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The Effect of Aloe Leaf Extract on Growth and Physio-biochemical Characteristics of Jojoba Plants Cultivated under Normal and Salt Stress Conditions.

Wanas, A.L.I [1] and Shabka, Eman. M.A* [1]
[1] Agricultural botany Department, Faculty of Agriculture, Damietta University, Egypt

Corresponding author*: Email : eman_sh@du.edu.eg

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Abstract:

Two preliminary trials were conducted. The first aimed to identify the seawater salinity level beyond which germination percentage and performance drop below 50% of the control values, considering it is the maximum tolerable salinity for jojoba plants; this was 14,000 ppm. The second trial evaluated three aloe leaf extract (ALE) concentrations (5%, 7.5%, and 10%), revealing that 10% had the greatest effect on seed germination and seedling vigor when compared to the control. As a result, two main experiments were done during the 2021/22 and 2022/23 seasons to assess the effects of 14,000 ppm salinity and 10% ALE, both alone and in combination, on the growth and physiological performance of jojoba plants. The results reveal that irrigation jojoba plants with seawater at a salinity of 14,000 ppm caused significant reductions in the root system size, stem length, number of leaves and branches, total leaf area, fresh and dry weights of roots, stems, and leaves, root/shoot ratio, photosynthetic pigments, total carbohydrates, crude protein, and concentrations of NPK, Ca, and Mg. However, leaf area ratio (LAR) and proline, polyphenols, and Na concentrations increased compared to control plants. Foliar application of 10% ALE on salt-unstressed jojoba plants (irrigated with tap water) significantly enhanced various growth parameters and concentrations of bioconstituents and minerals while decreasing LAR and Na concentration. Furthermore, spraying 10% ALE on salt-stressed jojoba plants (irrigated with 14,000 ppm seawater) not only mitigated the detrimental effects of salinity but also led to remarkable improvements in growth parameters and concentrations of photosynthetic pigments, total carbohydrates, polyphenols, proline, protein, and mineral nutrients, while significantly reducing Na level compared to the control in both seasons. This study recommends applying 10% ALE to improve the growth and physiological performance of jojoba plants, whether under normal or stressful conditions.

INTRODUCTION

Climate change and its consequences, such as expanding desertification, land degradation, and increasing soil salinity indeed pose substantial threats to agricultural sustainability, particularly in regions like the Middle East and North Africa. Land degradation in these regions has reached 40% to 70% during the past two decades (World Bank, 2019; Golla, 2021). Therefore, it is essential to choose plant species that can withstand adverse environmental conditions, such as salinity for agricultural development in arid and semi-arid regions (Benzioni *et al.*, 1992).

Jojoba (*Simmondsia chinensis* (Link) Schneider) is an evergreen, dioecious shrub belonging to the Simmondsiaceae family, primarily cultivated in desert regions as a seed oil crop called "desert gold"

(Bala, 2021). Jojoba oil, which constitutes about 52% of the seed's weight, is the only unsaturated liquid wax and is extensively used in lubricants, cosmetics, and pharmaceuticals (Arya and Khan, 2016). It also has traditional medicinal applications for numerous ailments (El Gendy *et al.*, 2023). The jojoba plant is known for its drought and salinity resistance, adaptability to extreme temperatures, and low needs for soil fertility and irrigation, alongside its significant financial benefits, making it an ideal option for areas facing water scarcity and unproductive farming practices (Arya and Khan, 2016; Al Obaidi *et al.*, 2017).

Salinity is a paramount agricultural issue, particularly in arid and semi-arid regions where there is insufficient rainfall to eliminate excess salts from the root zone. It can also impact irrigated agricultural lands, particularly those using poor-quality irrigation water and drainage systems (Aboryia *et al.*, 2022).

Salinity negatively affects plant growth through ionic imbalances, osmotic stress, and oxidative stress, which disrupt biochemical and physiological processes, ultimately reducing productivity (Islam *et al.*, 2021; Linić *et al.*, 2021). Despite this, plants exhibit resilience to salt stress through mechanisms like osmotic adjustment, hormonal regulation, and ion homeostasis, effusing or compartmentalizing excessive Na^+ (Mushtaq *et al.*, 2020). They also counteract cell wall acidification and reactive oxygen species (ROS) by activating antioxidant defenses (Alkharabsheh *et al.*, 2021). However, these defenses may be inadequate under extreme conditions, necessitating additional support to enhance stress tolerance (Islam *et al.*, 2021). Many plant extracts contain natural growth promoters (e.g., phytohormones, nutrients, osmoprotectants, and antioxidants) that can bolster plants' resilience to stress (Wanas *et al.*, 2018; Desoky *et al.*, 2019; Merwad, 2020).

Aloe (*Aloe barbadense*, Mill) leaf gill extract (ALE) is a rich source of bioactive compounds, including 20 amino acids (7 essential), enzymes (lipase, catalase, peroxidase, etc.), phytohormones (gibberellins and auxins), vitamins (A, B, E, C, B12, choline, folic acid), and minerals like Ca, Cr, Cu, Fe, Mn, K, Na, and Zn (Akev *et al.*, 2015). It also contains a phenolic concentration of 17.85 mg g^{-1} dry matter (Hęś *et al.*, 2016). Despite its potential as a biostimulant, the use of ALE to enhance plant growth and productivity under normal or stressful conditions is limited. Therefore, this study aims to explore the effects of aloe leaf extract on the growth and physio-biochemical characteristics of jojoba plants under both normal and salt-stress conditions.

Materials and Methods:

1-Experimental Procedures:

In This study was conducted at the Experimental Station of the Faculty of Agriculture, Damietta University, Egypt (31°25'38"N and 31°39'06"E), during the 2021/2022 and 2022/2023 seasons to examine the effects of salinity and aloe leaves extract (ALE) on the growth and physio-biochemical characteristics of jojoba (*Simmondsia chinensis* (Link) Schneider) plants, as well as the potential of OLE to mitigate salinity's negative effects. To achieve these objectives, three experiments were performed: two preliminary germination trials and a main experiment. Jojoba seeds, obtained from MK Group for Desert Land Reclamation, were disinfected before sowing in each experiment. The disinfection comprised washing the seeds with running tap water, soaking them for 5 minutes in 1% sodium hypochlorite, and rinsing thoroughly distilled water to eliminate any residual sodium hypochlorite.

