3 *Env.Biodiv. Soil Security*, **Vol. 8**, pp: 27 - 37 (2024)

Environment, Biodiversity & Soil Security

http://jenvbs.journals.ekb.eg/

Influence of Ascorbic Acid on some sugar beet (*Beta vulgaris* L.) cultivars under Drought Conditions

Soad A. Mahmoud[a], **Nasr A. Ghazy**[b] and **Maher A. Kotb**[a]

[a]*Agronomy Department, Faculty of Agriculture, Suez Canal University Ismailia, Egypt*

[b]*Sugar Crops Diseases Department, Plant Pathology Research Institute, Agricultural Research Center, Giza, Egypt.*

WATER stress is considered one of the most widespread limitations to crop productivity and yield stability causing yield reductions between 10 and 30 % of sugar beet. Drought tolerance is a complex trait controlled by many metabolic pathways and genes. Identifying a solution to increase the tolerance of plants to drought stress is one of the grand challenges in plant biology. This study provided compelling evidence of increased drought stress tolerance in four sugar beet cultivars namely Del 1135 R2, Collins, BTS 7245 R1 and Aseel planted under three levels of field capacity (100 -75 -50 % FC) and treated with foliar application of ascorbic acid at three concentrations (0-350-550 ppm). Study was established throughout two winter growing seasons 2021/2022 and 2022/2023 at the experimental farm of Agronomy Department-Faculty of Agriculture- Suez Canal University in Ismailia, Egypt. Results were observed that drought stress expressively reduced plant growth, photosynthetic pigments, and sugar yield, while foliar application of ascorbic acid caused significant increase on growth and yield parameters. It can trigger some physiological processes and stimulate total soluble sugars in plants. Tolerance indices like MP-TOL-YSI-GMP indicated that cultivars Aseel and Collins with treatment 550 ppm AsA gave the highest yield and gave the most tolerant treatments. Furthermore, values of genetic parameters; GVC, PVC, GA and h2 exhibited increasing in number of studied characters of root and shoot that can used for selection in successive breeding programs.

Keywords: Sugar beet (Beta vulgaris L.), Drought, Ascorbic acid, Genetic variability, Tolerance indices.

2. Introduction

Sugar beet is considered an important sugar crop in temperate region. In Egypt (semi –arid region) sugar beet cultivated beside sugar cane crop to provide people with sugar needs consumption which increased with increasing number of populations. Sugar beet produced 12.54 million tons of sugar represented about 50% from the local production (Egyptian Society of Sugar Technologies and Sugar Crops Research Institute, 2022). Abiotic stresses carriage a great challenge for plant growth and development by causing morphological, biochemical and physiological changes in plant cells (Mishra et al., 2023). Generally, drought stress is one of the abiotic stresses that have limits on growth development and plant yield (Pitman & Lauchli, 2002 and Shao et al., 2008). Drought stress happens when available water in the soil becomes rare and atmospheric conditions cause constant loss of water through evaporation or transpiration. Water stress also results from lack of rainfall, salinity, high light intensity, high and low temperatures, among others (Seleiman et al., 2021 and Tan et al., 2023). Equally drought stress and salt have a multifaceted effect, causing changes in most biochemical, morphological, physiological, and molecular features. There is a reduction in turgor, leaf water potential and stomatal closure and a decrease in expansion and cell growth (Hussain et al., 2018, Hannachi et al., 2023 and Tan et al., 2023). These stresses prevent plant growth by affecting various biochemical and physiological functions such as chlorophyll synthesis, photosynthesis, ion uptake and movement, carbohydrate metabolism and nutrient metabolism (Kang et al., 2023 and Tan et al., 2023). Water deficit in Egypt in current time is major limit to increase the cultivated area. Besides,

*Corresponding author e-mail: nasrghazy724@gmail.com
Received: 12/02/2024; Accepted: 18/04/2024
DOI: 10.21608/JENVBS.2024.269366.1242

some planted area might be suffered from this water deficit. Sugar beet crop is sensitive to shortage of water especially in seedling stage (Caro & Cucci, 1986). Water stress caused several metabolic and morphological changes in cells and whole plant as tolerant responses of it (Blum, 1996). Water stress reduced root fresh & dry weights and root length (Rozita et al., 2012). Drought caused significant reduction in each of leaf area index and total chlorophyll of wheat plants (Kotb, 2014. Drought stress reduced the plant growth, fresh and dry biomass, and photosynthetic pigments of maize plants (Noman et al., 2015). Under drought stress, photosynthetic pigments, seedlings growth and development and photosynthetic quantum yield expressively reduced compare to control in all sugar beet genotypes (Islam et al., 2020).

