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SCREENING SUGAR BEET GENOTYPES IN DROUGHT STRESS CONDITION USING TOLERANCE INDICES

SUMMARY

Drought is one of the major problems affecting crops production, including sugar beet. In order to identify drought tolerant sugar beet genotypes, an experiment with forty three sugar beet genotypes was conducted during 2016 in West Azerbaijan Province of Iran, using a complete randomized block design with three replications, under normal and water-stressed states. Analysis of variance revealed variability among studied genotypes in response to moisture conditions. Genotypes "HSF-861" and "HSF-844" produced the highest root yield and genotypes "F-205051" and "HSF-883" produced the highest white sugar yield under well-watered and water-stressed states, respectively. Assessing genotypes according to some selection indices lead to introduce promising genotypes (Group A) for root yield ("HSF-844", "HSF-859", "HSF-861", "HSF-883" and "32434-91") and white sugar yield ("HSF-841", "HSF-844", "HSF-847", "HSF-861"). In this study, genotype "HSF-844" possessed acceptable root and white sugar yield in both states simultaneously. Classification of studied genotypes using calculated tolerance indices, located them into three (root yield data) and five (white sugar yield data) groups. These differentiate groups relies on the existence of genetic variability in studied sugar beet germplasm. Hence, sugar beet breeders could effectively use selected parental lines from this germplasm for further research works like genetic analysis of drought tolerance and hybrid breeding programs.

Keywords: Drought tolerance, genetic variability, sugar beet

INTRODUCTION

Drought stress is one of the several environmental factors that greatly limiting crop production and plant distribution worldwide. Sugar beet (*Beta vulgaris* L.) supplies about a quarter of the world's sugar demand (Draycott, 2006). Assuming its origin from the indigenous Mediterranean *B. maritima*, sugar beet is a relatively young crop possessing a narrow genetic base (Van Geyt et al., 1990). In sugar beet, drought causes yield reductions about 10-30% in

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central and western Europe (Ober, 2001; Pidgeon et al., 2001; Jones et al., 2003), which increase in arid and semiarid regions (Sadeghian et al., 2000), especially where precipitation is low. Results indicated that root yield was more by 20% in 100% water requirement treatment compared with 50% treatment but sugar percentage in drier conditions was achieved more than wet conditions.

Identification of drought-tolerant sugar beet germplasm and determination of their genetic variability level in order to improvement of sugar beet varieties is considered as one of the most important strategies.

Albeit, improved tolerance to drought has been a goal but unfortunately, success in breeding for drought tolerance has been limited because (I) it is controlled by several genes, and their simultaneous selection is difficult (Richards, 1996; Yeo, 1998; Flowers et al., 2000), (II) tremendous effort is required to eliminate undesirable genes tightly linked to favorable ones, that are also incorporated during breeding (Richards, 1996) and (III) there is a lack of efficient selection procedures particularly under field conditions (Ribaut et al., 1997; Kirigwi et al., 2004).

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 (Adamczewska et al., 2009). These indices are either based on drought resistance or susceptibility of genotypes. 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 (Cieslik et al., 2009). Accordingly, geometric mean (Fernandez, 1992), mean productivity (Rosielle and Hamblin, 1981), harmonic mean (Jafari et al., 2009), stress susceptibility index (Fischer and Maurer, 1978), yield stability index (Bouslama and Schapaugh, 1984), yield index (Gavuzzi et al., 1997), stress tolerance index (Fernandez, 1992) and tolerance index (Rosielle and Hamblin, 1981) were introduced.

Genotypes can be categorized into four groups based on their yield in stress and non-stress environments: genotypes express uniform superiority in both stress and non-stress environments (Group A); genotypes perform favorably only in non-stress environments (Group B); genotypes yield relatively higher only in stress environments (Group C); and genotypes perform poorly in both stress and non-stress environments (Group D). The optimal selection criterion should distinguish Group A from the other three groups (Fernandez, 1992). Clarke et al., (1992) showed that yield-based SSI index did not differentiate between potentially drought resistant genotypes and those that possessed low overall yield potential. Similar limitations were reported by White and Singh (1991). Selection through TOL chooses genotypes with low Yp but with high Ys (group C) hence, TOL cannot distinguish between group C and group A (Fernandez, 1992). MP is mean yield for 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 (Rosielle and Hamblin, 1981; Fernandez, 1992). There are several studies about drought screening in crops such as wheat (Sio-Se Mardeh et al., 2006), sunflower (Darvishzadeh et al., 2010), rice (Ouk et al., 2006) and so on. While, there is narrow studies about utilization of above mentioned tolerance indices in evaluation of sugar beet reaction into stress states. For instance, Vahidi et al. (2013), were proved that drought stress could significantly influenced white sugar yield of a studied sugar beet germplasm and therefore, application of tolerance indices for screening and identification of desirable genotype was recommended. Considering Korshid (2016), tolerance indices including STI, GMP, MP and YI could effectively screen sugar beet genotypes against salinity stress. About drought stress, there is narrow study about utilization of tolerance selection indices in sugar beet. However, literature review depicted a sharp contrast between the root and the shoot in their response to water deficit. Abdollahian-Noghabi and Froud-Williams (1998), also noted a drastic reduction in the leaf area and a smaller decrease in the taproot growth of sugar beet when subjected to drought stress. In another study (Mahmoodi et al., 2008), revealed that irrigation treatments had a significant effect on sugar yield and its quality and optimum soil water content for root yield is 70% of field capacity.

