Ameliorative Effect of Micro-Algal and Medicinal Plants on Some Biochemical Properties of Bean Plants under Salinity Stress

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This study was conducted to examine the ameliorative effects of foliar application of some micro-algal (*Chlorella vulgaris* and *Spirulina platensis*) and some medicinal plant leaves (*Salix alba*, *Psidium guajava*, and *Olea europaea*) extracts on *Phaseolus vulgaris* (Bean) under salinity stress. On a loamy soil, a pots trial was carried out on bean plants grown under salinity stress. Growth characteristics, pigments, osmolytes, total phenol, and antioxidant enzyme contents were determined. *S. platensis* extract application showed the greatest improvement in shoot length and fresh weight of shoot, which rose 23.5% and 65.1%, respectively compared to the control. The utilized bio-stimulants, particularly *S. platensis* extracts, remarkably increased the chlorophyll content compared to the control under salinity stress. The photosynthetic pigment, soluble sugars, and soluble protein levels were strengthened by foliar application of bio-stimulant extract. Proline and antioxidant enzyme levels are significantly reduced using algal and plant extracts treatment. These findings support the treatment's increased contribution to reducing salt stress and their detrimental effects on bean plants.The findings of this study indicate that the use of these biostimulants, especially *S. alba*, *P. guajava*, and *O. europaea* leaf extracts can be considered as an unconventional, ecofriendly, and novel tool in the mitigation of salinity stress.

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INTRODUCTION

Haque *et al*. (2022) stated that in order to assist national economies, it is essential to grow crops and fruits and increase their yields. The great majority of issues that endanger human existence can be solved through agriculture (Abdul Rajak 2022). Crops are directly impacted by soil salinity. As a result of its terrible impact on agricultural areas and decreased crop quality and productivity, salinity is one of the most damaging abiotic stresses (Abdel Latef *et al.* 2020). The accumulation of reactive oxygen species, which results in oxidative stress and causes oxidative damage to proteins, pigments, and DNA in salt-stressed plants, is one of the most serious issues that depend on soil salinity (Shokri-Gharelo and Noparvar 2018). There are numerous disruptions caused by high sodium content in plant cells that reduce plant development (Kumar *et al*. 2020). Reduced

photosynthetic pigments, leaf area, and photosynthetic efficiency were seen in plants exposed to excessive salt concentration (Ashraf and Harris 2013). Moreover, the accumulation of hydrogen peroxide (H_2O_2) from salinity stress leads to oxidative stress, which causes DNA fragmentation, cell shrinkage, and the accumulation of malondialdehyde (MDA), a marker for lipid peroxidation (Zhu *et al*. 2020). In the authors' study, microalgae was used, which have not garnered enough attention as a potential source of plant biostimulants (Farid *et al*. 2019). Carillo *et al*. (2020) stated that algal material extracts or derivatives have long been valued as a resource that can help people and domesticated plants. In recent years, it has been clear that algal formulations can have a variety of impacts on plants, including an increase in biomass, production, and quality. These algal extracts also contain several bioactive chemicals and signaling molecules in addition to minerals and organic elements. Algal extracts are now being used more frequently as plant biostimulants as a non-renewable chemical input in agriculture, as they can help plants flourish in less-than-ideal surroundings like saline situations. The use of plant extracts from *Salix alba, Psidium guajava, Olea europaea*, and *Punica granatum* as a medicinal plant to lessen the negative effects of salinity stress on crop growth and biochemical constituents of common bean plants has not been reported, but many extracts from the other plants have been used to enhance the growth of other crops. Agbagwa (2014) investigated how well *Senna alata* crude extracts improved *Celosia argentea* vegetative and reproductive growth. He demonstrated how soaking seeds in the extract prior to planting boosted and improved seedling length, leaf area, dry weight, and leaf area ratio. The current study intends to investigate how extracts from medicinal herbs and algae (*Chlorella vulgaris, Spirulina platensis, S. alba, P. guajava,* and *O. europaea*) can reduce the stress caused by salinity on common bean plants. This study investigates how extracts from medicinal plants and algae alter some metabolic constituents of common bean plants. Additionally, it makes evident the importance of a novel class of biostimulants (*S. alba, P. guajava,* and *O. europaea* leave extracts), which have a protective effect against salinity stress. However, it also highlights the pressing need to address the underlying processes underlying these benefits.