Ascorbic acid (AsA) plays an important role in protecting plant tissues from harmful oxidative damage by acting as reductant (Anjum et al., 2016 and Alamri et al., 2018). It can regulate several processes in cells such as cell division, cell differentiation, and senescence (Alamri et al., 2018). L-ascorbic acid (vitamin C) is an important vitamin in the human diet and is abundant resources in plant tissues. Ascorbate contributes to electron low and to formation of zeaxanthin which acts as a photoprotectant. Activities of enzymes in the ascorbate glutathione cycle are increased by drought and low temperature suggesting a requirement for increased activity of the cycle under these conditions (Smirnoff, 1993 and 1995). As an antioxidant, AsA has an important role in protection against oxidative stress. Reactive oxygen species (ROS) such as hydrogen peroxide (H_2O_2), superoxide (O^{2-}), and the hydroxyl radical cause oxidative stress and are generated by a wide variety of factors in plants. Under normal conditions, ROS are generated during photosynthesis by singlet oxygen formation as well as oxygen photoreduction. Photooxidative damage can occur when ROS production exceeds that of the antioxidant capacity. Such conditions occur when high light is combined with other environmental conditions such as drought, temperature extremes, or nutrient deprivation (Luwe et al., 1993). Under normal conditions, the effects of foliar application of vitamin C on many plants were indicated. Abdel-Halim (1995), Dolatabadian et al. (2010), Kotb and Elhamahmy (2013), Abo-Marzoka et al., (2016) and Qasim et al. (2019) found that foliar application of ascorbic acid caused significant increase on growth parameters as well as total weight, number of fruits and total yield. Foliar application of ascorbic acid significantly enhanced all growth parameters compared to un treated plants, especially on the high concentration of ascorbic acid (Abd El-Aziz et al., 2007 & Farahat et al., 2007 and Mazher et al. 2011). Application of AsA saved approximately 852m3/h of irrigation water without reducing wheat productivity (Kotb and Elhamahmy, 2013). Also, response of peanut crop to irrigation intervals and spraying with ascorbic acid in sandy soils, there was significant interaction between irrigation intervals and spraying with ascorbic acid on growth characters as well as total yield (Yakout et al., 2013). Application of AsA on wheat plants improved the oxidative stress damage of drought, reflected by improving growth characters as well as decreasing the activity of antioxidant enzymes in the leaves by approximately 14-16% compared to untreated plants under water stress (Kotb, 2014). On the other hand, under salinity stress conditions, the foliar spraying of ascorbic acid by 200 ppm significantly increased root yield and sugar yield over that gained by untreated plants (Abdel Fatah and Sadek, 2020). Also, exogenous AsA responded salt-induced photoinhibition mostly by controlling the endogenous AsA level and oxidation-reduction state in the chloroplast to encourage chlorophyll synthesis and improve the damage of oxidative stress to photosynthetic apparatus (Chen et al., 2021). Ascorbic acid in mitigation stress proved to be beneficial in most cases in imparting tolerance through increased carotenoids which played a protective role against stress (Abd El-Baki et al., 2022). Meanwhile, the response of sugar beet is not affected by the utilization of ascorbic acid via irrigation water at the concentrations used in the study of Gonçalves et al., 2022. Stress tolerance improvement through stress-mitigating strategies including the exogenous application and breeding drought/salt -tolerant varieties. These methods would assist in achieving sustainable yields despite global climatic changes (Islam et al., 2022 and Alavilli et al., 2023). The foliar application of ascorbic acid increased growth and yield by increasing photosynthetic pigments and up-regulating the enzymatic antioxidants under non-stressed and water stressed conditions (Sultan et al., 2023). To improve drought tolerance cultivars, must be a better understanding of different mechanisms related to the adaptability of sugar beet in drought conditions (Islam et al., 2020).

This study was conducted to evaluate some sugar beet cultivars in their drought tolerance using ascorbic acid, and to select a drought-tolerant cultivar to recommend its cultivation in Egyptian marginal areas.

2. Materials and Methods

Plant Material and Experimental Design:

A field experiment was carried out to investigate the effect of ascorbic acid on four sugar beet cultivars under water stress conditions. Sugar beet genotypes namely Del 1135 R2, Collins, BTS 7245 R1 and Aseel Table 1. These genotypes planted were under three levels of field capacity (100 – 75 – 50 % FC) and treated with foliar application of ascorbic acid at three concentrations (0-350-550 ppm). This study was established throughout two winter growing seasons 2021/2022 and 2022/2023 at experimental farm of Agronomy Department- Faculty of Agriculture- Suez Canal University in Ismailia, Egypt. The sowing date was 15 November in both the experimental design was a split-split plot design within a randomized complete block design (RCBD) with three replications. Main plots were designated for water treatments, while AsA treatments were allocated to subplots and varieties to sub-subplots.

distance between was hills 20 cm apart. Drought stress treatments were applied by preventing irrigation to maintain soil moisture content at field capacity of 75% and 50%, in addition to control treatment, where, soil moisture was maintained to field capacity (100%) until harvest. Experimental sub plot consisted of 5 rides 3 m in length and 60 cm in width (3*3 =9m2).

Table (1). Cultivars, cultivars name and source of sugar beet used in the present investigation.

No.	Cultivar name	Source
1	Del 1135 R2	France
2	Collins	France
3	BTS 7245 R1	Germany
4	Aseel	Germany

Recorded data:

At 150 days after sowing, five plants were taken randomly to recorded:

Total chlorophyll content (SPAD)

Chlorophyll meter reading as a SPAD values (502 plus- Minolta, Japan) were repeatedly taken at fully expanded sugar beet leaves through the experiments three times and average was calculated.

Number of leaves/plant:

Morphological characteristics:

At harvest (200 days after sowing) ten plants were taken randomly to recorded:

Root diameter and length (cm)

Root fresh and dry weights (g /plant)

Shoot fresh and dry weights (g/plant)

Sucrose content (%)

Sucrose percentage in juice of beet root was determined by Digital Sucrose Refractometer, MA871, Milwaukee Electronics Kft, http://www.milwaukeeinst.com.

Genetic variability:

The genotypic variance $\sigma 2$ g = M2 – M1 / r

The phenotypic variance $\sigma 2$ p = $\sigma 2$ g + $\sigma 2$ e

σ2p denote to phenotypic variance, σ2g denote to genotypic variance and σ2e denote to environmental variance, M1 denote to expected mean squares of genotypes which calculated from ANOVA Table, M2 denote to expected mean squares of error which calculated from ANOVA Table.

The genotypic (G.C.V %) and phenotypic (P.C.V %) coefficients of variability were calculated as σg /x- and σp /x-, respectively.

Heritability in broad sense (h2): heritability in broad sense and coefficient of variation (CV) were calculated for each trait. The calculation of these summary statistics requires knowledge of the error variance for the trait, according to **Hallauer & Miranda (1988).**

The genetic advance (GA): calculated according to **Allard (1964)** was estimated from the following formula: GA= I h2 Vp. where I = 2.06 (at 5 % selection intensity), h2: heritability in broad sense.

Tolerance indices:

Stress tolerance and susceptibility

1. Geometric Mean Productivity (GMP) = √(Y p*Ys)

2. Mean productivity (MP) = Yp + Ys /2 **according to Gupta et al. (2001)**

3. Tolerance index (TOL) = Y p - Ys **Gupta et al. (2001)**

4. Yield stability index (Y SI) = Ys /YP

5. Drought susceptibility index = (1- Ys /Yp)/ DII, according to **Chaudhuri & Kanemasu (1982),** where:

Ys = mean root yields of a given genotype in WS (50% FC) condition; Yp = mean root yields of a given genotype in NS (100% FC) condition; DII = Drought intensity index.

