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Research Article

The Individual and Combined Effects of *Cystoseira compressa* Extracts and Inoculation of Arbuscular Mycorrhizal on Growth and Yield of Wheat under Salinity Conditions

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Abstract: Combined treatments are a successful way to overcome salinity damage in an environmentally safe and cost-effective method. So this experiment aimed to study the individual and combined effects of a seaweed extract of *Cystoseira compressa* (SWE) and Arbuscular Mycorrhizal Fungi (VA-M) on the growth and yield of *Triticum aestivum L.* cultivar (ACSAD 1398), under salinity conditions. In general, the study showed a significant decrease in morphological and biochemical parameters of the wheat under salinity levels. On the contrary, the results showed that all treatments significantly increased shoot and root length, number of leaves /plant, leaf area, seedling length, fresh and dry weight seedlings, spike length, fresh and dry weight spike, chlorophyll (a b), carotenoids, total pigments, Ca, Mg, P, K, Cu, N, crude protein, and total soluble sugars. As caused a decrease in proline content. The findings revealed that the (SWE+VA-M) combined treatment was superior to the foliar individual application of (SWE), and (VA-M) individual inoculation.

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1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important staple foods (cereal) in terms of global production and use, providing about 55% of starch and more than 20% of food calories(Gupta et al., 2021). Salinity is one of the most dangerous environmental phenomena threatening the growth and productivity of crops (Salih and Abdulrraziq, 2023), where wheat is exposed to losses of about 60% of the total crop production as a result of salt stress (Chaurasia and Kumar, 2023). This abiotic major stress condition causes yield reductions, due to changes in morpho-physiological and biochemical activity (Ramzan et al., 2023), in a negative way, such as increasing oxidative stress, osmotic stress, ionic toxicity, ion homeostasis conditions, and reduction of nutrient mobilization (Riseh et al., 2021). Also, hormonal imbalance, disruption of cellular homeostasis, deterioration of photosynthesis, protein synthesis, amino acid biosynthesis, lipid metabolism, nucleic acid damage, and reactive oxygen species ROS (Sharaya et al., 2023).

In recent years, the use of biological applications (Mycorrhizal symbiosis) and seaweed extracts has received greater attention as a method to alleviate abiotic and biotic stresses as an environmentally friendly tool (Rana et al., 2023; Wahab et al., 2023).

Previous studies have demonstrated the beneficial effect of Arbuscular mycorrhizal fungi such as improved uptake of phosphorus and other essential minerals (such as zinc, copper, and nitrogen) from the soil, by increasing the root surface area, nitrogen fixation, promoting soil fertility, and stress modulation (Ortas, 2023). Huang et al. (2023) found that arbuscular mycorrhizal fungus (AMF) increased in root and shoot length, fresh and dry weight, chlorophyll a, b, total, and carotenoids in the wheat under salt stress conditions. Also, inoculation with Funneliformis mosseae showed salt tolerance of wheat cultivars by improving osmoregulation, antioxidant enzyme activity, and reducing lipid peroxidation (Fayaz and Zahedi, 2021). On the other hand, natural seaweed extracts, are a substitute for synthetic fertilizers, that promote root growth, and improve increasing crop yields (Prajapati et al., 2023). They contain micro and macronutrients, amino acids, and organic matter, as well as vitamins, polysaccharides, auxins, gibberellins, and cytokinins, used either by adding them directly to the soil or spraying them on the vegetative parts of plants (Al-Ealayawi and Al-Dulaimy, 2023). Laboratory experiments showed that *Ulva linza* extract application in low concentrations (5, 10 and15%) improves physiological features (germination rate, total plant length, total fresh and dry mass, chlorophyll, carotenoids, sugars, proteins, lipids, proline, and alkaloids) in wheat seedlings, and mitotic and abnormality indices of wheat root cells (Hamouda et al., 2022).

There are many reports of applications of mycorrhizal fungi and seaweed extracts on the growth and productivity of wheat, but there are no studies on the application of arbuscular mycorrhiza (VA-M) inoculation within the combination of seaweed extract (SWE), under salinity conditions. The purpose of this research was to determine the individual and combined effects of a seaweed extract of *Cystoseira compressa* (SWE) and Arbuscular Mycorrhizal Fungi (VA-M) on the growth and yield response of the wheat cultivar (Acsad 1398), under salinity conditions**.**

2. Material and Methods

2.1. Seed selection

The genotype of bread wheat (ACSAD 1398), is one of the genotypes that have not been tested in Lybia. was obtained from The Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), Cleaned of impurities, and tested for viability by soaking in distilled water to remove empty seeds floating on the surface, were soaked in 1% sodium hypochlorite solution for 3 minutes, and washed with distilled water (Dafaallah et al., 2019).

