ارزیابی ده رقم چغندرقند از لحاظ رشد، عملکرد و کیفیت تحت سطوح مختلف شوری خاک

Evaluation of ten sugar beet varieties in terms of growth, yield and quality under different soil salinity levels

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چکیده

شوری خاک بر تولید گیاه، از جمله رشد چغندرقند، به ویژه در استان الفایوم کشور مصر تأثیر می‌گذارد. گزینش ارقام متحمل به شوری یکی از متداول‌ترین روش‌هایی است که توسط به‌نژادگران چغندرقند استفاده می‌شود. این تحقیق در استان الفایوم (مصر) واقع در ۲۹ درجه و ۱۷ درجه شمالی؛ ۳۰ درجه و ۵۳ درجه شرقی، در طول فصل زراعی ۲۰۱۸/۲۰۱۷ و ۲۰۱۹/۲۰۱۸ انجام شد. هدف از این تحقیق مطالعه اثر شوری خاک بر روی رشد، کیفیت و عملکرد ۱۰ رقم مولتی‌ژرم چغندرقند در سه منطقه منشات سینریس(S1)، ۳/۵۷ dSm^{-1}، منشات بنی‌عثمان (S2)، ۸/۶ dSm^{-1} و منشات تنتاوی (S3)، ۱۱/۸۴ dSm^{-1} بود. آزمایش به صورت طرح بلوک کامل تصادفی با سه تکرار انجام شد. نتایج نشان داد که عملکرد ریشه و عملکرد شکر و همچنین اندازه ریشه با افزایش سطح شوری خاک در مقایسه با تیمار شاهد به‌طور معنی‌داری کاهش یافت. تحت شوری شدید خاک، عملکرد ریشه و شکر رقم Florima به‌ترتیب برابر ۳۲/۶۴ و ۴/۳۳ تن در هکتار بود؛ از طرف دیگر، رقم Euklid کمترین مقادیر را به ترتیب برابر ۲۷/۱۰ و ۳/۳۱ تن در هکتار داشت. در مورد اثر متقابل سطح شوری خاک و ارقام چغندرقند، بیشترین مقدار عملکرد ریشه و شکر توسط ارقام Florima، Toro، Cleopatra و Tarbelli، تحت شدید شوری خاک) ۱۱/۸۴ (dSm^{-1}) ثبت گردید. با توجه به نتایج پیشنهاد می‌شود چهار رقم فوق توسط کشاورزان تحت خاک شور کشت شوند. این ارقام متحمل به شوری خاک هستند و می‌توانند عملکرد ریشه و شکر پایدار در خاک تحت تنش‌شوری ایجاد کنند. برآورد تخمین وراثت‌پذیری با قند قابل استحصال (۹۴/۹ درصد)، طول ریشه (۹۳/۳۶ درصد) و وزن ریشه (۹۲/۰۵ درصد) ثبت شد. وراثت‌پذیری صفات برای به‌نژادگران از اهمیت زیادی برخوردار است، زیرا اندازه آن بیان‌گر صحت تشخیص انواع مختلف بیان فنوتیپی است. نتایج نشان داد که چهار رقم ارقام Florima، Toro، Cleopatra و Tarbelli، دارای شاخص حساسیت به شوری (SSI) بر اساس عملکرد ریشه و شکر <1 و نسبتاً به تنش شوری متحمل هستند.

واژه‌های کلیدی: چغندرقند، رقم، شوری خاک، عملکرد ریشه، عملکرد شکر

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Introduction

Sugar beet (*Beta vulgaris* L.) is cultivated in Al-Fayoum Governorate, Egypt, in an area of about 35.2 thousand feddan (fed=0.42 ha) and is dominated by a low percentage in the city of Sinnuris. Most of the lands in the city of Sinnuris are affected by salinity and located around Lake Qaroun in large areas connected to most of the villages of the city, such as Monshat bani Othman, Monshat Tantawy and Monshat Sinnuris. In these villages the soil salinity ranges from 4 dSm^{-1} to 16 dSm^{-1} and has a significant impact on the growth of agricultural crops and reduces agricultural production in general (National Report No. 235 "taxonomic inventory of land for the city of Sinnuris" March 1981). Soil salinity is a part of natural ecosystems under arid and semi-arid conditions (Pathak and Rao 1998), and an increasing problem in agricultural soils throughout the world (Qadir *et al*. 2000). Egypt is one of the countries that suffer from severe salinity problems. For example, 33% of the cultivated land which comprises only 4% of total land area in Egypt, is already salinized due to low precipitation (<25mm annual rainfall) as well as irrigation with saline water (El-Hendawy *et al.* 2004; Abdel-Latef 2005). Salinity stress is a primary cause of crop loss throughout the world which reduces average yield of major crops by more than 50% (Bray *et al*. 2000). Plant growth is suppressed severely at high salinity stress due to factors such as osmotic stress, mineral nutrition absorption imbalance, and specific ion toxicity, all combining to reduce nutrient uptake consequentially causing physiological drought to plants (Yusuf *et al.* 2007). However, during early growth stage of sugar beet, the soil electrical conductivity (ECe) should not exceed 3 dSm^{-1} (Steduto *et al.* 2012).