Hence, this project was aimed for evaluation of several tolerance indices in screening of studied sugar beet germplasm against drought stress and identification of drought tolerant genotypes of sugar beet based on root and white sugar yield.

MATERIALS AND METHODS

Plant material and experimental methodology

This research was conducted at Agricultural Research Station of Miandoabm located in West Azerbaijan province of Iran. This research station with a latitude of 36º 58´ N, longitude of 46º 90´ E and altitude of 1314m has possess silty-loam soil. This area has the Feric temperature regime (the average annual temperature of soil is 8-15 ºC) and Xeric moisture regime (semi-arid). In this study, 43 sugar beet half-sib families were evaluated in two (normal water and water-stressed states) separate randomized complete block design with three replications in field state.

Seedbed preparation practices such as plowing, disking and leveling were uniformly applied. Potassium and phosphorous fertilizers were applied at the time of seedbed preparation and nitrogen fertilizer was applied as topdressing. The between- and within-row spacing was 50 and 15 cm, respectively. Each plot consisted of three rows of 8m length. Cultural practices including irrigation and control of diseases and pests were applied when needed. After plant establishment (4-6-leaf stage), furrow irrigation was applied on the basis of cumulative evaporation from the class A evaporation pan. The inlet and outlet irrigation water was measured by using WSC flumes. Plants were harvested at maturity, and then root yield accompanied with white sugar yield were measured for all genotypes in each replication. Drought tolerance indices were calculated using the equations cited in Table 1.

Table 1. List of drought tolerance indices used for evaluation of the reaction of sugar beet genotypes to drought conditions

Drought tolerance indices	Equation	Reference
Stress Susceptibility Index	$SSI = \frac{1-(\frac{Y_S}{Y_P})}{1-(\frac{\bar{Y}_S}{\bar{Y}_P})}$	Fischer and Maurer, 1978
Geometric Mean Productivity	$GMP = \sqrt{(Y_S)(Y_P)}$	Fernandez, 1992 and Kristin *et al.*, 1997
Mean Productivity	$MP = \frac{Y_S + Y_P}{2}$	Rosielle and Hambling, 1981
Harmonic Mean	$HM = \frac{2(Y_P \ . \ Y_S)}{Y_P + Y_S}$	Jafari et al. 2009
Tolerance index	$TOL = Y_P - Y_S$	Rosielle and Hambling, 1981
Stress Tolerance Index	$STI = \frac{(Y_S)(Y_P)}{(\bar{Y}_P)^2}$	Fernandez, 1992
Yield Index	$YI = \frac{Y_S}{\bar{Y}_S}$	Gavuzzi *et al.*, 1997
Yield Stability Index	$YSI = \frac{Y_S}{Y_P}$	Bouslama and Schapaugh, 1984

Y_S and Y_P are stress and optimal (potential) yield of a given genotype, respectively. $\bar{Y}_S$ and $\bar{Y}_P$ are average yield of all genotypes under stress and optimal conditions, respectively.

Statistical analysis

The data were analyzed using the general linear model (GLM) procedure in the SAS software (SAS Institute Inc., Cary, NC, USA). Correlations between root and white sugar yield in each of the water regimes with drought tolerance indices were determined using SPSS 18.0. Multivariate statistical analysis comprising three dimensional plots as well as cluster analysis were performed using the STASTICA ver. 7.0 software.

RESULTS AND DISCUSSION

Genetic variability for root and white sugar yield

Results revealed that there are significant differences among studied sugar beet genotypes for both root and white sugar yield traits under stress and non-stress conditions and their related tolerance indices (data not shown). Similar to finding of Abdollahian-Noghabi et al. (2011) and Korshid (2016), variability of yield in both stressed and non-stressed environments can imply the existence of useful resource for selection of drought tolerant genotypes through classical breeding methods.

In this study, the maximum and minimum value of root yield under normal condition (Yp) were belonged to genotypes "HSF-861" and "HSF-877" with value of 84.66 and 39 $t.ha^{-1}$, respectively (Table 2). Results showed that root yield under stress condition (Ys) varied from 19.50 (HSF-862) to 61.33 (HSF-844) $t.ha^{-1}$. Regarding Table 2, genotype "HSF-844" had the maximum values of several tolerance indices including MP, GMP, HM, YSI, SSI, STI, YI (Table 2) accompanied with high Yp (root yield under normal state) value (75.67 $t.ha^{-1}$) and therefore could be consider as drought tolerant genotype (Table 2).

Such root yield response to water stress was also reported by Fabiro et al. (2003), Mahmoodi et al. (2008), and Ober and Rajabi (2011). Generally, water deficit reduces plant growth as a result of first; inhibition of leaf growth and development due to the lower water availability and turgor pressure, and secondly; photosynthesis decrease due to the stomata closure (Smirnoff, 1995; Clover, 1997).

