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Effect of Salt Stress on Growth, Productivity and Root Quality of Two Sugar Beet (*Beta vulgaris* L.) Cultivars

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ABSTRACT

Understanding how different crops respond to salinity stress can provide valuable insights for managing salt-affected soils, ultimately leading to improved agricultural production and enhanced soil health. Therefore, this research objected the effects of five salinity concentrations (50 , 100, 150, 200 and 250 mM of NaCl), while the control treatment was irrigated using a normal water on growth, yield and quality of two sugar beet (*Beta vulgaris* L.) cultivars ('Maged' and Dreeman). The results indicated that 'Maged' cultivar exhibited high significant mean values of growth, yield and quality characters compared with 'Dreeman'cultivar, in addition the results showed significant variation between the salinity levels, whereas sugar beet can tolerant up to 250 mM NaCl of salinity and reducing stabiles yield, productivity and quality. The interaction among the two investigated cultivars and salinity levels affected significantly most studied characters. In general, it could be recommended that the sugar beet cultivar 'Maged' tolerated salinity up to 250 mM NaCl. Therefore, it is recommended that these sugar beet cultivars can be cultivated in new reclaimed soil as affected by salinity conditions and helps in decreased the salinization in arid area.

Keywords: Sugar beet, Salinity, Cultivars, Yield, Growth, Quality

INTRODUCTION

It is very crucial to enhance the soil quality and crop production in Egyptian old as well as newly cultivated lands in order to adopt the sustainable agriculture practices which mitigate climate changes' impacts, and maximize the farmer's income (Mustafa and Moursy 2020). Moreover, by improving soil health, soil erosion reduces, water infiltration maximizes, nutrient cycling improves, and costs reduce (Mhalla *et al*., 2019). Moreover, by achieving the good agricultural practices such as organic farming and water conservation, the soil health and crop production can be improved (Moursy *et al*., 2020). Understanding the soil dynamic processes and plant physiological responses helps in better evaluating of land capability and suitability (Abd-Elazem *et al*., 2024).

Sugar is considered as one of the strategic goods as the cheapest energy source produced from sugar cane and sugar beet (*Beta vulgaris* L) which are the most important sugar crops as high energy sources to human as well as its importance in feeding the livestock. Sugar beet grows in the newly reclaimed soil where producing high sugar quantity with low water requirement, compared to sugarcane (Makram Sayed 2018). Furthermore, Egyptian annual sugar mass production recorded 1.27 million tons by the sugar beet (57% of the total production), compared to 0.95 million tons (43%) for sugar cane (Shaltout and Ramadan 2024).

Increasing sugar beet's salinity tolerance could increase sugar yields in several irrigated sites as experimented by Eisa *et al*. (2011). Makram Sayed (2018) determined different salinity concentrations' impacts on sugar beet plants by detecting the physiological functions, vegetation measurements, and yield responses using the pot experiments. Several research studies such as those done by Ali *et al*. (2019); ElGhamry *et al*. (2022); Shaib and Hany (2023); Seadh *et al*. (2024) revealed that sugar beet is one of the most salt tolerant crops which commonly grown in salt affected soil. Although the salt tolerance; sugar beet's seed germination, emergence and seedling are affected by the soil salinity compared to other growth's stages as described by Durr and Boiffin (1995) who observed that during the first ten weeks of growth which is critical period for sugar beet establishment. Other research studies *i.e.* (Ghoulam and Fares, 2001; Deinlein *et al*., 2014) indicated salinity impacts on sugar beet's early growth stage are because of the ionic toxicity and osmotic adjustment. Taffouo *et al*. (2010) described negative or positive influences of salinity could be observed in sugar beet's fresh and dry weights which based on the salinity concentrations and plant species accordingly. Moreover, leaf area is declined with salinity increase (Zhao *et al*. 2007; Yilmaz and Kina 2008). Jamil *et al*. (2007) and Liu *et al*. (2009) noticed a reduction in sugar beet's plant length when sodium chloride concentrations' increase. However, El Etreiby (2000) stated that, there are main controlling factors of sugar beet's production under salinity like water quality as well as soil nutrients. Furthermore, Khalil *et al*. (2001) pointed out

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that sucrose (%), total soluble solids (TSS), as well as sugar juice purity (%) decreased under the salinity stress.