EXPERIMENTAL

Field Experiment

During the spring of 2020 to 2021, a pot experiment was conducted with loamy soil. Prior to planting, a surface soil sample (0 to 30 cm) from the experimental area was taken for investigation, and some physical and chemical parameters were determined using the reported methods (Klute 2018). The data of analyses are presented in Table 1.

The experimental treatments were arranged within the sample groups in a completely randomized block design. The studied area was divided into 6 groups; the area of each group was tested in 6 replicates. *Phaseolus vulgaris* L. var. Bronco seeds were sown in hills (2 seeds $bill^{-1}$) at soil depth of 2 to 3 cm. Additionally, ammonium nitrate (33.5% N) was added at the rate of 50 kg N $fed.^{-1}$, after 23 days of planting. All plots were irrigated at 200 ppm of sodium chloride as a control. Algae and medicinal plant tissues were extracted in sterile distilled water at a ratio of 1:200 (w/v) for 45 min at 60 °C. The extracts were kept at 4 °C for field testing purposes and filtered through a filter paper (Anisimov *et al*. 2013). At 20 and 35 days of sowing, the extracts were sprayed on the leaves as a foliar treatment at a dosage of 5 g of powdered medicinal plants or algae/L (400 $L \cdot fed^{-1}$). A preliminary

experiment in which they induced the highest percentage of germination led to the selection of the extracts' concentration. The experiment included six treatments as follows: (1) Control (saline soil without any foliar of algal and medicinal plant), (2) Algal extract of *C. vulgaris*, (3) Algal extract of *S. platensis*, (4) Medicinal plant extract of *S. alba*, (5) Medicinal plant extract of *P. guajava*, and (6) Medicinal plant extract of *O. europaea*. Analysis of material extracts are shown in Table 2 as mentioned previously in other studies.

Table 1. Some Physical and Chemical Properties of the Experimental Soil

Particle-Size Distribution (%)								pH (1: 2.5 in suspension)							7.20
C. Sand						20.0		EC (dS/m, in soil paste)							3.38
F. Sand						18.1		Soluble Ions (meq/L)						Ca^{++}	4.8
Silt						40.6								Mg^{++}	2.3
Clay						21.3								Na^{+}	96.4
Texture class						Loamy								K^{+}	0.3
O.M (%)						0.44								CO_3^{2-}	-
$CaCO_3$ (%)						1.42								HCO_3^{-}	1.7
SP (%)						35.0								Cl^{-}	92.7
W.H.C (%)						33								SO_4^{2-}	9.4
Available nutrient (mg/kg)															
N	23.8	P	9.34	Mn	0.39	Fe	0.43	Zn	0.13	Fe	0.43	Cu	1.37	K	123.0

Table 2. Analysis of Material Extracts

Extracts Species	Analysis	Reference
C. vulgaris	According to a chromatographic analysis, the main phenolic constituents were gallic, caffeic, *p*-coumaric, and ferulic corrosives.	(Wan *et al*. 2019)
S. platensis	Analysis by gas chromatograph-/mass spectrometry (GC-MS) found that 9,12-Hexadecanoic acid, 15-octadecadienoic acid methyl ester, and 9,12- octadecatrienoic acid methyl ester are all present in methanol extract in amounts of 29%, 24%, and 24.36%, respectively.	(Deyab *et al*. 2021)
S. alba	Analysis by ultra-performance liquid chromatography photodiode detector-quadrupole/time-of-flight mass spectrometry (UPLC-PDA-Q/TOF-MS) showed that 29 phenolic compounds were found in the leaves and, there were 5575.96 mg of phenolic compounds overall per 100 g of dry weight (DW).	(Piątczak *et al*. 2020)
P. guajava	GC–MS analysis of the essential oil showed that the dominant chemical compounds present in the leaf oil were iso-caryophyllene (33.53%), veridiflorene (13%), farnesene (11.65%), dl-limonene (9.84%), d-cadinene (1.75%), a-copaene (2.80%), a-humulene (3.74%), aromadendrene (1.70%), and scadinol (0.08%).	(Weli *et al*. 2019)
O. europaea	High-Performance Liquid Chromatography Coupled with Diode-array Detection and Electrospray Ionization Tandem Mass Spectrometry (HPLC/DAD/MS) analysis indicated that hydroxytyrosol and flavonoids, including rutin, luteolin-7-glucoside, verbascoside, and oleuropein were the major phenolic components in leaves.	(Silva *et al*. 2006)

