تقدير وانتخاب بعض المعايير لتحمل الإجهاد المائي في عشائر من الذرة الصفراء

Assessment and Selection of Some Drought Tolerance Indices in Maize Populations

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الملّخص

نُفذ البحث في قسم بحوث الذرة في الهيئة العامة للبحوث العلمية الزراعية السورية (دمشق/سورية) خلال المواسم الزراعية للأعوام 2009، 2010 و2011، بهدف دراسة أثر الإجهاد المائي متوسط الشدة في غلة 16 تركيباً وراثياً من الذرة الصفراء، ولدراسة أهمية معايير تحمل الإجهاد في الانتخاب لتراكيب متحملة لنقص الماء، ودراسة علاقة الارتباط الظاهري، ومعامل المرور بين الغلة ومعايير تحمل الإجهاد في البيئة المجهدة. اشتملت المادة الوراثية على أربعة هجن فردية وآبائها وعشائر الجيل الثاني لهذه الهجن، أظهرت التراكيب الوراثية المدروسة تبايناً عالي المعنوية للغلة في البيئة المجهدة وغير المجهدة، وتبايناً عالي المعنوية لجميع معايير تحمل الإجهاد المدروسة، وبلغت الزيادة في الغلة في البيئة غير المجهدة عن البيئة المجهدة 15 %. ووفق معايير تحمل الإجهاد تميز الهجينان (IL.275-06 x IL.362-06) و(IL.260-06 x IL.792-06)، والسلالات (IL.275-06) و(IL.256-06)، وعشيرة الجيل الثاني للهجين (IL.275-06 x IL.362-06) بأفضل قدرة على تحمل نقص الماء، وارتبطت صفة الغلة في البيئة المجهدة بقيم موجبة وعالية المعنوية مع الغلة في البيئة المثالية ومع المعايير TOL، DRI، HM، GMP، SDI، بينما كانت قيم الارتباط سالبةً وعالية المعنوية مع المعايير RDY، SSI، وبين تحليل معامل المرور أهمية الانتخاب للمعايير DRI، HM، GMP لتحسين الغلة الحبية في البيئة المجهدة.

الكلمات المفتاحية : الذرة الصفراء، الإجهاد المائي، معايير تحمل الإجهاد.

Abstract

This Research was conducted at the Department of Maize Research -General Commission for Scientific Agricultural Research (GCSAR- Damascus / Syria) during the growing seasons of 2009, 2010 and 2011, to study the effects of mild water stress on the yield of 16 genotypes of maize, in order to evaluate the ability of several selected indices to identify drought tolerance genotypes, and to study the phenotypic correlation and path coefficient analysis among yield and drought indices under stress conditions. The genetic material included four single hybrids F_1 , their parents and their F_2 populations. The analysis of variances indicated significant differences among the genotypes for yield under stress and normal conditions and between the genotypes for all drought indices. The yield under normal conditions was 15% more than under stress. According to drought indices, the single hybrids S0 (IL.275-06 x IL.362-06), S_0 (IL.260-06 x IL.792-06) and the inbred lines (IL.256-06), (IL.275-06) and the F_2 population S_1 (IL.362-06 x IL.275-06) were the most tolerant under water stress. Grain yield under stress condition was positively and significantly correlated with grain yield under

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non stress condition, GMP, HM, SDI, DRI and ATI, and the correlation were negative and significant with SSI, RDY. Path coefficient analysis indicated that HM, GMP and DRI are important selection criteria for improving yield under stress.
Keywords: Maize; Drought stress; Drought Tolerance Index.