The drought intensity index (DII) for each water regime (FC%) was calculated as: DII =1 - Xs/Xp where, Xs= mean yield of all genotypes under stress and Xp= mean yield of all genotypes without stress.

Statistical analyses

Data were subjected to analysis of variance and combined analysis throughout the two seasons. The least significant difference (L.D.S) test at a significance level of $P < 0.05$ was employed to distinguish between the averages of each factor in this study.

3. Results and Discussion

A- Growth

- Total chlorophyll content (SPAD)

Results in **Table 2.** showed that plants of Collins cultivar had the highest mean value for chlorophyll content (45.2). The forced to water stress caused degradation in chlorophyll content by increasing the activity of the chlorophyllase enzyme which causing the insulting of chlorophyll, chloroplast structure, and pigment-protein complexes unstable (**Jamil *et al.*, 2012 and Bayoumi *et al*., 2015**). Tolerant cultivars with high chlorophyll content might be due to their ability to repair the damage mechanism, but sensitive cultivars did not have this mechanism (**Afiah et al., 2016**). AsA at 550 ppm gave the highest value (47.3). Interactions between (AsA* FC), (C * FC), (C * AsA) and (C * AsA* FC) were highly significant. These results are in the same line with the findings of **Kotb, (2014), Chen *et al*. (2021), Kang *et al*. (2023), Sultan *et al*. (2023) and Tan *et al*. (2023).**

Number of leaves/plants

Results in **Table (2)** showed that cultivars differences, concentrations of ascorbic acid and water stress regime have significanteffects on number of leaves/plant) of sugar beet plants.

Aseel cultivar recorded high values for number of leaves/plant (24.1). The differences between cultivars are due to their differences in genetic makeup **(Azab *et al*., 2017; Islam *et al*., 2020).**

Data in **Table (2)** explained that increasing concentration of ascorbic acid from 350 ppm up to 550 ppm in the foliar spray treatments significantly increased number of leaves/plant. AsA at 550 ppm gave the highest value in number of leaves/plant compared with 0 ppm and 350 ppm (Table 2). These results are in agreement with those found by **Islam *et al*. (2022), Alavilli *et al*. (2023) and Sultan *et al*. (2023).**

Results in **Table (2)** presented that more water regime stress expressed as 50% FC or 75% FC significantly decreased number of leaves/plant comparing with control treatment 100%FC. The same results were obtained by **Noman *et al.* (2015)** and **Islam *et al.* (2020).** Interactions between (AsA* FC), (C * FC), (C * AsA) and (C * AsA* FC) were high significant in number of leaves/plant. These results are confirmed with those reported by **Gonçalves *et al*. (2022), Hannachi *et al.* (2023), Kang *et al*. (2023), Mishra *et al*. (2023) and Tan *et al*. (2023).**

Table 2. Mean performance of sugar beet cultivars for number of leaves/plant and SPAD reading under drought stress using ascorbic acid with different concentrations.

Treatment	Number of leaves/plant	Chlorophyll SPAD Value
Field capacity (FC)		
100% FC	26.1 a	47 a
75% FC	22.3 b	43.7 b
50% FC	19.8 c	40.3 c
Ascorbic Acid (AsA)		
0 ppm AsA	19.6 c	39.3 c
350 ppm AsA	22.1 b	44.3 b
550 ppm AsA	26.6 a	47.3 a
Cultivars (C)		
Del 1135 R2	23.9 b	43.8 b
Collins	20.6 d	45.2 a
BTS 7245 R1	22.4 c	43.8 b
Aseel	24.1 a	41.9 c
Interactions		
AsA* FC	***	***
C * FC	***	***
C * AsA	***	***
C * AsA* FC	***	***

B- Harvest

Root characters

Results in **Table (3)** cleared that cultivars differences, concentrations of ascorbic acid and water stress regime have significant effects on all studied root characters (diameter, fresh and dry weights) of sugar beet plants, except root length for cultivars differences.

Del 1135 R2 cultivar recorded the highest and lowest values for root diameter (30.7 cm) and root length (17.2 cm), respectively. Meanwhile, BTS 7245 R1 cultivar recorded the highest values for root length (19.2 cm) and root fresh weight (603.1 g/plant and 19.9 ton/fad). Meanwhile, Aseel cultivar recorded the maximum root dry weight (157.9 g/plant and 5.2 t/fad). The differences between cultivars in root characters might be due to their genetic makeup **(Islam *et al.*, 2020)**. Also, data in **Table (3)** showed that increasing concentration of ascorbic acid from 0.0 ppm up to 550 ppm in the foliar spray treatments gradually and significantly increased root diameter, root length, root fresh weight and root dry weight. AsA at 550 ppm gave the highest values in root characters compared with 0 ppm and 350 ppm **(Table 3)**. These results are in harmony with many studies (**Kotb, 2014; Abdel Fatah and Sadek, 2020; Islam *et al*., 2022; Alavilli *et al*., 2023 and Sultan *et al*., 2023).**

Our results in **Table (3)** indicated that more water regime stress expressed as 50% FC or 75% FC significantly decreased the studied root characters comparing with control treatment 100 FC%. Interaction between (AsA* FC) was high significant with all root characters. Meanwhile, the other interactions of (C * FC), (C * AsA) and (C * AsA* FC) were high significant in root characters, except root length. These results are confirmed with many studies **(Kotb and Elhamahmy, 2013; Gonçalves *et al*., 2022; Hannachi *et al*., 2023; Kang *et al*., 2023; Mishra *et al*., 2023 and Tan *et al*., 2023).**

Table 3. Mean performance of sugar beet cultivars for root characters under drought stress using ascorbic acid with different concentrations.

