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Screening Drought Tolerance Criteria in Maize

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Abstract

Six pure lines of maize were tested in a randomized complete block design with three replication under irrigated and rainfed conditions. Genetic variation was found between the genotypes for yield potential (Y_p) stress yield (Y_s), tolerance index (TOL), geometric mean productivity (GMP), harmonic mean (HM) and stress tolerance index (STI). Stress tolerance index was corrected using a correction coefficient (Ki) and thus a modified stress tolerance index (MSTI) was introduced as the optimal selection criterion for drought-tolerant genotypes. The results of three-D plotting indicated that the most desirable genotype for irrigated and rainfed conditions was the genotype K1515, for non-stressed conditions K18 and for stress conditions K104/3, K760/7 and K126/10.

Keywords: Maize, Drought tolerance, Biplot, Modified stress tolerance index

Introduction

The improvement of drought tolerance has been defined as a desirable breeding objective in crops such as maize (Clark *et al.*, 1992). Drought tolerance in native plant species is often defined as survival, but in crop species it should be defined in terms of productivity (Passioura, 1983). The definition of drought tolerance as the ability of plants to grow satisfactorily when exposed to water deficits has little direct applicability to either quantifying or breeding for the character in crop species (Clark *et al.*, 1992). In the absence of an understanding of the special mechanisms of tolerance the quantification of drought tolerance should be based on the grain yield under dry conditions (Fischer and Maurer, 1978). It is worthwhile, therefore, to look at the methods that have been used to quantify tolerance. Several selection criteria are proposed to select genotypes based on their performance in stress and non-stress environments (Fernandez, 1992). Rosielle and Hamblin (1981) defined stress tolerance as the difference between grain yield in stress (Y_s), and non-stress (Y_p) environments, and mean

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productivity (MP) as the average of Y_p and Y_s. Fischer and Maurer (1878) proposed a stress susceptibility index (SSI). Fernandez (1992) defined a new stress tolerance index (STI).

Genotypes can be categorized into four groups based on their performance in stress and non-stress environments: genotypes which express uniform superiority in both stress and non-stress environments (Group A); genotypes which perform favourably only in non-stress environments (Group B); genotypes which yield relatively well only in stress environments (Group C) and genotypes which perform poorly in both stress and non-stress environments (Group D). The optimal selection criteria should distinguish Group A from the other three groups (Fernandez, 1992).

The objectives of the current experiment, carried out in the Agricultural research Station of Dezful, Iran the year 2000, were (i) the screening of quantitative criteria of drought tolerance, (ii) the introduction of a new drought tolerance index and (iii) the identification of drought tolerant genotypes.

Materials and Methods

Six pure lines of maize, namely K104/3(1), K760/7(2), K1515(3), K18(4), K19(5) and K126/1(6), were cultivated in a randomized complete block design with three replications under two different environments (irrigated and rainfed) in the Agricultural Research Station of Dezful, Iran. From each pure line 50 seeds were selected and single seeds were sown in 5m rows with 20×75cm plant to pant and row to row distances, respectively. The minimum and maximum temperatures at the station were 5.6°C and 54.6°C, respectively. The average rainfall in 2000 was 250mm and the region was arid. The chemical properties of the soil in the experiment were reported as:

Soil properties	Value
E.C.	0.04ds/m
PH	7.87
O.C.	0.48%
Mn	2.55ppm
P	6.7ppm
K	101ppm
Cu	1.31ppm
Fe	3.17ppm
Zn	0.32ppm

Each plot consisted of 4 rows, the two middle rows being planted with the tested genotypes and the two lateral rows with the genotype SC 704 to eliminate the border effect. Ten competitive plants were randomly selected from each entry in both the irrigated and rainfed treatments and the yield potential (Y_p) and stress yield (Y_s) were recorded. Using Y_p and Y_s the following quantitative indices of drought tolerance were calculated:

Tolerance index (TOL) and mean productivity (MP) (Rosielle and Hamblin, 1981) :

$$TOL = \left(Y_P - Y_S\right) and MP = \frac{Y_P - Y_S}{2}$$

Harmonic mean (HM) (Zahravi, 1999):

$$HM = \frac{2(Y_P \times Y_S)}{Y_P + Y_S}$$

Stress susceptibility index (SSI) (Fischer and Maurer, 1978):

$$SSI = \frac{1-(Y_s / Y_p)}{SI}; SI = 1-(Y_s / Y_p)$$

Where SI is stress intensity and Y_s and Y_p are the means of all genotypes under stress and irrigated conditions, respectively.

