

Research Article

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Protective role of *Spirulina platensis* liquid extract against salinity stress effects on *Triticum aestivum* L.

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Abstract: Salt stress is one of the most serious factors that influence the plant growth and yield. The extensive use of chemical fertilizers caused an increase in land contamination and hence effects on human health. The use of biofertilizers can solve these problems. In the present work, different concentrations of *Spirulina platensis* liquid extracts (SLEs; 1%, 2%, and 4%) were used to enhance seeds germination, seedling growth, length of radical, number of leaves, and plant height of *T. aestivum* L. *S. platensis* liquid extract (SLE) 2% was chosen to test against salt stress with 10% and 25% seawater in *T. aestivum* L. watered. The growth parameters such as shoot, root, length, fresh, dry weight, leaf width, number, and area were used to estimate the effects of 2% SLE against salt stress caused by seawater. Also the carbohydrate, protein, phenol, and total antioxidant contents were measured in *T. aestivum* L. treated with 2% SLE in combination with seawater and watered with

different concentrations with seawater alone. The results denote that the best concentration of SLEs was 2%, which promoted the germination growth of *T. aestivum* L. in comparison to control and other concentrations. SLE (2%) enhanced the carbohydrates, protein, total phenol contents, and antioxidant contents of *T. aestivum* L., treated with seawaters (SW10% and SW25%) and SLEs in comparison to *T. aestivum* L. SW 10% and 25% alone. *S. platensis* liquid extract (SLE) can be used as biofertilizer to enhance the growth and phytochemical contents of *T. aestivum* L. and to make tolerance of *T. aestivum* L. against salinity.

Keywords: *Triticum aestivum* L., *Spirulina platensis* liquid extract, growth parameters, salinity

1 Introduction

Agriculture plays multiple tasks to yield more nutrition to face the development of the population, and chemical fertilizer is unwanted due to its being a costly process and it is made from nonrenewable fossil fuel, which causes substantial pollution [1,2]. The prolonged use of chemical fertilization has a negative influence on soil fertility and microbiota, leading to reduction in fertilizer effectiveness and amassing of its residues in soil [3]. Recent agricultural practices tend to look for unconventional biotechnology (biofertilizers) for control of the chemical fertilizers without any effect on crop yields and income with cost-effective feasibility [4,5]. Rengasamy et al. [6] reported the growing demand for organic food as well as increasing environmental consciousness, so the bio-stimulants marketplace is increasing all over the world. Algae are eco-friendly natural products commonly consumed as organic fertilizer; seaweed extracts represent the major group of biostimulants that advance seed germination, plant growth, and crop yields [7]. *Spirulina* is an edible blue-green microalga (cyanobacterium) that

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has major contents of beneficial quality protein as well as being valuable contents of vitamins, minerals, and other components that are helpful for health, such as principal fatty acids and antioxidant pigments such as carotenoids, chlorophyll, and phycocyanin [8]. *Spirulina platensis* is described as a simple cultivation and harvesting process and is also the most popular species in microalgae biotechnology research [9,10]. *Spirulina* contains a lot of photosynthetic pigments with high intensities that reach 20% of dry weight, which may be useful and have commercial values, and those pigments are chlorophylls, beta-carotene, phycocyanins, and xanthophylls [11,12]. Godlewska et al. [13] reported that algal extracts have a lot of potential in modern horticulture and agriculture. The usage of *Spirulina*-based products is in line with the concept of sustainable agriculture, which could assist to secure the production of enough human food to fulfill the rising population demands while also protecting the environment. Blue-green alga *S. platensis* significantly increase the protein contents in *Trigonella foenum-graecum* [14]. There were an increase in the seedling growth and an increase in phytochemicals content in leaves of Lettuce when *S. platensis* was applied as biofertilizers [15]. *S. platensis* is used to treat wastewater and to stimulate the growth of leafy vegetables such as *Eruca sativa*, *Amaranthus gangeticus*, and *Brassica rapa* sp. [16]. The yield of *Florida prince* peach trees was promoted quantitatively and qualitatively when *S. platensis* was used beside humic acid [17]. Today, about 20% of the world's cultivated land and approximately half of all irrigated lands are influenced by salinity [18,19]. Salinity is one of the highest environmental stresses that extremely decrease the crop yield and growth. Millions of hectares of working land will be unsuitable for plant cultivation due to the incessant highest salinity [20]. Salinity may influence the seedling growth by reducing the absorption of water and/or reducing the level of gibberellins in germinating seeds [21]. Applications of different types of marine algal had a significant enhancement in the growth parameters of wheat seedlings under salinity stress. The existence of some bioactive contents in marine algae, such as ascorbic acid, auxins, and gibberellins, alleviates the adverse effect of salinity on the wheat seedling growth [22–24]. The occurrence of inorganic phosphate algae extract makes a fundamental in the growth and protection of wheat seedlings from salt toxicity [18]. *S. platensis* displayed a worthy potential to advance the growth and yield of *Vicia faba* grown under salt stress [25]. Globally, wheat is the second most yielded food among the cereal crops after maize and rice, and wheat is a moderately salt-tolerant crop and its yield is noticeably reduced to the soil salinity level [26]. Wheat

