Yield Stability Parameters of Sugar Beet (*Beta vulgaris L.*) Cultivars in Iran

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Abstract

The present study focused on estimating yield stability of sugar beet cultivars in Iran. The data were collected from pilot studies on imported and domestic cultivars. Twenty-one cultivars of sugar beet were compared in 12 main spring growing regions of Iran in 2014, in randomized complete block design, with three replications. The effect of location and cultivar was significant (P≤0.05) on root yield. Among the cultivars, Pauletta and Fernando had the highest root yield (75.8-80.5 t/ha), followed by SBSI034 and BTS 335 (70 t/ha), whereas Canaria, Rasta, Torbat, Novodoro, Tucan, Morly, Aria, Pars, Antec, Nagano, Rosier, Iris, Flores, Boomrang, Sanetha, and Ekbatan had the lowest root yield (56.267.2- t/ha). The significance of location × cultivar interaction (P≤0.05) showed that cultivars did not have uniform performance at different locations. Estimation of different stability parameters revealed that Fernando, Pauletta, SBSI-034 and BTS-335 had high root yield and stability, while Boomrang, Iris, Isabella, Morly, Novodoro, Rasta, and Rosier were found to be cultivars with low yield and stability. Pars, Torbat, Iris, Flores, Morly, Ekbatan, BTS-335, Canaria, Antec, and Rosier displayed moderate stability. The estimation of the reliability of root yield for different cultivars at different levels of agriculture development indicated that Pauletta, Fernando, SBSI-034, TBS-335 and Aria had higher reliability than the other cultivars under both modern and subsistence farming conditions.

Keywords: Location × cultivar interaction, Sugar beet, Stability, Root yield.

Introduction:

Sugar beet is an important sugar crop in Iran, which provides about 50% of the national sugar production. It is mainly grown as a temperate crop in spring season with an approximate area of 110, 000 ha and average yield of 54 t/ha, although about 10,000 ha of the crop is grown in autumn season in southern Iran (Anonymous, 2017). Sugar yield of sugar beet, as its final product, is affected by various factors including year and location. Accordingly, the soil and climatic condition variation in different regions of a country necessitates the evaluation of cultivar performance in different regions and years, which contributes to the selection of stable cultivars (Hozayn *et al*., 2014)

The breeders' priority is to select high yielding genotypes with stable performance but it is constrained by genotype × environment (G×E) interaction (Zhang *et al*., 2017). In breeding programs, cultivars must be evaluated in a wide range of environmental conditions (location/year) to reliably recommend their planting (Fasahat *et al*., 2015). In cultivar development studies, a cultivar is said to be stable if it produces almost same yield in various environments, and a cultivar is said to be adapted if it has high yield in various environments. The breeding goal for extensive adaptability is to obtain cultivars with optimum performance in most environments, but in specific adaptability, the goal is to obtain cultivars with optimum performance in certain environments.

In some literature, breeding for wide adaptation is assumed identical to breeding for high yield stability and reliability. Stability of a genotype is possible to estimate when appropriate methods are used to estimate GE interaction for them (Fasahat *et al*., 2015). Analysis of variance for a specific environment merely shows the difference of genotypes in that specific environment and cannot estimate GE interaction. Combined analysis of variance merely shows the presence or absence of GE interaction and provides partial information about the stability of cultivars in various environments. In case there is GE interaction, cultivar(s) selection based on only yield in one environment would not be a suitable criterion, and cultivars need to be evaluated in a wide range of environmental variations in different locations and years. Then, estimation of adaptability and yield stability of genotypes would be more reliable criterion for cultivar recommendation and its planting expansion. Analysis of variance, regression analysis, non-parametric methods and multi-variant techniques are among mostly used methods for GE interaction study. Different stability methods were applied for sugar beet (Fasahat *et al*., 2015). Parvizi and Sadeghian (1996) found that the multigerm cultivar PP22 was a stable cultivar with tolerance to environmental variations because of its relatively high root, sugar and white sugar yield, regression coefficient of >1, and relatively low regression deviation and ecovalence. Campbell and Kern (1982) used combined analysis of variance for the analysis of the variance of quantitative and qualitative traits of sugar beet and found that cultivar × location, cultivar × year, and cultivar × year × location interactions were rather low for sugar, Na and K contents. They concluded that year had relatively higher effect on sugar percentage, Na, K, and α-amino N. In order to reduce the trial costs of cultivars comparison in different years and locations, they suggested that a three-year trial in seven locations would suffice for such traits. Ggyllenspetz (1998) found that high-yielding cultivars of sugar beet are much more unstable than moderate-yielding ones, and introduced the deviation from regression line index as a good indicator of sugar beet stability.

New varieties are instigated to undergo official registration trials before they can be marketed in Iran. For sugar beet varieties, statutory registration is followed by multi-location trials to identify the best varieties to be promoted onto a recommended list. Therefore, the objectives of the present study were to (1) examine the effect of cultivar, location and cultivar×location interactions on root yield of 21 sugar beet cultivars, (2) estimate their stability parameters, and (3) determine cultivars with high reliability and yield.

Materials and Methods:

Plant materials and cultivation site:

Twenty-one monogerm (exotic and domestic) sugar beet cultivars were evaluated in terms of root yield in 12 main sugar beet growing regions in Iran in 2014. The growing regions included Bisotun, Eqlid, Isfahan, Fariman, Qazvin, Khoy, Lorestan, Marvdasht, Naqadeh, Nishabur, Shahrud and

TorbatJam. Cultivars included 16 exotic cultivars (Antec, Boomrang, BTS 335, Canaria, Fernando, Flores, Iris, Isabella, Morly, Nagano, Novodoro, Pauletta, Rasta, Rosier, Sanetha, and Tucan) and five domestic cultivars (Ekbatan, Pars, Aria, SBSI-034 and Torbat). The geographical position of the locations is shown in Table (1).

