DOI: 10.21608/alexja.2025.400559.1153

Changes in Chemical Compounds in *Cordia myxa* L. Exposed to Salt Stress due to Stimulatory Action of Sodium Nitrophenolate

Ashraf M. Shehata[1*], Maneea Moubarak[2]

[1] *Department of Floriculture, Faculty of Agriculture, Alexandria University, Alexandria, Egypt:* ashraf.shehata@alexu.edu.eg

[2] *Horticulture Department, Faculty of Agriculture, Damanhour University, Egypt;* Drmaneea1981@agr.dmu.edu.eg

[*]Corresponding Author

#Authors contributed equally to this work

ARTICLE INFO

Article History

Received: 03/07/2025

Revised: 10/07/2025

Accepted: 12/07/2025

Key words: *Cordia myxa*; chemical composition; salt stress; seedling growth; sodium nitrophenolate.

ABSTRACT

The effects of soil salinization on the growth and chemical composition of *Cordia myxa* seedlings sprayed with the compound sodium nitrophenolate (CSN) were studied. In the current study, sodium chloride salt was mixed with potting media at rates of 0, 2000, 4000, and 6000 mg/kg soil. The seedlings were sprayed with CSN at 0, 5, and 10 mg/L. Growing seedlings exposed to salinity, especially at high concentrations, coincides with the decrease in various growth measurements including survival percentage, number of leaves per plant, leaf area, fresh and dry leaf weight, and chemical components. CSN treatment had a substantial effect on improving the growth aspects and various chemical components of *C. myxa* seedlings. Maximum measurements of the growth and chemical components such as chlorophylls a and b and carotenoids, N, P, and K percentages, and total phenolics were recorded when the plants were grown in soil exposed to salinity at a rate of 2000 mg NaCl/kg soil and sprayed at a rate of 10 mg/L CSN. In contrast, higher free proline content coincided with 6000 and 4000 mg NaCl/kg soil. It could be suggested that *C. myxa* trees can grow in moderately saline conditions, and to improve their growth, they are sprayed with CSN at a rate of either 5 or 10 ml/l. Our findings support the future development of efficient growth methods for *C. myxa*.

INTRODUCTION

Cordia myxa L. (Boraginaceae family) is well known as the “Indian cherry or Assyrian plum” because of its edible fruit (Al-Snafi, 2016). It is a small tree with great environmental and aesthetic value, as it provides shade and produces firewood, timber, and fodder for livestock (Heuze *et al.*, 2021). The tree is spread from the eastern Mediterranean region to eastern India, tropical Africa, tropical Asia, and Australia (Chaharlang and Samavati, 2015). Its leaves are used to treat stomach, brain, and breast cancer in Ghana, and cough and cold in India (Rao *et al.*, 2015 and Agyare *et al.*, 2018). *C. myxa* fruit has high nutritional and medicinal value (Askar, 1994). The antioxidant, antidiabetic, antimicrobial, cytotoxic, analgesic, anti-inflammatory, antipyretic, and trypanocidal activities of its leaves have been studied by Afzal *et al.* (2004) and Najib and handayani (2019). In this concern, Kumar *et al.* (2022) studied the chemical components and metabolomics of *C. myxa* leaves and fruits revealing that both leaves and fruits exhibited phenolic compounds at a range of 5.35-33.28 mg GAE/g and 9.65-26.22 mg GAE/g, respectively. They added other valuable components, such as flavonoids, antioxidants, ascorbic acid, glycine, alanine, microelements, and macroelements.

Newly reclaimed soils are one solution for expanding crop cultivation and afforestation programs. Such lands suffer from problems, such as drought, salinity, and heat stress, which affect the success of these plantations. Salt stress is considered one of the most prominent of these problems, which determines plant growth through osmotic stress, toxicity of Na^+ and Cl^-, and ions uptake imbalance, which is reflected in the deficiency of nitrogen, phosphorus, K, Ca, and micronutrients (Munns, 2005). For typical growth, the optimum salt concentration of any agricultural plant is approximately 1500 mg/1 NaCl, and if the plant is subjected to a higher level, its growth and physiological functions are influenced and differ from before and are called salt-stressed (Taiz and Zeiger, 1998). Jahan *et al.* (2018) studied the effects of salt stress on the growth and biochemical characteristics of neem seedlings and reported that these parameters were affected by salt stress. They added that among all the different salinity rates, neem can grow better, up to 10 dS/m. Salinity stress causes a deficiency in the leaf chlorophyll content by decreasing in number and size and area (Abdul Hameed, 2002). Ibrahim (2002) reported that salinity in irrigation water inhibited the seedling growth of *Ziziphus spina* by reducing plant height, leaf area, leaf number, and total chlorophyll content. The presence of salt ions in the soil causes high salt stress, which is harmful to plant cells. The soluble salts that cause salinity are Na^+ and Cl^-, which are among the ions that cause soil salinity. In addition, an increase in sodium ions contributes to the sodicity of the soil (Foronda, 2022).

Previous studies have shown that sodium nitrophenolate positively affects various processes controlling plant growth, development, and productivity. Sodium nitrophenolate (CSN) is a broad-spectrum plant growth regulator that can be used in different plants during any growth period and all show excellent effects. A low concentration of CSN acts as a biostimulator and was found to increase the rate of flowering in oil tea by increasing indole-3-acetic acid, zeatin-riboside, and gibberellic acid content in flower buds during petal formation, while reducing abscisic acid content in the late stages of flower bud differentiation (Zou, 2020). Bio stimulant-treated plants are more advanced in growth and development and accumulate more biomass (Borowski and Blamowski, 2009). It increases photosynthesis and transpiration rates, but usually does not reduce the relative water content**.** On the other hand, the positive effect of CSN is much more evident when plants are grown under stressful conditions. It has been proved that bio stimulant plays a protective role against various abiotic stresses, such as salinity, drought, low or high temperatures and heavy metals (Wrochna, 2008). Moreover, some studies have shown that if plants are grown under optimal conditions, the positive effects of this preparation might not be noticed (Ksiezak, 2008). Xiao-yue (2008) pointed out that spraying CSN on *Camellia oleifera* led to increased diameter, weight of fruit, yield of tree, and fruit quality compared with the control. It is recommended to use liquid nitrophenolates in *Ficus deltoidea* seedlings as a foliar spray or as a soil drench at a rate of 1.0 cm^3/l to attain the best growth performance and chemical composition (Fouly *et al.*, 2014). Also, Ashvathama (2020) reported that among the used rates of sodium nitrophenolate, a rate of 2 ml/l mL/L recorded a high yield of cucumber.