has a wide adaptation to diverse environmental circumstances, and it is cultured over a wide range of environments and adaptable to cultivation in moderate salty soils [27]. Wheat growth and yield parameters were negatively affected by salt, although cyanobacteria was applied as an extract and grains coating alleviated the salinity impacts. At all salinity levels studied, a combination of cyanobacteria extract and grain coating with 50% of chemical fertilizer (NP) generated the wheat growth and output comparable to a full dose of chemical fertilizer [28]. This study aimed to elucidate the enhancing potentiality of different concentrations of *S. platensis* liquid extracts on seed germination, plant growth parameters, pigments, and enzymes (α -amylase and protease) of *Triticum aestivum* L. and investigate the effects of *S. platensis* liquid extracts improving salt tolerance of *T. aestivum* L.

2 Materials and methods

2.1 Alga used and growth condition

Cyanobacterium *S. platensis* was achieved from the Culture Collection of the Algal Laboratory, Faculty of Science, Alexandria University, Egypt. *Spirulina* was grown in Zarrouk's medium [29], with continuous illumination ($35 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}$) at $30 \pm 2.0^\circ\text{C}$ in pH 9–10. After 24 days of growth (in the stationary phase), pellets were harvested by filtration, washed thoroughly with distilled water, and then dried at 60°C until constant weight. The characterization of *S. platensis* was previously published by El Din [30].

2.1.1 *Spirulina* liquid extracts

To obtain the 1%, 2%, and 4% of *Spirulina* liquid extract, approximately 1, 2, and 4 g of fine powder dry *Spirulina* was added to 100 mL distilled water, heated at 50°C with stirring for 60 min, and the extracts were cooling, filtered, and kept at 4°C until usage.

2.2 Bioassays for seeds germination using *Spirulina* liquid extract (SLE)

A pure strain of the *T. aestivum* L. was obtained from the Ministry of Agriculture, Field Crop Institute, Agriculture Research Center, Giza, Egypt (the seeds were selected

according to the relevant institutional, national, and international guidelines and legislation). Seeds were selected carefully and sterilized by using 0.01% HgCl_2 for 3 min, then washed under running tap water for 10 min. The number of germinated seeds, weight, and radical length were found. Ten seeds were spread on filter paper placed on glass Petri-dishes containing 5.0 mL of SLE (2%), and seeds without algal extract served as a control. The Petri-dishes were placed at natural illumination at 25°C [31,32]. The germination percentage (GP), germination index (GI), relative seed germination (RSG), seedling vigor index (SVI), and relative root elongation (RRE) were achieved according to the following equations [33]:

$$\begin{aligned} \text{Germination percentage (GP)} \\ = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100 \end{aligned} \quad (1)$$

$$\text{Germination index (GI)} = \sum (Gt/Tt) \quad (2)$$

where Gt is the number of seeds germinated on day t and Tt is the number of days.

$$\begin{aligned} \text{Relative seed germination (RSG)} \\ = \frac{\text{Number of seeds germinated in test solution}}{\text{Number of seeds germinated in control}} \times 100 \end{aligned} \quad (3)$$

After 7 days of germination, seedling vigor index (SVI) was calculated:

$$\text{SVI} = \text{Seedling length (cm)} \times \text{Germination percentage} \quad (4)$$

$$\begin{aligned} \text{Relative root elongation (RRE)} \\ = \frac{\text{Mean root length in test solution}}{\text{Mean root length in control}} \times 100 \end{aligned} \quad (5)$$

2.3 Crude extracts of enzymes

One gram of germinating seeds (hypocotyl) was blended and homogenized with potassium phosphate buffer (pH = 7) followed by centrifugation at 1,643g for 15 min, and the resultant crude preparation was used for the estimation of protease activity.