Agricultural practices:

The trial fields were prepared according to the conventional practices of the locations. These included autumn deep plow (40 cm) and P fertilization at a rate of 250 kg/ha according to fertilizer recommendation given by experts. Surface plow (25 cm), disking and leveling were carried out in spring. Then, the field was fertilized by 150 kg/ha urea according to the fertilizer recommendation, followed by making furrows with an inter-row spacing of 50 cm. Seeds were sown by a self-propelled planter in April on the basis of a randomized complete block design with three replications. Then, they were immediately irrigated. The plants in all locations were thinned at 4- 6-leaf stage adjusting the on-row spacing at 15- 20 cm. Afterward, the fields were irrigated at 12- 15 days intervals. The pests and diseases were controlled according to the experts' recommendations at each location. Agricultural practices are shown in Table (1). To determine the root yield, the trials were harvested in October according to the pre-defined instructions. Then, the roots were washed and weighed.

Statistical analysis and stability parameters:

When data were gathered, a simple analysis of variance was conducted for each location, Then, uniformity of variances was checked by Bartlett's test, followed by combined analysis of variance using SAS Software Package. F test was carried out by expected value of mean of squares assuming that the effects of genotype and location were constant and random, respectively. Means of root yield were compared at 5% probability level by least significant difference test. In order to analyze cultivars stability, the parameters of environmental variance (S^2_i), coefficient of environmental variation (CV_i), Finlay and Wilkinson's linear regression coefficient (b_i), mean of squares of deviation from regression line (S^2d_i), Wricke's ecovalence (W^2_i), Shukla's stability variance (σ^2_i) and linear coefficient of determination (R^2) were estimated (Fasahat *et al*., 2015).

Reliability index (I) proposed by Kataoka (1963) was used to determine the reliable yield of cultivars. This index is used for estimating, on the basis of the distribution of yield values observed across tested environments, the lowest yield expected for a given genotype (Eskridge, 1990). It was calculated on the basis of the following equation:

$$\mathbf{I = m_i - Z\,(P)\,S_i}$$

where m_i = mean yield, S_i = square root of the environmental variance (S^2_i) and Z(P) = percentile from the standard normal distribution for which the cumulative distribution function reaches the value P. The Z(P) can assume the following values depending on the chosen P level: 0.675 for P = 0.75; 0.840 for P = 0.80; 1.040 for P = 0.85; 1.280 for P = 0.90; and 1.645 for P = 0.95. P values may vary between 0.95 (for subsistence agriculture in unfavorable cropping regions) to 0.70 for modern agriculture in most favorable regions (Annicchiarico, 2002). Assuming that the technological level of agriculture and field conditions in the 12 regions in this study falls between subsistence agriculture and modern agriculture, we took (P) = 0.75, which corresponds to a Z(P) = 0.675and (P)=0.95, which corresponds to a Z(P) = 1.645, for modern and subsistence agriculture systems, respectively.

Results and Discussion:

Analysis of variance and means comparison:

Location and cultivar had significant ($p \leq 0.05$) effect on root yield (Table 2), which indicates differences in genetic potential of the cultivars and variation in productivity potential of the locations. Similar results were found by others (Chloupek *et al*., 2004; Ebrahimian *et al*., 2008; Moradi *et al*., 2012; Ghareeb *et al*., 2014; Al Jbawi *et al*., 2017). In a related study, Hoffmann *et al*., (2009) evaluated the root quality of nine sugar beet varieties at 52 sites across Europe. They observed that about 80% of the variation was attributed to the environment, while less than 10% was exerted by the variety differences. Similar trend was also reported by Akter *et al*., (2015). Among the locations, the highest (102.6 t/ha) and the lowest (18.4 t/ha) root yield were obtained in Isfahan and Torbat Jam, respectively (Table 3). Among the cultivars, the highest root yield (75.880.5- t/ha) was belonged to Pauletta and Fernando followed by SBSI-034 and BTS-335 (70 t/ha), whereas the lowest root yield (56.267.2- t/ha) was recorded for Canaria, Rasta, Torbat, Novodoro, Tucan, Morly, Aria, Pars, Antec, Nagano, Rosier, Iris, Flores, Boomrang, Sanetha and Ekbatan. The results of the present study are slightly lower than those of Hoffmann *et al*., (2009) who reported the root yield variation ranged from 60 to110 t/ha. El-Kammash *et al*., (2014) evaluated 14 exotic sugar beet cultivars performance under two growing seasons in Egypt and reported root yield of monogerm cultivars exceeded that of multigerm cultivars in both growing seasons.

Nonetheless, the significance of location × cultivar interaction (Table 2), as reported also by other researchers (Moradi *et al*., 2012; Hozayn *et al*., 2014; Hoberg *et al*., 2015; Al Jbawi *et al*., 2017) showed that the locations and cultivars selected for the study were highly diverse in one hand, and the studied cultivars did not have uniform performance in different locations on the other hand. In other words, no cultivar can be strongly recommended for all locations by only resorting to the combined analysis of variance (Al Jbawi *et al*., 2017). Comparison of root yields of Canaria, Fernando, Nagano, Rasta and SBSI-034 in three regions with high, moderate and low yield potential (Esfahan, Eqlid and TorbatJam, respectively) (Table 3) can help better analysis of the results. Though being superior cultivars in high yield potential region (Esfahan), Canaria and Nagano produced lower root yield than superior cultivars in regions with moderate and low yield potential ($P \leq 0.05$). Fernando, which was one of the superior cultivars in low-efficient region, produced significantly lower yield than the regional superior cultivar in high-potential region. Conversely, Rasta, which was one of the superior cultivars in Esfahan and Eqlid, produced significantly lower yield than the superior cultivar in TorbatJam. Finally, SBSI-034, which was the superior cultivar in Eqlid, lost its relative competitive advantage in regions with higher or lower production potential (Table 3).

Stability parameters:

Fernando, Pauletta, SBSI-034 and BTS-335 were cultivars that produced high root yield and displayed low S^2_i (Table 4; Fig. 1a), indicating that yield stability and high yield are not mutually exclusive (Zhang *et al*., 2017).

