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Research Article

Biplot analysis of salinity tolerance indices in sugar beet breeding lines

Abstract

In order to determine the performance of sugar beet breeding lines under salinity stress conditions and screening quantitative indices of salinity tolerance, 12 sugar beet (Beta Vulgaris L.) genotypes were tested in a randomized complete block design with three replications under salinity and normal conditions. Significant positive correlation was found between Root yield in the stress condition (Ys) with indicators geometric mean productivity (GMP), mean productivity index (MP), stress tolerance index (STI), yield index (YI), Relative drought index (RDI), drought resistance index (DI), Stress susceptibility index (SSI), Yield stability index (YSI), Stress susceptibility percentage index (SSPI) and Stress non-stress production index (SNPI) indicating that these indices are suitable criteria for screening drought tolerant genotypes. No significant correlation was observed between Ys with Abiotic tolerance index (ATI) and tolerance index (TOL), hence they can be discarded as the desirable markers for identifying drought tolerant genotypes. Principal component analysis (PCA), indicated that the first and second components justified 93.50% of variations between the criteria. Screening salinity tolerant genotypes using biplot analysis, discriminated genotypes (5), (11) and (3) as the most salinity tolerant.

Keywords: sugar beet, salinity tolerance, biplot, screening criteria

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Introduction

Salinity is the most important devastating problems in most regions of the world. It is commonly accepted that most seed species cannot tolerate salinity higher than 10-20 percent sea water, and many do not growth of even lower concentrations.[1] For improving yield under salinity conditions, the development of new sugar beet cultivars with high root yield potential through identifying salinity tolerance mechanism is of great significance.[2] Achieving a genetic increase in yield under stress environments has been recognized to be a difficult challenge for plant breeders while progress in yield has been much higher in favorable environments.[3] Thus, the indices which provide a measure of stress based on yield loss under stress conditions in comparison to normal conditions have been used for screening stress tolerant genotypes.[4] These indices are either based on drought resistance or susceptibility of genotypes.[5] Various quantitative criteria have been proposed for selection of genotypes based on their yield performance in stress and non-stress environments. Based on these indicators genotypes are compared in normal and stress conditions.[6] Drought resistance is defined by Hall[7] as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress[8] whilst the values are confounded with differential yield potential of genotypes.[9] Rosielle et al.,[10] defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp) environments and mean productivity (MP) as the average yield of Ys and Yp. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) of the cultivar. Geometric mean productivity (GMP) is often used by breeders interested in relative performance, since drought stress can vary in severity in the field environment over years.[9]

Fernandez[5] defined a new advanced index (STI=stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Fernandez,[5] divided the manifestation of plants into the four groups of (I) – genotypes that express uniform superiority in non-irrigated and irrigated conditions (group A), (II) - genotypes which perform favorably only in nonstress conditions (group B), (III) - genotypes which yield relatively higher only in stress conditions (group C) and (IV) - genotypes which perform poorly in non-irrigated and irrigated conditions (group D). Fisher and wood (1979) introduced another index as relative drought index (RDI). Yield stability index (YSI) also was computed and suggested by Bouslama et al.,[11] This parameter is calculated for a given genotype using yield under stressed relative to its yield under non-stressed conditions. The genotypes with high YSI are expected to have high yield under stressed and low yield under non-stressed conditions Mohammadi et al.,[12] Clark et al.,[13] used stress susceptibility SSI for evaluation of drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes and their ranking pattern. In spring wheat cultivars, Guttieri et al.,[14] used SSI criterion and suggested that SSI more than 1 indicated above-average susceptibility to drought stress. Lan[15] defined new index of drought resistance index (DI), which was commonly accepted to identify genotypes producing high yield under both stress and nonstress conditions. The DI and STI consider not only the ability of genotypes to grow well under stressed environments, but also good performance in non-stressed environments. Indices ATI and SSPI are able to separate relative tolerant and non tolerant genotypes better than previous indices, while SNPI is able to separate group A from others and has an emphasis on high and stable yield in both environmental conditions.[16]

The objectives of the present investigation were

i. to identify salinity tolerant breeding lines of sugar beet genotypes in Iran and

ii. screening yield based indices of salinity tolerance.