Introduction

Maize is produced in nearly 100 million hectares in developing countries (FAOSTAT, 2010), One possible way to ensure future food need of the increasing world populations should involve a better use of water by the development of drought tolerant varieties which needs less amount of water and more tolerance of crops to drought (Shao *et al*., 2006). The development of improved germplasm to meet the needs of future generations in light of climate change and population growth is the most important (Easterling *et al*., 2007) especially when that more than 1/4 of the world land is dry and about 1/3 of the world's cultivable land under water shortage conditions (Kirigwi *et al*., 2004). In maize, grain yield reduction caused by drought ranges from 10 to 76% depending on the severity and stage of occurrence (Bolaòos *et al*., 1993), Conventional drought breeding has yielded significant dividends in maize (Bänziger *et al*., 2006), and has resulted in gains of up to 144 kg .ha^{-1}. yr^{-1}. When water stress was imposed at flowering (Edmeades *et al*., 1999) and there was an increase of 73 kg ha^{-1}. yr^{-1}. for mild stress (Campos *et al*., 2004). The relative yield performance of genotypes in drought-stressed and favorable environments seems to be a common starting point for the identification of desirable genotypes stress conditions (Mohammadi *et al*., 2010). In the absence of an understanding of the special mechanisms of tolerance the quantification of drought tolerance should be based on the grain yield in both stress and non-stress environments. This can lead to the selection of high yielding genotypes under stress condition, since the response of selection under non-stress condition is maximal and heritability of the yield under these conditions is high (Talebi, 2009; Shirinzadeh *et al*., 2010; Geravandi *et al*., 2011). To evaluate the response of plant genotypes to drought stress, some selection indices based on mathematical relation between stress and non-stress (optimum) conditions have been proposed (Rosielle and Hamblin, 1981; Clarke *et al*., 1992). drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). These indices are either based on drought resistance or susceptibility of genotypes (Fernandez, 1992), which is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp), geometric mean (GMP). Harmonic mean (Harm) and (TOL) are other important stress indices (Golbashy *et al*., 2010), The geometric mean is often used by breeders interested in relative performance since drought stress can vary in severity in field environment over years (Ramirez and Kelly, 1998). Fernandez (1992) estimated the yield of genotypes in two experiments (stress and non stress) and divided genotypes into four groups:

1- The genotypes that have high yield in stress and non stress environments (group A).
2- The genotypes that have high yield only in non stress environments (group B).
3- The genotypes that have high yield in stress environments (group C).
4- The genotypes that have weak yield in stress and non stress environments (group D), the objective of this research is to improve maize yield under stress condition, through distinguish high yielding maize inbred line, single hybrid S_0 and S_1 segregation generation and compare the efficiency of different selection indices in selecting drought tolerant genotypes.

Material and Methods

The present research was conducted at maize research department, crops research administration, The General Commission for Scientific Agricultural Research (GCSAR- Damascus/ Syria). The genetic material comprised of 16 genotypes of maize (four single hybrids and their parents and the F2 populations) (Table 1), the four single hybrids were selected from 28 single crosses resulted from the half diallel cross among 8 inbred lines in the growing season of 2009, and through the growing season of 2010 we get the F2 populations of four single hybrids by inbreeding enough plants of F1 population for each hybrids. The 16 genotypes were grown in the growing season of 2011 in two separate experiments, Each one contained three replications using randomized block design. Each replication consisted of four rows for F1, P1, P2 and eight rows of F2 population for each hybrid. The row length was 6 m with a spacing of 70 cm between rows and 25 cm between plants in the row.

Table 1. The pedigree of 16 genotypes of maize.

Genotype pedigree		
1	IL.275-06	Inbred line
2	IL.362-06	Inbred line
3	S0 (IL.275-06 x IL.362-06)	Single hybrid
4	S1(IL.275-06 x IL.362-06)	F2 population
5	IL.260-06	Inbred line
6	IL.792-06	Inbred line
7	S0(IL.260-06 x IL.792-06)	Single hybrid
8	S1(IL.260-06 x IL.792-06)	F2 population
9	IL.375-06	Inbred line
10	IL.256-06	Inbred line
11	S0(IL.375-06 x IL.256-06)	Single hybrid
12	S1(IL.375-06 x IL.256-06)	F2 population
13	IL.363-06	Inbred line
14	IL.459-06	Inbred line
15	S0(IL.363-06 x IL.459-06)	Single hybrid
16	S1(IL.363-06x IL.459-06)	F2 population

The first experiment was without stress application, so it was irrigated every 10±2 days regularly so the total number of irrigations was 10, while in the stress experiment (mild stress) the crop was irrigated every (17±2) through the growing season (two irrigations for planting and germination, two irrigations at the vegetative stage and three irrigations at the reproductive stage), so the water stress was done during the vegetative stage (V_{10}, V_{14}, V_{16}), and through the reproductive stage (R_4). The data on yield per plant was recorded on 20 individuals per replication of P_1, P_2, F_1 and on 40 individuals per replication of F_2 populations for each experiment.

