RESEARCH ARTICLE OPEN ACCESS

NEW VALLEY JOURNAL OF AGRICULTURAL SCIENCE

Published by Faculty of Agriculture, New Valley University, Egypt

Print ISSN 2805-2420 **Online ISSN** 2805-2439

10.21608/NVJAS.2023.205547.1198

Evaluation of New White Maize (*Zea mays* L) Genotypes Under Drought Stress Using Selection Indices

Abd El-Azeem M. El. M., Abd El-Moula, M.A., Mostafa A.K., El-Mottalb, A.A. and El Sayed W.M.

Maize Research Department, Field Crops Research Institute, ARC, Egypt

Corresponding author

Abd El-Moula, M.A.

Received: 14/04/2023

Revised: 04/07/2023

Accepted: 19/07/2023

Published: 19/07/2023

ABSTRACT

Thirteen drought tolerance or resistance indices including stress tolerance index (STI), stress susceptibility index (SSI), tolerance index (TOL), geometric mean production (GMP), mean production (MP), harmonic mean (HM), yield index (YI), yield stability index (YSI), drought resistance index (DI), sensitivity drought index (SDI), relative drought index (RDI), stress susceptibility percentage index (SSPI) and modified stress tolerance (K1STI and K2STI) were calculated based on grain yield under drought and normal irrigation conditions to identify the best maize genotypes that can be grown under water stress condition. Yield under stress and favorable conditions were significantly and positively correlated with MP, GMP, YI, STI, KI.STI and K2.STI at Sids and Sakha environments. These results indicated that these indices were more effective in identifying high-yielding genotypes under drought stress as well as normal conditions. Cluster and biplot methods for screening drought-tolerant genotypes revealed that genotypes G5, G15, G20, G21, G22 and G23 at Sids and G3, G5, G8, G10, G11, G12, G13 and G21 at Sakha as the most drought tolerant genotypes. Cluster analysis divided the genotypes into three groups i.e., tolerant, sensitive and semi-sensitive to drought conditions. The tolerant group consists of 5 and 9 genotypes, the semi-sensitive group consists of 13 and 15 genotypes and the sensitive group consists of 12 and 6 genotypes at Sids and Sakha, respectively.

KEYWORDS: maize (zea mays l.), correlation, drought stress, selection indices

Introduction

Drought stress is the most important production constraint in maize production, especially in rainfed agriculture. The development of genotypes with tolerance to drought stress is one of the important goals in maize breeding programs. The present study was undertaken to identify maize hybrids that perform better under drought-stress and normal irrigation conditions by using various selection indices. These selection indices were calculated on the yield (ton ht^{-1}) performance of hybrids measured under drought stress and normal environments on the yield (ton ht^{-1}) performance measured under drought stress and normal environments.

Drought tolerance is a complicated trait that is hampered by low heritability and deficiency of successful selection approaches **(Blum 1988, Kirigwi *et a*l. 2004).** Therefore, the selection of maize genotypes to drought stress should be adapted. Moreover, drought tolerance mechanisms should be identified during the development of new genotypes to increase productivity **(Rajaram *et al.* 1996).** Stable yield performance of genotypes under both favorable and drought-stress conditions is vital for plant breeders to identify drought-tolerant genotypes **(Pirayvatlou 2001).** In addition, high-yielding genotypes under optimum conditions may not be drought tolerant **(Mardeh *et al.* 2006)**. Therefore, many studies preferred the selection under stress and normal conditions **(Clarke *et al.* 1992, Fernandez 1992, Byrne *et al.* 1995, Rajaram and Van Ginkle 2001). Ali and El-Sadek (2016)** illustrated that grain yield under drought and normal environments were highly correlated with MP, GMP, STI, YI, HM, DRI, and STI. They found that MP, GMP and STI were considered the best indices for the selection of relatively tolerant lines. Principal component analysis indicated that the first two components represented more than 98% of the total variations for drought-tolerant indices.

Several researchers have used different ways to evaluate genetic differences for drought tolerance. According to **Fernandez (1992),** the best measure for selection in the case of drought should be able to separate genotypes that have eligible and similar yield in stress and normal conditions from other groups and also, the best indices which have a high correlation with kernel yield under both conditions. Otherwise, drought tolerance is defined by **Hall (1993)** as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Several selection criteria have been proposed to select genotypes based on what they perform in stress and normal environments. **Rosielle and Hamblin (1981)** demonstrated that a lower stress tolerance index (STI), showed that yield in normal irrigation and drought condition was close to each other. Also, they defined Stress Tolerance (TOL) as the differences in yield between stress and normal environments and Mean Productivity (MP) as the average yield of genotypes under stress and normal conditions. **Blum (1988)** defined new indices of Drought Resistance Index (DI), which was commonly accepted to identify genotypes producing high yields at both stress and normal conditions. Because drought stress can differ in severity in field environments over years the Geometric Mean Productivity (GMP) is often used by breeders interested in relative performance **(Fernandez, 1992). Fischer and Maurer (1978)** suggested the Stress Susceptibility Index (SSI) for measurement of yield stability that provided the changes in both potential and actual yields in different environments. **Clarke *et al.* (1992)** used SSI to evaluate drought tolerance in wheat genotypes. They found year-to-year variation in SSI for genotypes which could affect their ranking pattern. In spring wheat cultivars, **Guttieri *et al.* (2001)** using SSI, illustrated that an SSI> 1 indicated above-average susceptibility to drought stress. The Yield Index YI; suggested by **Gavuzzi *et al.,* (1997**) and Yield Stability Index (YSI) was suggested by **Bouslama and Schapaugh (1984)** to evaluate the stability of genotypes in both stress and normal conditions. The stress tolerance index (STI) was defined as a useful tool for determining the high yield and stress tolerance potential of genotypes **(Fernandez, 1992).** To improve the efficiency of STI a Modified Stress Tolerance Index (MSTI) was suggested by **Farshadfar and Sutka (2002)** which corrects the STI as a weight. **Moosavi *et al.* (2008)** suggested Stress Susceptibility Percentage Index (SSPI) for screening drought-tolerant genotypes in stress and normal conditions. Harmonic Means (HM) according to **Schneider *et al*., (1997**). **Mardi *e al.,* (2012)** found that among drought tolerance indices, MP, GMP, STI and HM were the best tolerance indices for maize. **Naghavi *et al.,* (2013)** identified that Yield in stress and normal conditions were significantly and positively correlated with STI, GMP, MP, YI, TOL, DI, RDI, YSI, SSPI, K1STI, and K2STI and negatively correlated with SSI. Cluster analysis classified the cultivars into three groups i.e., tolerant, sensitive and semi-tolerant to drought conditions. **Shahrokhi *et al* (2020)** evaluated 24 super sweet maize inbred lines with the highest yield potential and drought tolerance performance, they found that all drought indices revealed significant differences among inbred lines, except GM. Using the ranking method, indicated that STI, GMP, MP, HARM, MRP, REI and RDY are appropriate indicators because of positive correlations among each other and also the highest correlation with grain yield (GY) in both environments. The Biplot diagram based on PCs, and drought tolerance indices showed that MP, GMP, STI, HARM, MRP, REI, MSTIK1, MSTIK2 and YI were the best indices for screening tolerant inbred lines. **Bonea (2020)** found that yield in normal conditions (Yp) showed prominent correlations with ATI, SSPI, STI and MP and negative correlations with RDI and GM. Yield under drought stress (Ys) showed a prominent correlation with RDI and GM, and a negative correlation with ATI and SSPI.

This study aimed to (1) compare and evaluate yield based on drought-tolerance selection indices, (2) identify the most stable high-yielding genotypes under both favorable and drought stress environments, and (3) determine the suitable environment to use drought stress to evaluate drought stress tolerance.

