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EVALUATION OF DROUGHT TOLERANCE INDICES FOR BARLEY LANDRACES UNDER IRRIGATED AND DRY CONDITIONS

AVALIAÇÃO DE ÍNDICES DE TOLERÂNCIA SECA PARA TERRAÇOS DE CEVADA EM CONDIÇÕES IRRIGADAS E SECAS

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ABSTRACT: Barley cultivation for drought areas requires a reliable assessment of drought tolerance variability among the breeding germplasms. Hence, 121 barley landraces, advanced breeding lines, and varieties were evaluated under both moisture non-stress and stress field conditions using a lattice square (11×11) design with two replications for each set of the trials. Twelve drought tolerance indices (SSI, TOL, MP, GMP, STI, YI, YSI, HM, SDI, DI, RDI, and SSPI) were used based on grain yield under normal (Yp) and drought (Ys) conditions. Analysis of variance showed a significant genetic variation among genotypes for all indices except for TOL and SSPI indices. Yp had a very strong association with Ys ($r = 0.92^{**}$) that indicates high yield potential under non-stress can predict better yield under stress conditions. Yp and Ys were positively and significantly correlated with MP, GMP, STI, YI, HM, and DI indices, whereas they were negatively correlated with SSI and SDI. In principal component analysis (PCA), the first PC explained 64% of total variation with Yp, Ys, MP, GMP, STI, YI, HM, and DI. The second PC explained 35.6% of the total variation and had a positive correlation with SSI, TOL, SDI, and SSPI. It can be concluded that MP, GMP, STI, YI, HM and DI indices with the most positive and significant correlation with the yield at both non-stress and stress environments would be better indices to screen barley genotypes, although none of the indices could undoubtedly identify high yield genotypes under both conditions.

KEYWORDS: Drought Index. Principal component analysis. Germplasm. Yield.

INTRODUCTION

Drought is one of the most important abiotic stresses that adversely affects growth, metabolism, and yield of barley under dryland conditions. In arid and semi-arid climates, either reduction in water supply in soil or high transpiration rate can cause drought experience in crops (REDDY ET AL., 2004). Drought tolerance is based on different strategies like dehydration [illegible] Drought declines root growth, leaf water potential, cell membrane stability, photosynthetic rate, and carbohydrate accumulation (JIANG; HUANG, 2000; TARDIEU et al., 2014; ASSAHA et al., 2016).

Drought tolerance improvement has been a goal in crop breeding, although, success in breeding for tolerance has been restricted because this trait is quantitative and controlled by many genes (Von KORFF et al., 2008; WEHNER et al., 2016), dif ficult to eliminate adverse genes (RICHARDS, 1996), lack of suitable screening procedures particularly under field conditions (KIRIGWI et al., 2004).

To identify drought-tolerant genotypes, yield stability of genotypes under both drought stress and optimum conditions is vital for plant breeders. Moreover, high-yielding genotypes under favorable conditions may not be drought tolerant (SIO-SE MARDEH et al., 2006); therefore, many researches preferred screening under stress and [illegible]SAVI et al., 2008). [illegible]-stress conditions was negatively correlated with stress conditions, and a high potential yield under favorable conditions does not necessarily result in improved yield under stress conditions (SIO-SE MARDEH et al., 2006). Also, genotypes with high yield may not be stress-tolerant, so increasing the yield in these genotypes may be especially due to their high potential yield (BLUM, 1996).

Different indices were introduced such as geometric mean productivity (GMP), stress

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susceptibility index (SSI), tolerance (TOL), mean productivity (MP), harmonic mean (HM), stress tolerance index (STI), yield index (YI), yield stability index (YSI), sensitivity drought index (SDI), drought response index (DSI), drought resistance index (DI), relative drought index (RDI), stress susceptibility percentage index (SSPI), and modified stress tolerance index (MSTI). These indices have been used to select stable genotypes according to their performance under stress and favorable conditions (ABEBE et al., 1998; MURSALOVA et al., 2015). A study on barley indicated that STI, MP, and GMP are the best criteria for screening high yielding genotypes under both stress and non-stress conditions (NAZARI; PAKNIYAT, 2010). However, screening of genotypes based on these criteria has generally been ineffective due to their higher relation with survival mechanisms in crops. Moreover, drought tolerance is connected with many other stress factors like salt, high temperature, senescence, development, cell circle, flowering, signal transduction, etc. In another word, drought stress is interconnected with almost all aspects of biology, and the recommendation of an appropriate index for its screening is really difficult and complex (MOOSAVI et al., 2008). So, none of the indices could effectively identify genotypes with high yield under both stress and non-stress conditions. The effectiveness of the indices in the screening depends on the stress severity (KUTLU; KINACI, 2010).