Based on the previous introduction, this study hypothesized different responses of two sugar beet cultivars under various salinity concentrations in pot-experiment.

MATERIALS AND METHODS

Experimental site

The current investigation was conducted at El-Sabahia research station, Alexandria, Egypt (Figure 1) where located with latitude 31.21° N, longitude 29.94° E, and altitude of 4.45 m during 2021/2022 and 2022/2023 seasons.

Figure 1. The location map of the experimental site.

Experimental design

In the pots experiment, polyethylene bags were utilized with dimensions of 70 cm x 50 cm; and capacity of 30 kg soil. Soil texture is a clay loam having 23.3% sand, 36.95% silt and 39.75% clay. Main chemical properties are EC of 3.49 dS/m and pH value of 7.٨٤ (Black., 1965)

The experiment was conducted under the greenhouse conditions with two factorial factors (i) two multigerm sugar beet cultivars namely 'Maged' and Dreeman; and (ii) five sodium chloride 'NaCl' salt concentrations (50, 100, 150, 200 and 250 mM); while the control treatment was irrigated using a normal water. The treatments were distributed in split plot design in three replicates, where different measurements of growth, productivity and quality characteristics of the two sugar beet cultivars were recorded. However, the two cultivars were sown in pots on October 25th of each season 2021/2022 and 2022/2023. The meteorological data of the area of study are shown in Table 1.

Each pot received tap water in the 1st irrigation, and saline water in the 2nd irrigation (three weeks after sowing). Soil moisture content was kept around 70% of the field capacity. Moreover, the plants were weekly irrigated under different salinity levels (NaCl concentrations), besides the control. The tap water was alkaline (pH 8.2 – 8.8), with turbidity not exceeding 1.0 NTU, and not exceeding 0.3 NTU in 95% of daily samples, Chlorine ≈ 5 mg/L, Alachlor ≈ 20 mg/L, Sodium ≈ 40 mg/L, Free residual chlorine (0.5 - 1.5 mg/L) and Nitrate ≈ 3 mg/L. The plants were thinned once at the age of 35 days whereas one plant was left per pot. Thereafter, Ammonium Nitrite (33.5% Nitrogen) at the a rate of 75 Kg fed^{-1} was added in three equal doses after thinning, two and four weeks later. Potassium and phosphorus were applied as usually recommended. Lastly, the plants were harvested after 180 days from sowing in both seasons 2021/2022 and 2022/2023.

Table 1. Meteorological data of the investigated area

	Air temperature (^{0} C)		Rainfall (mm)		Relative humidity (%)	
	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
October	22.6	22.9	4.00	4.10	59	58
November	19.0	19.2	9.00	9.20	61	60
December	14.7	14.9	14.00	14.30	65	67
January	12.6	12.5	19.30	19.15	70	65
February	13.3	13.2	13.30	13.00	62	66
March	15.6	15.7	6.00	6.00	56	64
April	18.7	18.3	4.20	4.10	56	58

Source: Alexandria Meteorological Station

Measurements

Several growth traits were determined starting at 60 days of growth, while yield parameters were recorded at harvest after (180 days). The investigated traits are plant weight (g), root weight (g), number of leaves per plant, root diameter (cm), root length (cm), leaf area index (LAI) as in equation 1, and net assimilation rate (NAR) as in equation 2. purity percentages was calculated according to Devillers (1988) as in equation 3, as well as total soluble solids (TSS) which measured by hand refractometer (Simon *et al*., 1980), and root and sugar yields (ton/fed) as in equation 3.

$$LAI = \frac{Leaf\ area}{Ground\ area\ per\ plant} \quad \textbf{Equation (1)}$$

$$NAR\left(\frac{\frac{g}{cm^2}}{day}\right) = \frac{(w_2-w_1)*(\log A_2 - \log A_1)}{(A_2-A_1)*(T_2-T_1)} \quad \textbf{Equation (2)}$$

Purity % = 99.36 – [14.27 (Na + K + α amino N)/sucrose %]. Equation (3)

