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Improving Drought Tolerance in Sugar Beet by Foliar Application of Anti-Stress Compounds

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DROUGHT stress affects greatly on sugar beet productivity; thus, two field trials were conducted to investigate the effects of foliar applications of L-ornithine (150 ppm), ascorbic acid (500 ppm), and silicon (2000 ppm) regarding the performance of three sugar beet cultivars (Neagre, Dreeman, and BTS 645) under four irrigation levels (50%, 40%, 30%, and 20% of field capacity (FC)) in clay loam soil. Results showed that anti-stress compounds, irrigation levels, and cultivars significantly affected growth traits (dry weight of leaves and roots, leaf area index) and yields of top, root, and white sugar. Sucrose and extractable sucrose percentages were enhanced under moderate drought levels. However, irrigation at 20% FC had the most adverse effects, reducing extractable sucrose by 1.3-2.7%, root yield by 29-33%, and white sugar yield by 38-40% compared to irrigation at 50% FC. Cultivar performance varied under different drought and anti-stress compound combinations. Watering plants at 40 or 50% FC and spraying it with L-ornithine increased root weight and yields, while watering at 30 or 40% FC and spraying with ascorbic acid or silicon increased sucrose and extractable sucrose contents. Among the compounds, L-ornithine had the greatest impact on growth and yield traits, while ascorbic acid and silicon influenced the chemical constituents of beet juice. The Dreeman cultivar exhibited the highest drought tolerance based on tolerance index (TOL), stress susceptibility index (SSI), geometric mean production (GMP), and stress tolerance index (STI) for root and sugar yields. GMP and SSI indices are effective for selecting high-yielding, stress-tolerant genotypes.

Keywords: Sugar beet, Quality and yield, Water stress, Anti-stress compounds, Drought indices.

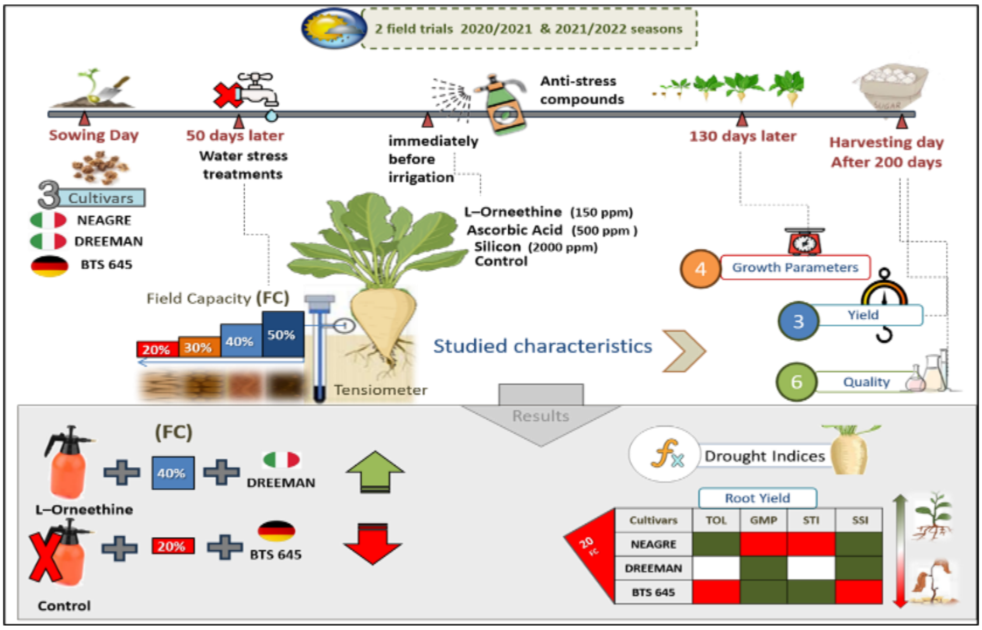

Fig. 1. Scheme referring methodology and important results of study along plant growth for determining performances of three sugar beet cultivars (NEGRE , DREEMAN and BTS-645), due to influence of anti-drought stress compounds (L-Ornethine, Ascorbic Acid and Silicon) compared control for increase yield productivity under different four water treatments according field capacity (FC %) during two field trials.

: increasing and, reduction of yield respectively, stress tolerance (TOL), geometric mean of productivity (GMP), stress tolerance index (STI),) and stress susceptibility index (SSI).

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Introduction

In Egypt, sugar beet (Beta vulgaris L.) contributes about 64% of sugar production annually. It's considered the greatest benefits of sugar beet crop due to its potentiality grown under the margin lands (calcareous, saline, alkaline and poor fertile soils), as a strategic crop as well as its more exceeded production of sugar under these conditions comparing with sugar cane. However, water stress problems are classified as one of the most obstacles that facing these areas. Obviously fresh water is necessary for vegetative growth in order to exceed plant crop productivity noted by Darwesh et al., 2019). Therefore, water limits and drought conditions especially in arid and semiarid zones which influenced by dramatic climate changes are considered the main factors affecting the yield and productivity of agricultural crops in many regions all over the world (Riccardi et al., 2016). The response of sugar beet plants to drought at the crop level is a complex process because its response involves the integration of stress effects at all stages of crop development. Drought stress inhabits growth of crop plants by several influences of physiological and biochemical metabolic processes, for example respiration, photosynthesis systems, ion uptake, translocation, carbohydrates, nutrient metabolism and growth promoters (Farooq et al., 2008). Basically, fresh root weight of sugar beet under water stress will almost always decrease, although dehydration brought on by water stress can raise sucrose content on a fresh weight basis. (Masri et al., 2015) reported that in spite of 75 % of irrigation water requirements were applied, the production of sucrose was scarcely affected. However, Hoffmann (2010) reported that the presence of compatible solutes such as K, Na, amino acids, glycine betaine, glucose, and fructose in the storage root of sugar beet during drought conditions could potentially hinder the accumulation of sucrose. (Bnhassan-Kesri et al., 2002). reported that abiotic stresses, especially drought stress, influenced greatly of plant cell growth. Besides, this type of stress induced multiple effects behave habitat of cell division and growth rates. (Richter et al., 2001). found that drought stress is playing vital role of yield loss on sugar beet in the UK. (Jaggard et al.,1998) recorded a reduction of 10% annually in sugar beet yield production and in rare rains dates it decreasedyields by up to 50%, equivalent to 4 tons of sugar ha^{-1}. Many investigators recorded variable and significant decreases in growth, quality and assessment characteristics of sugar beet varieties that were grown under water stress conditions; (Stagnari etal., 2014), (Tarkalson and King, 2014), (Masri et al.,2015), Moosavi*et al.* (2017), Mahmoud etal., 2018), (Hamed and Emara, 2019), (Abu-Ellail and El-Mansoub, 2020). Islam et al.,(2020), (Ghaffari et al., 2021), (Yassin et al.,2022) and (Prysiazhniuk et al., 2023). Generally, Agricultural sector faces a significant challenge in producing more food with less water. This can be accomplished by effectively managing the water requirements of plants grown under deficit irrigation. Nowadays, new released varieties have been developed to improve plant performance in stressful environmental conditions. Exogenous administration of antioxidants including silicon, ascorbic acid, and L-ornithine has been shown in numerous experiments to improve agricultural drought resistance. (Ahmed et al., (2013), Latif et al., (2016), Hussein et al., (2019), Abid et al., (2020). Veroneze-Júnior *et al.,* 2020; Abd El-Gawad*et al.,* 2021). Referring to these studies, applying these compounds can improve several plant parameters, including morphology studies, photosynthetic system, gas exchange attributes and relative water content (RWC). Additionally, using of these compounds facilitates the accumulation of osmoles and antioxidants, which helps in maintaining osmotic balance within the plants. Although polyamines are recognized to be important plant growth regulators and to have a good effect under a variety of stressors, that are relatively expensive compounds.Therefore, the beneficial effects of polyamines can be obtained at low cost by using the precursor of these compounds. L-ornithine is the promoter of polyamines which are very important for plant growth regulation and its development (Martin-Tanguy, 2001). Using of L-ornithine via spraying application has been linked to improvements in various aspects of plant physiology. These include enhanced levels of photosynthetic pigments, protein profiles, and antioxidant enzymes like catalase and peroxidase, alongside reduced lipid peroxidation. Moreover, it increases amino acids and total soluble sugars, raising up enhancement drought tolerance in sugar beet plants. (Hussein et al., 2019). Application of Silicon to plants, actually, impacted for dehydration resistance at tissue or cellular levels by development the water status (Gao et al., 2006). Due to silicon reduces oxidative damage to functional molecules and amplifies anti-oxidant defense mechanisms; it improves drought tolerance in plant crops(Gong et al., 2005). According to Cooke and Leishman (2011), silicon strengthens cells and helps plants adapt to environmental stressors. Under stressed situations, plants frequently produce excessive amounts of reactive oxygen species (ROS).One of the most common non-enzymatic antioxidants, ascorbic acid (vitamin C) has the ability to both scavenge reactive oxygen species (ROS) and modify a number of essential plant processes in both stressed and unstressed environments (Fig. 1).

In addition to, Ascorbic acid is playing a vital role to support formation for proteins and lipids under stress conditions. where the applying seed soaking with the addition of foliar spraying by 200 ppm concentration of ascorbic acid for sugar beet grown under salt stress significantly increased root yield by (6.99 and 4.54 tons/fed) and productivity sugar yield by (2.19 and 2.06 tons/fed) over that gained by untreated plants (Abdel Fatah and Sadek, 2020). This investigation study was carried out to mining valuable information that can be used to adopt proper treatments for improving sugar beet productivity with future drought prospects under arid regions. Thus, the objectives of the study were to: a- Evaluation of yield and quality traits of some sugar beet cultivars under different water stress regimes, b- Study the role of some anti-stress compounds in enhancing yield and quality traits of sugar beet under different water stress conditions, c- Estimating the most selection criteria related to drought tolerant in sugar beet.

Materials and Methods:

Experimental site and its characteristics

Two field experiments were carried out during the Two field experiments were carried out during the 2020/2021 and 2021/2022 seasons at the Agriculture Experimental Research Station, Faculty of Agriculture, Cairo University, Giza, Egypt. The Experiment location was 22.50 m above sea level and it is situated within 30°, 02´ N latitude and 31°, 13´ E longitude. Averages of weather parameters obtained from Nasa pro in the experimental location such as (temperature **c°**, Precipitation mm and relative humidity %) whereas Figure 2 presented the recorded data monthly during plant growth habit.

