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Response of Non-stressed and Salt-stressed Jojoba Plants to Foliar Spray with Moringa Leaf Extract

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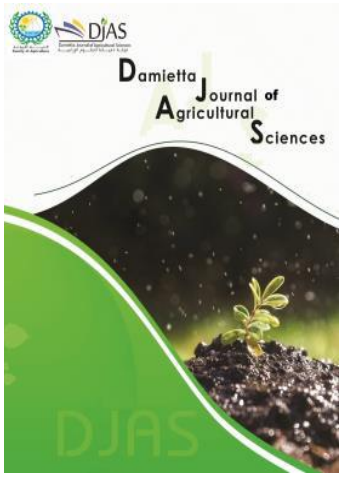

ABSTRACT

Jojoba is a key oil shrub, valued for its role in combating land degradation and its oil's unique composition, which is particularly sought after in the cosmetics industry for its beneficial properties. This study investigated whether moringa leaf extract (MLE) could enhance the growth and physiological performance of jojoba plants, both under normal conditions and salt stress. The seawater salinity level and MLE concentration used were selected based on findings of two preliminary germination trials. The first trial identified 14000 ppm as the maximum salinity level tolerable by jojoba plants, while the second determined 0.5 g l^{-1} MLE as the optimal concentration for improving germination characteristics. Results indicated that irrigating jojoba plants with 14000 ppm salinity alone caused significant reductions in root system size, stem length, number of leaves and branches, total leaf area, fresh and dry weights of roots, stems, and leaves $plant^{-1}$, root/shoot ratio, photosynthetic pigments, total carbohydrates, crude protein, NPK, and Mg, while proline, polyphenol, and the Na+ level increased compared to plants irrigated with tap water. On the contrary, using MLE at 0.5 g l^{-1} as a foliar spray for unstressed jojoba plants significantly reinforced the root system size, stem length, root/shoot ratio, total dry weight, total carbohydrates, polyphenols, proline, crude protein concentrations, NPK, Ca, and Mg levels, whereas it decreased the leaf area ratio and Na^+ compared to the control. Foliar spraying with MLE in combination with irrigation using diluted seawater (14,000 ppm) effectively mitigated the negative effects of salinity, resulting in significant improvements in growth aspects, photosynthetic pigment, carbohydrates, polyphenols, proline, protein levels, and mineral content, in addition to a marked reduction in Na levels versus the salt-stressed jojoba plants. Consequently, this study recommends the use of 0.5 g l^{-1} MLE to improve the growth and physiological performance of jojoba plants under both non-stressful and stressful conditions.

Keywords: Jojoba,Moringa,Leaf extract,Salinity,Salt stress,Growth,Chemical*bioconstituent*

INTRODUCTION

Climate change and a deteriorating economic condition are key barriers to development in many countries. (Hayder *et al.* 2012). The Middle East and North Africa are experiencing major land degradation. Egypt, Jordan, and Palestine have lost up to 80% of their vegetation over the last two decades (World Bank, 2019).

With rising aridity and population growth, water shortage becomes more acute, particularly in developing countries, necessitating the pursuit of alternative water sources. The biggest challenge, however, remains minimizing salinity issues. (Dawood *et al.*, 2014). Furthermore, combating soil deterioration and desertification requires the adoption of plant-based strategies, such as cultivating economically viable and resilient plant species capable of thriving in adverse conditions (Wanas, Shabka, 2025).

Jojoba (*Simmondsia chinensis* (Link) Schneider) is a perennial shrub of the Simmondsiaceae family. It is a valuable oil crop for agricultural and commercial growth in arid and semi-arid locations with harsh climatic circumstances. (Arya, Khan, 2016). Its advantageous properties have piqued the interest of specialists, who regard it as a viable replacement for diesel fuel (Ghannam and Selim,

2021). It is the only unsaturated liquid wax that can be readily obtained in significant quantities, accounting for around 52% of the seed's total weight. (Gad *et al.*,2021). Jojoba is a drought-tolerant plant that can assist in battling soil degradation and desertification in arid areas (Al Obaidi *et al.*, 2017).

Concerning the salinity, it disrupts plant growth by interfering with key physiological and biochemical processes, including photosynthesis, antioxidant systems, nitrogen metabolism, ion balance, and osmolyte accumulation. It causes injury through osmotic stress and ionic toxicity, which impair mineral nutrient uptake and trigger oxidative stress (Khan *et al.*, 2013). To maintain turgor and water absorption, plants require an internal water potential lower than that of the soil. Achieving this often involves increasing osmolytes, either by absorbing soil solutes or producing compatible solutes (Tester and Davenport, 2003). Accumulating these osmolytes helps plants enhance water uptake from the soil and mitigate cellular water shortages.

Several proteins, amino acids (including proline), and soluble sugars are examples of compatible osmolytes (Ashraf, 2010). To improve the internal defense mechanisms of plants to better withstand environmental stresses, there has been a recent surge in interest in using plant extracts as natural sources of several bioactive compounds, including osmoprotectants, phytohormones, antioxidants, and nutrients (Wanas *et al.*, 2018; Desoky *et al.*, 2019; Merwad, 2020; Wanas and Shabka, 2025; Wanas *et al.*, 2025)

Moringa leaf extract (MLE) offers a cost-effective and sustainable organic solution to enhance plant growth and productivity under both optimal and stressful conditions. MLE represents a rich source of antioxidants, including ascorbic acid, carotenoids, flavonoids, vitamins A and C, riboflavin, β-carotene, and phenolic compounds. It also contains zeatin, a key cytokinin-related hormone, which promotes cell division and differentiation, enhances enzymatic antioxidant activity, protects cells from free radical damage, and improves nutrient absorption (Hwang *et al.*, 2012; Liu *et al.*, 2022).

This study aimed to investigate the impact of salinity and foliar spraying with moringa leaf extract on the growth and physiological traits of jojoba plants while also assessing the effectiveness of moringa leaf extract in mitigating the harmful effects of salinity on jojoba plants.

MATERIALS AND METHODS

1. Experimental Procedures

This study was carried out to investigate the impact of salinity and moringa leaf extract (MLE) individually or in combination on the growth and physio-biochemical traits of jojoba (*Simmondsia chinensis* (Link) Schneider), besides evaluating MLE's potential to diminish the adverse effects of salinity. Two preliminary germination trials were conducted, firstly in the Botany Department laboratory at the Faculty of Agriculture, Damietta University, commencing on August 1st, 2021. The main experiment, designed based on the findings of these trials, was conducted during the 2021/2022 season and repeated in the 2022/2023 season at the Experimental Station of the Faculty of Agriculture, Damietta University, Egypt (31°25'38"N and 31°39'06"E). Jojoba seeds, sourced from MK Group for Desert Land Reclamation, were surface-sterilized with tap water, immersed in 1% sodium hypochlorite for five minutes, and rinsed with distilled water prior to sowing in each experiment.

In the first preliminary experiment, jojoba seeds were exposed to varying seawater salinity levels (2000–20000 ppm, with 2000 ppm increments) and tap water (236.16 ppm, as a control) to identify the highest salinity level above which germination drops below 50% of the control to use it in the main experiment Thirty disinfected seeds were allotted for each salinity level and planted in 7 cm diameter plastic pots, each containing two seeds, filled with a 2:1 (v/v) sand-peat moss mixture. The study used a completely randomized block design with 11 treatments, each replicated three times (five pots per replicate). Irrigation solutions matching the designated salinity levels were applied as needed.

The second preliminary experiment determined the optimal moringa leaf extract (MLE) concentration (0.0, 0.5, 1, and 2 g l^{-1}) based on germination criteria for use in the main experiment. Thirty disinfected jojoba seeds were soaked in each MLE concentration for 24 hours. The seeds were then sown in 7 cm plastic pots filled with a sand and peat moss mixture (2:1 v/v). Each treatment had 3 replicates, each with 5 pots containing 2 seeds, arranged in a completely randomized block design. Irrigation with tap water was uniformly applied as needed.