The relative yield performance of genotypes in stress and non-stress environments in small-size populations seems to be a common starting point in the identification of traits related to drought tolerance and the selection of genotypes in breeding for dry environments in so many studies. Because of the lack of enough genotypic variation in small-size populations, the effectiveness of these criteria in finding drought-tolerant genotypes are still controversial and questionable. In the same pattern, the selection in the current study was conducted under non-stress and stress conditions, but in a large population (121 very diverse barley population from all around the world) to empower the quality of the study. Hence, this study aimed to (i) compare and evaluate different yield-based drought-tolerance screening indices in a very large population, (ii) determine the efficiency of tolerance indices to classify barley genotypes, (iii) interpret interrelationships among the tolerance indices by biplot analysis.

MATERIAL AND METHODS

A set of 121 barley landraces, advanced breeding lines, and varieties was compiled from Seed and Plant Improvement Institute (SPII), Iran. The accessions were geographically originated from 12 countries (United Kingdom, Iran, Egypt, China, USA, India, Pakistan, Algeria, Ethiopia, Turkey, Spain, and Russia) (Table 1). To minimize the heterogeneity of landraces, the ear-to-row pure line selection method was applied at the Dryland Agricultural Research Institute (DARI). The genotypes were planted in two distinct water treatments (drought stress and non-stress) in the experimental field of DARI under lattice square (11×11) design with two replications, in autumn 2014. The plants of drought stress treatment were subjected to moisture stress from the booting stage to maturity. Each plot consisted of 6 rows of 2 m long and 0.20 m apart. At harvest, the yield of 1 m^2 was used to measure potential yield (Yp) and stress yield (Ys) (g m^{-2}).

Drought tolerance indices were calculated for lines based on grain yield (g $plot^{-1}$) using the following relationships. Where Yp and Ys were the yield of each genotype under non-stress and stress conditions, respectively. $\hat{Y}p$ and $\hat{Y}s$ represent yield mean in non-stress and stress conditions for all genotypes, respectively.

$$SSI = [1-(Ys/Yp)]/[1-(\hat{Y}p/\hat{Y}s)] \quad (1)$$
$$TOL = Yp - Ys \quad (2)$$
$$MP = (Yp + Ys)/2 \quad (3)$$
$$GMP = (Yp \times Ys)^{1/2} \quad (4)$$
$$STI = (Yp \times Ys) / (\hat{Y}p)^2 \quad (5)$$
$$YI = Ys/\hat{Y}s \quad (6)$$
$$YSI = Ys/Yp \quad (7)$$
$$HM = 2(Yp \times Ys)/(Yp + Ys) \quad (8)$$
$$SDI = (Yp - Ys)/Yp \quad (9)$$
$$DI = Ys \times [(Ys/Yp)/\hat{Y}s] \quad (10)$$
$$RDI = (Ys/Yp)/(\hat{Y}s/\hat{Y}p) \quad (11)$$
$$SSPI = [(Yp - Ys)/2\hat{Y}p] \times 100 \quad (12)$$

The data were tested for skewness, kurtosis, homogeneity of variance, and normality by GenStat 12.0 statistical software. Then, correlation analysis between grain yield and drought tolerance indices was performed to determine the best drought-tolerant indices. Principal component analysis (PCA) was performed based on the observations. The correlation analysis and principal component biplot analysis were performed in SPSS and GenStat software, respectively.

Table 1. Distribution of 121 barley landraces, advanced breeding lines and varieties used in this study according to their origin.