2- The first preliminary experiment:

In this experiment, jojoba seeds were exposed to a series of seawater salinity levels ranging from 2000 to 20000 ppm in 2000 ppm increments along with tap water (236.16 ppm, control) to determine the threshold after which the germination percentage declines below 50% of the control value. This threshold was identified as the maximum salinity level tolerable by plants following Wanas (1996) and was used in the main experiment. Thirty disinfected jojoba seeds were tested at each salinity level beside tap water as a control. The seeds were planted in 7 cm diameter plastic pots (2 seeds per pot) filled with a sand and peat moss mixture (2:1 v/v). The empirical design was a completely randomized block design with 11 treatments, each replicated three times with five pots per replicate. Salinity levels and tap water were used as irrigation solutions, uniformly applied as needed to all pots according to their assigned salinity levels. The experiment was done on August 1st, 2021, at the laboratory of the Botany Dept., Fac. Agric., Damietta Univ.

3- The second preliminary experiment:

This experiment aimed to explore the optimal concentration of aloe leaf gel extract (ALE) among three specified concentrations, based on some

germination criteria, for applying it in the main experiment. Thirty disinfected jojoba seeds were soaked in four concentrations, i.e., 0.0 (distilled water; control), and 5%, 7.5%, and 10% of ALE, for 24 hours. Subsequently, the treated seeds were sown in plastic pots, 7 cm in diameter, filled with a sand and peat moss mixture (2:1 v/v). Each treatment consisted of three replicates with five pots replicate^{-1} (2 seeds pot^{-1}), arranged in a completely randomized block design. The experiment was conducted on August 1st, 2021, at the Botany Department laboratory, Faculty of Agriculture, Damietta University. Uniform irrigation was applied simultaneously to all treatments as needed, using tap water.

In both preliminary experiments, germinated seeds were counted daily starting from the 9th until the 23rd day, with seeds deemed germinated once the plumule emerged above the soil. This data was then used to calculate the following germination criteria:

a) Germination percentage (GP) according to Tanaka-Oda, *et al.,* (2009) =

$$\frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ sown\ seeds} \times 100$$

b) Mean rate of Germination (MRG) according to Edwards and Sundsrom (1987):

$$MRG = \frac{\sum T_n N_n}{\sum N_n}$$

MGR is expressed as the mean number of days required for germination, where: T_1= No. of days passed from soaking till the first count; T_2= No. of days passed from soaking till the second count… to Tn; N_1= No. of germinated seeds at the first count; N_2= No. of germinated seeds at the second count…to Nn.

c) Seedling vigor index (SVI) = Germination % × Seedling length {Root + Shoot) (Vashisth and Nagarajan, 2010).

d) Germination performance index (GPI) according to (Edwards and Sundstrom, 1987) =

$$\frac{Germination\ percentage}{MRG}$$

The first preliminary experiment indicated that jojoba could withstand salinity levels up to 14,000 ppm, while the second experiment identified that 10% of ALE was the most effective among its concentrations tested. This led to the selection of 14,000 ppm salinity and 10% of ALE for the main experiment.

4- The main experiment:

The experiment was conducted twice during two successive seasons of 2021/2022 and 2022/2023 at the Faculty of Agriculture's Nursery, Damietta University, Egypt. Jojoba seeds were disinfected and soaked in water for 24 hours to promote germination before being sown on September 23 in both seasons. The seeds were planted in plastic pots, 7 cm in diameter, filled with a 2:1 mixture of sand and peat moss, and they were regularly irrigated with tap water. After 79 days, uniform young plants were selected and transplanted into perforated 30 cm diameter black polyethylene bags containing 10 kg of sandy soil, with one seedling per bag. Forty-two days after transplantation, healthy plants were categorized into four treatment groups. The experiment followed a completely randomized block design (CRBD) with four treatments; each replicated six times (two bags per replicate). The details of the four treatments are as follows:

T_1: Control - Plants were irrigated with tap water and sprayed with distilled water .
T_2: Salinity (14000 ppm): Plants received seawater irrigation at 14000 ppm and sprayed with distilled water .
T_3: ALE (10%): Plants were irrigated with tap water and sprayed with ALE at 10%
T_4: Salinity (14000 ppm) + ALE (10%): Plants were irrigated with seawater at 14000 ppm salinity and sprayed with ALE at 10%

Foliar sprays of ALE at 10% were applied to plants T_3 and T_4, while distilled water was used for T_1 and T_2, on days 45, 75, 105, and 135 post-transplantation. A few drops of Tween-20 were added to the spray solutions as a surfactant to ensure effective and complete penetration of the solutions. Simultaneously, plants in treatments T_2 – T_4 received weekly irrigation with 250 ml of seawater at a concentration of 10,000 ppm, starting on day 45 post-transplantation until the experiment concluded. To prevent salt accumulation due to seawater irrigation, each bag in T_2 and T_4 was rinsed with 250 ml of tap water every three weeks.

5- Preparation of the assigned treatments:

5.1- Salinity levels:

Salinity levels for all experiments were prepared by diluting seawater with tap water. The seawater was collected from the Mediterranean Sea at Ras El-Bar, Damietta, Egypt (31°31'10"N and 31°49'49"E). The elemental compositions of both tap and seawater were analyzed using inductively coupled plasma optical emission spectroscopy, as shown in Table 1. Electrical conductivity and pH were measured in both water types following the method of Jackson (1973)

Table 1. The most abundant elements concentration (ppm), EC (ppm) and pH of both tap water and seawater.

Type of water	pH	EC (ppm)	Elements (ppm)						
			Ca	Mg	K	Zn	Se	Na	Cl
Tap water	7.72	236.16	27.17	12.52	5.41	0.05	0.02	36.77	67.77
seawater	8.15	34688.00	460.43	1,038.00	351.50	1.36	1.67	8,259.33	13,450.75

5.2- Aloe leaf gel extract (ALE).

Aqueous extract of aloe leaf gel (ALE) was freshly prepared before use, following the method described by Ghosh et al. (2011) with some modifications. Aloe plants were purchased from a private nursery in Kafr El-Bateekh, Damietta governorate. The leaves were collected, washed, and spines removed, after which the green rind was peeled off to extract the gel. The gel was squeezed in a blender, and 200 ml of the resultant gel was re-blended with distilled water to make a 20% aloe leaf aqueous extract. This extract was then filtered through muslin cloth and stored overnight at 4°C. The next day, it was brought to room temperature, further diluted to the desired concentrations, and used directly in the morning. Table 2 shows the most important bioactive compounds and minerals found in aloe species according to Akev et al. (2015).