MATERIALS AND METHODS

Fourteen white maize inbred lines derived from different drought tolerant populations under drought stress conditions at Sids Agriculture Research Station. In the 2018 growing season, these inbred lines were top-crossed to two inbred lines as testers, *i.e.,* SD-1185 and SD-1193. The resultant 28 maize single crosses and two commercial hybrids SC10 and SC2031 were evaluated in the 2019 summer season under normal irrigation (Experiment 1) and water stress (preventing the 3rd and 4th irrigations) environments (Experiment2) using RCBD with three replications for each trial at two locations, Sakha (North Egypt) and Sids (north upper Egypt) Agriculture Research Stations. Plot size was one row, 4 m long and 0.8 m apart, with a distance of 25 cm between hills. All the recommended agronomic practices for maize production were applied at the proper time. Data were recorded for grain yield kg/ plot. adjusted at 15.5% moisture content and converted to ton/ha.

Calculation of Indices

Thirteen drought tolerance indices were calculated using the next relationships **(Fischer and Maurer, 1978; Fischer *et al,* 1998; Fernandez, 1992; Rosielle and Hamblin, 1981; Bouslama and Schapaugh, 1984; Lan, 1998; Moosavi *et al,* 2008; Farshadfar and Sutka, 2002):**

1- Stress intensity $SSI= (1-(Ys/Yp)/SI \quad SI= 1-(\bar{Y}s/\bar{Y}p)$. The genotypes with SSI are lower than 1 are more resistant to drought stress conditions.

2- Stress tolerance index $STI= Ys \times Yp/(Yp)^2$, the genotypes with high STI values are considered tolerant to drought stress.

3- Geometric mean productivity $GMP= \sqrt{Ys \times Yp}$, the genotypes with a high value of this index will be more desirable.

4-Mean productivity MP= (Ys+Yp)/2, the genotypes with a high value of this index will be more desirable.

5- Tolerance TOL=Yp-Ys, the genotypes with low values of this index are more stable under two different conditions.

6- Harmonic mean HM= (2xYsxYp)/Ys+Yp, the genotypes with high HM value will be more desirable.

7- Yield index YI= Ys/$\bar{Y}$s, the genotypes with a high value of this index will be suitable for drought stress conditions.

8- Yield stability index YSI=Ys/Yp, the genotypes with high values can be regarded as stable genotypes under stress and normal conditions.

9- Sensitivity drought index SDI= (Yp-Ys)/Yp, the genotypes with a low value of this index will be more desirable.

10-Drought resistance index DI=((Ys x(Ys/Yp)) /$\bar{Y}$s, the genotypes with a high value of this index will be more desirable.

11- Stress susceptibility percentage index SSPI= (Yp-Ys)/2($\bar{Y}$s)) x100, the genotypes with a high value of this index will be more desirable.

12-Modified stress tolerance index MSTI= K1STI, K1=Y^2p/$\bar{Y}^2$p and K2STI= Y^2s/$\bar{Y}^2$s, the genotypes with high value of this index will be more eligible.

13-Relative drought index RDI= (Ys/Yp)/($\bar{Y}$s/$\bar{Y}$p), the genotypes with a low value of this index will be more eligible.

Where, Ys and Yp represent yield in stress and normal conditions, respectively, where yield is the mean yield of all genotypes in stress and normal conditions respectively. The genotypes will be categorized into four groups based on their performance in stress and normal environments: cultivars express uniform superiority in both stress and normal conditions (Group A), cultivars perform favorably only in normal conditions (Group B), cultivars give relatively high yield only under stress conditions (Group C), and cultivars perform poorly in both stress and normal conditions (Group D). The optimal selection criterion should distinguish Group A from the other three groups.

Correlation among indices and grain yield under the two conditions, principal component, biplot of the first two principal components and cluster analysis drawing were done by SPSS ver. 23 and SAS ver. 9 soft wears, respectively.

RESULTS AND DISCUSSIONS

COMPARING GENOTYPES BASED ON DROUGHT TOLERANCE INDICES

There were significant differences among genotypes for grain yield (Table 1), which demonstrates high diversity among them that enabled us to screen drought-tolerant genotypes. Results revealed that hybrids G5, G13, G15, G20, G21, G22, G23 and G24 at Sids; G5, G11, G13, G21 and SC-10 at Sakha had the highest grain yield under favorable and drought stress environments. Meanwhile, genotypes G3 and G4 at Sids; G9, G19 and SC2031 at Sakha under stress environment and G21, G8, G20 and G22 at Sids; G9, G15, G25, G27 and SC2031 at Sakha under favorable environment condition had the highest grain yield (Tables 2,3).

Descriptive statistics of drought indices under favorable and water stress conditions are presented in Table 1. Many studies (**Zeynali et al., 2004, Mardeh 2006, Talebi et al., 2009, Sanjari and Yazdansepas 2008, Nouri et al., 2011, Mohammadi et al., 2010 and Ali and El-Sadek 2016)** indicated that these indices are the most suitable parameters for screening for drought-tolerant high-yielding genotypes. The genotype that possesses high values of STI, MP, GMP, YI, K1.STI and K2.STI can be considered tolerant to water stress. Meanwhile, genotypes G5, G15, G13, G21, G22 and G23 at Sids and SC10, G5, G11 and G13 at Sakha were ranked as the best based on STI, MP, GMP, HM, YI, and K2.STI indices; therefore, it was considered the most tolerant and high-yielding genotypes under favorable and drought stress conditions (Tables 3 and 4). While genotypes G1, G12, G16, G17, SC10 and G26 at Sids and G4, G6, G18, G24 and G28 at Sakha displayed the lowest values for these indices. Other genotypes were identified as semi-tolerant or semi-susceptible to drought stress. Also, according to the SSPI index, genotypes G1, G11, G16, G19, G27 and SC10 at Sids and G15, G17, G23, G25, G27 and SC2031 at Sakha were the relatively tolerant genotypes Meanwhile, according to TOL index, the genotypes G2, G6, G13, G15, G20 and G22 at Sids and G5, G8, G10, G12, G13 and G21 at Sakha are considered relatively tolerant genotypes. It seems that using TOL was successful in selecting genotypes with high yield under water stress conditions.

For genotypes that ranked differently at Sids and Sakha conditions due to high genotype × environment interaction, we found that the Sakha environment was less discriminative than Sids for some indices. Sids environment causes a reduction in metabolic activity than Sakha which affected yield under drought stress for all tested genotypes, this may be due to high temperature in summer at Sids along with water stress which enhanced water stress effect on plants as compared to Sakha climatic conditions. Therefore, we recommend using the Sids environment to identify drought-tolerant genotypes.

Table 1: Descriptive statistics of drought indices for grain yield at Sids and Sakha locations.

Drought indices	SIDS				SAKHA			
	Max.	Min.	Mean	Standard deviation	Max.	Min.	Mean	Standard deviation
YS+	9.43	3.93	6.09	1.52	9.35	4.86	6.93	1.16
YP+	13.58	8.07	10.10	1.32	12.45	7.71	9.82	1.25
SSI+	1.48	0.28	1.00	0.29	1.35	-0.20	0.99	0.34
STI+	1.24	0.37	0.62	0.22	1.20	0.38	0.71	0.19
GMP+	11.25	6.14	7.81	1.36	10.78	6.12	8.24	1.09
MP+	11.45	6.55	8.09	1.29	10.90	6.28	8.38	1.08
TOL+	5.72	1.18	4.01	1.22	4.66	-0.48	2.88	1.06
HM+	1.47	1.29	1.37	0.04	1.51	1.37	1.41	0.32
YI++	1.55	0.64	1.00	0.25	1.34	0.70	1.00	0.17
YSI+	0.88	0.41	0.60	0.12	1.06	0.60	0.71	0.10
SDI+	0.59	0.11	0.39	0.12	0.39	-0.59	0.29	0.10
DI+	1.37	0.26	0.62	0.26	1.31	0.44	0.72	0.21
SSPI+	28.29	5.86	19.84	6.03	23.75	-2.44	14.67	5.43
RDI+	1.47	0.68	0.99	0.19	1.49	0.85	1.00	0.14
K1STI+	1.81	0.64	1.01	0.27	1.61	0.61	1.01	0.26
K2STI+	2.39	0.42	1.06	0.54	1.82	0.49	1.03	0.35

+(Yp) grain yield (ton $hect^{-1}$.) of genotypes under favorable condition; (Ys) grain yield (ton $hect^{-1}$.) of genotypes under drought stress ; (SSI) Stress susceptibility index; (TOL) tolerance; (MP) mean productivity; (GMP) Geometric mean productivity; (STI) Stress tolerance index; (YI) Yield index; (YSI) Yield stability index; (SDI) Sensitivity drought index; (DI) Drought resistance index; (SSPI) Stress susceptibility percentage index; (RDI) relative drought index; (K1STI) Modified stress tolerance index for favorable condition; (K2STI) Modified stress tolerance index for stress condition; and (HM) Harmonic mean.

