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RESEARCH

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Sargassum sp. as a biofertilizer: is it really a key towards sustainable agriculture for The Bahamas?

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Abstract

Background Macroalgae blooms (*Sargassum* sp.) occur annually in The Bahamas due to the integration of various events related to human intercession with the roles of algae in biogeochemical cycles. These blooms are of great concern, as they are associated with many negative effects; thus, the primary aims of this study were to assess the quality of soils collected from South, Central, and North Long Island, and to determine whether *Sargassum* sp. can be used as a biofertilizer for soils on Long Island. A 60-day pot trial method was established to determine the efficacy of different concentrations (1%, 5%, and 10%) of *Sargassum* sp. as a biofertilizer on cherry tomato cultivation. Additionally, the soil quality before and after fertilizer amendment was evaluated.

Results The results show that *Sargassum* sp. increased nutrient content of the soil, specifically nitrate nitrogen and phosphorus; however, plant growth performance parameters (plant height, leaf number, bud number, flower number, and root and shoot weights) were negatively affected.

Conclusions Due to the obtained results, it is recommended that serious consideration be taken when utilizing *Sargassum* sp. as a biofertilizer because the pH and type of soil in Long Island, Bahamas, affects the bioavailability of the nutrients released from the algae.

Highlights

- *Sargassum* sp. was used as a soil amendment for *Lycopersicon* sp.
- *Sargassum* sp. increased soil nutrients, soil organic matter content, and salinity levels.
- *Sargassum* sp. treatments negatively affected the growth of tomatoes compared to the control group.

Keywords Alkaline soil, Microalgal biofertilizer, *Sargassum* species, Tomato cultivation, Soil nutrients, Long Island, Bahamas

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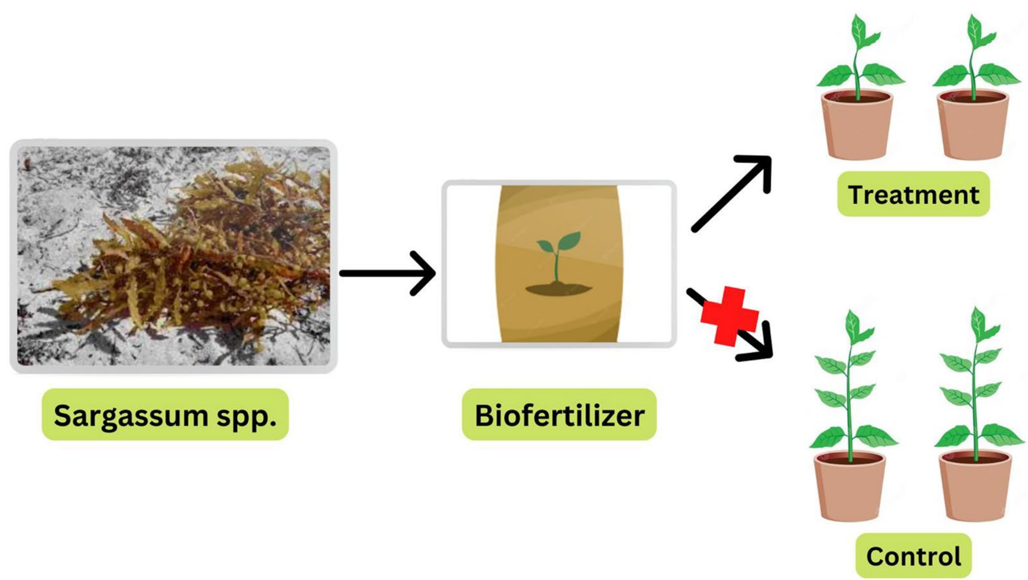
Graphical abstract



Background

The increasing food prices and limited agricultural sectors have resulted in a significant economic problem for Bahamians. This generated an increase in sustainable organic farming, also referred to as 'backyard farming' (Simpson Miller 2022). Additionally, The Bahamas has poorly developed alkaline soils referred to as protosols which have a pH range of 7.5–8.5 (Thomas 2017; Taylor and Ngatia 2021). The Bahamas also experiences hurricanes and floods which result in salt intrusion. Salinity negatively impacts the soil by increasing soil pH and decreasing organic matter content and the soil microbial biomass (Zhang et al. 2019; Wang et al. 2022). Despite the subtropical climate, the soil present on the limestone archipelago of The Bahamas is undesirable; however, it can be amended using fertilizers.