In both preliminary experiments, the numbers of germinated seeds were recorded every day from the ninth to the twenty-third day. The seeds were considered to have germinated when the plumule appeared above the soil. The following

germination criteria were then computed using the obtained data:

Germination percentage (GP) according to Tanaka-Oda, *et al.*, (2009) = $(Number\ of\ germinated\ seeds \div Total\ number\ of\ sown\ seeds) \times 100$

Mean rate of Germination (MRG) according to Edwards and Sundsrom (1987) = $\sum T_n N_n \div \sum N_n)$

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 T_n; N_1= No. of germinated seeds at the first count; N_2= No. of germinated seeds at the second count…to N_n.

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

Germination performance index (GPI) according to (Edwards and Sundstrom, 1987) = $GP \div MRG$

While the second experiment found that 0.5 $^{g\ l\text{-}1}$ of MLE was the most effective among the tested treatments, the first preliminary experiment showed that jojoba could tolerate salinity levels up to 14,000 ppm. As a result, 0.5 g l^{-1} of MLE and 14,000 ppm salinity were chosen for our main experiment.

2. The main experiment

This experiment was carried out at the Nursery of the Faculty of Agriculture, Damietta University, Egypt, during the season of 2021–2022 and repeated in the 2022–2023 season. Before sowing on September 23 in both seasons, jojoba seeds were disinfected and immersed in water for an entire day in order to promote germination. The seeds were planted in 7 cm-diameter plastic pots that were filled with a 2:1 sand and peat moss mixture and were frequently watered with tap water. After 79 days, uniform seedlings were selected and transplanted, one seedling per bag, into perforated black polyethylene bags with a 30 cm diameter and 10 kg of washed sandy soil. Healthy plants were divided into four treatment groups 42 days after transplantation. The experiment was laid out in a completely randomized block design (CRBD), comprising 4 treatments with 6 replicates each containing 6 bags. The details of the four treatments were as follows:

T_1: Control - Plants were irrigated with tap water and sprayed with distilled water .

T_2: Salinity (14000 ppm): Plants were irrigated with seawater at 14000 ppm and sprayed with distilled water .

T_3: 0.5 g l^{-1} of MLE: Plants were irrigated with tap water and sprayed with 0.5 g l^{-1} of MLE.

T_4: Salinity (14000 ppm) + 0.5 g l^{-1} of MLE: Plants were irrigated with seawater at 14000 ppm salinity and sprayed with 0.5 g l^{-1} of MLE.

Foliar sprays were applied on days 45, 75, 105, and 135 post-transplantation, with Tween-20 added as a surfactant to enhance solution penetration. From day 45 post-transplantation onward, plants in treatments T_2–T_4 were irrigated weekly with 250 ml of seawater salinity at 14,000 ppm. To prevent salt accumulation, the soil in both T_2 and T_4 bags was rinsed every three weeks with 250 ml of tap water. In contrast, plants in treatments T_1 and T_3 received regular weekly irrigation with 250 ml of tap water.

3. Preparation of the assigned treatments

3.1. Salinity levels

Seawater was sampled from the Mediterranean Sea near Ras El-Bar in Damietta, Egypt (31°31'10"N and 31°49'49"E). It was diluted with tap water to create the salinity levels. Inductively coupled plasma optical emission spectroscopy was used to determine the elemental compositions of both tap and seawater, as indicated in Table 1. Both types of water tested for pH and electrical conductivity following the technique 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^{+2}	Mg^{+2}	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	1,037.98	351.50	1.36	1.67	8,259.33	13,450.75

3.2. Moringa leaves extract (MLE)

Leaves from 5-month-old Moringa (*Moringa oleifera* Lam.) plants were collected from the experimental farm of the Horticulture Department at Damietta University, Faculty of Agriculture. After cleaning, the leaves were air-dried in shad for 15 days and ground into a fine powder. Using a modified method from Abdel-Daim et al. (2020), 200 g of the dried powder

was soaked in 1000 ml of 70% ethanol at 50 °C for 24 hours. The mixture was filtered through a Buchner funnel, and the solvent was evaporated using a rotary evaporator at 50 °C to yield a paste-like extract. This stock extract was stored in a brown glass bottle at 2°C for use in preparing the concentrations used. Table 2 lists the levels of osmoprotectants, phytohormones, antioxidants, and mineral elements in the moringa leaf extract (MLE), as determined by Rehman *et al*. (2017).

Table 2. Some chemical constituents of MLE (Rehman *et al.,* 2017.)

Component	Value	Unit	Component	Value	Unit
Osmoprotectants and Antioxidants			**Menial elements**		
Amino acids	106.20	mg g^{-1} DW	Ash	102.00	mg g^{-1} DW
Proline	21.00		Calcium	28.00	
Total soluble sugars	248.70		Magnesium	6.70	
Soluble phenols	6.20		Potassium	25.10	
Total carotenoids	3.10		Phosphorus	8.10	
Ascorbic acid	242.40	mg $100g^{-1}$ FW	Sodium	0.75	
Phytohormones			Iron	1.60	
Indole-3-acetic acid	0.83	µg g^{-1} DW	Manganese	0.84	
Gibberellins	0.74		Zinc	0.27	
Zeatin	0.96		Copper	0.14	
Abscisic acid	0.29				

4. Soil sampling and analysis

Table 3 presents the results of the chemical analysis of soil samples collected before transplantation in both seasons. To estimate anion and cation concentrations, pH, and EC, an aqueous soil extract was prepared using a 2:1 ratio of distilled water to soil following Jackson (1973). Soil organic carbon was determined according to Dewis and Freitas (1970). The percentage of organic matter was calculated using the equation of Schulte (1995).

% Organic matter = (% total C ×1.72) ÷ 0.58

5. Sampling and collecting data

5.1. Vegetative growth parameters

In both experimental seasons, six randomly selected plants from each treatment were assessed for various growth characteristics 250 days after planting (DAP). Plant height (cm), number of branches and leaves, root size (cm^3), fresh and dry weights (g) of leaves, stems and roots, total leaf area (cm^2 $plant^{-1}$) were all measured. Waidyanatha and Goonasekera's (1975) disk method was used to calculate the total leaf area, while Wanas' (1996) method was utilized to measure the size of the root.

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

Soil properties		Year		Soil properties	Year	
		2021/2022	2022/2023		2021/2022	2022/2023
Soil particles distribution%				**Soluble cations (meq/100g)**		
Sand	Coarse	1.94	1.50			
	Medium	51.91	51.41	Mg^{+2}	0.23	0.24
	Fine	44.63	45.51	Ca^{+2}	0.4	0.45
	Very fine	1.26	1.28	Na^{+}	0.62	0.63
Silt		0.20	0.22	K^{+}	0.11	0.12
Clay		0.6	0.8			
Textural class		Sandy		**Soluble anions (meq/100g)**		
Hygroscopic humidity		0.36%	0.37%			
Chemical properties				Cl^{-}	0.64	0.65
pH		8.23	8.24	HCO^{-}_{3}	0.39	0.40
E.C. (ppm)		447.36	448.39	CO_3^{-2}	N.D.	N.D.
Organic matter %		0.28	0.32	SO_4^{-}	0.33	0.39

Additionally, the following growth indices were calculated from the recorded data on plant dry matter and total plant leaf area:

a) Root/shoot ratio = $(Root\ dry\ weight Plant^{-1} \div Shoot\ dry\ weight Plant^{-1}$

b) Leaf area ratio (LAR) according to Radford (1967) = $Total\ leaf\ area\ (cm^2) Plant^{-1} \div Plant\ dry\ weight\ (g)$

Leaf area ratio (LAR) expressed as $cm^2\ g^{-1}$ DW and represents the total leaf area $plant^{-1}$ relative to its total dry matter.

5.2. Photosynthetic pigments

At 250 DAP in both seasons, the concentrations of carotenoid and chlorophylls "a" and "b" were estimated in the fourth apical leaf. In accordance with Wellburn (1994), photosynthetic pigments were extracted using dimethylformamide (DMF), and their optical densities were measured using spectrophotometry at 664, 647, and 480 nm. Concentrations were expressed as mg g^{-1} fresh weight (FW).