Table 2: Drought tolerance indices of 30 maize genotypes for grain yield at Sids environment.

Genotypes	YS⁺	YP⁺	SSI⁺	STI⁺	GMP⁺	MP⁺	TOL⁺	HM⁺	YI⁺	YSI⁺	SDI⁺	DI⁺	SSPI⁺	RDI⁺	K1STI⁺	K2STI⁺
G1	4.01	9.56	1.46	0.38	6.19	6.79	5.55	1.30	0.66	0.42	0.58	0.28	27.44	0.70	0.90	0.43
G2	5.61	8.54	0.86	0.47	6.92	7.07	2.93	1.40	0.92	0.66	0.34	0.60	14.49	1.09	0.71	0.85
G3	5.31	8.91	1.02	0.46	6.88	7.11	3.60	1.37	0.87	0.60	0.40	0.52	17.81	0.99	0.78	0.76
G4	5.00	9.81	1.23	0.48	7.01	7.41	4.81	1.34	0.82	0.51	0.49	0.42	23.78	0.85	0.94	0.67
G5	8.60	13.08	0.86	1.10	10.60	10.84	4.48	1.40	1.41	0.66	0.34	0.93	22.19	1.09	1.68	1.99
G6	5.97	8.56	0.76	0.50	7.15	7.26	2.59	1.41	0.98	0.70	0.30	0.68	12.83	1.16	0.72	0.96
G7	4.73	8.39	1.10	0.39	6.30	6.56	3.67	1.36	0.78	0.56	0.44	0.44	18.14	0.93	0.69	0.60
G8	5.58	10.90	1.23	0.60	7.80	8.24	5.32	1.34	0.92	0.51	0.49	0.47	26.32	0.85	1.16	0.84
G9	5.52	9.21	1.01	0.50	7.13	7.36	3.69	1.37	0.91	0.60	0.40	0.54	18.25	0.99	0.83	0.82
G10	5.60	9.15	0.98	0.50	7.16	7.37	3.56	1.38	0.92	0.61	0.39	0.56	17.61	1.01	0.82	0.84
G11	5.48	10.81	1.24	0.58	7.70	8.15	5.32	1.34	0.90	0.51	0.49	0.46	26.35	0.84	1.14	0.81
G12	5.03	8.08	0.95	0.40	6.38	6.56	3.05	1.38	0.83	0.62	0.38	0.51	15.07	1.03	0.64	0.68
G13	7.42	9.42	0.53	0.68	8.36	8.42	2.00	1.44	1.22	0.79	0.21	0.96	9.88	1.31	0.87	1.48
G14	5.84	8.97	0.88	0.51	7.24	7.41	3.13	1.39	0.96	0.65	0.35	0.62	15.49	1.08	0.79	0.92
G15	9.43	10.62	0.28	0.98	10.01	10.02	1.19	1.47	1.55	0.89	0.11	1.37	5.87	1.47	1.10	2.40
G16	3.94	9.60	1.49	0.37	6.15	6.77	5.67	1.29	0.65	0.41	0.59	0.26	28.05	0.68	0.90	0.42
G17	4.69	9.99	1.34	0.46	6.84	7.34	5.30	1.32	0.77	0.47	0.53	0.36	26.22	0.78	0.98	0.59
G18	5.63	9.54	1.03	0.53	7.33	7.58	3.91	1.37	0.92	0.59	0.41	0.54	19.35	0.98	0.89	0.85
G19	6.71	12.43	1.16	0.82	9.14	9.57	5.72	1.35	1.10	0.54	0.46	0.60	28.29	0.90	1.51	1.21
G20	7.81	10.09	0.57	0.77	8.88	8.95	2.28	1.44	1.28	0.77	0.23	0.99	11.26	1.28	1.00	1.64
G21	8.40	11.66	0.70	0.96	9.90	10.03	3.26	1.42	1.38	0.72	0.28	0.99	16.13	1.19	1.33	1.90
G22	7.77	10.37	0.63	0.79	8.98	9.07	2.59	1.43	1.28	0.75	0.25	0.96	12.84	1.24	1.05	1.63
G23	9.32	13.58	0.79	1.24	11.25	11.45	4.26	1.41	1.53	0.69	0.31	1.05	21.09	1.14	1.81	2.34
G24	7.40	11.10	0.84	0.80	9.06	9.25	3.69	1.40	1.21	0.67	0.33	0.81	18.28	1.11	1.21	1.48
G25	5.69	9.66	1.03	0.54	7.41	7.67	3.97	1.37	0.93	0.59	0.41	0.55	19.62	0.98	0.91	0.87
G26	4.39	9.40	1.34	0.40	6.43	6.90	5.01	1.32	0.72	0.47	0.53	0.34	24.80	0.77	0.87	0.52
G27	4.86	10.34	1.33	0.49	7.09	7.60	5.48	1.32	0.80	0.47	0.53	0.38	27.11	0.78	1.05	0.64
G28	6.14	10.93	1.11	0.66	8.19	8.54	4.80	1.36	1.01	0.56	0.44	0.57	23.74	0.93	1.17	1.01
SC10	4.46	9.91	1.38	0.43	6.65	7.18	5.45	1.31	0.73	0.45	0.55	0.33	26.95	0.75	0.96	0.54
SC2031	6.47	10.55	0.97	0.67	8.26	8.51	4.07	1.38	1.06	0.61	0.39	0.65	20.16	1.02	1.09	1.13

Table 3: Drought tolerance indices of 30 maize genotypes for grain yield at Sakha environment.