Many studies have reported positive effects of sodium nitrophenolate on different plants (Przybysz *et al.*, 2014, Zhang *et al.*, 2017, Szparaga *et al.*, 2018, and Sun *et al.*, 2020). El-Fouly *et al.* (2014) indicated that the application of sodium nitrophenolate on *Ficus deltoidea* Jack as a foliar spray or as a soil drench led to improved growth performance and chemical composition. In addition, the results of Attia (2022) showed that treating Le Conte pear trees with 200 ppm nitrophenolate sodium improved fruit set, fruit firmness, TSS, and carotenoid content. The main objective of this investigation was to evaluate the beneficial role of sodium nitrophenolate in the salt tolerance of *C. myxa* seedlings

MATERIALS AND METHODS

The present study was conducted in a private nursery in Damanhour, Beheira Governorate, Egypt, during the two seasons of 2023 and 2024 in the open field. The study aimed to evaluate the effect of spraying with compound sodium nitrophenolate (CSN) on the growth characteristics and chemical composition of *C. myxa* grown under salt stress conditions. Seedlings of *C. myxa* Linnaeus, were obtained from the Agricultural Research Station of Al-Marashda, Qena Governorate, Egypt. Homogenous seedlings (25 cm height) of *C. myxa* were transplanted into plastic pots (30 cm diameter) filled with approximately 5 kg of sand, clay, and peat moss mixture (1:1:1, v/v/v) and one transplant/pot. The physical and chemical properties of the sand, clay, and peat moss are listed in Tables 1 and 2, respectively. Different salinity treatments were applied by mixing them with the soil before transplanting. Saline-treated soil without salinity; saline-treated soil with 2000 mg NaCl/kg soil, saline-treated soil with 4000 mg NaCl/kg soil and saline-treated soil with 6000 mg NaCl/kg soil. The salt was mixed with the soil before planting according to the treatment, and the pots were filled with soil. Three levels of CSN (0, 5, and 10 mg/L) were used as foliar sprays at the beginning of the salinity treatments. CSN was obtained from the Al-Gomhouria Company, Cairo, Egypt. It was added five times (El-Fouly *et al.*, 2014), starting from 1st March until the 1st of July during the two growing seasons at different rates.

NPK fertilizer was used at a ratio of 12:10:5 g per pot. Nitrogen was applied as ammonium sulphate (20.5 % N), phosphorus as calcium superphosphate (15.5 % P_2O_5), and potassium as potassium sulfate (48 % K_2O). NPK fertilizers were applied as a top dressing to the pots, followed by irrigation. NPK fertilizer levels were divided into two equal portions; the 1st dose was added one month after the transplanting date, while the 2nd dose was added one month after the first addition (Ali, 2023). The pots were irrigated twice per week with tap water at a rate of 200 m/pot.

1. Experimental Design

The experiments were arranged in a completely randomized design (CRD) with three replicates and five pots in each replicate. There was a total of ten treatments, 15 pots in each treatment, and Table 3 lists the different treatments that used salinity and CSN treatments.

Table 1: Some physical and chemical properties of the used sand and clay during the studied seasons

Soil type	Particle size distribution (%)				S. P	E.C. (ds/m)	pH	Cations (meq/l)				Anions (meq/l)		
	Coarse sand	Fine sand	Silt	Clay				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{--}
Sand	18.28	71.72	4.34	5.76	21.80	2.18	8.33	2.60	2.5	21.9	0.77	3.80	13.0	10.9
Clay	7.75	16.46	34.89	40.53	41.70	1.50	8.25	16.80	9.2	20.3	0.35	3.70	1.40	41.8

Table 2: Some physical and chemical properties of the used peatmoss during the studied seasons

Character	Value
Organic matter	95%
Ash	5%
Density (Dry volume)	90 mg/L.
pH value	3.6
Water relation capacity	75%
Salinity	0.31 g/l
N	1.07 %
P	0.24%
K	1.75
Fe	420 ppm
Mn	25 ppm
Zn	40 ppm

Table 3: The different salinity and CSN treatments tested in the study

Treatments	
T1	Untreated (control)
T2	2000 mg NaCl/kg soil
T3	4000 mg NaCl/kg soil
T4	6000 mg NaCl/kg soil
T5	2000 mg NaCl/kg soil plus CSN at 5 mg/L
T6	2000 mg NaCl/kg soil plus CSN at 10 mg/L
T7	4000 mg NaCl/kg soil plus CSN at 5 mg/L
T8	4000 mg NaCl/kg soil plus CSN at 10 mg/L
T9	6000 mg NaCl/kg soil plus CSN at 5 mg/L
T10	6000 mg NaCl/kg soil plus CSN at 10 mg/L

2. Measurements

2.1 Growth Parameters

At the end of the experiment (on the 1st of August for each season), the following data were recorded: survival percentage, seedling height (cm), number of leaves per plant, leaf area (cm^2), and leaf fresh and dry weight (g).

2.2 Chemical Analysis

Photosynthetic pigments (chlorophyll a and b, and carotenoids, mg/g FW) were assessed according to the method of Saric (1976). Total carbohydrates (%) in dried leaves were measured as described by Doubios et al. (1956). Nitrogen (N), phosphorus (P), and potassium (K) were determined in dry leaves using the methods described by AOAC (1995). Total phenolic content (mg GAE/g) of the leaf-water extract was determined using Folin-Ciocalteu reagent, as reported by Stanković (2011). Free proline (µg/g dry leaves) was measured according to the method described by Troll and Lindsey (1955).

2.3 Statistical Analysis

The average data for the two seasons were statistically analyzed using an analysis of variance (Snedecor and Cochran, 1980). Least significant differences (LSD) were used to differentiate means at the 5% level of probability. Means were compared using the computer program of Statistics version 9 (Analytical Software, 2008).

RESULTS

1. Survival Percentage

The effects of CSN and salt stress on the survival (%) of *C. myxa* plants are presented in Table 3. The results showed that there were significant differences in the survival percentage of

C. myxa. The highest salt concentrations (6000 and 4000 mg NaCl/kg soil) harmed the survival % when compared with the control. Seedlings treated with CSN had a significant positive effect on the survival of *C. myxa* seedlings at the two concentrations used (10 and 5 mg/L). Although seedlings were affected by increased salt concentrations, adding CSN improved the survival rate, especially at a rate of 10 mg/L. In general, the highest survival (100%) values were observed in untreated plants and those treated with 2000 mg NaCl/kg and 10 mg/L CSN.