Treatment	Root diameter (cm)	Root length (cm)	Root fresh weight (g/plant)	Root fresh weight (t/fad)	Root dry weight (g/plant)	Root dry weight (t/fad)
Field capacity (FC)						
100% FC	33.1 a	20.1 a	719.8 a	23.75 a	176.5 a	5.82 a
75% FC	26.75 b	18.3 b	485.1 b	16.01 b	124.5 b	4.11 b
50% FC	23.5 c	16.3 c	371.6 c	12.26 c	79.6 c	2.63c
Ascorbic Acid (AsA)						
0 ppm AsA	21.8 c	15.7 c	325.5 c	10.74 c	70.4 c	2.3 c
350 ppm AsA	27.6 b	18.2 b	525.9 b	17.35 b	127.8 b	4.22 b
550 ppm AsA	33.9 a	20.8 a	725.4 a	23.94 a	182.4 a	6.02 a
Cultivars (C)						
Del 1135 R2	30.7 a	17.2 a	492.1 c	16.24 c	104.8 d	3.46 d
Collins	25.3 d	18.7 a	447.9 d	14.78 d	110.1 c	3.63 c
BTS 7245 R1	27.5 b	19.2 a	603.1 a	19.9 a	134.7 b	4.45 b
Aseel	27.4 c	17.8 a	558.9 b	18.44 b	157.9 a	5.2 a
Interactions						
AsA* FC	***	***	***	***	***	***
C * FC	***	ns	***	***	***	***
C * AsA	***	ns	***	***	***	***
C * AsA* FC	***	ns	***	***	***	***

Shoot characters

Results in **Table (4)** showed that cultivars differences, concentrations of ascorbic acid and water stress regime have significant effects on the studied shoot characters (shoot fresh and shoot dry weights) of sugar beet plants.

BTS 7245 R1 cultivar recorded the highest values for shoot fresh weights (404.2 g/plant and 13.3 ton /fad) and shoot dry weights (70.4 g/plant and 2.3 ton /fad). The differences between cultivars are due to their differences in genetic makeup **(Azab *et al*., 2017 and Islam *et al.,* 2020).**

Data in **Table (4)** explained that increasing concentration of ascorbic acid from 0.0 ppm up to 550 ppm in the foliar spray treatments gradually and significantly increased shoot fresh and dry weights. AsA at 550 ppm gave the highest values in shoot characters compared with 0 ppm and 350 ppm. These results are in agreement with those found by **Abo-Marzoka *et al.,* (2016) and Qasim *et al*. (2019); Islam *et al*., 2022; Alavilli *et al*., 2023 and Sultan *et al*., 2023.**

Results in **Table (4)** presented that more water regime stress expressed as 50% FC or 75% FC significantly decreased the studied shoot characters comparing with control treatment 100%FC. The same results were obtained by **Noman *et al.*, (2015)** and **Islam *et al.* (2020).**

Interactions between (AsA* FC), (C * FC), (C * AsA) and (C * AsA* FC) were high significant with shoot characters. These results are confirmed with many studies **(Kotb and Elhamahmy, 2013; Gonçalves *et al*., 2022; Hannachi *et al.*, 2023; Kang *et al.*, 2023; Mishra *et al*., 2023 and Tan *et al*., 2023).**

Table 4. Mean performance of sugar beet cultivars for shoot fresh and dry weights (g/plant), shoot fresh and dry weights (ton/fad) under drought stress using different concentrations of ascorbic acid.

Treatment	Shoot fresh weight (g/plant)	Shoot fresh weight (ton/fad)	Shoot dry weight (g/plant)	Shoot dry weight (ton/fad)
Field capacity (FC)				
100% FC	426.8 a	14.1 a	66.8 a	2.2 a
75% FC	266.3 b	8.8 b	50.5 b	1.7 b
50% FC	199.9 c	6.6 c	40.8 c	1.3 c
Ascorbic Acid (AsA)				
0 ppm AsA	190.5 c	6.3 c	38.2 c	1.3 c
350 ppm AsA	298.6 b	9.9 b	52 b	1.7 b
550 ppm AsA	404 a	13.3 a	67.8 a	2.2
Cultivars (C)				
Del 1135 R2	242.3 c	7.99 c	46.3 c	1.5 c
Collins	196.2 d	6.5 d	37.7 d	1.2 d
BTS 7245 R1	404.2 a	13.3 a	70.4 a	2.3 a
Aseel	348 b	11.5 b	56.2 b	1.9 b
Interactions				
AsA* FC	***	***	***	***
C * FC	***	***	***	***
C * AsA	***	***	***	***
C * AsA* FC	***	***	***	***

Sucrose content and sugar yield

Our data in **Table (5)** exhibited that Collins cultivar had the highest mean value for Sucrose content % (23.8%). Meanwhile, BTS 7245 R1 cultivar had the highest mean value for Sugar yield (ton/fad) (4.6 ton/fad). In addition, AsA at 550 ppm gave the highest values from sucrose content (24.2 %) and sugar yield (5.8 ton sugar/fad). Significant increases were found in sucrose content accompanied with increasing water stress. Interactions between (AsA* FC), (C * FC), (C * AsA) and (C * AsA* FC) were high significant. These results are confirmed many studies (**Abdel Fatah and Sadek, 2020; Islam *et al.*, 2020; Gonçalves *et al*., 2022 and Sultan *et al*., 2023).**

Table 5. Mean performance of sugar beet cultivars for sucrose content and sugar productivity under drought stress using different concentrations of ascorbic acid.

Treatment	Sucrose content (%)	Sugar productivity (ton/fad)
Field capacity (FC)		
100% FC	20.0c	4.75a
75% FC	22.9b	3.67b
50% FC	25.8a	3.16c
Ascorbic Acid (AsA)		
0 ppm AsA	21.4 c	2.3 c
350 ppm AsA	23.2 b	4.02 b
550 ppm AsA	24.2 a	5.8 a
Cultivars (C)		
Del 1135 R2	22.2 d	3.6 c
Collins	23.8 a	3.5 d
BTS 7245 R1	22.4 c	4.6 a
Aseel	23.2 b	4.3 b
Interactions		
AsA* FC	***	***
C * FC	***	***
C * AsA	***	***
C * AsA* FC	***	***

Genetic variability

Results of genetic variation of the studied characters are illustrated in **Table (4)**. The magnitude of the phenotypic coefficient of variation (PCV) values for all traits was higher than the corresponding GCV values, indicating that these traits may be influenced by environmental factors (**Mesfin *et al*., 2019 and Tadele *et al*., 2021**). Phenotypic coefficients of variability ranged from 12.8 to 225.34% and the highest PCV attained from shoot fresh weight and the lowest from sucrose content. Genotypic coefficient of variation also had similar trend as phenotypic coefficient of variation. The broad sense heritability was high for all the recorded characters, except for root diameter. For effective selection we cannot only believe on heritability, the combination of high heritability with high genetic advance will deliver a clear base on the reliability of that particular character in the selection of variable appearances. The genetic advance as percentage of means (GA) for characters ranged from 19.76 to 443.24 % and the highest GA obtained from shoot fresh weight and the lowest from root diameter. In the breeding program, high range of heritability, variability, and genetic improvement among characters could be an excellent tool for improving or selection genotype (**Akbar *et al*., 2003 and Alavilli *et al*., 2023**).