Fertilizers seem to be the best solution, but inorganic or synthetic fertilizers can be an economic challenge and extremely problematic for the environment (Mishra et al. 2013). The use of synthetic fertilizers, such as nitrogen, phosphorus, and potassium (NPK) fertilizer, is expensive; sustainable farmers are unable to afford it. Sustainable farmers are those that adopt conservative methods of cultivation that meet their needs without compromising environmental health nor the ability for upcoming generations to acquire their needs (Campos 2022). Moreover, the use of inorganic fertilizers has polluted water sources, contaminated the soil, killed microbes and organisms, reduced soil fertility, and increased the vulnerability of plants to disease. These consequential results have led to the driven necessity for biofertilizers (Mishra et al. 2013). Biofertilizers are substances that can be plant derived (lignocellulosic biomass) or animal derived, consisting of microorganisms that support plant growth by enhancing the nutrient supply when applied to the seeds, plants, or soil (Daniel et al. 2022).

Numerous studies have found that organic fertilizers, specifically algae biofertilizers, can maximize plant growth rate and crop yield while improving soil quality (Das et al. 2019; Kholssi et al. 2022; Bind et al. 2023). Furthermore, most importantly, the use of algal biofertilizer will combat the major issue of annual macroalgal blooms in the country. Macroalgae blooms are a natural phenomenon; however, their magnitude, duration, and frequency have proliferated due to both direct and indirect anthropogenic influences (Saedi et al. 2023). Godínez-Ortega et al. (2021) specifically articulated that these blooms are due to a combination of several incidences primarily related to human intercession with the roles of algae in biogeochemical cycles. Moreover, global warming and climatic change also contribute to the increase in macroalgae blooms (Zerrifi et al. 2018). Each year the beaches and coastlines of The Bahamas are engulfed with an abundant amount of *Sargassum* seaweed, specifically *Sargassum* fluitans and *Sargassum* natans (Mendez-Tejeda and Rosado 2019). There are several negative impacts associated with the mass influx of *Sargassum* sp. This influx impacts marine fauna, the livelihood of coastal communities, and the tourism sector (Mendez-Tejeda and Rosado 2019).

Furthermore, the use of organic fertilizers, especially algae biofertilizers, instead of synthetic fertilizers is the way forward. Seaweeds have been used historically as a fertilizer for many years, but the applications are advancing. Thompson et al. (2020) conducted a study in which the economic feasibility of utilizing seaweeds, specifically *Sargassum sp*., for biogas and biofertilizer production was evaluated. Moreover, in a study conducted by Coppens et al. (2016) to determine how microalgae affected the quality of tomatoes, it was found that the biofertilizer increased the sugar and carotenoid concentrations of the tomatoes. This resulted in tomatoes with better quality and higher economic value. As it pertains to the growth and yield rates, a study done in 2018 found that utilizing marine microalgae in the cultivation of rice increased yields by 7–20.9% (Dineshkumar et al. 2018). Additionally, in an experiment to determine the effectiveness of algae biofertilizer on onion cultivation, it was confirmed that microalgal biofertilizers have the potential to supercede inorganic fertilizers due to its successful increase in seed germination, seed quality, plant growth parameters, physical chemical parameters, and yield production (Dineshkumar et al. 2020). Prior research has agreed with the idea that biofertilizers, specifically algae, are the most desirable when compared to inorganic fertilizers. The implementation of algal biofertilizer use will conduce a healthy environment, socio-economic equity, and economic profitability globally (Win et al. 2018). Utilizing algal biofertilizers as an alternative to inorganic fertilizers correlates with long-term, organic, agricultural sustainability.