2. Vegetative Measurements

Measurements of the seedling heights of *C. myxa* indicated that the shortest seedlings were attained in treated plants at a rate of 6000, followed by 4000 mg NaCl/kg soil, whereas the plants in combination with 2000 mg NaCl/kg soil and 10 or 5 mg/L CSN were significantly taller (Table 4). Overall, the *C. myxa* seedlings were the tallest in the treatment with 2000 mg NaCl/kg soil with 10 mg/L CSN in the mean of both seasons.

There were significant differences between salinity and CSN treatments in the leaf area of *C. myxa* seedlings (Table 4). The treatment of *C. myxa* with salinity caused a significant decrease in leaf area, especially at higher levels (6000 and 4000 mg NaCl/kg soil), when compared with the untreated plants. On the other hand, seedlings treated with salinity and CSN showed a significant increase in leaf area when compared with plants treated with salinity only. Plants exposed to moderate salt stress (2000 mg NaCl/kg soil) and sprayed with CSN showed a significant increase in leaf area, especially at a rate of 10 mg/L CSN, which gave the highest increase compared to all other treatments.

There were significant differences in the number of leaves of *C. myxa* seedlings with respect to the salinity and CSN treatments. The mean number of leaves was significantly lower with salinity treatment at 6000 or 4000 mg NaCl/kg soil. Plants grown under conditions of 2000 mg NaCl/kg and treated with 10 or 5 mg/L CSN had the maximum number of leaves (Table 4).

Table 5 shows that there were significant differences between salinity and CSN treatments on the leaf fresh and dry weights of *C. myxa*.

Table 4: Survival (%), seedling height (cm), leaf area (cm^2) and number of leaves of *Cordia myxa* plant as affected by CSN under salt stress, as the average of the 2023 and 2024 seasons

Treatments	Survival (%)	Seedling height (cm)	Leaf area (cm^2)	Number of leaves
Control	100.00	75.00	73.67	22.00
2000 mg NaCl/kg soil	93.33	67.67	67.00	19.00
4000 mg NaCl/kg soil	73.33	59.33	62.00	17.00
6000 mg NaCl/kg soil	53.33	55.33	56.00	15.00
2000 mg NaCl/kg soil+5mg/L CSN	100.00	83.33	74.33	22.00
2000 mg NaCl/kg soil+10mg/L CSN	100.00	86.33	78.00	24.00
4000 mg NaCl/kg soil+5mg/L CSN	93.33	69.67	71.00	20.33
4000 mg NaCl/kg soil+10mg/L CSN	93.33	68.00	74.67	22.00
6000 mg NaCl/kg soil+5mg/L CSN	73.33	63.67	66.33	17.67
6000 mg NaCl/kg soil+10mg/L CSN	93.33	69.67	64.67	20.33
Mean	87.33	69.80	68.77	19.93
LSD 5%	15.76	4.77	2.68	1.37

Table 5: Leaf fresh and dry weights (g) of *Cordia myxa* as affected by CSN under salt stress, as the average of the 2023 and 2024 seasons

Treatments	Leaf fresh weight (g)	Leaf dry weight (g)
Control	8.83	2.30
2000 mg NaCl/kg soil	7.73	1.90
4000 mg NaCl/kg soil	7.30	1.67
6000 mg NaCl/kg soil	6.77	1.50
2000 mg NaCl/kg soil+5mg/L CSN	7.67	2.10
2000 mg NaCl/kg soil+10mg/L CSN	7.90	2.30
4000 mg NaCl/kg soil+5mg/L CSN	7.17	1.90
4000 mg NaCl/kg soil+10mg/L CSN	7.43	2.07
6000 mg NaCl/kg soil+5mg/L CSN	7.17	1.80
6000 mg NaCl/kg soil+10mg/L CSN	7.47	2.00
Mean	7.54	1.95
LSD 5%	0.54	0.14

The highest salt concentrations (6000 and 4000 mg NaCl/kg soil) harmed the leaf fresh and dry weights when compared with the control. Seedlings treated with CSN had a significant positive effect on weight improvement at both concentrations used (5 and 10 mg/L). The *C. myxa* seedlings treated with 2000 mg NaCl/kg soil plus CSN at a rate of 10 mg/L was characterized by the highest fresh and dry weights of leaves compared to those grown under salinity conditions only. The lowest fresh and dry weights of leaves were observed in plants treated with 6000 mg NaCl/kg soil. Overall, untreated *C. myxa* seedlings (control) registered the heaviest fresh weight compared with the other treatments.

3. Biochemical parameters

Table 6 shows that there were significant differences in the effects of salinity and CSN treatments on the chlorophyll a and b and carotenoids of *C. myxa* leaves. The highest salt concentrations (6000 and 4000 mg NaCl/kg soil) harmed chlorophyll a and b and carotenoids when compared with untreated plants. Seedlings treated with CSN had a significant positive effect on improving the photosynthetic pigments at the two concentrations used (5 and 10 mg/L). Although *C. myxa* seedlings are affected by increased concentrations of salt stress, adding CSN improves the photosynthetic pigments of leaves, especially at a concentration of 10 mg/L. In general, the highest chlorophyll a &b and carotenoids values (1.70, 1.30 and 1.31 mg/gFW) were produced with untreated plants, followed by (1.60, 1.30 and 0.90 mg/g FW) those treated with 2000 mg NaCl/kg soil +10 mg/L CSN, respectively. Meanwhile, plants treated with the 6000 mg NaCl/kg soil resulted in the lowest values (0.90, 0.63 and 0.64 mg/g FW) of chlorophyll a &b and carotenoids, respectively.

Figures 1-3 show the effects of salinity and CSN on the nitrogen, phosphorus, and potassium percentages in the leaves of *C. myxa* seedlings. There were significant differences in the nitrogen, phosphorus, and potassium content of the treatments. The highest salt level (6000 mg NaCl/kg soil) had a negative effect on the nitrogen, P, and K percentages when compared with the other treatments. Spraying seedlings of *C. myxa* with CSN had a significant positive effect on improving the nitrogen, phosphorus, and potassium contents at the two rates used (5 and 10 mg/L). While *C. myxa* seedlings are affected by increased levels of salt stress, adding CSN improves the N, P, and K content of leaves, especially at a concentration of 10 mg/L. Generally, higher values of nitrogen and phosphorus (1.40 and 0.21 %) were produced with 2000 mg NaCl/kg soil +10mg/L CSN, respectively. Whereas the Higher potassium contents (0.91 and 0.80 %) were registered with untreated plants, followed by those treated with the 2000 mg NaCl/kg soil+10mg/L CSN treatment, respectively. Treating plants with 6000 mg NaCl/kg soil resulted in the lowest values (0.82, 0.12 and 0.64 %) of the nitrogen, phosphorus and potassium, respectively.