Egyptian Government imports about 1.14 million ton of sugar annually to face the rapid increase of population; the total sugar production is about 2.16 million tons and the total consumption is about 3.3 million tons (Annual Report of Sugar Crops Council 2019). Sugar beet plays an important role in sugar production, so that about 57.7% of the local sugar production which amounted to 1.25 million tons is produced from sugar beet; so that the sugar beet is considered as the second sugar crop after sugarcane. Sugar beet has been an important crop in crop rotation as a winter crop both in poor and fertile soils. Sugar beet seeds are imported and hence beet varieties should be evaluated under the Egyptian conditions to select the best varieties in respect to yield and quality traits. The government encourages sugar beet growers to increase the cultivated area with sugar beet for decreasing the gap between sugar production and consumption. Improvement of sugar beet production can be achieved through optimizing the cultural practices.

Genetic improvement of sugar beet depends on the magnitude of genetic variability and the extent to which the desirable traits are transmissible. Heritability plays a predictive role in breeding, expressing the reliability of phenotype as a guide to its breeding value. Johnson *et al.* (1955) indicated that high heritability is not always associated with high genetic gain. Quantitative traits present particular difficulty in selection programs because heritable variations are often masked by non-heritable variations. The utility of heritability estimates increases when they are used in conjunction with genetic advance expressed as a percentage of the mean (Allard 1960). In addition, the availability of information on the extent to which variation in individual plant character is transmitted to the next generation is also important to fasten the process of population screening in breeding programs. The objectives of the present study were (1) to assess the effect of soil salinity levels on growth, yield and quality of ten sugar beet varieties, (2) to determine varieties with high stable root and sugar yields and (3) to estimate the broad-sense heritability for yield and its components.

Materials and Methods

The study was carried out at Al-Fayoum Governorate, (29°17` N; 30°53` E), Egypt, to evaluate the effect of saline soil of three locations S^1,3.57 dSm^{-1} (Monshat Sinnuris), S^2 ,8.6 dSm^{-1} (Monshat bani Othman), and S^3, 11.84 dSm^{-1} (Monshat Tantawy), on plant growth, quality and yield traits of ten multigerm sugar beet varieties (Table.1) during the two successive winter seasons of 2017- 2018 and 2018- 2019. The experimental design was a randomized complete block design (RCBD) with three replications. Each experimental unit included five rows with 60 cm apart and 5 m long, comprising an area of 15 m^2. Experiments were sown on 25^{th} and 21^{th} September in the first and second seasons, respectively.

Table 1 Origin and seed type of the studied sugar beet varieties

No.	Varieties	Company	Country
1	Tarbelli	Semences	France
2	Pleno	SESVanderhave	Belgium
3	Farida	SESVanderhave	Belgium
4	Florima	Desprez	France
5	Cleopatra	Desprez	France
6	Dlamand	SESVanderhave	Belgium
7	Toro	Strube	Germany
8	Capel	Desprez	France
9	Almas	Strube	Germany
10	Euklid	Strube	Germany

Source: Sugar Crops Research Institute, ARC, Egypt

The experimental soil samples were collected from two successive mixed depths of 0-30 cm and 30- 60 cm from soil surface before cultivation to determine some physicochemical properties according to Black *et al*., (1965) and Jackson (1973, the description was given in Table 2). The fertilizers, surface irrigation and all other agronomic practices were applied as recommended at three locations. Each treatment was irrigated by normal water from Yussef Lake; the chemical composition of the used water is given in Table 3.

Table 2 Chemical and physical properties of the experimental soil at three locations in Al-Fayoum

Location	S[1] (Monshat Sinnuris)		S[2] (Monshat bani Othman)		S[3] (Monshat Tantawy)	
Seasons	2017-18	2018-19	2017-18	2019-19	2017-18	2018-19
Mechanical analysis			Partial soil distribution			
Sand %	21.9	23.6	21.2	34.4	24.1	25.5
Silt %	39.9	29.9	35.8	31.9	36.6	37.6
Clay %	38.2	46.5	43.0	33.7	39.3	36.9
Soil texture				Clay Loamy		
Chemical analysis						
EC(dSm^{-1})	3.43	3.71	8.6	8.7	11.94	11.75
Mean of two seasons	3.57		8.6		11.84	
pH(1:2.5)	8.31	8.29	8.16	8.29	8.00	7.80
*Sp%	70.0	60.0	39.0	40.0	85.0	83.6
Ca^{++}	9.80	11.3	25.5	26.3	22.47	22.12
Mg^{++}	5.55	5.64	19.5	19.7	27.53	26.88
Na^{+}	18.3	19.7	39.65	40.7	58.35	57.65
K^{+}	0.65	0.42	1.23	1.24	0.46	0.44
HCO_3^{-}	2.50	2.80	6.50	6.90	2.83	2.71
Cl^{-}	26.1	29.2	70.5	70.8	33.33	32.87
SO_4^{-}	5.70	5.10	8.88	8.91	72.65	71.52