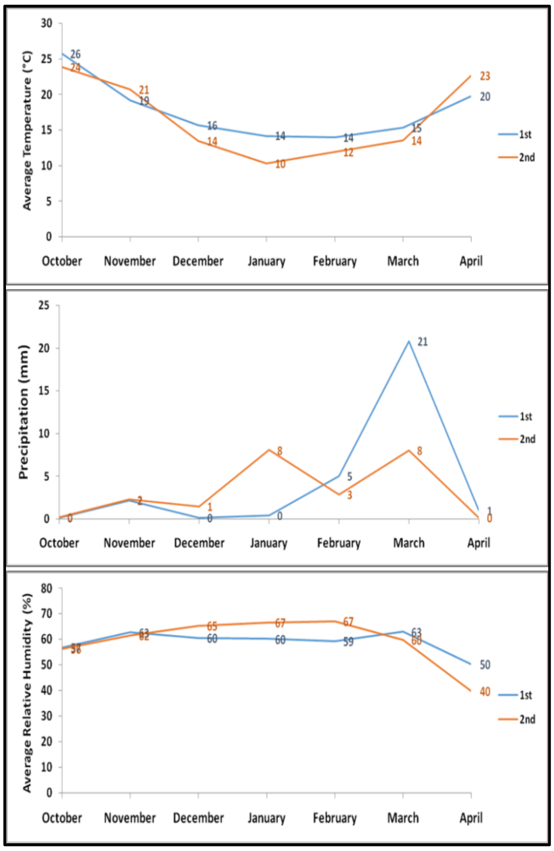

Fig. 2. Averages of weather parameters (temperature c°, Precipitation (mm) & relative humidity %) recorded monthly during plant growth habit in the experimental site for both seasons.

Soil samples (0–0.3 m) were taken in autumn before application of fertilizers and soil properties were determined according to the standard method. Preceding crops and soil properties of the sugar beet experimental fields in both seasons are listed in Table (1). Data in Table (1) indicated that the soil of the experimental site was clay loam and poor in organic matter and no salinity problems were observed.

Table 1. Preceding crops and properties of sugar beet experimental fields during 2020/21and 2021/22 seasons.

	2020/21 season	**2021/22 season**
Preceding crop	Faba bean	Corn
Physical properties		
Sand %	40	38
Silt %	20	23
Clay %	40	39
Soil texture	Clay loam	Clay loam
Chemical properties		
pH	7.30	7.50
EC (mmhos/cm)	0.72	0.80
Organic matter %	2.15	1.95
Available N %	0.52	0.46
Available P (mg kg^{-1})	4.85	4.22
Available K (mg kg-1)	74.00	65.00
Available Na (mg kg-1)	85.00	98.00
Available Fe (ppm)	4.20	4.12
Available Zn (ppm)	3.40	3.25
Available Mn (ppm)	4.30	4.20

Experimental materials and procedures

Plant materials:

Multi-germ seeds of three sugar beet cultivars; Neagre, Dreeman, and BTS 645 were obtained from Nobaria Sugar and Refining Company. Seeds of sugar beet cultivars were sown on ridges 60 cm apart and 17.5 cm between hills to ensure 40 thousand plants/feddan (feddan= 4200 m^2). Sugar beet seeds were sown on the second week of October of each season. Nitrogen was added at a rate of 60 kg N/feddan in the form of ammonium nitrates (33.5% N) in two equal splits, the first was applied after thinning at 5-leaf stage and other split were added at one month later. Phosphorous in the form of superphosphate (15.5%) at the rate of 15.5 Kg P2O5 /feddan was added before sowing and during soil preparation. Potassium in the form of potassium sulfate (48%) was added at the rate of 24 Kg K2O/feddan with the first dose of nitrogen. Thinning took place to one plant/hillat 5-leaf stage (about 5 weeks from planting). Other cultural practices were done as recommended. Water stress treatments: Soil moisture depletion of 50%, 40%, 30% and 20% of field capacity under surface irrigation system were considered for experimentation. The field capacity of the soil is the amount of water a well-drained soil holds after free water has drained off. It is thus, the maximum amount of water, a soil can hold against gravity. After 48 hours of field surface irrigation, soil samples were taken from the experimental treatments at depths of 20, 30 and 40 cm from three different sites of experimental field by Soil Auger. Mixed samples were weighed and put in an electric oven at a temperature of 105 C0 for 24 hours. Dried samples were weighed and field capacity was recognized via Souza et al. (2000). The field capacity of the experimental soil (clay loam) was found to be 50 %. For measuring soil moisture content during the different stages of crop growth, Tensiometerswere placed at the top, middle, and bottom regions of the field in the plant row where roots are concentrated and taking up the most water. Water stress treatments started 50 days later after seed sowing. Anti-stress compounds: Three different compounds were applied; L-ornithine (150 ppm), Ascorbic Acid (500 ppm) and Silicon (2000 ppm). Foliar application of anti-stress compounds as well as the control treatment (no spraying) started 35 days after planting and immediately before irrigation. Each water stress treatment received three spraying of each anti-stress compound across the growing season. Experimental design: Experimental treatments were laid out in figure 3 as a strip split plot design with three replicates in according to Gomez and Gomez (1984). The experimental treatments were distributed as follows: the horizontal factor (three different anti-stress compounds as well as the control treatment), the vertical factor (4 levels of water stresses treatments) and the subplot factor (three sugar beet cultivars). The sub plot area was 15m^2 and consisted of five ridges of 5m in length and 60cm apart to ensure about 143 plants/sub plot.

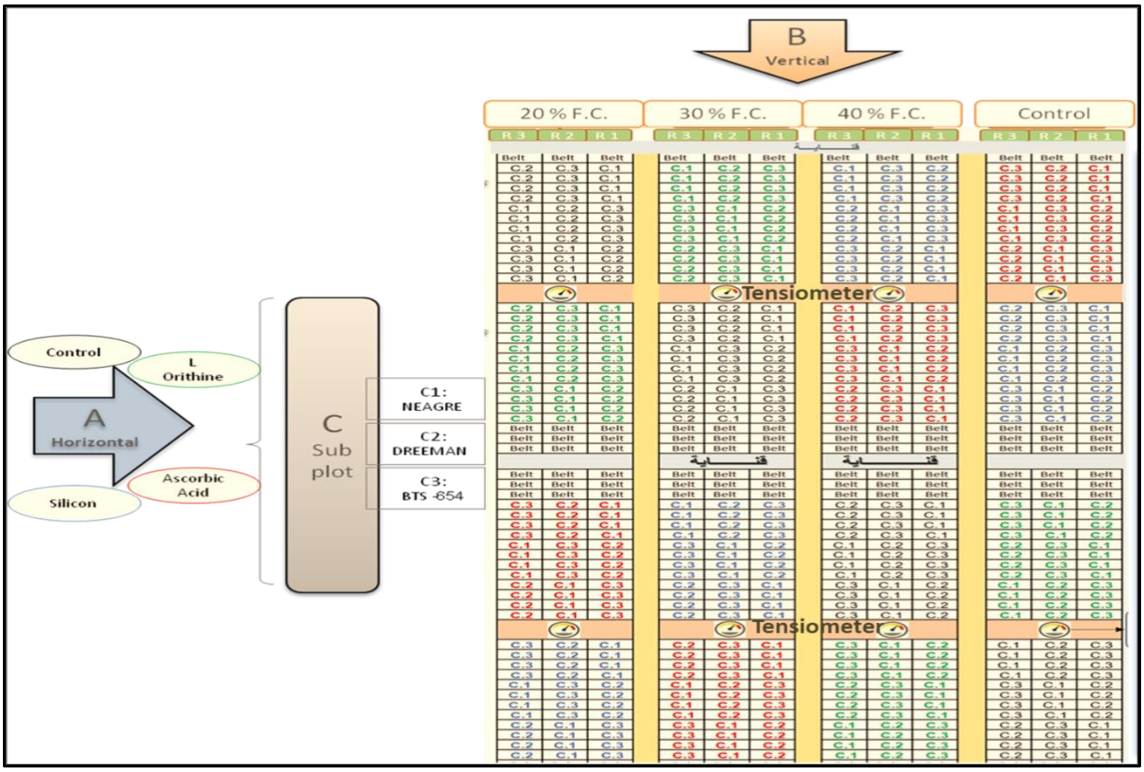

Fig. 3. Experimental layout for 3 studied factors (A,B and C) arranged due to Strip split plot design with 3 replicates.

Data recorded:

At 130 days after planting a representative sample was taken from each treatment to determine Leaf area index, shoot and root weights per plant. Shoots and roots were dried at 70c^0 for 72 hours then root top ratio was calculated. Leaf area index (LAI) = unit leaf area per plant (cm2)/ plant ground area (cm2)] was determined according to Watson (1958) and leaf area was determined using area meter, ATA60, Model 3100. Sugar beet plants harvest took place after 200 days from sowing in both seasons. At harvest twenty roots from each subplot were taken to determine the following traits at the lab of Nobaria Sugar and refining companies that determine sucrose percentage in juice quality characteristics by using a saccharometer with lead acetate extract from freshly moderated roots according to Carruthers and Oldfield (1960). The percentages of Potassium (K), Sodium (Na) and α-amino-N were determined. Extractable sugar percentage (ES %) was determined according to the following formula ES% = pol- [0.343(K + Na) + 0.094 α-amino N + 0.29] according to Renfield*et al* (1974), where Pol = sucrose percentage, juice quality percentage (QZ) = (ES%/ pol) x 100, impurities percentage = [0.343(K + Na) + 0.094 α-amino N + 0.29]. Yields: top and root yields (ton/fed) were calculated on plot basis and white sugar yield (ton/fed) = root yield x (ES%/100).

Drought tolerance indices:

Selection criteria for identification of drought tolerant genotypes have been proposed. These criteria are based on relative yields in stress and non-stress conditions. Stress tolerance indicators useful for selecting adapted genotypes included: Tolerance index (TOL) = YP - YS (Rosielle and Hamblin, 1981), Geometric mean productivity (GMP) = $\sqrt{Yp\,.Ys}$ (Fernandez, 1992), Stress tolerance index (STI) = [(YP × YS) / (Ÿp)^2] (Fernandez, 1992), Stress susceptibility index (SSI) = [1 - (YS/YP)]/DII and drought intensity index (DII) = 1 - (ŸS / ŸP) (Fischer and Maurer, 1978), where Yp and Ys represents a genotype mean yield under non stress and stress conditions, respectively, while ŸP and ŸS represents mean yield of all genotypes under non stress and stress conditions, respectively.