Table 2. The most important biochemical compounds and minerals found in aloe species (Akev *et al.*, 2015)

Class	Compounds
Anthraquinones	Aloe-emodin, aloetic-acid, anthranol, aloin A and B, barbaloin, isobarbaloin, emodin, ester of cinnamic acid, resistannol etc.
Carbohydrates	Monosaccharides, mucopolysaccharides (glucomannans, acemannan, polymannose)
Enzymes	Alkaline phosphatase, amylase, bradykinase, carboxypeptidase, catalase, cyclooxidase, lipase, oxidase, Alliinase, bradykinase, peroxidase, cellulase etc.
Minerals	Calcium, chromium, copper, iron, magnesium, manganese, potassium, sodium, zinc
Amino acids	20 of the 22 human required amino acids required for nutrition
Vitamins	B, B_{12}, C , A, choline, folic acid, E
Hormones	Auxins and gibberellins

6- Soil sampling and analysis:

Soil samples were taken for chemical analysis before transplantation in both seasons. A soil aqueous extract was prepared using a 2:1 ratio of distilled water to soil, based on moisture content, to determine anion and cation concentrations using the iCAP 7400 - OES Spectrometer, as well as pH, and EC, following the method described by Jackson (1973). Soil organic carbon was also determined according to Dewis and Freitas (1970). Then organic matter percentage was calculated using the following equation:

$$\% \text{ Organic matter} = \frac{\% \text{ total C} \times 1.72}{0.58}$$ (Schulte, 1995). The results are shown in Table 3.

Table 3: Physical and chemical properties of the experimental soil before cultivation in both seasons (2021/2022 and 2022/2023).

Soil properties		Season	
		2021/2022	2022/2023
Soil particles distribution%			
Sand	**coarse**	1.94	1.50
	medium	51.92	51.41
	Fine	44.63	45.51
	Very fine	1.26	1.28
Silt and clay		0.26	0.30
Textural class		Sandy	
Hygroscopic humidity		0.36%	37%
Chemical properties			
pH		8.23	8.24
E.C. (ppm)		447.36	448.39
O.M%		0.28	0.32
Soluble cations (mg/100g)			
Mg^{+2}		2.80	2.91
Ca^{+2}		8.02	9.08
Na^{+}		14.25	14.49
K^{+}		4.30	4.68
Soluble anions (mg/100g)			
Cl^{-}		22.72	23.08
HCO^{-}_{3}		23.79	24.40
CO_3^{-2}		N.D.	N.D.

7- Sampling and collecting data:

7.1- Vegetative growth parameters:

250 days after planting (DAP), six randomly selected plants from each treatment were assessed for various growth parameters in both experimental seasons. The measurements included plant height (cm), stem diameter (mm) at the fourth apical internode, and the number of branches and leaves, along with fresh and dry weights (g) of stems, leaves and roots, total leaf area (cm^2 $plant^{-1}$), and root system size (cm^3). The total leaf area was determined using the disk method described by Waidyanatha and Goonasekera (1975), while root system size was measured following the method of Wanas (1996).

The data on plant dry matter and total leaf area $plant^{-1}$ were used to compute some important growth indices:

a) Root/shoot ratio:

$$Root/shoot\ ratio = \frac{Root\ dry\ weight Plant^{-1}}{Shoot\ dry\ weight Plant^{-1}}$$

b) Leaf area ratio (LAR): This index represents the total leaf area $plant^{-1}$ relative to its total dry matter, expressed as cm^2 g^{-1} DW, calculated using the formula of Radford (1967):

$$\text{LAR } (cm^2\ g^{-1}) = \frac{Total\ leaf\ area\ (cm^2) Plant^{-1}}{Plant\ dry\ weight\ (g)}$$

7.2- Determination of some bioconstituents in jojoba leaves:

Samples for estimating some bioconstituents in jojoba leaves were randomly selected from 3 replicates per treatment on the 250th DAP in both seasons. To determine of some bioconstituents in dry matter, a portion of these samples was dried in an oven at 70°C until stable weight was obtained, then ground and stored for analysis.

7.3- Photosynthetic pigments:

Chlorophylls "a" & "b" and carotenoid concentrations were measured in the 4th apical leaf at 250 DAP in both seasons. Pigments were extracted using dimethylformamide (DMF), and their optical densities were assessed via spectrophotometry at 664, 647, and 480 nm, following Wellburn (1994). Concentrations were expressed as mg g^{-1} fresh weight (FW).

7.4- Proline concentration:

It was determined in fresh leaves according to the method of Bates *et al.* (1973). The concentration was expressed as mg g^{-1} FW.

7.5- Total phenolic concentration:

Total phenolics were extracted from 0.2 g of fresh leaves following Stabell et al. (1996). The Folin-Ciocalteu method, as outlined by Lin and Tang (2007), was used to determine total phenolic content. Pyrogallol (PG) was employed as the standard solution at concentrations ranging from 50 to 500 µg ml-1, with absorbance measured at 750 nm using a spectrophotometer. Total phenolic concentration was shown as mg PG g-1 FW.

7.6- Total carbohydrates

Dry leaf powder samples (0.1 g each) were used to determine total carbohydrate concentration using the anthrone method described by Sadasivam (1996), then expressed as mg g^{-1} dry weight (DW).

7.7- Nutrients and cured protein

To determine macro-elements, 0.2 g of dry leaf powder was wet digested with sulfuric and perchloric acids. The resulting clear solution was transferred to a volumetric flask and diluted to 100 ml with distilled water for analysis (Nagornyy, 2013). Total nitrogen was assessed using the micro Kjeldahl method according to Jackson (1973), and crude protein was calculated as Crude protein = total nitrogen × 6.25 (A.O.A.C., 1990). Phosphorus concentration was determined by the Olsen method (Murphy and Riley, 1962). Potassium, sodium, and calcium were measured using flame emission spectrophotometry (Jenway PFP 7) as per Horneck and Hanson (1997), while magnesium was analyzed using an atomic absorption spectrophotometer following the method of Wright and Stuczynski (1996). Concentrations were reported as mg g^{-1} dry weight (DW).