Although many studies and reviews have been conducted on the effects of algae biofertilizers on the cultivation of various plants, The Bahamas' soil type and pH are different from many of the soils used in the previous research. This study will assist in expanding the knowledge of macroalgae biofertilizer usage, specifically for the Bahamian soil type. The Bahamas has the potential to give the burden of macroalgal blooms both agricultural and economic value as a biofertilizer. Furthermore, most of the previous research only focuses on liquid extracts of algae as a biofertilizer instead of using shredded macroalgae or the macroalgae in its natural form. Thus, conducting an experimental study to determine the potential of *Sargassum* species in its granular form as a biofertilizer in alkaline soils will be beneficial.

The research questions for this study include: in using soil from South, Central, and North Long Island, what soil-to-algae biofertilizer ratio is needed for maximum growth performance of tomato plants during a 60-day period? What is the physicochemical status of the soil prior to the addition of the algae biofertilizer? How does different application rates of the algae biofertilizer affect the physicochemical properties of the soils using health indicators? And is there a difference in plant health and growth with the use of the control fertilizer (NPK fertilizer) and the experimental fertilizer (algae biofertilizer)?

The aim of this research is to determine whether *Sargassum* sp. is really a key towards sustainable agriculture for The Bahamas. The objectives are to assess the soil quality of soils collected in South, Central, and North Long Island using health indicators (pH, macronutrients (N, P, K), organic matter content, and soil water holding capacity), to determine whether *Sargassum* sp. can be used as a biofertilizer for soils on Long Island, to investigate how *Sargassum* sp. affects soil health and fertility, and to establish which application rate of *Sargassum* sp. is most ideal for cherry tomato cultivation within a 60-day period. It is hypothesized that: soil from South Long Island will have the best quality as compared to soils from Central and North Long Island; algae biofertilizer will improve soil health and fertility; and algae biofertilizer will result in better plant growth performance as compared to the control fertilizer (NPK fertilizer).

Methods

Algae collection and preparation

On 24 June and 26 June 2022, a total of 14.75 kg of damp *Sargassum* sp. was collected from Clarence Town, Long Island, Bahamas (23.10058° N, 74.96306° W). The *Sargassum* sp. was desalinated by placing it in a black fifty-five-gallon drum filled with water from a groundwater well located in Morrisville, Long Island, Bahamas (23.03597° N, 74.90030° W). From the 26 June to the 29 June 2022, the algae were soaked in the drum and the water was changed daily. From 30 June to 6 July 2022, the algae were laid on a black tarp to thoroughly dry in the sun. The algae were shredded into an almost powder-like form and stored in ziplock bags until needed (Kaladharan et al. 2021). This algae biofertilizer was added to the pots based on soil weight ratio. The treatments were mixed in batches and divided by 5 for each treatment (1%, 5%, and 10% application rates).

Experimental design

A 60-day pot trial method was utilized to test the effect of NPK fertilizer (Black Kow 0.5 - 0.5 - 0.5) and various application rates of brown algae, specifically *Sargassum* sp., on the growth of Yates Small Fry cherry tomatoes from 1 September 2022 to 30 October 2022 (Kumar and Nikhil 2016). Black Kow was utilized according to the manufacturers' protocol. In addition, the macroalgae were classified to the genus level using the phenotypic characteristics described by Mattio and Payri (2011).

Moreover, this pot trial method was completed outdoors in Morrisville, Long Island, Bahamas (23.03597° N, 74.90030° W), to ensure that the plants and soil experienced the environmental conditions of the island.