5.3. Proline concentration

Using the Bates *et al.* (1973) method, the concentration of proline was estimated in the fresh jojoba leaves and reported as mg g^{-1} FW.

5.4. Total phenolic concentration

Following Stabell *et al.* (1996), 0.2 g of fresh leaves were used to extract total phenolics. Total phenolic content was determined using the Folin-Ciocalteu method as described by Lin and Tang (2007). The standard solution, pyrogallol (PG), was used at concentrations ranging from 50 to 500 µg ml^{-1}. A spectrophotometer was used to measure absorbance at 750 nm. The concentration of total phenolics was expressed as mg PG g^{-1} FW.

5.5. Total carbohydrates

The total carbohydrate concentration was assessed at 250 DAP in the dry leaves using the anthrone method detailed by Sadasivam (1996) on 0.1 g dry leaf powder samples, and the concentrations were then reported as mg g^{-1} DW.

5.7. Nutrients and cured protein

Sulfuric and perchloric acids were used to wet digest 0.2 g of dry leaf powder in order to determine the macro-elements. For analysis, the resultant clear solution was diluted with 100 milliliters of distilled water into a volumetric flask (Nagornyy, 2013). Using Jackson's (1973) micro Kjeldahl method, total nitrogen was determined, and crude protein was calculated as 6.25 times the total nitrogen (A.O.A.C., 1990). Phosphorus was measured using the Olsen method (Murphy and Riley, 1962). Potassium, sodium, and calcium were analyzed via flame emission spectrophotometry (Jenway PFP 7) accorging Horneck and Hanson (1997), while magnesium was measured using atomic absorption spectrophotometry (Wright and Stuczynski, 1996).

6. Statistical analysis

All obtained data were statistically analyzed using CoStat program version 6.311 as a completely randomized block design. The treatment means were compared to the control means using the least significant difference (L.S.D.) test at $P \leq 0.05$, following Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

1. The first preliminary experiment

Data in Table 4 show that increasing seawater salinity level from 2000 to 6000 ppm significantly improved various germination aspects of jojoba seeds, such as germination percentage (GP), seedling vigor (SV), germination performance index (GP1), and the lengths of the root, shoot, and entire seedling. However, the mean rate of germination (MRG), i.e., the number of days needed for germination, slightly decreased compared to the control (tap water). These positive effects gradually waned with increasing salinity levels up to 6000 ppm.

At higher salinity levels (8000 to 20000 ppm), GP, SV, GPI, and seedling measurements significantly diminished, while MRG increased significantly beyond 6000 ppm compared to the control. These negative impacts were directly proportional to the applied salinity level.

Notably, a salinity level of 14,000 ppm emerged as a critical threshold, beyond which most germination parameters, particularly GP, GPI, and SV, dropped below 50% of control values. This level is considered the maximum salinity tolerable by jojoba plants, as proposed by Wanas (1996). It was utilized in the main experiment to assess its impact on the growth and physio-biochemical aspects of jojoba plants.

The germination of jojoba seeds was enhanced by seawater salinity levels of 2000, 4000, and 6000 ppm. These findings align with Hassanein *et al.* (2012), who reported improved jojoba seedling growth at low NaCl concentrations compared to the control. However, NaCl doses of 4 g l^{-1} or higher suppressed seedling growth. Tahir *et al.* (1993) observed that jojoba germination decreased to 55% and 30% when NaCl levels reached 15,000 and 20,000 ppm, respectively. This indicates that while jojoba seed germination declines with increasing salinity level, seeds can still germinate at elevated NaCl levels, confirming jojoba's high salt tolerance.

The advantageous impact of MLE on jojoba seed germination could be attributed to its high content of

natural growth substances, which includes micro- and macronutrients, vitamins, amino acids, antioxidants, and phytohormones, involving gibberellins, auxins, and cytokinins (Table 2).

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

parameters / Treatments		Root length (cm)	Shoot length (cm)	Seedling length (cm)	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.

2. The second preliminary experiment

As shown in Table 5, presoaking jojoba seeds in MLE at concentrations of 0.5, 1.0, and 2.0 g l^{-1} significantly increased GP, SV, GPI, and the lengths of root, shoot, and total seedling, whereas MRG did not show any significant difference compared to the control. MLE's stimulatory effect on germination characteristics was lowered as concentrations increased, making 0.5 g l^{-1} the most effective concentration. Therefore, this dosage was selected for the main experiment to investigate its effects on the growth and properties of jojoba plants under both normal and salt-stress circumstances.

Table 5. Effect of MLE on some germination parameters of jojoba seeds.

Parameters / Treatment		Root length (cm)	Shoot length (cm)	seedling length (cm)	GP	MRG	SV	GPI
Distilled water		8.83	7.83	16.66	56.67	15.71	944.12	3.61
MLE	0.5 g l^{-1}	14.83	9.47	24.30	80.00	15.25	1944.00	5.26
	1 g l^{-1}	14.23	11.33	25.56	66.67	16.40	1704.09	4.07
	2 g l^{-1}	13.13	11.27	24.40	60.00	16.54	1464.00	3.66
LSD at 0.05		1.88	1.88	2.83	1.92	1.88	192.50	0.53

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

The advantageous impact of MLE on jojoba seed germination could be attributed to its high content of natural growth substances, which includes micro- and macronutrients, vitamins, amino acids, antioxidants, and phytohormones, involving gibberellins, auxins, and cytokinins (Table 2).According to Taiz *et al.* (2014), these growth-promoting hormones stimulate cell proliferation, elongation, and differentiation, which accelerate embryonic growth and improve germination. Rehman *et al.* (2014) revealed that osmopriming seeds with MLE improve seedling growth by boosting amylase activity, which triggers starch metabolism. The resulting simple sugars via the hydrolysis of complex carbohydrates are readily used in protein synthesis. MLE also promotes biochemical changes, such as dormancy breaking, enzyme activation, and the mobilization of reserves from cotyledons or endosperms to the embryo by diminishing sugar levels and raising amylase activity, which improves early seedling development.

2. The main experiment

2.1. Vegetative characteristics of jojoba plants

As demonstrated in Table 6, the salinity treatment (spraying with distilled water and irrigating with seawater at 14,000 ppm) negatively impacted jojoba plant growth during the 2021–2022 and 2022–2023 growing seasons. Compared to control plants irrigated with tap water, this treatment significantly reduced root system size, stem length, leaf and branch number, fresh and dry weights of roots, stems, and leaves, total leaf area per plant, and the root/shoot ratio. However, the leaf area ratio (LAR) showed a slight increase under the seawater salinity treatment.

Foliar application of MLE at 0.5 g l^{-1} significantly enhanced growth in salt-unstressed jojoba plants (tap water-irrigated), resulting in increases in root system size, stem length, numbers of leaves and branches, total leaf area, and fresh and dry weights of roots, stems, and leaves. It also improved the root/shoot ratio but decreased the leaf area ratio (LAR) compared to control plants. Similarly, MLE at 0.5 g l^{-1} effectively mitigated salt stress in plants irrigated with 14,000 ppm seawater. This application not only improved growth parameters compared to salt-stressed plants but also surpassed control values for root system size, dry weights of roots and stems, and total plant dry weight. However, LAR was notably reduced with MLE application. These positive effects of MLE were consistently observed during both the 2021/22 and 2022/23 seasons.

Consistent with Hussein *et al.* (2017) and Aboryia *et al.* (2022), the findings showed that salinity had a detrimental effect on jojoba plant growth. Salinity damages plants through influencing metabolism, raising ion accumulation, and lowering soil water potential (Kalaji and Pietkiewicz, 1993). Long-term exposure to salinity exacerbates stress from harmful accumulation of salt and inhibits growth and yield. Plants use techniques such as ion compartmentalization, the generation of organic osmolytes, and modifications to their membrane structure to combat the impacts of salinity (Torabi *et al.*, 2013). Furthermore, excessive production of reactive oxygen species (ROS), which can harm cellular membranes, is a common occurrence of abiotic stressors, such as salinity (Schutzendubel and Polle, 2002).