8- Statistical analysis:

Data of germination criteria, vegetative growth parameters and chemical constituents were statistically analyzed as a completely randomized block design using CoStat program version 6.311. The least significant difference (L.S.D.) test at $P \leq 0.05$ was employed to compare the treatment means with those of the control following Snedecor and Cochran (1989).

Results and Discussion

1- The first preliminary experiment:

Table 4 shows that increasing seawater salinity level from 2000 to 6000 ppm significantly improved jojoba seeds germination percentage (GP), seedling vigor (SV), and germination performance index (GP1), and the lengths of the root, shoot, and entire seedling. Conversely, the mean rate of germination (MRG), or the number of days needed for germination, was marginally decreased compared to the control (tap water). These positive effects gradually diminished as salinity levels increased to 6000 ppm. On the contrary, raising seawater salinity from 8000 to 20000 ppm substantially reduced GP, SV, GPI, and the lengths of the root, shoot, and complete seedling, even though MRG increased significantly with increasing seawater salinity from 8000 ppm to 16000 ppm compared to the control. These negative effects were parallel to the applied salinity level.

Table (4). Effect of different seawater salinity levels on some germination properties of jojoba seeds.

parameters / Treatments		Root length	Shoot length	Seedling length	GP	MRG	SV	GPI
Control (Tap water)		6.27	6.07	12.33	60.00	13.67	739.80	4.39
Seawater salinity levels	**2000 ppm**	12.33	9.80	22.13	80.00	12.42	1770.40	6.44
	4000 ppm	10.33	6.67	17.00	73.33	13.45	1246.61	5.45
	6000 ppm	8.13	6.83	14.97	66.67	12.30	998.05	5.42
	8000 ppm	6.10	3.43	9.53	53.33	13.25	508.23	4.02
	10000 ppm	7.63	2.87	10.50	50.00	15.60	525.00	3.21
	12000 ppm	7.10	1.83	8.93	43.33	15.83	386.94.	2.74
	14000 ppm	5.20	1.33	6.53	36.67	16.00	239.47	2.26
	16000 ppm	1.67	0.40	2.07	26.67	16.25	55.21	1.64
	18000 ppm	0.00	0.00	0.00	00.00	00.00	00.00	0.00
	20000 ppm	0.00	0.00	0.00	00.00	00.00	00.00	0.00
	LSD at 0.05	1.44	1.25	2.62	1.53	1.53	81.23	0.39

Abbreviations: GP= Germination percentage, MRG= Mean rate of germination, SV= seedling vigor, GPI= Germination performance index.

Data in Table 4 also indicate that a seawater salinity level of 14,000 ppm is the threshold beyond which most germination parameters, particularly GP, GPI, and SV, fall below 50% of control values. According to Wanas (1996), this threshold considers the highest salinity level that jojoba plants can withstand. It was used in the main experiment to evaluate its effects on the growth and physio-biochemical properties of jojoba plants.

It is worth noting that seawater salinity levels of 2000, 4000, and 6000 ppm enhanced jojoba seed germination, which agrees with the findings of Hassanein *et al.* (2012), who reported that low NaCl concentrations improved seedling growth compared to the control. On the contrary, seedling growth was suppressed by NaCl concentrations of 4 g l^{-1} or higher. Tahir *et al.* (1993) revealed that increasing NaCl levels (0, 5000, 10000, 15000, and 20000 ppm) reduced germination percentage to 55% and 30% at 15000 and 20000 ppm, respectively. This shows that while jojoba seed germination decreases with increasing salinity level, seeds can still germinate at elevated NaCl levels, indicating the plant's high salt tolerance.

2-The second preliminary experiment:

Table 5 demonstrates that applying ALE at 5%, 7.5%, and 10% as seed soaking treatments resulted in significant increases in various germination characteristics of jojoba seeds, including germination percentage, seedling vigor, and germination rate index, alongside the roots and shoot lengths of the resulting seedlings, whereas the mean rate of germination showed no significant difference from the control. The positive impact of ALE was parallel with the concentration used, making 10% the most efficacious. This concentration was selected for the main experiment to examine its influence on some growth and biochemical aspects of jojoba plants under both normal and salt-stress conditions.

Table 5. Effect of OLE, MLE and ALE on some germination parameters of jojoba seeds.

Parameters / Treatments		Root length	Shoot length	Seedling length	GP	MRG	SV	GPI
Distilled water		8.83	7.83	16.66.	56.67	15.71	944.12	3.61
ALE	**5%**	12.20	10.37	22.57	63.33	16.42	1429.36	3.86
	7.5%	15.20	12.13	27.33	73.33	14.59	2004.11	5.03
	10%	15.90	11.13	27.03	76.67	14.91	2072.39	5.14
LSD at 0.05		1.70	1.70	3.41	1.70	1.70	161.05	0.35

Abbreviations: GP= germination percentage, MRG= Mean rate of germination, SV= seedling vigor, GPI= germination percentage index.

The positive influence of ALE on jojoba seed germination may be due to its richness of natural growth substances, such as micro- and macronutrients, vitamins, amino acids, antioxidants, and

phytohormones, like gibberellins, auxins, and cytokinins (Table 2). Gibberellins play a key role in the beginning of germination via enhancing amylase activity, which promotes starch metabolism. Simple sugars resulted from the hydrolysis of complex carbs are easily consumed in protein synthesis. Furthermore, IAA, GAs, and cytokinins play a crucial role in stimulating cell division and development, consequently promoting embryonic growth and improving germination quality (Taiz *et al.*, 2014).

2- The main experiment:

3.1- Vegetative growth characteristics of jojoba plants:

During both growing seasons 2021/22 and 2022/23 as shown in Table 6, the individual salinity treatment (irrigating with seawater at 14,000 ppm and spraying with tap water) had a deleterious impact on jojoba plant growth. This treatment significantly reduced the root system size, stem length, number of leaves and branches, fresh and dry weights of roots, stems, and leaves, total leaf area plant^{-1}, and root/shoot ratio. However, it significantly increased the leaf area ratio (LAR) compared to control plants (irrigated and sprayed with tap water).