Table 4. Estimation of variance components phenotypic (PCV) (%) and genotypic (GCV) (%) coefficients of variation, broad sense heritability (h2) (%) and genetic advance (GA) (%) for each trait.

Traits	PCV (%)	GCV (%)	GA (%)	h2 (%)
Root diameter (cm)	24.24	15.25	19.76	39.57
Root length (cm)	14.74	14.11	27.83	91.62
Root fresh weight (g/plant)	39.38	36.58	69.99	86.27
Root dry weight (g/plant)	57.8	55.83	111.1	93.32
Shoot fresh weight (g/plant)	225.34	220.20	443.24	95.48
Shoot dry weight (g/plant)	80.1	77.58	154.8	93.83
Number of leaves/plant	21.61	19.3	35.5	79.74
Sucrose content (%)	12.8	11.8	22.3	84.4

Tolerance indices

Data in **Table (5)** showed that yield decreased about 32.6% to 48.4% when plants exposed to 75 and 50% FC, respectively. The cultivar Aseel with treatment 550 ppm AsA gave the highest yield of root fresh under the three water regimes (1178 g/plant for100 %FC, 725 g/plant for 75% FC and 721 g/plant for 50% FC). The values of geometric mean productivity (GMP) ranged from 881.61 g/plant to 247.99 g/plan. The cultivar Aseel with treatment 550 ppm AsA recorded the highest value for geometric mean productivity (GMP) (881.61g/plant**).** Mean productivity (MP) ranged between 899.5 g/plant to 252.5 g/plant. Also, the cultivar Aseel with treatment 550 ppm AsA recorded the maximum value for mean productivity (MP) (899.5 g/plant**).**

Tolerance (TOL) index ranged between 95 and 747. The lower and the mild values of TOL are the most stress tolerance. Yield Stability index (YSI) ranged from 0.31 - 0.75 and the highest values indicate high stress tolerance. Besides mean productivity (MP), geometric mean productivity (GMP) and the yield stability offered similar ranking pattern as in drought susceptibility index (DSI). Drought susceptibility index (DSI) has been used to characterize relative drought tolerance of treatments. Low drought susceptibility index ($S < 1$) is synonymous with higher stress tolerance. The DSI ranged from 0.52-1.42. The cultivar Collins with treatment 550 ppm AsA gave low value (0.52) for drought susceptibility index (DSI) under the three water regimes. The determination of traditional yield indices, e.g. MP, GMP, TOL, YSI and DSI measurements, is helpful in the screening of drought tolerance (**Jones, 2007**). Generally, the former indices indicated that treating the cultivars Aseel and Collins with treatment 550 ppm AsA gave the highest yield gave the most tolerant treatments. Results were in harmony with **Bayoumi *et al*., (2015); Azab *et al*., 2017; Khatab *et al*., (2019); Memari *et al*., (2021) and Abd EL-Mageed *et al*., (2022)** who stated MP, GMP, TOL, YSI and DSI indices had the most preferable selection criteria for screening drought-tolerant genotypes and high-yielding.

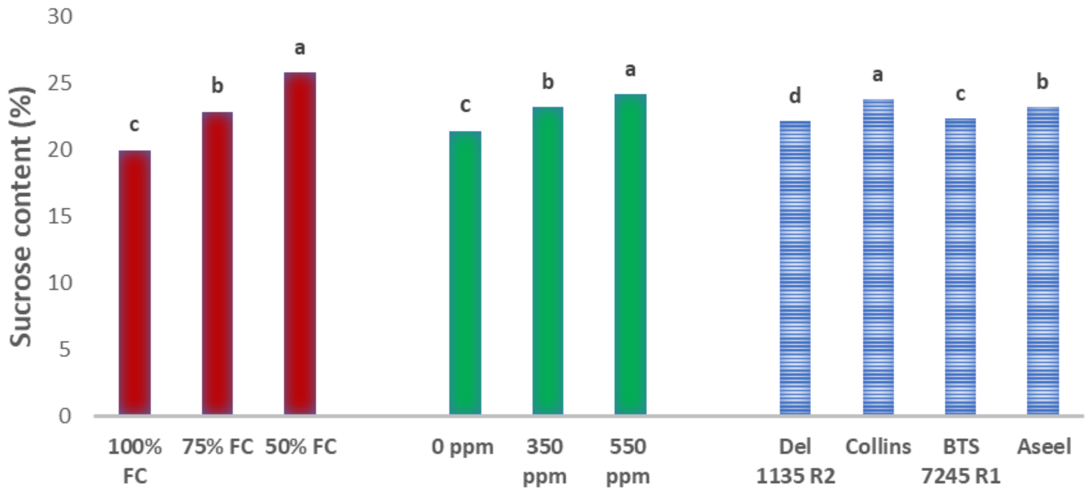

Fig 1: Means performance of sugar beet cultivars for sucrose content under drought stress using different concentrations of ascorbic acid