The CVi of the cultivars revealed the superiority of Fernando, Pauletta, SBSI-034 and BTS-335 (Table 4; Fig. 1b). This parameter put most cultivars in low yield, less stable zone (Zone II). Accordingly, Tucan, Torbat, Pars, Sanetha, Canaria, Morly, Iris, Antec, Novodoro, Flores, Rosier, Rasta, Ekbatan, Nagano, Boomrang and Isabella were the cultivars that had low yield stability and low root yield (Fig. 1b). According to W^2_i and σ^2_i indices, the cultivars Fernando, Pauletta, SBSI-034 and BTS-335 were found to be the cultivars with high yield and stability, whereas Boomrang, Iris, Isabella, Morly, Novodoro, Rasta, and Rosier were cultivars with low yield and stability (Table 4; Fig. 2). The comparison of these two indices revealed that σ^2_i was stricter than W^2_i. In other words, while W^2_i categorized Antec and Flores as stable (Fig. 2), σ^2_i found them to be unstable. Other cultivars (Canaria, Nagano, Sanetha, Tucan, Ekbatan, Pars, Aria and Torbat) were categorized as low-yielding, still stable, cultivars (Fig. 2). On the basis of b_i, Pars, Torbat, Iris, Flores, Morly, Ekbatan, BTS-335, Canaria, Antec and Rosier with b_i of 0.9421.086- were cultivars with moderate stability, which can be recommended for a wide ecological range (Table 4), whereas Isabella, Rasta, Nagano, Novodoro and Boomrang with b_i of 1.118- 1.308 were found to be cultivars whose b_i were significantly higher than 1 and were adapted to high-yielding environments. In other words, the latter cultivars are usually unstable whose yield increased with the improvement of environment and are usually recommended for fertile regions (Perkins and Jinks 1968; Lin *et al*., 1986). Nenadic *et al*., (1996) examined the stability of root yield and technological quality of 30 sugar beet cultivars and found a positive correlation between CV_i and b_i. Al Jbawi *et al*. (2017) studied the stability parameters for 14 sugar beet varieties in Syria and recommended three stable varieties.

Based on S^2d_i and R^2, Fernando, SBSI-034, Aria, Tucan, Pauletta and Sanetha were found to be stable cultivars as they had the lowest S^2d_i and R^2 (Table 4). Eberhart and Russell (1966) used S^2d_i as well as Finlay and Wilkinson's (1963) regression line slope (b_i) and mean yield ($\bar{Y}$) of cultivars to select stable cultivars. Pinthus (1973) proposed that R^2 is better to be used instead of S^2d_i because the former is highly dependent upon the latter. Zhang *et al*., (2017) used Finlay and Wilkinson's regression and factor analysis to identify high-yielding, stable genotypes of canola. Al Jbawi *et al*., (2016) studied G×E in 16 sugar beet cultivars over three years in Syria and recommended 8 genotypes as stable ones on the basis of yield stability index (YSi).

Cultivar reliability index:

Pauletta, Fernando, SBSI-034, BTS-335 and Aria cultivars had more reliable yields than the other cultivars under both conditions (Table 5), consistent with Zhang *et al*., (2017), while other cultivars exhibited variations in their ranking and minimum expected yield with the changes in farmers' economic conditions. A good example is the ranking of Isabella under modern and subsistence farming conditions (9 and 19, respectively), according to which the reliability of its root yield decreased at lower development level. In contrast, Sanetha whose minimum yield of 38.41 t/ha was ranked 17th under modern conditions was promoted to the rank 11th under subsistence conditions producing minimum expected yield of 12.17 t/ha (Table 5). The modern crop production requires not only high-yielding cultivars but also genotypes capable of a maximal utilization of environmental resources and genotypes resistant to stress conditions (Nenadict et al., 1996). Karimizadeh *et al*., (2012) used yield reliability index to identify the most reliable durum wheat genotypes. Also, the spring wheat genotypes were ranked on the basis of yield reliability index (Hugo Ferney *et al*., 2006).

In total, the cultivars Pauletta, Fernando, SBSI-034, TBS-335 and Aria that were able to maintain their yield under both development levels were recognized as reliable cultivars, and those whose yields were increased or decreased with the changes in agriculture system from modern to subsistence were recognized as low-demanding or high-demanding, still unreliable, cultivars, respectively.

Conclusion

The analysis of yield and yield stability in this study revealed considerable genetic variation for yield and strong G×E interaction in sugar beet. Therefore, selection for specific adaptation to low and high yielding environments remains a useful approach. However, despite strong G×E interaction in sugar beet, some cultivars such as Fernando, Pauletta, SBSI-034 and BTS-335 were broadly adapted, consistently producing high yields across all locations. Therefore, breeding for broadly-adapted high yielding sugar beet is possible. This simplifies both breeding and farmer decision making.

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Table 1. Trial sites, agricultural practices, and sowing and harvesting dates of sugar beet, Iran 2014