2.2. Arbuscular Mycorrhizal Fungi (VA-M) source

Glomus mosseae strain kindly supplied by the Department of Microbiology, Faculty of Agriculture, El-Minia University, Egypt. The endomycorrhizal species (*Glomus mosseae* Nicol and Gerd.), Gerdman and Tappe, a representative species from a temperate agrosystem was obtained from a stock pot culture of *Allium cepa L*. as a host plant to produce a rhizosphere soil containing spores mycelia and mycorrhizal root. Each pot holding 5kg of soil received 20g of autoclaved soil containing mycorrhiza hyphae.

2.3. Seaweed extract collected and preparation

Fresh brown seaweed *Cystoseira compressa* were collected from the coastline of Al-Hamamah/ Al-Jabal Al-Akhdar/ Libya, and classified in the Department of Biology/ Faculty of Education/ Omar Al-Mukhtar University, They were washed and rinsed with distilled water in order to eliminate sand and plankton, drained, cut into small pieces and stored at -20 $^{\circ}$C until further use. Fresh seaweed (1 kg) was crushed and suspended in (1L) boiling distilled water for 1 h and filtered through double-layered muslin tissue (Sivasankari et al., 2006). The obtained filtrate was chosen as a 100% concentrated seaweed extract. A 5% concentration of *Cystoseira compressa* solution was prepared by adding distilled water. Later, the application of extract was through foliar spraying twice a week during the morning for two weeks (14 days) after sowing.

2.4. Preparation of salt solutions

The brine was prepared using sodium chloride salt (0, 100, and 200 mM NaCl), regional agricultural conditions as follows:

1 mMol = molecular weight of the solute / 1000 * concentration
100 mMol= molecular weight of the solute /1000 *100
100 mMol=58.5 / 1000* 100
100 mMol=5.85g/L

Take weight 5.85 g of NaCl salt, then dissolve it in a standard flask of capacity 1000 ml and complete the volume with distilled water to the mark and the same steps were followed for the concentration of 200 mM, according to(Salih and Abdulrraziq, 2023).

2.5. The pot experiments

The pot experiment was carried out in greenhouse conditions, the soil samples were sterilized at (90 ºC for 48 h). Five kilograms of sterilized clay-sandy soil were put into pots, a ratio of 2:1 (w/w). Ten seeds of wheat (ACSAD1398) were sown in each pot. The seedlings were removed and adjusted to five plants/pot after the plant reached a height of 12 cm each/pot. In greenhouse conditions, the experiment was conducted using 36 pots, 75 days after sowing (spike maturity stage), and with inon-applied chemical fertilizers. The experiment was set up in a completely random arrangement with twelve treatments and three repetitions as follows:
Treatments:

NaCl	SWE	VA-M	SWE+VA-M
0, 100, 200 mM NaCl	0, 100, 200 mM NaCl	0, 100, 200 mM NaCl	0, 100, 200 mM NaCl

2.6. Morphological Parameters

In the study, the roots were washed very carefully and care was taken not to break the capillary roots. seedling length, shoot and root length, and spike length (cm) parameters were measured by using a graduated ruler. The leaf area (cm^2) of each plant was measured and calculated according to the equation given below;

$$\text{Leaf Area / Plant (cm2)} = K\ (y*m) \quad (1)$$

Where: K=0.7, y=leaf length, m=leaf width, according to (Mokhtarpour *et al*., 2010).

- Fresh and dry weight of seedlings and spikes (g): fresh weights were determined (seedlings and spikes), and dried in an oven at 70 C^0 for 72h.

2.7. Biochemical parameters

2.7.1. Photosynthetic pigments

The following equations were used to calculate photosynthetic pigments (carotenoids, chlorophyll a, and b) spectrophotometrically (based on the Metzner et al., 1965):

$$Chlorophyll\ a = 10.3 \times 663 - 0.918 \times 644 = mg/ml \quad (2)$$

$$Chlorophyll\ b = 19.7 \times 644 - 3.87 \times 663 = mg/ml \quad (3)$$

$$Carotenoids = 4.2 \times 452.5 - 0.0264 \times chl.a + 0.4260 \times chl.b \quad (4)$$

2.7.2. Estimation of minerals

Oven-dry samples of seedlings were finely ground and assayed for mineral ion content by the wet digestion method. Minerals (Ca, Mg, P, K, and Cu) were determined using an atomic absorption spectrophotometer and flame photometer expressed based on dry weight (Humphries, 1956).

2.7.3. Estimation of total nitrogen(N)

0.2 g powder plant (stem of leaves) was digested by using 2 ml concentrated sulfuric acid and 1 ml of H_2O_2 (50%), the solution was then completed with H_2O or distilled water to a fixed volume. Absorption was measured by spectrophotometer at 420 nm according to Nessler's method as described by Hesse (1971).