Phaseolus vulgaris L. var. Bronco-treated plant samples (six plants) were randomly selected after 45 days of seeding to examine their morphological plant traits (lengths of shoot, fresh, and dry weights of shoot, and number of leaves). Fresh leaf pigments, dry shoot carbohydrates, protein, phenol, and proline, as well as the antioxidant enzyme content of apical buds, were all subject to biochemical investigation. The number of biochemical determinations that were made, and the nature of those determinations are described below.

Estimation of pigments and carotenoids

Vernon and Seely (2014) developed a technique for measuring the pigments in plants. Approximately 1 g of leaves was chopped into tiny pieces. The fragments were blended for 2 min in 100 mL of 80% acetone. The mixture was transferred quantitatively and filtered using Whatman No. 1 filter paper using a Buchner filter. The filtrate was poured into a 100-mL volumetric flask, and 100 mL of acetone at 80% was then added to the flask. Estimated chlorophylls "a" and "b" (Lichtentahler 1989).

Estimation of total soluble carbohydrates and protein

One gram of the dried plant tissues was extracted in 5 mL of phenol solution (2%) and 10 mL of trichloroacetic acid solution (30%) to determine the amount of carbohydrates present. 2 mL of the extract was added to 4 mL of anthrone reagent, the green-blue color was determined at 620 nm Umbreit *et al.* (1957)

The dried shoot's soluble protein content was evaluated by Lowry *et al*. (1951). The dried material (0.1 g) was homogenized with 5 mL of phenol solution (2%) and 10 mL of distilled water. The acquired extract was combined with 5 mL of alkaline reagent {containing: 50 mL from solution A (50 mL of 2% sodium carbonate and dissolved in 0.1 N sodium hydroxide): 1 mL from solution B (0.5 g copper sulfate dissolved in 1.0% potassium sodium tartrate)} and homogenized thoroughly. Then, 0.5 mL of the diluted folin phenol reagent (1:3 v/v) was added. After 30 min, the developed color at 750 nm was measured.

Estimation of total phenols

The colorimetric method of Folin-Denis as described by Daniel and George (1972) was used. One gram of dry plant were extracted with 5 to 10 mL 80% ethanol for at least 24 h at 0 °C. The alcohol was clarified, the remaining residue was re-extracted with 5 to 10 mL 80% ethanol 3 times. At the end, the clarified extract was completed to 50 mL using 80% ethanol. The total phenolic constituents were estimated using the Folin-Ciocalteu method. An aliquot of 0.5 mL of the previous extract and 0.5 mL of Folin-Denis reagent were well mixed in a dry test tube, the tube was thoroughly shaken for 3 min. 1.0 mL of saturated Na_2CO_3 solution was added, mixed well, and 3 mL of distilled water were added. After one hour, the development colour was read at 725 nm.

Calculation of free proline

According to Bates *et al*. (1973)**,** the proline content in the dried shoot samples was evaluated. Briefly, 10 mL of sulfosalicylic acid (3%), together with a half gram of the dried material, were combined. The mixture was filtered, and 2 mL of the filtrate was then added to 2 mL of acid ninhydrin, which was made by heating 1.25 ml of ninhydrin with 30 mL of glacial acetic acid and 20 mL of 6 M phosphoric acid for one hour. The reaction was continued in an ice bath, and the preceding combination was then given 4 mL of toluene.

The absorbance of the produced color was measured at 520 nm. On the basis of a developed standard curve with known L-proline concentration, proline contents in the sample were identified.

Extraction of enzymes catalase, peroxidase, and polyphenol oxidase

Young leaves and terminal buds have antioxidant enzymes such as peroxidase, catalase, superoxide dismutase (SOD) and polyphenol oxidase. According to this procedure, two grams of plant buds were mixed with 10 mL of phosphate buffer (0.1 M, pH 6.8), and the mixture was centrifuged while chilling for 20 min at 20,000 rpm. The enzyme source was the clear supernatant, which contained the enzymes (Mukherjee and Choudhuri 1983) and assessed as follows.