To counteract oxidative stress, plants are fortunate to have strong antioxidant defense mechanisms that include both enzymatic and non-enzymatic components (Apel and Hirt, 2004). The efficiency of these systems is correlated with the degree of oxidative damage (Rady *et al.*, 2018). External support, such as plant extracts, is necessary to improve stress resilience because internal antioxidant systems might not be enough for healthy development (Desoky *et al*., 2018; Wanas *et al*., 2018; Wanas and Shabka, 2025).

The results also showed that MLE effectively acts as a growth biostimulent, significantly enhancing jojoba plants growth and resistance under salt-stressed conditions (Table 6). MLE has been shown to enhance the vegetative development of several plants, including maize (Biswas *et al.*, 2016; Williams *et al.*, 2018) and wheat (Chattha *et al.*, 2018; Bazeed, 2023). Beneficial effects of MLE on jojoba growth under both normal and salt-stressed circumstances are primarily ascribed to its richness in growth promoters, such as osmoprotectants, phytohormones, antioxidants, and nutrients, which strengthen the plants' defense mechanisms against environmental stressors. Moreover, the presence of zeatin, a hormone linked to cytokinins, gives it effects like those of cytokinins (Taiz *et al.*, 2014). Zeatin plays a crucial role in anti-senescence by maintaining chlorophyll levels and enhancing antioxidant enzyme activity. It also improves stress tolerance, promotes lateral root and branch development, and extends plant longevity (Hwang *et al.*, 2012; Taiz *et al.*, 2014). Additionally, MLE is rich in natural antioxidants, including ascorbic acid, carotenoids, flavonoids, and phenolics, which effectively neutralize ROS (Siddhuraju and Becker, 2003; Rehman *et al.*, 2017). All of these provide plants with enhanced resilience to survive and thrive under high salt concentrations.

2.2. Biochemical constituents

2.2.1. Photosynthetic pigments

Table 7 demonstrates that irrigating jojoba plants with 14,000 ppm seawater significantly decreased chlorophyll a, chlorophyll b, total chlorophyll, and carotenoid levels compared to control values. These reductions were 64.15%, 64.29%, 64.71%, and 35.71% in the first season and 62.96%, 68.75%, 64.29%, and 46.67% in the second season. In contrast, foliar spraying with 0.5 g l^{-1} MLE on non-stressed plants (irrigated with tap water) increased pigment levels above control values. In the first season, increases were 11.32% for chlorophyll a, 35.71% for chlorophyll b, 14.71% for total chlorophyll, and 21.43% for carotenoids. In the second season, these increases were 7.41%, 6.25%, 7.14%, and 0.00%, respectively.

During both seasons, foliar spraying with 0.5 g l^{-1} MLE on salt-stressed plants (irrigated with 14,000 ppm seawater) substantially mitigated the negative effects of salinity. This treatment resulted in notable rises in chlorophyll a, chlorophyll b, total chlorophyll,

and carotenoids as compared to salt-stressed plants sprayed with distilled water. In most cases, the increases exceeded the control values, but not significantly.

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

Treatments / Parameters			Root size (cm^3)	Stem length	No. of branches	No. of leaves	Total leaf area (cm^2)	Root FW (g) $plant^{-1}$	Roots DW (g) $plant^{-1}$	Stems FW (g) $plant^{-1}$	Stems DW (g) $plant^{-1}$	Leaves FW (g)	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	22.37
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	0.46	1.80	23.16
		±%	-61.11	-20.51	-71.24	-43.48	-44.54	-66.55	-50.00	-32.92	-58.06	-28.08	-39.38	-9.80	-46.43	+3.53
MLE 0.5 g l^{-1}		x̄	14.67	21.77	3.00	28.67	85.69	14.18	2.11	1.88	0.73	7.81	1.87	0.81	4.71	18.19
		±%	+22.25	+19.10	+28.76	+24.65	+14.03	+2.46	+85.09	+16.77	+17.74	+3.44	+16.88	+58.82	+40.18	-18.69
Seawater salinity (14000 ppm)	**MLE 0.5 g l^{-1}**	x̄	14.35	18.37	2.67	24.67	75.42	13.48	1.42	1.61	0.65	9.14	2.07	0.52	4.14	18.22
		±%	+19.58	+0.49	+14.59	+7.26	+0.36	-2.60	+24.56	-0.00	+4.84	+21.06	+29.38	+1.96	+23.21	-18.55
LSD at 0.05			1.47	1.84	0.82	7.38	13.78	1.62	0.33	0.28	0.12	0.31	0.12	0.04	0.41	4.13
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	0.48	3.23	25.16
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	0.36	2.08	25.87
		±%	-62.90	-25.35	-89	-39.40	-33.80	-69.27	-47.62	-58.43	-32.76	-22.48	-28.75	-25.00	-35.60	+2.82
MLE 0.5 g l^{-1}		x̄	14.47	23.17	3.00	29.00	89.39	15.59	1.80	1.87	0.73	7.97	1.65	0.76	4.18	21.39
		±%	+24.00	+24.71	0.00	+31.82	+9.99	+11.92	+71.43	+12.65	+25.86	+13.37	+3.13	+58.33	+29.41	-14.98
Seawater salinity (14000 ppm)	**MLE 0.5 g l^{-1}**	x̄	13.83	19.77	3.33	24.00	81.43	13.67	1.35	1.67	0.61	8.60	2.01	0.52	3.97	20.51
		±%	+18.51	+6.40	+11.00	+9.09	+0.20	-1.87	+28.57	+0.60	+5.17	+22.33	+25.63	+8.33	+22.91	-18.48
LSD at 0.05			1.50	2.16	0.82	5.00	14.40	1.40	0.12	0.18	0.15	0.95	0.15	0.05	0.37	3.75

Abbreviations: MLE= moringa leaf extract, DAP= days after planting, No. = number, DW= dry weight, LAR= leaf area ratio, ± %= relative to the control values.

Our findings align with those of Aboryia *et al.* (2022) and Sharaf El-Din *et al.* (2014), who observed a reduction in photosynthetic pigments in jojoba leaves under seawater salinity. Also, Abdel Latef *et al.* (2017) noted that MLE application stimulated photosynthetic pigments in fenugreek plants.

The reduction in chlorophyll content in salinity-stressed jojoba leaves likely results from ionic imbalance, leading to Na^+ and Cl^- accumulation, which accelerates leaf senescence and chlorophyll degradation (Munns and Tester, 2008; Roy *et al.*, 2014). High salinity also promotes excessive ROS generation, damaging cell membranes, particularly thylakoids, which contain photosynthetic pigments. This damage can ultimately lead to cell and plant death under severe conditions (Hasanuzzaman et al., 2021).

The positive impact of MLE on photosynthetic pigments may result from its rich content of growth-promoting hormones such as GAs and zeatin, alongside antioxidants such as vitamins, soluble sugars, carotenoids, amino acids, and phenolics (Table 2). GAs and zeatin enhance chlorophyll synthesis and maintenance, thereby retarding senescence (Hwang *et al.*, 2012; Taiz *et al.*, 2014). Additionally, amino acids (e.g., proline), phenolics, vitamins, and reducing sugars act as powerful antioxidants that protect chloroplasts from ROS, preventing chlorophyll breakdown and photo-oxidation (Rehman *et al.*, 2017; Wanas *et al.*, 2018).

The observed elevation in photosynthetic pigments in jojoba leaves by exogenously applied MLE was concomitant with a reduction in the LRE index (the leaf area in cm^2 required for producing one gram of dry weight), indicating the effectiveness of MLE in enhancing photosynthetic efficiency, thus increasing total plant biomass.