2.7.4. Estimation of crude protein

The percentage of crude protein in spike tissues (including grain) was found by multiplying the total nitrogen content (%N) by factor 6.25 (A.O.A.C., 1975).

2.7.5. Estimation of Total soluble sugars (TSS)

The total soluble sugars were measured in an ethanolic extract of wheat plants (stem, leaves, and spike), using phenol-sulfuric with the using Pure glucose as standard (Dubois et al., 1966).

2.7.6. Estimation of proline

Proline in all leaves *w*as extracted using the ninhydrin reagent method and assayed according to (Bates et al., 1973).

2.8.Statistical Analysis

The complete random design (CRD) was used in the creation of the study experience. ANOVA variance analysis tables and the Minitab 17 application were used for statistical analysis. Tukey's test was used to compare the averages at $P < 0.05$.

3. Results

3.1.The effect of salinity levels on morphological and biochemical parameters

Current work shows in Tables (1, and 2) an effect of salinity levels (0, 100, and 200 mM) on some morphological parameters after 75 days of sowing. The results showed NaCl application decreased Morphological parameters by increasing salt concentration compared to the control. The concentration of 100mM caused a decrease in (shoot and root length, number of leaves /plant, leaf area, seedling length, fresh and dry weight seedlings, spike length, fresh and dry weight spike), from (100%) of control to (81.4, 95.2, 93.0, 83.4, 85.2, 66.5, 69.0, 83.3, 86.5 and 63.6%) respectively. The adverse effect of saline stress was obtained, (in the concentration of 200 mM), which recorded the highest rates of decline in all evaluated parameters in general, with (72.0, 82.3, 69.7, 69.1, 74.8, 50.8, 52.3, 70.2, 65.8 and 45.4%), for all parameters respectively. The results also showed that in Table 3 the results of salinity levels' effect on photosynthetic pigments, where the concentration of 100 mM caused a decrease of chlorophyll (a, b), carotenoids, and total pigments from (100%) of control to (70.8 and 91.1%) of chlorophyll (a, b), (79.5%) of carotenoids and total pigments by up to (76.5%). As salinity rose, so did the rates at which photosynthetic pigments decreased. Showed a concentration of 200 mM a significant decrease for chlorophyll (a, b), carotenoids, and total pigments with (60.9, 83.0, 61.,3 and 66.4 %) respectively. The data recorded in Table 4 showed the effect of salinity levels on the content of minerals in the seedling of the wheat, recorded a concentration of 100 mM decrease from (100%) of control to (91.3, 86.9, 92.5, 76.9, and 88.2%), while recorded a concentration of 200 mM largest rates the decrease of (84.7, 95.6, 85.1, 48.2, and 52.9%), for (Ca, Mg, P, K, and Cu) respectively. Figure 1 presents the effect of salinity levels on the total nitrogen (N) content, and crude protein (%). According to the observed values the a decrease in the contents of the N, contents from (1.3%) of the control to (0.4%), and a decrease in crude protein in spike tissues, from (1.8%) of the control to (2.5%), for concentration 200 mM, while concentration 100 mM had no significant effect on the content of percentage total nitrogen and crude protein. Data indicated in Figure 2 to the effect of salinity levels on the total soluble

solids (TSS), and proline of the wheat. The contents of total soluble solids in the seedling fresh weight decreased, according to the results, from (22.5 mg/g) in the control to (19.8, and 13.2 mg/g), at concentrations of 100 and 200 mM, respectively. Proline content in leaves also increased, from (34.0mg/g) of control to (56.4, and 89.7 mg/g), for concentrations (100 and 200 mM) respectively.

3.2. Effect of foliar application of *Cystoseira compressa* extract on some morphological and biochemical parameters under salinity levels