*SP= poorly graded sand

Table 3 Chemical composition of the water used for irrigation

Water used	pH	ECe dSm^{-1}	*SAR	Na+	Ca++	Mg++	K+	Cl-	CO3-	HCO3-	SO4-
				Cations and Anions (mmhos/cm)							
	7.75	1.03	1.1	2.2	5.9	4.0	0.2	3.6	0.01	5.5	0.9

*SAR=Sodium Adsorption Ratio

At harvest, the three guarded central rows of each plot per variety in three locations were harvested to estimate the following traits from random five plants:

Growth traits

Root length (cm), root diameter (cm), root fresh weight/plant (kg), and top fresh weight/plant (kg).

Productivity traits

1. Root yield (ton/fed): calculated from root weight of experimental unit.

2. Top yield (ton/fed): calculated from top weight of experimental unit.

3. Sugar yield (ton/fed)= extractable sugar% × root yield (ton/fed)/100

4. Harvest index (HI): root yield (ton/fed)/ (root yield (ton/fed) + top yield (ton/fed)) ×100

Quality traits

Quality traits were determined in Al-Fayoum sugar company laboratories.

1. Impurities of juice, (K and Na) concentrations were estimated as meq/100g beet according to the procedures of Sugar Company by automated analyzer, as described by Brown and Lilliand (1964). α- amino- N was determined using Hydrogenation method according to Carruthers *et al.* 1962.

2. Sucrose percentage was Polari metrically determined on a lead acetate extract of fresh macerated root according to the method of Le-Docte (1927).

3. Purity %= 99.36- 14.27 (Na + K + Alpha-amino nitrogen) / Sucrose % (Devillers 1988).

4. Sucrose loss to molasses (SLM %)= 0.14 (Na + K) + 0.25 (Alpha-amino nitrogen) + 0.50 (Devillers 1988).

5. Extractable sugar % Sucrose % – SLM% - 0.6 (Dexter *et al.*, 1967).

Statistical analysis

Data collected of each season and each location was statistically analyzed according to Gomez and Gomez (1984) using MSTAT-C software package. The separate analysis of variance for each experiment (year), and then the combined analysis of variance for different characters were performed on plot mean basis. Revised L.S.D at 5% level was used to compare means according to Waller and Duncan (1969). Broad-sense heritability on genotype mean basis was estimated using variance components following the formula according to Johnson *et al.* (1955): $H= \sigma^2g/ (\sigma^2g + \sigma^2e /r + \sigma^2gy /ry)$.

Where, σ^2g and σ^2e refer to genotypic and error variance, respectively. The divisor (r) refers to the number of replications. σ^2gy refers to genotype by year interaction variance, the divisor y refers to the number years.

Salinity susceptibility index (SSI) was calculated for each sugar beet variety according to the method of Fischer and Maurer (1978) as follows:

SSI= $(1-(\frac{Yd}{Yw}))/D$

Where:

(Yd)= mean yield for a variety in stress environment

(Yw)= mean yield for a variety in normal environment

D= environmental stress intensity, which was calculated as:

D= $1-(\frac{\times d}{Xw})$

Xd= mean of all varieties in stress environment

Xw= mean of all varieties in normal environment

Sugar beet varieties with "SSI" value of 1.0 or more than one are susceptible to salinity, while those with values less than 1.0 are less susceptible (tolerant to salinity).

Results and Discussion

Effect of soil salinity on growth traits

1. Root length and diameter (cm)

Mean root length, and root diameter as affected by soil salinity levels are given in Table 4 Root length significantly increased but the root diameter decreased by increase in soil salinity level. Cleopatra recorded the highest root length, 25.0 cm which was significantly higher than the lowest one Capel by about 3.2 cm under severe saline soil (11.84 dSm^{-1}) as compared with the lowest soil salinity (3.57dSm^{-1}), which had the average of root length ranging from 17.5 cm recorded by Tarbelli to the highest mean root length (20.6 cm) recorded by Cleopatra. This finding could be explained by the increase in soil salinity levels; more water was depleted from the lower depths due to the lack of available water in the upper layer. Roots tracing behind soil water within the subsoil layer led to increase in root length. Ibrahim *et al.*, (2002) found that root grows longer under moisture stress.

The interaction between soil salinity and varieties on root diameter combined over two seasons was significant (Table 4). The variety Toro had the highest value of root diameter (11.6 cm) which was significantly higher than the lowest ones including Almas and Pleno, by about 1.4 cm, under the severe soil salinity level (11.84dSm^{-1}). Also, the same variety (Toro) recorded the biggest root diameter (14.0 and 12.8 cm) under the lowest soil salinity (3.57dSm^{-1}) and the moderate level of soil salinity (8.6 dSm^{-1}), respectively, while the narrow diameter was recorded by varieties Capel, Carnute, and Almas under the soil salinity levels of 3.57, 8.60 and 11.84 dSm^{-1}, respectively. Increase in salinity can rapidly inhibit root growth and hence the capacity of water uptake and essential mineral nutrition from soil (Neumann 1995). The above-mentioned results also indicate that the studied parameters of sugar beet growth (root length and root diameter) were influenced by salinity stress.