Foliar application of ALE at 10% on jojoba plants irrigated with tap water significantly enhanced root system size, stem length, number of leaves and branches, fresh and dry weights of roots, stems, and leaves, total leaf area plant^{-1}, and the root/shoot ratio. In contrast, it reduced the leaf area ratio (LAR) compared to the control plants. While foliar application of 10% of ALE on salt-stressed jojoba plants (irrigated with 14,000 ppm seawater) effectively alleviated and overcame salinity stress, resulting in remarkable increases in growth parameters compared to control plants (irrigated and sprayed with tap water). The increases significantly exceeded control values for root size, root dry weight, stem dry weight, and both fresh and dry leaf weights, as well as total plant dry weight, although leaf area ratio (LAR) was significantly reduced with ALE treatment. This pattern was consistent in both the 2021/22 and 2022/23 seasons.

The results indicated that salinity negatively affected jojoba growth, aligning with Hussein *et al.* (2017) and Aboryia *et al.* (2022). Salinity harms plants through decreasing soil water potential and increasing ion accumulation, disrupting metabolism (Kalaji and Pietkiewicz, 1993). Prolonged salinity exposure hampers growth and yield while exacerbating stress from toxic salt accumulation. To counter salinity effects, plants employ strategies such as ion compartmentalization, compatible solute production, and membrane structure alterations (Torabi *et al.*, 2013). Additionally, the common phenomenon of abiotic stresses, including salinity, is the excessive generation of reactive oxygen species (ROS), which can damage cellular membranes (Schutzendubel and Polle, 2002). Fortunately, plants possess robust antioxidant defense systems with enzymatic and non-enzymatic components to combat oxidative stress (Apel and Hirt, 2004). The extent of oxidative damage is linked to the effectiveness of these systems (Rady *et al.*, 2018). However, internal antioxidant mechanisms may be insufficient for optimal growth, necessitating external support, such as plant extracts, to enhance stress resilience (Desoky *et al.*, 2018; Wanas *et al.*, 2018).

The results also reveal that aloe leaf extract (ALE) effectively acts as a growth biostimulent, significantly enhancing various growth parameters of jojoba plants under both normal and salt-stressed conditions (Table 6). This supports the findings of El-Sherif (2017). Akev *et al.* (2015) highlighted that ALE contains vital phytohormones (auxins and gibberellins), 20 amino acids (7 essential), and several vitamins (B, B_{12}, C, A, choline, folic acid, and E). Thus, the growth enhancement of jojoba attained by ALE can be ascribed to its biostimulant properties, which promote cell division and elongation, and chlorophyll synthesis due to its content of GAs, IAA, essential minerals (Fe^{+2}, Mg^{+2}, and Ca^{+2}), and its antioxidant properties that mitigate excess free radicals produced under stress, thereby fostering vegetative growth in adverse conditions.

3.2- Biochemical constituents:

3.2.1- Photosynthetic pigments:

Table 7 shows that applying the maximum tolerable salinity level to jojoba plants significantly reduced chlorophyll a, chlorophyll b, total chlorophyll, and carotenoid concentrations below control values by 64.15%, 64.29%, 35.71%, and 62.96% in the first season, 62.96%, 68.75%, 64.29%, and 46.67% in the second season. In contrast, foliar spraying with 10% ALE on salt-unstressed jojoba plants (irrigated with tap water) significantly increased levels of these pigment above control values, with increases of 24.53%, 107.14%, 39.71%, and 42.86% in the first season, and 24.07%, 87.50%, 38.57%, and 26.67% in the second season. Furthermore, spraying 10% ALE to salt-stressed jojoba plants (irrigated with seawater salinity at 14,000 ppm) not only attenuated salinity effects but also led to significant increases in chlorophylls a, chlorophyll b, total chlorophyll, and carotenoids above control values, by 9.43%, 7.14%, 7.35%, and 35.71% in the first season and 14.81%, 18.75%, 15.71%, and 20.00% in the second season.

Table (6): Effects of seawater salinity and ALE applied separately and in combination on some jojoba growth aspects at 250 DAP during 2021/22 and 2022/23 seasons.

Parameters / Treatments			Root size (cm^3) $plant^{-1}$	Stem length (cm)	No. of branches $plant^{-1}$	No. of leaves $plant^{-1}$	Total leaf area (cm^2) $plant^{-1}$	Root FW (g) $plant^{-1}$	Roots DW (g) $plant^{-1}$	Stems FW (g) $plant^{-1}$	Stems DW (g) $plant^{-1}$	Leaves FW (g) $plant^{-1}$	leaves DW (g) $plant^{-1}$	Root/ shoot ratio	Total DW (g) $plant^{-1}$	LAR $cm^2 g^{-1}$ DW
Season 2021/2022																
Control		x̄	12.00	18.28	2.33	23.00	75.15	13.84	1.14	1.61	0.62	7.55	1.60	0.51	3.36	22.34
Seawater salinity (14000 ppm)		x̄	4.67	14.53	0.67	13.00	41.68	4.63	0.57	1.08	0.26	5.43	0.97	0.45	1.80	23.37
		±%	-61.11	-20.47	-71.43	-43.48	-44.53	-66.53	-50.29	-33.07	-58.18	-28.10	-39.09	-12.37	-46.43	+4.61
ALE 10%		x̄	19.70	25.68	3.67	37.00	110.48	16.27	2.31	2.13	0.91	11.42	2.74	0.63	5.96	18.54
		±%	+64.17	+40.48	+57.51	+60.87	+47.01	+17.56	+102.63	+32.30	+46.77	+51.26	+71.25	+23.53	+77.38	-17.12
Seawater salinity 14000 ppm	**ALE 10%**	x̄	15.67	22.07	2.67	26.00	80.70	14.52	1.93	1.88	0.76	13.24	2.65	0.57	5.34	15.11
		±%	+30.58	+20.73	+14.59	+13.04	+7.39	+4.91	+69.30	+16.77	+22.58	+75.36	+65.63	+11.76	+58.93	-32.45
LSD at 0.05			2.42	1.78	0.77	3.19	6.31	1.45	0.24	0.28	0.11	1.00	0.17	0.09	0.34	3.34
Season 2022/2023																
Control		x̄	11.67	18.58	3.00	22.00	81.27	13.93	1.05	1.66	0.58	7.03	1.60	0.49	3.23	25.03
Seawater salinity (14000 ppm)		x̄	4.33	13.87	0.33	13.33	53.80	4.28	0.55	0.69	0.39	5.45	1.14	0.35	2.08	27.15
		±%	-62.86	-25.35	-88.89	-39.39	-33.80	-69.30	-47.76	-58.45	-33.34	-22.50	-28.63	-28.35	-35.69	+8.47
ALE 10%		x̄	15.33	25.00	3.67	36.33	115.44	19.17	2.05	1.95	0.88	10.26	2.70	0.57	5.63	20.50
		±%	+31.36	+34.55	+22.33	+65.14	+42.04	+37.62	+95.24	+17.47	+51.72	+45.95	+68.75	+18.75	+74.30	-18.52
Seawater salinity 14000 ppm	**ALE 10%**	x̄	15.33	20.37	3.33	26.33	85.56	14.67	1.89	1.95	0.72	14.04	2.72	0.55	5.33	16.05
		±%	+31.36	+9.63	+11.00	+19.68	+5.28	+5.31	+80.00	+17.47	+24.14	+99.72	+70	+14.58	+65.02	-36.21
LSD at 0.05			2.18	2.19	0.77	4.00	5.69	1.65	0.29	0.29	0.12	0.94	0.24	0.10	0.42	4.96