The data presented in Tables 1 and 2 show the individual effect of the foliar application of *C. compressa* extract on wheat growth. Results indicated a positive effect of the treatment (SWE + 100 mM NaCl) increase in (shoot and root length, number of leaves/plant, seedling length, fresh and dry weight seedlings, spike length, fresh and dry weight spike) by (4.5, 7.7, 13.9, 3.0, 5.3, 5.8, 7.1, 11.9, 4.9 and 4.5%) respectively. Furthermore, treatment (SWE + 200 mM NaCl), showed an increase of (3.9, 4.7, 23.3, 2.5, 4.2, 1.3, 7.2, 4.7, 15.9, and 9.1%), respectively for the same previous parameters, compared to the untreated plant. Findings in Table 3 demonstrate that in comparison to the untreated plant, the contents of the photosynthetic pigments have slightly increased. Pigments, which increased by (2.2, 3.0, 13.6, and 3.3%) of treatment (SWE + 100 mM NaCl), (5.4,1.5, 11.4, and 4.9%) of treatment (SWE + 200 mM NaCl), of chlorophyll contents (a, b), carotenoids, and total pigments respectively, compared to the untreated plant. Table 4 showed an increase in the content of minerals compared to the untreated plant, by (2.2, 13.0, 7.4, 27.3, and 23.5%) of treatment (SWE + 100 mM NaCl). Also by (6.5, 17.4, 18.6, 15.4, and 14.7%) of treatment (SWE + 200 mM NaCl) of (Ca, Mg, P, K, and Cu) respectively. The findings displayed in Figure 1 demonstrated that there were no discernible variations in the total nitrogen (N) level, and crude protein between concentrations 100 mM and treatment (SWE + 100mM NaCl), while the increase occurred in treatment (SWE + 200 mM NaCl), by (0.9 and 5.6 %) of total nitrogen (N) content, and crude protein respectively, compared to the untreated plant. The results showed in Figure 2, an increase in the contents of the total soluble solids in the seedling fresh weight by (12.4 and 11.1%) of treatment (SWE + 100 and 200 mM NaCl), respectively, compared to the untreated plant. Also, a decrease of proline by (31.7 and 11.5%) of treatment (SWE + 100 and 200 mM NaCl), respectively, compared to the untreated plant.

3.3. Effect of Arbuscular Mycorrhizal Fungi (VA-M) inoculation on some morphological and biochemical parameters under salinity levels

Tables 1 and 2 presented an effect of the individual Arbuscular Mycorrhizal Fungi (VA-M) inoculation on some morphological parameters of the wheat under salt stress conditions. Inoculation with (VA-M) showed there were highly significant differences, compared with foliar application of *Cystoseira compressa* extract of all parameters. The increase was obvious in (shoot and root length, number of leaves/plant, leaf area, seedling length, fresh and dry weight seedlings, spike length, fresh and dry weight spike) by (11.7, 18.9, 23.2, 8.0, 13.6, 19.0, 19.0, 66.7, 23.2, and 36.4%) respectively, of treatment (VA-M + 100mM NaCl), compared to the untreated plant. In addition, treatment (SWE + 200 mM NaCl), showed an increase of (12.1, 23.5, 39.6, 7.4, 15.2, 16.1, 26.2, 25.0, 37.8, and 45.5%) respectively for the same previous parameters, compared to the untreated plant. Tables (3) reveal that the application of Arbuscular Mycorrhizal Fungi (VA-M) enhanced a significant increase in the pigments in wheat leaves under NaCl stress, which were found to increase by (15.9, 8.1, 13.6, and 34.1%) of treatment (VA-M + 100 mM NaCl), and (15.3,5.9, 13.7, and18.1%) of treatment (VA-M + 200 mM NaCl), of chlorophyll contents (a, b), carotenoids, and total pigments respectively, compared to the untreated plant. The results in Table 4 showed a significant increase in the content of minerals by (38.7, 34.8, 37.1, 78.3, and 38.2%) of treatment (VA-M+100 mM NaCl), and (50.0, 56.5, 29.7, 46.9, and 35.3%) of treatment (VA-M+200 mM NaCl) of (Ca, Mg, P, K, and Cu) respectively. Figure 1 shows that there were no discernible variations in the total nitrogen (N) content between the concentration of 100 mM NaCl and treatment (VA-M+100 mM NaCl), while the increase occurred in treatment (VA-M+200 mM NaCl), by (0.8 %) of Total nitrogen (N) content. The increase appears in crude protein by (0.6 and 5.0%), of treatment (VA-M+100 and 200 mM NaCl) respectively, compared to the untreated plant. Also, Figure 2 a significant increase in the contents of the total soluble solids by (27.1 and 30.7%) of treatment (VA-M+100 and 200 mM NaCl) respectively, compared to the untreated plant. Data also

indicated a decrease of proline by (47.9 and 53.0%)of treatment (VA-M+100 and 200 mM NaCl) respectively, compared to the untreated plant.