2. Root and top fresh weight/plant

Root and top fresh weight/plant were greatly reduced by high levels of soil salinity (Table 4). The root weight of plants at the highest soil salinity (11.84 dSm^{-1}) was decreased by 0.37 kg as compared with the control treatment (3.57 dSm-1). Soil salinity caused positive and significant effects on root weight and the top weight of sugar beet varieties grown in saline soil. The highest values of root weight and top weight (0.62 and 0.25 kg/plant, respectively) were obtained by variety Toro under severe soil salinity (11.84 dSm^{-1}). This superiority may be due to the genetic makeup of this variety while the lowest values were obtained by varieties Pleno (0.52 kg/plant) and Tarbelli (0.21 kg/plant) under severe treatment (11.84 dSm^{-1}). Salinity stress not only affects one growth stage, but it also affects the plant differently by considering the stress intensity, stress type, plant tolerance, various growth stages, tissue type and plant organ (development). These results are in agreement with those obtained by Munns (2002) who added that highly soluble salts in the root zone cause physiological scarcity in the plant to absorb water, thus, the availability of water may then become so critically low since growth parameters are inhibited.

Effect of soil salinity on productivity traits

1. Top yield (ton/fed) and harvest index

As shown in Table 5, soil salinity affects clearly sugar beet productivity traits. The results indicate that top yield decreased significantly with increase in soil salinity levels. Top yield (ton/fed) decreased significantly (31.61% under severe saline soil (11.84 dSm^{-1}) compared with the normal treatment (9.08 ton/fed). Under severe saline soil (11.84 dSm^{-1}), the average of top yield for the variety Toro was 6.82 ton/fed which was significantly higher than the lowest one (Capel) by about 1.14 ton/fed, as compared with normal soil (3.57dSm^{-1}). Under normal treatment, the average of top yield ranged from 11.02 ton/fed recorded by variety Cleopatra to the lowest mean root (8.39 ton/fed) recorded by variety Tarbelli.

Table 4 Means of root length, root diameter and root and top fresh weights of ten sugar beet varieties as affected by soil salinity (levels; data are combined across two seasons)

Varieties	Root length (cm)			Mean	Root diameter (cm)			Mean	Root weight (kg)			Mean	Top weight (kg)			Mean
	S 1 3.57 dSm^{-1}	S2 8.6 dSm^{-1}	S3 11.84 dSm^{-1}		S 1 3.57 dSm^{-1}	S2 8.6 dSm^{-1}	S3 11.84 dSm^{-1}		S 1 3.57 dSm^{-1}	S2 8.6 dSm^{-1}	S3 11.84 dSm^{-1}		S 1 3.57 dSm^{-1}	S2 8.6 dSm^{-1}	S3 11.84 dSm^{-1}	
Tarbelli	17.5	20.6	22.8	20.3	12.3	11.2	10.7	11.4	0.87	0.85	0.53	0.75	0.31	0.25	0.21	0.26
Pleno	18.2	20.4	22.9	20.5	12.3	10.9	10.2	11.1	0.88	0.84	0.52	0.75	0.33	0.26	0.22	0.27
Farida	18.7	19.2	22.3	20.1	12.3	11.3	10.5	11.4	0.91	0.85	0.54	0.77	0.32	0.25	0.23	0.27
Florima	19.0	21.5	24.2	21.6	13.6	12.7	11.2	12.5	1.01	0.91	0.61	0.84	0.35	0.30	0.23	0.29
Cleopatraa	20.6	22.9	25.0	22.8	13.8	12.1	10.7	12.2	1.04	0.90	0.62	0.85	0.40	0.30	0.25	0.32
Carnute	17.7	20.1	22.7	20.2	12.2	10.5	10.3	11.0	0.93	0.86	0.54	0.78	0.32	0.25	0.22	0.26
Toro	20.6	21.6	24.7	22.3	14.0	12.8	11.6	12.8	1.02	0.95	0.62	0.86	0.33	0.31	0.25	0.30
Capel	18.7	20.6	21.8	20.4	12.0	11.5	10.9	11.5	0.91	0.83	0.53	0.76	0.32	0.24	0.21	0.25
Almas	17.6	19.5	22.2	19.8	12.2	11.3	10.2	11.3	0.90	0.85	0.57	0.77	0.33	0.26	0.22	0.27
Euklid	18.1	20.6	22.8	20.5	12.7	12.2	10.8	11.9	0.86	0.81	0.56	0.74	0.33	0.24	0.21	0.26
Mean	18.7	20.7	23.1	20.8	12.7	11.7	10.7	11.7	0.93	0.87	0.56	0.79	0.33	0.26	0.22	0.27
L.S.D at 0.05																
Salinity (S)				0.339				0.216				0.019				0.010
Varieties (V)				NS				NS				0.035				0.031
SxV				NS				0.310				NS				0.018

* and ** Significant at 0.05 and 0.01 levels of probability, NS= not significant

In this regard, Farkhondeh *et al*. (2012) reported that the reduction in top yield as a result of salinity may be attributed mainly to the osmotic inhibition of water absorption, the excessive accumulation of ions such as Na^+ or Cl^- in plant cells and inadequate uptake of essential nutrients. In this regard, Eisa *et al*. (2012) stated that salinity adversely affects the physiological and metabolic processes which finally reducing the growth and yield of the plant.