Statistical analysis

Collected data were statistically analyzed using analysis of variance of the strip spilt plot design according to procedures outlined by Gomez and Gomez (1984) using MSTAT-C computer package (Freed et al., 1989). Treatment mean comparisons were performed using least significant difference (LSD) at 5% level of probability. The correlation coefficients between different stress tolerance indicators (TOL, GMP, STI and SSI) and the differential yield responses under the contrasting environments were computed using MSTAT-C computer package.

Results and Discussion:

Main effects:

Data presented in Table 2 show effects of anti-stress compounds, drought treatments and sugar beet cultivars on dry leaves and roots, root top ratio and leaf area index in 2020/2021 and 2021/2022 seasons. Anti-stress compounds had a significant ($P \leq 0.05$) effect on all studied growth traits in both seasons except root top ratio in the first one. Foliar application of L-ornithine showed superiority over the other two compounds for dry leaves and roots weight and leaf area index. However, no one of the three compounds surpassed the control treatment (no spraying) except L-ornithine for leaves dry weight in the 2nd season and leaf area index in the first season, which indicates that these compounds may have been used below the ideal rate. Water stress treatments had a significant ($P \leq 0.05$) effect on growth characteristics. Increasing water stress levels up to 30% and 20% of field capacity had a negative and significant effect on dry leaves and roots and leaf area index during the two seasons. The lowest values of dry leaves (73.69 and 73.58 g), dry roots (151.26 and 167.48 g) and leaf area index (1.21 and 1.18) were recorded when irrigation of sugar beet plants at 20% of field capacity in both first and second seasons, respectively. Three studies have demonstrated adverse impacts of water stress on sugar beetroot growth: Mahmoud *et al*. (2018), Ghaffari*et al.* (2021), and Stagnari et al. (2014). The four growth characteristics dry leaves and roots, root top ratio, and leaf area index were very different amongst the cultivars of sugar beetroot over the two growing seasons. Dreeman showed superiority in most growth traits except for leaves dry weight in the first season.

Table 2. Main effects of anti-stress compounds, water stress and varieties on some growth parameters of sugar beet during 2021 and 2022 harvesting seasons.

Treatments	Leaves dry weight (g)		Root dry weight (g)		Root Top Ratio		Leaf area index (LAI)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
				Anti-stress compounds				
Control	96.70a	99.57b	269.30a	238.34a	2.86a	2.39bc	2.16b	2.09a
L-Ornithine (150 ppm)	95.40a	107.21a	240.97b	249.00a	2.70a	2.40b	2.49a	2.19a
Ascorbic Acid (500 ppm)	89.09b	93.11c	227.08c	202.89b	2.70a	2.30c	1.90c	1.90b
Silicon (2000 ppm)	74.60c	86.29d	212.56d	248.61a	2.93a	3.02a	1.98c	1.97b
L.S.D.at 5%	**3.29**	**3.86**	**10.03**	**10.79**	**ns**	**0.81**	**0.11**	**0.10**
				Water stress (As % of field capacity)				
50	97.13 b	106.18 b	270.98 b	329.26 a	2.98b	3.14 a	3.10 a	2.79 a
40	111.49 a	114.30 a	286.91 a	217.15 b	2.76 c	1.95 c	2.47 b	2.53 b
30	73.48 c	92.12 c	240.76 c	224.94 b	3.33 a	2.52 b	1.76 c	1.65 c
20	73.69 c	73.58 d	151.26 d	167.48c	2.12 d	2.50 b	1.21 d	1.18 d
L.S.D.at 5%	**3.29**	**3.77**	**11.48**	**15.08**	**0.11**	**0.14**	**0.13**	**0.14**
				Sugar beet varieties				
Neagre	90.42a	94.44b	233.02b	223.02b	2.67b	2.54b	2.01b	1.85b
Dreeman	83.77b	100.22a	235.46b	262.81a	2.96a	2.67a	2.19a	2.11a
BTS 645	92.66a	94.97b	243.95a	218.29b	2.76b	2.38c	2.20a	2.15a
L.S.D.at 5%	**3.27**	**3.03**	**6.37**	**9.55**	**0.12**	**0.10**	**0.10**	**0.08**

Data presented in Table 3 show the effects of anti-stress compounds, drought treatments and sugar beet cultivars on impurities contents (K%, Na % and α- amino Nitrogen %) in sugar beet juice in 2020/2021 and 2021/2022 seasons. Quality of sugar beet root depends not only on the amount of sucrose in the collected roots but it also on the amount of naturally occurring soluble components of the root, known as contaminants, which prevent sucrose from being extracted during regular factory operations (Campbell, 2002). 1.5 to 1.8 kg of sucrose cannot crystallize for every kilogram of impurities; as a result, the sucrose is lost to molasses (Dutton and Huijbregts, 2006). Sodium has a greater influence than potassium or amino-nitrogen on determining the relative sucrose concentration (Campbell and Fugate, 2015). In the present study, anti-stress compounds had no appreciable impact on contaminantscontents throughout either season. Except for sodium content in the first season. Impurities contents in terms of Sodium and α- amino Nitrogen insignificantly were affected by water stress levels, while potassium content was significantly affected by water stress conditions and the high percentage of potassium (4.50 and 5.08%) was recorded in plants irrigated at 50% of field capacity in both seasons. Sugar beet cultivars varied significantly in their contents of juice impurities in both seasons except for sodium and α- amino Nitrogen in the first season.

Table 3. Main effects of anti-stress compounds, water stress and varieties on impurities content in sugar beet juice during 2021 and 2022 harvesting seasons.

Treatments	Potassium (K %)		Sodium (Na %)		α- amino Nitrogen %	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
			Anti-stress compounds			
Control	4.02a	4.67a	1.49b	2.64a	1.30a	1.68a
L-Ornithine (150 ppm)	4.10a	4.64a	1.39b	2.49a	1.38a	1.77a
Ascorbic Acid (500 ppm)	4.12a	4.51a	1.529ab	2.40a	1.30a	1.60a
Silicon (2000 ppm)	4.15a	4.60a	1.74a	2.60a	1.35a	1.64a
L.S.D.at 5%	**ns**	**ns**	**0.23**	**ns**	**ns**	**ns**
			Water stress (As % of field capacity)			
50	4.50 a	5.08 a	1.90 a	2.24 a	1.45 a	1.64 a
40	3.92 b	4.71 ab	1.56 a	2.54 a	1.17 a	1.50 a
30	3.80 b	4.21 b	1.29 a	2.76 a	1.30 a	1.75 a
20	4.16 ab	4.42 b	1.39 a	2.58 a	1.42 a	1.79 a
L.S.D.at 5%	**0.41**	**0.56**	**ns**	**ns**	**ns**	**ns**
			Sugar beet varieties			
Neagre	3.94b	4.63b	1.47a	2.54a	1.42a	1.86a
Dreeman	3.96b	4.36c	1.53a	2.74a	1.25a	1.59b
BTS 645	4.39a	4.82a	1.61a	2.32b	1.32a	1.57b
L.S.D.at 5%	**0.19**	**0.18**	**ns**	**0.21**	**ns**	**0.17**

Data presented in Table 4 show the effects of anti-stress compounds, drought treatments and sugar beet cultivars on juice characteristics to sugar%, quality % and extractable sucrose % in 2020/2021 and 2021/2022 seasons. As a result of their insignificant effects on impurities contents, anti-stress compounds had no discernible impact on the quality attributesexcept for extractable sucrose in the second season. Foliar application of ascorbic acid in the second season was recorded the highest percentage of extractable sucrose (17.09 %). Drought treatments had a significant effect on all studied quality traits in both seasons except on quality percent in the first season. The lowest percentage of sucrose (17.57 and 17.83 %) and extractable sucrose (15.24 and 14.98%) was obtained by increasing drought level up to 20% of field capacity in the first and second seasons, respectively. The adverse effect of drought stress on the quality traits of sugar beet has been reported by (Masri et al., 2015), (Hamed and Emara 2019), Abu-Ellail and El-Mansoub 2020). Sugar beet cultivars varied significantly in their quality traits only in the first season and the highest percentage of sucrose (19.15 and 19.78 %) and extractable sucrose (16.87 and 16.86 %) was recorded by the cultivar Neagre in both seasons. Differences Among sugar beet cultivars in quality traits have been reported by (Masri and Safina 2015) and (Mahmoud et al., 2018).

Table 4. Main effects of anti-stress compounds, water stress and varieties on juice quality traits of sugar beet during 2021 and 2022 harvesting seasons.

Treatments	Sucrose %		Quality %		Extractable sucrose %	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
			Anti-stress compounds			
Control	18.55 a	19.61 a	87.52 a	84.86 a	16.25 a	16.66 b
L-Ornithine (150 ppm)	18.57 a	19.55 a	87.54 a	84.98 a	16.27 a	16.64 b
Ascorbic Acid (500 ppm)	18.77 a	19.90 a	87.42 a	85.82 a	16.43 a	17.09 a
Silicon (2000 ppm)	18.90 a	19.85 a	87.07 a	85.19 a	16.47 a	16.94 ab
L.S.D.at 5%	ns	ns	ns	ns	ns	0.36
			Water stress (As % of field capacity)			
50	19.16 ab	20.65 a	86.29 a	85.62 a	16.53 ab	17.69 ab
40	18.71 b	20.80 a	87.76 a	85.88 a	16.43 b	17.88 a
30	19.36 a	19.62 a	88.79 a	85.46 a	17.20 a	16.78 b
20	17.57 c	17.83 b	86.71 a	83.89 b	15.24 c	14.98 c
L.S.D.at 5%	**0.44**	**1.24**	**ns**	**1.47**	**0.72**	**1.06**
			Sugar beet varieties			
Neagre	19.15 a	19.78 a	88.06 a	85.11 a	16.87 a	16.86 a
Dreeman	18.46 b	19.61 a	87.55 a	85.21 a	16.17 b	16.73 a
BTS 645	18.48 b	19.77 a	86.55 b	85.31 a	16.01 b	16.90 a
L.S.D.at 5%	**0.24**	**ns**	**0.70**	**ns**	**0.30**	**ns**

Data presented in Table 5 show the effects of anti-stress compounds, drought treatments and sugar beet cultivars on mean root weight and yields of top, roots and white sugar in 2020/2021 and 2021/2022 seasons. Data in Table 5 revealed that mean root weight and yields of top, roots and white sugar were significantly affected by application of anti-stress compounds during the two growing seasons. The control (no spraying) and L-ornithine treatments were significantly better than ascorbic acid and silicon in their effects on all the previously mentioned traits in both seasons. It is noted that although anti-stress compounds used in this study varied significantly among themselves in their effect on the traits under study, none of them significantly outperformed the control treatment. Therefore, the use of such substances as anti-drought stress in sugar beets requires further study, either in terms of the doses used or in the methodology and timing of their use to elucidate the biochemical impact of such compounds on plants. Mean root weight and yields of top, roots and white sugar were significantly influenced by irrigation levels for each season. Increasing water stress from one level to another led to a noticeable significant decrease in the value of the previously mentioned traits in both seasons. However, the most adversely affect was when watering sugar beet plants at 20% of field capacity. Increasing drought level up to 20% reduced the values of root weight (about 33% and 30%), top yield (about 32% and 28%), root yield (about33% and 29%) and sugar yield (about 38% and 40%) as compared to watering plants at 50% of field capacity in the first and second seasons, respectively. The reduction in sugar beet yields due to drought stress has been reported by Tarkalson and King (2014), (Masri et al., 2015), (Mahmoud et al., 2018), (Ghaffari et al., 2021 and Yassin et al., 2022).Sugar beet cultivars varied significantly in their mean root weight, top yield, roots yield and white sugar yield in both seasons. The cultivar Dreeman gave the highest and significant beet root yield (19.41 and 17.85 ton/fed.) and beet sugar yield (3.13 and 3.01 ton/fed.) in the first and second seasons, respectively. The superiority of the cultivar Dreeman in sugar yield was due to its superiority in root yield rather than its sucrose content. Variability in beet yields among sugar beet genotypes was recorded by Tarkalson and King (2014), Mahmoud et al., 2018) and Abu-Ellail and El-Mansoub (2020).