Figure 4 shows the effect of salinity and CSN on the TPC of *C. myxa* leaves. Treating plants with different salinity levels (2000, 4000, and 6000 mg NaCl/kg soil) resulted in a decrease in total phenolic content when compared with untreated plants. On the other hand, plants sprayed with CSN showed a significant increase in total phenolics as compared to plants exposed to salinity without CSN. Higher phenolics (361.7 and 347.7 mg GAE/g DW) were recorded with 2000 mg NaCl/kg soil plus 10 mg/L CSN, followed by 2000 mg NaCl/kg soil plus 5 mg/L CSN, respectively. The lowest total phenolics (276.3 mg GAE/g DW) were registered in the 6000 mg NaCl/kg soil treatment.

Table 6: Chlorophyll a & b and Carotenoids (mg/g FW) of *Cordia myxa* as affected by sodium nitrophenolate (CSN) under salt stress, as the average of the2023 and 2024 seasons

Treatments	Chlorophyll a (mg/gFW)	Chlorophyll b (mg/gFW)	Carotenoids (mg/gFW)
Control	1.70	1.30	1.31
2000 mg NaCl/kg soil	1.20	1.00	0.80
4000 mg NaCl/kg soil	1.00	0.80	0.74
6000 mg NaCl/kg soil	0.90	0.63	0.64
2000 mg NaCl/kg soil+5mg/L CSN	1.50	1.20	0.86
2000 mg NaCl/kg soil+10mg/L CSN	1.60	1.30	0.90
4000 mg NaCl/kg soil+5mg/L CSN	1.30	0.90	0.78
4000 mg NaCl/kg soil+10mg/L CSN	1.60	0.94	0.63
6000 mg NaCl/kg soil+5mg/L CSN	1.20	0.75	0.67
6000 mg NaCl/kg soil+10mg/L CSN	1.50	0.83	0.73
Mean	1.35	0.97	0.81
LSD 5%	0.16	0.08	0.16

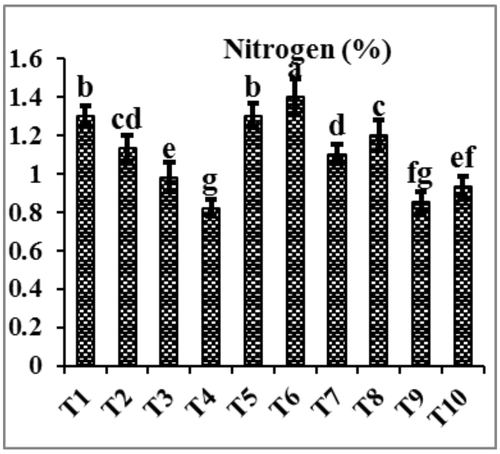

Figure 1: Nitrogen of *Cordia myxa* leaves as affected by CSN under salt stress, as average of 2023 and 2024 seasons

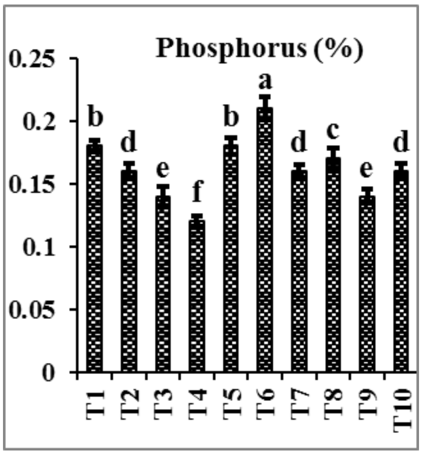

Figure 2: Phosphorus (%) of *Cordia myxa* leaves as affected by CSN under salt stress, as average of 2023 and 2024 seasons.

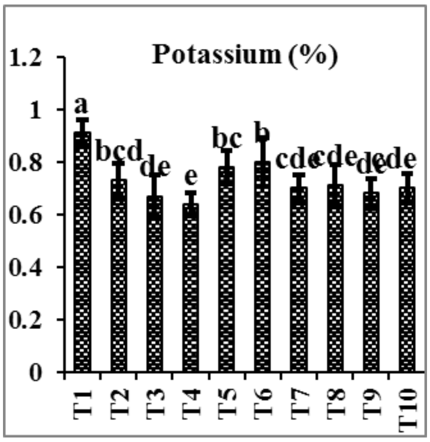

Figure 3: Potassium content (%) of *Cordia myxa* leaves as affected by CSN under salt stress, as average of 2023 and 2024 seasons

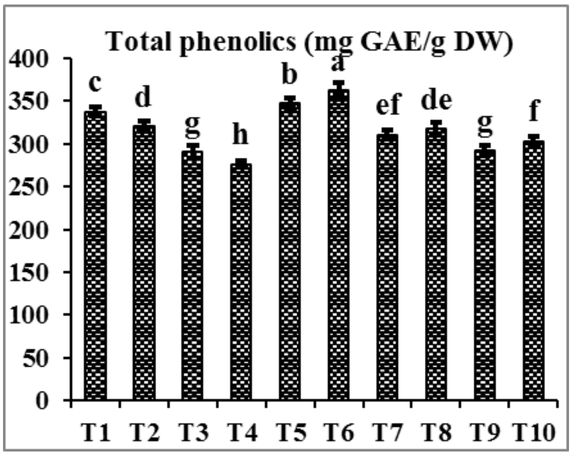

Figure 4: Total phenolics (mg GAE/g DW) of *Cordia myxa* leaves as affected by CSN under salt stress, as average of 2023 and 2024 seasons.

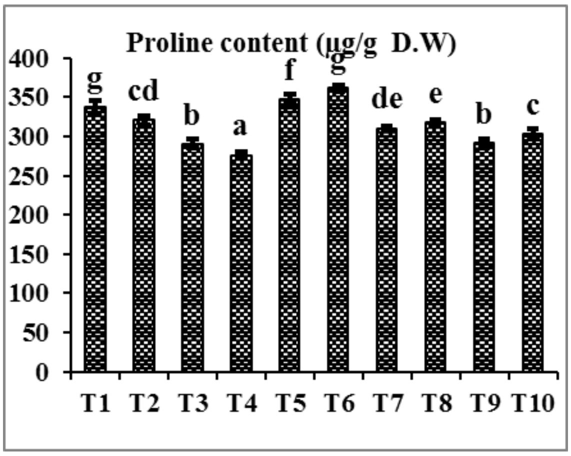

Figure 5: Free proline (µg/g D.W) of *Cordia myxa* leaves as affected by CSN under salt stress, as average of 2023 and 2024 seasons.