Gen.	GB number (KC)	Origin	Gen.	GB number (KC)	Origin	Gen.	GB number (KC)	Origin
1	71411	UK	42	72498	IRAN	83	72726	IRAN
2	71411	UK	43	72498	IRAN	84	72372	CHINA
3	71426	ALGERIA	44	72500	IRAN	85	72382	CHINA
4	71426	ALGERIA	45	72520	IRAN	86	72472	IRAN
5	71482	USA	46	72522	IRAN	87	72472	IRAN
6	71530	RUSSIA	47	72524	IRAN	88	72482	IRAN
7	71530	RUSSIA	48	72524	IRAN	89	72553	AZERBAIJAN
8	71538	SPAIN	49	72524	IRAN	90	72588	IRAN
9	71538	SPAIN	50	72545	IRAN	91	72646	IRAN
10	71557	EGYPT	51	72546	IRAN	92	72646	IRAN
11	71576	EGYPT	52	72550	USA	93	72680	IRAN
12	71608	EGYPT	53	72557	AZERBAIJAN	94	72680	IRAN
13	71657	EGYPT	54	72557	AZERBAIJAN	95	72686	IRAN
14	71663	INDIA	55	72562	IRAN	96	72704	IRAN
15	71704	ETHIOPIA	56	72565	IRAN	97	72744	IRAN
16	71850	RUSSIA	57	72566	IRAN	98	72747	IRAN
17	71938	PAKISTAN	58	72566	IRAN	99	CWB117-77-9-7/3/TOKA	UNKNOWN
18	71938	PAKISTAN	59	72566	IRAN	100	Tokak/Demir-2	UNKNOWN
19	72113	CHINA	60	72568	IRAN	101	Zarjau/80-5151//DZ-40-	UNKNOWN
20	72295	CHINA	61	72581	IRAN	102	AZE-Lerik-ICB-123363/	UNKNOWN
21	72295	CHINA	62	72584	IRAN	103	CWB117-5-9-5//CWB1	UNKNOWN
22	72295	CHINA	63	72587	IRAN	104	Ste/Antares//YE A762-	UNKNOWN
23	72322	CHINA	64	72602	IRAN	105	Alpha/Gumhuri yet//Sonja	UNKNOWN
24	72322	CHINA	65	72611	IRAN	106	Makoee	IRAN
25	72322	CHINA	66	72646	IRAN	107	Sahand	IRAN
26	72322	CHINA	67	72647	IRAN	108	Abidar	IRAN
27	72368	CHINA	68	72649	IRAN	109	Dayton/Ranney	ICARDA
28	72368	CHINA	69	72650	IRAN	110	Yea/168	ICARDA
29	72368	CHINA	70	72653	IRAN	111	Denmark	ICARDA
30	72368	CHINA	71	72655	IRAN	112	Obruk-86	TURKEY
31	72406	CHINA	72	72664	IRAN	113	UNKNOWN	UNKNOWN
32	72406	CHINA	73	72665	IRAN	114	Bulbul	TURKEY
33	72439	CHINA	74	72666	IRAN	115	Dicktoo	RUSSIA
34	72439	CHINA	75	72668	IRAN	116	Radical	RUSSIA
35	72439	CHINA	76	72672	IRAN	117	Dobrynya	RUSSIA
36	72466	IRAN-MIYANDOAB	77	72673	IRAN	118	UNKNOWN	UNKNOWN
37	72472	IRAN	78	72674	IRAN	119	UNKNOWN	UNKNOWN
38	72480	IRAN-Karand	79	72675	IRAN	120	ChiC/An57//Alb ert	UNKNOWN
39	72480	IRAN	80	72684	IRAN	121	Pamir-65/Pamir-15	UNKNOWN
40	72488	IRAN	81	72689	IRAN			
41	72494	IRAN-Gazvin	82	72703	IRAN			

RESULTS AND DISCUSSIONS

Based on analysis of variance, there were highly significant differences for yield on non-stress (Yp) and drought stress (Ys) conditions as well as for all drought tolerance indices, but tolerance (TOL) and stress susceptibility percentage indices (SSPI) (Table 2), which indicated that genotypes were differing for genes controlling yield and drought tolerance indices (GHOLIPOURI et al., 2009; YAGDI; SOZEN, 2009; ANWAR et al., 2011). Genotypic coefficient of variability (GCV%), phenotypic coefficient of variation (PCV%), and broad-sense heritability (h^2) were high for Yp, Ys, and all the indices but yield stability index (YSI) and relative drought index (RDI). Hence, a great improvement in these indices can be possible through screening under drought stress conditions (SABA et al., 2010; ANWAR et al., 2011).