Whereas w_1 and w_2 are plant dry weight at 1st time 'T_1' and 2nd time 'T_2'; A_1 and A_2 are the leaf area at the 1st and 2nd times (Waston, 1958).

$$Sugar\ Yield = Root\ yield \times Sucrose\ percentage \quad \textbf{Equation (4)}$$

Statistical analysis

All data were computed statistically using the statistical package in MSTATC software based on Freed (1991) , and means were compared using Duncan's Multiple Range (DMR) test described by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Plant weight, root weight and number of leaves

Data demonstrated in Table (2) revealed that 'Maged' sugar beet variety attained significant higher mean values of plant weight, root weight and number of leaves compared to 'Dreeman' variety observations in 2021/2022 and 2022/2023 seasons. This suggests that 'Maged' possesses superior salt tolerance mechanisms, such as efficient ion compartmentalization and osmotic adjustment, which mitigate the salinity stress (Rozema *et al.*, 2015). These results may be referred to the genetic structural variances among the two investigated varieties. However, no significant differences were detected between 'Maged' and 'Dreeman' varieties in plant weight in the 1st season as well as number of leaves in 2nd season.

Moreover, plant weight was affected by the various salinity levels applied in the two investigated seasons, whereas the highest mean values were recorded for 100 and 150 mM NaCl concentrations in the 1st and 2nd seasons, respectively. Besides, increasing salt concentrations to 200 and 250 mM of NaCl influenced reduction in the fresh weight of sugar beet plants during the both seasons. These results are probably due to the reduction of water absorption, photosynthesis process, plant growth, and dry matter while salinity increases (Shehata, *et al.* 2000; Abdel-Mawly and Zanouny, 2004).

Moreover, regarding the number of leaves per plant, the highest means were observed for 250 mM of NaCl. No significant differences were recorded of an interaction among sugar beet cultivars and levels of salinity at the 1st season against the plant weight, while high significant differences were observed at the 2nd season. Vise-versa, significant differences were recorded for number of leaves per plant during the 1st season without significant differences in the 2nd season.

Table 2. Plant weight, root weight and number of leaves of (A) the two sugar beet cultivars as affected by (B) the applied salt concentrations in 2021/2022 and 2022/2023 seasons.

Treatments	Plant weight (g)		Root weight (g)		Number of leaves	
	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
		A- Sugar beet cultivars				
'Maged'	572.22a	717.22a	316.67a	375.00a	29.56a	25.28a
'Dreeman'	559.72a	572.22b	236.11b	296.11b	25.11b	25.17a
		B- Salt concentrations (mM of NaCl)				
Control	533.33b	723.33ab	308.33ab	363.33ab	25.16bc	26.83a
50	566.67b	605.00bc	328.33a	325.00b	24.83c	24.83ab
100	691.67a	620.00bc	266.67b	325.00b	27.50abc	25.33ab
150	575.00b	828.33a	350.00a	425.00a	28.67ab	24.00ab
200	520.83b	575.00c	233.33b	325.00b	27.83abc	23.50b
250	508.33b	546.67c	241.67b	250.00c	30.00a	26.83a
		Interaction				
LSD at 0.05(A x B)	Ns	*	*	*	*	Ns

***: significant at 0.05 level of probability and ns: Not significant at 0.05 level of probability.**

Regarding the salt concentration effects on these investigated plat parameters, the moderate salinity levels (150 mM NaCl) significantly enhanced root weight as observed as 425 g in 2022/2023 season, indicating activation of stress-responsive pathways such as increased synthesis of osmolytes like proline as well as soluble sugars. These substances help maintain cellular turgor and protect against oxidative stress (Yang *et al.*, 2019). At higher salinity levels (250 mM NaCl), plant weight and root weight declined sharply, likely due to ionic toxicity disrupting photosynthesis and carbon assimilation processes. For instance, plant weight dropped to 546.67 g for 'Maged' and 508.33 g for 'Dreeman' in 2022/2023 season, reflecting impaired physiological functions under extreme stress conditions (Mostafavi *et al.*, 2012).

Moreover, the seasonal differences were observed, with generally higher performance in the 2022/2023 season compared to 2021/2022 season for most treatments. For example, the root weight was higher at 250 mM NaCl in 2022/2023 (250 g) compared to 241.67 g in 2021/2022, suggesting environmental indicators like temperature or soil moisture influencing salt tolerance.