3.4. Effect of combined treatment *Cystoseira compressa* extract +Arbuscular Mycorrhizal Fungi (SWE+VA-M) on some morphological parameters and biochemical under salinity levels

Data regarding the treatment (SWE+VA-M), in Tables 1, 2, 3, and 4 indicated that there were highly significant differences, compared with the individual foliar application of SWE, and individual (VA-M) inoculation. Showed the highest registered increments of the shoot and root length by (15.2, and 22.4%). The number of leaves/plant (30.2%). Leaf area (20.6%). Seedling length, fresh and dry weight seedlings (17.2, 29.3, and 23.6%). Spike length, fresh and dry weight spike (59.5, 36.6 and 45.4%). respectively, of treatment (SWE+VA-M +100 mM NaCl), compared to the untreated plant. On the other hand, the treatment showed (SWE+VA-M +200 mM NaCl), increments in shoot and root length by (15.2 and 24.7%). The number of leaves/plant (34.9%). Leaf area (22.1%). Seedling length, fresh and dry weight seedlings (17.8, 27.2, and 23.8%). Spike length, fresh and dry weight spike (40.5, 36.6, and 50.0%) respectively, compared to the untreated plant. Also caused an increase in the contents of the photosynthetic pigments (chlorophyll a, b carotenoids, and total pigments), which reached (14.1, 8.1, 34.1, and 15.3%) of treatment (SWE+VA-M +100 mM NaCl). Likewise (9.7, 8.9, 11.4and 9.6%) of treatment (SWE +VA-M +200 mM NaCl), respectively, compared to the untreated plant. Moreover, recorded increase in the content of minerals of (Ca, Mg, P, K, and Cu) by (50.0, 65.2, 40.8, 73.4, and 23.5%) of treatment (SWE+VA-M +100 mM NaCl). Likewise (52.2, 39.1, 26.0, 38.5, and 41.2%) of treatment (SWE+VA-M +200 mM NaCl) of (Ca, Mg, P, K, and Cu) respectively. Figure 1 reveals significant differences in the increase in the Total nitrogen (N) by (0.2 and 0.9%) of treatment (SWE+VA-M+100 and 200 mM NaCl) respectively, compared to the untreated plant. while crude protein recorded an increase of (1.2 and 5.6%), in treatment (SWE+ VA-M+100 and 200 mM NaCl), respectively, compared to the untreated plant. Also, Figure 2 a significant increase in the contents of the total soluble solids TSS by (28.4 and 32.5%) of treatment (SWE+VA-M+ 100 and 200 mM NaCl) respectively, compared to the untreated plant. The decrease of proline by (50.0 and 18.3%)of treatment (SWE+VA-M+ 100 and 200 mM NaCl) respectively, compared to the untreated plant.

Table 1. Effect of different treatments on shoot length, root length, leaves/plant, leaf area, and seedling length of the wheat cultivar ACSAD under salinity levels

Treatments		Shoot length		Root length		Leaves/plant		Leaf area		Seedling length	
		cm	%	cm	%	N	%	cm^2	%	cm	%
	0	45.4 d	100	17.0 def	100	4.3 cd	100	52.5 c	100	62.4 e	100
NaCl	100	37.0 g	81.4	16.2 efg	95.2	4.0 de	93.0	43.8 f	83.4	53.2 h	85.2
	200	32.7 h	72.0	14.0 g	82.3	3.0 e	69.7	36.3 h	69.1	46.7 j	74.8
	0	48.2 c	106.1	17.9 cde	105.2	5.3 abc	123.2	56.0 b	106.6	66.1 c	105.9
SWE	100	39.0 f	85.9	17.5 cdef	102.9	4.6 cd	106.9	45.4 e	86.4	56.5 g	90.5
	200	34.5 h	75.9	14.8 fg	87.0	4.0 de	93.0	37.6 h	71.6	49.3 i	79.0
	0	52.8 b	116.2	21.0 ab	123.5	6.4 a	142.2	64.2 a	122.2	73.8 b	118.2
VA-M	100	42.3 e	93.1	19.4 bcd	114.1	5.0 bcd	116.2	48.0 d	91.4	61.7 e	98.8
	200	38.2 fg	84.1	18.0 cde	105.8	4.7 cd	109.3	40.2 g	76.5	56.2 g	90.0
	0	55.0 a	121.1	22.3 a	131.1	6.0 ab	139.5	65.5 a	124.7	77.3 a	123.8
SWE+VA-M	100	43.9 de	96.6	20.0 abc	117.6	5.3 abc	123.2	54.6 b	104.0	63.9 d	102.4
	200	39.6 f	87.2	18.2 cde	107.0	4.5 cd	104.6	47.9 d	91.2	57.8 f	92.6

Different letters in each column denote statistical differences at $P < 0.05$.