2.3.1 α -Amylase

The α -amylase activity was investigated based on the methodology described by Franco *et al.* [34]. Enzyme activity unit (U) was defined as the amount of enzyme

releasing 1 μmol of glucose from the substrate in 1 min under the assay conditions.

2.3.2 Protease

The crude extracts of the enzyme (0.5 mL) were mixed with 1 mL of casein (1%) in 0.2M phosphate buffer at pH 6 and incubated at 37°C for 30 min. The reaction was terminated by the addition of 0.5 mL of (10%) trichloroacetic acid (TCA). Enzyme activity was estimated at 660 nm after treating with Folin phenol reagent (1:2 v/v) [35] and presented in terms of μmol amino acids released by unit time.

2.4 Pot experiments

Ten healthy seeds of *T. aestivum* (five seeds in each pot and three pots for each treatment) were cultivated in 1 L pots for 20 days. No fertilizer was applied, but the soil of the treated seedlings was sprayed with 200 mL of 1%, 2%, and 4% of *Spirulina* liquid extracts every 2 days. Weekly measurement of the plant growth was recorded in terms of leaf number per plant and plant height. At the end of the trials, the plants were harvested, and their leaf number, plant height, root length, fresh weight, and dry weight were determined, and pigment content was determined according to Inskeep and Bloom [36].

2.5 Ameliorating effect of SLEs on *T. aestivum* seedling grown under salinity stress

Seeds of *T. aestivum* that were treated with 2% SLE were watered with tap water and 10% and 25% seawater (collected from the Mediterranean Sea, at Alexandria), and other seeds that remained untreated were also watered with tap water and 10% and 25% seawater. After 20 days of sowing, the growth, carbohydrates, proteins, phenol, and antioxidant contents were investigated [25].

2.6 Bio-stimulant assays

After 20 days of sowing, ten replicates of the growing plant were used to estimate morphological criteria of

the growing plant (shoot height, root length, leaves the area, and width of leaves).

$$\text{Leaf area (cm}^2\text{)} = \text{Length} \times \text{Breadth} \times 0.75 \quad (6)$$

The equation was computed as suggested by Quarrie and Jones [37]. The dry biomass of the grown plants was estimated after drying at 80°C for 3 days.

Total protein content was investigated related to the method by Lowry et al. [35]. Carbohydrate fractions were determined following the colorimetric phenol method described by Dubois et al. [38], using glucose as a standard. Total phenolic contents were estimated using Folin-Ciocalteu and gallic acid reagents as standards [39]. The total antioxidant capacity was determined by the reaction of antioxidants in the sample with a definite amount of exogenously provided hydrogen peroxide as performed by Koracevic et al. [40].

2.7 Statistical analysis

All results were exposed to the analysis of variance (ANOVA) [41]. Significance of the variable was investigated using Duncan's multiple range tests ($P \leq 0.05$). All analyses were performed using SPSS 16 software.

3 Results and discussion

3.1 Seeds germination under the influence of *Spirulina* liquid extract (SLE)

During the experiment, the germination percentage of *T. aestivum* was significantly increased when treated with SLE, compared with the corresponding control. Results presented in Table 1 indicate that germination indices (GP, GI, RSG, SVI, and RRE) of *T. aestivum* were increased when soaking in 2% SLE compared to control (without algal extract). The germination percentage was 97.77% relative to control 88.88%, GI (2.09), RSG (110.07), RRE (113.85), and SVI (378.48). The increased seed germination