Geometric mean productivity (GMP) and stress tolerance index (STI) (Fernandez, 1992; Kristin *et al.*, 1997):

$$GMP = \sqrt{(Y_p)(Y_s)}, STI = \frac{(Y_s) \times (Y_p)}{(Y_p)^2}$$

Modified stress tolerance index (MSTI):

$$MSTI = k_i STI, K_1 = \frac{Y_p^2}{Y_p^2} and K_2 = \frac{Y_s^2}{Y_s^2}$$

Where k_i is the correction coefficient.

Analysis of variance mean comparison, correlation analysis and three-dimensional plotting were done using the MSTAT-C and SPSS statistical softwares.

Results and Discussion

The results of analysis of variance (Table 1) for various quantitative criteria of drought tolerance showed highly significant differences for all the indices except SSI, indicating the presence of genetic variation and the possibility of selection for drought tolerant genotypes based on Y_p, Y_s, TOL, GMP, HM and STI.

Genetic variation between maize genotypes was reported for yield by Bolanos and Edmeades (1996) and Morris *et al.* (1991), for drought resistance by Vasal *et al.* (1997) and Banziger *et al*. (1997) and for Y_p, Y_s, TOL, MP, GMP, SSI, HM and STI by Ahmadzadeh (1997) and Afarinesh (2000).

The estimates of stress tolerance attributes (Table 2) indicated that the identification of drought-tolerant genotypes based on a single criterion was contradictory. For example, according to TOL, the desirable drought-tolerant genotype was K104/3(1), while according to STI the most desirable drought-tolerant line was K1515(3). Moreover, MP failed to distinguish the group A and group B genotypes, while TOL and SSI failed to distinguish between group C and group A (Fernandez, 1992). To determine the most desirable drought tolerance criteria, the correlation coefficient between Y_p, Y_s and quantitative indices of drought tolerance was calculated (Table 2).

Table 1: Analysis of Variance for Different Indices of Drought Tolerance Irrigated and Rainfed Conditions

Source of variation	d.f.	Mean square							
		Y_p	Y_s	TOL	MP	GMP	HM	SSI	STI
Genotypes	3	5480**	3382**	766**	4232**	4145**	4262**	0.60	0.83**
Replication	2	534	631	1421*	26.18	11.07	68.9	0.79	0.03
Error	10	127*	418.8	415.4	70.70	76.90	122.9	0.38	0.03

*, ** significant at the 5% and 1% probability level, respectively

Table 2: Estimates of stress tolerance attributes from potential yield and stress yield data for maize genotypes

Lines	Y_p	Y_s	TOL	MP	GMP	HM	SSI	STI	K_1STI	K_2STI
K104/3	51.9	48.4	3.6	50.2	50.2	50.1	0.27	0.19	9.4	11.8
K760/7	52.9	48.9	3.9	50.9	50.8	50.8	0.31	0.19	9.9	12.3
K1515	78.4	42.9	25.7	65.5	64.1	62.8	1.32	0.30	34.7	22.6
K18	50.3	14.2	20.9	32.7	26.7	22.1	1.09	0.05	2.5	0.29
K19	61.5	31.6	29.8	46.5	44.8	44.4	1.9	0.14	10.2	3.91
K126	33.9	31.2	6.2	32.8	32.5	32.6	0.65	0.07	1.5	1.83

Table 3 showed that MP and STI had a positive significant correlation with Y_p and Y_s; thus, MP and STI were better predictors of mean Y_p and mean Y_s than the other indices. However, MP fails to distinguish between group A and group B, while STI is estimated based on GMP; the rank correlation between STI and GMP is thus equal to 1 (Rosielle and Hamblin, 1981; Fernandez, 1992). The higher the value of STI for a genotype, the higher its stress tolerance and yield potential. The stress intensity value is also incorporated in the estimation of STI. Therefore, STI is expected to distinguish group A from group B and group C. This result was in close agreement with the findings of Fernandez (1992), Maroufi (1998), Imamjomah (1999) and Farshadfar *et al*. (2001).