Harvest index was significantly decreased with increase in soil salinity (Table 5). The results indicate significant difference among varieties for harvest index as a result of variation in soil salinity. Under severe saline soil (11.84 dSm^{-1}), the average of harvest index for the variety Florima was 68% which was significantly higher than the lowest one (Euklid) by about 3%. Miransari and Smith, (2007) found that soil salinity decreases crop yield through increasing osmotic stress on the plant.

2. Root and sugar yields (ton/fed)

Root and sugar yields were significantly decreased by increase in soil salinity levels as compared with the control treatment (3.57 dSm^{-1},

Table 5). The magnitude of reduction differed from one trait to another. The lowest values of sugar and root yields were registered under severe soil salinity (11.84 dSm^{-1}) as compared with control treatment. Munns and Tester (2008) suggested that the depressive effects of NaCl on the yield of plants may be due to the inhibitory effect of salinity on plant growth and yield, the reduction was ascribed to osmotic effect on water availability, ion toxicity, nutritional imbalance, and reduction in enzymatic and photosynthetic efficiency and other physiological disorders.

The interaction between salinity levels and sugar beet varieties significantly affected root yield and sugar yield. Regardless of plant variety, the increase in soil salinity level reduced all growth criteria for all varieties with different magnitude. However, variety Florima recorded the highest root and sugar yields of 13.71 and 1.82 ton/fed, respectively under severe saline soil (11.84 dSm^{-1}) which was significantly higher than the lowest one (Euklid) by about 2.4 and 0.43ton/fed, as compared with normal soil (3.57dSm^{-1}). The reason for decrease in sugar and root yield under considerable salinity levels may be due to osmotic stress which reduces leaf area and decreases chlorophyll contents which in turn reduces sugar beet yield. Yield parameters of sugar beet were reduced with an increase in soil salinity concentration as reported by Mekki and El-Gazzar (1999). Such reduction might be due to the lowering of the external water potential or the effect of ion toxicity on metabolic process (De-Herralde *et al*. 1998).

Effect of soil salinity on quality traits

1. Sucrose and extractable sugar percentage

Sucrose percentage as well as extractable sugar percentage decreased significantly to 15.35 and 12.67, respectively under severe soil salinity of 11.84 dSm^{-1} compared with normal treatment (16.83% and 14.12%, respectively, Table 6). Under severe saline soil (11.84 dSm^{-1}), the average of sucrose percentage and extractable sugar percentage for the highest variety Cleopatra was 16.14 and 13.52 % which was significantly higher than the lowest one (Almas) by about 1.49 and 1.56%, as compared with the normal soil (3.57dSm^{-1}). The reduction in sucrose and extractable sugar percentage may be due to salt stress and ion imbalance stress as well as the toxic effect of Na^- or Cl^- ions and the osmotic potential of the soil solution (Gobarh 2001).

Table 5 Means of top yield, root yield, sugar yield and harvest index of ten sugar beet varieties as affected by soil salinity levels; data are combined across two seasons

Varieties	Top yield (ton/fed)			Mean	Root yield (ton/fed)			Mean	Sugar yield (ton/fed)			Mean	Harvest index %			Mean
	S 1 3.57 dSm^{-1}	S2 8.6 dSm^{-1}	S3 11.84 dSm^{-1}		S 1 3.57 dSm^{-1}	S2 8.6 dSm^{-1}	S3 11.84 dSm^{-1}		S 1 3.57 dSm^{-1}	S2 8.6 dSm^{-1}	S3 11.84 dSm^{-1}		S 1 3.57 dSm^{-1}	S2 8.6 dSm^{-1}	S3 11.84 dSm^{-1}	
Tarbelli	8.39	6.77	6.05	7.07	20.13	19.04	12.30	17.16	2.80	2.50	1.56	2.28	71	74	67	70
Pleno	8.89	7.17	5.89	7.31	20.42	19.71	11.71	17.28	2.86	2.49	1.45	2.27	70	73	67	69
Farida	8.75	6.75	6.25	7.25	20.42	19.75	11.46	17.21	2.88	2.58	1.41	2.29	70	75	65	69
Florima	9.48	8.07	6.37	7.97	22.13	20.58	13.71	18.81	3.31	2.85	1.82	2.66	70	72	68	70
Cleopatraa	11.02	8.18	6.73	8.64	22.13	20.21	13.08	18.47	3.24	2.78	1.77	2.60	67	71	66	68
Carnute	8.80	6.72	6.00	7.17	21.21	20.08	11.83	17.71	3.04	2.58	1.46	2.36	71	75	66	71
Toro	8.98	8.55	6.82	8.11	22.13	20.58	13.33	18.68	3.26	2.85	1.80	2.64	71	71	66	69
Capel	8.59	6.43	5.68	6.90	20.50	19.83	12.13	17.49	2.74	2.52	1.51	2.25	70	76	68	71
Almas	8.98	7.04	6.05	7.35	20.38	19.92	11.71	17.34	2.81	2.50	1.40	2.24	69	74	66	70
Euklid	8.93	6.46	6.23	7.21	20.25	19.67	11.38	17.10	2.72	2.48	1.39	2.20	69	75	65	69
Mean	9.08	7.21	6.21	7.5	20.97	19.94	12.26	17.72	2.96	2.61	1.55	2.37	70	73	66	70
L.S.D at 0.05																
Salinity (S)				0.490				0.282				0.100				NS
Varieties (V)				0.269				0.315				0.055				0.043
SxV				0.380				0.542				0.078				NS