There was a significant effect of salinity and CSN treatments on the free proline content of *C. myxa* leaves as shown in Figure 5. Higher free proline content (815.80 and 762.87 µg/g D.W.) was measured in 6000 and 4000 mg NaCl/kg soil, respectively. On the other hand, the lowest values (655.43 and 665.60 µg/g D.W.) of free proline were recorded with un-stressed plants and those treated with 2000 mg NaCl/kg soil plus 10 mg/L CSN, respectively.

DISCUSSION

Our results clearly showed that *C. myxa* seedlings tolerate salinity to a moderate degree, as plant growth and its chemical components decrease with increasing levels of salt stress. This was evident in the decrease in survival percentage and reduction in growth measurements when plants were treated with a higher salt concentration of 6000 mg/kg soil. *C. myxa* is a fast-growing evergreen tree that presents salinity tolerance levels because of dilution effects, which reduce the negative effects of excessive sodium ions (Yeo and Yeo, 1990). Rapid plant growth helps to avoid salt stress, resulting in regular growth and high biomass. Hence, growth response is considered an indicator for estimating the tolerance of plants to stress (Akter and Oue, 2018). Our results were following those of Atteya *et al.* (2022), who indicated that high salinity levels decreased the growth parameters, that is, plant height, stem diameter, and leaf weights, as well as the chemical composition of moringa trees. In this regard, the adverse effects of salt stress on *C. myxa* growth characteristics may be due to the obstruction of the uptake of K^+ and Ca^{2+} and increasing the toxicity of Na^+ at high salt levels, which disrupts vital plant functions (Arif *et al.*, 2020, and Bayomy *et al.*, 2023). Debez *et al.*, (2001) suggested that salinity slows down metabolic and physiological activities, and reduces cell division and growth. In addition, salinity stress negatively affects the growth and productivity of plants through osmotic stress. An increase in salinity in the soil solution causes a decrease in water potential in the soil and prevents water absorption by roots, causing a water deficit in the plant (Pardo, 2010, Roy *et al.*, 2014, and Meng *et al.*, 2020). Furthermore, the reduction in the growth characteristics may be due to changes in xylem vessel anatomy, which leads to a decrease in the amount of water transferred to the shoot system from the soil, and then a reduction in the leaf area, contents of elements, proteins, and pigments in the plant (Atteya *et al.*, 2022). The proline concentration in plants is correlated with salinity tolerance because of its efficiency in decreasing oxidative stress (Molinari *et al.*, 2007). Moreover, proline acts as a solute to decrease leaf water potential, improve water uptake, and reduce transpiration to maintain cell turgor pressure (Ashraf and Harris, 2004). Proline accumulation significantly increased in *C. myxa* leaves with increasing salinity levels. This was stated in a previous study by Suleiman *et al.* (2023), who reported that proline concentration is a common indicator of salt stress. Proline content increased in the plant tissues of *Suaeda nudiflora* with increasing levels of soil salinity (Patel and Pandey, 2009). The increase in the proline content of the seedling tissues with increasing salinity showed that higher proline content may contribute to alleviating NaCl stress.

It is known that increased salinity reduces photosynthetic activity (chlorophyll a, b, and carotenoids), which was demonstrated in our results. High salinity concentrations reduce plant growth and development as a result of an imbalance in the photosynthetic machinery and a change in the fine structure of cell components through an increase in reactive oxygen species (Hasanuzzaman *et al.*, 2014). Reducing the values of photosynthetic pigments as well as decreasing nitrogen, phosphorus, and potassium uptake as a result of high salinity levels is supported by previous studies (Soliman *et al.*, 2015, Abd-Allah *et al.*, 2015, Iqbal *et al.*, 2015, Arif *et al.*, 2020 and Bayomy *et al.*, 2023).

In the present study, the accumulation of phenolics decreased with increasing salinity in the leaves of *the C. myxa* seedlings. Similar findings have been reported by Jaleel *et al.* (2008), Nouman *et al.* (2012) and Jahan *et al.* (2018). Phenolics are very important components of the hydroxyl groups in plants because of their scavenging ability. These constituents also act as powerful antioxidants and play a defensive role against reactive oxygen species (Sreenivasulu *et al.*, 2000). In our study, the decreased levels of phenolic compounds as a result of 6000 or 4000 mg/kg NaCl soil levels may be related to the disruption of important physiological functions in the plant.

Sodium nitrophenolate (CSN), an active ingredient, stimulates plant growth by altering the activity of specific antioxidant enzymes involved in the scavenging of reactive oxygen species (ROSROS). The reactive oxygen species can attack polysaccharides, nucleic acids, and proteins (Matysik *et al.*, 2002). Oxidative stress occurs when more ROS is produced than metabolized (Dhindsa *et al.*, 1981). The ability to reduce the impact ROS on plant physiology, growth, and chemical composition of the plant species through nitrophenolates is a desirable goal (El-Fouly *et al.*, 2014). This was corroborated by our study, which indicated that using sodium nitrophenolate (CSN) at the rate of 5 or 10 mg/L resulted in higher growth and chemical composition of *C. myxa* seedlings compared to seedlings exposed to salinity without CSN alone. These results may be due to an increase in the concentration of endogenous auxins, which stimulate plant growth and development by promoting cell division, expansion, and elongation. The positive effects of sodium nitrophenolate were also suggested by Yao *et al.* (2023), who claimed that this compound has a promising application in high-salt wastewater treatment. El-Fouly *et al.* (2014) pointed out that spraying *Ficus deltoidea* foliage with low and medium levels of sodium nitrophenolate improved the growth and chemical content of chlorophyll a and b, carotenoids, nitrogen, phosphorus, and potassium. These findings offer new insights into enhancing salt tolerance in cotton. Our findings are in agreement with those reported by Djanaguiraman *et al.* (2005). Furthermore, Zou *et al.* (2020) reported that low concentrations of the compound sodium nitrophenol (CSN) led to improved growth and flowering in oil tea by increasing IAA, ZR, and GA_3 content, while decreasing the content of abscisic acid. The results of Attia (2022) indicated that treatment with 200 ppm nitrophenolate sodium improves the productivity of LeConte pear trees. These results are similar to the findings of Svobodová and Misa (2004), Kumar *et al.* (2017), Suseendran *et al.* (2020), Das *et al.* (2022) and Kumar *et al.* (2022).