In the STI index, Y_p^2 is a constant value, while the square root of the multiplication of Y_p and Y_s is the geometric mean of a genotype under stress and non-stress condition. For this reason a pair of numbers with different natures may have the same geometric mean. For example, the geometric mean for the data pairs 1 and 12, 2 and 6, and 3 and 4 is 3.46, while these data, if related to the yield of the genotypes, have clearly different natures. This problem arises in the stress tolerance index (STI) and hence decreases its efficiency in distinguishing group A genotypes from the other group (Naderi *et al.*, 1999).

To improve the efficiency of STI a modified stress tolerance index (MSTI) was calculated as k_i STI, where k_i is a correction coefficient which corrects the STI as a weight. Therefore, k_1 STI, k_2 STI are the optimal selection indices for stress and non-stress condition, respectively. Considering Y_p and Y_s as dependent and k_1 STI, k_2 STI and STI as independent variables, the contribution of k_1 STI to Y_p in relation to STI was R^2=0.817, while the contribution of STI to Y_p was R^2=0.65. the contribution of k_2 STI to Y_s was R^2=0.78, while that of STI was R^2=0.72. thus, k_1 STI, and k_2 STI are better predictors of Y_p and Y_s respectively, in non-stress environments.

Table 3: Correction Coefficients between Y_p, Y_s and Drought Tolerance Index

	Y_p	Y_s	TOL	MP	GMP	HM	SSI	STI	K_1STI	K_2STI
Y_p	1	0.46	0.65	0.85*	0.77	0.69	0.50	0.82*	0.90*	0.74
Y_s	-	1	-0.29	0.86*	0.92*	0.96**	-0.34	0.88*	0.66	0.88*
TOL	-	-	1	0.20	0.10	-0.07	0.96**	0.15	0.42	0.03
MP	-	-	-	1	0.99*	0.97**	0.086	0.99**	0.92*	0.95**
GMP	-	-	-	-	1	0.99	0.014	0.99**	0.87*	0.95**
HM	-	-	-	-	-	1	-0.08	0.97**	0.83*	0.94**
SSI	-	-	-	-	-	-	1	0.034	0.28	-0.12
STI	-	-	-	-	-	-	-	1	0.92**	0.97**
K_1STI	-	-	-	-	-	-	-	-	1	0.90*
K_2STI	-	-	-	-	-	-	-	-	-	1

*,** significant at the 5% and 1% levels of probability respectively

Using STI, k_1 STI and, k_2 STI as the optimal selection criteria the most desirable genotypes for irrigated and rainfed conditions was K1515 (STI = 0.30, and k_1 STI = 34.7 and k_2 STI = 22.6). A three-dimensional plot between Y_p, Y_s and STI (Fig.1) was used to distinguish the group A genotypes from the other three groups (B, C and D) (Fernandez, 1992; Farshadfar *et al*., 2001). In this case the most desirable genotype for irrigated and rainfed conditions was K1515, for non-stress conditions K18 and for stress conditions K760/7 and K126/1.

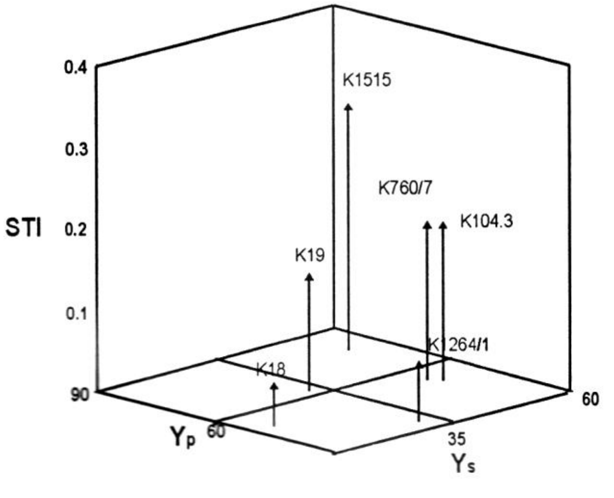

Fig 1: Three-dimensional Plot between Y_p, Y_s and STI

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