Catalase (CAT) activities were calculated as mentioned by Aebi (1984). For catalase (CAT, EC 1.11.1.6) activity, 10 mL of the whole mixture (40 L of the enzyme extract + 9.96 mL of pH 7.0 oxygen water phosphate buffer; 0.16 mL H_2O_2 (30%) + 100 mL 50 mM phosphate buffer) was used. Using UV-colorimetry at 250 nm, the change in H2O2 absorbance after 60 seconds was used to determine the catalase enzyme activity.

Peroxidase (POX) activities were estimated according to Castillo *et al*. (1984). The test solution (5 mL) for peroxidase activity (POD, EC 1.11.1.7) contained the following ingredients: 50 µM pyrogallol + 50 µM H_2O_2 + 125 µM of phosphate buffer (pH 6.8) + 1.0 mL of the 20 × diluted enzyme extract. At an absorbance of 420 nm, the color created as a result of the purpurogallin concentration was determined. The peroxidase enzyme's activity was measured in enzyme units (EU)/mg protein.

Polyphenoloxidase (PPO) activity was evaluated according to the method of Matta and Diamoned (1963). In a nutshell, the solution assay entails the mixing of 100 µmol of pyrogallols with 125 µmol of phosphate buffer (pH 6.8) and 2 mL of crude enzyme extract, followed by 5 min of incubation at 25 °C. The reaction was halted after the incubation period by adding 1.0 mL of 5% H_2SO_4 to the mixture. The above-mentioned procedures were used on the blank control sample. At 430 nm, the developed color was measured in the treated and control solutions. The difference between two optical densities/g of fresh weight/hour was used to calculate the enzyme activity.

The activity of superoxide dismutase (SOD) was estimated according to methods described by Marklund and Marklund (1974). In this method, 10 mL test solution containing the following ingredients was used: 3.6 mL of pure water, 5.5 mL of 50 mM phosphate buffer (pH 7.8), 0.1 mL of enzyme extract, and 0.8 mL of 3 mM pyrogallol (dissolved in 10 mM HCl). Pyrogallol's decrease percentage was determined at 325 nm. An EU mg-1 protein was required to prevent 50% of the autoxidation of pyrogallol at 25 °C in order to evaluate the activity of SOD.

Statistical Analysis

At the 0.05 level of probability, statistical calculations were carried out using the computer programs Microsoft Excel version 365 (Microsoft Corp., Redmond, WA, USA) and SPSS v.25 (statistical package for the social science version 25.0) (Snedecor and Cochran 1980) (SPSS Inc., Chicago, IL, USA). To analyze the variance of quantitative data with a parametric distribution, one-way analysis of variance (ANOVA) and *post hoc* Tukey test were utilized. The confidence interval was set at 95%, while the allowed margin of error was set at 5%.

RESULTS AND DISCUSSION

Algal and Medicinal Plants Extract Improved Morphological Parameters of Common Bean under Saline Soil Stress

Through pleiotropic pathways involving osmotic stress, nutritional imbalance, ion toxicity, and oxidative stress, salinity adversely impacts plant growth, development, and yield (Ferchichi *et al.* 2018). It has been demonstrated that salinity (salt stress) negatively affects common bean plants by lowering shoot height, fresh weight, and leaf count. Salinity may have a growth-reducing effect on common bean plants for a variety of reasons, including severe osmotic stress and ion toxicity (Chung *et al*. 2020). Salinity stress can also prevent cell division, cell elongation, and cell expansion, as indicated by Radi (2013). The use of natural plant extracts to support the growth of various crop plants, such as maize under salt stress, has been documented (Abdel Latef *et al*. 2019).

Data in Table 3 show that foliar application of algal (*S. platensis*) and medicinal plant (*O. europaea*) extracts caused significant increase of growth parameters of common bean under study compared to the control and other treatments. *S. platensis* extract appeared to cause the highest improvement of shoot length and fresh weight of shoot by 23.5% and 65.1%, respectively, rather than the control. *S. platensis* extract's stimulating effects were evident as a result of its abundance in contents of proteins, minerals, trace elements, and numerous vitamins, including B1, B2, B12, and E (Sall *et al*. 1996).