CONCLUSIONS

C. myxa is a rare tree in Egypt, and given its desired importance, it is an ornamental tree or fruit with medicinal effects. Therefore, this experiment was designed to study the behavior of this tree when it grows under soil salinity and to study the role of adding CSN to alleviate the harmful effects of salt stress on *C. myxa* plants. It became clear that increasing the levels of NaCl from 2000 to 6000 mg/kg decreased the growth characteristics and biochemical constituents of the seedlings. The addition of CSN significantly improved the survival percentage, growth, and biochemical composition, and reduced salt stress, especially at a concentration of 10 mg/L. Based on the data obtained from this study, it is recommended to supply *C. myxa* plants exposed to salinity stress with CSN at either 5 or 10 mg/L, based on the salinity level, to ensure the highest growth characteristics and biochemical compositions and confirm the performance of these trees.

REFERENCES

Abd-Allah, EF, Hashem, A, Alqarawi, A A, Bahkali, A H, Alwhibi, M S. (**2015**). Enhancing growth performance and systemic acquired resistance of medicinal plant *Sesbania Sesban* (L.) Merr Using Arbuscular Mycorrhizal Fungi under Salt Stress. Saudi J. Biol. Sci., **22 (3)**:274–283.

Abdul Hameed, AH. (**2002**) Crops physiology. Dept. of Crops, Faculty of Agriculture, Al Azhar Univ., Egypt.

Afzal, M, Obuekwe, C, Shuaib, N, Barakat, H. (**2004**). Photosynthetic pigment profile of *Cordia myxa* L and its potential in folklore medicinal application. Food Agric Environ, **2**:114–20.

Agyare, C, Spiegler, V, Asase, A, Scholz, M, Hempel, G, Hensel, A. (**2018**). An ethnopharmacological survey of medicinal plants traditionally used for cancer treatment in the Ashanti region, Ghana. J Ethnopharmacol, **212**: 137–52. https:// doi. org/ 10. 1016/j. jep. 2017. 10. 019.

Akter, M, Oue, H. (**2018**). Effect of saline irrigation on accumulation of Na+, K+, Ca2+, and Mg2+ ions in rice plants. Agriculture, **8,164.**

Ali, Sahar S M. (**2023**). Effect of NPK fertilizer levels and growing media on the growth characteristics and chemical compositions of *Chrysophylum oliviforme* tree seedlings under Aswan conditions. Thesis M.Sc. Department of Natural Resources (Plant resources), Institute of African Research and Studies and Nile Basin Countries, Aswan University, Egypt.

Al-Snafi, AE. (**2016**). The Pharmacological and therapeutic importance of *Cordia myxa*- A review. IOSR J Pharm **6 (6):** 47–57.

Analytical Software (**2008**). Statistix Version 9, Analytical Software, Tallahassee, Florida, USA.

AOAC (**1995**). Official Methods of Analysis of the Association of Analytical Chemists,14th. Ed., Benjamin Franklin, Washington DC.

Arif, Y, Singh, P, Siddiqui, H, Bajguz, A, Hayat, S. (**2020**). Salinity induced physiological and biochemical changes in plants: an omic approach towards salt stress tolerance. plant physiol. Biochem., **156**: 64–77.

Ashraf, M Harris, PJC. (**2004**). Potential biochemical indicators of salinity tolerance in plants. Plant Sci., **166**: 3–16.

Ashvathama, VH, Gollagi, SG, Soregaon, CD, Mangi, VL. (**2020**). Effect of sodium para nitrophenolate on flowering and yield of cucumber (*Cucumis sativus* L.). International Journal of Chemical Studies, **8 (4)**: 2557-2559.

Askar, M A A. (**1994**). Chemical and morphological study of seeds and fruits of Lasura (*Cordia myxa* L.) grown in Iraq. M. Sc, Thesis, College of Agriculture, Basra Univ., Iraq, pp. 80.

Atteya, AKG, El-Serafy, RS, El-Zabalawy, KM, Elhakem, A, Genaidy, EAE. (**2022**). Exogenously supplemented proline and phenylalanine improve growth, productivity, and oil composition of salted moringa by up-regulating osmoprotectants and stimulating antioxidant machinery. Plants, **11**: 1553. https://doi.org/10.3390/ plants11121553

Attia, SM. (**2022**). Enhancing fruit set, yield and quality of LeConte pear trees by preharvest foliar spray of some plant growth regulators SVU-International Journal of Agricultural Sciences, **4 (4)**:1-7.

Bayomy, Hala M, Alamri, Eman S, Alharbi, Basmah M, Foudah, Shaden H Genaidy, EA Atteya, Amira K. (**2023**). Response of *Moringa oleifera* trees to salinity stress conditions in Tabukregion, Kingdom of Saudi Arabia. Saudi Journal of Biological Sciences, **30**:103810.

Borowski, E, Blamowski, ZK. (**2009**). The effects of triacontanol'TRIA' and Asahi SL on the development and metabolic activity of sweet basil (*Ocimum basilicum* L.) plants treated with chilling. Folia Hort., **21**: 39-48. doi: 10.2478/fhort-2013-0124

Chaharlang, M, Samavati, V. (**2015**). Steady shear flow properties of *Cordia myxa* leaf gum as a function of concentration and temperature. Int J Biol Macromol, **79**: 56–62. https:// doi. org/ 10. 1016/j. ijbio mac. 04. 049.

Das, SK, Samui, S, Nandy, P. (**2022**). Influence of sodium para nitrophenolate 0.3% SL on growth and yield of rice in new Alluvial Zone (NAZ) of West Bengal Journal of Crop and Weed, **18(2)**: 64-70.

Debez, A, Chaibi, W, and Bouzid, S. (**2001**). Effect of NaCl and growth regulators on germination of *Atriplex halimus* L. Cah. Agric., **10**:135–138.

Dhindsa, RS, PlumbDhindras, PL Thrope, TA. (**1981**). Leaf senescence: Correlated with increased levels of membrane permeability & lipid peroxidation and decreased levels of superoxide dismutase & catalase. J. Exp. Bot., **126**: 93-101.

Djanaguiraman, M, Sheeba, JA, Devi, DD, Bangarusamy, U. (**2005**). Response of cotton to Atonik and TIBA for growth, enzymes and yield. J. Biol. Sci., **5(2)**:158-162.