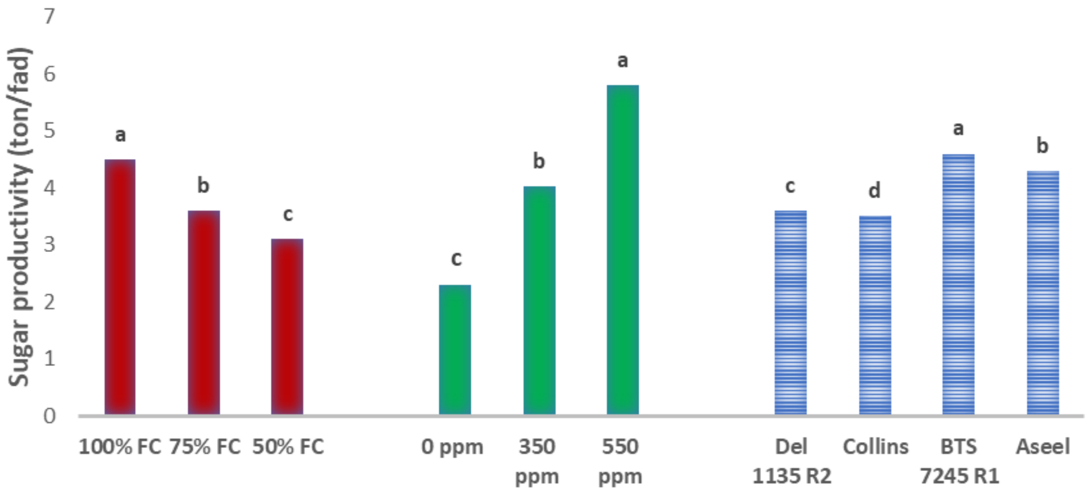

Fig 2: Means performance of sugar beet cultivars for sugar produchvity under drought stress using different concentrations of ascorbic acid.

Results in Table (6) exhibited that the indices MP and GMP were very similar to the selection based on Yis and Ys. This was confirmed by positive and highly correlations between Yis and MP (r = 0.90) and GMP (r = 0.91) and the correlation between Ys and MP (r = 0.92) and GMP (r = 0.96). MP is the mean production under both stress and non-stress conditions, and it was highly correlated with yield under both conditions. Therefore, MP can be used to recognize treatments in the tolerant group. Whereas, there was negative correlation between drought susceptibility index (DSI) and the other tolerance indices, except TOL (r = 0.60). Thus, these indices were able to recognize superior treatments under drought stress. GMP, MP , YSI and DSI were associated with yield under stress conditions, suggesting that these factors are suitable for selecting drought tolerant and high yielding treatments in drought stress conditions (**Bayoumi et al., 2015; Azab *et al*., 2017 and Mohamed *et al*., 2022**).

Table 6. Simple correlation of root fresh weight per plant in 100% FC (Yp), 75% FC (YIS) and stressed 50% FC (Ys) conditions with mean productivity (MP), geometric mean productivity (GMP), tolerance index (TOL), yield stability index (YSI) and drought susceptibility index (DSI).

Variable	Yp	Yis	Ys	MP	GMP	TOL	YSI	DSI
Yp	1.00	0.85**	0.80**	0.97**	0.93**	0.80**	-0.04	0.04
Yis		1.00	0.87**	0.90**	0.91**	0.48	0.23	-0.23
Ys			1.00	0.92**	0.96**	0.27	0.53	-0.53
MP				1.00	0.99**	0.62*	0.19	-0.19
GMP					1.00	0.53	0.29	-0.29
TOL						1.00	-0.60*	0.60*
YSI							1.00	-1.00
DSI								1.00

Conclusion

It was determined that drought stress can seriously inhibit sugar beet growth but ascorbic acid might be improving this side effect of this stress. There are many physiological and agronomical responses are reflected the effect of both drought and ascorbic acid (AsA) and show how AsA can be used to improve the growth and productivity of sugar beet. In our experiment, Application of AsA with 550 ppm has enhanced growth performance and production parameters and this reflected on tolerance indices.

Conflicts of interest

There are no conflicts to declare

Acknowledgments

We would like to express our sincere gratitude to our colleagues who played a crucial role in the success of this research. Their invaluable contributions, insights, and collaborative efforts greatly enhanced the quality and depth of our work. We are truly thankful for their support and dedication throughout the research process

Reference

Abd El –Aziz, N. G.; Fatama, E.M. EL-Quesni and Farahat ,M.M. (2007). Response of vegetative growth and some chemicals constituents of syngonium podophyllum L. to foliar application of Thiamine, Ascorbic Acid and Kinetin at Nubaria. World J. Agric. Sci. 3: 301-305.

Abd El-Baki G.K.; Al-Shima R. and Doaa M. (2022) . Differential Responses of Common Bean, (Phaseolus vulgaris L.) to the Interactive Effects of Ascorbic Acid and *Trichoderma harzianum* under Salinity Stress Egypt. Acad. Journal Biolog. Sci., 13(2):11-29 .

Abdel-Halim, S.M. (1995). Effect of some vitamins as growth regulators on growth, yield and endogenous hormones of tomato plants during winter. Egypt. J. Appl. Sci., 10(12): 322-334.

Abdel Fatah E. M. and Sadek K.A. (2020). Impact of Different Application Methods and Concentrations of Ascorbic Acid on Sugar Beet under Salinity Stress Conditions. Alex. J. Agric. Sci. Vol. 65, No. 1, pp. 31–44.

Abd EL-Mageed AM, Mahmoud SA, Emam MA, AbuElsaoud AM, Sabry SA (2022). Assessing Drought Tolerance of some Faba Bean (Vicia faba L.) Cultivars Using Genetic Variability, Tolerance Indices and ISSR Markers. Journal of Plant Production Sciences, 11(1), pp. 111-121. doi: 10.21608/jpps.2022.284078

Abo-Marzok, E.A; Rania F.Y., El-Mantawy and Iman M. Soltan (2016). Effect of irrigation intervals and foliar spray with salicylic and ascorbic acids on maize. J. Agric. Res. Kafr El-Sheikh Univ, 42(4): 506-518.

Akbar, M.; Mahmood, T.; Yaqub, M.; Anwar, M. M. and Iqbal, A. N. (2003) Variability, correlation and path coefficient studies in summer mustard (Brassica juncea L.). Asian. J. Plant Sci. 2, 696-698.

Alamri, S.A.; Siddiqui M.H.; Al-Khaishany M.Y.; Khan M.N.; Ali H.M.; Alaraidh I.A., Alsahli A.A.; Al-Rabiah H. and Mateen M., (2018). Ascorbic acid improves the tolerance of wheat plants to lead toxicity. J Plant Interact 13(1):409–419 .