The common bean culture trial's findings revealed that plants treated with *S. platensis* algae extract had generally improved the growth parameters. In this concern, Farooq *et al*. (2017) observed that the efficiency of wheat under salt stress was improved by the foliage application of all plant extracts (sorghum extract, common bean extract, brassica extract, and moringa extract), as evidenced by improvements in grain weight, grain number, and grain yield.

Table 3. Effects of Algal and Medicinal Plants Extraction on Shoot Lengths, Fresh and Dry Weights of Shoot, and Number of Leaves of *Phaseolus vulgaris* L. var. Bronco under Saline Soil Stress

Treatments	Shoot Length (cm)	Fresh Weight of Shoot (g pol^{-1})	Dry Weight of Shoot (g $plant^{-1}$)	Number of Leaves (g $plant^{-1}$)
Control	22.76 ± 0.21b	1.72 ± 0.03c	0.143 ± 0.01b	4.34 ± 0.002b
C. vulgaris	24.95 ± 0.36ab	2.10 ± 0.04bc	0.171 ± 0.02a	4.66 ± 0.004a
S. platensis	28.11 ± 0.25a	2.93 ± 0.02a	0.182 ± 0.02a	4.83 ± 0.003a
S. alba	23.48 ± 0.45b	2.44 ± 0.06b	0.150 ± 0.04b	4.66 ± 0.010a
P. guajava	22.15 ± 0.41b	2.62 ± 0.12b	0.165 ± 0.02a	4.50 ± 0.020b
O. europaea	26.03 ± 0.22a	2.84 ± 0.02a	0.173 ± 0.03a	4.70 ± 0.005a
$LSD_{0.05}$	3.214	0.952	0.21	0.291

Data represents mean ± standard error (n = 10). Different lowercase letters in the same species within a column indicate significant differences ($P \leq 0.05$) by Tukey's test (LSD).

Biochemical Parameters of *Phaseolus vulgaris* L. var. Bronco Affected by Algal and Medical Plant Extracts

Pigments contents

One of the major determinants of photosynthetic capacity is the amount of chlorophyll. The data in this study (Fig. 1) show that, in comparison to those found with other extras applied, salt stress caused a considerable decrease in the amounts of carotenoid and chlorophyll content in common bean leaves.