However, Rozema *et al.* (2015) found that domesticated sugar beet's varieties retained significant salt tolerance inherited from their wild ancestor, sea beet, allowing them to maintain productivity under saline conditions. This aligns with the stable growth observed for both cultivars at moderate salinity levels in this study. Sadeghian and Yavari (2004) pointed out that more plant morphological differentiation caused by environmental stress can be noticed in greenhouse compared to laboratory. Thus, the variability in germination's percentage of the sugar beet is related to the interaction between the different genotypes, environmental factors, as well as the germination ability (Sadeghian and Khodaii 1998).

Another study of Mostafavi *et al.* (2012) demonstrated that sugar beet genotypes under salt stress exhibit improved root elongation and water uptake efficiency at moderate salinity levels, consistent with the peak root weights observed at 150 mM NaCl. Yang *et al.* (2019) reported that sugar beet tolerate the salinity till 500 mM NaCl without losing viability but suffers yield reductions due to oxidative stress at extreme salinity levels, explaining the decline in plant weight at 250 mM NaCl. The enhanced root weight at moderate salinity levels reflects activation of adaptive mechanisms like osmotic adjustment through proline accumulation as well as antioxidant enzyme activity (e.g., SOD and CAT). The decline at higher salinity levels is attributed to ionic toxicity causing cellular dehydration and disruption of photosynthetic machinery (Marschner, 1995; Dohm *et al.*, 2013).

Root diameter, Root length, LAI and NAR

Data of root diameter (cm), root length (cm), leaf area index (LAI) in $g/cm^2/day$, and net assimilation rate (NAR) were shown in Table (3). Root diameter (cm) and root length (cm) were significantly affected by saline water, sugar beet cultivars, and their interactions.

Moreover, significant decreases of root diameter have been observed by the salinity increase. Data also indicated that under the 250 mM of NaCl, a small reduction was observed in root diameter. The 'Maged' cultivar showed the highest root diameter comparing with the 'Dreeman' cultivar for both seasons 2021/2022 and 2022/2023. Under 100 mM of NaCl, the root diameter was significantly higher than control treatment. Concerning to root length under the different salinity concentrations, the highest value was obtained by 250 m M of NaCl in the 1st season than the 2nd season. These disparities align with studies showing that salt-tolerant cultivars like 'Maged' enhance ion homeostasis through vacuolar Na^+ sequestration via NHX1 antiporters, minimizing cytoplasmic toxicity and preserving root architecture. At 250 mM NaCl, both cultivars showed reduced performance, likely due to oxidative stress overwhelming antioxidant systems (e.g., Superoxide Dismutase and Catalase 'SOD' & 'CAT'), as observed in proteomic analyses of sensitive genotypes (Yu *et al.*, 2019; Yang *et al.*, 2019). Regarding the interaction, significant difference was recorded for the root diameter and root length as well.

The obtained data also revealed that the 'Maged' cultivar recorded the highest mean values for leaf area index (LAI) and NAR compared to the 'Dreeman' cultivar in respect of the two investigated seasons. However, the analysis of variances demonstrated significant variations among the cultivars in relation to root diameter, root length, LAI, and NAR. Under the high salt concentrations, the results showed increase in LAI because of the tolerant of sugar beet to high salinity levels as observed and notices in similar research studies. However, the LAI values increased from 4.02 (control) to 4.98 (under 250 mM of NaCl) in the 1st season and from 3.96 to 5.61 in the 2nd. Regarding the NAR, similar observations were recorded regarding the significant increase of NAR with salinity increasing from 0 to 250 mM of NaCl. For example, the maximum NAR mean value was recorded in the 2nd season for the 150 mM of NaCl, which was 0.89 $g/cm^2/day$ compared to the control treatment. The seasonal variation in LAI for example 5.61 in 2022/2023 season compared to 4.98 in 2021/2022 season at 250 mM NaCl revealed the epigenetic or environmental acclimation, potentially through betaine biosynthesis pathways that stabilize photosynthetic machinery under stress. Notably, the non-significant interaction for LAI in 2022/2023 season implies leaf development is less affected by cultivar-salinity interplay over time, possibly due to conserved genetic regulation of leaf expansion (Rozema *et al.*, 2015; Wang *et al.*, 2019). These findings were found in harmony with what were observed by Shehata, *et al.* (2000); Abdel-Mawly and Zanouny (2004); and El Etreiby (2000). Rozema *et al.* (2015) found domesticated sugar beet varieties retained ~90% of sea beet's salt tolerance, consistent with 'Maged's resilience at 150 mM NaCl. On the other hand, Yu *et al.* (2019) linked salt tolerance to upregulated betaine synthesis and SOS1 expression, explaining 'Maged's sustained NAR under stress. Proteomic studies highlight that tolerant cultivars maintain ion balance through enhanced H^+-ATPase activity and ROS scavenging, aligning with 'Maged's superior root diameter and LAI under salinity.