Abbreviations: ALE= Aloe leaves extract, DAP= Days after planting, No. = Number, DW= Dry weight, LAR= Leaf area ratio, ± %= Relative to the control values.

Table 7: Effects of seawater salinity and ALE individually and in combination on photosynthetic pigment concentrations (mg g^{-1} FW) in jojoba leaves at 250 DAP during 2021/22 and 2022/23 seasons.

Parameters / Treatments			Season 2021/2022				Season 2022/2023			
			Chlorophyll			Carot.	Chlorophyll			Carot.
			a	b	Total		a	b	Total	
Control		x̄	0.53	0.14	0.67	0.14	0.54	0.16	0.70	0.15
Seawater salinity (14000 ppm)		x̄	0.19	0.05	0.24	0.09	0.20	0.05	0.25	0.08
		±%	-64.15	-64.29	-64.71	-35.71	-62.96	-68.75	-64.29	-46.67
ALE 10%		x̄	0.66	0.29	0.95	0.20	0.67	0.30	0.97	0.19
		±%	+24.53	+107.14	+39.71	+42.86	+24.07	+87.50	+38.57	+26.67
Seawater salinity (14000 ppm)	**ALE 10%**	x̄	0.58	0.15	0.73	0.19	0.62	0.19	0.81	0.18
		±%	+9.43	+7.14	+7.35	+35.71	+14.81	+18.75	+15.71	+20.00
LSD at 0.05			0.08	0.05	0.12	0.03	0.08	0.04	0.11	0.02

Abbreviations: ALE= Aloe leaves extract, FW= fresh weight, Carot. = carotenoids, DAP= Days after planting, ± %= ± relative to the control values.

The decline in photosynthetic pigments due to seawater salinity is consistent with the findings of Sharaf El-Din *et al.* (2014) and Aboryia *et al.* (2022). This reduction may result from ionic imbalance, leading to the accumulation of Na^+ and Cl^-, which precipitates premature leaf senescence and chlorophyll

degradation (Munns and Tester, 2008; Roy *et al.*, 2014). Additionally, high salinity promotes excessive ROS production, causing oxidative damage to cell membranes, including thylakoids where photosynthetic pigments are found, ultimately resulting in cell and plant death under severe conditions (Hasanuzzaman *et al.*, 2021).

The increase in photosynthetic pigments with ALE, whether alone or with salinity, closely correlates with greater plant biomass (Table 6), which explains the lower LAR recorded with ALE treatment. This positive effect may be ascribed to ALE's content of GAs, IAA, and essential elements like Fe, Mg, and Ca, which promote chlorophyll biosynthesis (Taiz *et al.*, 2014). Additionally, its antioxidant properties that protect chloroplasts from free radical damage, prevent chlorophyll degradation, and reduce chlorophyll photo-oxidation (Sidduraju and Becker, 2003).

3.2.2- Total carbohydrates, polyphenols, proline and crude protein:

Table 12 shows that irrigating Jojoba plants with seawater at a salinity of 14,000 ppm significantly lowered total carbohydrate concentrations in their leaves compared to the control across both growing seasons. Similar results were reported by Aboryia *et al.* (2022) using 15,000 ppm seawater. Additionally, seawater salinity decreased crude protein concentration in jojoba leaves, aligning with Ali *et al.* (2012). In contrast, irrigation with 14,000 ppm of seawater salinity markedly increased proline and polyphenol concentrations compared to the control in both seasons, agreeing with Laz *et al.* (2005).

Foliar application of ALE at 10% significantly increased total carbohydrates, polyphenols, proline, and crude protein levels in the leaves of salt-unstressed jojoba plants. In salt-stressed jojoba plants, the extract not only mitigated but also reversed salinity's harmful effects, significantly boosting these constituents compared to control plants receiving only tap water. The highest increases were observed in polyphenol and proline concentrations, which rose by 65.39% and 90%, respectively, in the first season, and by 70.59% and 95.00% in the second season.

Table 8: Effects of seawater salinity and ALE, individually and in combination, on the levels of certain bioconstituents in jojoba leaves at 250 DAP during the 2021/22 and 2022/23 seasons.

Bioconstituents / Treatments			Season 2021/2022				Season 2022/2023			
			Total carbohydrate (mg g^{-1} DW)	Polyphenols (mg g^{-1} FW)	Proline (mg g^{-1} FW)	Crude Protein (mg g^{-1} DW)	Total carbohydrate (mg g^{-1} DW)	Polyphenols (mg g^{-1} FW)	Proline (mg g^{-1} FW)	Crude Protein (mg g^{-1} FW)
Control		$\bar{x}$	126.38	9.16	0.20	157.06	124.42	9.25	0.20	158.56
Seawater salinity (14000 ppm)		$\bar{x}$	100.84	12.85	0.33	146.25	102.13	13.66	0.36	146.44
		±%	-20.21	+40.28	+65.00	-6.88	-17.92	+47.68	+80.00	-7.87
ALE 10%		$\bar{x}$	155.61	12.11	0.27	170.81	156.19	13.30	0.28	171.81
		±%	+23.13	+32.21	+35.00	+8.75	+25.53	+43.78	+40.00	+8.25
Seawater salinity (14000 ppm)	**ALE 10%**	$\bar{x}$	128.28	15.15	0.38	159.56	127.58	15.78	0.39	160.63
		±%	+1.50	65.39	+90.00	+1.59	+2.54	+70.59	+95.00	+1.13
LSD 0.05			3.57	0.66	0.02	8.22	3.80	0.78	0.04	5.15

Abbreviations: ALE= Aloe leaves extract, FW= Fresh weight, DW= Dry weight, DAP= Days after planting, ± %= ± relative to the control values.