	Nishabur	TorbatJam	Fariman	Shirvan	Shahrud	Naqadeh	Khoy	Bisotun	Eqlid	Marvdasht	Isfahan	Qazvin
Longitude	58°	60°	59°	57°	54°	45°	44°	47°	52°	52°	51°	50°
Latitude	36°	35°	35°	37°	36°	36°	38°	34°	30°	29°	32°	36°
Altitude (m)	1250	928	1393	1097	1380	1299	1149	1200	2300	1620	1590	1278
Land preparation	Autumn, 2013											
Fertilizer application	Autumn, 2013											
Sowing date	08.05.2014	05.05.2014	05.05.2014	18.05.2014	12.04.2014	13.04.2014	06.04.2014	28.03.2014	05.05.2014	12.04.2014	17.04.2014	16.04.2014
First irrigation	31.05.2014	07.05.2014	08.05.2014	01.06.2014	14.04.2014	20.04.2014	14.04.2014	30.03.2014	10.05.2014	15.04.2014	25.04.2014	23.04.2014
Thinning	03.07.2014	10.06.2014	10.06.2014	06.07.2014	11.05.2014	20.05.2014	17.05.2014	02.05.2014	11.06.2014	15.05.2014	28.05.2014	18.05.2014
Crust removing	05.07.2014	13.06.2014	17.06.2014	13.07.2014	24.05.2014	23.05.2014	18.05.2014	05.05.2014	12.06.2014	17.05.2014	30.05.2014	20.05.2014
Top dressing	05.07.2014	12.06.2014	15.06.2014	11.07.2014	22.05.2014	22.05.2014	18.05.2014	04.05.2014	12.06.2014	17.05.2014	29.05.2014	20.05.2014
Herbicide application	15.06.2014	29.05.2014	02.06.2014	19.06.2014	08.05.2014	10.05.2014	06.05.2014	19.04.2014	31.05.2014	02.05.2014	18.05.2014	04.05.2014
Insecticide application	22.06.2014	31.05.2014	28.05.2014	26.06.2014	10.05.2014	10.05.2014	28.04.2014	22.04.2014	31.05.2014	25.04.2014	18.05.2014	06.05.2014
Last irrigation	23.10.2014	23.10.2014	23.10.2014	27.10.2014	29.10.2014	21.09.2014	27.09.2014	19.10.2014	22.10.2014	27.10.2014	26.09.2014	02.10.2014
Harvest	11.11.2014	18.11.2014	23.11.2014	14.12.2014	18.11.2014	11.10.2014	11.11.2014	30.10.2014	06.11.2014	16.11.2014	16.10.2014	29.10.2014

Table 2. Combined analysis of variance for root yield of 21 sugar beet monogerm cultivars in 12 regions in 2014

S.O.V.	df	Mean of squares	P-value
Location	11	54345.12**	<0.0001
Replication withinLocation	24	237.97	
Cultivar	20	1464.84**	<0.0001
Location×Cultivar	220	401.41**	<0.0001
Error	480	105.83	
CV (%)	16.0		

**: significant at 1% probability level.

Table 3. Means comparison for root yield of 21 sugar beet monogerm cultivars in 12 regions in 2014

Cultivar	Source	Location												Mean
		Biston	Eqlid	Esfahan	Fariman	Ghazvine	Khoy	Lorestan	Marvdasht	Naghadeh	Neishabour	Shahrood	TorbatJam	
Antec	Germany	85.8**	68.8**	105.8**	29.3**	32.7**	20.6**	58.7**	84.7**	110.1^{ns}	42.5**	78.3**	13.7**	60.9 *cd*
Boomrang	Belgium	84.2**	57.6**	98.5**	22.5**	37.4**	27.8**	63.1*	96.1*	93.5**	15.3**	78.3**	7.8**	56.8 *d*
BTS 335	Germany	104.2^{ns}	68.7**	107.6**	40.3**	53.0^{ns}	63.1**	66.0*	97.6*	93.0**	36.0**	91.2*	19.6**	70.0 *bc*
Canaria	Denmark	102.1*	68.9**	113.1^{ns}	41.5**	35.2**	52.3**	49.0**	95.4*	95.4*	42.3**	102.2^{ns}	9.4**	67.2 *bcd*
Fernando	Germany	95.8*	75.9*	97.7**	67.4^{ns}	38.1**	80.0	71.8^{ns}	97.8*	103.2^{ns}	45.3*	85.2**	51.9^{ns}	75.8 *ab*
Flores	Denmark	98.8*	58.1**	84.6**	36.8**	41.0**	19.5**	60.2*	94.8*	83.5**	17.1**	87.2**	10.2**	57.6 *d*
Iris	Holland	62.9**	60.2**	98.7**	35.7**	37.2**	24.4**	72.5^{ns}	89.0**	96.8*	31.0**	78.1**	10.1**	58.1 *d*
Isabella	Germany	121.7	71.0**	109.1*	43.1**	40.8**	21.1**	59.7*	111.0^{ns}	100.9^{ns}	13.8**	118.0	22.7**	69.4 *bc*
Morly	France	92.1**	66.5**	99.24**	43.5**	34.2**	26.1**	93.8	92.8*	101.5^{ns}	33.1**	69.5**	11.7**	63.7 *cd*
Nagano	Belgium	92.5**	53.7**	123.2^{ns}	29.7**	35.3**	17.8**	70.4^{ns}	99.1^{ns}	84.9**	33.6**	73.2**	11.7**	60.4 *cd*
Novodoro	Sweden	96. 7*	71.6**	106.3**	36.5**	54.0	16.5**	71.8^{ns}	100.6^{ns}	100.7^{ns}	26.8**	78.2**	10.2**	64.2 *cd*
Pauletta	Germany	109.2^{ns}	79.1^{ns}	127.3	71.7	41.7**	76.6^{ns}	68.7*	111.6	103.6^{ns}	43.3*	77.0**	56.1	80.5 *a*
Rasta	Sweden	105.8^{ns}	79.4^{ns}	119.2^{ns}	43.8**	45.8**	22.2**	52.7**	105.6^{ns}	113.6	26.6**	72.3**	15.5**	66.9 *bcd*
Rosier	France	76.3**	64.2**	104.3**	24.1**	36.6**	14.6**	73.3^{ns}	103.1^{ns}	100.4^{ns}	34.8**	75.8**	17.8**	60.4 *cd*
Sanetha	Sweden	88.3**	58.6**	109.3*	47.7**	41.3**	34.9**	52.3**	70.8**	94.4*	25.8**	30.9**	25.7**	56.7 *d*
Tucan	France	115.4^{ns}	66.0**	82.32**	62.5^{ns}	24.9**	56.4**	52.8**	95.3*	93.0**	50.3^{ns}	47.0**	20.3**	63.9 *cd*
Ekbatan	Iran	102.9^{ns}	59.1**	102.0**	35.3**	37.8**	25.2**	41.1**	82.3**	83.7**	26.5**	71.7**	6.9**	56.2 *d*
Pars	Iran	88.3**	76.4*	101.0**	38.8**	37.6**	40.0**	56.5**	96.2*	97.2*	37.7**	73.8**	6.5**	62.5 *cd*
Aria	Iran	96.7*	70.0**	86.4**	55.6**	34.6**	47.8**	61.2*	93.4*	98.2*	31.1**	53.4**	35.6**	63.7 *cd*
SBSI 034	Iran	94.2*	87.2	78.3**	59.0*	46.0**	65.5**	69.0*	96.3*	111.3^{ns}	51.3	69.4**	17.1**	70.4 *bc*
Torbat	Iran	92.5**	73.5*	100.8**	44.4*	40.8**	51.3**	67.3*	92.5*	96.0*	35.0**	71.6**	7.0**	64.4
LSD 0.05		*19.22*	*10.29*	*12.69*	*10.74*	*5.29*	*8.14*	*23.74*	*13.36*	*13.46*	*5.67*	*21.12*	*12.40*	*7.80*
LSD 0.01		*27.66*	*14.81*	*18.26*	*15.46*	*7.61*	*11.71*	*34.16*	*19.23*	*19.37*	*8.15*	*30.39*	*17.84*	*11.07*
Mean		*95.5 b*	*68.3 d*	*102.6 a*	*43.3 e*	*39.3 e*	*38.3 ef*	*63.4 d*	*95.5 b*	*97.8 ab*	*33.3 f*	*75.3 c*	*18.4 g*	*64.3*