* and ** Significant at 0.05 and 0.01 levels of probability, NS= not significant

Effect of soil salinity on quality traits

1. Sucrose and extractable sugar percentage

Sucrose percentage as well as extractable sugar percentage decreased significantly to 15.35 and 12.67, respectively under severe soil salinity of 11.84 dSm^{-1} compared with normal treatment (16.83% and 14.12%, respectively, Table 6). Under severe saline soil (11.84 dSm^{-1}), the average of sucrose percentage and extractable sugar percentage for the highest variety Cleopatra was 16.14 and 13.52 % which was significantly higher than the lowest one (Almas) by about 1.49 and 1.56%, as compared with the normal soil (3.57dSm^{-1}). The reduction in sucrose and extractable sugar percentage may be due to salt stress and ion imbalance stress as well as the toxic effect of Na^- or Cl^- ions and the osmotic potential of the soil solution (Gobarh, 2001).

2. Purity percentage and sucrose loss to molasses (SLM) percentage

Data in Table 6 indicate purity percentage was decreased significantly by about 18.25 under severe saline soil (11.84 dSm^{-1}) compared to the normal treatment (79.97%), but sucrose loss to molasses (SLM %) was increased non-significantly by about 1.92% under severe soil salinity compared with the normal treatment (2.08%). Under severe saline soil (11.84 dSm^{-1}), the average of sucrose percentage and extractable sugar percentage for the highest varieties Florima and Almas was 70.39 and 2.19%, respectively which was significantly higher than the lowest ones (Pleno and Cleopatra) by about 12.83 and 0.13 %, respectively, as compared with the normal soil (3.57dSm^{-1}). The significance of soil salinity levels × varieties interaction ($P \leq 0.05$) showed that cultivars did not have the uniform performance at different soil salinity levels. Khalil *et al*. (2001) found that sucrose, total soluble solids and purity of sugar beet juice increased with increase in K level but decreased with salinity stress.

Table 6 Means of SLM (%), extractable sugar (%), purity (%) and sucrose (%) of ten sugar beet varieties as affected by soil salinity **(**levels; data are combined across two seasons)

Varieties	SLM (%)			Mean	Extractable sugar (%)			Mean	Purity (%)			Mean	Sucrose (%)			Mean
	S^1 3.57 dSm^{-1}	S^2 8.6 dSm^{-1}	S^3 11.84 dSm^{-1}		S^1 3.57 dSm^{-1}	S^2 8.6 dSm^{-1}	S^3 11.84 dSm^{-1}		S^1 3.57 dSm^{-1}	S^2 8.6 dSm^{-1}	S^3 11.84 dSm^{-1}		S^1 3.57 dSm^{-1}	S^2 8.6 dSm^{-1}	S^3 11.84 dSm^{-1}	
Tarbelli	2.13	2.02	2.08	2.08	13.89	13.13	12.68	13.23	79.80	74.31	68.51	74.21	16.57	15.75	15.41	15.91
Pleno	2.07	2.08	2.13	2.09	13.99	12.65	12.42	13.02	79.53	63.52	57.56	66.87	16.72	15.33	15.09	15.71
Farida	2.13	2.08	2.08	2.10	14.09	13.05	12.30	13.15	79.01	74.34	67.96	73.77	16.77	15.73	15.03	15.84
Florima	2.03	1.95	2.06	2.01	14.94	13.85	13.30	14.03	81.46	76.00	70.39	75.95	17.6	16.4	15.93	16.64
Cleopatraa	2.02	2.02	2.06	2.03	14.63	13.77	13.52	13.97	81.68	65.67	59.78	69.04	17.29	16.39	16.14	16.61
Carnute	2.11	2.10	2.15	2.12	14.32	12.85	12.36	13.18	79.77	73.82	68.00	73.86	17.07	15.55	15.07	15.90
Toro	2.01	2.01	2.07	2.03	14.74	13.83	13.51	14.03	81.59	75.70	70.26	75.85	17.41	16.44	16.12	16.66
Capel	2.05	2.08	2.13	2.09	13.35	12.69	12.44	12.83	79.57	73.61	66.62	73.27	16.08	15.37	15.09	15.51
Almas	2.09	2.09	2.19	2.12	13.80	12.56	11.96	12.77	78.24	63.36	57.85	66.48	16.59	15.25	14.65	15.50
Euklid	2.11	2.21	2.18	2.17	13.43	12.61	12.22	12.75	79.02	72.59	66.75	72.79	16.21	15.42	14.93	15.52
Mean	2.08	2.06	2.12	2.09	14.12	13.10	12.67	13.29	79.9٧	71.2٩	65.3٧	72.21	16.83	15.76	15.35	15.98
L.S.D at 0.05																
Salinity (S)				0.091				0.354				0.709				0.196
Varieties (V)				0.050				0.194				0.389				0.358
SxV				0.070				0.274				0.549				NS