The negative effect of salinity on total carbohydrates level could be ascribed to its adverse effect on photosynthetic efficiency as indicated by the increase in LAR, the leaf area in cm^2 required to produce one gram of plant biomass (Tables 10 & 11), and the decrease in photosynthetic pigment levels (Table 12). Salt stress disrupts photosynthesis by impacting enzymes and structural proteins essential for energy absorption, electron transport, and CO_2 fixation, leading to decreased net photosynthesis (Hao *et al.*, 2021). Besides, in response to abiotic stresses like salinity, plants convert starch into simple sugars, providing energy and carbon while acting as osmoprotectants to promote growth under stress (Krasensky and Jonak, 2012). Sugars also act as signaling molecules that activate the ABA-dependent pathway, inducing stress response mechanisms (Rook *et al.*, 2006). Additionally, the impaired photosynthesis under salt stress leads to excessive reactive oxygen species production, which stimulates the synthesis of various secondary metabolites, including phenolic compounds (Waśkiewicz *et al.*,

2013). Salinity triggers the phenylpropanoid biosynthesis pathway, resulting in increased accumulation of phenolic compounds that scavenge harmful reactive oxygen species due to their potent antioxidant properties (Chen *et al.,* 2019; Sharma *et al.,* 2019). Polyphenols aid in nutrient mobilization and facilitate signaling between roots and shoots (Sharma *et al.,* 2019).

Plants also respond to stress by enhancing proline synthesis while reducing its degradation (Liang *et al.,* 2013). The balance between proline synthesis and degradation is crucial for its osmoprotective and developmental functions. Proline acts as an antioxidant, eliminating excess reactive oxygen species produced during stress, and serves as a quick source of carbon and nitrogen, aiding the recovery of stressed plants. It also acts as an osmolyte and as an energy source during stress, while functioning as a metal chelator, ROS scavenger, stress reliever, and antioxidant defense molecule (Dar *et al.,* 2016). Additionally, it has been shown to increase the activities of peroxidase, glutathione-S-transferase, superoxide dismutase, and catalase, as well as enhance the glutathione redox state (Hoque *et al.,* 2008; Islam *et al.,* 2010).

As for the reduction that existed in crude protein concentration in salt-stressed jojoba leaves, it might be related to the plant's inability to absorb NH_4^+ and NO_3 (Song *et al.,* 2006).

The enhancing effect of ALE on total carbohydrates, phenolics, proline, and protein levels can be attributed to its high content of growth-promoting substances, including 20 of the 22 essential amino acids, 12 vitamins, auxins, gibberellins, and key minerals like Ca, Mg, and Fe (Akev *et al.* 2015). This positions ALE as a powerful biostimulant that supports plant growth by promoting chlorophyll, carbohydrate, and protein biosynthesis. Its antioxidant properties also help eliminate excess free radicals created under stress conditions.

3.2.3- Mineral nutrients:

Table 9 shows that seawater at the highest tolerated salinity for jojoba plants (14,000 ppm) significantly reduced the concentrations of N, P, K, Ca, and Mg while markedly increasing Na levels compared to the control in both seasons. These results are in line with those published by Ali *et al.* (2012) and Hassan and Ali (2014) using NaCl.

Table (9): Effects of seawater salinity and ALE separately and in combination on the concentrations of certain mineral nutrients in jojoba leaves at 250 DAP during the 2021/22 and 2022/23 seasons.

Treatment \ Parameters			mg g^{-1} DW					
			N	P	K	Na	Ca	Mg
Season 2021/2022								
Control		x̄	25.13	0.73	23.60	28.30	65.27	16.92
Seawater salinity (14000 ppm)		x̄	23.40	0.47	20.10	42.50	61.23	15.92
		±%	-6.88	-35.62	-14.83	+50.18	-6.19	-5.91
ALE 10%		x̄	27.33	1.53	27.53	20.50	89.60	18.60
		±%	+8.75	+109.59	+16.65	-27.56	+37.28	+9.93
Seawater salinity (14000 ppm)	**ALE 10%**	x̄	25.53	0.90	25.23	25.44	75.60	16.92
		±%	+1.59	+23.29	+6.91	-10.11	+15.83	0.00
LSD 0.05			1.32	0.20	0.57	2.14	9.55	0.52
Season 2022/2023								
Control		x̄	25.37	0.71	23.60	28.36	63.62	17.26
Seawater salinity (14000 ppm)		x̄	23.43	0.52	20.60	41.49	59.2	16.67
		±%	-7.65	-26.76	-12.71	+46.30	-6.95	-3.42
ALE 10%		x̄	27.49	1.53	27.37	20.3	88.21	18.47
		±%	+8.36	+115.49	+15.97	-28.42	+38.65	+7.01
Seawater salinity (14000 ppm)	**ALE 10%**	x̄	25.70	1.00	25.6	25.6	73.24	17.63
		±%	+1.30	+40.85	+8.47	-9.73	+15.12	+2.14
LSD 0.05			0.82	0.11	0.84	1.75	4.45	0.38

Abbreviations: ALE= Aloe leaves extract, DAP= Days after planting, DW= Dry weight, ± %= ± relative to the control values.

The unfavorable effect of salinity on the levels of mineral nutrients in jojoba leaves is primarily due to the excess Na^+ and Cl^- in the soil solution. Salt-exposed plants accumulate Na^+ and Cl^- in their shoots,

leading to ionic imbalance and loss of K^+, Ca^{2+}, and Mg^{2+} (Borromeo *et al.*, 2023). High Na^+ concentrations lower membrane potential and enhance Cl^- absorption due to the chemical gradient (Flowers and Colmer, 2015). Excessive Cl^- concentration can damage cell and organelle membranes and decrease chlorophyll content, further inhibiting plant growth (Munns and Tester, 2008). Na^+ not only exerts a toxic effect but also competitively inhibits K^+ due to their similar ionic radii and hydration energies. Most cells maintain high K^+ and low Na^+ concentrations in the cytoplasm to support their physiological functions. Thus, excessive Na^+ influx can suppress K^+ uptake, leading to K^+ deficiency and subsequent plant damage (Hao *et al.*, 2021).