Table 2. Effect of different treatments on fresh weight and dry weight seedling, spike length, fresh weight and dry weight spike of the wheat cultivar ACSAD under salinity levels

Treatments		Freshweight Seedling		Dry weight seedling		Spike length		Fresh weight spike		Dry weightspike	
		g	%	g	%	cm	%	g	%	g	%
	0	24.2 cd	100	4.2abcd	100	8.4 cde	100	0.82 f	100	0.22 c	100
NaCl	100	16.1 g	66.5	2.9 cd	69.0	7.0 ef	83.3	0.71 gh	86.5	0.14 de	63.6
	200	12.3 h	50.8	2.2 d	52.3	5.9 f	70.2	0.54 i	65.5	0.10 e	45.4
	0	25.9bc	107.0	4.4 abc	104.7	10.3 bc	122.6	0.93 d	113.4	0.23 bc	104.5
SWE	100	17.5 fg	72.3	3.2 bcd	76.1	8.0 def	95.2	0.75 g	91.4	0.15 d	68.1
	200	13.6 h	56.1	2.5 cd	59.5	6.3 ef	75.0	0.67 h	81.7	0.12 de	54.5
	0	28.2 ab	116.5	5.2 ab	123.8	12.0 ab	142.8	1.11 b	135.3	0.27 ab	122.7
VA-M	100	20.7 e	85.5	3.7 abcd	88.0	12.6 a	150.0	0.90 de	109.7	0.22 c	100
	200	16.2 g	66.9	3.3 bcd	78.5	8.0 def	95.2	0.85 ef	103.6	0.20 c	90.9
	0	29.8 a	123.1	5.5 a	130.9	13.6 a	161.9	1.17 a	142.6	0.28 a	127.2
SWE+VA-M	100	23.2 d	95.8	3.9 abcd	92.6	12.0 ab	142.8	1.01 c	123.1	0.24 abc	109.0
	200	18.9 ef	78.0	3.2 bcd	76.1	9.3 cd	110.7	0.84 f	102.4	0.21 c	95.4

Different letters in each column denote statistical differences at P <0.05.

Table 3. Effect of different treatments on photosynthetic pigments of the wheat cultivar ACSAD under salinity levels

Treatments		Chlorophyll a		Chlorophyll b		Carotenoids		Total pigments	
		mgg^{-1}	%	mg g^{-1}	%	mg g^{-1}	%	mg g^{-1}	%
	0	3.71 b	100	1.36 d	100	0.44 de	100	5.51 b	100
NaCl	100	2.63 d	70.8	1.24 fg	91.1	0.35 f	79.5	4.22 ef	76.5
	200	2.26 f	60.9	1.13 h	83.0	0.27 g	61.3	3.66 g	66.4
	0	3.79 b	102.1	1.42 bc	104.4	0.47 cd	106.8	5.68 b	103.0
SWE	100	2.71 d	73.0	1.28 e	94.1	0.41 e	93.1	4.40 de	79.8
	200	2.46 e	66.3	1.15 h	84.5	0.32 f	72.7	3.93 fg	71.3
	0	4.07 a	109.7	1.45 b	160.6	0.53 b	120.4	6.05 a	109.8
VA-M	100	3.22 c	86.7	1.35 d	99.2	0.50 bc	113.6	5.07 c	92.0
	200	3.12 c	76.2	1.21 g	88.9	0.33 f	75.0	4.66 d	84.5
	0	4.18 a	112.6	1.49 a	109.5	0.58 a	131.8	6.25 a	113.4
SWE+VA-M	100	3.15 c	84.9	1.41 c	103.6	0.50 bc	113.6	5.06 c	91.8
	200	2.62 d	70.6	1.25 ef	91.9	0.32 f	72.7	4.19 ef	76.0

Different letters in each column denote statistical differences at P <0.05.

Table 4. Effect of different treatments on the content of minerals in the Seedling of the wheat cultivar ACSAD under salinity levels

Treatments		Ca		Mg		P		K		Cu	
		mg g^{-1}	%	mg g^{-1}	%	mg g^{-1}	%	mg g^{-1}	%	mg g^{-1}	%
	0	4.6 abc	100	2.3 ab	100	2.7 bc	100	14.3 c	100	3.4ab	100
NaCl	100	4.2 bc	91.3	2.0 b	86.9	2.5 bc	92.5	11.0 d	76.9	3.0 ab	88.2
	200	3.9 c	84.7	2.2 ab	95.6	2.3 bc	85.1	6.9 e	48.2	1.8 b	52.9
	0	5.3 abc	115.2	2.9 ab	126.0	3.2 abc	118.5	18.5 b	129.3	3.9 ab	114.7
SWE	100	4.5 abc	97.8	2.4 ab	104.3	3.0 abc	111.1	13.2 c	92.3	3.5 ab	102.9
	200	4.0 c	86.9	2.5 ab	108.6	2.5 bc	92.5	10.8 d	75.5	2.6 ab	76.4
	0	6.3 ab	136.9	3.5 a	152.1	4.0 a	148.1	21.2 a	146.8	4.5 a	132.3
VA-M	100	6.0 abc	130.4	2.8 ab	121.7	3.5 abc	129.6	22.2 a	155.2	4.3 a	126.4
	200	6.2 ab	134.7	3.5 a	152.1	3.1 abc	114.8	13.6 c	95.1	3.0 ab	88.2
	0	5.9 abc	128.2	3.3 ab	143.4	4.2 a	155.5	23.1 a	161.5	4.8 a	141.1
SWE+VA-M	100	6.5 a	141.3	3.5 a	152.1	3.6 ab	133.3	21.5 a	150.3	3.8 ab	111.7
	200	6.3 ab	136.9	3.1 ab	134.7	3.0 abc	111.1	12.4 cd	86.7	3.2 ab	94.1