Table 3. Root diameter, Root length, LAI and NAR of (A) the two sugar beet cultivars as affected by (B) the applied salt concentrations in 2021/2022 and 2022/2023 seasons.

Treatments	Root diameter (cm)		Root length (cm)		LAI		NAR ($g/cm^2/day$)	
	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/ 2023	2021/2022	2022/2023
			A- Sugar beet cultivars					
'Maged'	19.50a	15.78a	28.06a	24.17a	4.71a	5.3a	0.7a	0.86a
'Dreeman'	14.72a	14.06b	25.28b	21.72b	3.54b	3.56b	0.58b	0.55b
		B- Salt Concentrations (mM of NaCl)						
0	14.67ab	15.33a	26.67ab	23.67a	4.02bc	3.96bc	0.55ab	0.54e
50	15.83a	15.67a	27.17ab	23.67a	3.53c	3.91c	0.65a	0.67cd
100	16.67a	16.17a	26.83ab	23.00a	3.52c	3.85c	0.51ab	0.79ab
150	14.17ab	15.00ab	23.83b	22.17a	4.22b	4.55bc	0.73a	0.89a
200	12.83b	13.00b	25.50b	22.67a	4.51ab	4.71b	0.71a	0.61de
250	11.50c	14.33ab	30.00a	22.50a	4.98a	5.61a	0.71a	0.77bc
			Interaction					
LSD at 0.05(A x B)	*	*	*	Ns	*	Ns	*	*

***: significant at 0.05 level of probability and ns: Not significant at 0.05 level of probability.**

Root yield and sugar yield

The obtained observations in Table (4) revealed that 'Maged' cultivar consistently showed higher sugar yield (3.02 t/fed) compared to the 'Dreeman' cultivar (3.01 t/fed) in 2022/2023 season but with no significant differences. Moreover, the root yield was comparable among the two cultivars whereas 'Maged' cultivar slightly better than 'Dreeman' with values of 16.80 and 16.28 t/fed, respectively in the 2021/2022 season. These behaviors occurred in the two investigated varieties indicated salt tolerance with an advantage for 'Maged' cultivar. This is because of enhancing the physiological mechanisms which are like the efficiency of the osmotic regulation as well as ion compartmentalization (Dunajska-Ordak *et al.*, 2014). However, at the medium salinity levels such as in 100 mM NaCl; sugar yield was highest for the two investigated varieties whereas both reached 3.10 t/fed. These findings are matched with those for Yu *et al.* (2019) and Dunajska-Ordak *et al.* (2014) who pointed out that the low and moderate salinity can stimulate sugar beet growth through enhancing osmotic adjustment as well as enhancing the photosynthetic efficiency by increasing the chlorophyll retention and the stomatal conductance.