Table 5. Main effects of anti-stress compounds, water stress and varieties on mean root weight and sugar beet yields during 2021 and 2022 harvesting seasons.

Treatments	Mean root weight (kg)		Top yield (ton/fed.)		Root yield (ton/fed.)		Sugar yield (ton/fed.)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
				Anti-stress compounds				
Control	0.98[a]	0.92[a]	9.73[a]	9.46[a]	19.09[b]	18.33[a]	3.10[b]	3.07[a]
L-Ornithine (150 ppm)	0.98[a]	0.90[b]	9.65[ab]	8.89[bc]	20.25[a]	18.19[a]	3.31[a]	3.06[a]
Ascorbic Acid (500 ppm)	0.80[c]	0.78[d]	9.03[c]	8.72[c]	16.67[d]	16.36[b]	2.74[c]	2.81[b]
Silicon (2000 ppm)	0.86[b]	0.82[c]	9.29[bc]	9.08[b]	17.56[c]	16.48[c]	2.89[c]	2.82[b]
L.S.D.at 5%	**0.04**	**0.02**	**0.37**	**0.26**	**0.51**	**0.41**	**0.18**	**0.09**
				Water stress (As % of field capacity)				
50	1.11[a]	1.04 [a]	11.37 [a]	10.55 [a]	21.78 [a]	20.34 [a]	3.59 [a]	3.60 [a]
40	0.93 [b]	0.85 [b]	10.02 [b]	9.58 [b]	20.11[b]	18.11 [b]	3.31 [b]	3.23 [b]
30	0.83 [c]	0.80 [c]	8.61 [c]	8.41 [c]	16.99 [c]	16.47 [c]	2.90 [c]	2.76 [c]
20	0.74 [d]	0.73 [d]	7.70 [d]	7.63 [d]	14.70 [d]	14.44 [d]	2.23 [d]	2.16 [d]
L.S.D.at 5%	**0.05**	**0.03**	**0.45**	**0.19**	**0.55**	**0.50**	**0.18**	**0.17**
				Sugar beet varieties				
Neagre	0.83[b]	0.84[b]	8.85[b]	8.83[c]	16.83[c]	16.87[c]	2.84[c]	2.86[b]
Dreeman	0.93[a]	0.87[a]	9.63[a]	9.04[b]	19.41[a]	17.85[a]	3.13[a]	3.01[a]
BTS 645	0.95[a]	0.86[ab]	9.80[a]	9.25[a]	18.94[b]	17.30[b]	3.05[b]	2.95[ab]
L.S.D.at 5%	**0.03**	**0.02**	**0.22**	**0.18**	**0.32**	**0.33**	**0.07**	**0.09**

Interaction effects:

Means effect of the interaction between anti-stress compounds and water stress in 2020/2021 and 2021/2022 seasons: Results in Table 6 indicated that dry leaves and root, root top ratio, leaf area index and impurities contents (potassium, sodium and α- amino nitrogen) were significantly affected by the interaction between anti-stress compounds and water stress in both seasons except for potassium content in the first one. The interaction effect on studied traits fluctuates from one season to another, since irrigation plants at 40 % of field capacity with no spraying of anti-stress compounds gave the highest value of leaves dry weight (130.96 g) and root dry weight (349.76 g) in the first season. In the second season, irrigation plants with 40 % of field capacity and spraying them with L-ornithine gave the highest value of leaves dry weight (140.79 g), while irrigation plants at 50 % of field capacity with no spraying of anti-stress compounds gave the highest value of root dry weight (364.24 g). The highest value of leaf area index (3.65 and 2.94) was recorded for plants irrigated at 50 % of field capacity and sprayed with L-ornithine in both seasons. The lowest value of sodium (1.07 and 1.75 %); the most effective component of beet juice impurities in determining relative sucrose concentration (Campbell and Fugate, 2015) was recorded in plants irrigated at 30 % of field capacity and sprayed with ascorbic acid and plants irrigated at 50 % of field capacity and sprayed with L-ornithine in the first and second seasons respectively. The significance of interaction between drought stress and L-ornithine has been reported for growth traits in sugar beet by (Hussein et al., 2019).

Results in table 7 presented that interaction between anti-stress compounds and water stress in both seasons were significantly affected for the weight of mean root and yields of top, roots and sugar. However, sucrose content, quality percent and extractable sucrose content were significantly affected by the interaction only in the second season. Watering sugar beet plants at 40 or 50 % of field capacity and spraying them with L-ornithine gave the highest value of root weight (1.19 and 1.14 kg), top yield (11.79 and 11.53 ton/fed.), root yield (24.14 and 22.15 ton/fed.) and sugar yield (4.03 and 3.92 ton/fed.) in the first and second seasons, respectively. Exceeding sugar beet yield through L-ornithine application was due to the role of this compound as a precursor and formed of polyamines that are proper in the regulation of plant growth and development especially under stress environments (Martin-Tanguy, 2001). Watering sugar beet plants at 30 or 40 % of field capacity and sprayed it with ascorbic acid or silicon gave the highest value of sucrose content (19.96 and 21.42 %) and extractable sucrose (17.89 and 18.62 %) in the first and second seasons, respectively. Compounds such as ascorbic acid and silicon appear to play an important role in the biochemical reactions of plants grown under abiotic stress conditions (Gong et al., 2005, Gao et al., 2006, Cooke and Leishman, 2011). The role of ascorbic acid in reducing juice impurities and increasing sucrose content in sugar beet was reported by (Abdel Fatah and Sadek 2020).

Table 6. Interactive effect of anti-stress compounds × water stress on some agronomic traits of sugar beet during 2021 and 2022 harvesting seasons.

Anti-stress compounds	Water stress as % of field capacity	Leaves dry weight (g)	Root dry weight (g)	Root Top Ratio	Leaf area index (LAI)	Potassium (K %)	Sodium (Na %)	α- amino Nitrogen %
					2020/2021 season			
Control	**50**	102.70	328.11	3.31	3.01	4.54	1.51	1.43
	40	130.96	349.76	2.81	2.86	3.88	1.79	1.30
	30	76.32	246.36	3.30	1.35	3.57	1.23	0.94
	20	76.80	152.95	2.03	1.41	4.09	1.44	1.51
L-Ornithine (150 ppm)	**50**	115.33	251.78	2.39	3.65	4.19	1.65	1.67
	40	111.42	292.53	2.88	2.82	3.91	1.49	1.12
	30	79.35	265.16	3.42	2.19	3.97	1.12	1.29
	20	75.51	154.40	2.10	1.30	4.31	1.31	1.45
Ascorbic Acid (500 ppm)	**50**	93.27	262.26	2.88	2.91	4.69	1.96	1.33
	40	121.48	253.14	2.11	2.21	3.95	1.53	1.09
	30	67.53	231.85	3.48	1.45	3.77	1.07	1.25
	20	74.08	161.06	2.33	1.04	4.07	1.53	1.52
Silicon (2000 ppm)	**50**	77.23	241.77	3.35	2.82	4.59	2.50	1.35
	40	82.10	252.18	3.25	2.00	3.96	1.42	1.15
	30	70.70	219.66	3.11	2.04	3.89	1.75	1.71
	20	68.35	136.63	2.03	1.07	4.16	1.30	1.18
L.S.D.at 5%		**9.09**	**13.81**	**0.23**	**0.27**	**ns**	**0.50**	**0.39**
					2021/2022 season			
Control	**50**	105.37	364.24	3.53	2.93	5.55	2.65	1.93
	40	105.73	237.05	2.25	2.74	4.72	2.11	1.51
	30	99.51	201.74	1.99	1.29	3.96	3.48	1.46
	20	87.66	150.32	1.80	1.41	4.44	2.31	1.83
L-Ornithine (150 ppm)	**50**	107.89	337.60	3.22	2.94	4.62	1.75	1.78
	40	140.79	251.46	1.79	2.74	5.15	2.50	1.56
	30	89.01	188.11	2.16	1.88	4.12	2.76	1.74
	20	91.17	218.80	2.45	1.19	4.67	2.95	1.98
Ascorbic Acid (500 ppm)	**50**	100.15	288.18	2.88	2.56	4.98	2.03	1.40
	40	105.71	159.43	1.62	2.44	4.55	3.08	1.50
	30	97.47	216.18	2.38	1.58	4.37	2.10	1.68
	20	69.13	147.76	2.33	1.01	4.16	2.37	1.81
Silicon (2000 ppm)	**50**	111.32	327.02	2.93	2.74	5.19	2.54	1.47
	40	104.97	220.65	2.17	2.17	4.43	2.48	1.44
	30	82.51	293.73	3.56	1.87	4.40	2.69	2.12
	20	46.35	153.05	3.40	1.09	4.40	2.70	1.52
L.S.D.at 5%		**5.36**	**23.23**	**0.23**	**0.15**	**0.48**	**0.67**	**0.61**

Table 7. Interactive effect of anti-stress compounds × water stress on some agronomic traits of sugar beet during 2021 and 2022 harvesting seasons.