Different letters in each column denote statistical differences at P <0.05.

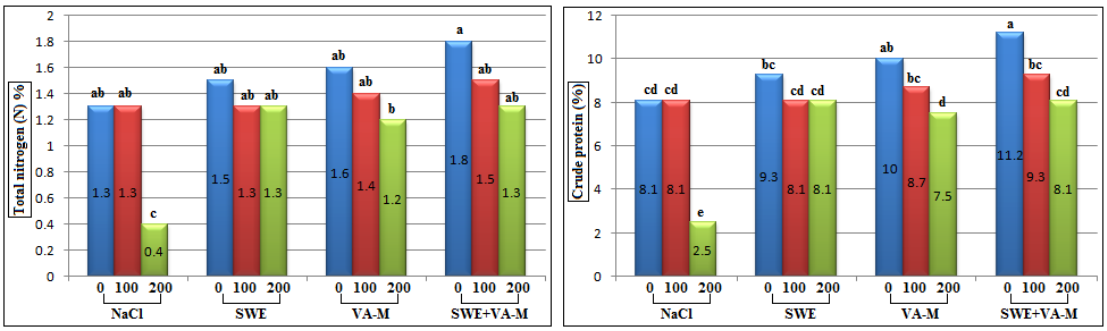

Figure 1. Effect of different treatments on the Total nitrogen (N) content, and crude protein of wheat cultivar ACSAD under salinity levels.

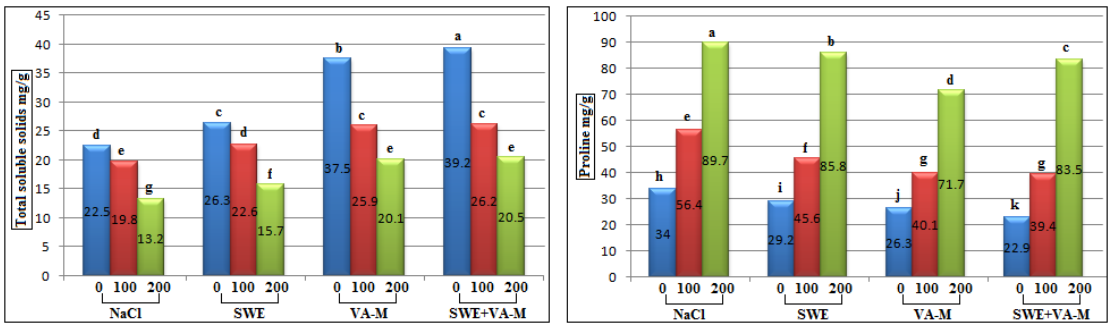

Figure 2. Effect of different treatments on the Total soluble solids (TSS), and Proline of wheat cultivar ACSAD under salinity levels.