2.2.2. Total carbohydrates, polyphenols, proline and crude protein

Table 8 shows that jojoba plants irrigated with seawater at a salinity of 14,000 ppm exhibited significantly lower total carbohydrate levels in their leaves than the control during both growing seasons. This aligns with Aboryia *et al.* (2022), who reported similar results by using 15,000 ppm seawater salinity. Additionally, seawater irrigation reduced crude protein levels in jojoba leaves, consistent with findings of Ali *et al.* (2012). However, in both seasons, 14,000 ppm seawater significantly increased proline and

polyphenol contents compared to the control, aligning with the results documented by Laz *et al.* (2005).

Table 7: Effects of seawater salinity and MLE 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			Carotenoids	Chlorophyll			Carotenoids
			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
MLE 0.5 g l^{-1}		x̄	0.59	0.19	0.78	0.17	0.58	0.17	0.75	0.15
		±%	+11.32	+35.71	+14.71	+21.43	+7.41	+6.25	+7.14	0.00
Seawater salinity (14000 ppm)	MLE 0.5 g l^{-1}	x̄	0.55	0.14	0.69	0.16	0.56	0.18	0.74	0.15
		±%	+3.77	0.00	+2.99	+14.29	+3.70	+12.50	+5.71	+0.00
LSD at 0.05			0.06	0.03	0.10	0.03	0.09	0.02	0.11	0.02

Abbreviations: MLE= moringa leaves extract, FW= fresh weight, Carot. = carotenoids, DAP= days after planting, ± %= ± relative to the control values.

The decrease in total carbohydrates in salt-stressed jojoba leaves was primarily due to salinity impairing photosynthetic efficiency, as shown by an increased leaf area ratio (LAR, Table 6) and a significant drop in photosynthetic pigment levels (Table 7). Salt stress also hinders photosynthesis by damaging enzymes and structural proteins involved in light energy absorption, electron transfer, and CO_2 fixation (Hao *et al.*, 2021). Under stress, plants often convert starch into simple sugars to supply energy and carbon and to work as osmoprotectants and compatible solutes, thereby alleviating stress damage (Krasensky and Jonak, 2012). Sugars also function as signaling molecules that trigger stress response mechanisms by activating the ABA-dependent pathway (Rook *et al.*, 2006).

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

Parameters / Treatment			Season 2021/2022				Season 2022/2023			
			Total carbohydrates	Polyphenols (mg g^{-1} FW)	Proline (mg g^{-1} FW)	Crude Protein (mg g^{-1} DW)	Total carbohydrates	Polyphenols (mg g^{-1} FW)	Proline (mg g^{-1} FW)	Crude Protein (mg g^{-1} DW)
Control		x̄	126.38	9.16	0.20	157.06	124.42	9.25	0.20	158.56
Seawater salinity (14000 ppm)		x̄	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
MLE 0.5 g l^{-1}		x̄	151.53	10.46	0.24	164.81	152.02	10.55	0.23	164.19
		±%	+19.90	+41.19	+20.00	+4.93	+22.18	+14.05	+15.00	+3.53
Seawater salinity (14000 ppm)	MLE 0.5 g l^{-1}	x̄	126.45	13.05	0.28	157.50	125.66	14.30	0.31	158.75
		±%	+0.06	+42.47	+40.00	+0.28	+1.00	+54.59	+55.00	0.00
LSD 0.05			3.70	0.21	0.03	7.07	3.97	0.52	0.04	2.89

Abbreviations: MLE= moringa leaves extract, FW= fresh weight, DW= dry weight, DAP= days after planting, ± %= ± relative to the control values.

The foliar application of MLE at 0.5 g significantly increased total carbohydrates, polyphenols, proline, and crude protein in leaves of jojoba plants under both salt stress and non-stressed conditions. In salt-stressed plants, MLE effectively mitigated the adverse effects of salinity, as evidenced by substantial increases in polyphenol and proline levels that even significantly surpassed those in non-stressed control plants.

Salinity increases polyphenol levels because plants respond to stress by altering protein gene expression, which drives the formation of metabolites such as polyphenols. Abiotic stressors such as salinity trigger the phenylpropanoid synthesis pathway, resulting in increased levels of phenolic compounds that neutralize ROS due to their high antioxidant capabilities (Waśkiewicz *et al.,* 2013; Chen *et al.,* 2019; Sharma *et al.,* 2019). Polyphenols also help to mobilize nutrients and convey signals between roots and shoots (Sharma *et al.,* 2019).

In response to stress, plants increase proline synthesis while reducing its degradation (Liang *et al.,* 2013). The balance between synthesis and degradation is crucial for proline's osmoprotective and developmental functions. Proline aids stressed plants in recovery by acting as an antioxidant, neutralizing reactive oxygen species produced during stress, and providing a rapid source of carbon and nitrogen. It also serves as a metal chelator, ROS scavenger, stress reliever, and antioxidant defense molecule, while functioning as an osmolyte and energy source under stress (Dar et al., 2016). Additionally, proline has been shown to enhance the glutathione redox state and boost the activities of enzymes such as peroxidase, glutathione-S-transferase, superoxide dismutase, and catalase (Hoque *et al.,* 2008; Islam *et al.,* 2010).

The plant's inability to absorb NH_4^+ and NO_3 under salt stress conditions may be the cause of the decrease in crude protein concentration observed in salt-stressed jojoba leaves (Song *et al.,* 2006).

MLE positively influenced the levels of carbohydrates, phenolics, proline, and proteins in the leaves of both unstressed and salt-stressed jojoba plants. This improvement may be due to enhanced photosynthetic efficiency, evidenced by higher photosynthetic pigments (Table 7) and a larger total leaf area coupled with a reduced leaf area ratio (LAR; Table 6). Improved photosynthetic efficiency increases hexose production, which provides energy and carbon for other metabolite synthesis. Furthermore, MLE contains growth-enhancing substances such as antioxidants, osmoprotectants, minerals, and phytohormones, making it a potent biostimulant that mitigates the adverse effects of salinity and enhances growth-related processes (Rehman *et al.,* 2017; Bahgat *et al.,* 2023).

2.2.3. Mineral nutrients

In comparison to the control, applying seawater salinity at 14,000 ppm to markedly reduced the concentrations of N, P, K, and Mg while significantly increased Na levels in jojoba leaves in both experimental seasons. These findings are consistent with those reported by Hassan and Ali (2014) and Ali *et al*. (2012) using NaCl.

The excess Na^+ and Cl^- in the soil solution are major contributors to salinity's adverse effects on mineral nutrient levels in jojoba leaves. Salt-exposed plants accumulate higher Na^+ and Cl^- in their shoots, disrupting ionic balance and reducing K^+, Ca_2^+, and Mg_2^+ levels. Increased shoot Na+ enhances Cl^- uptake and decreases membrane potential due to chemical gradients (Flowers and Colmer, 2015). Excess Cl^- can further impede growth by damaging cell and organelle membranes and lowering chlorophyll content (Munns and Tester, 2008). Na^+ is not only toxic but also a competitive inhibitor of K^+ uptake, as their ionic radii and hydration energies are analogous. Since cells need high cytoplasmic K^+ and low Na^+ levels to sustain physiological processes, hence , excessive Na^+ inflow can restrict K^+ uptake, leading to K^+ shortage and harm to the plant (Hao *et al.,* 2021).

In contrast, applying MLE as a foliar spray on both unstressed and salt-stressed jojoba plants significantly increased N, P, K, Mg, and Ca levels while reducing Na levels. This suggests that MLE may enhance membrane permeability, preventing Na^+ uptake while facilitating the absorption of essential nutrients. Additionally, MLE is rich in essential minerals such as Ca^{2+}, K^+, P, and Mg^{2+}, as well as osmoprotectants, antioxidants, and phenolic compounds (Table 2), which play a crucial role in mitigating stress and promoting plant growth (Rehman et al., 2017). Furthermore, MLE may improve nutrient uptake by enhancing the growth of various plant organs, particularly the root system (Table 6).

Table (9): Effects of seawater salinity and MLE separately and in combination on the concentrations of certain mineral nutrients (mg g^{-1}) in jojoba leaves at 250 DAP during the 2021/22 and 2022/23 seasons.