Anti-stress compounds	Water stress as % of field capacity	Mean root weight (kg)	Sucrose %	Quality %	Extractable sucrose %	Top yield (ton/fed.)	Root yield (ton/fed.)	Sugar yield (ton/fed.)
					2020/2021 season			
Control	**50**	1.14	18.71	86.64	16.21	11.21	20.72	3.36
	40	1.05	18.71	87.34	16.35	11.48	22.73	3.72
	30	0.85	19.24	89.42	17.21	8.26	17.60	3.02
	20	0.83	17.54	86.67	15.21	8.00	15.32	2.31
L-Ornithine (150 ppm)	**50**	1.15	19.11	87.17	16.67	10.78	23.26	3.88
	40	1.19	18.95	88.12	16.70	11.79	24.14	4.03
	30	0.90	18.92	88.52	16.76	8.09	18.81	3.11
	20	0.75	17.31	86.36	14.96	7.93	14.78	2.21
Ascorbic Acid (500 ppm)	**50**	1.07	19.19	85.90	16.49	11.57	21.82	3.58
	40	0.66	18.35	87.56	16.08	8.66	14.53	2.34
	30	0.77	19.96	89.63	17.89	8.28	15.57	2.78
	20	0.71	17.59	86.59	15.24	7.61	14.77	2.24
Silicon (2000 ppm)	**50**	1.06	19.61	85.45	16.76	10.91	21.33	3.55
	40	0.90	18.84	88.03	16.60	9.17	19.03	3.14
	30	0.78	19.32	87.59	16.94	9.82	15.97	2.71
	20	0.69	17.83	87.21	15.56	7.25	13.93	2.16
L.S.D.at 5%		**0.63**	**ns**	**ns**	**ns**	**0.48**	**0.76**	**0.26**
					2021/2022 season			
Control	**50**	1.10	20.08	83.59	16.80	11.09	21.69	3.64
	40	0.99	21.22	86.88	18.44	10.56	19.90	3.67
	30	0.77	18.92	84.25	15.94	7.97	16.10	2.57
	20	0.80	18.21	84.71	15.44	8.22	15.65	2.41
L-Ornithine (150 ppm)	**50**	1.14	21.08	87.44	18.44	11.53	22.15	3.92
	40	0.90	19.91	84.57	16.85	9.87	19.73	3.32
	30	0.83	19.64	85.56	16.82	7.86	17.24	2.90
	20	0.76	17.55	82.34	14.46	7.42	14.51	2.10
Ascorbic Acid (500 ppm)	**50**	0.95	20.98	86.52	18.16	10.27	19.50	3.53
	40	0.71	20.66	85.14	17.62	9.22	15.83	2.78
	30	0.80	19.69	86.46	17.03	8.00	16.32	2.78
	20	0.67	18.28	85.16	15.58	7.40	13.78	2.15
Silicon (2000 ppm)	**50**	0.96	20.45	84.94	17.38	10.40	18.88	3.30
	40	0.81	21.42	86.91	18.62	8.65	16.97	3.16
	30	0.78	20.23	85.55	17.31	9.80	16.24	2.81
	20	0.71	17.29	83.33	14.43	7.48	13.82	1.99
L.S.D.at 5%		**0.07**	**1.01**	**1.97**	**1.15**	**0.47**	**0.63**	**0.23**

Effect of the interaction between anti-stress compounds and sugar beet cultivars in 2020/2021 and 2021/2022 seasons: Results in Table 8 indicated that dry leaves and root, root top ratio, leaf area index was significantly affected by the interaction between anti-stress compounds and sugar beet cultivars in both seasons. However, the interaction was insignificant for impurities contents (potassium, sodium and α- amino nitrogen) in both seasons. In the first season, non-spraying cultivars BTS 645 and Dreeman gave the highest value of leaves dry weight (110.59 g) and root dry weight (275.07 g), respectively, while the cultivar Neagre gave the highest value of leaf area index (2.68) when sprayed with L-ornithine. In the second season, foliar application of L-ornithine recorded the highest value of leaves dry weight (115.47 g) for the cultivar Neagre and the highest value of root dry weight (278.95 g) and leaf area index (2.52) for the cultivar Dreeman. In the first season, spraying cultivar Neagre with L-ornithine recorded the lowest percentage of sodium (1.32 %), while spraying cultivar Dreeman with silicon recorded the lowest percentage of α- amino nitrogen (1.17 %). In the second season, foliar application of silicon recorded the lowest percentages of sodium (2.10 %) and α- amino nitrogen (1.50 %) in juice extracted from cultivars BTS 645 and Dreeman, respectively. Results in Table 9 revealed that mean root weight and yields of top, roots and sugar were significantly affected by the interaction between anti-stress compounds and sugar beet cultivars in both seasons. However, the interaction was insignificant for quality traits (sucrose %, quality % and extractable sucrose %) in both seasons. In the first season, spraying the cultivar Dreeman with L-ornithine gave the highest value of mean root weight (1.03 kg), top yield (10.11 ton/fed.), root yield (21.91 ton/fed.) and white sugar yield (3.53 ton/fed.), while in the second season, non-spraying the cultivar BTS 645 recorded the highest value of mean root weight (0.97 kg), top yield (9.85 ton/fed.), root yield (19 ton/fed.) and white sugar yield (3.20 ton/fed.). Foliar application of silicon recorded the highest percentage of sucrose (19.43%) and extractable sucrose (17.09 %) in juice of Neagre cultivar in the first season, corresponding to 20.20 % and 17.42 % in juice of BTS 645 cultivar in the second season and this may be due to the role of silicon in decreasing impurities contents in beet juice. Results cleared that among used compounds, L-Ornithine played a larger role in growth traits, while silicon played a larger role in chemical constituents of beet juice and this may account for the discrepancy in the physiological effects of each (Martin-Tanguy, 2001 and Gong et al., 2005).

Table 8. Interactive effect of anti-stress compounds × Varieties on some agronomic traits of sugar beet during 2021 and 2022 harvesting seasons.

Anti-stress compounds	Varieties	Leaves dry weight (g)	Root dry weight (g)	Root Top Ratio	Leaf area index (LAI)	Potassium (K %)	Sodium (Na %)	α- amino Nitrogen %
					2020/2021 season			
Control	**Neagre**	86.74	264.35	3.02	2.01	3.94	1.47	1.41
	Dreeman	92.76	275.07	2.92	2.23	3.88	1.52	1.25
	BTS 645	110.59	268.47	2.66	2.24	4.24	1.49	1.22
L-Ornithine (150 ppm)	**Neagre**	110.12	225.09	2.06	2.68	3.86	1.32	1.57
	Dreeman	103.27	253.38	2.65	2.53	4.05	1.41	1.26
	BTS 645	72.82	244.44	3.39	2.25	4.38	1.45	1.31
Ascorbic Acid (500 ppm)	**Neagre**	86.80	222.68	2.78	1.68	3.96	1.51	1.28
	Dreeman	79.89	215.98	2.85	1.96	3.99	1.43	1.31
	BTS 645	100.59	242.58	2.47	2.07	4.40	1.63	1.31
Silicon (2000 ppm)	**Neagre**	78.01	219.96	2.84	1.68	4.01	1.57	1.43
	Dreeman	59.14	197.40	3.45	2.02	3.91	1.77	1.17
	BTS 645	86.64	220.32	2.52	2.24	4.53	1.89	1.45
L.S.D.at 5%		**6.54**	**12.75**	**0.24**	**0.19**	**ns**	**ns**	**ns**
					2021/2022 season			
Control	**Neagre**	87.90	224.43	2.64	1.97	4.64	2.58	1.86
	Dreeman	101.49	273.79	2.62	1.94	4.52	2.83	1.63
	BTS 645	109.31	216.79	1.93	2.37	4.85	2.50	1.57
L-Ornithine (150 ppm)	**Neagre**	115.47	259.81	2.36	2.14	4.58	2.32	2.05
	Dreeman	110.25	278.95	2.61	2.52	4.54	2.72	1.65
	BTS 645	95.92	208.22	2.24	1.91	4.80	2.44	1.60
Ascorbic Acid (500 ppm)	**Neagre**	91.59	182.36	2.09	1.60	4.45	2.59	1.63
	Dreeman	103.54	225.30	2.21	2.01	4.16	2.37	1.60
	BTS 645	84.21	201.01	2.61	2.08	4.92	2.23	1.56
Silicon (2000 ppm)	**Neagre**	82.79	225.50	3.08	1.70	4.86	2.65	1.88
	Dreeman	85.62	273.18	3.22	1.97	4.23	3.04	1.50
	BTS 645	90.45	247.15	2.74	2.24	4.72	2.10	1.54
L.S.D.at 5%		6.06	19.09	0.20	0.15	ns	ns	Ns

Table 9. Interactive effect of anti-stress compounds × water stress on some agronomic traits of sugar beet during 2021 and 2022 harvesting seasons.

Anti-stress compounds	Varieties	Mean root weight (kg)	Sucrose %	Quality %	Extractable sucrose %	Top yield (ton/fed.)	Root yield (ton/fed.)	Sugar yield (ton/fed.)
				2020/2021 season				
Control	Neagre	0.90	18.94	87.96	16.66	9.41	17.25	2.88
	Dreeman	1.00	18.32	87.53	16.06	9.80	20.29	3.24
	BTS 645	1.03	18.39	87.06	16.02	10.00	19.75	3.19
L-Ornithine (150 ppm)	Neagre	0.93	18.94	88.27	16.72	9.37	19.22	3.23
	Dreeman	1.03	18.46	87.63	16.18	10.11	21.91	3.53
	BTS 645	0.96	18.32	86.72	15.91	9.47	19.61	3.16
Ascorbic Acid (500 ppm)	Neagre	0.74	19.30	88.06	17.01	8.25	15.33	2.61
	Dreeman	0.83	18.33	87.56	16.06	9.02	17.65	2.84
	BTS 645	0.84	18.68	86.64	16.20	9.82	17.04	2.77
Silicon (2000 ppm)	Neagre	0.74	19.43	87.96	17.09	8.35	15.54	2.66
	Dreeman	0.87	18.73	87.47	16.39	9.60	17.78	2.92
	BTS 645	0.97	18.55	85.79	15.92	9.92	19.37	3.09
L.S.D.at 5%		0.06	ns	ns	ns	0.44	0.64	0.15
				2021/2022 season				
Control	Neagre	0.88	19.76	85.07	16.82	9.36	17.39	2.93
	Dreeman	0.93	19.51	84.71	16.55	9.17	18.61	3.10
	BTS 645	0.97	19.56	84.80	16.60	9.85	19.00	3.20
L-Ornithine (150 ppm)	Neagre	0.89	19.76	85.37	16.91	9.03	18.31	3.14
	Dreeman	0.90	19.60	84.89	16.67	8.74	18.54	3.12
	BTS 645	0.89	19.28	84.67	16.36	8.91	17.73	2.93
Ascorbic Acid (500 ppm)	Neagre	0.80	19.87	85.54	17.01	8.32	15.78	2.69
	Dreeman	0.80	19.72	86.37	17.04	8.71	17.33	2.97
	BTS 645	0.75	20.12	85.56	17.23	9.15	15.96	2.77
Silicon (2000 ppm)	Neagre	0.80	19.75	84.46	16.72	8.60	16.01	2.69
	Dreeman	0.83	19.60	84.86	16.67	9.54	16.93	2.86
	BTS 645	0.82	20.20	86.23	17.42	9.10	16.49	2.90
L.S.D.at 5%		0.04	ns	ns	ns	0.36	0.66	0.19