Genotypes	YS+	YP+	SSI+	STI+	GMP+	MP+	TOL+	HM+	YI+	YSI+	SDI+	DI+	SSPI+	RDI+	K1STI+	K2STI+
G1	6.37	9.33	1.08	0.62	7.71	7.85	2.96	1.41	0.92	0.68	0.32	0.63	15.05	0.97	0.90	0.84
G2	6.12	9.09	1.11	0.58	7.46	7.61	2.97	1.40	0.88	0.67	0.33	0.59	15.13	0.95	0.86	0.78
G3	6.64	8.95	0.88	0.62	7.71	7.80	2.31	1.43	0.96	0.74	0.26	0.71	11.78	1.05	0.83	0.92
G4	5.80	8.80	1.16	0.53	7.15	7.30	3.00	1.40	0.84	0.66	0.34	0.55	15.27	0.93	0.80	0.70
G5	9.26	10.35	0.36	0.99	9.79	9.80	1.09	1.47	1.33	0.89	0.11	1.19	5.57	1.27	1.11	1.78
G6	6.00	9.02	1.14	0.56	7.36	7.51	3.02	1.40	0.87	0.67	0.33	0.58	15.35	0.94	0.84	0.75
G7	6.06	9.01	1.12	0.57	7.39	7.54	2.95	1.40	0.87	0.67	0.33	0.59	15.04	0.95	0.84	0.76
G8	7.19	9.00	0.69	0.67	8.05	8.10	1.81	1.44	1.04	0.80	0.20	0.83	9.23	1.13	0.84	1.07
G9	7.48	10.70	1.03	0.83	8.95	9.09	3.23	1.41	1.08	0.70	0.30	0.75	16.43	0.99	1.19	1.16
G10	7.19	9.12	0.72	0.68	8.09	8.15	1.93	1.44	1.04	0.79	0.21	0.82	9.82	1.12	0.86	1.07
G11	9.06	11.33	0.68	1.06	10.13	10.20	2.27	1.44	1.31	0.80	0.20	1.05	11.54	1.13	1.33	1.71
G12	6.65	7.77	0.49	0.54	7.19	7.21	1.12	1.46	0.96	0.86	0.14	0.82	5.70	1.21	0.63	0.92
G13	8.49	10.54	0.66	0.93	9.46	9.51	2.05	1.45	1.22	0.81	0.19	0.99	10.42	1.14	1.15	1.50
G14	7.01	9.45	0.88	0.69	8.14	8.23	2.44	1.43	1.01	0.74	0.26	0.75	12.44	1.05	0.93	1.02
G15	6.79	10.83	1.27	0.76	8.58	8.81	4.03	1.39	0.98	0.63	0.37	0.61	20.54	0.89	1.22	0.96
G16	5.24	8.21	1.23	0.45	6.56	6.73	2.97	1.39	0.76	0.64	0.36	0.48	15.11	0.90	0.70	0.57
G17	6.12	10.12	1.35	0.64	7.87	8.12	4.00	1.38	0.88	0.60	0.40	0.53	20.38	0.86	1.06	0.78
G18	4.86	7.71	1.26	0.39	6.12	6.29	2.85	1.39	0.70	0.63	0.37	0.44	14.49	0.89	0.62	0.49
G19	7.37	10.41	0.99	0.80	8.76	8.89	3.04	1.41	1.06	0.71	0.29	0.75	15.47	1.00	1.12	1.13
G20	6.84	10.23	1.13	0.73	8.36	8.53	3.39	1.40	0.99	0.67	0.33	0.66	17.25	0.95	1.08	0.97
G21	8.62	8.14	-0.20	0.73	8.37	8.38	-0.48	1.51	1.24	1.06	-0.06	1.32	-2.45	1.50	0.69	1.54
G22	6.58	9.63	1.08	0.66	7.96	8.11	3.06	1.41	0.95	0.68	0.32	0.65	15.57	0.97	0.96	0.90
G23	8.02	11.93	1.12	0.99	9.78	9.98	3.91	1.40	1.16	0.67	0.33	0.78	19.88	0.95	1.48	1.34
G24	5.73	9.16	1.28	0.54	7.25	7.45	3.44	1.38	0.83	0.63	0.37	0.52	17.49	0.88	0.87	0.68
G25	6.97	10.76	1.20	0.78	8.66	8.86	3.79	1.39	1.00	0.65	0.35	0.65	19.30	0.92	1.20	1.01
G26	6.20	9.75	1.24	0.63	7.78	7.98	3.55	1.39	0.89	0.64	0.36	0.57	18.07	0.90	0.99	0.80
G27	7.12	11.78	1.35	0.87	9.16	9.45	4.67	1.38	1.03	0.60	0.40	0.62	23.75	0.86	1.44	1.05
G28	5.53	9.17	1.35	0.53	7.12	7.35	3.64	1.38	0.80	0.60	0.40	0.48	18.52	0.85	0.87	0.64
SC10	9.35	12.45	0.85	1.21	10.79	10.90	3.10	1.43	1.35	0.75	0.25	1.01	15.78	1.06	1.61	1.82
SC2031	7.47	11.86	1.26	0.92	9.41	9.67	4.39	1.39	1.08	0.63	0.37	0.68	22.33	0.89	1.46	1.16

PRINCIPAL COMPONENT ANALYSIS

PCA showed that the first two components explained about 99% of the total variance. The first PCA explained 74.02% at Sids and 62.47% at Sakha of the obtained variation and showed a positive correlation with Ys, Yp, STI, GMP, MP, HM, YI, YSI, DI, RDI, K1STI and K2STI indices at Sids and Sakha environments. The PC2 explained 25.60% at Sids and 37.06% at Sakha of the total variation and had a positive correlation with YP, SSI, STI, GMP, MP, TOL, YI, SDI, SSPI, K1STIand K2STI indices (Table 3 and Figure 1).

Genotypes that possessed high PC1 and low PC2 values are considered more stable under both stress and favorable environments (Golbadi et al., 2006). Results based on the first two components analysis (Fig 1) revealed that the genotypes G13, G15, G20, G21 and G22 at Sids and G8, G10, G11, G12, G13, G21 and G23 at Sakha possessed the most stable high yield under both environments. On the opposite, G16 and G18 at Sids and G7 and G12 at Sakha was the most sensitive genotype to drought stress.

Table 4. Principal component analysis for drought tolerance indices of grain yield at Sids and Sakha environments.

	Sids		Sakha	
	PC1	PC2	PC1	PC2
Percentage of Variance	74.02	25.60	62..47	37.06
Cumulative percentages	74.02	99.63	62.47	99.53
Eigen Values	11.84	4.09	9.99	5.93
YS⁺	0.29	0.09	0.29	0.15
YP⁺	0.14	0.43	0.08	0.39
SSI⁺	-0.26	0.18	-0.28	0.19
STI⁺	0.25	0.24	0.22	0.29
GMP⁺	0.26	0.23	0.22	0.29
MP⁺	0.24	0.28	0.21	0.31
TOL⁺	-0.20	0.35	-0.22	0.30
HM⁺	0.27	-0.17	0.28	-0.18
YI⁺	0.29	0.09	0.29	0.15
YSI⁺	0.27	-0.18	0.28	-0.19
SDI⁺	-0.27	0.18	-0.28	0.19
DI⁺	0.29	-0.02	0.31	-0.02
SSPI⁺	-0.20	0.35	-0.22	0.30
RDI⁺	0.27	-0.18	0.28	-0.17
K1.STI⁺	0.14	0.43	0.09	0.39
K2.STI⁺	0.28	0.11	0.29	0.15