Measured indices

Drought tolerance indices were calculated as following:

-stress susceptibility index (SSI)

$$\mathbf{SSI = (1-ys/yp)/(1-\overline{ys}/\overline{yp}}$$

the genotypes with SSI < 1 are more resistant to drought stress (Fischer and Maurer, 1978).

-Stress tolerance (TOT)

$$\mathbf{TOT = (Yp - Ys)}$$

The genotypes with low values of this index are more stable in two different treatments (Hossain *et al*., 1990)

-Geometric mean productivity (GMP)

$$GMP = \sqrt{(Yp \text{ x } Ys)}$$

The genotypes with high GMP value will be the best (Ramirez and Kelly, 1998).

-Relative decrease in yield (RDY)

$$RDY = 100 - \left(\frac{Ys}{100} \text{ x } Yp\right)$$

The genotypes with low value of this index will be more desirable (Emre *et al.*, 2011).

-Harmonic mean (HM)

$$HM = 2 \text{ x } (Ys) \text{ x } (Yp)/(Ys + Yp)$$

The genotypes with high value of this index will be more desirable (Kristin *et al.*, 1997).

- Sensitivity drought index (SDI)

$$SDI = (Yp - Ys)/Yp$$

The genotypes with low value of this index will be more desirable (Farshadfar and Javadinia, 2011).

-Drought resistance index (DRI)

$$DRI = Ys \text{ x } \left(\frac{Ys}{Yp}\right)/Ys$$ (Lan, 1998).

-A Biotic tolerance index (ATI)

$$ATI = \left[(Yp - Ys)/\frac{\overline{Yp}}{\overline{Ys}}\right] \text{ x } \sqrt{(Yp \text{ x } Ys)}$$ (Moosavi *et al.*, 2008)

Where: **Ys** and **Yp** are the mean yield of each genotype under stress and normal experiments respectively. $\overline{\mathbf{Ys}}$ and $\overline{\mathbf{Yp}}$ are the mean yield of all genotypes under stress and non stress conditions respectively.

The phenotypic correlation coefficients calculated as described by Snedecor and Cochran (1981) for all possible pairs of the drought indices including grain yield. To obtain more information about the relative contribution of these indices to grain yield and remaining indices. Partitioning correlation coefficients into direct and indirect effects at phenotypic level made by determining path coefficients using the method proposed by Wright (1934) and utilized by Dewey and Lu (1959).

Results and Discussion

Means and analysis of variance

The analysis of variances indicated significant differences in the yield between the 16 genotypes under stress and normal conditions and significant differences for all drought indices, and this results showed the diversity among genotypes for yield under different conditions and for drought tolerance indices (Table 2 and 3).

Table 2. Analysis of variance for stress indices.

S.O.V	YP	YS	SSI	TOL	GMP
R	35.2515	123.60	0.0467	32.4669	5.8363
G	14029.96^{**}	12820.53^{**}	1.965^{**}	358.7769^{**}	13400.68^{**}
GR	76.37	128.44	0.023	12.59	2.46

Y_P: Yield in normal condition; Y_S: Yield under stress SSI: Stress Susceptibility Index; TOL: Stress Tolerance; GMP: Geometric Mean Productivity.

Table 3. Analysis of variance for stress indices.

S.O.V	RDY	HM	SDI	DRI	ATI
R	52.1195	4.3238	31.6744	0.0008	746706.2
G	120140.5**	13479.12**	14007.48**	0.7818**	15652815**
GR	35.61	2.14	11.01	0.001	388484.2

RDY: Relative Decrease In Yield; HM: Harmonic Mean; SDI: Sensitivity Drought Index; DRI: Drought Resistance Index; ATI: A Biotic Tolerance Index.

The yield under non stress conditions was 15% higher than the stress conditions, so the stress intensity (SI= 15%) was mild stress (Fischer and Maurer, 1978; Bonea and Urechean, 2011).