Effect of the interaction between water stress and sugar beet cultivars in 2020/2021 and 2021/2022 seasons: Results in Table 10 indicated that dry leaves and root, root top ratio, and leaf area index were attributed significantly effect by the interaction between water stress and sugar beet cultivars in both seasons. However, the interaction was significant for only potassium content in the second season. The highest weight of dry leaves was obtained for the cultivars Neagre (115.94 g) and Dreeman (117.34 g) when irrigated at 40 % of field capacity in the first and second seasons, respectively, while the highest weight of dry root was obtained for the cultivars BTS 645 (309.93g) and Dreeman (434.84 g) when irrigated at 50% of field capacity in the first and second seasons, respectively. Watering the cultivar BTS 645 at 50 % of field capacity gave the highest value of leaf area index (3.28 and 2.99) in both seasons. It was observed that subjected sugar beet cultivars to high levels of water stress (30 and 20 % of field capacity) significantly decreased growth traits in terms of dry weight of leaves and root and leaf area index in both seasons and also, increased impurities contents in terms of sodium and amino nitrogen in the second season (Islam, et al., 2020 and Ghaffari et al., 2021).Results in Table 11 revealed that mean root weight and yields of top, roots and sugar were influenced significantly by the interaction between drought levels and sugar beet cultivars in both seasons. In the first season, the highest percentage of sucrose (19.75 %), quality (89.31 %) and extractable sucrose (17.64

%) was obtained for the cultivar Neagre when irrigated at 30 % of field capacity, while the highest yield of root (23.07 ton/fed.) and white sugar (3.75 ton/fed.) was obtained for the cultivar Dreeman when irrigated at 50 % of field capacity. In the second season, watering sugar beet cultivar BTS 645 at 50 % of field capacity gave the highest value of mean root weight (1.12 kg), sucrose content (21.02 %), quality percent (86.38 %), extractable sucrose content (18.17 %), top yield (11.41 ton/fed.), root yield (21.29 ton/fed.) and white sugar yield (3.86 ton/fed.). The results indicated a noticeable decrease in the mean performance of sugar beet cultivars with an increase in the level of water stress, especially at the level of 20 %, with regard to the quality and yield traits. The adverse effect of drought stress on top and root yields of sugar beet cultivars was primarily due to its negative effect on growth traits during growing seasons, while the adverse effect of drought on extractable sucrose might be due to increasing impurities contents under high levels of drought (Dutton and Huijbregts 2006, Moosavi, et al., 2017, Mahmoud et al., 2018, Abu-Ellail and El-Mansoub, 2020,Ghaffari et al., 2021).

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Table 10. Interactive effect of water stress × varieties on some agronomic traits of sugar beet during 2021 and 2022 harvesting seasons.

Water stress as % of field capacity	Varieties	Leaves dry weight (g)	Root dry weight (g)	Root Top Ratio	Leaf area index (LAI)	Potassium (K%)	Sodium (Na %)	α- amino Nitrogen %
					2020/2021 season			
50	**Neagre**	96.12	273.10	3.04	2.91	4.28	1.75	1.47
	Dreeman	86.57	229.92	2.98	3.10	4.37	1.99	1.37
	BTS 645	108.71	309.93	2.93	3.28	4.86	1.97	1.50
40	**Neagre**	115.94	299.73	2.70	2.42	3.83	1.63	1.29
	Dreeman	107.42	295.46	2.95	2.49	3.86	1.47	1.01
	BTS 645	111.12	265.53	2.64	2.51	4.09	1.58	1.19
30	**Neagre**	78.19	211.70	2.79	1.54	3.65	1.22	1.50
	Dreeman	70.98	256.14	3.59	1.76	3.72	1.12	1.18
	BTS 645	71.26	254.44	3.60	1.97	4.03	1.53	1.21
20	**Neagre**	71.42	147.55	2.15	1.19	4.01	1.28	1.44
	Dreeman	70.10	160.32	2.34	1.39	3.89	1.54	1.43
	BTS 645	79.54	145.91	1.87	1.04	4.57	1.37	1.38
L.S.D.at 5%		6.54	12.75	0.24	0.19	ns	ns	ns
					2021/2022 season			
50	**Neagre**	90.66	248.55	2.86	2.47	5.23	2.35	1.78
	Dreeman	113.85	434.84	3.85	2.92	4.93	2.41	1.59
	BTS 645	114.04	304.39	2.71	2.99	5.09	1.97	1.56
40	**Neagre**	115.33	219.41	1.96	2.15	4.57	2.64	1.66
	Dreeman	117.34	221.31	1.95	2.56	4.37	2.75	1.31
	BTS 645	110.22	210.73	1.95	2.87	5.19	2.25	1.54
30	**Neagre**	103.22	242.22	2.46	1.57	4.31	2.60	2.08
	Dreeman	87.44	219.98	2.59	1.68	3.89	2.94	1.61
	BTS 645	85.71	212.61	2.52	1.70	4.43	2.73	1.57
20	**Neagre**	68.55	181.91	2.88	1.21	4.42	2.56	1.90
	Dreeman	82.27	175.09	2.28	1.29	4.26	2.87	1.85
	BTS 645	69.91	145.45	2.34	1.03	4.57	2.32	1.60
L.S.D.at 5%		**6.06**	**19.09**	**0.20**	**0.15**	**0.37**	**ns**	**ns**

Table 11. Interactive effect of water stress × varieties on some agronomic traits of sugar beet during 2021 and 2022 harvesting seasons.

Water stress as % of field capacity	Varieties	Mean root weight (kg)	Sucrose %	Quality %	Extractable sucrose %	Top yield (ton/fed.)	Root yield (ton/fed.)	Sugar yield (ton/fed.)
					2020/2021 season			
50	**Neagre**	1.01	19.67	87.32	17.17	10.23	19.50	3.34
	Dreeman	1.13	18.87	86.21	16.27	11.75	23.07	3.75
	BTS 645	1.20	18.94	85.34	16.16	12.13	22.78	3.68
40	**Neagre**	0.84	19.09	88.01	16.81	9.63	18.36	3.09
	Dreeman	0.96	18.56	88.06	16.35	9.92	21.23	3.47
	BTS 645	0.99	18.49	87.22	16.14	10.51	20.73	3.37
30	**Neagre**	0.78	19.75	89.31	17.64	8.24	15.77	2.78
	Dreeman	0.82	19.29	89.31	17.24	8.39	17.23	2.93
	BTS 645	0.88	19.04	87.76	16.73	9.20	17.97	3.00
20	**Neagre**	0.69	18.11	87.62	15.87	7.27	13.71	2.17
	Dreeman	0.82	17.12	86.62	14.84	8.46	16.10	2.37
	BTS 645	0.73	17.48	85.89	15.02	7.36	14.29	2.15
L.S.D.at 5%		**0.06**	**ns**	**ns**	**ns**	**0.44**	**0.64**	**0.15**
					2021/2022 season			
50	**Neagre**	0.97	20.63	85.13	17.58	9.89	18.96	3.34
	Dreeman	1.02	20.29	85.35	17.33	10.34	20.77	3.59
	BTS 645	1.12	21.02	86.38	18.17	11.41	21.29	3.86
40	**Neagre**	0.84	20.82	85.88	17.91	9.48	17.60	3.15
	Dreeman	0.89	20.72	86.15	17.87	9.50	18.97	3.38
	BTS 645	0.83	20.87	85.61	17.88	9.74	17.76	3.17
30	**Neagre**	0.79	19.57	85.35	16.72	8.40	16.23	2.72
	Dreeman	0.84	19.89	86.00	17.11	8.46	17.17	2.94
	BTS 645	0.76	19.40	85.01	16.51	8.37	16.02	2.64
20	**Neagre**	0.76	18.11	84.08	15.25	7.54	14.70	2.24
	Dreeman	0.72	17.52	83.33	14.62	7.86	14.51	2.12
	BTS 645	0.72	17.87	84.25	15.06	7.49	14.11	2.12
L.S.D.at 5%		**0.04**	**ns**	**ns**	**ns**	**0.36**	**0.66**	**0.19**

Effect of the interaction among anti-stress compounds, water stress and sugar beet cultivars in 2020/2021 and 2021/2022 seasons:

The second order interaction (data not presented here) was significant for growth traits and yields of sugar beet, while it was insignificant for impurities contents and quality traits in both seasons. Three sugar beet cultivars showed variability in their performance under different combinations of drought stress levels and anti-stress compounds. In the first season, the cultivars Neagre, Dreeman and BTS 645 gave the highest percentage of sucrose (20.43, 19.54 and 19.90 %) and extractable sucrose (18.40, 17.46 and 17.82%) when grown under combination of ascorbic acid and 30% drought level, while foliar application of silicon at 40 % drought level in the second season recorded the highest percentage of sucrose (21.78, 21.50 and 21.42 %) and extractable sucrose (18.98, 18.37 and 18.71 %) for the three cultivars, respectively. Foliar application of L-ornithine to the cultivar Neagre at 50% drought level gave the highest yields of root (23.75 and 21.84 ton/fed.) and white sugar (4.01 and 4.08 ton/fed.), while spraying the cultivar BTS 645 with silicon at 50% drought level gave the highest yields of root (25.63 and 22.12 ton/fed.) and white sugar (4.14 and 4.01 ton/fed.) in the first and second seasons, respectively. Foliar application of ascorbic acid and L-ornithine at 50 % drought level gave the highest yields of root (25.23 and 21.35 ton/fed.) and white sugar (4.05 and 3.90 ton/fed.) for the cultivar Dreeman in the first and second seasons, respectively. Differential responses of sugarbeet verities to drought levels and anti-stress compounds have been reported by (Moosavi, et al., 2017), (Husseinet al., 2019), (Ghaffariet al.2021).