In each column, the highest (underlined) value was considered as control and all the remaining cultivars were compared by LSD test at 5%(*) and 1% (**) probability levels.

Mean root yields of cultivars and locations were compared by Duncan test at 5% probability level.

Therefore, means with at least one common letter did not show significant difference.

Table 4. Stability indices for 21 sugar beet monogerm cultivars in 12 regions in 2014

Rank	*Root yield*		S^2_i		CV_i		w_i^2		σ_i^2		*b*		S^2d		R^2	
	Cultivar	Index	Cultivar	Index	Cultivar	Index	Cultivar	Index	Cultivar	Index	Cultivar	Index	Cultivar	Index	Cultivar	Index
1	Pauletta	80.5	Fernando	436	Fernando	27.55	Sanetha	6714	Sanetha	621	Pars	1.023 ^{ns}	Fernando	0.429	Tucan	0.708
2	Fernando	75.8	Aria	570	Pauletta	32.57	Pauletta	7530	Pauletta	702	Torbat	0.969 ^{ns}	SBSI 034	0.588	Sanetha	0.762
3	SBSI 034	70.4	SBSI 034	600	SBSI 034	34.83	Aria	8267	Aria	776	Iris	0.957 ^{ns}	Aria	0.623	SBSI 034	0.778
4	BTS 335	70.0	Pauletta	687	Aria	37.53	Ekbatan	8411	Ekbatan	790	Flores	1.045 ^{ns}	Tucan	0.662	Fernando	0.780
5	Isabella	69.4	Sanetha	732	BTS 335	39.66	Fernando	8672	Fernando	816	Morly	1.045 ^{ns}	Pauletta	0.695	Pauletta	0.804
6	Canaria	67.2	Tucan	742	Tucan	42.67	Tucan	8955	Tucan	845	Ekbatan	1.056 ^{ns}	Sanetha	0.703	Aria	0.867
7	Rasta	66.9	BTS 335	771	Torbat	43.32	BTS 335	9280	BTS 335	877	BTS 335	0.942 ^{ns}	BTS 335	0.887	Isabella	0.876
8	Torbat	64.4	Torbat	778	Pars	46.83	Torbat	9490	Torbat	898	Canaria	1.077 ^{ns}	Iris	0.915	Iris	0.885
9	Novodoro	64.2	Iris	821	Canaria	47.70	Pars	10171	Pars	966	Antec	1.082 ^{ns}	Torbat	0.939	Canaria	0.895
10	Tucan	63.9	Pars	857	Sanetha	47.74	SBSI 034	11000	SBSI 034	1049	Rosier	1.086 ^{ns}	Pars	1.047	Morly	0.896
11	Morly	63.7	Ekbatan	937	Morly	48.89	Canaria	11015	Canaria	1051	Boomrang	1.118*	Flores	1.092	Rosier	0.900
12	Aria	63.7	Flores	951	Iris	49.37	Nagano	11210	Nagano	1070	Novodoro	1.144*	Morly	1.093	Flores	0.912
13	Pars	62.5	Morly	969	Novodoro	51.79	Antec	11603	Antec	1109	Nagano	1.157*	Ekbatan	1.116	BTS 335	0.913
14	Antec	60.9	Antec	998	Antec	51.87	Flores	11811	Flores	1130	Sanetha	0.838*	Canaria	1.159	Nagano	0.919
15	Rosier	60.4	Canaria	1028	Rosier	53.35	Rasta	12214	Rasta	1171	Pauletta	0.834*	Antec	1.170	Antec	0.930
16	Nagano	60.4	Boomrang	1033	Flores	53.51	Morly	12251	Morly	1174	Tucan	0.814*	Rosier	1.179	Novodoro	0.940
17	Iris	58.1	Rosier	1039	Rasta	53.86	Novodoro	12291	Novodoro	1178	Aria	0.790*	Boomrang	1.249	Ekbatan	0.945
18	Flores	57.6	Novodoro	1104	Ekbatan	54.48	Iris	12570	Iris	1206	SBSI 034	0.767*	Novodoro	1.308	Torbat	0.959
19	Boom-rang	56.8	Nagano	1156	Nagano	56.27	Boomrang	12614	Boom-rang	1211	Rasta	1.253*	Nagano	1.338	Boom-rang	0.960
20	Sanetha	56.7	Rasta	1297	Boomrang	56.56	Rosier	13573	Rosier	1306	Isabella	1.308*	Rasta	1.570	Rasta	0.961
21	Ekbatan	56.2	Isabella	1551	Isabella	56.75	Isabella	16091	Isabella	1558	Fernando	0.655*	Isabella	1.710	Pars	0.971