Table (4) also demonstrated the root yield and sugar yield for the 'Maged' and 'Dreeman' sugar beet cultivars during the two investigated seasons 2021/2022 and 2022/2023 under different salt concentrations. The obtained data indicated a significant increase in root and sugar yield for the both sugar beet varieties and salt concentrations. A slight enhancement in the roots' yield was recorded for 'Maged' cultivar compared to 'Dreeman' cultivar. However, the highest means of root and sugar yield were noticed under the 100 mM of NaCl during the both investigated seasons. The peak sugar yield at 100 mM NaCl reflects optimal activation of stress-responsive pathways such as osmotic adjustment through proline accumulation and enhanced antioxidant activity. At 250 mM NaCl salinity, the sugar yield significantly declined because of oxidative stress affecting cellular functions like photosynthesis as well as carbon assimilation. Moreover, root yield reduced at this salinity level which indicated damage in the root structure (caused by excessive ion accumulation and dehydration) as mentioned by Dunajska-Ordak *et al.* (2014). However, the differences observed among the two investigated seasons highlighted several environmental indicators like the temperature as well as the soil properties which affect the salt tolerance. For example, sugar yield at 250 mM NaCl was higher in 2022/2023 compared to 2021/2022 season with values of 2.92 and 2.68 t/fed, respectively.

Table 4. Root yield and sugar yield of (A) the two sugar beet cultivars as affected by (B) the applied salt concentrations in 2021/2022 and 2022/2023 seasons.

Treatments	Root Yield (t/fed)		Sugar Yield (t/fed)	
	2021/2022	2022/2023	2021/2022	2022/2023
	A- Sugar beet cultivars			
'Maged'	16.80a	16.16a	2.69a	3.02a
'Dreeman'	16.28a	16.39a	2.48b	3.01a
	B- Salt Concentrations (mM of NaCl)			
0	17.67ab	16.44ab	2.58abc	2.55d
50	15.57c	16.28ab	2.29c	2.71cd
100	18.38a	18.03a	2.77a	3.10abc
150	16.28bc	15.75b	2.31bc	3.40ab
200	14.87c	14.70b	2.76a	3.44a
250	16.44bc	16.45ab	2.68ab	2.92bcd
	Interaction			
LSD at 0.05 A x B	*	*	*	*

***: significant at 0.05 level of probability.**

Regarding the interaction among the investigated cultivars as well as salinity levels was reflected as a significant effect in root and sugar yield during the seasons**.** The results displayed in figures (2 to 5) revealed that 'Maged' sugar beet cultivar achieved the highest means of root yield (t/fed) in 2nd season under 100 mM NaCl. while the 'Dreeman' achieved the highest root yield (18.90 t/fed) during 2021/2022.

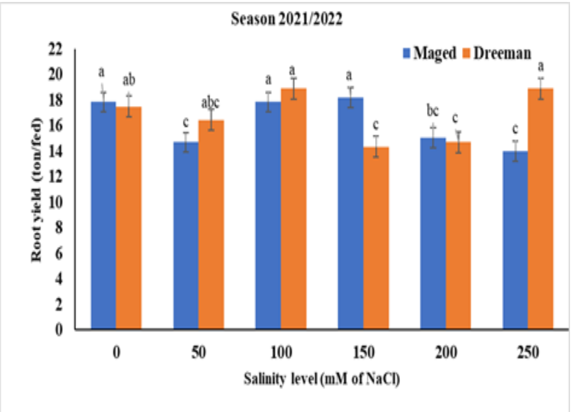

Figure 2. Interaction effect between sugar beet and salinity levels on root yield (ton/fed) in 2021/2022 season.

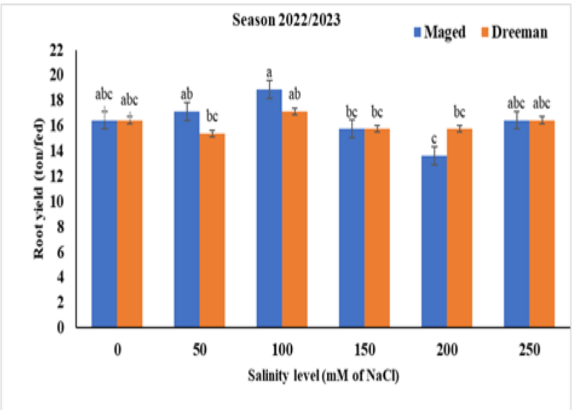

Figure 3. Interaction effect between sugar beet and salinity levels on root yield (ton/fed) in 2022/2023 season.

