with grain yield increased. Drought stress tolerance index was higher than other cultivars for SSI, STI, MP, GMP, HM and YI indices.

Acknowledgements

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Keywords: 1000-grain weight, Water use efficiency, Variety, Evapotranspiration

Table 1 - Water Sample Analysis Results

Cl^-	SO_4^{-2}	HCO_3	Na^+	Mg^{2+}	Ca^{2+}	T.D.S	pH	EC
------ meq/l ------						mg/lit		(µS/m)
8.8	8.0	3.2	8.0	3.2	8.8	1140	7.4	1740

Table 2. Sample analysis of soil samples before planting

Year	FC	pb	K^+	P	Organic crbon	pH	EC	Soil deapth	Soil texture
	%	g/cm^2	mg/kg		%		dS/cm	cm	
2014	24	1.57	245	9.8	0.64	7.6	2.8	0-30	**Silty clay loam**
2015	24	13.57	250	9.2	0.66	7.5	3	0-30	

Table 3. Cumulative evaporation from Class A pan during the experiment (mm) (from 25 July to 3 December)

Year	August-july	July - September	September - October	October - November	November-December	Total
2014-15	533.8	437.9	268.4	155.6	25	1420.7
2015-16	504.6	405.7	309.2	129.2	22	1370.7
Mean	519.2	421.8	288.8	142.4	23.5	1395.7

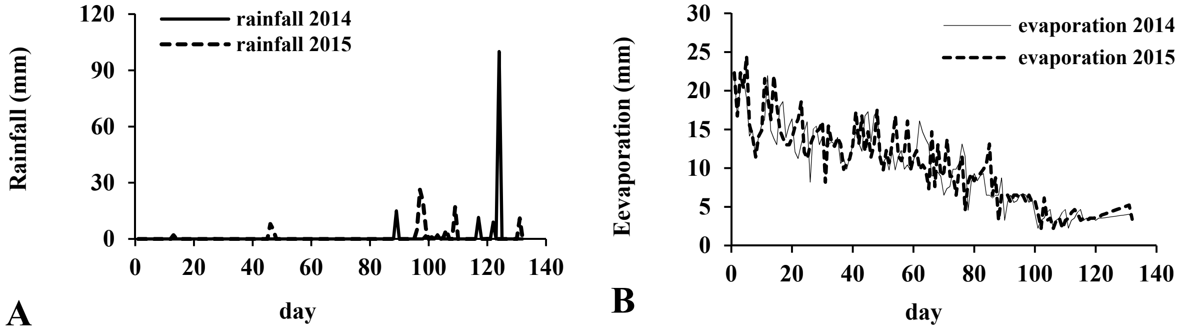

Fig. 1. Precipitation (a) and evaporation from Class A pan (b) daily for two years of experiment (from 25 July to 3 December)

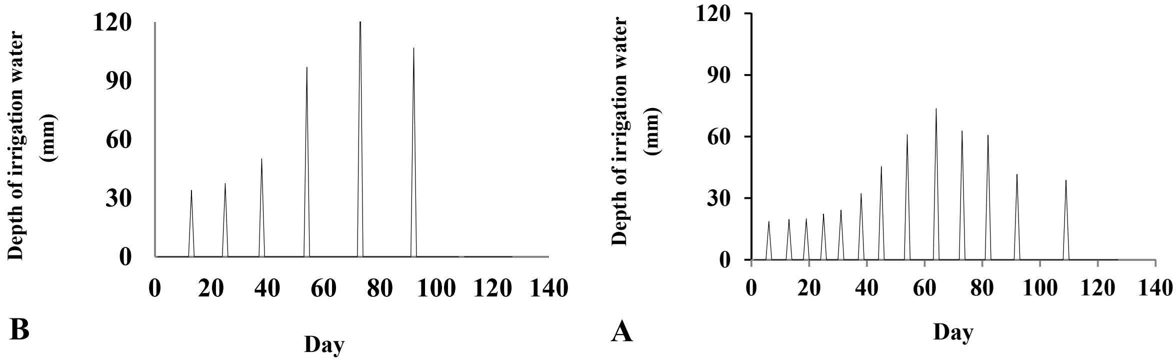

Fig. 2. Water depth in irrigation treatments and irrigation intervals (A = 100 mm treatment and B = 200 mm treatment) in the first year of experiment (from 25 July to 3 December 2014)