Among the inbred lines IL.275-06 (129.63 g, 99.59 g), IL.362-06 (100.49g, 77.03 g) achieved the highest yield per plant under both normal and stress condition respectively (table 4 and 5), which indicat the importance of these inbred lines under stress and non stress conditions. Among the single hybrids, the hybrid (IL.275-06 x IL.362-06) had the best yield per plant (275.68 g, 246.17 g) under normal and stress conditions respectively. On the other hand, its F2 population achieved the best yield per plant among the F2 populations which reveals the importance of the (IL.275-06 x IL.362-06) population for getting new inbred lines of maize under stress and non stress conditions. These results explained that the best inbred lines IL.275-06 , IL.362-06 get the best progenies. The second best single hybrid was (IL.363-06 x IL.459-06) which had 251.24 g under non stress conditions but 207.92g under stress ones, and based on means, testing and selection under non-stress conditions may be effective for increasing yield under drought stress. Many researchers prefer genotypes that produce high yields when water is not limiting, but suffer acceptable loss during drought conditions (Nasir Ud-Din *et al*., 1992), while others prefer selection under target environment (Talebi, 2009). Our results are in the harmony with the conclusions of (Blum, 1996) which explained that under moderate stress conditions, potential yield greatly influences yield under stress.

Table 4. The estimation of yield Y_p, Y_S and stress indices for 16 genotypes at mild drought conditions.

Genotype	Y_P	Y_S	SSI	TOL	GMP
1	129.63	99.59	1.37	30.04	113.62
2	100.49	77.03	1.58	23.46	87.98
3	275.68	246.17	0.72	29.51	260.51
4	172.20	158.00	0.56	14.20	164.95
5	97.42	66.76	2.13	30.66	80.65
6	66.38	42.72	2.41	23.66	53.25
7	201.87	188.28	0.46	13.59	194.96
8	147.08	123.87	1.07	23.21	134.98
9	99.00	75.00	1.64	24.00	86.17
10	64.87	59.19	0.59	5.68	61.96
11	227.35	201.50	0.77	25.85	214.04
12	154.26	139.66	0.64	14.60	146.78
13	102.41	71.33	2.05	31.08	85.47
14	65.45	37.67	2.87	27.78	49.65
15	251.24	207.92	1.17	43.32	228.56
16	166.00	135.13	1.26	30.87	149.77

Y_P: Yield in normal condition; Y_S: Yield under stress; SSI: Stress Susceptibility Index; TOL: Stress Tolerance; GMP: Geometric Mean Productivity.

Table 5. The estimation of stress indices for 16 genotypes at mild drought conditions.

Genotype	RDY	HM	SDI	DRI	ATI
1	-29.10	112.64	128.86	0.63	2837.5
2	22.59	87.21	99.72	0.49	1718.9
3	-578.64	260.09	274.79	1.82	6397.1
4	-172.08	164.79	171.28	1.20	1954.8
5	34.96	79.23	96.73	0.38	2062.6
6	71.64	51.98	65.74	0.23	1052.3
7	-280.08	194.84	200.94	1.46	2215.3
8	-82.19	134.48	146.24	0.86	2618.5
9	25.75	85.34	98.24	0.47	1739.5
10	61.60	61.90	63.96	0.45	300.0
11	-358.11	213.65	226.46	1.48	4715.0
12	-115.44	146.60	153.35	1.05	1824.3
13	26.95	84.09	101.71	0.41	2262.2
14	75.34	47.82	64.87	0.18	1173.0
15	-422.38	227.54	250.41	1.43	8417.9
16	-124.32	148.98	165.19	0.91	3931.2

RDY: Relative Decrease In Yield; HM: Harmonic Mean; SDI: Sensitivity Drought Index; DRI: Drought Resistance Index; ATI: A Biotic Tolerance Index.