Materials and methods

12 seeds of sugar beet (*Beta Vulgaris* ssp. vulgaris) listed in Table 1 were provided from sugar beet seed Institute of Karaj, Iran. They were assessed in a randomized complete block design with three replications under two salinity and normal conditions in 2012 growing season in the experimental field of the research station of Sugar Beet Seed Institute in Mian-Doab, Iran. The seeds from I-4 have been provided by paired crossed method and are open pollinated, 5-9 are hybrids, 10 is first origin of 8001 (with no selection), 11 and 12 are tolerance and susceptible varieties, respectively. All of the seeds have been provided under salinity stress conditions between years 2006-2011 in SBSI. The soil of experimental field was clay loam with pH7.1 with Electronic Conductivity (EC) was more than 14mmohs/cm. Sowing was done by hand in plots with 3 rows 7 m in length and 50cm apart. In the saline experiment just a little done for thinning because some of the plants were died before 4 leaf stage and the rest kept living till end of the experiment. In Non-stressed plots all the cultivation activities were done the same the normal conditions. Plants were thinned to 7 plants per meter of a row at the 4-8 leaf stage. At harvest time, yield potential (Yp) and stress yield (Ys) were measured from 3 rows 6 m in length.

Table 1 List of genotypes tested in 2012

Code	Genotype	Characteristic	Ploidy
1	8001-P.2	Open pollination	Diploid
2	8001-P.3	Open pollination	Diploid
3	8001-P.7	Open pollination	Diploid
5	8001-P.8	Open pollination	Diploid
5	MSC2*8001*P.7	Hybrid	Diploid
6	MSC2*8001*P.10	Hybrid	Diploid
7	MSC2*8001*P.11	Hybrid	Diploid
8	(261*231)*8001P.1	Hybrid	Diploid
9	(261*231)*8001P.3	Hybrid	Diploid
10	8001 CHECK	First generation	Diploid
11	7233*MSC2 HECK	Moderately tolerant to drought stress	Diploid
12	191 CHECK	Sensitive to salinity stress	Diploid

Results and discussion

Data concerning yield (Yp and Ys) and indices are given in Table 2. The estimates of stress tolerance attributes (Table 2A) indicated that the identification of salinity-tolerant genotypes based on a single criterion was contradictory. For example, according to STI, tol, Yi, ATI, GMP and MP genotypes 5 and 11 were the most, whereas genotype 9 the least relative tolerant genotype. For SSI the desirable salinity tolerant genotypeswas 5. As to SSPI genotypes 6 and 3 were the most and 9 and 1 the least relative tolerant genotypes (Table 2B). According to YSI, SSPI, RDI and ATI indices selected the genotype 5 as the most relatively tolerant genotype. DI selected the genotypes 5 as the best, while the genotypes 9, 12, 11 and 10 as the worst relatively tolerant genotypes. Majidi et al.,[17] reported that GMP, STI and HM indices were similarly able to separate drought sensitive and tolerant genotypes of safflower in both mild and intense water stress environments. Talebi et al.,[18] also reported that cultivars producing high yield in both drought and well watered conditions can be identified by STI, GMP and MP values. Pireivatlou et al.,[19] was also noted that STI can be a reliable index for selecting high yielding genotypes. They reported that correlations between YS with GMP, STI, and HM indicated that selection based on these indices may increase yield in stress and non stress conditions. Farshadfar et al.,[20] believed that most appropriate index for selecting stress-tolerant cultivars is an index which has partly high correlation with seed yield under stress and non-stress conditions. The observed relations were consistent with those reported by Fernandez[5] in mungbean, Farshadfar et al.,[21] in maize and Golabadi et al.[22] in durum wheat Ramirez ET AL.,[9] reported that selection based on a combination of both SSI and GM indices may provide a more desirable criterion for improving stress resistance in common beans. Guttieri et al.,[14] using SSI criterion in spring wheat, suggested that more than 1 unit of SSI value may indicate above-average susceptibility for drought stress and less than 1 unit has below-average susceptibility. Golabadi et al.[22] found that STI, MP, and GMP are superior indices for selecting high yield durum wheat genotypes both under moisture stress and non-stress field environments. Pourdad[23] reported that STI was the best index to identify superior cultivated safflower genotypes in conditions both with and without drought stress (Table 3A), (Table 3B).