Alavilli, H.; S. Yolcu; M. Skorupa; S. B. Aciksoz and M. Asif. (2023). Salt and drought stress mitigating approaches in sugar beet (Beta vulgaris L.) to improve its performance and yield. Planta 258:30 https://doi.org/10.1007/s00425-023-04189.

Allard, R.W. (1964). "Principles of Plant Breeding". John Wiley and Sons. Inc. New York, London.

Anjum, S.A.; Tanveer M.; Hussain S.; Shahzad B.; Ashraf U.; Fahad S.; Hassan W.; Jan S.; Khan I.; Saleem M.F.; Bajwa A.A.; Wang L.; Mahmood A.; Samad R.A. and Tung S.A. (2016). Osmoregulation and antioxidant production in maize under combined cadmium and arsenic stress. Environ Sci Pollut Res 23(12):11864–11875.

Bayoumi, T.Y.; A. M. Abd EL-Mageed; E. S. Ibrahim; Soad A. Mahmoud; I. S. El -Demardash and A. Abdel-Raheem (2015). The impact of drought stress on some morpho-physiological traits and RAPD markers in wheat genotypes. J. of Plant Production Sci.; Suez Canal University, (4): 27- 37, doi:10.21608/jpps.2015.7396.

Blum, A. (1996) Crop responses to drought and the interpretation of adaptation. Plant Growth Regulation 20, 135-148.

Caro, A.D. and Cucci, G. (1986). Four year experiment on spring-seeded sugar beet irrigation and harvest time in southern Italy. Irrigation, 33 (3), 21-25.

Chaudhuri, U.N. and Kanemasu, E. T. (1982). Effect of water gradient on sorghum growth, water relations and yield. Canadian Journal of Plant Science, 62, 599- 607. http://dx.doi.org/10.4141/cjps 82-090.

Chen X; Zhou Y; Cong Y; Zhu P; Xing J; Cui J; Xu W; Shi Q; Diao M and Liu H-y (2021) Ascorbic Acid-Induced Photosynthetic Adaptability of Processing Tomatoes to Salt Stress Probed by Fast OJIP Fluorescence Rise. Front. Plant Sci. 12:594400. doi: 10.3389/fpls.2021.594400

Dolatabadian, A.; Modarressanavy S.A.M., and Asilan K.S., (2010). Effect of ascorbic acid foliar application on yield, yield component and several morphological traits of grain corn under water deficit stress conditions. Notulae Scientia Biologicae., 2(3): 45-50 .

Azab E. S.; Mahmoud S. A.; Abd elmageed A. M. and Bayoumi T. Y. (2017). Influence of Gibberellic Acid on Beta vulgaris L. Plants under Drought Conditions. Egypt. J. Agron. Vol. 39, No.1, pp.99-116.

Farahat, M.M.; Soad M.M. I.; Lobna S.T. and Fatama E.M. EL., (2007). response of vegetative growth and some chemical constituents of Cupressus sempervirens L. to foliar application of ascorbic acid and zinc at Nubaria . World. J. Agric. Sci., 3: (4) 694-502.

Gonçalves, A.; J. S. Filho; V. F. O. Sousa; T. I. Silva; T. J. Dias; A. G. Souza and J. G. Moura (2022). Chlorophyll index, maximum fluorescence, and water use efficiency in sugar beet under water deficit and ascorbic acid application. Bioagro 34(3): 319-326 .

Gupta, N.K.; Gupta, S. and Kumar, A. (2001). Effect of water stress on physiological attributes and their relationship with growth and yield in wheat cultivars at different growth stages. Journal of Agronomy and Crop Science, 186, 55-62.

Hallauer, A. R. and Miranda, J. B. (1988). "Quantitative Genetics in Maize Breeding". 2nd ed. Iowa State Univ. Press, Ames. pp 71.

Hannachi S; Signore A and Mechi L (2023). Alleviation of associated drought and salinity stress' detrimental impacts on an eggplant cultivar ('Bonica F1') by adding biochar. Plants (basel). https:// doi.org/10.3390/plants12061399.

Hussain HA; Hussain S; Khaliq A; Ashraf U; Anjum SA; Men S and Wang L (2018). Chilling and drought stresses in crop plants: implications, cross talk, and potential management opportunities. Front Plant Sci 9:393. https://doi.org/10.3389/fpls.2018. 00393.

Islam, J.; J. W. Kim; K. Begum; A. Sohel and Y. Lim . (2020). Physiological and Biochemical Changes in Sugar Beet Seedlings to Confer Stress Adaptability under Drought Condition. Plants, 9, 1511; doi:10.3390/plants9111511.

Islam MJ; Uddin MJ; Hossain MA; Henry R; Begum M.K and Sohel M.AT. (2022). Exogenous putrescine attenuates the negative impact of drought stress by modulating physio biochemical traits and gene expression in sugar beet (Beta vulgaris L.). PLoS ONE 17(1): e0262099. https://doi.org/10.1371/journal .

Jamil, M.; S. Bashir; S. Anwar; S. Bibi; A. Bangash; F. Ullah and E. Shikrha, 2012. Effect of salinity on physiological and biochemical characteristics of different varieties of rice. Pakistan Journal of Botany, 44: 7-13.

Jones, H.G. (2007). Monitoring plant and soil water status: established and novel methods revisited and their relevance to studies of drought tolerance. J. Exp. Bot. 58, 119-130.

Kang BH; Kim WJ; Chowdhury S; Moon CY; Kang S; Kim SH; Jo SH; Jun TH; Kim KD and Ha BK (2023). Transcriptome analysis of differentially expressed genes associated with salt stress in cowpea (Vigna unguiculata L.) during the early vegetative stage. Int J Mol Sci. https://doi.org/10.3390/ijms24054762.

Khatab I. A.; A. B. A. El-Mouhamady; S. A. Mariey and T. A. Elewa (2019). Assessment of water deficiency tolerance indices and their relation with ISSR markers in barley (Hordeum vulgare L.). Curr. Sci. Int., 8(1): 83-100.