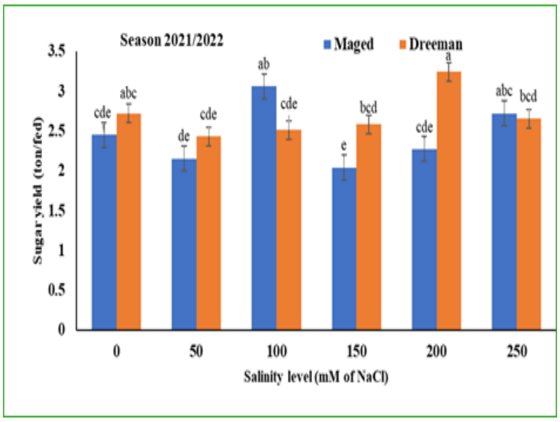

Figure 4. Interaction effect between sugar beet and salinity levels on sugar yield (ton/fed) in 2021/2022 season.

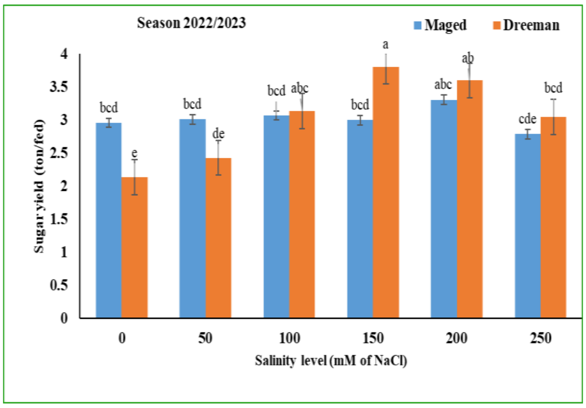

Figure 5. Interaction effect between sugar beet and salinity levels on sugar yield (ton/fed) in 2022/2023 season.

Rozema *et al.* (2015) found that sugar beet's cultivars retained significant salt tolerance lead to stable yields under moderate salinity. Furthermore, Yu *et al.* (2019) identified transcriptomic changes associated with salt tolerance, including upregulated genes for osmotic adjustment and ion transporters, which may explain the resilience of 'Maged' under higher salinity levels. Additionally, Wang *et al.* (2019) reported that salt-tolerant genotypes displayed higher photosynthetic rates and chlorophyll content under stress, supporting the enhanced sugar yields observed at moderate salinity levels in this study.

Total soluble solids (TSS) and purity percentage

Concerning to total soluble solids (TSS) of sugar beet roots (Table 5), during the both investigated seasons, 'Maged' variety demonstrated higher TSS values which ranged between 21.72 and 22.00% as compared to 'Dreeman. The sustained data (Table 5) significantly increased with salinity increase in the 1st harvested season; while no significant differences were recorded for these parameters in the 2nd season. The TSS enrichment was due to salt absorption increase. Regarding the purity percentage, no significant differences were observed among the two varieties and also during salinity increase in the two investigated seasons. Moreover, slight decrease in juice purity was recorded during salinity increase, whereas the concentrations 100 mM of NaCl recorded best juice purity during the second season.

Table 5. Total soluble solids (TSS) and purity percentage of (A) the two sugar beet cultivars as affected by (B) the applied salt concentrations in 2021/2022 and 2022/2023 seasons.

Treatments	TSS (%)		Purity (%)	
	2021/2022	2022/2023	2021/2022	2022/2023
A- Sugar beet cultivars				
'Maged'	22.00a	21.72a	80.85a	80.78a
'Dreeman'	21.11b	21.77a	83.21a	80.77a
B- Salt concentrations (mM of NaCl)				
0	21.00b	22.00a	81.17a	80.17b
50	21.50b	21.67a	80.08a	76.58c
100	20.67b	21.33a	82.91a	86.77a
150	22.00ab	21.66a	81.77a	81.83b
200	23.00a	22.16a	84.35a	79.19bc
250	21.16b	21.66a	81.93a	80.11b
Interaction				
LSD 0.05 A x B	*	Ns	Ns	Ns

***: significant at 0.05 level of probability and ns: Not significant at 0.05 level of probability.**

Maged cultivar performed better than Dreeman during the two seasons, while there are seasonal differences were observed in TSS values which was higher in the 2021/2022 season than 2022/2023 season. This variability may reflect environmental factors such as temperature or soil conditions as previously mentioned.