Doubios, AA Gilles, Hamelton, JK, Robers, PA, Smith, PA. (**1956**). A colorimetric method for determination of sugar and related substances. Anal. Chem., **28**:350-356.

El-Fouly, Amal S, Abdel-Moneim, Azza M, Ibrahim, Hanan E. (**2014**). Response of the slow-growing mistletoe fig (*Ficus deltoidea* jack.) plant to fertilization treatments and growth activator 1. the liquid commercial product of nitrophenolates. Scientific J. Flowers & Ornamental Plants, **1(1)**:17-24.

Foronda, DA. (**2022**). Reclamation of a saline-sodic soil with organic amendments and leaching. Environ. Sci. Proc., **16**: 56.

Hasanuzzaman, M, Alam, M, Rahman, A, Nahar, K, Fujita, M. (**2014**). Exogenous proline and glycine betaine mediated upregulation of antioxidant defense and glyoxalase systems provides better protection against salt-induced oxidative stress in two rice (*Oryza sativa* L.) varieties. Biomed Res. Int.

Heuze, V, Tran, G, Lebas, F. (**2021**). Assyrian plum (*Cordia myxa*). Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. https://www.feedipedia.org/node/163 Last updated on November **22**: 9-13.

Ibrahim, MAH. (**2002**). The effect of salinity of irrigation water on the growth of *Ziziphus spina* – Christi Wilds seedlings. Basra J. Agric. Sci., **15**: 4.

Iqbal, N, Umar, S, Khan, NA. (**2015**). Nitrogen availability regulates proline and ethylene production and alleviates salinity stress in mustard (*Brassica Juncea*). J. Plant Physiol., **178**: 84–91.

Jahan, I, Parvin, S, Miah, MG, Ahmed, JU. (**2018**). Effect of salinity on the physiological and biochemical responses of neem. International Journal of Environmental & Agriculture Research (IJOEAR) **4 (5)**: 47-54.

Jaleel, CA, Lakshmanan, GMA, Gomathinayagam, M, Panneerselvam, R. (**2008**). Triadimefon induced salt stress tolerance in *Withania somnifera* and its relationship to antioxidant defense system, South African J Bot., **74**: 126-132.

Ksiezak, J. (**2008**). Effect of biostimulator Asahi SL on yield of maizegrain, in Monographs Series: Biostimulators in Modern Agriculture: Field Crops, ed Z.T. D, abrowski (Warsaw: Editorial House Wie´s Jutra), 60-65.

Kumar, A, Joshi, R, Vasishth, A, Guleria, V, Kumar, D. (**2022**). UHPLC-IMS-based metabolite fingerprinting of underutilized *Cordia myxa* fruits and leaves: A nutraceutical source. ACS Food Science & Technology, **2 (5)**: 793-807.

Kumar, R, Singh, A, Yadav, RB, Kumar, A, Kumar, S, Shahi, UP, Singh, AP. (**2017**). Growth, development and yield response of rice (*Oryza sativa* L.) as influenced by efficient nitrogen management under subtropical climatic condition. J. Pharmacog. Phytochem, **1**: 791-797.

Matysik, J, Alia, A, Bhalu B, Mohanty, P. (**2002**). Molecular mechanisms of quenching of reactive oxygen species by proline under stress in plants. Curr. Sci., **821**: 525-532.

Meng, Y,Yin, Q,Yan, Z, Wang, Y, Niu, J, Zhang, J, Fan, K. (**2020**). Exogenous silicon enhanced salt resistance by maintaining K+/Na+ homeostasis and antioxidant performance in alfalfa leaves. Front. Plant Sci., **11**: 1183.

Molinari, HBC, Marur, CJ Daros, E, De Campos, MKF, De Carvalho, JFRP, Filho, JCB, Vieira, LGE. (**2007**). Evaluation of the stress-inducible production of proline in transgenic sugarcane (*Saccharum spp*.): Osmotic adjustment, chlorophyll fluorescence and oxidative stress. Physiol. Plant, **130**: 218-229.

Munns, R. (**2005**). Genes and salt tolerance: bringing them together-New Phytol., **67**: 645-663.

Najib, A, Ahmad, AR, Handayani, V. ELISA (**2019**). Test on *Cordia myxa* L. leaf extract for alpha-glucosidase Inhibitor. Pharmacogn J., **11(2)**: 358–61.

Nouman, W, Siddiqui, MT Basra, S MA, Khan RA, Gull, T, Olson ME, Munir. H. (**2012**). Response of *Moringa oleifera* to saline conditions, Int. J. Agric. Biol., **14**:757-762.

Pardo, JM. (**2010**). Biotechnology of water and salinity stress tolerance. Curr. Opin. Biotechnol., **21**: 185-196.

Patel, NT, Pandey, AN. (**2009**). Effect of soil salinity on growth, water status and nutrient. accumulation in seedlings of *Suaeda nudiflora* (Chenopodiaceae). Anales de Biología., **31**: 61-70.

Przybysz, A, Gawronska, H, Gajc-Wolska, J. (**2014**). Biological mode of action of a nitrophenolates-based biostimulant: case study. Original Research article published: doi: 10.3389/fpls.2014.00713.

Rao, PK, Hasan, SS, Bhellum, BL, Manhas, RK. (**2015**). Ethnomedicinal plants of Kathua district, J&K, India. J Ethnopharmacol, **171**: 12–27. https:// doi. org/ 10. 1016/j. jep. 2015. 05. 028.

Roy, SJ, Negrão, S, Tester, M. (**2014**). Salt resistant crop plants. Curr. Opin. Biotechnol., **26**: 115–124.

Saric, M, Kastrori, R, Curic, R, Cupina, T, Geric, I. (**1976**). Chlorophyll Determination. Univ. U Noven Sadu Parktikum is Fiziologize Anjiga, 215 pp.

Snedecor, CW Cochran, WG. (**1980**). Statistical Methods.6th ed. Iowa State Univ., Press, Iowa USA.

Soliman, AS, El-feky, SA, Darwish, E. (**2015**). Alleviation of salt stress on *Moringa peregrina* using foliar application of nanofertilizers. J. Hortic. For., **7:(2),** 36-47.

Sreenivasulu, N, Grimm, B, Wobus, U, Weschke, W. (**2000**). Differential response of antioxidant compounds to salinity stress in salttolerant and salt-sensitive seedlings of foxtail millet (*Setaria italica*), Physiol. Plant, **109**, pp. 435-442.