In this experiment, the maximum value of white sugar yield under normal condition (Yp) was belonged to genotype "F-205051" with value of 8.69 $t.ha^{-1}$ (Table 3) and the minimum value (2.02 $t.ha^{-1}$) was obtained for genotype "HSF-877". White sugar yield under stress condition (Ys) was varied from 1.67 (HSF-854) to 4.60 (HSF-883) $t.ha^{-1}$ (Table 3). In controversy, Last et al. (1983) stated that genotypes produced high root yield in both normal and water stress conditions, could resulted high white sugar yield regardless of water state, because of no reduction in sugar content.

Regarding root yield data and according to Fischer and Maurer index (SSI) (1978), the genotype "HSF-862" with high SSI value was found to be the most susceptible genotypes whereas genotype "HSF-844 "with low value were found to be tolerant to drought stress (Table 2).

The less numerical rate of SSI indicates less stress susceptibility and more drought stress tolerance of a genotype. Yadav and Bhatnagar (2001) suggested the use of SSI in combination with yield value under stressed condition for identifying drought tolerant/susceptible genotypes. As shown in Table 2, selection based on SSI index identified genotypes with relatively high Yp and Ys (for example: genotype "HSF-844") and this is not in agreement with Sio-Se Mardeh et al. (2006) and Clarke et al. (1992) reported that SSI index does not differentiate between potentially drought resistant genotypes.

Table 2. Average root yield of sugar beet genotypes under optimal and stress conditions, and calculated different drought tolerance indices

Genotype	Yp	Ys	TOL	MP	GMP	HM	YSI	SSI	STI	YI
HSF - 841	71.22	48.89	22.33	60.06	58.86	57.70	0.70	0.74	0.79	1.25
HSF - 842	65.22	37.89	27.33	51.56	49.43	47.42	0.59	1.01	0.56	0.97
HSF - 843	72.56	39.89	32.67	56.22	53.65	51.22	0.56	1.09	0.68	1.02
HSF - 844	75.67	61.33	14.33	68.50	68.07	67.64	0.80	0.48	1.07	1.56
HSF - 846	57.33	32.78	24.56	45.06	43.30	41.61	0.56	1.08	0.47	0.84
HSF - 847	74.00	35.56	38.44	54.78	49.83	45.82	0.52	1.18	0.59	0.91
HSF - 848	72.00	42.67	29.33	57.33	54.61	52.15	0.63	0.92	0.68	1.09
HSF - 849	64.78	33.89	30.89	49.33	46.45	43.79	0.55	1.11	0.51	0.86
HSF - 850	70.11	38.89	31.22	54.50	51.28	48.41	0.58	1.04	0.62	0.99
HSF - 851	61.22	40.00	21.22	50.61	49.45	48.32	0.67	0.81	0.60	1.02
HSF - 852	66.00	38.89	27.11	52.44	50.04	47.84	0.63	0.89	0.58	0.99
HSF - 854	66.22	25.00	41.22	45.61	39.70	34.90	0.40	1.46	0.37	0.64
HSF - 855	75.67	41.11	34.56	58.39	55.45	52.70	0.56	1.07	0.70	1.05
HSF - 856	73.67	42.89	30.78	58.28	55.91	53.68	0.59	1.00	0.72	1.09
HSF - 857	59.11	32.22	26.89	45.67	43.53	41.52	0.55	1.11	0.46	0.82
HSF - 859	83.67	53.17	30.50	68.42	66.61	64.86	0.63	0.91	1.08	1.35
HSF - 860	65.11	40.56	24.56	52.83	51.31	49.84	0.63	0.91	0.60	1.03
HSF - 861	84.67	46.33	38.33	65.50	61.92	58.62	0.56	1.08	0.91	1.18
HSF - 862	65.67	19.50	46.17	42.58	35.70	29.97	0.30	1.71	0.29	0.50
HSF - 864	52.89	38.33	14.56	45.61	44.99	44.38	0.73	0.66	0.46	0.98
HSF - 865	67.89	41.67	26.22	54.78	53.16	51.59	0.61	0.96	0.68	1.06
HSF - 866	69.44	45.67	23.78	57.56	56.11	54.72	0.66	0.83	0.72	1.16
HSF - 867	58.00	35.89	22.11	46.94	45.60	44.31	0.62	0.94	0.49	0.91
HSF - 868	67.89	42.78	25.11	55.33	53.04	50.98	0.63	0.90	0.67	1.09
HSF - 869	63.00	39.44	23.56	51.22	49.44	47.79	0.62	0.93	0.57	1.00
HSF - 870	52.00	27.33	24.67	39.67	37.63	35.71	0.53	1.16	0.33	0.70
HSF - 871	64.56	44.67	19.89	54.61	53.69	52.79	0.69	0.75	0.66	1.14
HSF - 872	69.00	37.22	31.78	53.11	50.18	47.50	0.58	1.02	0.60	0.95
HSF - 873	65.78	37.44	28.33	51.61	49.35	47.23	0.56	1.09	0.58	0.95
HSF - 875	65.78	34.00	31.78	49.89	47.01	44.35	0.51	1.21	0.53	0.87
HSF - 876	66.78	52.17	14.61	59.47	58.88	58.31	0.79	0.52	0.79	1.33
HSF - 877	39.00	26.33	12.67	32.67	31.91	31.19	0.67	0.82	0.24	0.67
HSF - 881	73.00	42.22	30.78	57.61	54.72	52.08	0.62	0.93	0.68	1.08
HSF - 882	69.89	35.22	34.67	52.56	49.15	46.04	0.52	1.18	0.56	0.90
HSF - 883	70.67	54.00	16.67	62.33	61.61	60.90	0.76	0.59	0.88	1.38
HSF - 884	82.33	38.56	43.78	60.44	56.16	52.22	0.47	1.31	0.73	0.98
HSF - 885	56.33	32.78	23.56	44.56	42.87	41.26	0.57	1.05	0.43	0.84
110	63.44	36.11	27.33	49.78	47.63	45.61	0.56	1.07	0.54	0.92
191	46.78	27.22	19.56	37.00	35.59	34.24	0.58	1.03	0.29	0.69
31265	61.89	33.89	28.00	47.89	45.27	42.92	0.55	1.09	0.47	0.86
32434-91	75.78	53.11	22.67	64.44	63.10	61.80	0.72	0.68	0.91	1.35
32926-92	55.33	35.22	20.11	45.28	44.01	42.80	0.64	0.89	0.45	0.90
F - 20505	71.44	45.22	26.22	58.33	56.69	55.10	0.64	0.89	0.75	1.15
$LSD_{5\%}$	19.74	16.55	22.19	14.47	14.77	15.65	0.23	0.59	0.36	0.43