* and ** Significant at 0.05 and 0.01 levels of probability, NS= not significant

Effect of soil salinity on sugar beet impurities

There were significant differences among varieties for potassium (K) and sodium (Na) as well as α- amino nitrogen (N) under different soil salinity levels (Table 7). The mean values for K, Na and N increased with increase in soil salinity level. Under severe soil salinity (11.84 dSm^{-1}), the highest values of K and N of 5.30 and 2.05, respectively were recorded by variety Almas, while the highest values of Na (3.48) was registered by variety Capel. There was non-significant variance for soil salinity levels × varieties interaction ($P \leq 0.05$) for all impurities except Na. The accumulation of Na in leaves in parallel with decrease in K content, may give us an important explanation for the reflection of salt stress on yield (Eisa *at al*. 2011). Selective K+ uptake has been reported to be associated with salt tolerance in sugar beet (Deinlein *et al*. 2014).

Table 7 Means of potassium (K), sodium (Na) and alpha-amino nitrogen (N) of ten sugar beet varieties as affected by soil salinity levels; data are combined across two seasons

Varieties	Potassium (K)			Mean	Sodium (Na)			Mean	Alpha-amino (N)			Mean
	S^1 3.57 dSm^{-1}	S^2 8.6 dSm^{-1}	S^3 11.84 dSm^{-1}		S^1 3.57 dSm^{-1}	S^2 8.6 dSm^{-1}	S^3 11.84 dSm^{-1}		S^1 3.57 dSm^{-1}	S^2 8.6 dSm^{-1}	S^3 11.84 dSm^{-1}	
Tarbelli	5.06	5.15	5.17	5.13	3.10	2.99	2.91	3.00	1.97	1.53	1.81	1.77
Pleno	5.25	5.11	5.12	5.16	2.97	3.04	3.32	3.11	1.67	1.76	1.81	1.74
Farida	5.26	5.18	5.25	5.23	3.10	2.90	3.08	3.03	1.85	1.80	1.64	1.76
Florima	4.80	4.86	4.85	4.84	2.92	2.91	2.96	2.93	1.79	1.45	1.87	1.70
Cleopatra	4.97	4.73	4.79	4.83	3.07	3.08	2.98	3.04	1.59	1.71	1.88	1.73
Carnute	5.17	5.17	5.16	5.17	2.99	2.98	3.35	3.11	1.87	1.83	1.83	1.84
Toro	4.70	4.87	4.77	4.78	3.03	3.01	3.07	3.04	1.72	1.62	1.88	1.74
Capel	4.95	5.01	5.11	5.02	2.94	3.19	3.48	3.20	1.79	1.72	1.70	1.74
Almas	5.19	5.03	5.30	5.17	3.25	3.21	3.08	3.18	1.65	1.75	2.05	1.82
Euklid	5.24	5.09	5.15	5.16	3.21	3.49	3.41	3.37	1.72	2.05	1.93	1.90
Mean	5.06	5.02	5.07	5.05	3.06	3.08	3.18	3.11	1.76	1.72	1.84	1.77
L.S.D at 0.05												
Salinity (S)				0.163				0.160				NS
Varieties (V)				NS				0.088				0.094
SxV				NS				0.124				NS

* and ** Significant at 0.05 and 0.01 levels of probability, NS= not significant

Broad-sense heritability

The genotypic coefficient of variations is not a correct measure to know the present heritable variation and should be considered together with heritability estimates. In this study, high broad-sense heritability estimates over two years were recorded for purity (95.42%), extractable sugar (94.9%), root length (93.36%), sucrose (92.94%), harvest index (92.55%) and root weight (92.05 %), respectively (Fig.1). However, the lowest heritability was recorded by root diameter (35.71%), top weight (37.04%), SLM% (21.81%), and N (21.84%), respectively. Abu-Ellail *et al.* (2017) reported that estimates of heritability are of important for selection. The significant genotypic effects indicated the existence of genetic variability among the varieties and the possibility of utilizing them in saline soil. Falconer and Mackey (1996) suggested that estimates of heritability are subjected to environmental conditions, and therefore may be used with great care and caution in plant development programs. Broad-sense heritability degrees are useful parameters that can help the breeder during different stages of crop development. The success of the breeding programs will depend largely on the extent of heritability of important economic traits by sugar beet varieties.