percentage may be due to the existence of growth-promoting substances like gibberellins in cyanobacteria [42]. The growth stimulations of pepper using *Spirulina* extract may be related to nutrient contents of *Spirulina*, which are simply absorbed by plants [43]. The highest germination of chickpea and soybean was obtained when treated with *Spirulina* [44]. The highest growth of Indian mustard was obtained when fertilized with 3 g·L⁻¹ *Spirulina* suspension [45]. The growth of cowpea was enhanced using *Spirulina* suspension as a biofertilizer [46]. Crouch and Van Staden [46] detected that *Spirulina* liquid extracts enhanced the nutrient uptake by roots with amended water and nutrient efficiency. Kumari et al. [47] reported that *S. platensis* can promote root growth and plant development. *S. platensis* extracts are an important source of plant nutrition in sustainable agricultural production as they contain vitamins, various trace elements, and amino acids that are beneficial to the plant growth and development [48]. The promotion of maize plants was obtained with applied red algae as biofertilizers [49]. Seaweed algae *Ulva lactuca* and *Sargassum vulgare* are used to biocontrol nematode and promote the growth banana plants [50]. Selvam and Sivakumar [51] reported that seaweed extract of *Ulva reticulata* increased the crop productivity of *Arachis hypogea* by spraying 2% concentration. In particular, the growth of *V. mungo* plant when treated with seaweed extracts like *Caulerpa scalpelliformis* [52] and *U. reticulata* [53] increased.

3.2 Enzyme activities

Concerning the start of germination, the cotyledon reserves (polysaccharides and proteins) are degraded under the action of amylases and proteases that yield respiratory substrates. Generally, amylase and protease activities demonstrate significant positive responses under the SLE treatments relative to control (Figures 1 and 2). The maximum amylase activity was 0.71 μmole sugar·min⁻¹·g⁻¹ FW under the SLE treatment. A similar result was achieved with protease activity giving 0.26 μmole amino acids·min⁻¹·g⁻¹ FW under the SLE treatment. The application of 2% SLE has

Table 1: Seed germination parameters of *T. aestivum* L. germination percentage (GP), germination index (GI), relative seed germination (RSG), seedling vigor index (SVI), and relative root elongation (RRE) as affected by SLE 2% of *S. platensis*

Plants	SLEs treatments	GP%	GI	RSG	RRE	SVI
<i>T. aestivum</i>	Control	88.88 ± 3.85	1.90 ± 0.08	—	—	302.24 ± 16.61
	SLE	97.77 ± 3.85	2.09 ± 0.08	110.07 ± 4.6	113.85 ± 1.95	378.48 ± 18.32

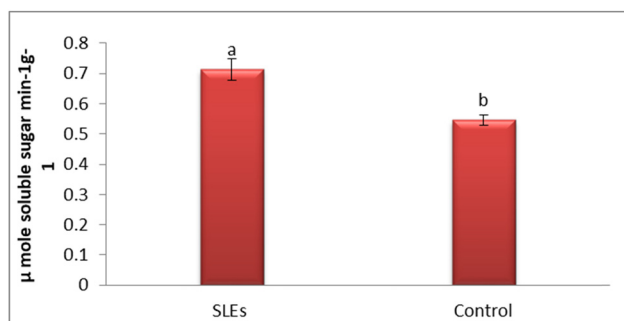


Figure 1: Amylase activity of *T. aestivum* L. that treated with 2% SLE is compared with control. The different letters are significantly different ($P \leq 0.05$) according to Duncan's multiple range tests.

increased the amylase and protease activities of leaves of *T. aestivum*. Sivasankari *et al.* [53] reported that *Sargassum wightii* and *Caulerpa chemnitzia* promoted the α -amylase and β -amylase activities of *Vigna sinensis*. The increase in amylase and protease activities at the concentration (2% SLE) may be due to the existence of growth-promoting substances like gibberellins. During seed germination, gibberellic acid encourages the synthesis and secretion of amylase, which decomposes starch into monosaccharides in the endosperm, and this enzyme is mainly responsible for the hydrolysis of starch in the endosperm [54].

3.3 Effect of different concentrations of *Spirulina* liquid extract (SLE) on growth parameters, and pigments contents of *T. aestivum*

3.3.1 Growth parameters

Compared to the control, the shoot height and root length of *T. aestivum* were significantly increased at all concentrations 1%, 2%, and 4% (ST1, ST2, and ST3, respectively) of the SLE

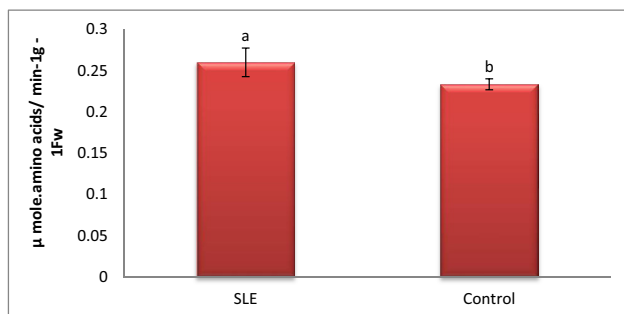


Figure 2: Protease activity of *T. aestivum* L. that treated with 2% SLE. The different letters are significant ($P \leq 0.05$) according to Duncan's multiple range tests.