Table 2. Mean square, genotypic coefficient of variation (GCV%), phenotypic coefficient of variation (PCV%), heritability in a broad sense (h^2, in %) of Yp, Ys, and drought tolerance indices.

Trait	Mean Square		CV (%)	GCV%	PCV%	h^2
	Genotype (df=120)	Error (df=120)				
Grain yield (g plot^{-1}) under favorable conditions (Yp)	16904**	3448	12	17	19	80
Grain yield (g plot^{-1}) under drought conditions (Ys)	15099**	2407	12	20	21	84
Stress susceptibility index (SSI)	0.5604*	0.3944	50	22	41	30
Tolerance (TOL)	2535^{ns}	2173	58	17	44	14
Mean productivity (MP)	15368**	2385	11	18	20	84
Geometric mean productivity (GMP)	15421**	2372	11	18	20	85
Stress tolerance index (STI)	0.208**	0.038	22	33	37	82
Yield index (YI)	0.085**	0.014	12	19	21	84
Yield stability index (YSI)	0.01*	0.007	10	5	8	30
Harmonic mean (HM)	15487**	2375	11	18	20	85
Sensitivity drought index (SDI)	0.01*	0.007	50	22	41	30
Drought resistance index (DI)	0.089**	0.021	18	23	26	76
Relative drought index (RDI)	0.013*	0.009	10	5	8	30
Stress susceptibility percentage index (SSPI)	26.9^{ns}	23.1	58	17	44	14

* and ** Significant respectively at $p < 0.05$ and $p < 0.01$; ns - not significant.

There was a great variation among 121 barley genotypes for the calculated drought tolerance indices based on grain yield under drought stress and non-stress conditions, indicating the presence of high genetic variability among the genotypes (Table 3). The average grain yield under non-stress and stress conditions were 489 and 408 g plot^{-1}, respectively, with a decrease of 17%. Line 107 had the highest grain yield under both conditions. This line had lower than all genotypes average SSI (0.76), TOL (65), SDI (0.1), SSPI (7); had higher than average YSI (0.9); and had maximum MP (628), GMP (627), STI (1.66), YI (1.41), HM (626), DI (1.27) and RDI (1.04). According to SSI, line 107 was considered as genotypes with low drought susceptibility and high yield stability under both stress and non-stress conditions. Moreover, the maximum STI amount of this line proves the power of the STI index in identifying tolerant genotypes that produce high yield under both conditions (FERNANDEZ, 1992). The lower value of TOL means minor yield reduction under stress conditions and lower the drought sensitivity. The genotypes' ranking for MP, GMP, and HM indices were almost identical (Table 3), which suggested that these three indices were equal for screening genotypes (RICHARDS, 1996; ANWAR et al., 2011). These indices have been compared by different researchers (FERNANDEZ, 1992; RICHARDS, 1996) and their genetic parameters have also been studied (DARVISHZADEH et al., 2011).

Table 3. Descriptive statistics of drought indices in 121 barley genotypes.

Drought index	Minimum	Maximum	Mean	Standard deviation
Grain yield (g plot^{-1}) under favorable conditions (Yp)	215	660	489	92
Grain yield (g plot^{-1}) under drought conditions (Ys)	160	595	408	87
Stress susceptibility index (SSI)	0.31	2.37	1.26	0.54
Tolerance (TOL)	15	180	81	36
Mean productivity (MP)	188	628	449	88
Geometric mean productivity (GMP)	186	627	446	88
Stress tolerance index (STI)	0.15	1.66	0.88	0.32
Yield index (YI)	0.38	1.41	0.97	0.21
Yield stability index (YSI)	0.69	0.96	0.84	0.07
Harmonic mean (HM)	184	626	444	88
Sensitivity drought index (SDI)	0.04	0.31	0.17	0.07
Drought resistance index (DI)	0.28	1.27	0.82	0.21
Relative drought index (RDI)	0.80	1.10	0.96	0.08
Stress susceptibility percentage index (SSPI)	2	19	8.3	4