Table 3. Average white sugar yield of sugar beet genotypes under optimal and stress conditions, and calculated different drought tolerance indices

	Yp	Ys	TOL	MP	GMP	HM	YSI	SSI	STI	YI
HSF - 841	5.33	4.31	1.02	4.82	4.75	4.69	0.85	0.46	0.99	1.35
HSF - 842	3.01	3.43	-0.43	3.22	3.07	2.92	1.34	-1.03	0.41	1.08
HSF - 843	4.45	4.44	0.01	4.45	4.44	4.42	1.00	0.01	0.90	1.39
HSF - 844	6.63	4.42	2.21	5.52	5.41	5.30	0.66	1.02	1.31	1.38
HSF - 846	3.40	3.74	-0.34	3.57	3.54	3.51	1.12	-0.36	0.60	1.17
HSF - 847	6.77	3.85	2.93	5.31	5.10	4.89	0.59	1.23	1.30	1.21
HSF - 848	5.15	3.59	1.57	4.37	4.23	4.10	0.74	0.78	0.78	1.12
HSF - 849	4.37	2.45	1.92	3.41	3.17	2.96	0.70	0.92	0.46	0.77
HSF - 850	4.15	2.69	1.46	3.42	3.33	3.25	0.64	1.08	0.51	0.84
HSF - 851	4.96	1.93	3.03	3.45	3.04	2.70	0.44	1.69	0.42	0.61
HSF - 852	4.64	3.48	1.16	4.06	3.80	3.58	0.91	0.26	0.63	1.09
HSF - 854	5.90	1.66	4.24	3.78	2.85	2.29	0.33	2.04	0.38	0.52
HSF - 855	4.11	3.83	0.28	3.97	3.73	3.52	1.26	-0.79	0.62	1.20
HSF - 856	4.34	3.65	0.70	4.00	3.93	3.87	0.89	0.34	0.68	1.14
HSF - 857	5.40	2.26	3.14	3.83	3.43	3.10	0.41	1.78	0.57	0.71
HSF - 859	4.63	3.75	0.88	4.19	4.13	4.07	0.79	0.63	0.81	1.18
HSF - 860	4.11	2.47	1.64	3.29	3.16	3.04	0.58	1.28	0.47	0.78
HSF - 861	5.74	4.08	1.66	4.91	4.79	4.68	0.68	0.96	1.10	1.28
HSF - 862	3.45	1.82	1.63	2.64	2.48	2.34	0.56	1.34	0.27	0.57
HSF - 864	3.15	3.84	-0.69	3.50	3.29	3.13	2.08	-3.28	0.51	1.20
HSF - 865	6.01	2.72	3.29	4.36	3.71	3.29	0.47	1.60	0.79	0.85
HSF - 866	5.10	3.05	2.05	4.08	3.81	3.57	0.75	0.76	0.64	0.96
HSF - 867	5.44	3.09	2.34	4.26	4.04	3.83	0.61	1.20	0.71	0.97
HSF - 868	5.22	3.26	1.96	4.24	3.86	3.55	0.79	0.64	0.66	1.02
HSF - 869	4.14	2.91	1.22	3.52	3.38	3.25	0.77	0.70	0.50	0.91
HSF - 870	3.77	3.10	0.67	3.43	3.34	3.26	0.85	0.46	0.50	0.97
HSF - 871	5.38	3.24	2.14	4.31	4.15	3.99	0.62	1.14	0.76	1.02
HSF - 872	4.80	2.62	2.18	3.71	3.55	3.39	0.55	1.37	0.55	0.82
HSF - 873	4.14	3.75	0.39	3.95	3.57	3.25	0.95	0.14	0.64	1.18
HSF - 875	6.91	2.39	4.52	4.65	4.01	3.48	0.37	1.90	0.70	0.75
HSF - 876	4.06	2.40	1.66	3.23	2.99	2.77	0.73	0.81	0.39	0.75
HSF - 877	2.02	2.58	-0.55	2.30	2.28	2.26	1.27	-0.83	0.24	0.81
HSF - 881	5.75	3.94	1.81	4.85	4.51	4.23	0.80	0.62	0.89	1.23
HSF - 882	4.70	2.67	2.03	3.68	3.52	3.37	0.59	1.24	0.55	0.84
HSF - 883	5.13	4.56	0.57	4.85	4.78	4.71	0.91	0.27	1.00	1.43
HSF - 884	5.47	3.00	2.47	4.23	3.93	3.66	0.72	0.86	0.72	0.94
HSF - 885	3.64	3.13	0.51	3.39	3.31	3.23	0.92	0.26	0.48	0.98
110	5.13	3.32	1.80	4.22	4.11	4.00	0.61	1.17	0.84	1.04
191	3.61	2.43	1.18	3.02	2.93	2.85	0.73	0.81	0.39	0.76
31265	4.46	3.69	0.77	4.07	4.04	4.01	0.82	0.56	0.74	1.16
32434-91	4.60	3.53	1.07	4.07	4.00	3.93	0.80	0.61	0.70	1.11
32926-92	4.11	3.64	0.46	3.87	3.83	3.78	0.89	0.33	0.66	1.14
F - 20505	8.69	2.48	6.21	5.59	4.64	3.86	0.29	2.16	0.98	0.78
$LSD_{5\%}$	2.73	1.94	3.38	1.66	1.59	1.607	0.82	2.51	0.56	0.60