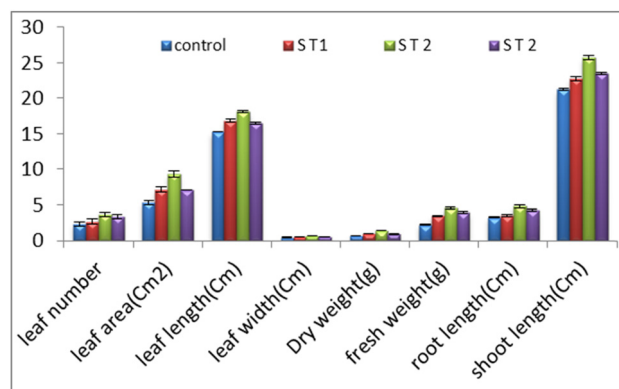


Figure 3: Effect of different concentrations (1%, 2%, 4%) of SLE in growth parameters of *T. aestivum* L.

treatment (Figure 3). ST2 induced the maximum increases in shoot height, root length, and leaf area of 25.72 cm, 4.81 cm, and 9.29 cm² of *T. aestivum*, respectively. In the case of seed treatment with SLE, all morphological parameters were amplified significantly in the following descending order ST2 > ST3 > ST1 > control. The lowest promoting effect was recorded in control giving the following increments 21.23 cm, 3.23 cm, and 5.32 cm² for shoot height, root length, and leaf area, respectively, of *T. aestivum*. The best concentration of SLE was 2%, which enhanced all growth characters in comparison with other treatments and control. The application of *Spirulina* liquid extract on *T. aestivum* increased the seed germination rate at a lower concentration, while the superior concentrations of these extracts decreased the rate of germination. The lower concentrations of *Sargassum polycystum* extract 1% promoted seed germination and the growth rate of *Cajanus cajan* [55]. *S. platensis* extract promoted seed germination and the plant growth of wheat and barley plants [56]. The application of *S. platensis* and antitranspirant weekly on chili pepper improved the marketable product by 2.1% [57]. Seaweed concentrate prepared from *Ecklonia maxima* was found to increase the root growth of tomato at 0.4% concentration [46].

3.3.2 Pigments

Table 2 presents the results of pigment contents of *T. aestivum* L. that were treated with different concentrations (1%, 2%, and 4%) of SLE. The same trend appears in the case of growth. All measured pigments were increased with concentrations of 1% followed by 2% SLE. Meanwhile, 4% SLE reduced the pigment contents of *T. aestivum* L. compared with 2% SLE, but the levels of pigment contents of *T. aestivum* L. treated with 4% SLE were still in the upper

Table 2: Effect of different concentrations of 1%, 2%, and 4% SLE on pigment contents (mg·g FW⁻¹) *T. aestivum* L.

	Chlorophyll <i>a</i>	Chlorophyll <i>b</i>	Carotenoid	Fucothan
Control	13.50 ± 0.143d	7.80 ± 0.99a	0.52 ± 0.02d	0.633 ± 0.006a
1% SLE	17.49 ± 0.05c	6.73 ± 0.23a	0.83 ± 0.01c	0.712 ± 0.01b
2% SLE	21.73 ± 0.08a	11.52 ± 0.20b	1.12 ± 0.03a	0.911 ± 0.01d
4% SLE	19.57 ± 0.19b	11.91 ± 0.2b	0.95 ± 0.1b	0.828 ± 0.01c

The different letters within a column are significant ($P \leq 0.05$) according to Duncan's multiple range tests $\pm$ standard error of means.

levels than 1% SLE and control. The lower concentration of the *Spirulina* liquid extracts also promoted the total chlorophyll and carotenoid contents of *T. aestivum* seeds up to 2% concentration of SLEs when compared to the control. Enhanced chlorophyll, carotenoid, and fucoxanthin contents at lower concentrations of SLEs have been reported for *Vigna catajung* [58], *Dolichos biflorus* [59], *Vigna sinensis* [53], *Cajanus cajan* [60], *Brassica nigra*, *Abelmoscus esculentus*, and *Cyamopsis tetragonoloba* [61].