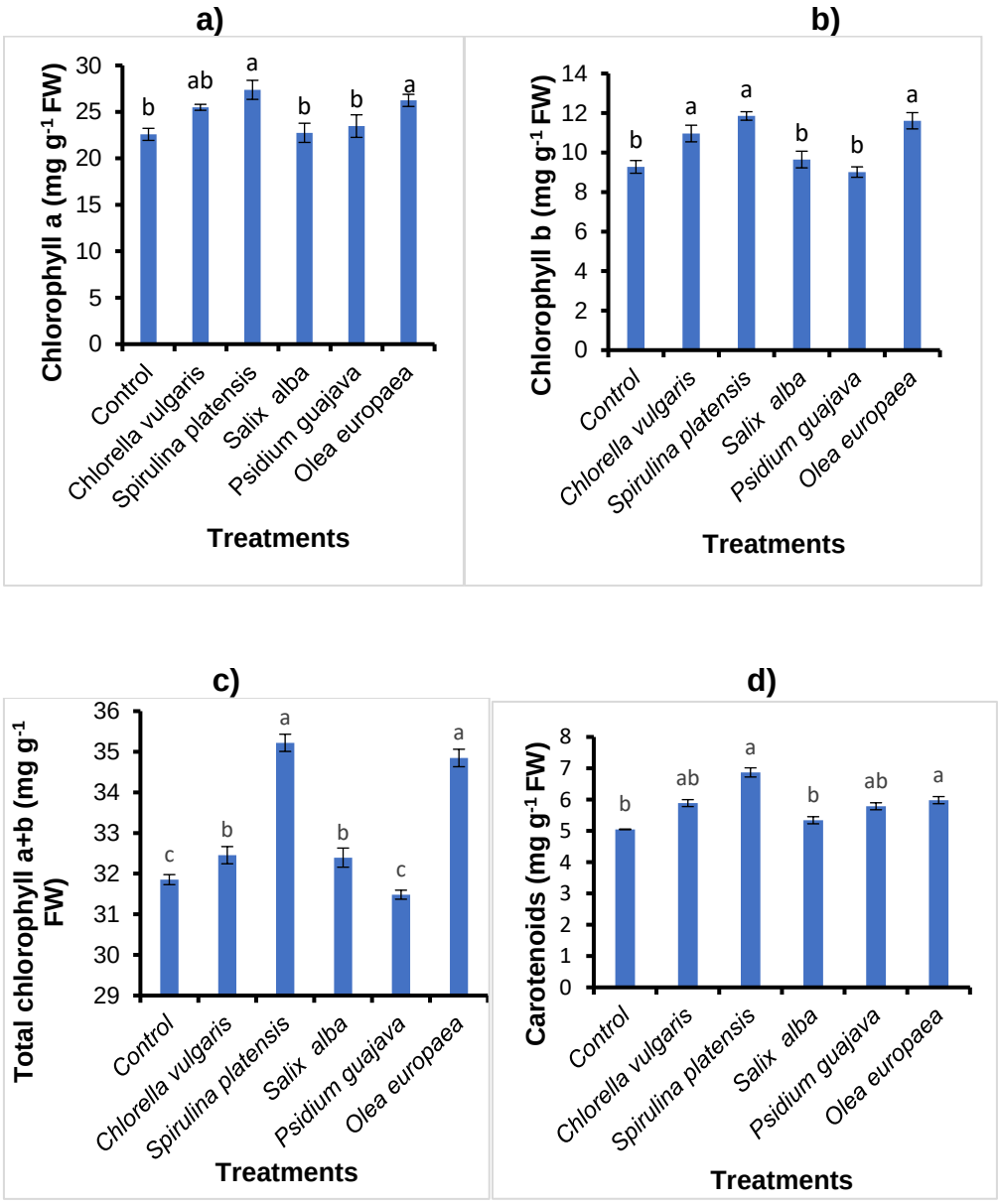

Fig. 1. Effects of algal and medicinal plant extracts on chlorophyll a, chlorophyll b, chlorophyll (a + b), and carotenoids (d) content of *P. vulgaris* L. plants under saline soil stress. (Bars represent means and standard errors of three independent replications (n = 3). Different letters indicate significant differences among the treatments at $P < 0.05$, according to LSD test.

Results in Fig. 1 confirmed that under salinity conditions, the use of biostimulants, especially *Spirulina platensis* and *O. europaea* extracts, significantly improved the chlorophyll and carotenoid contents compared with the stress sample of bean plant. This may be because seaweed and plant extracts include active ingredients including betaine, amino acids, and other compounds that prevent the degradation of chlorophyll (Blunden *et al*. (1996).

Other results, such as those in Fig. 1, also demonstrate that the use of biostimulants can mitigate the harm that salinity causes to the chlorophyll concentrations of common bean plants. The decrease in leaf area, which is crucial for catching light and enabling photosynthesis, may be the cause of the decline in photosynthetic pigments. Moreover, under abiotic stress circumstances, increases in the activity of chlorophyll-degrading enzymes including chlorophyllase caused declines in photosynthetic pigments (Abdel Latef *et al*. 2020). The high percentage of protein, Ca, Mg, Fe, and Zn ions, which have a direct impact on photosynthetic pigments because Ca and Fe decrease in chlorophyll biosynthesis, and vitamin E, which acts as an antioxidant, are all present in *S. platensis* extract, which may account for its protective effect on the extent of photosynthetic pigment and carotenoids. It was also shown to be connected to a variety of biological processes in the plant as an electron transport source and receptor and an enzyme catalyst (Abdel Latef *et al*. 2019).

Metabolite Contents

Data in Table 4 show that salinity stress significantly decreased the content of soluble carbohydrates, protein contents of shoot of common bean, and applications of bio-stimulants significantly enhanced the soluble carbohydrates, protein contents. The highest value was obtained with medicinal plant extract of *Psidium guajava* treatment, which caused relative increase of soluble sugars and protein content by 173% and 36.1%, respectively, over the control (Table 4).

Proline has the highest water solubility and exists in a zwitter ionic state. Proline shares this property with other compounds. It is collectively referred to as "compatible solutes" that are accumulated in the wide range of organisms to adjust cellular osmolality. The results from this study showed a significant increase in proline and phenol contents in response to salinity stress.