Considering TOL index, a genotype would be more tolerant if it has less TOL value. Based on TOL, the genotype "HSF-877" with lowest values was considered as tolerant genotypes, whereas the genotype 'HSF-862" with the highest TOL value was considered as susceptible (Table 2). Fernandez (1992) manifested that, TOL index was efficient in improving yield under stressed condition and the selected genotypes performed poorly under non-stressed condition.

Yield stability index (YSI) also was calculated for a given genotypes using root yield under stressed and non-stressed conditions. The genotypes with high YSI is expected to have high yield under stressed and low yield under non-stressed conditions. The lowest and highest of YSI were observed for genotypes "HSF-862" and "HSF-844", respectively (Table 2). Fernandez (1992) proposed that, high yield and stress tolerant genotypes can be discriminated based on STI index. A high STI demonstrates a high tolerance and the best advantage of STI is its ability to separate group A genotypes from other genotypes. Based on the STI index, the genotype "HSF-844" had the highest value and considered as tolerant genotype with high yield stability in the both conditions (Table 2). In this study, the results of GMP, MP, HM and YI indices in selection of tolerant genotypes were similar to STI index (Table 2).

Regarding white sugar yield data, the genotype "F-20505" with high SSI value was found to be the most susceptible genotypes, whereas genotype "HSF-864" with low value was found to be tolerant to drought stress (Table 3). Based on TOL index, the genotypes "HSF-864" and "F-20505" with lowest and highest value was considered as tolerant and susceptible genotypes, respectively (Table 3). The lowest YSI was observed for genotype "F-20505" and the highest was observed for genotype "HSF-864" (Table 3). Paralleled with finding of YSI index, this is inferable from Table 3 that genotype "F-20505" have maximum value of white sugar yield in normal condition while it possessed minimum value under stress state.

According to STI, HM and GMP indices, the genotype "HSF-844" had the highest value and considered as tolerant genotype with high yield stability in the both conditions (Table 3). From YI index view, genotype "HSF-854" was identified as drought tolerant genotype, whereas it have not acceptable white sugar yield under stress condition. Sadeghian et al. (2000) believes that sugar beet genotypes can be categorized into four groups according to their performance in drought and favorable conditions: 1. Genotypes with high productivity in both conditions, 2. Genotypes with higher yield in non-stress environment, 3.genotypes with a relatively high yield in stress environment and 4.genotypes with a poor yield in both conditions. Genotypes with high productivity in both stress and non-stress conditions are useful for breeding purposes.

Correlation between root and white sugar yield with drought tolerance indices

Correlation coefficients were used to identify the best criterion for identification and screening of drought tolerant genotypes. According to literature (Farshadfar and Sutka, 2002; Darvishzadeh et al., 2010), a suitable index must to have a significant correlation with yield in both stressed and non-stressed conditions. Correlation coefficients between both root yield (Yp and Ys) with studied tolerance indices (Table 4) revealed that indices including MP, GMP, HM, YSI, STI and YI could effectively use in screening of drought tolerant sugar beet genotypes. TOL index was strongly associated with YSI and YI indices and hence they could make similar ranking of genotypes. In this study, STI, YSI, HM, and GMP indices had significant correlations with each other in most cases (Table 4).

About white sugar yield (Table 4), both Yp and Ys possessed significant correlations with studied indices exception of YI. This is similar to findings of average white sugar yield (Table 3) which manifested that genotype "HSF-854" has not acceptable white sugar yield under stress state despite of having highest YI index. Considering Table 4, in most cases there is not any significant relation among studied indices and so, they could produce variable ranking of drought tolerant genotypes. Similar to our findings, Hesadi et al. (2015) investigated the response of five promising sugar beet genotypes against drought stress using tolerance indices and reported strong correlation between GMP, STI, MP and HM indices with white sugar yield in both normal and stress conditions.