Based on the genotypic correlation coefficient between Yp, Ys, and other drought indices (Table 4), Yp had a very strong association with Ys (r=0.92**) that indicates high yield potential under non-stress can predict better yield under stress conditions (Figure 1). Therefore, indirect screening under stress environment would be effective based on the performance of irrigated conditions (ALI; EL-SADEK, 2016). However, this result was not in agreement with Anwar et al. (2011) and Gholipouri et al. (2009). Yp and Ys were positively and significantly correlated with MP, GMP, STI, YI, HM, and DI indices, whereas they were negatively correlated with SSI and SDI. These results were consistent with the findings of Ali and El-Sadek (2016) in wheat, Golabadi et al. (2006) in durum wheat, Farshadfar, and Sutka (2002) in maize and Zare (2012) in barley. Highly positively correlated indices with both the Ys and Yp would be the most suitable indices in screening stress-tolerant genotypes (Farshadfar; Javadinia, 2011).

Table 4. Genotypic correlation of yield under non-stress condition (Yp), yield under drought stress (Ys), and drought tolerance indices in 121 barley genotypes.

Index	Yp	Ys	SSI	TOL	MP	GMP	STI	YI	YSI	HM	SDI	DI	RDI
Ys	0.92**												
SSI	-0.14	-0.51**											
TOL	0.33**	-0.06	0.88**										
MP	0.98**	0.98**	-0.32**	0.15									
GMP	0.98**	0.98**	-0.34**	0.13	0.99**								
STI	0.96**	0.98**	-0.34**	0.11	0.99**	0.99**							
YI	0.92**	0.99**	-0.50**	-0.06	0.98**	0.98**	0.98**						
YSI	0.14	0.50**	-0.99**	-0.88**	0.32**	0.34**	0.34**	0.50**					
HM	0.97**	0.99**	-0.36**	0.11	0.99**	0.99**	0.99**	0.99**	0.36**				
SDI	-0.14	-0.50**	0.99**	0.88**	-0.32**	-0.34**	-0.34**	-0.50**	-0.99**	-0.36**			
DI	0.78**	0.96**	-0.72**	-0.33**	0.89**	0.90**	0.89**	0.96**	0.72**	0.90**	-0.72**		
RDI	0.14	0.51**	-0.99**	-0.87**	0.32**	0.34**	0.34**	0.51**	0.99**	0.36**	-0.99**	0.72**	
SSPI	0.33**	-0.06	0.87**	0.99**	0.14	0.12	0.11	-0.06	-0.87**	0.10	0.87**	-0.33**	-0.87**

* and ** Significant respectively at $p < 0.05$ and $p < 0.01$. (Pearson correlation method)

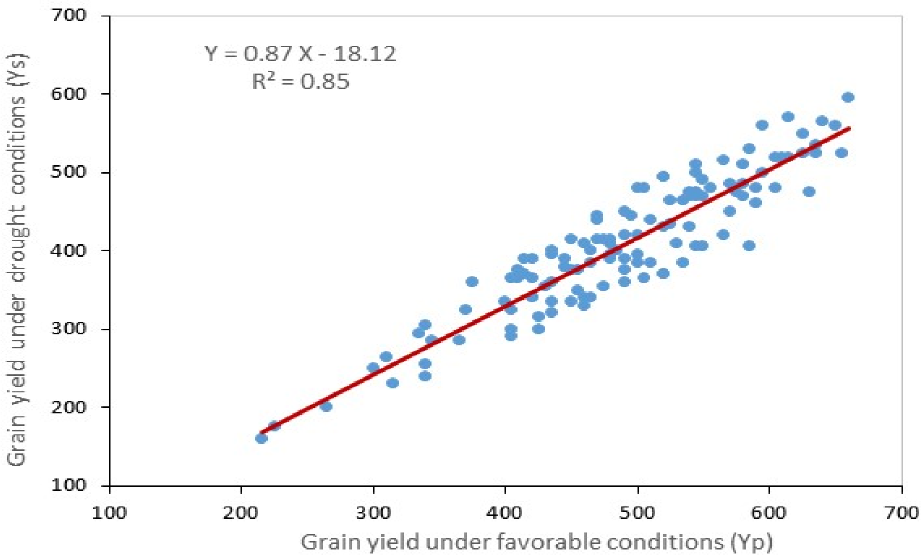

Figure 1. The relationship between grain yield produced under non-stress and drought stress conditions in 121 barley genotypes.