3.4 Effect of *Spirulina* liquid extract (SLE) on the *T. aestivum* L. was grown under salinity

3.4.1 Growth parameters

The results presented in Table 3 demonstrate that the maximum dry weight value of *T. aestivum* was recorded under the SLE treatment and tap water and was recorded at 1.45 g/seedling after 20 days of treatments. The highest promotion effect on growth parameters of *T. aestivum* was evident in treatment with 2% SLE consortium with 10% SW supplementation, given the following enhancement of 28.31 cm, 5.52 cm, and 8.20 cm² for shoot height, root length, and leaf area, respectively. The results demonstrated that when *T. aestivum* was treated with 2% SLE with 10% or 25% seawater, all growth parameters were increased when compared with seawater without SLE. The significant results were obtained with different treatments on shoot length, root length, total fresh weight, total dry weight, and leaf area and leaf numbers, but in the case of leaf width and leaf length, there are no significant effects on seeds treated with 10% SLE and SLE besides SLE. All morphological criteria increased in the following descending order: SLEs-T.W > Control > SLE-10% S.W > 10% S.W > SLE-25% S.W > 25% S.W.

S. platensis (100 mg·L⁻¹) enhanced the growth of *V. faba* grown under salt-stressed environment, which proved that *S. platensis* was more beneficial against salinity stress [25]. *Spirulina* is considered to be good dietary

addition and one of the best solutions for treating malnourishment problems in developing countries [62].

3.4.2 Total carbohydrate contents

The total carbohydrate content of *T. aestivum* seedlings decreased significantly under the influence of increased salinity, but SLE triggered an interaction with SW (seawater) supplementation that resulted in the accumulation of carbohydrates, compared to water-treated seeds and seedlings under salt stress. The highest total carbohydrate accumulation was recorded for SLE conjugated with tap water to trigger a consortium *T. aestivum* 77.04 mg·g FW⁻¹ (Figure 4). After treatment with *S. platensis* extract, the soluble carbohydrate content increased. Sridhar and Rengasamy [63] reported that the induction of *S. platensis* was associated with an increase in total soluble carbohydrates in *T. aestivum* and *L. termis*. Therefore, the increase in carbohydrates in the current results may be due to the effect of the extract of *S. platensis* on photosynthetic efficiency, which may be related to the cytokinins, auxins, macro, and micronutrients in the extract of cyanobacteria [64]. The carbohydrate and protein content of the seeds increases when plants are treated with a higher seaweed dosage and more than 2 g of chemical fertilizer. At higher doses, the carbohydrate and the protein content of algae plus chemical fertilizers will decrease [65]. The carbohydrate content of *Vigna radiata* L. was promoted at 2.0% concentration *Sargassum wightii* grev [66]. The treatments of different crops with *Spirulina* extract were of great importance due to higher levels of organic matter, microelements, vitamins, and fatty acids and also amusing in growth regulators such as auxin, cytokinins, and gibberellins [46].

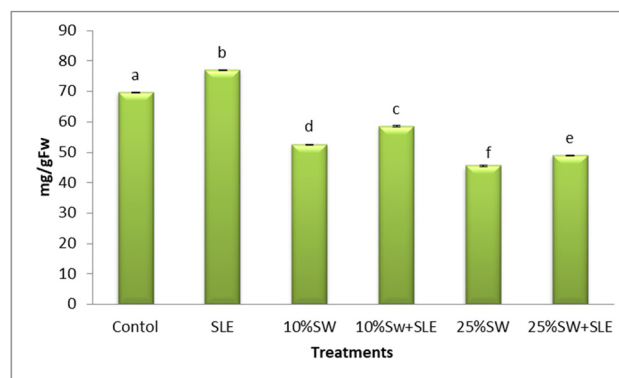
3.4.3 Protein contents

Compared with seedlings without hydroprime stress, a significant decrease in the protein contents of the studied

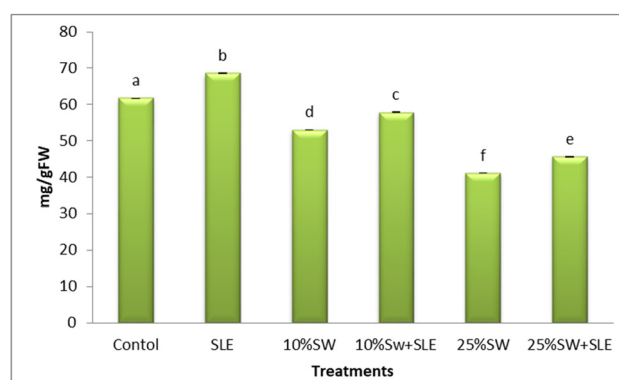
Table 3: Effect of different concentrations of sea waters with SLE 2% on the *T. aestivum* L. growth parameters