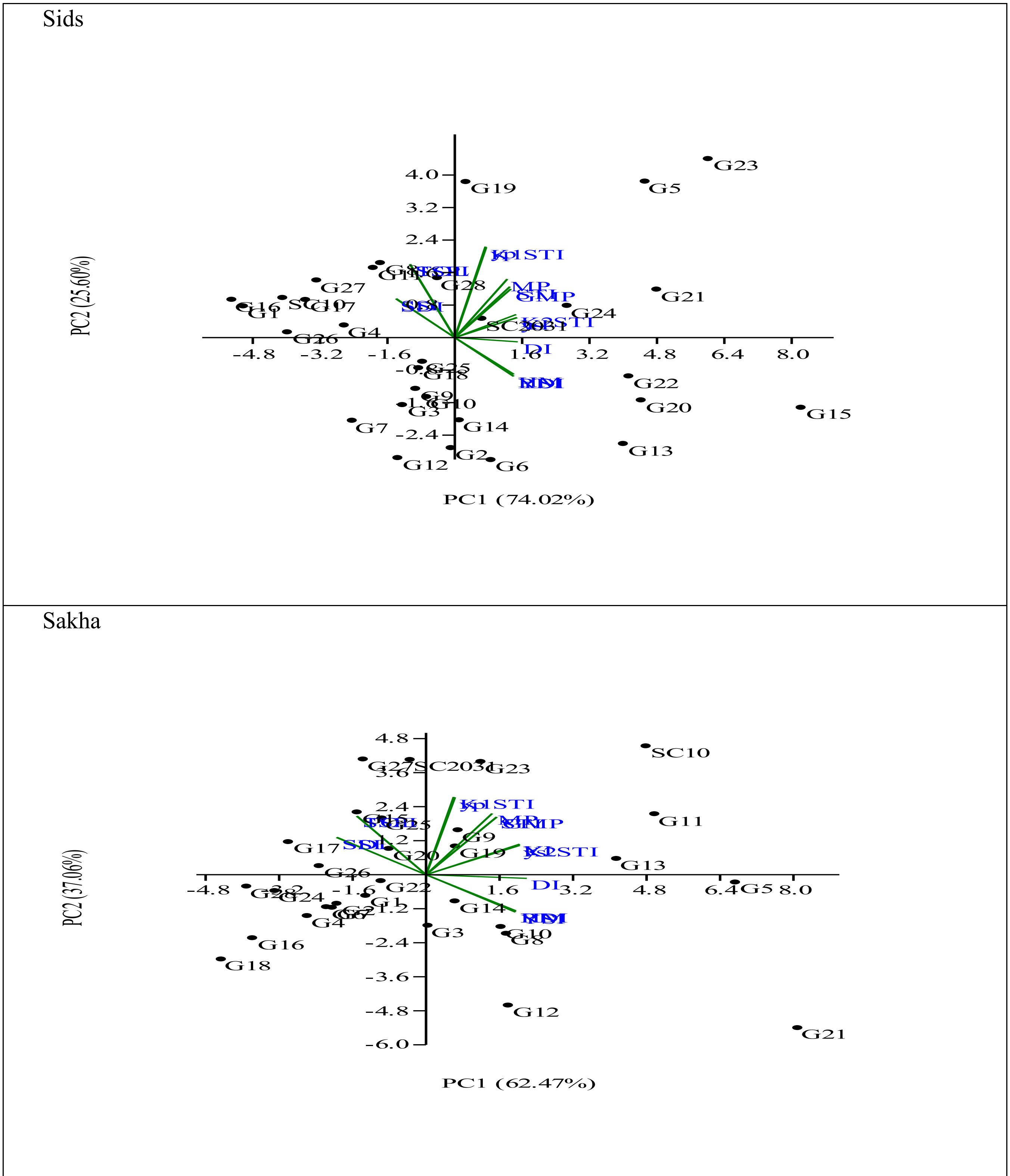

Figure 1: Biplot of the first two principal component axes for 30 maize genotypes at Sids and Sakha environments

Cluster analysis

Dendrogram was constructed using Ward's method. Based on drought indices, genotypes were classified into three groups: tolerant, semi-tolerant and sensitive genotypes. The cluster analysis based on Ward's method was performed to classify the genotypes based on drought tolerance indices; the results of cluster analysis for studied genotypes at Sids have been presented in Fig. 2. As it appears in Fig. 2, cluster analysis based on drought tolerance indices and grain yield under stressed and normal conditions classified the genotypes into three groups having 8, 10 and 12 genotypes, respectively. The 30 maize genotypes based on grain yield and indices were divided into three clusters, each cluster contained highly similar genotypes. The first cluster (tolerant) at Sids environment consisted of 5 genotypes (G13, G15, G20, G21 and G22. These genotypes had high STI, MP, GMP, HM, YI, RDI, K1STI and K2STI values. In addition, the first group (tolerant) at Sakha environment consists of 9 genotypes (G3, G5, G8, G10, G11, G12, G13, G14 and G21). These genotypes were high GMP, MP, HM, DI, K1STI and K2STI, thus they are considered the most desirable drought-tolerant genotypes under the two maize growth conditions (tolerant group). The semi-sensitive group consists of 13 and 15 genotypes, while the sensitive group consists of 12 and 6 genotypes at Sids and Sakha environments respectively.

CORRELATION ANALYSIS

Correlation coefficients between grain yield and drought indices are shown in Table 4. There was a positive significant correlation between *Yp* and *Ys* (*r*=0.64 and 0.61) at Sids and Sakha respectively. This indicates that high yield performance under favorable conditions resulted in relatively high yield under stress conditions. Both Yp and Ys were significantly and positively correlated (P<0.01) with STI, MP, GMP, YI, KISTI and K2STI at Sids and Sakha environments. This indicates that these indices were more effective in identifying high-yielding genotypes under drought stress as well as normal conditions (Tables 5 and 6). The correlation between Ys and SDI, SSI and SSPI was significant and negative correlation at Sids and Sakha environments. Correlated indices with both Ys and Yp are most suitable for identifying stress-tolerant genotypes **(Farshadfar *and* Javadinia. 2011 and Andjelkovic *et al* 2014).** The MP, GMP, HM, STI, YI, Di, K1STI and K2STI indices, which are highly significantly positively correlated to grain yield under both favorable and drought stress environments, are regarded as the best indices.

Ranking method

The drought tolerance indices estimate (Table 5) indicated that the identification of drought tolerance genotypes depending on a single criterion may be opposite. So, to accurately select the most tolerant genotypes to drought tolerance all drought indices, mean rank and standard deviation of ranks should be estimated. According to these two criteria, the most desirable drought tolerance genotypes were identified. Genotypes G5, G15, G20, G21, G22 and G23 at Sids and SC10, G5, G11, G13 and G23 at Sakha had the best mean rank and low standard deviation of rank, hence they have identified as the most drought tolerant genotypes, while G16 and G18 at Sids and G7 and G12 at Sakha as the most sensitive genotype. **Farshadfar *et al.,* 2012 a; Khalili *et al.,* 2012 and Naghafi *et al* 2013**, considered the mean rank and standard deviation of ranks as the best measure of selection for drought tolerance.

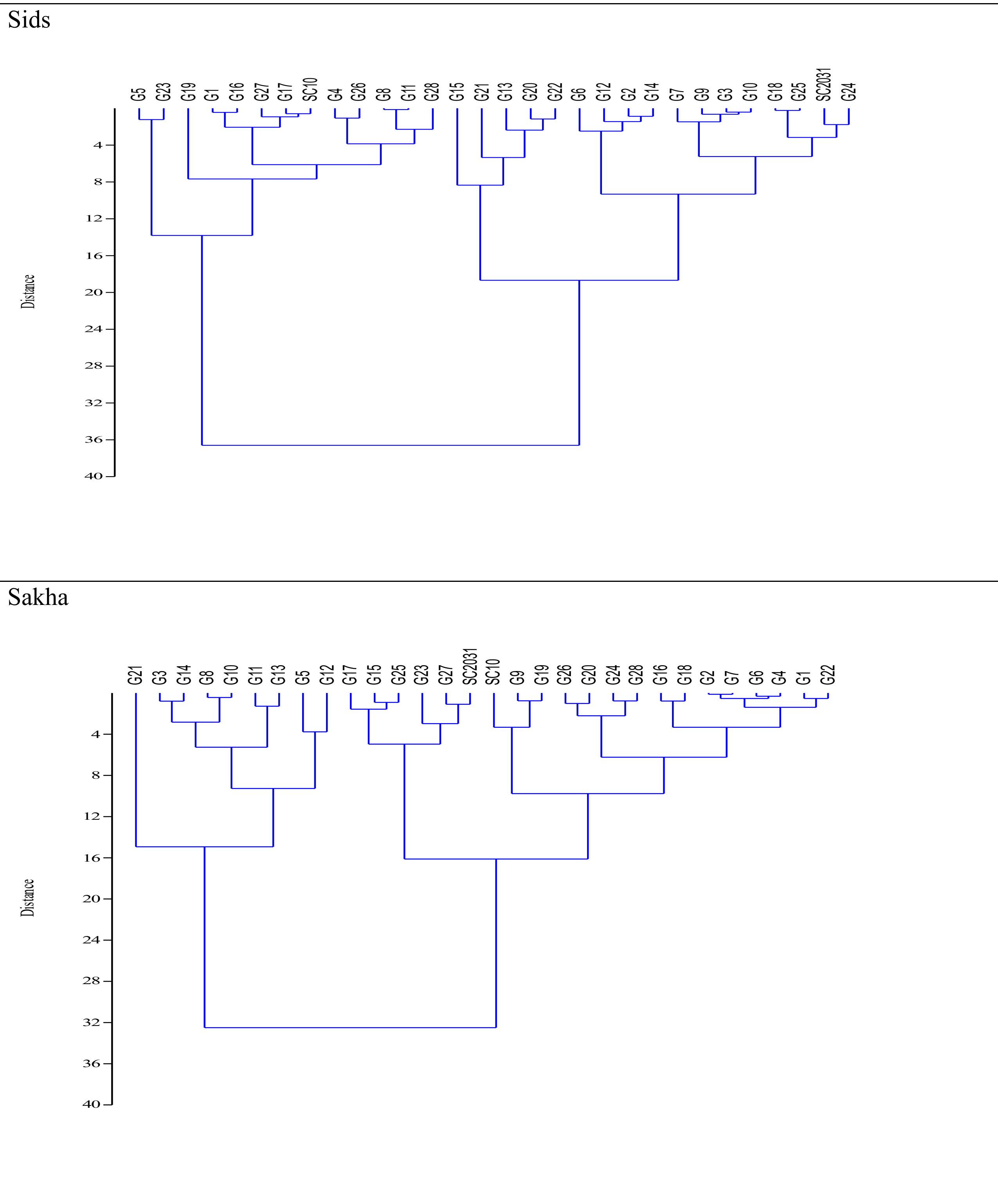

Fig. 2. Dendrogram using the Ward method between groups showing the classification of genotypes based on tolerance/ sensitive indices at Sids and Sakha environments.