The relationships among different indices are graphically displayed in a biplot of PCA1 and PCA2 (Figure 1). The first and second components justified 71.70% of the variations between criteria. The PCA1 and PCA2 mainly distinguish the indices in different groups. One interesting interpretation of biplot is that the cosine of the angle between the vectors of two indices approximates the correlation coefficient between them. The cosine of the angles does not precisely translate into correlation coefficients, since the biplot does not explain all of the variation in a data set. Nevertheless, the angles are informative enough to allow a whole picture about the interrelationships among the drought indices.[24] SSPI, YP, MP, STI,GMP, YS AND YI we refer to group 1= G1(A). The PCs axes separated SNPI, DI, YSI AND RDI in a single group (G2)(B) and TOL and SSI in a single group (G3)(C). The vector view of the biplot (Figure 1) provides a summary of the interrelationships among the SALINITY indicators.

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Table 2A Ranks (R) of salinity tolerance indicators

Genotype	Ys	R	Yp	R	SSI	R	RDI	R	TOL	R	MP	R	STI	R
1	10.71	5	12.83	5	0.48	5	1.28	5	2.12	5	11.77	5	0.9	5
2	9.41	11	13.85	11	0.93	11	1.04	11	4.44	11	11.63	11	0.85	11
3	8.52	8	11.26	8	0.7	8	1.16	8	2.74	8	9.89	8	0.63	8
4	8.5	3	13.87	3	1.12	3	0.94	3	5.37	3	11.19	3	0.77	3
5	8.5	7	12.83	7	0.97	7	1.01	7	4.33	7	10.67	7	0.71	7
6	8.22	10	11.52	10	0.83	10	1.09	10	3.3	10	9.87	10	0.62	10
7	8.2	2	11.67	2	0.86	2	1.07	2	3.47	2	9.93	2	0.62	2
8	8.13	6	13.86	6	1.19	6	0.9	6	5.73	6	10.99	6	0.73	6
9	8.08	4	13	4	1.09	4	0.95	4	4.92	4	10.54	4	0.69	4
10	7.97	1	11.8	1	0.94	1	1.03	1	3.83	1	9.89	1	0.61	1
11	7.16	12	13.14	12	1.31	12	0.83	12	5.98	12	10.15	12	0.61	12
12	3.73	9	8.95	9	1.68	9	0.64	9	5.21	9	6.34	9	0.22	9

Table 2B Ranks (R) of salinity tolerance indicators

Genotype	R	YI	R	YSI	R	DI	R	ATI	R	SSPI	R	SNPI	R
1	5	1.32	5	0.83	5	1.1	5	5.8	5	1240	5	127.8	5
2	11	1.16	11	0.68	11	0.79	11	11.83	11	1347	11	80.2	11
3	8	1.05	8	0.76	8	0.8	8	6.26	8	1092	8	76.9	8
4	3	1.05	3	0.61	3	0.64	3	13.6	3	1353	3	64.7	3
5	7	1.05	7	0.66	7	0.7	7	10.54	7	1249	7	67.6	7
6	10	1.02	10	0.71	10	0.73	10	7.49	10	1119	10	68.3	10
7	2	1.01	2	0.7	2	0.71	2	7.92	2	1134	2	67	2
8	6	1	6	0.59	6	0.59	6	14.19	6	1353	6	59.3	6
9	4	1	4	0.62	4	0.62	4	11.76	4	1267	4	60.3	4
10	1	0.98	1	0.68	1	0.67	1	8.66	1	1148	1	62.2	1
11	12	0.88	12	0.54	12	0.48	12	13.53	12	1285	12	47.8	12
12	9	0.46	9	0.42	9	0.19	9	7.03	9	880	9	17.4	9