Kotb, M. A., (2014). Effect of foliar application of non-enzymatic antioxidants on peanut yield and its quality under induced water stress conditions. Zagazig J. Agric. Res., 41 (5): 931-947.

Kotb, M. A. and Elhamahmy M.A.M., (2013). Foliar application of ascorbic acid improved drought tolerance and productivity of wheat (Triticum aestivum L.). Journal of Plant Production Sciences, Suez Canal University, 1: 1-16.

Le-Docte (1927). Commercial determination of sugar beet in the beet root using the sacks. Le-Docte process. Int. Sugar. J. 29, 488-492.

Luwe, M.F.; Takahama U. and Heber U., (1993). Role of ascorbate in detoxifying ozone in the apoplast of spinach (Spinacia oleracea) leaves. Plant Physiol., 101 (3): 969-976.

Mazher, A.A.M.; Zaghloul S. M.; Mahmoud S. A. and. Siam H. S., (2011). Stimulatory Effect of Kinetin, Ascorbic acid and Glutamic Acid on Growth and Chemical Constituents of Codiaeum variegatum L. Plants. American-Eurasian J. Agric. & Environ. Sci., 10 (3): 318-323.

Memari, M.; M.R. Dadashi; F. Sheikh and H. Ajamnorozei (2021). Evaluation of drought stress tolerance in some faba bean genotypes using drought tolerance indices and biochemical compounds. Tulīd va Farāvarī-i Maḥṣūlāt-i Zirā̒ī va Bāghī Vol 11, Iss 2, Pp 139-151.

Mesfin, T.; M. Wassu and J. Mussa (2019). Genetic Variability on Grain Yield and Related Agronomic Traits of Faba Bean (Vicia faba L.) Genotypes under Soil Acidity Stress in the Central Highlands of Ethiopia. Chemical and Biomolecular Engineering 4(4):52-58. doi: 10.11648/j.cbe.20190404.12

Ministry of Agriculture and Land Reclamation (2022). Sugar Crops and Sugar Production in Egypt and the World; MALR Annual Report; Council of Sugar Crops: Giza, Egypt.

Mishra N; Jiang C; Chen L; Paul A; Chatterjee A and Shen G (2023). Achieving abiotic stress tolerance in plants through antioxidative defense mechanisms. Front. Plant Sci. 14:1110622. doi: 10.3389/fpls.2023.1110622.

Mohamed A. E.; Amal M. Abd EL-Mageed; Gniewko Niedbała; Samah A. Sabrey; Ahmed S. Fouad; Tarek Kapiel; Magdalena Piekutowska and Soad A. Mahmoud (2022). Genetic Characterization and Agronomic Evaluation of Drought Tolerance in Ten Egyptian Wheat (Triticum aestivum L.) Cultivars Agronomy, 12, 1217. https://doi.org/10.3390/agronomy12051217.

Noman, A.; Ali S.; Naheed F.; Ali Q.; Farid M.; Rizwan M. and Irshad M. K., (2015) Foliar application of ascorbate enhances the physiological and biochemical attributes of maize (Zea mays L.) cultivars under drought stress. Archives of Agronomy and Soil Science, 61: 1659-1672.

Pitman, M.G. and Lauchli, A. (2002). Global impact of salinity and agricultural ecosystems. In : "Salinity:Environment-Plants Molecules", Lauchli, A. and V.Luttge (Ed.). Kluwer, Netherlands.

Qasim, M.; Aziz M.; Nawaz F. and Arif M. (2019). Role of salicylic acid and ascorbic acid in alleviating the harmful effects of water stress in Maize (Zea mays L.). Asian J. Agric. Biol. 7(3):442-449 .

Rozita, K.; Hassan, F. and Fatemeh, N. (2012). Effect of drought stress and its interaction with salicylic acid on Black Cumin (Nigella sativa) germination and seedling growth. World Applied Sciences Journal, 18 (4), 520-527.

Seleiman MF; Al-Suhaibani N; Ali N; Akmal M; Alotaibi M; Refay Y; Dindaroglu T; Abdul-Wajid HH and Battaglia ML (2021). Drought stress impacts on plants and diferent approaches to alleviate its adverse efects. Plants (basel). https://doi.org/10.3390/plants1002 0259

Shao, H.B.; Chu, Y.; Jaleel, C.A. and Zhao, C.X. (2008). Water deficit stress induced an atomical changes in higher plants. J. Plant Biol. Pathol. 331, 215-225.

Smirnoff, N. (1993). The role of active oxygen in the response of plants to water deficit and desiccation. New Phytol., 125: 27–58.

Smirnoff, N. (1995). Antioxidant systems and plant response to the environment. In: Smirnoff N, ed. En.ironment and plant metabolism. Flexibility and acclimation. Oxford: Bios Scientifc Publishers, 217-243.

Steel, G.D.; Torrie, J.H. and Diskey, D.A. (1997). "Principles and Procedures of Statistics : A Biometrical Approach" . 3rd ed. McGraw-Hill, New York.

Sultan, K.; Perveen, S.; Parveen, A.; Atif, M., and Zafar, S. (2023). Benzyl Amino Purine (BAP), Moringa Leaf Extract and Ascorbic Acid Induced Drought Stress Tolerance in Pea (Pisum sativum L.). Gesunde Pflanzen, 1-14.

Tadele, M.; W. Mohammed and M. Jarso, (2021). Variation in genetic variability and heritability of agronomic traits in faba bean (Vicia faba L.) genotypes under soil acidity stress evaluated with and without lime in Ethiopia. African Journal of Agricultural Research (17) 355–364, doi:10.5897/AJAR2020.15128

Tan W; Li W; Li J; Liu D and Xing W (2023). Drought resistance evaluation of sugar beet germplasms by response of phenotypic indicators. Plant Signal Behav 18(1):2192570. https://doi.org/10.1080/15592324.2023.2192570

Yakout, G. M.; Hafiz S. I.; Kotb M. A. and El-Mahdy G. S. (2013). Response of peanut crop to irrigation intervals and spraying with micronutrients and ascorbic acid in sandy soils. Journal of Plant Production Sciences, Suez Canal University, (1): 43-52.