S^2_i: environmental variance;

CV_i: coefficient of environmental variation;

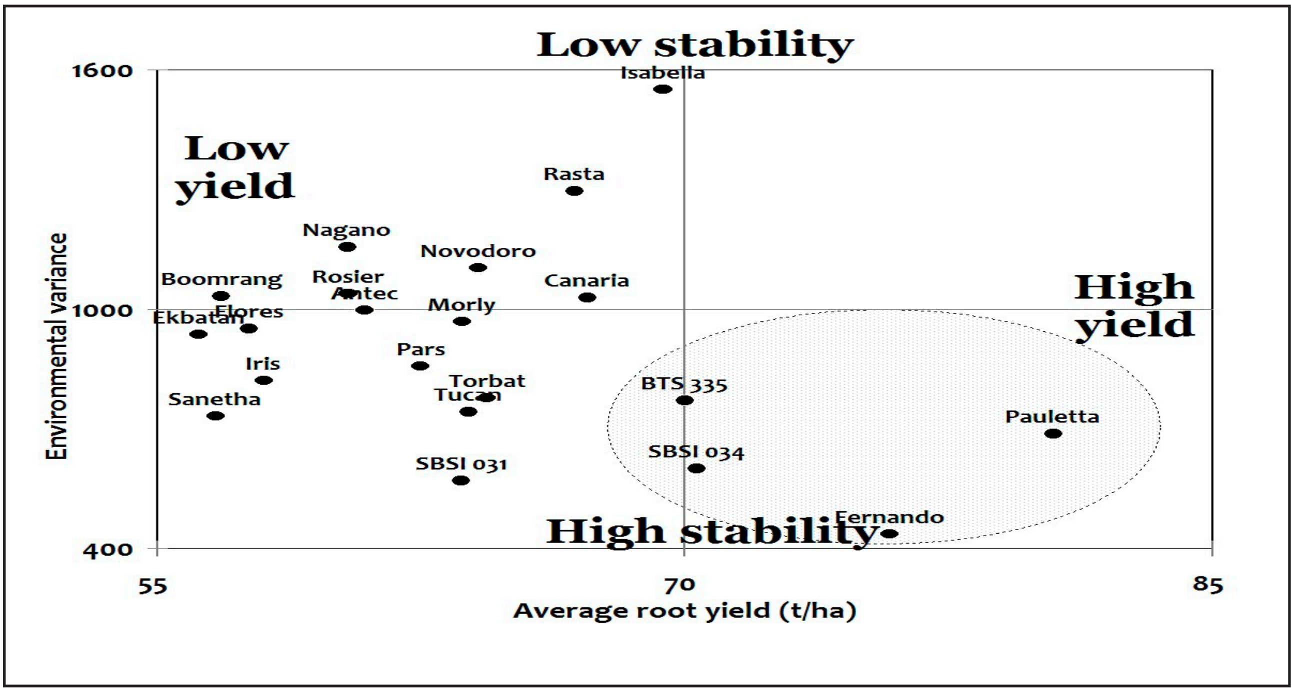
w_i^2: Wricke'secovalence;

σ_i^2: Shukla's stability variance;

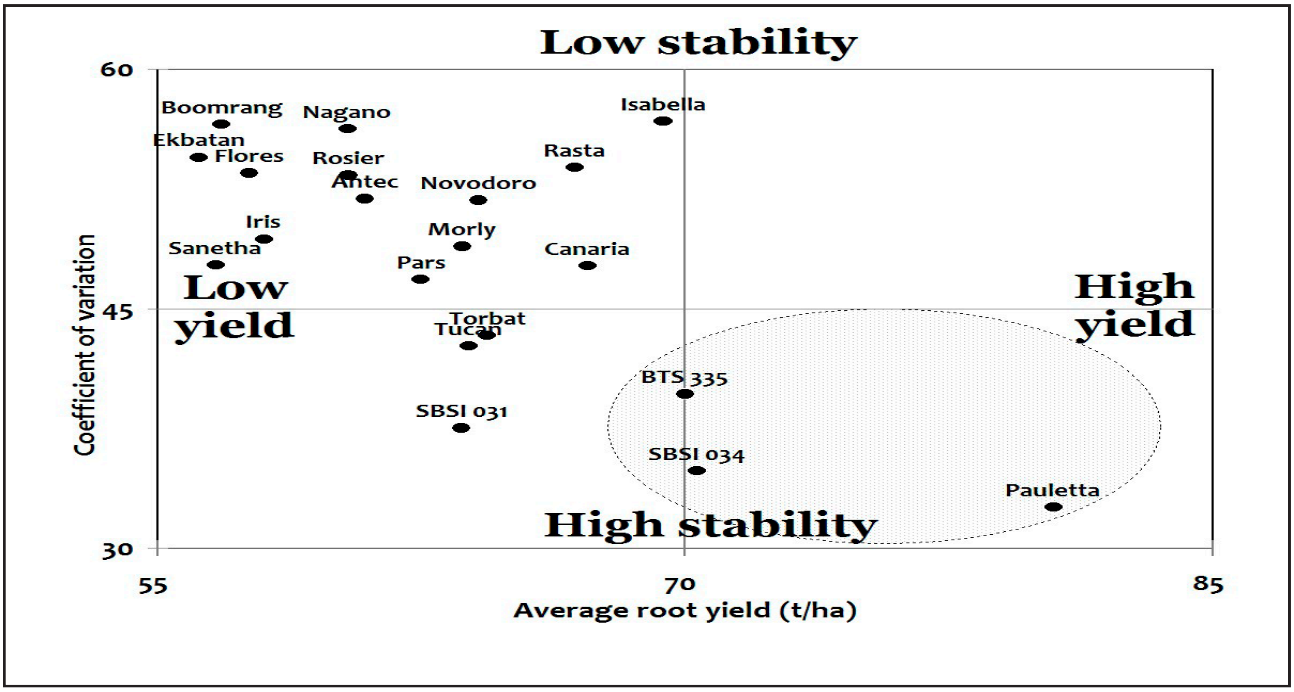
***b:* Finlay and Wilkinson's linear regression coefficient;**