Treatments	Shoot length (cm)	Root length (cm)	Total fresh weight (g)	Total dry weight (g)	Leaf width (cm)	Leaf length (cm)	Leaf area (cm ²)	Leaf number
Control	29.7 ± 0.01b	5.82 ± 0.01b	5.32 ± 0.02b	1.3103 ± 0.05b	0.582 ± 0.005b	18.578 ± 0.05b	8.53 ± 0.07b	2.33 ± 0.57a
SLE-T.W	32.46 ± 0.01a	6.37 ± 0.05a	5.863 ± 0.02a	1.457 ± 0.01a	0.65233 ± 0.01a	19.529 ± 0.04a	10.06 ± 0.1a	3.333 ± 0.57b
10% S.W	27.74 ± 0.01d	5.17 ± 0.08d	3.480 ± 0.06d	0.94 ± 0.02d	0.52433 ± 0.05c	18.243 ± 0.07c	7.55 ± 0.77d	3.333 ± 1.15d
SLE-10% S.W	28.31 ± 0.01c	5.52 ± 0.07c	3.493 ± 0.08c	0.97 ± 0.06bc	0.56 ± 0.05c	18.56 ± 0.08c	8.20 ± 0.88c	2.666 ± 0.57c
25% S.W	26.21 ± 0.01f	4.87 ± 0.07e	2.592 ± 0.07e	0.648 ± 0.10e	0.5 ± 0.154e	17.686 ± 0.79d	6.98 ± 0.72f	2.333 ± 0.57f
SLE-25% S.W	27.25 ± 0.1e	5.33 ± 0.58d	2.51 ± 0.248d	0.796 ± 0.09cd	0.539 ± 0.09d	17.663 ± 0.11d	7.39 ± 0.48e	1.666 ± 0.57e

The different letters within column are significant ($P \leq 0.05$) according to Duncan's multiple range tests ± standard error of means.

**Figure 4:** Effect of 2% SLE in carbohydrate contents of *T. aestivum* L. grown under salt stress. Control – tap water, SW – seawater, SLE – spirulina liquid extracts 2%. The different letters are significant ($P \leq 0.05$) according to Duncan's multiple range tests.

plant was observed under salinity treatments (10% and 25% SW). The conjugation effect of seawater and SLE preparations leads to a different increase in protein storage with seawater supplementation. The results obtained in Figure 5 demonstrated that the 2% SLE promoted the protein contents of *T. aestivum* more than the protein contents in control. The increase in protein content of *T. aestivum* exits after treatment with *S. platensis* extract, which indicates that *S. platensis* extract may contain substances that cause this increase. According to reports, *S. platensis* extract contains amino acids and zinc [25]. The highest protein, total carbohydrate contents, phenols, and antioxidant of *T. aestivum* were observed at a concentration of SLE of *S. platensis* (2%). There was such an increase in protein, amino acid, and total carbohydrate contents. Foliar applied *S. platensis* reduced adverse effects of salinity by improving the total protein level, N, P, K, and photosynthetic activity of *V. faba* L. [25].

**Figure 5:** Effect of 2% SLE in protein contents of *T. aestivum* L. grown under salt stress. Control – tap water, SW – seawater, SLE – spirulina liquid extracts 2%. The different letters are significant ($P \leq 0.05$) according to Duncan's multiple range tests.

3.4.4 Phenol contents

There was a remarkable induction of significant increments in total phenol contents of *T. aestivum* treated with SLE, the phenol content of *T. aestivum* irrigated with 10% and 25% seawater was reduced, but when treated with SLE, the phenol contents were increased but were still less than the control value (Figure 6).

3.4.5 Antioxidant activities

There was a remarkable initiation of significant increases in total antioxidant and phenol contents relative to the control of *T. aestivum* treated with SLE. Results in Figure 7 denote the maximum value of total antioxidant contents in *T. aestivum* that was treated with SLE and irrigated with tap water ($0.75 \text{ mg} \cdot \text{g FW}^{-1}$). Results demonstrate the treatments *T. aestivum* by seawater concentrations reduced the antioxidant contents, but the *T. aestivum* that seeds were treated in 2% SLE, showed more growth enhancement than those treated with seawater alone.