However, due to the high temperatures, the plants were placed in an area shaded by black, mesh greenhouse shade netting. To further optimize experimental conditions, the plants were undisturbed and watered twice a day (in the morning and afternoon, except when it rained). Seeds were planted in Jolly Gardener Potting Soil and transplanted into 1-gallon pots 6 weeks after sprouting, which was the 1 September 2022. Five replicates were used for each treatment with one (1) plant per pot. There were four treatments and a control group for each soil collected, giving a total of 75 pots and twelve (12) treatments—control group, 1% algae, 5% algae, 10% algae, and NPK fertilizer. Soil amendment was calculated based on the soils' dry weight.

Soil collection and analysis

Soils were collected from three locations in Long Island, Bahamas, to complete the 60-day pot trial method and determine which soil was best for the cultivation of tomato plants. Soil was collected from South, Central, and North Long Island, specifically from Roses (22.96511° N, 74.88258° W), Grays (23.21997° N, 75.10003° W), and Stella Maris (23.59067° N, 75.26932° W). The areas of soil collection in Roses (South Long Island) and Grays (Central Long Island) had been recently cleared by a tractor. Soil analysis was done prior to and after the experiment to determine soil pH levels, nitrate nitrogen, nitrite nitrogen, potassium, and phosphorus concentration levels using the LaMotte Agricultural Combination Soil Kit (Model STH – 14 - Soil Testing Outfit) (Jacobo et al. 2021). Prior to analysis, the soil samples were air-dried and sieved with a 5 mm sieve.

Soil type was determined using the Ribbon Method established by the Food and Agriculture Organization of the United Nations (FAO 2020). A five (5) in one (1) TDS/EC/pH/salinity/temperature meter (brand RRMY-Digital Multimeter) was used to measure soil salinity level percentage, salinity concentrations, total dissolved solids (TDS) value, and electrical conductivity (EC) value. The accuracy of the readings for salinity percentage was ± 0.1% for salinity levels of 0.01–5%, but ± 1% for salinity levels of 5.10% to 25%. The accuracy of EC and TDS readings was ± 2% of the reading. Moreover, a second meter (Portable Mini Digital Soil EC Meter Salinity Tester LCD) was used to measure electrical conductivity percentage from a soil slurry that was one part soil and two parts demineralized water (McCullough et al. 1999). The accuracy of the second meter for EC percentage was ± 2%.

In addition, the funnel method by Govindasamy et al. (2022) was modified to derive soil water holding capacity (SWHC) using 25 g of soil and 50 mL of water. From the SWHC obtained, the soil water retention percentage was calculated. Loss on ignition (LOI) tests were performed to determine organic matter percentage of the soil samples as soil weights were recorded after oven-drying at 105 °C for 24 h in a Fisher Scientific Isotemp Oven and after ignition (Heiri et al. 2001). An SH Scientific Muffle Furnace (version 2016) was used to combust the organic matter of the soil. The ignition conditions were 550 °C for 3 h (Hoogsteen et al. 2015).

Data collection

Growth performance parameters of the cherry tomato plants including plant height (cm), number of leaves plant^{-1}, number of buds plant^{-1}, and number of flowers plant^{-1} were recorded every 3 days. The plant height in centimetres was measured from the surface of the soil to the tip of fully opened leaves of the plant (Dineshkumar et al. 2020). Sixty days after transplanting, the plants were uprooted, washed, and dissected into roots and shoots. Root-to-shoot ratios were calculated from the dry biomass weights (Kumar and Nikhil 2016). To determine the dry weight of the roots and shoots, the plant material was weighed, wrapped in foil, oven-dried at 60 °C for 72 h in a Fisher Scientific Isotemp Oven, and re-weighed after drying (Hussain et al. 2010; Sultana et al. 2015).

Data analysis and statistical analysis

The growth parameters and soil analysis data (including soil pH, nitrate nitrogen levels, nitrite nitrogen levels, potassium levels, phosphorus levels, organic matter percentage, water retention percentage, salinity concentrations, TDS value, EC value, salinity level percentage, and EC percentage) were analysed via the software Microsoft Excel. The reported values for growth parameters are the means and standard error (means ± SE) of five replicates for treatments that did not experience plant death. The reported values for soil analysis data prior to the addition of treatment are the means and standard error (means ± SE) of three pseudoreplicates. The reported values for soil analysis data after the experiment and root and shoot dry weights are the means and standard error (means ± SE) of three of five replicates. The app 'Tiny Decisions' was used to randomly choose the three of the five replicates for treatments that had more than 3 plants.