Table 5. Estimation of reliability index (I) for root yield of 21 sugar beet monogerm cultivars at different levels of agricultural development in 2014

Rank	*P=0.75*		*P=0.80*		*P=0.85*		*P=0.90*		*P=0.95*	
	Cultivar	*I*	*Cultivar*	*I*	*Cultivar*	*I*	*Cultivar*	*I*	*Cultivar*	*I*
	Modern agriculture in most favorable regions		→						*subsistence agriculture in unfavorable regions*	
1	Pauletta	62.78	Pauletta	58.46	Fernando	54.10	Fernando	49.09	Fernando	41.46
2	Fernando	61.73	Fernando	58.28	Pauletta	53.22	Pauletta	46.93	Pauletta	37.36
3	SBSI 034	53.82	SBSI 034	49.78	SBSI 034	44.88	SBSI 034	39.00	SBSI 034	30.05
4	BTS 335	51.27	BTS 335	46.69	BTS 335	41.13	BTS 335	34.47	Aria	24.36
5	Aria	47.53	Aria	43.59	Aria	38.81	Aria	33.08	BTS 335	24.34
6	Canaria	45.59	Tucan	40.96	Tucan	35.51	Tucan	28.98	Tucan	19.03
7	Torbat	45.56	Torbat	40.95	Torbat	35.38	Torbat	28.68	Torbat	18.50
8	Tucan	45.46	Canaria	40.30	Canaria	33.89	Canaria	26.19	Canaria	14.49
9	Isabella	42.81	Pars	37.92	Pars	32.06	Pars	25.04	Pars	14.35
10	Pars	42.75	Morly	37.52	Morly	31.30	Morly	23.83	Morly	12.46
11	Morly	42.66	Rasta	36.62	Novodoro	29.60	Sanetha	22.04	Sanetha	12.17
12	Rasta	42.56	Isabella	36.32	Rasta	29.41	Novodoro	21.62	Iris	10.91
13	Novodoro	41.72	Novodoro	36.24	Sanetha	28.54	Iris	21.37	Novodoro	9.50
14	Antec	39.58	Antec	34.37	Isabella	28.44	Rasta	20.77	Antec	8.94
15	Iris	38.71	Iris	33.98	Iris	28.25	Antec	20.47	Rasta	7.63
16	Rosier	38.67	Sanetha	33.95	Antec	28.05	Rosier	19.16	Rosier	7.40
17	Sanetha	38.41	Rosier	33.35	Rosier	26.90	Isabella	18.99	Flores	6.90
18	Nagano	37.46	Nagano	31.85	Flores	25.56	Flores	18.16	Ekbatan	5.84
19	Flores	36.81	Flores	31.73	Nagano	25.05	Ekbatan	17.01	Isabella	4.62
20	Ekbatan	35.54	Ekbatan	30.49	Ekbatan	24.36	Nagano	16.90	Nagano	4.49
21	Boom-rang	35.14	Boom-rang	29.83	Boom-rang	23.40	Boom-rang	15.69	Boom-rang	3.96
Range		27.64		29.08		30.70		33.40		37.5

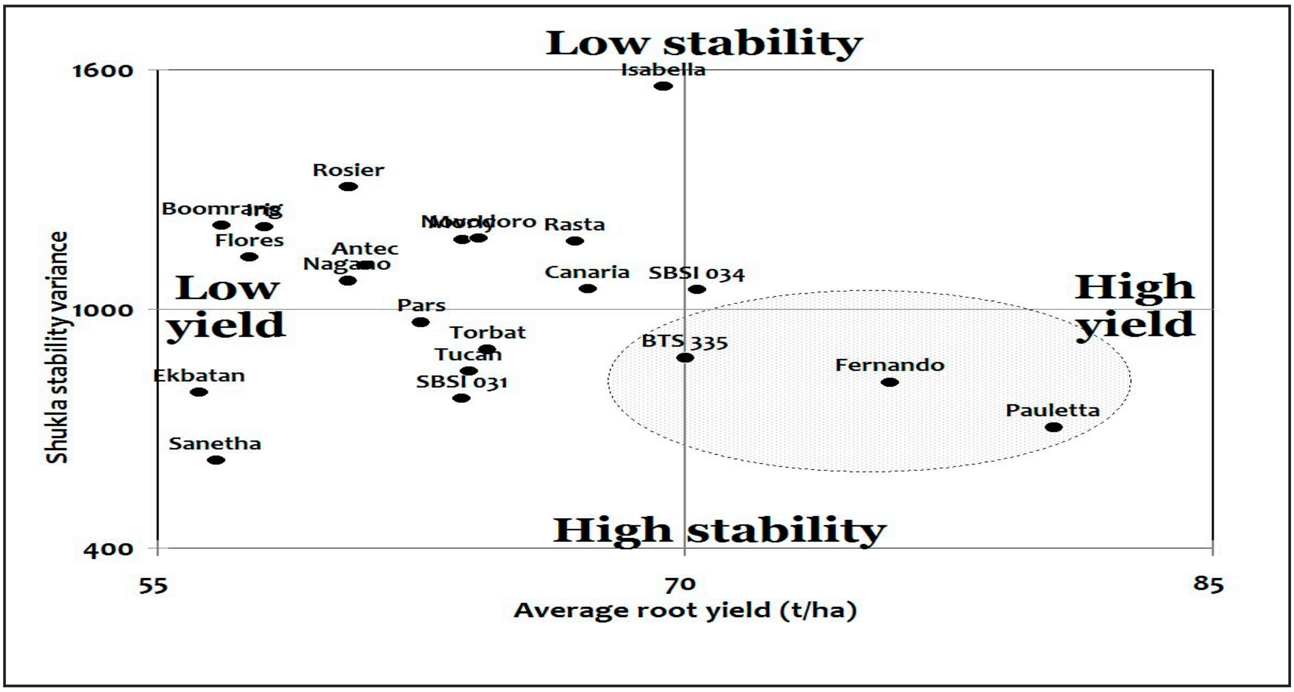


(a)