Table 4. Correlation between different drought tolerance indices and white sugar yield (above of diagonal) and root yield (below of diagonal) of sugar beet genotypes under optimal and stress conditions

	Yp	**Ys**	**TOL**	**MP**	**GMP**	**HM**	**YSI**	**SSI**	**STI**	**YI**
Yp	1.00	0.02	0.85**	0.85**	0.68**	0.52**	-0.65**	0.65**	0.69**	0.02
Ys	0.69**	1.00	-0.51**	0.54**	0.72**	0.81**	0.50**	-0.50**	0.69**	1.00**
TOL	0.47**	-0.28	1.00	0.45**	0.21	0.01	-0.82**	0.82**	0.23	-0.51**
MP	0.94**	0.89**	0.15	1.00	0.95**	0.86**	-0.29	0.29	0.94**	0.54**
GMP	0.89**	0.94**	0.02	0.99**	1.00	0.97**	-0.15	0.15	0.98**	0.72**
HM	0.82**	0.97**	-0.09	0.96**	0.99**	1.00	–0.04	0.04	0.95**	0.81**
YSI	0.30*	0.80**	-0.67**	0.58**	0.66**	0.72**	1.00	1.00**	-0.17	0.50**
SSI	0.17	-0.58**	0.84**	-0.16	-0.28	-0.39**	-0.70**	1.00	0.17	-0.50**
STI	0.75**	0.93**	-0.03	0.89**	0.92**	0.93**	0.54**	-0.445**	1.00	0.69**
YI	0.68**	1.00**	-0.28	0.89**	0.94**	0.97**	0.80**	-0.58**	0.93**	1.00

Multivariate analysis

To identify the relationship among Yp, Ys with their significant tolerance indices, three-dimensional graphs for each one were also employed. These graphs showed the ability of these indices to detect Fernandez (1992) groups (Figure 3). By using these indices and Yp and Ys variables, three dimensional diagrams could partition the genotypes in four groups: (1) Genotypes producing high yield under both water stress and non-stress environments (group A), (2) genotypes with high yield under either non-stress (group B) or (3) stress (group C) environments and (4) genotypes with poor performance under both stress and non-stress environments (group D).

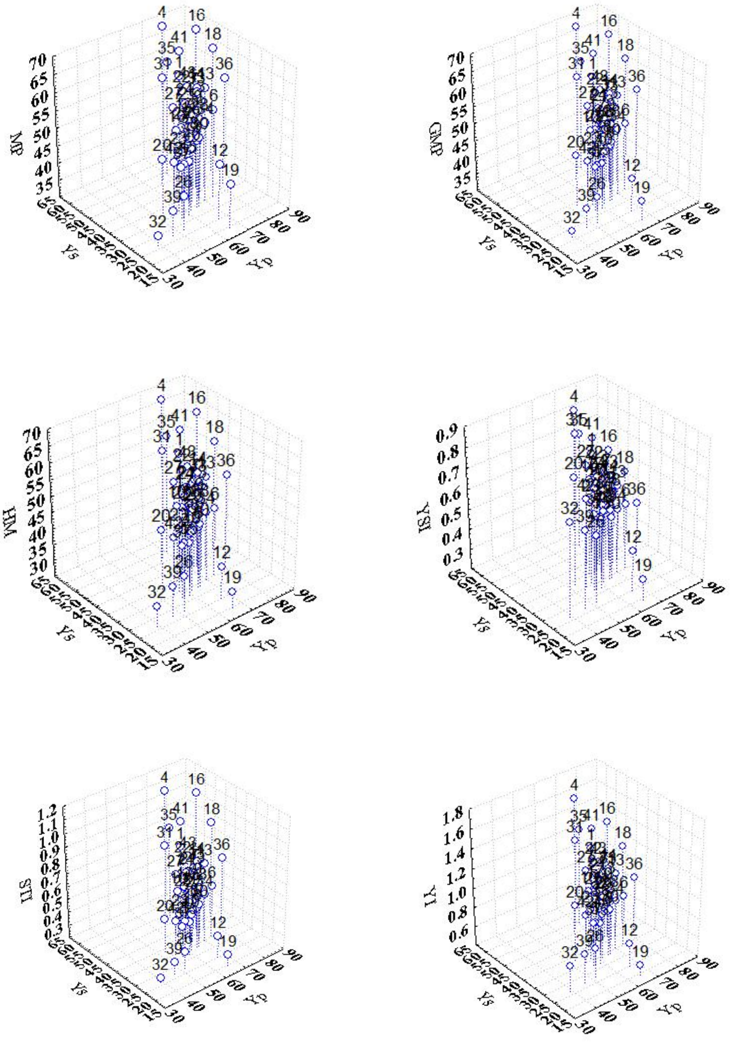

Figure 1. Tree dimension scheme of potential root yield (YP), stress root yield (YS) and geometric mean productivity (GMP), harmonic mean (HM), mean productivity (MP), stress tolerance index (STI) for sugar beet genotypes. Genotype codes: see Table 2.