Between the drought tolerance indices, larger values of TOL, SDI and SSI, ATI, represent relatively more sensitivity to stress, thus a smaller value of these indices are preferred. Selection based on these indices prefers genotypes with low yield under non-stress conditions and high yield under stress conditions (Golabadi et al., 2006). Selection based on higher HM, DRI and GMP will result in genotypes with higher stress tolerance and high yield potential (Fernandez, 1992). The results of estimated yield and stress indices in 16 genotypes at mild drought conditions (Table 6) indicated that according to YP, YS that the genotypes 1, 13, 3, 15, 4 were the best, while the genotypes 7, 4, 10, 12, 3 were the best for stress susceptibility index (SSI). According to tolerance index (TOL) the genotypes 10, 7, 4, 12, 8 were more favorable, and according to geometric mean productivity (GMP) the genotypes 3, 15, 11, 7, 4, 16, 12, 8, 1 were the best, and based on drought decrease index (DRY) the genotypes 3, 15, 11, 7 were selected, but by using harmonic mean (HM), the genotypes 3, 15, 11, 7, 4, 16, 12, 8, 1 were the best. Regarding the sensitivity drought index (SDI), the genotypes 9, 5, 6, 14, 10, 2, 13 were selected. On the other hand the genotypes (3, 11, 7, 15, 4), (12, 9, 2, 14, 6, 10) were the most favorable according to drought resistance index (DRI), and biotic tolerance index (ATI), respectively. Differences in ranking genotypes were found among stress indices referring that the stress indices differ in discriminating the drought tolerance genotypes. According to all stress indices, among the 16 genotypes, the single hybrids S0 (IL.275-06 x IL.362-06), S0 (IL.260-06 x IL.792-06) were selected, while among the F2 populations S1 (IL.275-06 x IL.362-06), S1(IL.375-06 x IL.256-06) was the best and the current selection can be used through the segregation generation to get new inbred lines from this population. On the other hand, the inbred lines IL.275-06 and IL.256-06 were the best among the inbred lines populations, and these inbred lines can be used to improve yield under water stress conditions.

Table 6. Selected genotypes based on drought tolerance indices.

Selected genotypes	Drought tolerance indices
1 ,3 ,13 ,15 ,4	YP
1 ,3 ,13 ,15 ,4	YS
11 ,3 ,12 ,10 ,4 ,7	SSI
2 ,8 ,12 ,4 ,7 ,10	TOL
1 ,8 ,12 ,16 ,4 ,7 ,11 ,15 ,3	GMP
7 ,11 ,15 ,3	RDY
1 ,8 ,12 ,16 ,4 ,7 ,11 ,15 ,3	HM
13 ,2 ,10 ,14 ,6 ,5 ,9	SDI
1 ,8 ,16 ,12 ,4 ,15 ,7 ,11 ,3	DRI
12 ,9 ,2 ,14 ,6 ,10	ATI

Phenotypic correlation analysis

The phenotypic correlation coefficient provides important information about interrelationships between two or more traits, and gives information to design a successful program to improve yield under stress condition.

Grain yield under non stress condition was positively and significantly correlated with grain yield under stress conditions (Table 7). The results showed that direct selection for drought tolerance under normal experiment will be efficient. On the other hand yield under non stress and stress conditions was positively and significantly correlated with GMP, HM, SDI, DRI, ATI, which indicates that these indices are able to discriminate group A which is the genotypes that have high yield under stress and non stress environments (Fernandez, 1992). The selection on the basis of these indices should give positive results for both water conditions. The correlation was negative and significant between YS, SSI, RDI, while the correlation between Ys and TOL was positive and non significant, but significant between Yp and TOL. The results of Ghasemi and Chokan, (2013) indicated positive and significant correlation between YP and TOL, GMP and between YS, GMP, HM, and negative and significant correlation between Ys and SSI, and negative but no significant with TOL.

The negative correlation between Ys, TOL and SSI shows that the selection for high yields in non-irrigated conditions should be made on the basis of the lowest values of these indices (Bonea and Urechean, 2011).

The correlation value was high between YP, SDI indicating that high yield genotype under non stress conditions will be more sensitive under stress conditions. The SSI was negatively and significantly correlated with all other stress indices except RDY, TOL, where the correlation was positive and highly significant. Therefore the indices SSI, RDY, TOL are ranking the genotypes at the same group. On the other hand, there was a positive and significant correlation between TOL and ATI, SDI values, but the correlation was negatively significant between TOL and RDY.

GMP correlated positively and significantly with HM, SDI, DRI and ATI, which indicated that any of these indices can get the same result for the evaluation of the tolerant genotypes as phenotypic correlation. Additionally the results showed differences among the selected group of each drought indices because there was a direct and indirect effect (through other indices) of each index on the other.

The phenotypic correlation was negatively significant between RDY, HM, SDI, DRI, ATI, but on the other side, the values of correlation were positively significant between SDI, DRI and ATI, and between ATI and DRI. These results are in agreement with the work of others (Bonea and Urechean, 2011; Moradi *et al.*, 2012; Ghasemi and Chokan, 2013).

Table 7. Phenotypic correlation among, Y_s, Y_p, stress indices.