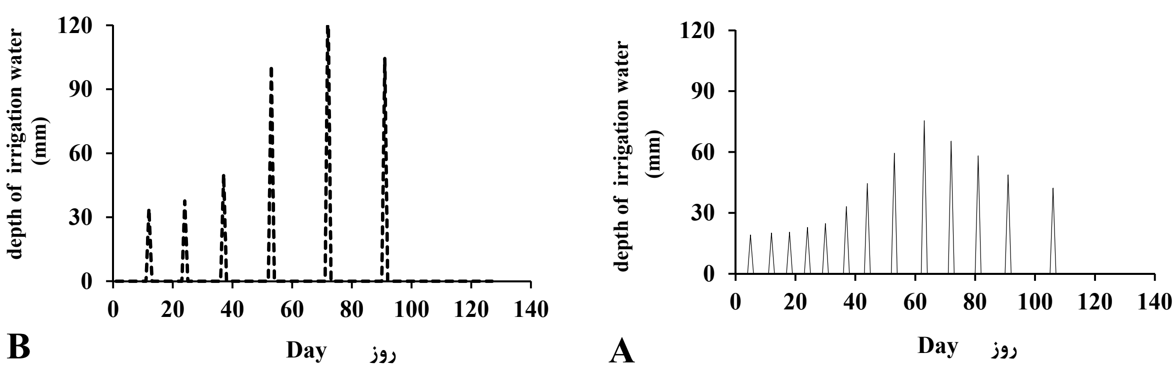

Fig. 3. Water depth in irrigation treatments and irrigation intervals (A = 100 mm treatment and B = 200 mm treatment) in the second experiment year (from 25 July to 3 December 2015)

Table 4. Comparison of mean squares and significance level of yield and water use efficiency of corn grain in experimental treatments in two-year composite analysis

Sources of variance	df	yield	Water use efficiency
Year	1	26532.6 n.s	0.008 n.s
Repeat (year)	6	333061.2 n.s	0.014 n.s
Irrigation	1	10509537.8**	0.021**
Year × irrigation	1	248.4 n.s	0.002 **
Error	6	1846.9	0.000
Variety	2	4355801.5**	0.168**
Year × variety	2	3311.9 n.s	0.000 n.s
Variety × irrigation	2	1037198.4**	0.032**
Year× irrigation × variety	2	79.2 n.s	0.000 n.s
Error	24	148259.6	0.006
Coefficient of variation%	–	6.93	6.93

**: Significant difference at 1% level; *: Significant difference at 5% level; n.s: There was no significant difference

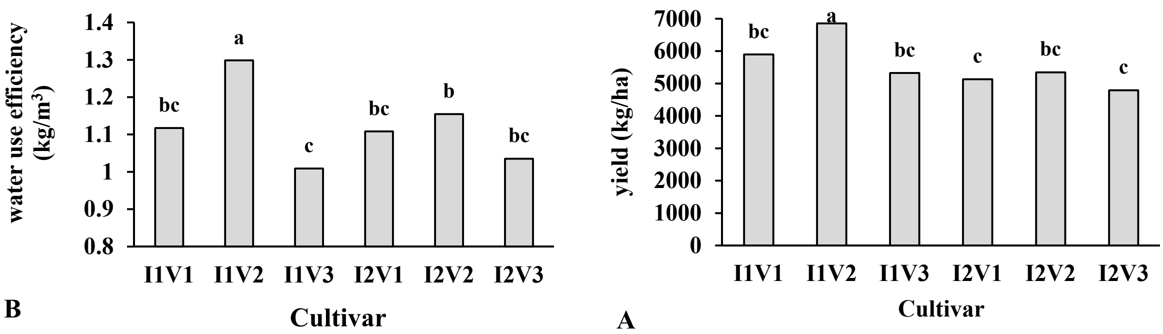

Fig. 4 - Average yield (A) and average water use efficiency (B) in interactions between irrigation levels and cultivar

Table 5. Calculated correlation coefficient for yield, yield components and water use efficiency (non-stress)

	1	2	3	4	5	6	7	8	9
	Seed yield (kg/ha)	**1000-grain weight (gr)**	**Number of seeds in a row**	**Number of rows of seeds**	**cob length (cm)**	**Day to maturity**	**Day until the emergence of cob**	**Volume of consumed water (m^3/ha)**	**water use efficiency (kg/m^3)**
1	1.0000	0.8439**	0.7674**	0.6208**	0.2318	-0.8620**	0.0427	-0.0354	0.9944**
2		1.0000	0.9381**	0.8270**	0.5313**	-0.9289**	0.0611	-0.1395	0.8504**
3			1.0000	0.8935**	0.4600*	-0.8672**	0.1327	-0.0636	0.7658**
4				1.0000	0.4469*	-0.7578**	0.1895	-0.1701	0.6310**
5					1.0000	-0.4731*	0.0203	-0.2982	0.2610
6						1.0000	0.1775	-0.0080	-0.8517**
7							1.0000	-0.0682	0.0489
8								1.0000	-0.1403
9									1.0000

N=24; 5%=0.4060; 1%=0.5164

Table 6. Calculated correlation coefficient for yield, yield components and water use efficiency (stress)