The accumulation of phenolic compound under abiotic stresses helps in the stabilization of the subcellular/non-photosynthetic membranes by detoxifying the reactive oxygen species, thus improving the osmotic adjustment (Farooq *et al*. 2009). The salinity stress in the presence of algal and medicinal plant extracts show a significant decrease in proline content. These findings support the stronger contribution from this treatment in reducing the detrimental effects of salt stress on common plants. Phenolics in algal and medicinal plant extracts may be responsible for the improved *P. vulgaris* performance (Jabran and Farooq 2013). Eventually, the common bean performance under stress circumstances was improved by the plant and algal extracts as a result of these extract treatments that increase water and nutrient uptake, enzyme activity, photosynthesis, gene expression, and signal transmission by modulating the metabolism of phytohormones (Macías *et al*. 2007).

Table 4. Effects of Algal and Medicinal Plants Extract Soluble Carbohydrates, Protein, Phenol, and Proline Contents of *P. vulgaris* L. Plants in Saline Soil

Treatments	Soluble Carbohydrates	Soluble Protein	Total Phenol	Total Proline
	(mg/g Dry Weight)			
Control	8.73 ± 0.21c	16.79 ± 0.54c	0.353 ± 0.07b	2.94 ± 0.15a
C. vulgaris	14.68 ± 0.36b	21.39 ± 0.31a	0.106 ± 0.06c	2.17 ± 0.09b
S. platensis	16.50 ± 1.3ab	19.88 ± 0.42ab	0.294 ± 0.11b	1.18 ± 0.25d
S. alba	19.85 ± 0.65ab	20.97 ± 0.75a	0.169 ± 0.03c	2.14 ± 0.21b
P. guajava	23.88 ± 0.74a	22.22 ± 0.65a	0.473 ± 0.04a	1.94 ± 0.32c
O. europaea	13.51 ± 1.32b	18.70 ± 0.63b	0.546 ± 0.05a	1.86 ± 0.24c
LSD $_{0.05}$	4.21	1.45	0.125	0.354

Data represent means ± standard error (n = 3). Different lowercase letters in the same species within a column indicate significant differences ($P \leq 0.05$) by Tukey's test (LSD).