Accordingly, data from root yield (Figure 1) revealed that genotypes such as G04 "HSF-844", G16 "HSF-859", G18 "HSF-861", G35 "HSF-883" and G41"32434-91" are promising sugar beet genotypes (Group A) which have suitable root yield in both conditions. Also, among studied genotypes, G26 "HSF-870", G32 "HSF-877", and G39 "191" having low root yield in both conditions (group C). Three dimensional plots of white sugar yield data showed that the response of white sugar yield against drought stress is varied from the response of root yield (Figure 2).

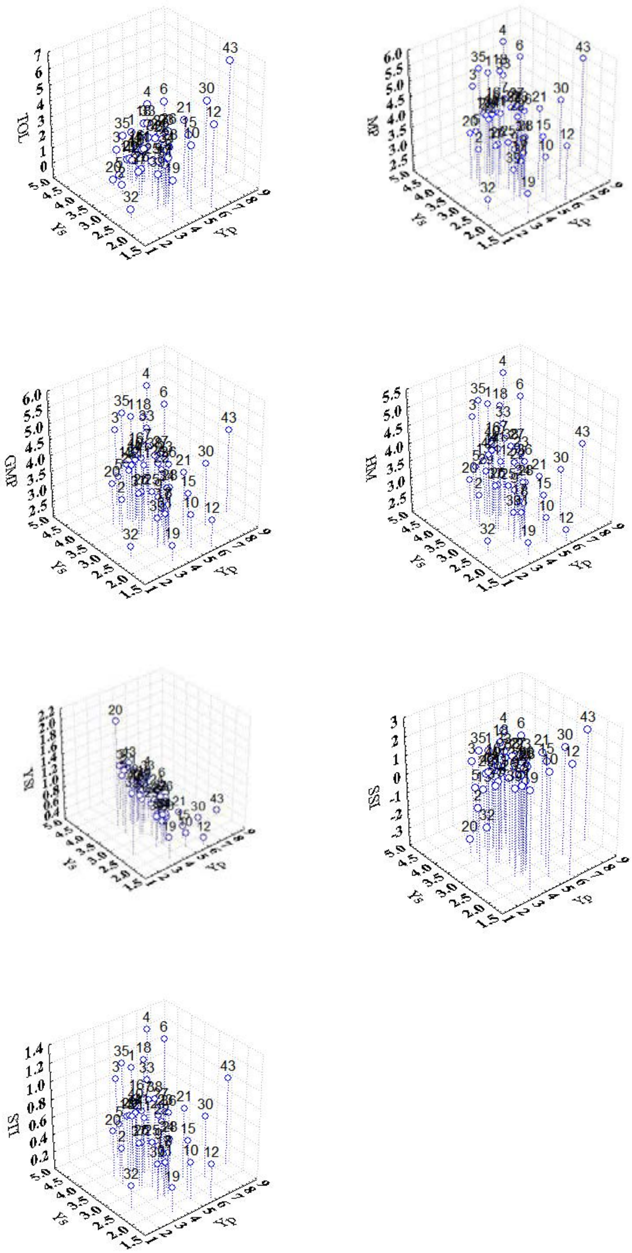

Figure 2. Tree dimension scheme of potential white sugar yield (YP), stress white sugar yield (YS) and geometric mean productivity (GMP), harmonic mean (HM), mean productivity (MP), stress tolerance index (STI) for sugar beet genotypes. Genotype codes: see Table 2.

Considering Figure 2, genotypes such as G01 "HSF-841", G04 "HSF-844", G06 "HSF-847", G18 "HSF-861" could be calculated as group A genotypes whereas G19 "HSF-862", G32 "HSF-877", G39 "" with low white sugar yield under both states divided into group C. Albeit, genotypes G12 "HSF-854", G15 "HSF-857", G21 "HSF-865", G30 "HSF-875" and G43 "F-20505" possessed high level of white sugar yield in normal state but they have not any suitable white sugar yield under stress condition.

The cluster analysis was done using UPGMA algorithm to classification and study the variation between sugar beet genotypes based on drought tolerance indices calculated using root and white sugar yield. Classification based on drought tolerance indices calculated via root yield in both conditions (Figure 3), grouped the studied genotypes into three main groups which involved 15 (group I), 17 (group II) and 11 (group III) genotypes, respectively, which each group could divided into several subgroups.

In this study, group I was comprised genotypes that had high root yield in both conditions (group A of Fernandez's classification) (Figure 1 and Figure 3).