In this study, the juice purity reduced with salinity increase which matched with the findings of Higazy *et al.* (1995); Darwish *et al.* (1995); and Kandil, *et al.* (1999) who mentioned that the juice impurity increased and quality decreased under the salinity conditions.

Irrigating sugar beet varieties (Maged and Dreeman) with different concentrations of saline water in the two seasons (2021/2022 and 2022/2023) set off a cascade of detrimental effects, ultimately reducing crop's yield and quality. The high water salinity affects plant's growth as well as structural changes, stemming from the disruption of essential physiological processes (Bharti *et al.*, 2014). This occurs because the increased salinity creates lower water potential outside the root cells, making it difficult for absorbing water, leading to a state of physiological drought. Moreover, the excessive accumulation of sodium and chloride ions within plant tissues causes ion toxicity, interfering with enzyme activity, protein synthesis, and damaging cell membranes (Cheng *et al.*, 2022). This ion toxicity, coupled with the induced water stress, also leads to nutrient imbalances, as the uptake of essential elements like potassium, calcium, and nitrogen is hampered. The combined effects of these stresses; water stress, salt stress, and ion imbalance stress result in smaller plants with reduced leaf size and root development, directly impacting the photosynthetic capacity and storage capability of the sugar beets (Flowers and Colmer 2008). Consequently, the sugar content and purity are also compromised, reducing the overall quality of the harvested beets (Zhang *et al.*, 2023).

CONCLUSION

Under greenhouse conditions, the sugar beet cultivar 'Maged' exhibited a notable tolerance to salinity up to 250 mM of NaCl, suggesting its potential for cultivation in newly reclaimed soils affected by saline conditions. While a significant interaction between sugar beet cultivars and salinity levels influenced most of the studied characteristics, sugar beets generally demonstrated a capacity to tolerate salinity up to 250 mM of NaCl, albeit with a reduction in yield, productivity, and quality. These findings underscore the need for further research to comprehensively investigate the effects of salt stress on the growth, productivity, and quality characteristics of various sugar beet cultivars across diverse locations. Moreover, expanding the application of these findings to field conditions in newly reclaimed, salinity-affected soils is crucial to validate the greenhouse results and optimize sugar beet production in real-world scenarios. Such research will pave the way for informed cultivar selection and management practices to maximize yields and quality in saline environments.

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تأثير الإجهاد الملحي على نمو وإنتاجية وجودة جذور صنفين من بنجر السكر

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الملخص

الفهم الكيفي لاستجابة النباتات المختلفة للإجهاد الملحي يمكن أن يوفر رؤى قيمة لإدارة الأراضى المتأثرة بالاملاح مما يؤدي إلى تحسين الإنتاج الزراعي وتعزيز صحة التربة. لذلك هدفت الدراسة إلى تقييم تأثير خمسة مستويات من الملوحة (٥٠، ١٠٠، ١٥٠، ٢٠٠، و٢٥٠ Mm من NaCl) على النمو والمحصول وجودة صنفين من بنجر السكر (Beta vulgaris L.)صنف "Maged" وصنف "Dreeman". أظهرت النتائج أن صنف "Maged" حقق قيماً عالية المعنوية في صفات النمو والمحصول والجودة مقارنةً بصنف "Dreeman". بالإضافة إلى ذلك، أظهرت النتائج تبايناً معنوياً بين مستويات الملوحة، حيث أظهر بنجر السكر تحملاً للملوحة حتى تركيز ٢٥٠ Mm من NaCl مع انخفاض مستقر في المحصول والإنتاجية والجودة. كما أثر التفاعل بين الصنفين المدروسين ومستويات الملوحة تأثيراً معنوياً في معظم الصفات المدروسة.بشكل عام، يمكن التوصية بصنف بنجر السكر "Maged" لقدرته على تحمل الملوحة حتى تركيز ٢٥٠ Mm من NaCl. لذا، توصي الدراسة بزراعة هذه الأصناف في الأراضي المستصلحة حديثًا المتأثرة بالملوحة، مما يساهم في تقليل الملوحة في المناطق الجافة.

الكلمات الدالة: بنجر السكر، الملوحة، الأصناف، المحصول، النمو، الجودة