Results

Soil analysis

The soils collected were alkaline prior to and after the addition of fertilizer treatments. The soil from North Long Island remained at a pH of 8.4, and the soils from

South and Central Long Island remained at a pH of 8. The soils acquired from North, Central, and South Long Island were classified as loamy sand, silt loam, and silt loam, respectively. The percentage of water retained in the soils from North, Central, and South Long Island were 28.7% ± 2.91, 42.7% ± 1.76, and 45.3% ± 1.76. Prior to the 60-day pot trial, soils collected from North, Central, and South Long Island had an organic matter percentage of 2.04% ± 0.07, 14.79% ± 2.24, and 15.78% ± 0.45, respectively. After the 60-day pot trial, most treatments experienced an increase in soil organic matter (SOM) (Additional file 1: Table S1). Preceding and following treatment, the soil obtained from Central Long Island had the highest salinity concentrations, TDS values, and EC values from the soils collected (Additional file 1: Tables S2 and S3).

The nutrient composition of each soil varied before and after the pot trial. The nitrate nitrogen levels for North, Central, and South Long Island soils before the pot trial were 5 ± 0 mg kg^{-1}, 26.7 ± 3.33 mg kg^{-1}, and 66.7 ± 8.33 mg kg^{-1}, respectively. The nitrite nitrogen levels for North, Central, and South Long Island soils were below detection, 5 ± 0 mg kg^{-1}, and 1 ± 0 mg kg^{-1}, respectively. The phosphorus concentration levels for North, Central, and South Long Island soils were 18.3 ± 6.67 mg kg^{-1}, 50 ± 0 mg kg^{-1}, and 5 ± 0 mg kg^{-1}, respectively. The potassium levels were below detection for all soils collected. After the 60-day pot trial, nitrite nitrogen and potassium levels were below detection in all soils and all treatments including NPK fertilizer treatment. However, the concentration of nitrate nitrogen and phosphorus varied among the control groups and all treatments (Fig. 3).

Growth performance parameters

Plant height (cm)

During the 60-day pot trial, there were fluctuations in plant height (Additional file 1: Fig. S1). The difference in initial and final plant height for the treatments in each soil varied; however, those plants in soil from North Long Island had the greatest change in height for most treatments (Fig. 1). All plants in Central Long Island soil, which had been treated with 10% algae, had a 0% survival rate.

Number of leaves plant^{-1}

Similar to plant height, during the 60-day pot trial, there were fluctuations in the number of leaves (Additional file 1: Fig. S2). The change in initial and final number of leaves for the treatments in each soil varied; however, those plants in soil from North Long Island had the greatest change in number of leaves for all treatments except the 5% algae treatment (Fig. 2).

Number of buds and flowers plant^{-1}

Five groups produced buds during the 60-day pot trial. These include the control groups for plants in North and Central Long Island soil and plants under NPK fertilizer treatment in all soils. During the last 24 days of the experiment, the control group for tomatoes planted in soil from North Long Island produced buds. The average number of buds plant^{-1} recorded every third day was 3, 3, 5, 3, 3.33, 7, 7.67, and 7.5. During the last 15 days of the experiment, the control group for tomatoes planted in soil from Central Long Island produced buds. The average number of buds plant^{-1} recorded every third day was 4, 5, 6, 4, and 3. During the last 15 days of the experiment, the tomatoes treated with NPK fertilizer planted in soil from North Long Island produced buds. The average number of buds plant^{-1} recorded every third day was 3, 3, 4.5, 5.5, and 6. During the last 15 days of the experiment, the tomatoes treated with NPK fertilizer planted in soil from Central Long Island produced buds. The mean of the buds plant^{-1} recorded every third day was 3, 4, 4, 7, and 4. During the last 6 days of the experiment, the tomatoes treated with NPK fertilizer planted in soil from South Long Island produced buds. On every third day, an average of 3 and 3 buds plant^{-1} were recorded (Fig. 3).