In principal component analysis (PCA), the first PC explained 64% of total variation with Yp, Ys, MP, GMP, STI, YI, HM, and DI. Thus, the first dimension can be named as the yield potential and drought tolerance. Based on the positive and high value of PC-1 on biplot, the selected genotypes would be high yielding under non-stress and stress conditions. As a result, line 107 with the biggest PC-1 was more suitable for both non-stress and stress conditions (Table 5 and Figure 2). Genotypes with lower PC-1 and larger PC-2 scores (such as line 104 with 0.69 yield stability score) had unstable yield, whereas genotypes with bigger PC-1 and smaller PC-2 scores (such as line 90 with 0.96 yield stability score) were more stable genotypes (KAYA et al., 2002). The second PC explained 35.6% of the total variation and had a positive correlation with SSI, TOL, SDI, and SSPI. Therefore, PC-2 can be named as a stress-tolerant dimension and it could differentiate the tolerant genotypes from susceptible ones. Hence, screening of genotypes with high PC-1 and low PC-2 would be appropriate for both non-stress and stress conditions (KAYA et al., 2006), as can be seen in line 107. Similar results were reported by Golabadi et al. (2006), Farshadfar and Sutka (2002) obtained similar results in multivariate analysis of drought tolerance in substitution lines.

Table 5. Principal components analysis for drought tolerance indices in 121 barley genotypes.

Index	PCA-1	PCA-2	PCA-3	PCA-4
Grain yield (g $plot^{-1}$) under favorable conditions (Yp)	0.26	0.28	0.13	0.09
Grain yield (g $plot^{-1}$) under drought conditions (Ys)	0.32	0.12	-0.06	0.17
Stress susceptibility index (SSI)	-0.24	0.31	-0.28	0.13
Tolerance (TOL)	-0.11	0.42	0.47	-0.17
Mean productivity (MP)	0.30	0.21	0.04	0.13
Geometric mean productivity (GMP)	0.30	0.20	0.03	0.13
Stress tolerance index (STI)	0.30	0.20	-0.43	-0.83
Yield index (YI)	0.32	0.12	-0.06	0.17
Yield stability index (YSI)	0.24	-0.31	0.28	-0.13
Harmonic mean (HM)	0.30	0.19	0.02	0.12
Sensitivity drought index (SDI)	-0.24	0.31	-0.28	0.13
Drought resistance index (DI)	0.33	0.00	-0.18	0.27
Relative drought index (RDI)	0.24	-0.31	0.28	-0.13
Stress susceptibility percentage index (SSPI)	-0.11	0.42	0.47	-0.17
Latent roots	8.95	4.98	0.06	0.01
Percentage of variation	63.9	35.6	0.4	0.1
Cumulative percentage	64.3	99.5	99.9	100

A combination of indices may provide a more useful criterion in screening drought tolerance genotypes; however, the study of a correlation coefficient can find out the degree of overall linear association between any two attributes. Hence, a better method than the correlation approach such as biplot would be useful to recognize the superior genotypes for both stress and non-stress conditions. Based on the cosine of the angle between indices vectors in Figure 2 (YAN; RAJCAN, 2002), there was i) a strong negative association between RDI and YSI with SDI, SSI, TOL, and SSPI, as indicated by the large angles between their vectors, (ii) almost no correlation of Yp and TOL with SDI and SSI, as well as Ys and YI with TOL and SSPI, (iii) a positive association among Yp, Ys, YI, HM, STI, GMP, and MP indices as indicated by the acute angles. The results obtained from the biplot graph confirmed correlation analysis (Figure 2). The results of biplot were almost consistent with correlation coefficients analysis (Table 4).