YP	.987**								
SSI	-.590**	-.464**							
TOL	0.196	.353*	.591**						
GMP	.997**	.996**	-.535**	0.27					
RDY	-.973**	-.984**	.445**	-.339*	-.981**				
HM	.998**	.995**	-.541**	0.263	1.000**	-.980**			
SDI	.986**	1.000**	-.463**	.355*	.996**	-.984**	.995**		
DRI	.992**	.958**	-.669**	0.071	.979**	-.946**	.981**	.958**	
ATI	.717**	.813**	-0.021	.772**	.765**	-.816**	.761**	.813**	.627**
Indices	**YS**	**YP**	**SSI**	**TOL**	**GMP**	**RDY**	**HM**	**SDI**	**DRI**

Path coefficient analysis

Path analysis was used to determine the amount of effects of the variables on the dependent variable (Li, 1956; Farshadfar, 2000). The direct effect (path coefficient), and indirect effects (effects exerted through other independent variables) of the causal components on the dependent variable (Li, 1975; Amjad *et al*., 2009) help breeders to select the best genotypes based on the yield and related traits.

Table 8. Direct and indirect effects of drought indices in yield under mild stress.

Source of variation		Effects
1-	Harmonic mean (HM)	
	Direct effect	-2.421
	Indirect effect via Geometric mean productivity	2.929
	Indirect effect via Drought resistance index	0.491
	Total	0.998
2-	Geometric mean productivity (GMP)	
	Direct effect	2.929
	Indirect effect via Harmonic mean	-2.421
	Indirect effect via Drought resistance index	0.490
	Total	0.997
3-	Drought resistance index (DRI)	
	Direct effect	0.500
	Indirect effect via Harmonic mean	-2.375
	Indirect effect via Geometric mean productivity	2.867
	Total	0.992

The results of path analysis showed that the Harmonic mean, Geometric mean productivity, and Drought resistance index led to the highest effects on grain yield under stress conditions (Table 8), The data showed that the direct effect of Harmonic mean on yield under stress conditions was -2.421, but the indirect effects of GMP, DRI were 2.929, 0.491, respectively. The direct effect of GMP in YS was 2.929, while the indirect effects were -2.421, 0.490 through HM, DRI, respectively. On the other hand the direct effect of DRI on YS was 0.500, but the indirect effects were -2.375, 2.867 through HM, GMP respectively.

The results of relative importance of the three HM, GMP, DRI drought indices in yield under mild water stress were 586.25, 857.76, 25.00 respectively (table 9), therefore it can be concluded that, the contribution of HM, GMP, DRI in grain yield variation account for 99.96%, which indicated that the selection for these indices can help the breeder to identify cultivars producing high yield under stress conditions. Khayatnezhad *et al*. (2010) concluded that GMP was able to identify cultivars producing high yield under both stress and non stress conditions, and the data of Golbashy *et al*., (2010) showed that HM, GMP were the best drought indices for selecting genotypes under stress conditions, Moradi et al., (2012) indicated that among drought tolerance indices, GMP and HM were the best indices for maize under stress conditions, and Mehrabi *et al*. (2011) indicated that maize hybrids with high yield can be obtained based on GMP.

Table 9. Relative importance (direct and joint effects) in yield under mild stress.

	Source of variation	CD	RI%
1	Harmonic mean (X_1)	5.8625	586.25
2	Geometric mean productivity (X_2)	8.5776	857.76
3	Drought resistance index (X_3)	0.2500	25.00
4	(X_1) × (X_2)	-14.1825	-1418.25
5	(X_1) × (X_3)	-2.3752	-237.52
6	(X_2) × (X_3)	2.8672	286.72
	Residual	0.0004	0.04
	Total relative importance		99.96

CD denote coefficient of determination. RI% denotes relative Importance.

Conclusions

The estimated yield and stress indices for 16 genotypes under drought and irrigated conditions indicated that the lines (IL.275-06), (IL.256-06), (IL.362-06) achieved the best values of yield per plant under both normal and stress conditions. Therefore these lines can be used through diallel cross to get new single hybrids of maize with high yield under non stress conditions and with good tolerance under stress conditions.

Yield under non stress and stress conditions were positively and significantly correlated with GMP, HM, SDI, DRI, ATI.

The contribution of HM, GMP, DRI in grain yield variation account for 99.96% which indicated that the selection for these indices in the segregation generation of (IL.275-06 x IL.362-06), (IL.375-06 x IL.256-06) will help to improve yield of maize under stress conditions.

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