Table 5. Correlation between different drought indices and grain yield at Sids environment.

Indices	YS	YP	SSI	STI	GMP	MP	TOL	HM	YI	YSI	SDI	DI	SSPI	RDI	K1	K2
YS	1.00	0.64**	-0.84**	0.95**	0.96**	0.92**	-0.56**	0.83**	1.00**	084**	-0.84**	0.97**	-0.56**	084**	0.65**	0.99**
YP		1.00	-012	0.84**	0.84**	0.89**	0.28	0.12	0.64**	0.12	-0.12	0.44*	0.28	0.12	0.99**	0.66**
SSI			1.00	-0.62**	-0.64**	-0.56**	0.92**	-0.99**	-0.84**	-1.00**	1.00**	-0.93**	0.92**	-1.00**	-0.13	-0.81**
STI				1.00	0.99**	0.99**	-0.27	0.62**	0.95**	0.62**	-0.62**	0.84**	-0.27	0.62**	0.85**	0.95**
GMP					1.00	0.99**	-0.29	0.64**	0.96**	0.65**	-0.65**	0.85**	-0.29	0.64**	0.84**	0.95**
MP						1.00	-0.19	0.55**	0.92**	0.56**	-0.56**	0.80**	-0.18	0.57**	0.89**	0.92**
TOL							1.00	091**	-0.56**	-0.91**	0.91**	-0.73**	1.00**	-0.91**	026	-0.53**
HM								1.00	0.83**	0.99**	-0.99**	092**	-0.91*	0.99**	0.13	0.80**
YI									1.00	0.84**	-0.84**	0.97**	-0.56**	0.84**	0.65**	0.99**
YSII										1.00	-1.00**	0.93**	-0.92**	1.00**	0.13	0.81**
SDI											1.00	-0.93**	0.92**	-1.00**	-0.13	-0.81**
DI												1.00	-0.73**	0.93**	0.45*	0.96**
SSPI													1.00	-0.91**	0.26	-0.53**
RDI														1.00	0.13	0.81**
K1															1.00	0.67**
K2																1.00

Table 6. Correlation between different drought indices and grain yield at Sakha environment.

Indices	YS	YP	SSI	STI	GMP	MP	TOL	HM	YI	YSI	SDI	DI	SSPI	RDI	K1	K2
YS	1.00	0.61**	-0.65**	0.91**	0.92**	0.89**	-0.35	0.66**	1.00**	0.64**	-0.64**	0.90**	-0.36*	0.65**	0.62**	0.99**
YP		1.00	0.19	0.87**	0.88**	0.91**	0.51**	-0.18	0.61**	-0.20	0.20	0.23	0.51**	-0.19	0.99**	0.60**
SSI			1.00	-0.29	-0.29	-0.23	0.91**	-0.99**	-0.64**	-1.00**	1.00**	-0.90**	0.93**	-1.00**	0.18	-0.65**
STI				1.00	0.99**	0.99**	0.04	0.30	0.92**	0.28	-0.28	0.66**	0.03	0.29	0.88**	0.91**
GMP					1.00	0.99**	0.04	0.31	0.92**	0.29	-0.29	0.66**	0.03	0.29	0.88**	0.90**
MP						1.00	-0.11	0.25	0.89**	0.29	-0.29	0.62**	0.10	0.24	0.91**	0.88**
TOL							1.00	0.93**	-0.35	-0.91**	0.91**	-0.69**	0.99**	-0.90**	0.51**	-0.37*
HM								1.00	0.66**	0.99**	-0.99**	0.91**	-0.93**	0.99**	-017	0.66**
YI									1.00	0.64**	-0.64**	0.90**	-0.36*	0.65**	0.62**	0.99**
YSII										1.00	-1.00**	0.90**	-0.93**	1.00**	-0.18	0.65**
SDI											1.00	-0.90**	0.93**	-1.00**	0.18	-0.64**
DI												1.00	-0.71**	0.91**	0.24	0.91**
SSPI													1.00	-0.93**	0.50**	-0.38*
RDI														1.00	-0.17	0.65**
K1															1.00	0.61**
K2																1.00

Table 7: Rank and rank mean (R̄) and slandered deviation of rank (SDR) of drought indices for grain yield at Sids environment.

Geno.	YS+	YP+	SSI+	STI+	GMP+	MP+	TOL+	HM+	YI+	YSI+	SDI+	DI+	SSPI+	RDI+	K1.STI+	K2.STI+	R̄	SDR
G1	29	19	29	29	29	27	29	29	29	29	29	29	3	2	19	29	24.31	8.87
G2	16	28	10	22	22	25	6	10	16	10	10	12	25	21	28	16	17.31	6.98
G3	21	26	16	23	23	24	11	16	21	16	16	19	20	15	26	21	19.63	4.17
G4	23	16	23	21	21	17	21	23	23	23	23	24	10	8	16	23	19.69	4.78
G5	3	2	9	2	2	2	19	9	3	9	9	7	12	22	2	3	7.19	6.03
G6	12	27	6	18	18	22	4	6	12	6	6	9	27	25	27	12	14.81	8.32
G7	25	29	19	28	28	29	12	19	25	19	19	23	19	12	29	25	22.50	5.52
G8	18	7	22	12	12	12	24	22	18	22	22	21	7	9	7	18	15.81	6.04
G9	19	23	15	19	19	20	13	15	19	15	15	18	18	16	23	19	17.88	2.78
G10	17	24	14	17	17	19	10	14	17	14	14	15	21	17	24	17	16.94	3.60
G11	20	8	24	13	13	13	25	24	20	24	24	22	6	7	8	20	16.94	6.81
G12	22	30	12	27	27	30	7	12	22	12	12	20	24	19	30	22	20.50	7.28
G13	7	21	2	9	9	11	2	2	7	2	2	5	29	29	21	7	10.31	9.14
G14	13	25	11	16	16	18	8	11	13	11	11	11	23	20	25	13	15.31	5.24
G15	1	9	1	3	3	4	1	1	1	1	1	1	30	30	9	1	6.06	9.41
G16	30	18	30	30	30	28	29	30	30	30	30	30	2	1	18	30	24.75	9.61
G17	26	14	26	24	24	21	23	26	26	26	26	26	8	5	14	26	21.31	6.82
G18	15	20	17	15	15	16	15	17	15	17	17	17	16	14	20	15	16.31	1.69
G19	9	3	21	5	5	5	30	21	9	21	21	13	1	10	3	9	11.63	8.32
G20	5	13	3	8	8	8	3	3	5	3	3	3	28	28	13	5	8.69	7.98
G21	4	4	5	4	4	3	9	5	4	5	5	4	22	26	4	4	7.00	6.59
G22	6	11	4	7	7	7	5	4	6	4	4	6	26	27	11	6	8.81	7.00
G23	2	1	7	1	1	1	18	7	2	7	7	2	13	24	1	2	6.00	6.66
G24	8	5	8	6	6	6	14	8	8	8	8	8	17	23	5	8	9.13	4.69
G25	14	17	18	14	14	14	16	18	14	18	18	16	15	13	17	14	15.63	1.76
G26	28	22	27	26	26	26	22	27	28	27	27	27	9	4	22	28	23.50	6.79
G27	24	12	25	20	20	15	27	25	24	25	25	25	4	6	12	24	19.56	7.18
G28	11	6	20	11	11	9	20	20	11	20	20	14	11	11	6	11	13.25	4.92
SC10	27	15	28	25	25	23	26	28	27	28	28	28	5	3	15	27	22.38	8.05
SC2031	10	10	13	10	10	10	17	13	10	13	13	10	14	18	10	10	11.94	2.56

Table 8: Rank and rank mean ($\bar{R}$) and slandered deviation of rank (SDR) of drought indices for grain yield at Sakha environment.