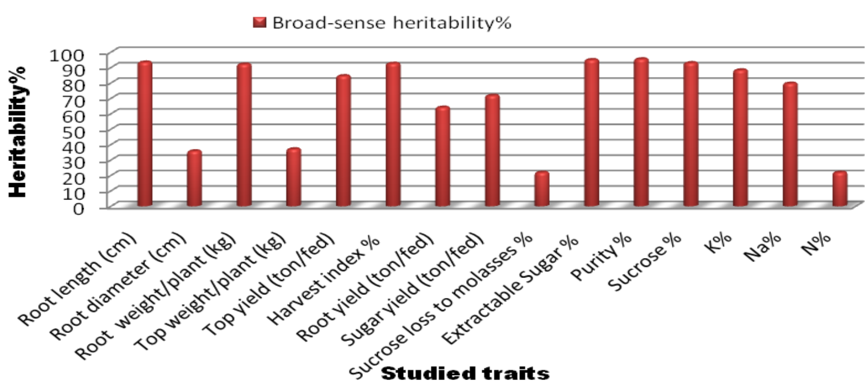

Fig. 1. The broad-sense heritability estimates over two years for studied traits

Salinity susceptibility of sugar beet varieties

Results showed that five varieties had a salinity susceptibility index (SSI) based on root and sugar yields less than one and were relatively tolerant to salinity stress. Salinity susceptibility index of root and sugar yields (ton/fed) results shwoed that the varieties Florima, Tarbelli, Toro, Cleopatra, and Capel were tolerant to soil salinity with SSI value less than one. In addition, severe soil salinity stress reduced root and sugar yields by reducing the root weight/plant, root diameter, sucrose percentage and extractable sugar percentage compared with the results obtained under normal soil condition. Yield components are the most important agronomic traits in variety selection for soil salinity tolerance. The sugar yield was more affected than the root yield, and the decrease in root and sugar yield ranged from 38.05 and 44.29 % for Florima and Tarbell, respectively to the highest values of 44.22 and 51.97% for Carnute. The most susceptible varieties were Almas, Euklid, Pleno, Farida, and Carnute which had SSI more than unity. Root length and root diameter results showed that they are important to be used as useful selection criteria for screening the soil salinity tolerance of sugar beet varieties at high soil salinity. Krishnamurthy *et al*. (2016) and Abu El-lail *et al*. (2014) found that the least SSI values differentiate genotypes with the highest rate of tolerance under salinity (the least yield difference under normal and stress conditions)

Table 8 Decrease percentage and salinity susceptibility index (SSI) of root and sugar yield (ton/fed) of ten sugar beet varieties as affected by soil salinity levels over two seasons

Varieties	Root yield (ton/fed)			Sugar yield (ton/fed)		
	SSI	Decrease percentage		SSI	Decrease percentage	
		S^1-S^2/S^1%	S^1-S^3/S^1%		S^1-S^2/S^1%	S^1-S^3/S^1%
Tarbelli	0.94	5.41	38.90	0.93	10.71	44.29
Pleno	1.03	3.48	42.65	1.03	12.94	49.30
Farida	1.06	3.28	43.88	1.07	10.42	51.04
Florima	0.92	7.00	38.05	0.94	13.90	45.02
Cleopatra	0.98	8.68	40.89	0.95	14.20	45.37
Carnute	1.06	5.33	44.22	1.09	15.13	51.97
Toro	0.96	7.00	39.77	0.94	12.58	44.79
Capel	0.98	3.27	40.83	0.94	8.03	44.89
Almas	1.02	2.26	42.54	1.05	11.03	50.18
Euklid	1.05	2.86	43.80	1.03	8.82	48.90
Mean	1.00±0.03	4.91±0.76	41.54±0.74	1.00±0.05	11.82±0.66	47.64±0.59

Conclusion

Based on the results, soil salinity stress significantly influenced root yield and sugar yield. The studied varieties showed different response to salinity stress. There are acceptable varieties to be introduced to the growers for cultivation under salinity condition however, further research may provide more comprehensive results. Varieties Florima, Toro, Cleopatra, and Tarbell had SSI less than unity and performed the best in relation to root and sugar yield. Hence, these varieties can be cultivated as commercial varieties in districts of high soil salinity. Generally, the screening of the varieties under real and high salt stress conditions provide the researcher with the ability to achieve interesting results regarding the selection of salt-tolerant genotypes. The supplementary experiments can be utilized to take more effective steps towards introducing more salt-tolerant varieties. Evaluating sugar beet crop response under stress is a useful and promising tool for the development of tolerant varieties.

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