	1	2	3	4	5	6	7	8	9
	Seed yield (kg/ha)	1000-grain weight (gr)	Number of seeds in a row	Number of rows of seeds	cob length (cm)	Day to maturity	Day until the emergence of cob	Volume of consumed water (m^3/ha)	water use efficiency (kg/m^3)
1	1.0000	0.3124	0.3320	0.0965	-0.5358**	-0.5447**	-0.4611*	-0.0545	0.9998**
2		1.0000	0.7708**	0.5805**	0.1798	-0.1646	-0.0290	-0.3357	0.3182
3			1.0000	0.7665**	-0.0957	-0.4079*	-0.2851	-0.1066	0.3334
4				1.0000	0.0058	-0.2643	-0.1560	-0.2470	0.1006
5					1.0000	0.6107**	0.6309**	-0.2553	-0.5303**
6						1.0000	0.9808**	-0.0029	-0.5438**
7							1.0000	-0.0126	-0.4602*
8								1.0000	-0.0727
9									1.0000

N=24; 5%=0.4060; 1%=0.5164

Table 7. Analysis of variance in regression model (stress treatments)

Sources of variance	Degrees of freedom	Mean squares	F Value	The regression coefficient	R-square	Corrected R-square	Sig.
Model	3	215897.8	1.439	0.421	0.178	0.054	0.261 n.s
Error	20	150036.1					
Total	23						

**: Significant difference at 1% level; *: Significant difference at 5% level, n.s: There was no significant difference.

Table 8. Coefficients of variables in the regression equation (stress treatments)

Model	Unstandardized Coefficients		Standardized Coefficients	t Value	Sig.
	B coefficient	The standard error	Beta		
Constant number	1806.293	3040.492	-	0.594	0.559
1000-grain weight=X_1	6.164	15.170	0.129	0.406	0.689 n.s
Number of seeds in a row=X_2	124.317	95.894	0.523	1.296	0.210 n.s
Number of rows of seeds=X_3	-172.118	143.154	-0.380	-1.202	0.243 n.s

**: Significant difference at 1% level, *: Significant difference at 5% level, n.s: There was no significant difference.

Table 9. Analysis of variance in regression model (non-stress treatments)

Sources of variance	Degrees of freedom	Mean squares	F محاسبه‌شده F Value	The regression coefficient	R-square	Corrected R-square	Sig.
Model	3	3105142.9	18.141	0.855	0.731	0.691	0.00**
Error	20	171169.9					
Total	23						

**: Significant difference at 1% level, *: Significant difference at 5% level, n.s: There was no significant difference.

Table 10. Coefficients of variables in the regression equation (non-stress treatments)

Model	Unstandardized Coefficients		Standardized Coefficients	t Value	Sig.
	B coefficient	The standard error	Beta		
Constant number	-2947.156	1403.992	-	-2.099	0.049
1000-grain weight=X_1	30.476	10.139	1.009	3.006	0.007**
Number of seeds in a row=X_2	13.157	93.401	0.059	.141	0.889 n.s
Number of rows of seeds=X_3	-131.952	128.296	-0.266	-1.028	0.316 n.s

**: Significant difference at 1% level, *: Significant difference at 5% level, n.s: There was no significant difference.

Table 11. Mean stress indices calculated in the studied cultivars

Variety	YS (kg/ha)	YP (kg/ha)	SSI	STI	MP	TOL	GMP	HM	YI	YSI
V1: S.C 704	5131.7	5898.5	0.837	0.839	5515.1	766.8	5501.7	5488.4	1.008	0.870
V2: PH3	5346.8	6854.9	1.417	1.010	6100.9	1508.1	6054.1	6007.7	1.050	0.780
V3: PH4	4793.7	5326.4	0.644	0.705	5060.1	532.6	5053.0	4793.7	0.942	0.900
Mean	5090.7	6026.6	0.966	0.852	5558.7	935.8	5536.3	5429.9	1.000	0.850

YS = Average cultivar yield per 200 mm treatment; YP = Average cultivar yield per 100 mm treatment

Table 12. Correlation coefficient of stress indices

	1	2	3	4	5	6	7	8	9	10
	YS (kg/ha)	**YP (kg/ha)**	**SSI**	**STI**	**MP**	**TOL**	**GMP**	**HM**	**YI**	**YSI**
1	1.0000	0.8931**	0.5358**	0.9595**	0.9538**	0.6228**	0.9598**	0.9368**	1.0000**	-0.5358**
2		1.0000	0.8574**	0.9821**	0.9870**	0.9081**	0.9835**	0.9792**	0.8931**	-0.8574**
3			1.0000	0.7469**	0.7641**	0.9927**	0.7508**	0.7753**	0.5358**	-1.0000**
4				1.0000	0.9987**	0.8152**	0.9990**	0.9862**	0.9595**	-0.7469
5					1.0000	0.8290**	0.9998**	0.9887**	0.9538**	-0.7641**
6						1.0000	0.8173**	0.8312**	0.6228**	-0.9927**
7							1.0000	0.9884**	0.9598**	-0.7508**
8								1.0000	0.9368**	-0.7753**
9									1.0000	-0.5358**
10										1.0000

n = 24; 5%=0.3976; 1%=0.5069

Y_S = Average cultivar yield per 200 mm treatment; Y_P = Average cultivar yield per 100 mm treatment