Table 3 Correlation coefficients between indicators of salinity tolerance

	Ys	yp	SSI	RDI	TOL	MP	STI
Ys	1						
yp	.688*	1					
SSI	-.880**	-0.272	1				
RDI	.880**	0.272	-1.000**	1			
TOL	-0.524	0.257	.853**	-.853**	1		
MP	.929**	.908**	-.648*	.648*	-0.172	1	
STI	.953**	.863**	-.696*	.696*	-0.256	.991**	1
GMP	.956**	.870**	-.709**	.709**	-0.252	.996**	.993**
YI	1.000**	.688*	-.880**	.880**	-0.524	.929**	.953**
YSI	.880**	0.272	-1.000**	1.000**	-.853**	.648*	.696*
DI	.952**	0.44	-.967**	.967**	-.751**	.774**	.828**
ATI	0.016	.732**	0.432	-0.432	.837**	0.382	0.291
SSPI	.663*	.999**	-0.239	0.239	0.29	.893**	.846**
SNPI	.925**	0.44	-.915**	.915**	-.714**	.759**	.823**

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Table 3B Correlation coefficients between indicators of salinity tolerance

	GMP	YI	YSI	DI	ATI	SSPI	SNPI
GMP	1						
YI	.956**	1					
YSI	.709**	.880**	1				
DI	.821**	.952**	.967**	1			
ATI	0.308	0.016	-0.432	-0.288	1		
SSPI	.852**	.663*	0.239	0.409	.754**	1	
SNPI	.799**	.925**	.915**	.982**	-0.283	0.411	1

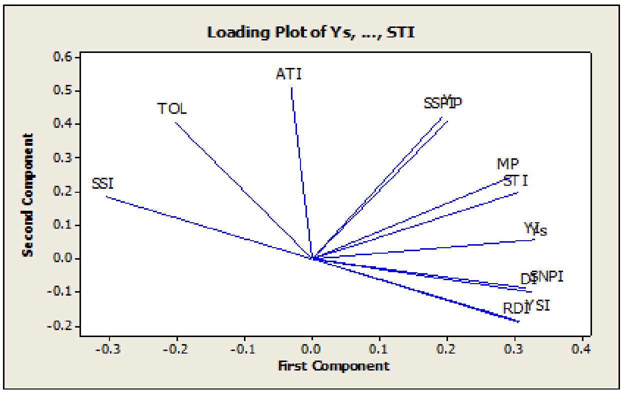

Figure 1 Biplot analysis of salinity tolerance criteria.

Using the biplot diagram (Figure 2) genotypes 5, 11, 3, 6, 7 and 4 were identified as tolerant and Genotype 12 was detected as sensitive to salinity. A three-dimensional representation of Ys, Yp and STI. The area of the 3D plot was divided into 4 regions, A, B, C and D.[5] Genotypes 9, 10, 16, 17, 18, 19, 24 and 25 were placed in a region of the plot which had the highest STI, Ys and Yp. Selection through SSI chooses genotypes with relatively low YP but high YS. This index ranges between 0 and 1 and the greater this index, the greater susceptibility of the genotype to stress. The main disadvantage of this index is the lack of separation of group A from group C.[5] YI, proposed by Gavuzzi et al.,[25] was significantly correlated with stress yield. This index ranks cultivars only on the basis of their yield under stress and so does not discriminate genotypes of group A. YSI, as Bouslama et al.,[11] stated, evaluates the yield under stress of a cultivar relative to its non-stress yield, and should be an indicator of drought resistant in the genetic materials.