Geno.	YS +	YP +	SSI +	STI +	GMP *	MP+	TOL +	HM +	YI +	YSI +	SDI +	DI +	SSPI +	RDI +	K1.STI+	K2.STI +	$\bar{R}$	SDR
G1	20	17	13	20	20	20	12	13	20	13	13	18	19	18	17	20	17.06	3.05
G2	22	21	15	22	22	22	14	15	22	15	15	21	17	16	21	22	18.88	3.24
G3	18	25	10	21	21	21	8	10	18	10	10	13	23	21	25	18	17.00	5.72
G4	26	26	20	27	27	27	15	20	26	20	20	25	16	11	26	26	22.38	4.90
G5	2	11	2	3	3	4	2	2	2	2	2	2	29	29	11	2	6.75	8.89
G6	25	22	19	24	24	24	16	19	25	19	19	23	15	12	22	25	20.81	3.86
G7	24	23	17	23	23	23	11	17	24	17	17	22	20	14	23	24	20.13	3.95
G8	10	24	6	16	16	18	4	6	10	6	6	6	27	25	24	10	13.38	7.81
G9	7	8	12	8	8	8	20	12	7	12	12	10	11	19	8	7	10.56	3.87
G10	11	20	7	15	15	15	5	7	11	7	7	8	26	24	20	11	13.06	6.35
G11	3	5	5	2	2	2	7	5	3	5	5	3	24	26	5	3	6.56	7.11
G12	17	29	3	26	26	28	3	3	17	3	3	7	28	28	29	17	16.69	10.87
G13	5	9	4	5	5	6	6	4	5	4	4	5	25	27	9	5	8.00	6.97
G14	13	16	9	14	14	14	9	9	13	9	9	12	22	22	16	13	13.38	4.04
G15	16	6	26	11	11	11	28	26	16	26	26	20	3	5	6	16	15.81	8.38
G16	29	27	22	29	29	29	13	22	29	22	22	28	18	9	27	29	24.00	6.03
G17	23	13	28	18	18	16	27	28	23	28	28	26	4	3	13	23	19.94	8.04
G18	30	30	24	30	30	30	10	24	30	24	24	30	21	7	30	30	25.25	7.04
G19	9	10	11	9	9	9	17	11	9	11	11	11	14	20	10	9	11.25	3.07
G20	15	12	18	13	13	12	21	18	15	18	18	15	10	13	12	15	14.88	2.91
G21	4	28	1	12	12	13	1	1	4	1	1	1	30	30	28	4	10.69	11.32
G22	19	15	14	17	17	17	18	14	19	14	14	17	13	17	15	19	16.19	1.98
G23	6	2	16	4	4	3	26	16	6	16	16	9	5	15	2	6	9.50	6.82
G24	27	19	27	25	25	25	22	27	27	27	27	27	9	4	19	27	22.75	6.75
G25	14	7	21	10	10	10	25	21	14	21	21	16	6	10	7	14	14.19	5.84
G26	21	14	23	19	19	19	23	23	21	23	23	24	8	8	14	21	18.94	5.06
G27	12	4	29	7	7	7	30	29	12	29	29	19	1	2	4	12	14.56	10.75
G28	28	18	30	28	28	26	24	30	28	30	30	29	7	1	18	28	23.94	8.45
SC10	1	1	8	1	1	1	19	8	1	8	8	4	12	23	1	1	6.13	6.68
SC2031	8	3	25	6	6	5	29	25	8	25	25	14	2	6	3	8	12.38	9.47

Conclusion

Among various resistance and tolerance indices that were evaluated, both Yp and Ys were significantly and positively correlated (P<0.01) with MP, GMP, YI, STI, KI.STI and K2.STI at Sids and Sakha environments. This indicates that these indices were more effective in identifying high-yielding genotypes under drought stress as well as normal conditions indicating more appropriateness of these indices for the selection of tolerant genotypes. Screening drought tolerant genotypes using principal components, ranking method and Cluster analysis differentiate genotypes G5, G15, G20, G21, G22 and G23 at Sids and G5, G11, G13, G23 and SC10 at Sakha as the most drought tolerant. Thus, they are advisable for use as parents for the improvement of drought tolerance in other genotypes. In addition, the results of this study showed that among drought tolerance indices MP, GMP, YI, STI, KI.STI and K2.STI can be used as the most appropriate indicator for screening drought-tolerant cultivars.

References

Ali, M B. & El-Sadek A N. (2016). Evaluation of drought tolerance indices for wheat (*Triticum aestivum L.*) under irrigated and rainfed conditions. *Communication In Biometry and Crop Sci vol. 11, no. 1, pp. 77-89.*

Andjelkovic, V.; Karavic, N.; Babic, V. & Ignjatovic-Mici, D. (2014). Estimation of drought tolerance among maize landraces from mini-core collection. *Genetika, 46,* (3), 775-788.

Blum,A. (1988). Plant breeding for stress environments. *CRC Press, Boca Raton, FL,* 38–78.

Bonea, D. (2020). Grain yield and drought tolerance indices of maize hybrids. Ntulae Scientia Biologica *12*(2),376-386

Bouslama, M. & Schapaugh, W.T. (1984). Stress tolerance in soybeans. I. Evaluation of three screening techniques for heat and drought tolerance. *Crop Sci., 24*(5), 933–937.

breed wheat for drought tolerance. *Euphytica 92, 147–153.*

Byrne, P.F., Bolanos, J., Edmeades, G.O. & Eaton, D.L (1995). Gains from selection under drought versus multilocation testing in related tropical maize populations. *Crop Sci. 35,* 63–69

Clarke, J.M.; DePauw, R.M. & Townley-Smith, T.F. (1992). Evaluation of methods for quantification of drought tolerance in wheat. *Crop Sci. 32,* 423–428.

Farshadfar, E, Farshadfar. M. & Dabiri S. (2012a). Comparison between effective Selection criteria of drought tolerance in bread wheat landraces of Iran. *Ann. Biol. Res. 3*(7):3381-3389.

Farshadfar, E. & Javadinia, J. (2011). Evaluation of Chickpea (*Cicer arietinum* L.) genotypes for drought tolerance. *Seed and Pl Improvement J. 27,* 517–537.

Farshadfar, E. & Sutka, J. (2002). Screening drought tolerance criteria in maize. *Acta Agronomica Hungarica 50,* 411–416.

Fernandez, G.C.J. (1992). Effective selection criteria for assessing stress tolerance.In: Kuo, C.G. (Ed.) Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress. Tainan, Taiwan.

Fischer, R.A. and Maurer, R. (1978). Drought resistance in spring wheat cultivars.I. Grain yield responses. *Crop and Pasture Sci. 29,* 897–912.

Fischer, R.A., Rees, D., Sayre, KD.; Lu ZM, Condon A.G. & Saavedra A.L. (1998). Wheat yield progress associated with higher stomatal conductance and photosynthetic rate, and cooler canopies. *Crop Sci 38:*1467-1475.

Gavuzzi, P., Rizza, F., Palumbo, M., Campanile, R.G.; Ricciardi, G. L. & Borghi, B. (1997). Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. *Canadian Journal of Plant Sci. 77,* 523–531.