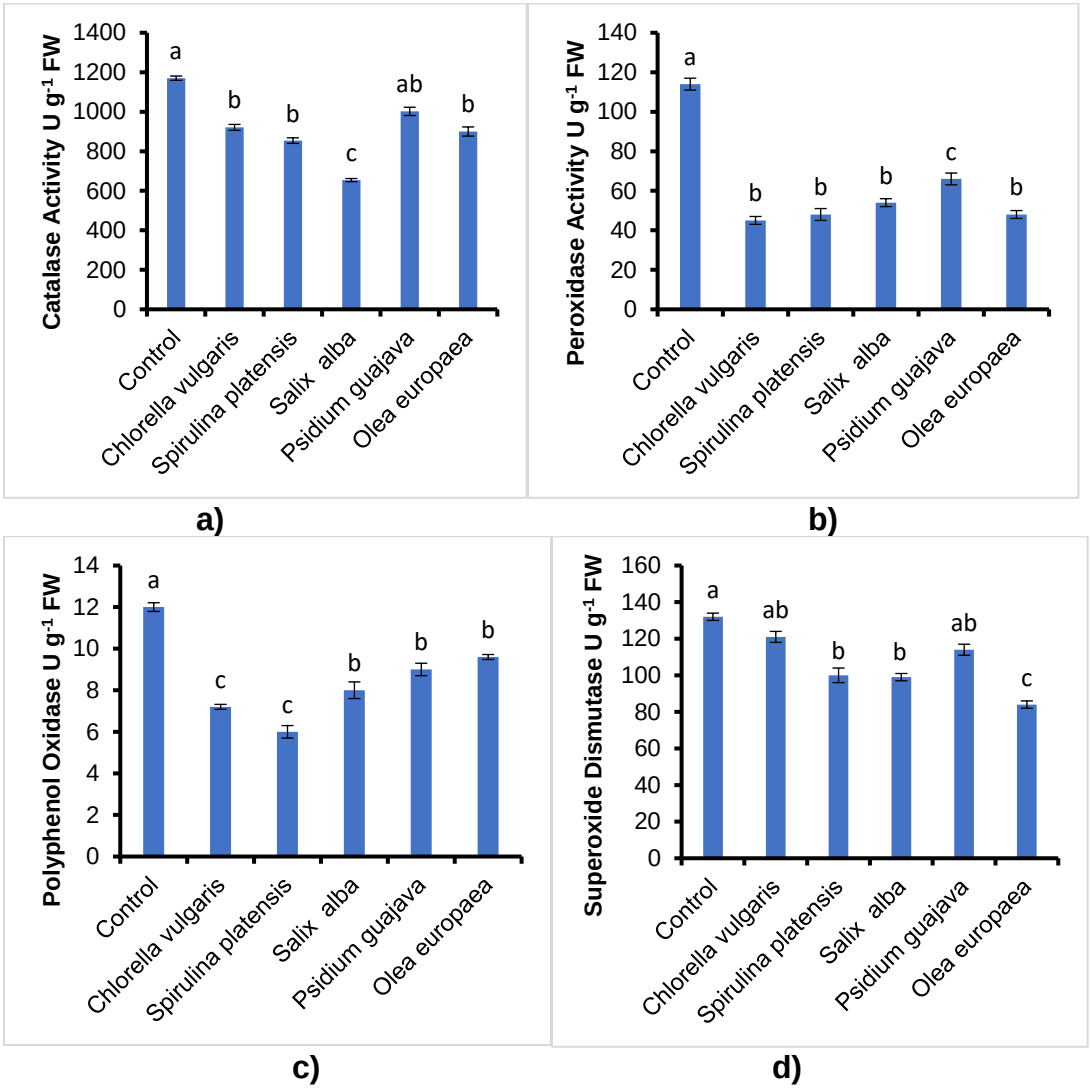

Fig. 2. Effects of algal and medicinal plant extracts on Catalase, Peroxidase, Polyphenol oxidase, and Superoxide dismutase content of common bean plants. (Bars represent means and standard errors of three independent replications (n = 3). Different alphabetical letters indicate significant differences among the treatments at $P < 0.05$, according to LSD test.

Enzyme Activities

The findings in Fig. 2 demonstrate the effects of salinity stress on the antioxidant enzyme activities that take part in scavenging reactive oxygen species (catalase, peroxidase, superoxide dismutase, and polyphenol oxidase) (ROS).

In comparison to foliar application of algal and medicinal plant extracts, the results revealed a considerable increase in the activities of catalase, peroxidase, superoxide dismutase, and polyphenol oxidase in the leaves of the apical tip of common bean plants under salinity treatment (control). Because of the increased accumulation of ROS, particularly O_2, in chloroplasts, mitochondria, and peroxisomes, salinity stress is eventually linked to enhanced oxidative stress. Plants typically use the stimulation of antioxidant enzyme activity as a defense mechanism against oxidative stress (Foyer and Noctor 2003). Additionally, the current findings in Fig. 2 demonstrate that a biostimulant might lessen the harm that oxidative stress produces to common bean plants by salt stress. Antioxidant enzymes may be drastically decreased by the addition of biostimulants; this might be because of the several osmo-protectant molecules present in biostimulants, which lessen the negative consequences of salinity stress.

CONCLUSIONS

1. The results of this study showed that natural agents play a significant impact in reducing the negative effects of salt stress on *P. vulgaris* L.
2. *Spirulina platensis* extract showed the greatest improvement in growth parameters and pigment levels compared to the stress sample.
3. Bio-stimulants, particularly *S. platensis* extracts, dramatically increased the levels of protein, phenol, total soluble carbohydrates, and chlorophyll compared to the control.
4. Algal and medicinal plant extracts showed significant decrease in proline and antioxidant enzymes' content. These findings support the treatment's larger contribution in reducing detrimental effects of saltwater stress on *P. vulgaris* L.
5. These results confirm the promising role of biofertilizers in stimulating growth and protecting against salt stress as an alternative way to chemical treatment.
6. This research emphasizes the bioprotective benefits against saline stress that agricultural biofertilizers may provide to make agriculture more sustainable, environmentally friendly, and robust as well as a replacement for synthetic protectants, which are eroding in consumer favor. Additionally, it makes evident the importance of a novel class of biostimulants (extracted from *S. alba*, *P. guajava*, and *O. europaea* leaves), which have a protective effect against abiotic stress. However, it also highlights the pressing need to address the underlying processes underlying these benefits.

Conflicts of Interest

The authors declare no conflict of interest

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