The total content of phenol and antioxidants can be attributed to the greater availability and absorption of essential elements (Ca, Na, K, Mg, N, and Zn) in seaweed extracts [60]. Salinity is one of the main environmental factors that limit the plant growth and productivity [47]. Salinity is a physiological parameter to investigate the capability of organisms to survive in their environment. The cyanobacterial retort to salinity includes many physiological and biochemical processes such as nucleic acid synthesis, carbohydrates and protein metabolism, photosynthesis, and respiration [50]. The increase in salinity

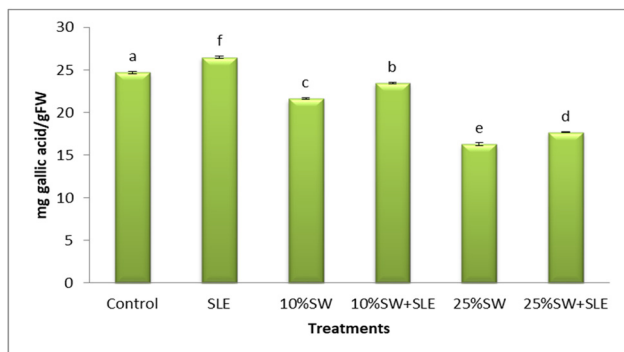


Figure 6: Effect of SLE on the phenol contents of *T. aestivum* L. grown under salt stress. Control – tap water, SW – seawater, SLE – spirulina liquid extracts 2%. The different letters are significant ($P \leq 0.05$) according to Duncan's multiple range tests.

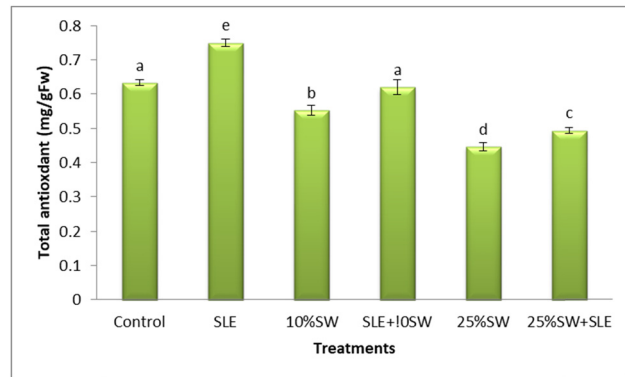


Figure 7: Effect of SLE on the total antioxidant contents of *T. aestivum* L. grown under salt stress. Control – tap water, SW – seawater, SLE – spirulina liquid extracts 2%. The different letters are significant ($P \leq 0.05$) according to Duncan's multiple range tests.

initiated a decrease in the growth [49]. Many previous studies have reported that high salt agronomy reduces chlorophyll and protein content [12]. *S. platensis* may be binding to many elements, such as potassium and calcium, and keeping in natural levels ratio and hence the cells remain alive [67]. *Spirulina maxima* and *Chlorella ellipsoidea* water extracts improved wheat tolerance to salinity and enhanced the antioxidant capacity of the whole grains [68]. *Scenedesmus obliquus* and *S. platensis* increased the activities of SOD, APX, CAT, POD, chlorophyll, and carotenoid content of *T. aestivum* grown under salt stress [69]. *Ulva lactuca* induced plant growth and yield and antioxidant enzyme activity (SOD, CAT, APX, and GR) of *T. aestivum* grown under salt stress [70]. *Ulva rigida* extract promoted leaf pigments, total phenolics, and antioxidant enzymatic activities of *Triticum durum* grown with salinity [71].

4 Conclusion

Spirulina liquid extracts successfully alleviated the harmful effects of salt stress on tested plants by significantly reducing the inhibition of the affected parameters, total protein, total carbohydrate accumulation, total phenol contents, and antioxidant activity. In this study, *T. aestivum* treated with *S. platensis* liquid extract (SLE) (biological fertilizer) significantly increased branch length, root length, number of leaves, fresh weight, and weight dried. Seedlings that received the application of biofertilizer for 20 days resulted in the maximum plant growth, which could theoretically mean higher growth parameters.

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