In contrast, foliar spraying with ALE significantly elevated N, P, K, Mg, and Ca levels while decreasing Na levels in both unstressed and salt-stressed jojoba leaves. This indicates that ALE may enhance cell membrane permeability, allowing for the absorption of N, P, K, Mg, and Ca while inhibiting Na uptake. Hanafy *et al.* (2012) stated that the direct effect of ALE boosts molecule penetration into cell membranes, which in turn enhances dry matter accumulation and nutrient absorption. Hamouda *et al.*, (2012) indicated that the intake and movement of nutrients, energy storage, and the development of the root system all depend on the high phosphorus content of ALE. Additionally, ALE is wealth in antioxidants such as phenolic compounds and vitamins, as well as osmoprotectants including sugars and amino acids, along with minerals like Ca^{+2}, Mg^{+2}, Fe^{+2}, and Zn^{+2} (Akev *et al.*, 2015), all of which are crucial for stress alleviation and improved plant growth (Marschner, 2012; Taiz *et al.*, 2014; Desoky *et al.*, 2018; Wanas *et al.*, 2018). Furthermore, the vigorous growth induced by ALE, particularly in root system size (Table 6), may improve nutrient absorption. It has been demonstrated that ALE increases protein synthesis, biomass production, membrane permeability, enzyme activation, and the assimilation of major and minor elements (El Sherif, 2017).

CONCLUSION

It can be concluded that jojoba can tolerate seawater salinity levels up to 14000 ppm. There was a negative correlation between seawater salinity level and germination parameters, which decreased with the increase of seawater salinity. On the other hand, seed soaking with three tested concentrations of ALE revealed that 10% ALE was the most effective concentration for improving germination parameters. In addition, the obtained results showed that using seawater with a salinity level of 14,000 ppm had a negative impact on all vegetative traits and the leaf content bioconstituents and mineral concentrations of jojoba plants. While applying ALE at 10% as a foliar spray on salt-unstressed jojoba plants resulted in significant increases in all of the abovementioned parameters. The foliar spray of 10% ALE on salt-stressed jojoba plants effectively abolished salinity's negative effects, promoting vegetative growth and increasing the leaf content of bioconstituents and mineral nutrients compared to the control. Thus, this study recommends the use of 10% ALE as an affordable natural growth promoter to enhance the growth and physiological performance of jojoba under both normal and salt stress conditions.

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The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION

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تأثير مستخلص أوراق الصبار على النمو والأداء الفسيولوجي لنباتات الجوجوبا المزروعة تحت الظروف الطبيعية وظروف الإجهاد الملحي

أحمد لطفي إبراهيم ونس [1]، إيمان محمد عبده شبكه[1]

[1] قسم النبات الزراعي ، كلية الزراعة ، جامعة دمياط ، مصر

الملخص العربى

أجريت تجربتين تمهيديتين، هدفت الأولى إلى تحديد مستوى ملوحة مياه البحر الذي تنخفض عنده نسبة ومؤشر أداء الإنبات إلى أقل من 50٪ من قيمة الكنترول، مع الأخذ في الاعتبار أنه الحد الأقصى للملوحة الذي يمكن لنباتات الجوجوبا تحمله ؛ وأظهرت التجربة أن هذا المستوى هو 14000 جزء في المليون. بينما هدفت التجربة الثانية إلى تقييم ثلاثة تركيزات من مستخلص أوراق الصبار (5٪ و 7.5٪ و 10٪)، وكشفت التجربة أن مستخلص أوراق الصبار بتركيز 10٪ كان له التأثير الأكبر على إنبات البذور وقوة البادرات عند مقارنتها بالكنترول. ونتيجة لذلك، تم إجراء تجربتين رئيسيتين خلال موسمي 22/2021 و 23/2022 لتقييم آثار ملوحة مياه البحر بتركيز 14000 جزء في المليون ومستخلص أوراق الصبار بتركيز 10٪ ، سواء كان كلاً منهما منفرداً أو استخدما معًا، على النمو والأداء الفسيولوجي لنباتات الجوجوبا. وكشفت النتائج أن ري نباتات الجوجوبا بمياه البحر عند مستوى ملوحة 14000 جزء في المليون قد تسبب في انخفاض معنوى في كلاً من: حجم المجموع الجذري ، طول الساق، عدد الأوراق والفروع، المساحة الورقية الكلية/نبات، الأوزان الطازجة والجافة للجذور والسيقان والأوراق، نسبة المجموع الجذري/ المجموع الخضري، صبغات البناء الضوئي، الكربوهيدرات الكلية، البروتين الخام، تركيزات العناصر (نيتروجين ، فوسفور، بوتاسيوم NPK ، كالسيوم، ماغنسيوم. بينما زاد معدل مساحة الورقة (LAR) ، تركيزات البرولين، الفينولات والصوديوم مقارنة بالكنترول. على الجانب الآخر أدى الرش الورقي لنباتات الجوجوبا غير المجهدة (المروية بماء الصنبور) باستخدام مستخلص أوراق الصبار ALE بتركيز 10٪ إلى زيادة معنوية في العديد من معايير النمو وتركيزات المكونات الحيوية والعناصر المعدنية مع تقليل معدل المساحة الورقية (LAR) وتركيز عنصر الصوديوم. علاوة على ذلك، فإن رش نباتات الجوجوبا الواقعة تحت تأثير الإجهاد الملحي (المروية بمياه البحر بتركيز 14000 جزء في المليون) باستخدام مستخلص أوراق الصبار بتركيز 10% لم يخفف فقط من الآثار الضارة للملوحة، بل أدى أيضًا إلى تحسينات ملحوظة في معايير النمو وتركيزات كلاً من :صبغات البناء الضوئي ، الكربوهيدرات الكلية ، الفينولات ، البرولين ، البروتين والعناصر المعدنية، مع تقليل مستوى الصوديوم بشكل كبير مقارنة بالكنترول في كلا الموسمين.

لــذا، توصي هذه الدراسة باستخدام مستخلص أوراق الصبار بتركيز 10% كمادة رش ورقي لتحسين النمو والأداء الفسيولوجي لنباتات الجوجوبا سواء في ظل الظروف الطبيعية أو تحت ظروف الإجهاد الملحي.