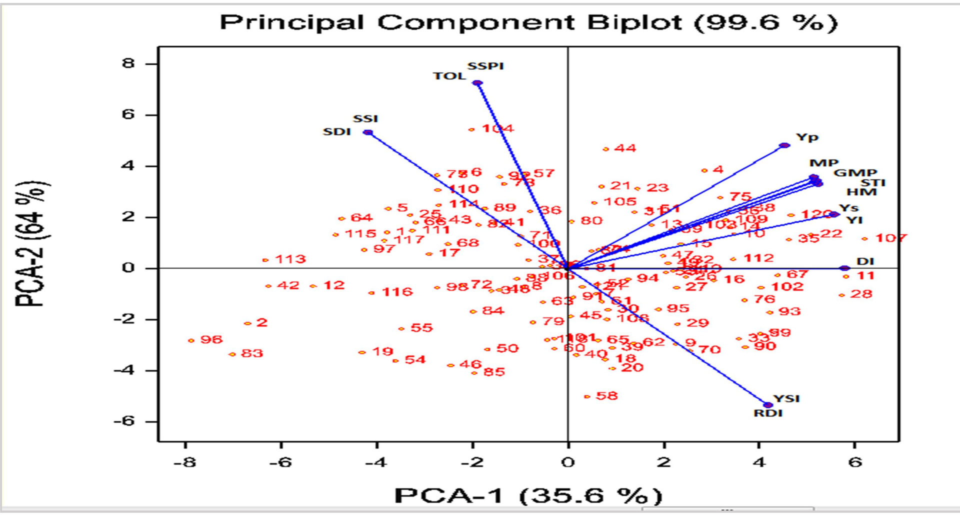

Figure 2. The genotype by trait biplots of the first two principal components of 121 barley genotypes. The indices are spelled out in capital letters, and each genotype is represented by numbers.

In this study, drought stress declined 20% average yield of the genotypes; however, some of them showed tolerance to drought, which suggests the existence of genetic variability for drought resistance among barley genotypes.

A large variation was found in drought tolerance index values of genotypes for grain yield, and significantly positive correlation was observed between Yp and Ys with the measured indices. A high STI score indicates higher stress tolerance and high yield potential as it was observed in Line 107 with the maximum STI score (1.66) among 121 genotypes.

Based on Fernandez's theory (1992), a proper criterion could identify genotypes with a steady superiority and has a high correlation with yield in both non-stress and stress conditions. Hence, MP, GMP, STI, YI, HM, and DI indices with the most positive and significant correlation with the yield at both non-stress and stress environments would be better indices to screen barley genotypes, although none of the indices could undoubtedly identify high yield genotypes under both conditions. Based on these indices, and the results of principal component and biplot analysis, the most tolerant and favorite genotypes were in Line 107, that had the maximum scores of these indices. On the other hand, the most sensitive genotypes based on these indices were in Line 96 that had the lowest score of these indices.

RESUMO: O cultivo de cevada para áreas secas exige uma avaliação confiável da variabilidade da tolerância à seca entre os germoplasmas reprodutores. Assim, 121 linhagens crioulas de cevada (linhas de reprodução avançada e variedades) foram avaliadas em campo sob condições sem estresse e com estresse de umidade do solo, utilizando-se para isso um arranjo experimental de malha quadrada (11×11), com duas repetições para cada conjunto de ensaios. Foram utilizados 12 índices de tolerância à seca (SSI, TOL, MP, GMP, STI, YI, YSI, HM, SDI, DI, RDI e SSPI), com base no rendimento de grãos sob condições normais sem estresse (Yp) e com estresse de seca (Ys). A análise de variância mostrou uma variação genética significativa entre os genótipos para todos os índices, com exceção dos índices TOL e SSPI. Yp teve uma associação muito forte com Ys (r = 0,92**), o que indica que o potencial de alto rendimento sob condições sem estresse pode prever melhor rendimento sob condições de estresse. Yp e Ys foram positivamente e significativamente correlacionados com os índices MP, GMP, STI, YI, HM e DI, enquanto, foram correlacionados negativamente com os índices SSI e SDI. Na análise de componentes principais (PCA), o primeiro PC explicou 64% da variação total com Yp, Ys, MP, GMP, STI, YI, HM e DI. O segundo PC explicou 35,6% da variação total e apresentou correlação positiva com SSI, TOL, SDI e SSPI. Pode-se concluir que, os índices MP, GMP, STI, YI, HM e DI com a correlação mais positiva e significativa com a produção nos ambientes sem estresse e com estresse seriam melhores índices para a seleção de genótipos de cevada, embora nenhum dos índices pudesse concretamente identificar genótipos de alto rendimento sob ambas as condições.

PALAVRAS-CHAVE: Biplot. Análise do componente principal. Germoplasma. Produção.

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