The results about the effects of foliar application of L-Ornithine, ascorbic acid and silicon on sugar beet plants of three cultivars grown under different irrigation levels showed that these compounds played a positive role in alleviating the debilitating effects of drought stress. The positive effects of such compounds were due to their physiological effects in several ways. L-ornithine is the precursor of polyamines that are essential in the regulation of plant growth and development (Martin-Tanguy, 2001). Furthermore, it is the intermediate compound in the arginine biosynthesis where the pathway divaricates to the production of compounds, such as proline that serve as osmoprotective substance in plants (Ali et al., 2016). Silicon reduces oxidative damage to functional molecules and amplifies anti-oxidant defense mechanisms(Gong et al., 2005). Ascorbic acid has the ability to scavenge reactive oxygen species (ROS) under drought stress environment. The regulatory role of ROS in plant abiotic defense responses was discussed by Zaid and Wani (2019). They are a by-product of aerobic metabolism and key signaling molecules which play a significant role in plants' responses to many of abiotic and biotic stresses. The production and scavenging of ROS are accomplished in various cellular compartments such as cell membrane, mitochondria, chloroplasts, and endoplasmic reticulum. Under abiotic stresses, an imbalance between ROS biosynthesis and scavenging and elimination in favor of biosynthesis with certain consequences for plant cell physiology has been termed as "oxidative stress." Rather than the indigenous antioxidant enzymes, treating plants that grown under drought stress environment with exogenous anti-stress compounds work in coordination to alleviate the oxidative damage induced by various ROS to engineer tolerance against various environmental stress conditions.

Drought tolerance indices

Data obtained from sugar beet plants irrigated at 50 % FC (non-stress environment) and 20 % FC (stress environment) under no application of anti-stress compounds were considered in calculation of drought tolerance indices (SSI, STI, GMP and TOL) over the two seasons (Table 12). According to what was mentioned in a study carried out by Hesadi *et al*. (2015) on screening for drought tolerance performances in sugar beet genotypes, "the genotype with SSI< 1, high STI value, high GMP value and low value of TOL will be more resistant to drought stress conditions and more desirable. In the present study, among the evaluated sugar beet cultivars, the cultivar Dreeman was the best for all the estimated drought indices for both root and sugar yields traits. The cultivar Dreeman gave the highest mean root yield (18.69 ton/fed) and sugar yield (2.73 ton/fed.) under stress conditions. The stress susceptibility index (SSI) for the cultivar Dreeman was less than one (0.51 and 0.64) for root and sugar yields, respectively, while it was greater than one for the other cultivars in both root and sugar yields. Tolerance index (TOL) estimated for root and sugar yields of the cultivar Dreeman were the lowest (2.99 and 0.74) and with a large difference from that estimated for the rest of cultivars. Both stress tolerance index (STI) and geometric mean productivity (GMP) were evaluated for root and sugar yields of the cultivar Dreeman were the highest compared to that estimated for the other cultivars. The previous results indicated that the cultivar Dreeman could be considered as drought tolerant genotype and more stable in the two different conditions.

Table 12. Drought tolerance indices for root and white sugar yield in three sugar beet genotypes irrigated at 50 % (non-stress) and 20 % (stress) of field capacity.

Genotype	Y_p	Y_s	Drought tolerance index			
			TOL	GMP	STI	SSI
			Root yield			
Neagre	20.77	14.60	6.16	17.40	0.67	1.11
Dreeman	21.69	18.69	2.99	20.12	0.91	0.51
BTS 645	21.16	13.15	8.01	16.67	0.62	1.42
			Sugar yield			
Neagre	3.50	2.36	1.14	2.88	0.67	1.01
Dreeman	3.47	2.73	0.74	3.07	0.78	0.64
BTS 645	3.53	1.99	1.54	2.65	0.58	1.34

Y_p, Y_s indicate yield (ton/fed.) under non-stress and stress environments, respectively.

The results of the correlations among drought tolerance indices and mean yields of root and white sugar under non-stress (Y_p) and stress (Y_s) conditions are shown in Table 13. The researchers believe that the best indicator of drought tolerance is the indices which have high correlation with yield under both stress and non-stress conditions (Fernandez, 1992). The results revealed that both of GMP and SSI indices had positive and significant correlations with root and white sugar yields under non-stress and stress conditions and also the correlations between GMP and SSI were positive and significant for both traits under the two environments. The correlation between STI and mean yields of root and white sugar was positive and significant only under a stress environment, while it was negative and significant under a non-stress environment. Although the correlations for GMP and SSI with STI were positive and significant for both traits under both environments, however both of GMP and SSI indices have the advantage rather than the STI index as a selection criterion for identifying high yielding stress tolerant genotypes. The index STI could be effective in stress environment. However, working with sugar beetSadeghianet *al*. (2000) concluded that STI could effectively identify genotypes with high yield potential in both stressed and non-stressed environments.

Table 13. Correlations between drought tolerance indices (TOL, GMP, STI and SSI), and means of yield under non-stress (Yp) and drought-stress environments (Ys), for root and white sugar yields.

	Drought tolerance index				YP	Ys
	TOL	GMP	STI	SSI		
			Root yield			
TOL	1.00	0.28	-0.98**	-0.92**	0.76**	-0.34
GMP	-	1.00	0.82**	0.89**	0.84**	0.80**
STI	-	-	1.00	0.91**	-0.63**	0.70**
SSI	-	-	-	1.00	0.81**	0.65**
Yp	-	-	-	-	1.00	0.36
			Sugar yield			
TOL	1.00	0.43	-0.97**	-0.52*	0.84**	-0.27
GMP	-	1.00	0.53*	0.57*	0.85**	0.75**
STI	-	-	1.00	0.48*	-0.71**	0.65**
SSI	-	-	-	1.00	0.68**	0.55*
Yp	-	-	-	-	1.00	0.30

Y_p, Y_s indicate yield (ton/fed.) under non-stress and stress environments, respectively.
***, ** indicate significance at the 0.05 and 0.01 probability levels, respectively.**

Conclusion

Drought stress has hampered most aspects of sugar beet growth which had a negative impact on the root and sugar yields of all cultivars under study. However, exogenous foliar spraying of low-cost compounds such as L-Ornithine, ascorbic acid and silicon on plants grown under drought stress played a significant positive role in mitigating and reversing the negative physiological effects of drought stress as well as increasing the yield and quality traits of sugar beet cultivars. Based on tolerance index (TOL), stress susceptibility index (SSI), geometric mean production (GMP), and stress tolerance index (STI) for root and sugar yields, the Dreeman sugar beet cultivar exhibited the highest drought tolerance. Under the circumstances of this study, GMP and SSI indices are effective for selecting high-yielding, stress-tolerant genotypes.

Declarations

Author contribution statement

M. I. Masri, A. A. Hoballah, I. H. Yacoub, Eman M. Mohamed:

Conceive and design experiments; conducted experiments; Contribute chemicals and tools, Analyze and interpret data; wrote the paper.

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Competing interest statement

The authors declare no conflict of interest

References

Abd El-Gawad, H. G., Mukherjee, S., Farag, R., AbdElbar, O. H., Hikal, M., Abou El-Yazied, A., ... & Ibrahim, M. F. (2021). Exogenous γ-aminobutyric acid (GABA)-induced signaling events and field performance associated with mitigation of drought stress in Phaseolus vulgaris L. Plant Signaling & Behavior, 16(2), 1853384. [PMCfree article] [PubMed] [Google Scholar]

Abid, G., Ouertani, R. N., Jebara, S. H., Boubakri, H., Muhovski, Y., Ghouili, E., ... &Jebara, M. (2020). Alleviation of drought stress in faba bean (Viciafaba L.) by exogenous application of β-aminobutyric acid (BABA). Physiology and molecular biology of plants, 26, 1173-1186.. [PMC free article] [PubMed] [Google Scholar]

Abu-Ellail, F. F., & El-Mansoub, M. (2020). Impact of water stress on growth, productivity and powdery Mildew disease of ten sugar beet varieties. Alexandria science exchange journal, 41(APRIL-JUNE), 165-179.

Ahmed, M., Kamran, A., Asif, M., Qadeer, U., Ahmed, Z. I., &Goyal, A. (2013). Silicon priming: a potential source to impart abiotic stress tolerance in wheat: A review. Australian Journal of Crop Science, 7(4), 484-491.

Ali, S. I., Mohamed, A. A., Sameeh, M. Y., Darwesh, O. M., &Abd El-Razik, T. M. (2016). Gamma-irradiation affects volatile oil constituents, fatty acid composition and antimicrobial activity of fennel (Foeniculumvulgare) seeds extract. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 7(1), 524-532.

Benhassaine-Kesri, G., Aid, F., Demandre, C., Kader, J. C., &Mazliak, P. (2002). Drought stress affects chloroplast lipid metabolism in rape (Brassica napus) leaves. PhysiologiaPlantarum, 115(2), 221-227.

Campbell, L. G. (2002). Sugar beet quality improvement. Journal of crop production, 5(1-2), 395-413.

Campbell, L. G., & Fugate, K. K. (2015). Relationships Among Impurity Components, Sucrose, and Sugarbeet Processing Quality. Journal of Sugar Beet Research, 52.

Carruthers, A. J. F. T., & Oldfield, J. F. T. (1961). Methods for the assessment of beet quality. Int. sugar J, 63, 72-74.

Cooke, J., & Leishman, M. R. (2011). Is plant ecology more siliceous than we realise. Trends in plant science, 16(2), 61-68.

Darwesh, O. M., Matter, I. A., &Eida, M. F. (2019). Development of peroxidase enzyme immobilized magnetic nanoparticles for bioremediation of textile wastewater dye. Journal of Environmental Chemical Engineering, 7(1), 102805.

Dutton, John, and ToonHuijbregts. (2006). "Root quality and processing." ,409-442.

Farooq, M., Basra, S. M. A., Wahid, A., Cheema, Z. A., Cheema, M. A., &Khaliq, A. (2008). Physiological role of exogenously applied glycinebetaine to improve drought tolerance in fine grain aromatic rice (Oryza sativa L.). Journal of Agronomy and Crop Science, 194(5), 325-333.

Fernandez, G. C. (1993). Effective selection criteria for assessing plant stress tolerance,257-270.

Fischer, R. A., & Maurer, R. (1978). Drought resistance in spring wheat cultivars. I. Grain yield responses. Australian Journal of Agricultural Research, 29(5), 897-912.