Treatment \ Parameters			Season 2021/2022						Season 2022/2023					
			N	P	K	Na	Ca	Mg	N	P	K	Na	Ca	Mg
Control		x̄	25.13	0.73	23.60	28.30	65.27	16.92	25.37	0.71	23.60	28.36	63.62	17.26
Seawater salinity (14000 ppm)		x̄	23.40	0.47	20.10	42.50	61.23	15.92	23.43	0.52	20.60	41.49	59.2	16.67
		±%	-6.88	-35.62	-14.83	+50.18	-6.19	-5.91	-7.65	-26.76	-12.71	+46.30	-6.95	-3.42
MLE 0.5 g l^{-1}		x̄	26.37	0.99	26.30	21.07	107.50	18.61	26.27	1.06	25.90	20.9	106.2	18.82
		±%	+4.93	+35.62	+11.44	-25.55	+64.70	+9.99	+3.55	+49.30	+9.75	-26.30	+66.93	+9.04
Seawater salinity (14000 ppm)	**MLE 0.5 g l^{-1}**	x̄	25.20	0.80	24.53	26.30	81.27	17.54	25.40	0.80	24.60	26.53	85.20	18.06
		±%	+0.28	+9.59	+3.94	-7.07	+24.51	+3.66	+0.12	+12.68	+4.24	-6.45	+33.92	+4.63
LSD 0.05			1.19	0.19	0.79	1.74	11.85	0.56	0.46	0.10	1.67	1.05	4.68	0.43

Abbreviations: MLE= moringa leaves extract, DAP= days after planting, DW= dry weight, ± %= ± relative to the control values.

CONCLUSION

In summary, it can be concluded that jojoba can tolerate salt stress up to 14000 ppm. A negative relationship was found between seawater concentration and germination parameters, which decreased with the increase of seawater salinity concentration. On the other hand, seed soaking with various concentrations of MLE revealed that the positive impact of MLE is inversely proportional to the concentrations, with 0.5 g l^{-1} being optimal for improving germination. Seawater at 14,000 ppm negatively impacted vegetative growth, photosynthetic pigments, and biochemical and mineral content in jojoba plants. However, foliar application of MLE at 0.5 g l^{-1}, regardless of salinity stress, enhanced all these parameters. Combining MLE 0.5 g l^{-1} with seawater at 14,000 ppm effectively mitigated salinity's adverse effects. This study suggests that MLE 0.5 g l^{-1} can enhance jojoba growth under normal conditions and serve as a potent, eco-friendly biostimulant to improve salt stress tolerance, making it a practical and safe option for farmers.

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The authors declare that they have no conflict of interest.

REFERENCES

A.O.A.C. (1990). Official Method of Analysis, 15th Ed., Association of Official Analytical Chemists, Inc., USA.

Abdel Latef, A. A. H.; Abu Alhmad, M. and Ahmad, S. (2017). Foliar application of fresh moringa leaf extract overcomes salt stress in fenugreek (*Trigonella foenum-graecum*) plants. *Egyp. J. Bot.*, 57(1): 157-179.

Abdel-Daim, M. M.; Khalil, S. R.; Awad, A.; Abu Zeid, E. H.; El-Aziz, R. A. and El-Serehy, H. A. (2020). Ethanolic extract of *Moringa oleifera* leaves influences NF-κB signaling pathway to restore kidney tissue from cobaltmediated oxidative injury and inflammation in rats. *Nutrients*, 12(4): 1031.

A**boryia, M.S.; El-Dengawy E-R. F.A.; El-Banna, M.F., El-Gobba, M.H.; et al. (2022).** Anatomical and Physiological Performance of Jojoba Treated with Proline under Salinity Stress Condition. *Horticulturae*, 8(8):716. https://doi.org/10.3390/horticulturae8080716

Ali, E. F.; Hassan, F., and El-Zahrany, O. M. (2012). Planting of jojoba for oil production under salt **and water stress in Taif region. Aust. J. Appl. and** *Basic Sci.*, 6: 358-371.

Al-Obaidi, J. R.; Halabi, M. F.; AlKhalifah, N. S.; Asanar, S.; Al-Soqeer, A. A. and Attia, M. F. (2017). A review on plant importance, biotechnological aspects, and cultivation challenges of jojoba plant. *Biological research*, 50(1): 1-9.

Apel, K. and Hirt, H. (2004). Reactive oxygen species: metabolism oxidative stress and signal transduction. *Ann. Rev. Plant Biol.*, 55 (1): 373–399.

Arya, D. and Khan, S. (2016). A review of *Simmondsia chinensis* (Jojoba) "the desert gold": A multipurpose oil seed crop for industrial uses. *J. Pharma. Sci. Res.*, 8(6): 381.

Ashraf, M. (2010). Inducing drought tolerance in plants: some recent advances. *Biotech. Adv.*, 28 (1): 169–183.

Bahgat, A. R.; Dahab, A. A.; Elhakem, A.; Gururani, M. A. and El-Serafy, R. S. (2023). Integrated action of rhizobacteria with aloe vera and moringa leaf extracts improves defense mechanisms in *Hibiscus sabdariffa* L. cultivated in saline soil. *Plants*, 12(21): 3684. https://doi.org/10.3390/plants12213684.

Bates, L. S.; Waldren, R. A., and Teare, I. D. (1973). Rapid determination of free proline for water-stress studies. *Plant and soil*, 39: 205-207.

Bazeed, Z. H. E. (2023). Physiological and Anatomical Studies on Wheat Plants Treated with Some Plant Extracts. M. Sci., Fac. Agric., Damietta Univ.

Biswas, A. K.; Hoque, T. S. and Abedin, M. A. (2016). Effects of moringa leaf extract on growth and yield of maize. *J. Progressive Agric.*, 27 (2): 136- 143.

Chattha, M.U.; Khan, I.; Hassan, M.U.; Chattha, M.B.; et al. (2018). Efficacy of Extraction Methods of *Moringa oleifera* Leaf Extract for Enhanced Growth and Yield of Wheat. *J. Basic & Appl. Sci.*, 14: 131-135.

Chen, S.; Wu, F.; Li, Y.; Qian, Y.; Pan, X.; Li, F., et al. (2019). NtMYB4 and NtCHS1 are critical factors in the regulation of flavonoid biosynthesis and are involved in salinity responsiveness. Frontiers in plant science, 10: 178. DOI:10.3389/fpls.2019.00178

Dar, M. I.; Naikoo, M. I.; Rehman, F.; Naushin, F., and Khan, F. A. (2016). Proline accumulation in plants: roles in stress tolerance and plant development. Osmolytes and plants acclimation to changing environment: emerging omics technologies, 155-166. https://doi.org/10.1007/978-81-322-2616-1_9.

Dawood, M.; Taie, H.; Nassar, R.; Abdelhamid, M. and Schmidhalter, U. (2014). The changes induced in the physiological, biochemical and anatomical characteristics of *Vicia faba* by the exogenous application of proline under seawater stress. *South Afr. J. Bot.*, 93: 54-63.

Desoky, E. M.; Merwad, A. M. and Rady, M.M. (2018). Natural biostimulants improve saline soil characteristics and salt stressed-sorghum performance. Commun. Soil Sci. *Plant Anal*., 49(8): 967–983.

Desoky, E.M.; Elrys, A.S. and Rady, M. M. (2019). Licorice root extract boosts *Capsicum annuum* L. production and reduces fruit contamination on a heavy metals-contaminated saline soil. International Letters of Natural Sciences, Sci. Press Ltd., Switzerland, 73: 1-16.

Dewis, J. and Freitas, F. (1970). Physical and chemical methods of soil and water analysis. FAO soils Bulletin, (10).

Edwards, R. L., and Sundstrom, F. J. (1987). Afterripening and harvesting effects on tabasco pepper seed germination performance. *HortScience* 22(3):473-475.

Flowers, T. J., and Colmer, T. D. (2015). Plant salt tolerance: adaptations in halophytes. Annals of botany, 115(3): 327-331.