Stanković, MS. (**2011**). Total phenolic content, flavonoid concentration and antioxidant activity of *Marrubium peregrinum* L. extracts. Kragujevac, Republic of Serbia, **33**: 63-72.

Suleiman, MK, Bhatt, A, Madouh, TA, Islam, MA, Jacob, S, Thomas, RR, Sivadasan, MT. (**2023**). Effects of salt stress on growth, proline and mineral content in native desert species. Sustainability, **15**, 6232.

Sun, S, Zhou, X, Cui, X, Liu, C, Fan, Y, McBride, MB, Li, Y, Li, Z, Zhuang, P. (**2020**). Exogenous plant growth regulators improved phytoextraction efficiency by *Amaranths hypochondriacus* L. in cadmium contaminated soil. Plant Growth Regul., **90**: 29-40. https://doi.org/10.1007/s10725-019-00548-5.

Suseendran, K, Kalaiyarasan, C, Jawahar, S, Stalin, P, Murugan, G, Vinodkumar, SR, Arivukkarasu, K. (**2020**). Response of rice to foliar application of plant growth regulator on growth and yield of rice. Plant Archives, **20(1)**:1510.

Svobodová, I, Misa, P. (**2004**). Effect of drought stress on the formation of yield elements in spring barley and the potential of stress expression reduction by foliar application of fertilizers and growth stimulator. Pl. Soil Environ, **50(10)**: 439-446.

Szparaga, A, Kocira, S, Kocira, A, Czerwinska, E, Swieca, M, Lorencowicz, E, Kornas, R, Koszel, M, Oniszczuk, T. (**2018**). Modification of growth, yield, and the nutraceutical and antioxidative potential of soybean through the use of synthetic biostimulants. Front. Plant Sci., 9 https://doi.org/10.3389/fpls.2018.01401.

Taiz, L; Zeiger, E. (**1998**). Plant physiology. 2nd ed., Univ. of California, USA.

Troll, W, Lindsey, J. (**1955**). A photometric method for determination of proline. J. Biol. Chem., **216**: 655-661.

Wrochna, M, Łata, B, Borkowska, B, Gawro, NH. (**2008**). The effect Asahi SL of bio stimulators on ornament amaranth (*Amaranthus* sp.) plants exposed to salinity in growing medium,"in Monographs Series: Biostimulators in Modern Agriculture: Ornament and Special Plants, ed A. Łukaszewska (Warsaw:Editorial HouseWie´s Jutra), 15–32.

Xiao-Yue, C. (**2008**). Field test on application of Na-ortho-nitrophenolate + Na-para-nitrophenolate + Na-5-nitronuacolate on *Camellia oleifera*. Journal of Fujian Forestry Science and Technology, **79 (4)**: 406-410.

Yao, N, Zhang, L, Tian, F, Wang, K, Li, Q, Lu, J, Lyu, M, Wang, S. (**2023**). Compound sodium nitrophenolate promotes denitrification by nitrifying bacteria by upregulating nitrate reductase. Appl. Sci., **13**: 6134. https://doi.org/10.3390/ app13106134

Yeo, AR, Yeo, ME, Flowers, SA, Flowers, TJ. (**1990**). Screening of rice (*Oryza sativa* L.) genotypes for physiological characters contributing to salinity resistance, and their relationship to overall performance. Theor. Appl. Genet., **79**: 377–384.

Zhang, J, Zhang, S, Chen, L, Wei, C. (**2017**). Alleviation of seeding chlorosis by plant growth regulators in drip-irrigated rice. Acta Agr Scand, B-S P., **67**: 184–190. https:// doi.org/10.1080/09064710.2016.1240828.

Zou, YL, Zhong, QP, Ge, XN. (**2020**). Effect of sodium compound nitinol on endogenous hormones and bud differentiation rate of oil tea flower bud. Econ. For. Res., **2**: 69-76.

الملخص العربي

التغيرات في المركبات الكيميائية في نبات المخيط المعرض للإجهاد الملحي بسبب التأثير التحفيزي لنيتروفينولات الصوديوم

أشرف مصطفى شحاته[١]، منيع مبارك[٢]

[١] قسم الزهور ونباتات الزينة وتنسيق الحدائق – كلية الزراعة – جامعة الأسكندرية – الأسكندرية – مصر

[٢] قسم البساتين – كلية الزراعة – جامعة دمنهور – البحيرة – مصر

تم دراسة آثار ملوحة التربة على النمو والتركيب الكيميائى لشتلات المخيط المرشوشة بمركب نيتروفينولات الصوديوم (CSN). في هذه الدراسة، خُلط ملح كلوريد الصوديوم مع تربة الزراعة بنسبة ٠، ٢٠٠٠، ٤٠٠٠، و٦٠٠٠ ملجم/كجم من التربة. تم رش الشتلات بمركب نيتروفينولات الصوديوم بنسب ٠، ٥، و١٠ ملجم/لتر. تزامن نمو الشتلات المعرضة للملوحة، وخاصةً بتركيزات عالية، مع انخفاض في مقاييس النمو المختلفة من حيث نسبة البقاء، وعدد الأوراق لكل نبات، ومساحة الورقة، ووزن الورقة الطازجة والجافة، والمكونات الكيميائية. كان لمركب نيتروفينولات الصوديوم تأثير كبير في تحسين جوانب النمو ومكوناته الكيميائية المختلفة لشتلات المخيط. تم تسجيل أقصى قياسات للنمو والمكونات الكيميائية، مثل الكلوروفيل أ و ب والكاروتينات، ونسب النيتروجين والفوسفور والبوتاسيوم، والفينولات الكلية، عند زراعة النباتات في تربة مُعرّضة للملوحة بمعدل ٢٠٠٠ ملجم كلوريد الصوديوم/كجم تربة، ورشّت بمعدل ١٠ ملجم/لتر من مُركّب نيتروفينولات الصوديوم (CSN). وفي المقابل، تزامن ارتفاع محتوى البرولين الحر مع تركيز ٦٠٠٠ و٤٠٠٠ ملجم كلوريد الصوديوم/كجم تربة. ويُمكن القول إن أشجار المخيط قادرة على النمو في ظروف معتدلة الملوحة، ولتحسين نموها فى التربة الملحية، يمكن رشها بـــمركب نيتروفينولات الصوديوم (CSN) بمعدل ٥ أو ١٠ ملجم/لتر. النتائج التى تم التوصل إليها فى تلك الدراسة تعمل على توفير ظروف نمو مثلى لأشجار المخيط النامية تحت ظروف إجهاد ملحى.