The four treatments that produced flowers were the control groups for tomatoes planted in soil from both North and Central Long Island, and the tomatoes under NPK fertilizer treatment planted in soils from North and Central Long Island. During the last 15 days of the experiment, the control group for tomatoes planted in soil from North Long Island produced flowers. The average number of flowers plant^{-1} recorded every third day was 4, 4, 4, 4, and 2.5. During the last 9 days of the experiment, the control group for tomatoes in Central Long Island soil produced flowers. The average number of flowers plant^{-1} recorded every third day was 2, 4, and 5. During the last day of the experiment, the tomatoes treated with NPK fertilizer planted in soil from both North and Central Long Island produced flowers. The average number of flowers plant^{-1} recorded for both treatments was 3.

Root-to-shoot biomass ratio

The root and shoot dry weights varied among all treatments; however, there is a clear depiction of the treatments that did the best for each soil location (Table 1). The control group had the highest dry root and shoot weights for plants in soil from North Long Island. The treatment that produced the plants with the highest dry biomass weights, in soil from Central Long Island, was the 5% algae treatment. Soil from South Long Island treated with NPK fertilizer produced the plants with the highest dry root and shoot weights.

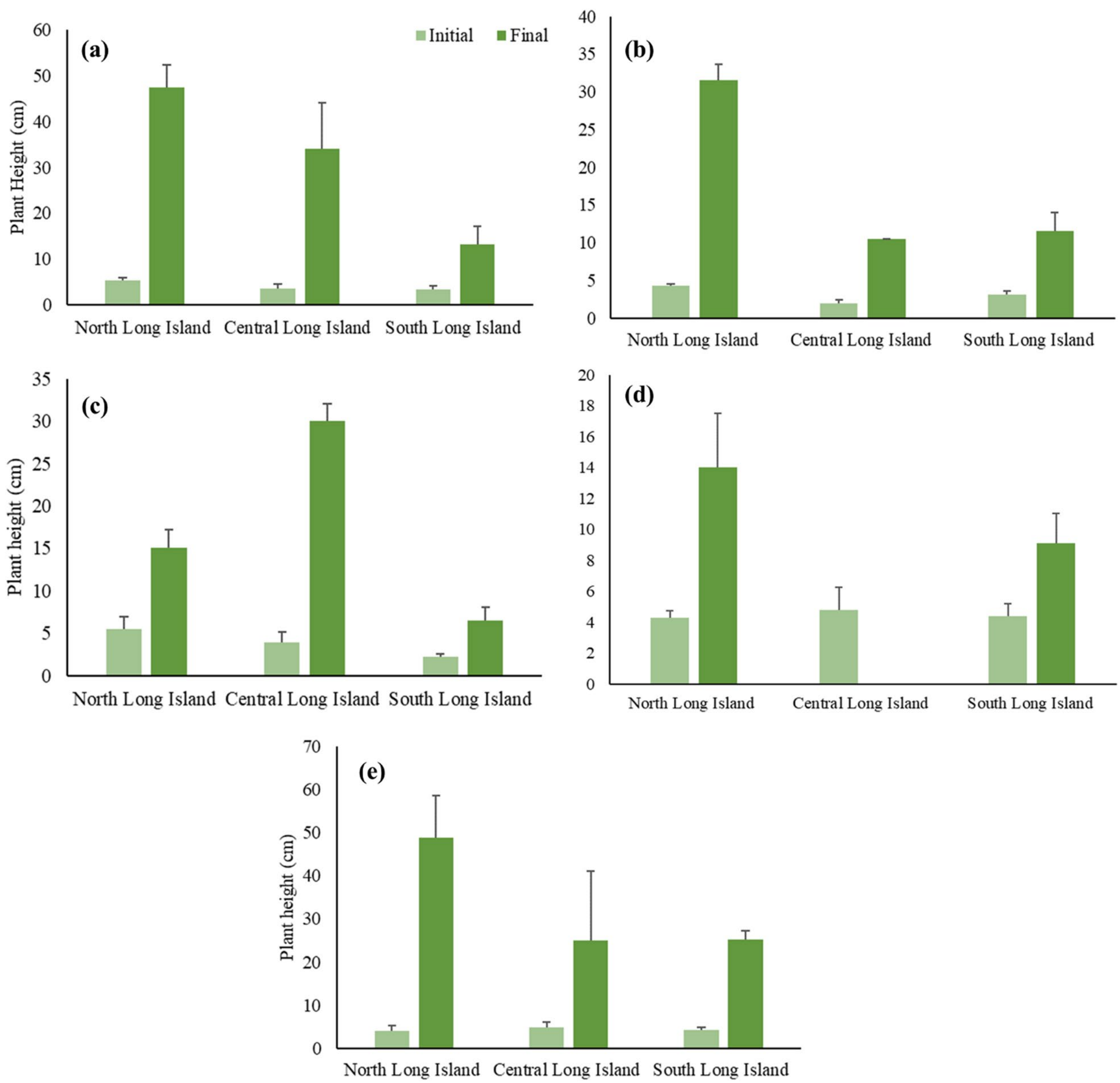


Fig. 1 Comparison of initial and final plant height for the 60-day pot trial for **a** control groups, **b** 1% algae treatment, **c** 5% algae treatment, **d** 10% algae treatment, and **e** NPK fertilizer treatment

Discussion

The Bahamas has alkaline, oolitic, and calcareous soils that are derived from dissolved limestone which is primarily calcium carbonate ($CaCO_3$). Soil pH is an excellent indicator of the relative availability of nutrients. Maximal availability of nutrients is seen in soils with a pH range of 6–7 (Taylor et al. 2017). Due to the alkalinity of soils in Long Island, nutrient bioavailability was reduced. The presence of carbonate ions affects the soil chemistry. Soils with a pH greater than 7.5 result in deficiencies in iron (Fe), phosphorus (P), and zinc (Zn). In addition, there is a nutrient imbalance of the cations calcium (Ca), magnesium (Mg), and potassium (K) (Msimbira and Smith 2020). In this study, the addition of *Sargassum* sp. did not affect soil pH as a result of the strong pH buffer capacity of soils containing clay (Senbayram et al. 2019). The *Sargassum* treatments also decreased plant growth; conversely, data from other studies are contrasting (Additional file 1: Table S4). However, there was an increase in SOM, nutrient concentration (nitrate nitrogen and