Gad, H. A.; Roberts, A.; Hamzi, S. H.; Gad, H. A.; et al. (2021). Jojoba Oil: An updated comprehensive review on chemistry, pharmaceutical uses, and toxicity. *Polymers*, 13(11): 1711.

Ghannam, M. T. and Selim, M. Y. (2021). Rheological properties of the jojoba biofuel. *Sustainability*, 13(11): 6047.

Hao, S.; Wang, Y.; Yan, Y.; Liu, Y.; Wang, J.; and Chen, S. (2021). A review on plant responses to salt stress and their mechanisms of salt resistance. *Hort.*, 7(6): 132. https://doi.org/10.3390/horticulturae7060132

Hasanuzzaman, M.; Raihan, M. R. H.; Chowdhury, A. M; Rahman, K.; Nowroz, F.; Rahman, M.; Nahar, K. and Fujita, M. (2021). Regulation of Reactive Oxygen Species and Antioxidant Defense in Plants under Salinity. *Inter J. Mole. Sci.*, 22(17). https://doi.org/10.3390/ijms22179326

Hassan, F. and Ali, E. (2014). Effects of salt stress on growth, antioxidant enzyme activity and some other physiological parameters in jojoba ['*Simmondsia chinensis*'(link) schneider] plant. Aust. *J. crop sci.*, 8(12): 1615-1624.

Hassanein, A.; Galal, E.; Soltan, D.; Abdelsabour K.; Saad, G. K.; Gaboor, G, and El Mogy, N. S. (2012). Germination of jojoba (*Simmondsia chinensis* L) seeds under the influence of several conditions. *J. Environ.Studies*, 9(1): 29-35.

Hayder, M.; Rakotondramanga, S. and Palmberg-Lerche, C. (2012). Oil trees for energy in the Near East Region. FAO. https://openknowledge.fao.org/handle/20.500.14283/i2559e

Hoque, M. A; Banu, M. N. A; Nakamura, Y; Shimoishi, Y; Murata, Y. (2008). Proline and glycine betaine enhance antioxidant defense and methylglyoxal detoxifi cation systems and reduce NaCl-induced damage in cultured tobacco cells. *J. Plant Physiol.*, 165 (8):813 – 824.

Horneck, D. A. and Hanson, D. (1997). Determination of potassium and sodium by flame emission spectrophotometry. Handbook of reference methods for plant analysis. CRC Press. pp: 153-155.

Hussein, M. M.; El-Faham, S. Y.; Abd El-Moti, E. Z. and Abou-Baker, N. H. (2017). Jojoba irrigated with diluted seawater as affected by ascorbic acid application. Inter. *J. Agric. Res.*, 12(1): 1-9.

Hwang, I.; Sheen, J. and Muller, B. (2012). Cytokinin signaling networks. *Annu. Rev. Plant* Biol., 63 (626): 353-380.

Islam, M. M.; Hoque, M. A.; Okuma, E.; Banu, M.N.A; et al. (2010). Exogenous proline and glycine betaine increase antioxidant enzyme activities and confer tolerance to cadmium stress in cultured tobacco cells. *J. Plant Physiol.*, 166 (15):1587 – 1597.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice Hall, Ic., Englewood Califfs, New Jersy.

Kalaji, M. H. and Pietkiewicz, S., (1993). Salinity effect in plant growth and other physiological process. Acta Physiol. *Plant.*, 15 (2): 89-124.

Khan, M. I.; Mughal, A.; Iqbal, N. and Khan, N.A. (2013). Potentiality of sulphur containing compounds in salt stress tolerance. In: Parvaiz, A.; Azooz, M. M.; Prasad, M. N. V. (Eds.). Ecophysiology and responses of plants under salt stress. Chapter 17 (2013), pp: 443–472, *Springer*.

Krasensky, J. and Jonak, C. (2012). Drought, salt, and temperature stress-induced metabolic rearrangements and regulatory networks. *J. Exper. Bot.*, 63(4): 1593-1608.

L**az, S. I.; Esmail, S. E., and Aly, A. E. (2005).** Responses of jojoba seedlings to different levels of salinity and sodium adsorption ratio: implication of foliar phosphorus nutrition for salt tolerance. *J. Plant Prod.*, 30(2): 1033-1054.

Liang, X.; Zhang, L.; Natarajan, S. K., and Becker, D. F. (2013). Proline mechanisms of stress survival. *Antioxidants & redox signaling*, 19(9): 998-1011.

Lin, J. Y. and Tang, C. Y. (2007). Determination of total phenolic and flavonoid contents in selected fruits and vegetables, as well as their stimulatory effects on mouse splenocyte proliferation. *Food chemistry*, 101(1): 140-147.

Liu, R.; Liu, J.; Huang, Q.; Liu, S., and Jiang, Y. (2022). *Moringa oleifera*: a systematic review of its botany, traditional uses, phytochemistry, pharmacology and toxicity. *J. Pharmacy and Pharmacology*, 74(3): 296- 320.

Merwad, A. M. A. (2020). Mitigation of salinity stress effects on growth, yield and nutrient uptake of wheat by application of organic extracts. Communications in Soil Science and Plant Analysis, 51(4):1-11. DOI: 10.1080/00103624.2020.1751188

Munns, R. and Tester, M. (2008). Mechanisms of salinity tolerance. Annu. Rev. *Plant Biol.*, 59: 651-681.

Murphy, J. and Riley, J. P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta*, 27: 31–36.

Nagornyy, V. D. (2013). Soil and plant Laboratory analysis Textbook. Moscow Peoples' Friendship University of Russia. pp: 103-104.

Radford, P. J. (1967). Growth analysis formulae-their use and abuse 1. *Crop science*, 7(3): 171-175.

Rady, M. M.; Taha, S. S. and Kusvuran, S. (2018). Integrative application of cyanobacteria and antioxidants improves common bean performance under saline conditions, *Sci. Hortic.*, 233 (5): 61–69.

Rehman, H.; Basra, S., Rady, M. M.; Ghoneim, A. M. and Wang, Q. (2017). Moringa leaf extract improves wheat growth and productivity by affecting senescence and source-sink relationship. *Inter. J. Agric. & Biol.*, 19(3):479–484.

Rehman, H.; Nawaz, Q.; Basra, S. M. A.; Afzal, I., and Yasmeen, A. (2014). Seed priming influence on early crop growth, phenological development and yield performance of linola (*Linum usitatissimum* L.). *J. Integrative Agric.*, 13(5): 990-996.

Rook, F.; Hadingham, S. A., Li, Y., and Bevan, M. W. (2006). Sugar and ABA response pathways and the control of gene expression. *Plant, cell & environment*, 29(3): 426-434.

Roy, S. J.; Negrão, S. and Tester, M. (2014) Salt resistant crop plants. *Current Opinion in Biotechnology*, 26: 115-124.

Sadasivam, S. (1996). Biochemical methods. New age international., pp: 8-9.

Schulte, E.E. (1995). Recommended soil PH and lime requirement test. In Sims, J.T and Wolf, A. (eds) Recommended soil testing procedures for the Northeastern United States. Northeastern Regional Publication, No. 493.

Schutzendubel, A. and Polle, A. (2002). Plant responses to abiotic stresses: heavy metal-induced oxidative stress and protection by mycorrhization. *J. Exp. Bot.*, 53 (372): 1351–1365.

Sharaf El-Din, M. N.; Taha, L. A., and Shawqy, K. F. (2014). Effect of different salinity levels on vegetative growth and chemical contents of jojoba (*Simmondsia chinensis*) Seedlings. *J. Plant Prod.*, 5(10): 1637-1650.

Sharma, A.; Shahzad, B.; Rehman, A.; Bhardwaj, R.; et al. (2019). Response of phenylpropanoid pathway and the role of polyphenols in plants under abiotic stress. Molecules, 24(13): 2452. DOI: 10.3390/molecules24132452

Siddhuraju P, and Becker, K. (2003). Antioxidant properties of various solvent extracts of total phenolic constituents from three different agro-climatic origins of drumstick tree (*Moring oleifera* lam). *J. Agric. and Food Chemi.*, 15:2144–2155.