Freed, R., Einensmith, S. P., Guets, S., Reicosky, D., Smail, V. W., &Wolberg, P. (1989). User’s guide to MSTAT-C analysis of agronomic research experiments. Michigan State University, USA.

Ghaffari, H., Tadayon, M. R., Bahador, M., &Razmjoo, J. (2021). Investigation of the proline role in controlling traits related to sugar and root yield of sugar beet under water deficit conditions. Agricultural Water Management, 243, 106448.

Gao, X., Zou, C., Wang, L., & Zhang, F. (2006). Silicon decreases transpiration rate and conductance from stomata of maize plants. Journal of Plant Nutrition, 29(9), 1637-1647.

Gomez, K. A. (1984). Statistical procedures for agricultural research. John NewYork: Wiley and Sons.

Gong HaiJun, G. H., Zhu XueYi, Z. X., Chen KunMing, C. K., Wang SuoMin, W. S., & Zhang ChengLie, Z. C. (2005). Silicon alleviates oxidative damage of wheat plants in pots under drought.

Hamed, L. M., &Emara, E. I. (2019). VARIETAL TOLERANCE OF SUGAR BEET (BETA VULGARIS L.) TO WATER STRESS. Misr Journal of Agricultural Engineering, 36(1), 217-238.

Hesadi, P., Taleghani, D. F., Shiranirad, A., Daneshian, J., &Jaliliyan, A. (2015). Selection for drought tolerance in sugar beet genotypes (Beta vulgaris L.).

Hoffmann, C. M. (2010). Sucrose accumulation in sugar beet under drought stress. Journal of agronomy and crop science, 196(4), 243-252.

Hussein, H. A. A., Mekki, B. B., Abd El-Sadek, M. E., & El Lateef, E. E. (2019). Effect of L-Ornithine application on improving drought tolerance in sugar beet plants. Heliyon, 5(10).

https://doi.org/10.1016/j.heliyon.2019.e02631

Islam, M. J., Kim, J. W., Begum, M. K., Sohel, M. A. T., & Lim, Y. S. (2020). Physiological and biochemical changes in sugar beet seedlings to confer stress adaptability under drought condition. Plants, 9(11), 1511.https://doi.org/10.3390/plants9111511.

Jaggard, K. W., Dewar, A. M., & Pidgeon, J. D. (1998). The relative effects of drought stress and virus yellows on the yield of sugarbeet in the UK, 1980–95. The Journal of Agricultural Science, 130(3), 337-343.

Latif, M., Akram, N. A., & Ashraf, M. (2016). Regulation of some biochemical attributes in drought-stressed cauliflower (Brassica oleracea L.) by seed pre-treatment with ascorbic acid. The Journal of Horticultural Science and Biotechnology, 91(2), 129-137.

M Abdel Fatah, E., &Sadek, K. A. (2020). Impact of different application methods and concentrations of ascorbic acid on sugar beet under salinity stress conditions. Alexandria Journal of Agricultural Sciences, 65(1), 31-44.

Mahmoud, E. S. A., Hassanin, M. A., Borham, T. I., &Emara, E. I. (2018). Tolerance of some sugar beet varieties to water stress. Agricultural Water Management, 201, 144-151.

Martin-Tanguy, J. (2001). Metabolism and function of polyamines in plants: recent development (new approaches). Plant growth regulation, 34, 135-148.

Masri, M. I., Ramadan, B. S. B., El-Shafai, A. M. A., & El-Kady, M. S. (2015). Effect of water stress and fertilization on yield and quality of sugar beet under drip and sprinkler irrigation systems in sandy soil. Int. J. Agric. Sci, 5(3), 414-42

Masri, M. I., &Safina, S. A. (2015). Agro-economic impact of intercropping canola and onion on some sugar beet varieties under different nitrogen rates. Journal of Plant Production, 6(10), 1661-1678.

Moosavi, S. G. R., Ramazani, S. H. R., Hemayati, S. S., &Gholizade, H. (2017). Effect of drought stress on root yield and some morpho-physiological traits in different genotypes of sugar beet (Beta vulgaris L.). Journal of Crop Science and Biotechnology, 20, 167-174.

Prysiazhniuk, O., Kononiuk, N., Zatserkovna, N., Chynchyk, O., Hryhoriev, V., Zhemoyda, V., ... &Svystunova, I. (2023). The Study of Drought Stress in Sugar Beet and the Ways of its Minimization. Ecological Engineering & Environmental Technology, 24.

Riccardi, M., Pulvento, C., Patanè, C., Albrizio, R., & Barbieri, G. (2016). RETRACTED: drought stress response in long-storage tomatoes: physiological and biochemical traits, 25-35.

Reinefeld, E., Emmerich, A., Baumarten, G., Winner, C., &Beiss, U. (1974). Zurvoraussage des melassezuckersausRubenanalysen. Zucker, 27: 2-15. The Sugar Beet Crop, science into practice, 1.

Richter, G. M., Jaggard, K. W., & Mitchell, R. A. (2001). Modelling radiation interception and radiation use efficiency for sugar beet under variable climatic stress. Agricultural and Forest Meteorology, 109(1), 13-25.

Rosielle, A. A., & Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non-stress environment 1. Crop science, 21(6), 943-946.

Sadeghian, S. Y., Fazli, H., Mohammadian, R., Taleghani, D. F., &Mesbah, M. (2000). Genetic variation for drought stress in sugarbeet. Journal of Sugar Beet Research, 37(3), 55-78.

Souza, C. C. D., Oliveira, F. A. D., Silva, I. D. F. D., &AmorimNeto, M. D. S. (2000). Evaluation of methods of available water determinaton and irrigation management in" terra roxa" under cotton crop. RevistaBrasileira de EngenhariaAgrícola e Ambiental, 4, 338-342.

Stagnari, F., Galieni, A., Speca, S., &Pisante, M. (2014). Water stress effects on growth, yield and quality traits of red beet. ScientiaHorticulturae, 165, 13-22.

Tarkalson, D. D., Eujayl, I. A., Beyer, W., & King, B. A. (2014). Drought tolerance selection of sugarbeet hybrids. Journal of Sugar Beet Research, 51(1 & 2), 14-30.

Veroneze-Júnior, V., Martins, M., Mc Leod, L., Souza, K. R. D., Santos-Filho, P. R., Magalhães, P. C., ... & Souza, T. C. (2019). Leaf application of chitosan and physiological evaluation of maize hybrids contrasting for drought tolerance under water restriction. Brazilian Journal of Biology, 80, 631-640.

Watson, D. J. (1958). The dependence of net assimilation rate on leaf-area index. Annals of Botany, 22(1), 37-54.

Yassin, O., Ismail, S., Gameh, M., Khalil, F., & Ahmed, E. (2022). Evaluation of chemical composition of roots of three sugar beets varieties growing under different water deficit and harvesting dates in Upper Egypt. Current Chemistry Letters, 11(1), 1-10.

Zaid, A., &Wani, S. H. (2019). Reactive oxygen species generation, scavenging and signaling in plant defense responses. In Bioactive molecules in plant defense: Signaling in growth and stress (pp. 111-132). Cham: Springer International Publishing.

تحسين تحمل الجفاف في بنجر السكر عن طريق الرش الورقي من المركبات المضادة للإجهاد

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أجريت تجربتان حقليتان بمحطة التجارب الزراعية بكلية الزراعة محافظة الجيزة، خلال موسمان ٢٠٢٠/٢٠٢١ و٢٠٢١/٢٠٢٢ بهدف دراسة تأثير معاملات الرش الورقي للحمض الأميني L–ornithine بتركيز (١٥٠ جزء في المليون)، وحمض الأسكوربيك (٥٠٠ جزء في المليون) والسيليكون (٢٠٠٠ جزء في المليون) كمركبات مضادة لاجهاد المائي بالمقارنة بمعاملة الكنترول على أداء ثلاثة أصناف من بنجر السكر Neagre، Dreeman، و645 BTS، والتي تمت زراعتها تحت أربعة مستويات ري مختلفة (٥٠%، ٤٠%، ٣٠%، ٢٠% من السعة الحقلية). أشارت نتائج الدراسة إلى أن التأثيرات الرئيسة للمركبات المضادة للإجهاد ومستويات الري والأصناف كانت معنوية في صفات النمو (الوزن الجاف للأوراق ودليل مساحة الجذر والورقة) وكذلك حاصل السكر الجذري والسكر المستخلص. كذلك لوحظ زيادة بنسبة السكروز والسكروز القابل للاستخراج في ظل مستويات الجفاف المعتدلة. في حين انخفضت القراءات الخاصة بصفات النمو ومحتوى السكروز ومحصول البنجر السكر مع زيادة مستوى الجفاف عند ٢٠% سعة حقلية. حيث أدى إلى انخفاض السكروز المستخرج (حوالي ١,٣ و٢,٧%) ومحصول الجذور (حوالي ٣٣% و٢٩%) ومحصول السكر الأبيض. (حوالي ٣٨% و٤٠%) مقارنة بباقي النباتات في الظروف المناسبة ٥٠% من السعة الحقلية في الموسمين الأول والثاني على التوالي. عامة أظهر أداء الأصناف تبايناً في التفاعل من مستويات المختلفة من إجهاد الجفاف والمركبات المضادة له. كتني افضل معاملة عند سعة حقلية ٤٠ أو ٥٠% ورشها بالأورنثين حيث أدت إلى زيادة وزن الجذور وإنتاجية السكر العلوي والجذري والأبيض. لذى أوضحت النتائج أنه من بين المركبات المستخدمة، لعب الاورنثين دورًا مهم في صفات النمو وإنتاجية البنجر، بينما لعب حمض الأسكوربيك والسيليكون دورًا أكبر في المكونات الكيميائية لعصير البنجر وهذا قد يفسر التناقض في التأثيرات الفسيولوجية لكل منهما. من حيث دلائل الانتخاب كتقييم لاداء الاصناف مقدرتها علي التحمل للجفاف تفوقال صنف دريمانDreeman من خلال مؤشرات تحمل الجفاف فيما يتعلق بمؤشر التحمل(TOL)، ومؤشر الحساسية للإجهاد (SSI)، ومتوسط الإنتاج الهندسي (GMP)، ومؤشر تحمل الإجهاد (STI) لمحصول الجذور والسكر. كذلك الدراسة وضحت بانة يمكن استخدام كل من مؤشرات GMP وSSI بشكل فعال كمعايير اختيار لتحديد الأنماط الجينية عالية الإنتاجية التي تتحمل الإجهاد المائي لمحصول بنجر السكر.