Golabadi, M.A., Arzani, S.A. & Maibody, M. (2006). Assessment of drought tolerance in segregating populations in durum wheat. *Afr., J. Agric. Res., 1(5):62- 171.*

Guttieri, MJ.; Stark, JC.; Brien. K. & Souza, E. (2001). Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. *Crop Sci.,41:*327-335.

Hall, AE. (1993). Is dehydration tolerance relevant to genotypic differences in leaf senescence and crop adaptation to dry environments? In: Close TJ, Bray EA (Eds.) Plant Responses to cellular Dehydration during environmental stress. *The Am. Soc. Pl. Path., Rockville, Maryland.*

Khalili, M., Naghavi, MR.; Pour Aboughadareh, AR. & Talebzadeh, J. (2012). Evaluating of drought stress tolerance based on selection indices in spring canola cultivars (*Brassica napus L.*). *JAS 4*(11),78-85.

Kirigwi, F.M., Van Ginkel, M., Trethowan, R., Sears, R.G., Rajaram, S. & Paulsen,G.M. (2004). Evaluation of selection strategies for wheat adaptation across water regimes. *Euphytica 135,* 361–371.

Lan, J. (1998). Comparison of evaluating methods for agronomic drought resistance in crops. Acta Agric Boreali-occidentalis *Sinica 7,* 85–87.

Mardeh, A.S.S., Ahmadi, A., Poustini, K. & Mohammadi V. (2006). Evaluation of drought resistance indices under various environmental conditions. *Field Crops Research 98,* 222– 229.

Mardi, H., Akbari, G.A., Khavari Khrasani, S. & Ramshini, H.A. (2012). Evaluation of drought tolerance in corn (Zea mays L.) new hybrids with using stress tolerance indices. *European J. of Sustainable Development. 1, 3,* 543-560.

Mohammadi, R.; Armion, M.; Kahrizi, D. & Amri A. (2010). Efficiency of screening techniques for evaluating durum wheat genotypes under mild drought conditions. *J of Pl Prod 4,* 11–24

Moosavi, S.S.; Yazdi Samadi, B.; Naghavi, M.R., Zali, A.A., Dashti, H. & Pourshahbazi A (2008). Introduction of new indices to identify relative drought tolerance and resistance in wheat genotypes. *Desert 12:165-178.*

Mostafavi, Kh.; Shoahosseini, M. & Sadeghi Geive, H. (2011). Multivariate analysis of variation among traits of corn hybrids traits under drought stress. *Inter. J. Agri. Sci., 1*(7), 416-422.

Naghavi, M R.; Aboughadareh, A P. & Khalili, M. (2013). Evaluation of drought tolerance for screening some of corn (*Zez mays* L.) cultivars under environmental conditions. Print ISSN 2067-3205; Electronic 2067-*3264 Not Sci. Biol.,5*(3):388-393

Nouri, A., Etminan, A., Teixeira da Silva, J.A. & Mohammadi, R. (2011). Assessment of yield, yield-related traits and drought tolerance of durum wheat genotypes (*Triticum turjidum* var. *durum* Desf.). *Aus J of Crop Sci 5, 8–16.*

Pirayvatlou, A.S. (2001). Relations among yield potential, drought tolerance and stability of yield in bread wheat cultivars under water deficit conditions. *Proceedings of the 10th Australian Agronomy Conference. Hobart, January 29, 2001*

Rajaram, S. & Van Ginkle, M. (2001). Mexico, 50 years of international wheat breeding. Bonjean A.P., Angus W.J., (Eds.) The world wheat book: A history of wheat breeding. *Lavoisier Publishing, Paris, France,* 579–604.

R**ajaram, S.; Braun, H.J. and Van Ginkel, M. (1996).** CIMMYT's approach to

Rosielle, A.A. &Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non-stress environment. *Crop Sci.21,* 943–946.

Sanjari, P. A. and Yazdansepas, A. (2008). Evaluation of wheat (*Triticum aestivum* L.) Genotypes under Pre-and post -anthesis drought stress conditions. *J. Agri. Sci., and Technology 10,* 109–121.

Schneider, K.A.; Rosales-Serna, R., Ibarra-Perez, F.; Cazares-Enriquez, B., Acosta-Gallegos, J.A.; Ramirez-Vallejo, P.; Wassimi, N. and Kelly, J.D. (1997). Improving common bean performance under drought stress. *Crop Sci 37, 43–50.*

Shahrokhi,M.; Khorasani,S. K. & Ebrahimi,A. (2020). Evaluation of drought tolerance indices for screening some of super sweet maize (Zea mays L. var. *Sacchrata*) inbreed lines. *Agrivita of Agric., Scin., 42*(3),435-448.

Talebi, R.; Fayaz, F. & Naji, A.M. (2009) Effective selection criteria for assessing drought stress tolerance in durum wheat (*Triticum durum* DESF.). *General and Applied Plant Physiology35,* 64-74

Zeinali Khanghah, H., Izanlo, A., Hosseinzadeh, A.; & Majnoun Hosseini, N. (2004). Determine of appropriate drought resistance indices in imported soybean cultivars. *Iran J. of Agri. Sci. 354,* 875–885.

تقييم طرز وراثية جديدة من الذرة الشامية البيضاء تحت الأجهاد المائي باستخدام الأدلة الانتخابية

محمد المهدي محمد عبد العظيم – مجدي احمد عبد المولى – أشرف كمال مصطفى
أيمن أحمد عبد المطلب – وائل محمد النبوي السيد
قسم أبحاث الذرة، معهد المحاصيل الحقلية، مركز البحوث الزراعية، جمهورية مصر العربية

تم حساب ثلاثة عشر دليلا إنتخابيا لتحمل الجفاف تشمل مؤشر تحمل الإجهاد (STI) ، ومؤشر القابلية للإجهاد (SSI) ، ومؤشر التسامح (TOL) ، ومتوسط الإنتاج الهندسي (GMP) ، ومتوسط الإنتاج (MP) ، والمتوسط التوافقي (HM) ، ومؤشر الغلة (YI) ، ومؤشر استقرار الغلة (YSI) ، ومؤشر مقاومة الجفاف (DI) ، ومؤشر حساسية الجفاف (SDI) ، ومؤشر الجفاف النسبي (RDI) ، ومؤشر النسبة المئوية للتأثر بالإجهاد (SSPI) وتحمل الإجهاد المعدل K1STI)

تم تقديرها لمحصول الحبوب تحت ظروف الاجهاد المائي والري العادي لتحديد أفضل التراكيب الوراثية للذرة الشامية التي يمكن زراعتها تحت ظروف الأجهاد المائي.

أظهرت النتائج وجود ارتباط معنوي وإيجابي بين كل من المحصول تحت الجفاف والري العادي و الأدلة الإنتخابية ,MP GMP, YI, STI, KI.STI and K2.STI في منطقتي سدس وسخا . هذا الأرتباط يدل على ان هذه الأدلة أكثر فعالية في تحديد التراكيب الوراثية المتحملة لظروف الأجهاد المائي والظروف العادية. أظهرت طرق التحليل العنقودي والثنائية cluster method and biplot لفحص التراكيب الوراثية المتحملة للجفاف ان التراكيب الوراثية G5, G15, G20, G21, G22 و G23 في سدس والطرز الوراثية G3, G5, G8, G10, G11, G12, G13 و G21 في سخا هي اكثر التراكيب الوراثية تحملا لظروف الأجهاد المائي . قسمت التراكيب الوراثية بناء على التحليل العنقوديcluster الى ثلاثة مجموعات وهي المتحملة للجفاف والحساسة و شبة حساسة لظروف للجفاف. احتوت المجموعة المتخملة على 5 , 9 تراكيب وراثية متحملة , 13 , 15 تراكيب وراثية شبة حساسة و 12 و 6 تراكيب وراثية حساسة للإجهاد المائي في كل من سدس وسخا على التوالي.

الكلمات الدالة: الذرة الشامية، معامل الإرتباط , الأجهاد المائي , الأدلة الأنتخابية