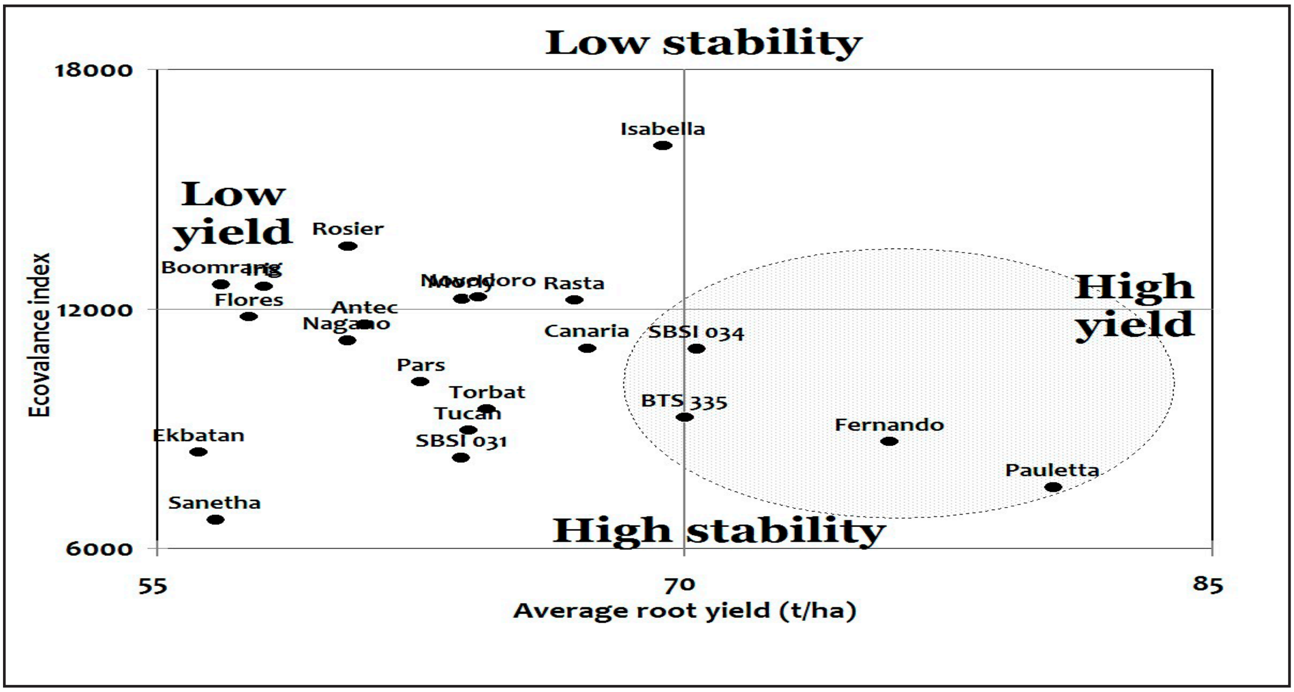


(b)

Fig. 1. Biplot for mean root yield with (a) environmental variance and (b) coefficient of environmental variation for 21 sugar beet monogerm cultivars in 2014.



(a)



(b)

Fig. 2. Biplot for mean root yield with (a) Shukla's stability variance and (b) ecovalence index for 21 sugar beet monogerm cultivars in 2014.

مؤشرات ثباتيّة الغلّة لأصناف الشّوندر السكّري (*Beta vulgaris* L.) المزروعة في إيران

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الملخص:

ركّزت الدّراسة الحالية على تقييم ثباتيّة الغلّة لأصناف الشّوندر السكّري المزروعة في إيران. جُمعت البيانات لواحدٍ وعشرين صنف من الشّوندر السكّري المستوردة والمحليّة التي زُرعت في أحد عشر موقعاً في إيران وذلك خلال الموسم 2014 في العروة الربيعية، بتصميم القطاعات الكاملة العشوائية بثلاثة مكررات. أظهر التفاعل بين المواقع والأصناف تأثيراً معنوياً (P≤0.05) في المردود الجذري. بلغت أعلى قيمة للمردود الجذري في الصنفين Pauletta وFernando (75.8 و80.5 طن/هكتار) على التوالي، يليهما SBSI-034 وBTS-335 (70 طن/هكتار)، في حين أعطت كل من الأصناف: Canaria، Rasta، Torbat، Novodora، Tucan، Morly، Aria، Pars، Antec، Nagano، Rosier، Iris، Flores، Boomrang، Sanetha، وEkbatan أقل مردود من غلّة الجذور (56.6-67.2 طن/هكتار). إنّ معنويّة التفاعل مابين الأصناف والمواقع يدلّ على تباين سلوكيّة الأصناف في مختلف المواقع. أظهرت مؤشرات الثباتيّة المختلفة، ثباتيّة وارتفاع المردود الجذري في كل من الأصناف Fernando، Pauletta، SBSI-034، وBTS-335، في حين تميّزت الأصناف: Boomrang، Iris، Isabella، Morly، Novodora، Rasta، وRosier بانخفاض كل من الثباتية والمردود الجذري. أما الأصناف Pars، Torbat، Iris، Flores، Morly، Ekbatan، BTS-335، Canaria، Antec، وRosier فقد تميّزت بثباتيّة متوسطة. بالنسبة لمؤشر درجة الموثوقية لصفة المردود الجذري للأصناف المختبرة في مختلف المواقع فقد تميّزت كل من الأصناف: Pauletta، Fernando، SBSI-034، TBS، و Aria بارتفاع قيمة هذا المؤشر مقارنةً مع باقي الأصناف.

الكلمات المفتاحية: تفاعل المواقع X الأصناف، الشّوندر السكّري، الثباتيّة، المردود الجذري.