Snedecor, G. W. and Cochran, W. G. (1989). Statistical methods, 8thEdn. Ames: Iowa State Univ. Press Iowa, 54: 71-82.

Song, J.; Ding, X.; Feng, G., and Zhang, F. (2006). Nutritional and osmotic roles of nitrate in a euhalophyte and a xerophyte in saline conditions. *New Phytologist*, 171(2): 357-366.

Stabell, E.; Upadhyaya, M. K. and Ellis, B. E. (1996). Development of seed coat-imposed dormancy during seed maturation in *Cynoglossum officinale*. *Physiologia Plantarum*, 97(1): 28-34.

Tahir, M.; Khan, M. A.; Munir, M., and Khan, M. M. (1993). Seedling establishment of jojoba as influenced by salt concentrations and soil types. Pakistan J. Agric. Res., 14 (4): 348-353.

Taize, L.; Zeiger, E.; Møller, I. M. and Murphy, A. (2014). Plant Physiology and Development. 6th ed., *Sinauer Associates, Oxford Univ. Press.*

Tanaka-Oda, A.; Kenzo, T., and Fukuda, K. (2009). Optimal germination condition by sulfuric acid pretreatment to improve seed germination of *Sabina vulgaris* Ant. *J. Forest Res.*, 14(4): 251-256.

Tester, M. and Davenport, R. (2003). Na+ tolerance and Na+ transport in higher plants. *Ann. Bot.*, 91(5): 503–527.

Torabi, M., Halim, R. A., Mokhtarzadeh, A., and Miri, Y. (2013). Physiological and biochemical responses of plants in saline environment. In: Crop Biology and Agriculture in Harsh Environments. Lambert Academic Publishing, Saarbrucken, Germany, pp. 47-80.

Vashisth, A., and Nagarajan, S. (2010). Effect on germination and early growth characteristics in sunflower (*Helianthus annuus*) seeds exposed to static magnetic field. *J. Plant Physiol.*, 167(2): 149-156.

Waidyanatha, U. D. S., and Goonasekera, G. A. J. P. R. (1975). Some methods for determining leaf areas in Hevea. Q. *Jl. Rubb. Res. Inst. Sri Lanka*, (52): 10-19.

Wanas, A. L. (1996). Botanical studies on some economical plants tolerating salinity. Ph. D. Thesis, Fac. Agric., Moshtohor, Zagazig Univ., Egypt.

Wanas, A. L.; Serag, M. S.; Abd Elhamied A. S. and Abd-Elaziz, H. O. (2018). Effect of some natural treatments on vegetative growth and leaf chemical composition of squash plants growing under cold conditions. J. *Plant Production, Mansoura Univ.*, 9 (6): 543– 551.

Wanas, A., and Shabka, E. (2025). The Effect of Aloe Leaf Extract on Growth and Physio-biochemical Characteristics of Jojoba Plants Cultivated under Normal and Salt Stress Conditions. *Damietta Journal of Agricultural Sciences*, *4*(1): 1-16. https://dx.doi.org/10.21608/djas.2025.409131

Wanas, A.; Hamada, M., and Shaimaa, M. (2025). Investigation the Ability of Olive Leaf Extract Enhance Growth and Physio-Biochemical Performance of Faba Bean Plants Under Salt Stress Conditions. *Damietta Journal of Agricultural Sciences*, *4*(1): 35-49. https://dx.doi.org/10.21608/djas.2025.409255

Waśkiewicz, A.; Muzolf-Panek, M., and Goliński, P. (2013). Phenolic content changes in plants under salt stress. In book: Ecophysiology and responses of plants under salt stress, 283-314. DOI:10.1007/978-1-4614-4747-4_11

Wellburn, A. R. (1994). The Spectral Determination of Chlorophylls a and b, as well as Total Carotenoids, Using Various Solvents with Spectrophotometers of Different Resolution. *J. Plant Physiol.*, 144(3): 307–313.

Williams, O. A.; Ogunwande, O. A. and Amao, A. O. (2018). Potentials of *Moringa oleifera* leaf extract in increasing maize (*Zea mays* L.) productivity in Nigeria. Inter. *J. Sci. and Res. Pub.*, 8 (12): 279-289.

World Bank. (2019). Sustainable Land Management and Restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations. Washington, DC. https://doi.org/10.1596/33037

Wright, R. J. and Stuczynski, T. (1996). Atomic absorption and flame emission spectrometry. Methods of Soil Analysis: Part 3 Chemical Methods, 5: 65-90.

استجابة نباتات الجوجوبا غير المجهدة والمجهدة بالملوحة للرش الورقى بمستخلص أوراق المورينجا

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الملخص العربى

الجوجوبا شجيرة زيتية رئيسية، تُقدّر لدورها في مكافحة تدهور الأراضي، وتركيبة زيتها الفريدة، والتي تحظى بطلب كبير في صناعة مستحضرات التجميل لخصائصها المفيدة. بحثت هذه الدراسة في قدرة مستخلص أوراق المورينجا (MLE) على تعزيز نمو نباتات الجوجوبا وأدائها الفسيولوجي، سواءً في الظروف العادية أو تحت تأثير الإجهاد الملحي.

. تم اختيار مستوى ملوحة مياه البحر وتركيز مستخلص أوراق المورينجا المُستخدمان بناءً على نتائج تجربتى إنبات تمهيديتين. حددت التجربة الأولى 14000 جزء فى المليون من ملوحة مياه البحر كأقصى مستوى ملوحة يمكن تتحمله نباتات الجوجوبا، بينما حددت التجربة الثانية 0.5 جم لتر$^{-1}$ كتركيز مثالي لمستخلص أوراق المورينجا لتحسين خصائص الإنبات.أشارت النتائج إلى أن رى نباتات الجوجوبا بمياه البحر بتركيز 14000 جزء في المليون تسبب فى حدوث انخفاضات معنوية فى حجم المجموع الجذرى، طول الساق، عدد الأوراق والأفرع، وإجمالى المساحة الورقية نبات$^{-1}$، الأوزان الطازجة والجافة لكل من الجذور والسيقان والأوراق، نسبة المجموع الجذرى إلى المجموع الخضرى، صبغات البناء الضوئى، الكربوهيدرات الكلية، البروتين الخام، تركيزات النيتروجين، الفوسفور، البوتاسيوم ، وكذلك الماغنسيوم، بينما زادت مستويات البرولين والفينولات والصوديوم مقارنة بالنباتات المروية بماء الصنبور. على العكس من ذلك، فإن استخدام مستخلص أوراق المورينجا بتركيز 0.5 جم لتر$^{-1}$ كرش ورقى لنباتات الجوجوبا غير المعرضة للإجهاد الملحى أدى إلى زيادة ملحوظة في حجم المجموع الجذرى، طول الساق، نسبة المجموع الجذرى إلى المجموع الخضرى، الوزن الجاف الكلى نبات$^{-1}$، الكربوهيدرات الكلية، الفينولات، والبرولين، البروتين الخام، ومستويات النيتروجين، الفوسفور، البوتاسيوم، والكالسيوم والماغنسيوم ، بينما انخفض معدل مساحة الورقة وتركيز الصوديوم مقارنة بالكنترول. أدى الرش الورقي بمحلول MLE مع الري بمياه البحر المخففة (14,000 جزء في المليون) إلى التخفيف الفعال من الآثار السلبية للملوحة، مما أدى إلى تحسينات ملحوظة في معايير النمو، وتركيز صبغات البناء الضوئي، والكربوهيدرات، والبوليفينولات، والبرولين، ومستويات البروتين، والمحتوى المعدني، بالإضافة إلى انخفاض ملحوظ في مستويات الصوديوم مقارنةً بنباتات الجوجوبا المعرضة للإجهاد الملحي.

بناءً على ذلك، توصي هذه الدراسة باستخدام 0.5 جم/لتر من محلول MLE لتحسين نمو نباتات الجوجوبا وأدائها الفسيولوجي في الظروف غير المجهدة والظروف المجهدة.