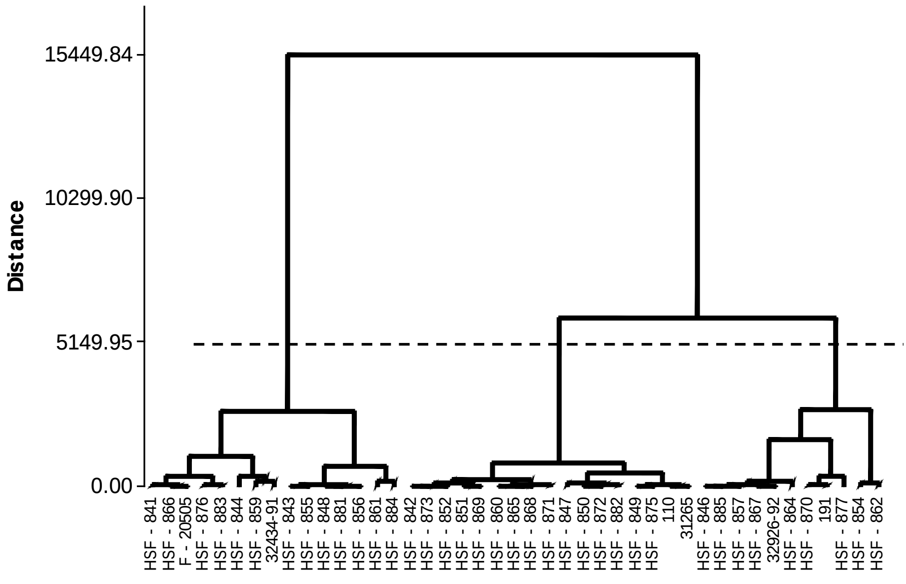

Figure 3. Cluster analysis of sugar beet genotypes based on drought tolerance indices and root yield in both normal and stress conditions.

Regarding tolerance indices calculated by means of white sugar yield in both conditions, the studied sugar beet genotypes located in five main groups involved 7 (group I), 14 (group II), 3 (group III), 5 (group IV) and 14 (group V) genotypes (Figure 4). Similar to finding of root yield based classification (Figure 3), group A of Fernandez's classification also fined by classification via white sugar yield. Here, in consistent with findings of Darvishzadeh et al. (2010), the genotypes classification based on cluster analysis was paralleled with output of three dimensional plots. Therefore, by using genotypes that are located in separate groups and have maximum genetic distance, it is possible to analyze genetic basis of these drought tolerance indices in sugar beet.

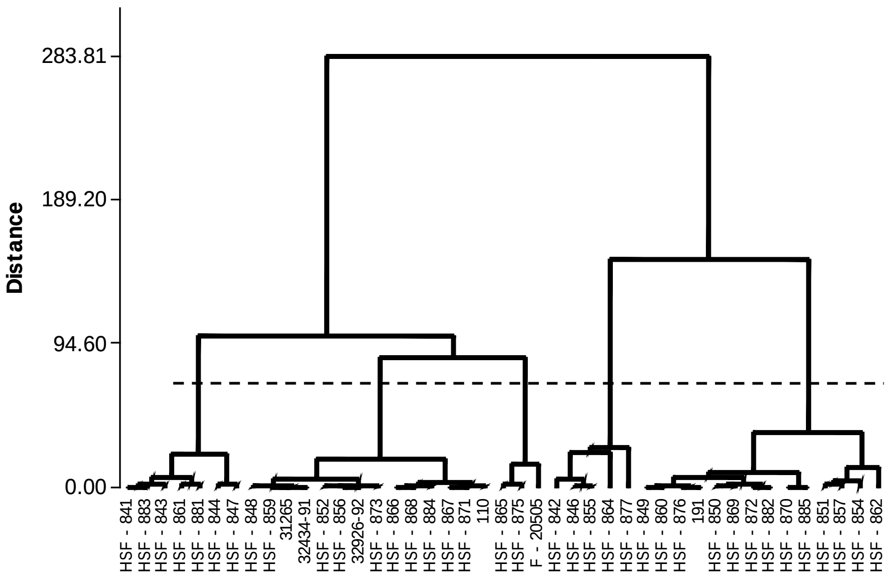

Figure 4. Cluster analysis of sugar beet genotypes based on drought tolerance indices and white sugar yield in both normal and stress conditions.

CONCLUSIONS

To sum up, in studied sugar beet germplasm, genotypes "HSF-861" and "HSF-844" having maximum root yield in non-stress and stress conditions, respectively. Here, the maximum values of white sugar yield in non-stress and stress conditions was belonged to genotype "F-205051" as well as "HSF-883". So, it is resulted that genotypes produced high root yield in both normal and stress conditions, could not resulted high white sugar yield regardless of water condition. Also, in this studied germplasm, genotype "HSF-877" had the minimum value of root and white sugar yield in normal condition. Regarding GMP, MP, HM, YI and STI indices, genotype "HSF-844" was introduced as tolerant genotype which produced acceptable root yield in both conditions. Based on white sugar yield trait, STI, HM and GMP indices also proposed "HSF-844" as tolerant genotype. It is concluded that indices are including STI, MP, GMP, HM and YSI owing significant correlation with Yp and Ys and hence, proposed for selection of a sugar beet genotype with stable and high root and white sugar yield in stressed and non-stressed conditions. From three dimensional view, genotypes such as "HSF-844", "HSF-859", "HSF-861", "HSF-883" and "32434-91" are promising sugar beet genotypes (Group A) which have suitable root yield in both states. Whereas, genotypes such as "HSF-841", "HSF-844", "HSF-847", "HSF-861" could be calculated as group A which have suitable white sugar yield in both states. Based on studied tolerance indices, the studied sugar beet germplasm classified into differentiate groups and these identified distant groups could effectively used in sugar beet breeding programs like selection of parents for confirmation of mapping population as well as in hybrid breeding programs.

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