4. Discussion

Salinity is the most environmentally important obstacle facing the productivity and quality of wheat crops (Salih et al., 2023), by disrupting the vital physiological, morphological, and biochemical parameters of plants (Ghonaim et al., 2023). This was clear from the results of this study which showed highly significant differences when ($P<0.05$) in reducing all morphological and biochemical parameters of wheat. Similar findings were reported for wheat by(Fairoj et al., 2023; Salih and Abdulrraziq, 2023; Singh, 2023; Paudel et al., 2023). This negative effect may be attributed to Increased Na+ disorganizing ionic balance in cells, disrupting the cell cycle and redistribution of cells in the phases of the cell cycle, inhibiting cell expansion, higher cellular membrane damage, an increased rate of lipid peroxidation, altering the nutrient level, inhibiting apical growth, inhibiting protein synthesis, and enhancing the generation of reactive oxygen species (Amin et al., 2023; Bogoutdinova et al., 2023; Sarkar and Sadhukhan, 2023). Furthermore, salinity stress limits CO_2 fixation in the leaves by stomatal closure, downregulation of the Calvin cycle, as well as increased proteolytic enzymes chlorophyllase responsible for the degradation of chlorophyll, and decreased activity of ribulose bisphosphate (Sadak and Ahmed 2016; Kwon et al., 2019; Sharma et al., 2020). The results of the data analysis showed that with increasing salinity, proline accumulation increases in wheat, this result agreed with many studies that confirmed that proline accumulation is evidence of plants' resistance to salt stress (Hussain et al., 2023; Zulfiqar and Ashraf, 2023). The reason is that proline preserves membrane structure, creating osmotic compatibility, and protecting plant cells from oxidative stress by stopping the synthesis of hydrogen peroxide, superoxide ions, and ROS hydroxyl ions (Chakraborty and Kumari, 2024). The individual foliar application of *Cystoseira compressa* extract alleviated the adverse effects of salinity levels in most morphological and biochemical parameters of wheat, compared to the untreated plant. Our results are consistent with many studies that showed seaweed extract treatments successfully increase the productivity of wheat crops (Latique et al., 2021; Sayyari Zahan et al., 2022). The increase in growth resulting from the effect of Foliar spray seaweed extract under salinity, was due to the content of important micronutrients, vitamins, and plant hormones, such as auxins, cytokinins, and gibberellins in seaweed (Al-Saif et al., 2023). Moreover, Seaweed polysaccharides increase plant resilience to abiotic stress and encourage crop growth (Zou et al., 2019). Data regarding the individual treatment inoculation

of wheat plants with Arbuscular Mycorrhizal Fungi (VA-M) individually indicated that there were highly significant differences when ($P<0.05$) in increasing all morphological and biochemical parameters of salt-stressed wheat compared to the untreated plant and foliar individual application treatment of Cystoseira compressa extract. Our result agrees with previous studies that reported beneficial changes in wheat due to Mycorrhizal inoculation in saline environments (Huang et al., 2023; Puccio et al., 2023). Mycorrhiza fungus provides many benefits through improving nutrient uptake and water, production of plant hormones, improvement of soil structure, and Mycorrhizal penetrates root skin cells and forms structures called vesicles and arbuscules, increasing the level of metabolic content (Bayanati et al., 2023). In addition, caused an increase in the biosynthesis of osmoprotectants, maintaining the integrity of plasma membranes and stability under salt stress by enhanced expression of genes related to signal transduction, vesicle trafficking, RNA processing, trehalose metabolism, and cell wall organization (Chandra et al., 2023; Puccio et al., 2023). On the other hand, mycorrhizae regulate the functions of a few important proteins involved in the metabolism of lipids, amino acids, and glutathione in root tissue (Chang et al., 2023). Also, mycorrhizae increase photosynthesis by increasing Rubisco activity, electron transport rates, and adenosine triphosphate (ATP) synthesis (Kaschuk et al., 2009). This was clear from the results of a study in terms of increased contents of photosynthetic pigments under conditions of salt stress.

In the current study, the obtained results showed that combined treatment (SWE+VA-M), was superior in recording the best indicators studied, compared to the untreated plant, foliar individual application of (SWE), and (VA-M) individual inoculation. Our results are consistent with many studies that showed combined application treatments successfully increased the productivity of wheat crops. For example, the combined application of biochar and arbuscular mycorrhizal fungi is a promising way to reduce the harmful effects of salt stress in wheat production observed by (Ndiate et al., 2022), and Rashed and Hammad (2023) that the interaction application between vinasse treatment and compost tea was efficient in improving the soil's bulk density and porosity, and availability of N, P, and K, this helped to promote the vegetative growth of the wheat.

According to Setta et al. (2018), foliar application of *Cystoseira compressa* extract decreased salt stress and enhanced wheat growth by excreting chemicals that promote plant growth, such as gibberellic acid (GA3) and indole acetic acid (IAA). Moreover, an extended mycelial network facilitates the growth of plant roots beyond the zone of root depletion, enabling the plant to absorb more water and mineral nutrients from the soil. It also offers a direct route for the translocation of carbon derived from photosynthetic processes to soil microsites and a sizable surface area for microbial interactions (Finlay, 2008).

Conclusion

With in light of the results obtained from this study, NaCl resulted in a progressive decrease in morphological parameters and biochemical of the (*Triticum aestivum L.*). The 200 mM NaCl level was the most toxic to the plant. All the treatments that were tested played a role in mitigating the detrimental impacts of salinity. The combined treatment (SWE+VA-M) had a superior effect to all tested treatments, followed by the (VA-M) treatment and finally the (SWE)treatment. Therefore, we suggest the co-application to improve the parameters and biochemical parameters of the wheat cultivars different under salinity levels, as a safe, easy-to-prepare, and inexpensive method.

Conflict of Interest

The authors declare the contribution of the authors is equal. The authors have declared no conflict of interest.

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