Clarke et al.,[13] showed that yield-based SSI index did not differentiate between potentially stress resistant genotypes and those that possessed low overall yield potential. Similar limitations were reported by White et al.[26] Selection through TOL chooses genotype with low YP but with high YS (group C), hence, TOL deficiencies to distinguish between group C and group A.[5] MP is mean yield for a genotype in two stress and non-stress conditions. MP can select genotypes with high YP but with relatively low YS (group B) and it fails to distinguish group A from group B. By decreasing TOL and increasing MP, the relative tolerance increases.[5,10] A high STI demonstrates a high tolerance and the best advantage of STI is its ability to separate group A from others. GMP is more powerful than MP in separating group A and has a lower susceptibility to different amounts of YS and YP so; MP, which is based on arithmetic mean, will be biased when the difference between YS and YP is high. The higher GMP value, the greater the degree of relative tolerance. The geometric mean is often used by breeders interested in relative performance since drought stress can vary in severity in the field environments and over years.[5] The two indices namely ATI and SSPI reveal the relative tolerance of a cultivar to drought stress. The nature of ATI and SSPI are such that they rely on crop survival mechanisms in stress conditions although these genotypes can have either high or low yields in two conditions so, they have not exhibited a significant correlation with high YS but have shown a significant correlation with YP. The yield stability is more important than high yield in non-stress and stressed conditions. In fact, this reveals the relative stability of yield with conditions changes, and the smaller ATI and SSPI the more relative tolerance crop is. Although ATI and SSPI have high correlation together and both of them select group C, but ATI has a more emphasis on YP than SSPI, SSI and TOL.[16] ATI or SSPI select genotypes especially on the basis of yield stability, while, selection by SNPI is based on two characteristics simultaneously, namely yield stability as well as high YP and YS (with more emphasis on high YS than high YP).[16]

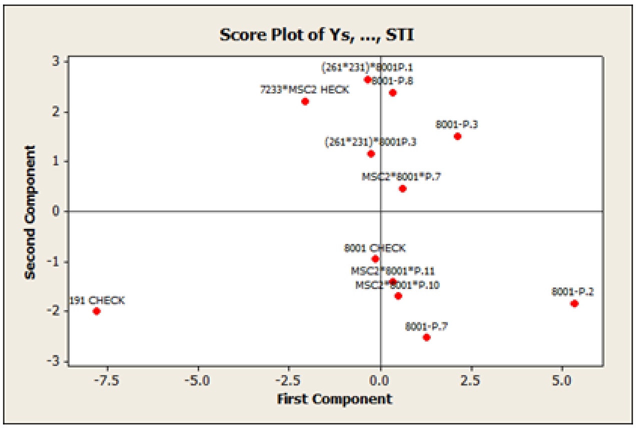

Figure 2 Biplot of first and second components for indices of salinity tolerance.

Ranking method

To determine the most desirable drought tolerant genotype according to the all indices mean rank and standard deviation of ranks of all in vivo drought tolerance criteria were calculated. In consideration to all indices, genotypes 17(RS=5.2664), 9(RS=8.737)

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and 18(RS=11.3364) were the most drought tolerant genotypes, respectively. While genotypes 15(RS=33.1464), 6(RS=29.877) and 21(RS=29.3623) were the most sensitive to drought, therefore they are recommended for crossing and genetic analysis of drought tolerance using diallel mating design or generation mean analysis and also for the QTLs (quantitative trait loci) mapping and marker assisted selection.

Conclusion

In conclusion, based on principal component and biplot analysis, the indices of group 2 (G2) Ys, DI, YI, STI, GMP, MP and Yp exhibited strong correlation (acute angles) with Ys and Yp, therefore, they can discriminate salinity tolerant genotypes with high sugar yield at the same manner under salinity and non- stress conditions (group A of Fernandez). With regard to all indices using rank some method genotypes 17(RS=5.2664), 9(RS=8.737) and 18(RS=11.3364) were the most drought tolerant genotypes, respectively.

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Conflict of interest

The author declares no conflict of interest.

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