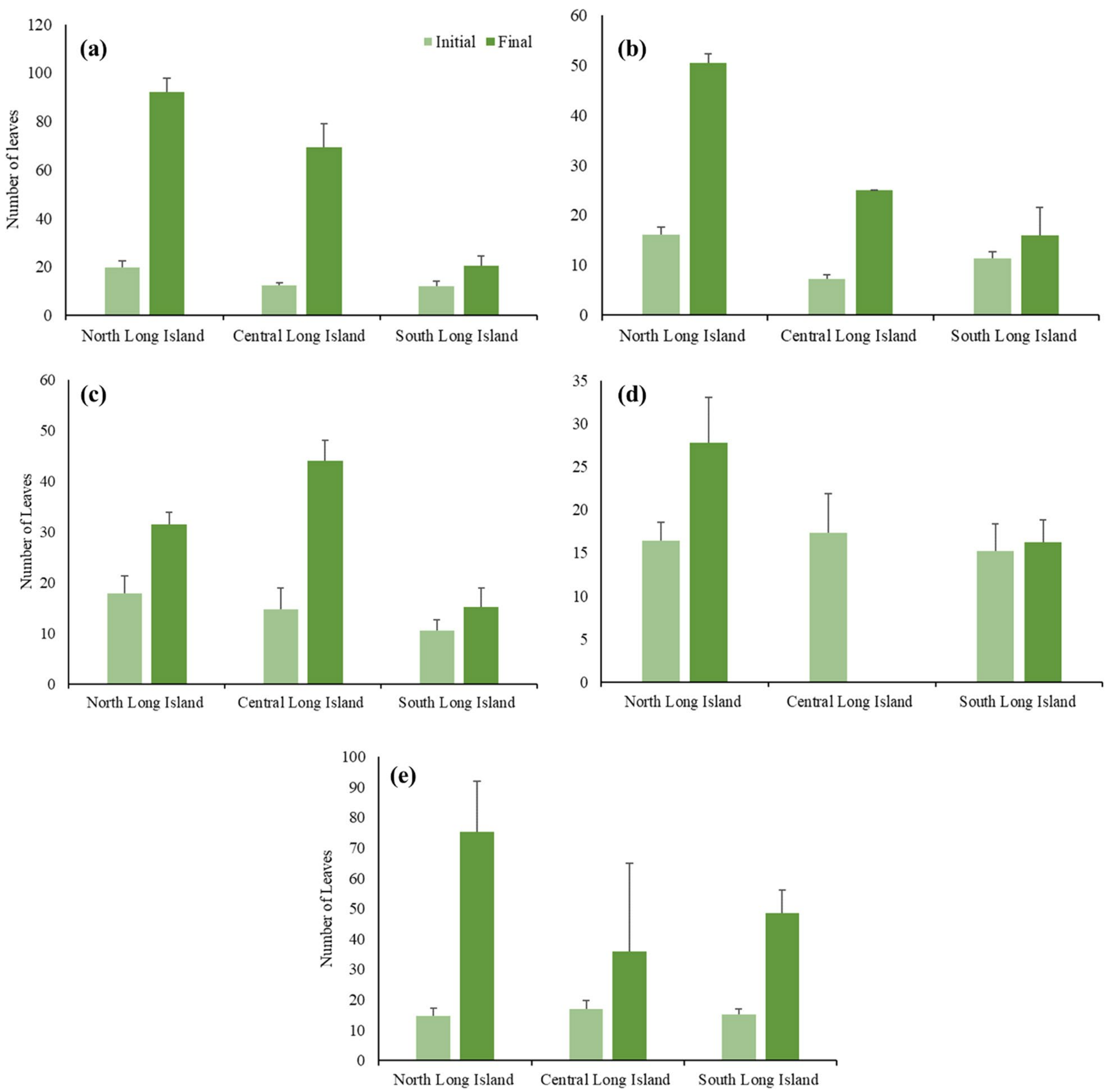


Fig. 2 Comparison of initial and final number of leaves for the 60-day pot trial for **a** control groups, **b** 1% algae treatment, **c** 5% algae treatment, **d** 10% algae treatment, and **e** NPK fertilizer treatment

phosphorus), and salinity levels. Similar results are seen in a study conducted by Izzati et al. (2019) as there was an increase in SOM, and nitrogen levels. Contrarily, the addition of the macroalgae reduced the pH to 7, thus increasing nutrient bioavailability. Additionally, Muarif et al. (2022) articulated that the addition of seaweed increases the amount of SOM, nitrogen, phosphorus, potassium, and sodium (when used in large quantities).

Soil pH, organic matter content, nutrient concentrations, and salinity levels have a significant role in plant growth and development. Alkalinity stress on crop plants such as tomatoes is similar to salt stress. Alkalinity stress results in stunted plant growth due to poor nutrient uptake as seen in most *Sargassum* sp. treatments of the 60-day pot trial when compared to the control groups (Fig. 1). Furthermore, tomatoes are classified as glycophytes: plants that are sensitive to salt and cannot tolerate salt stress despite their ability to adapt by developing protective measures (Safdar et al. 2019). Soil salinity levels become toxic for glycophytes between 50 and 100 mM

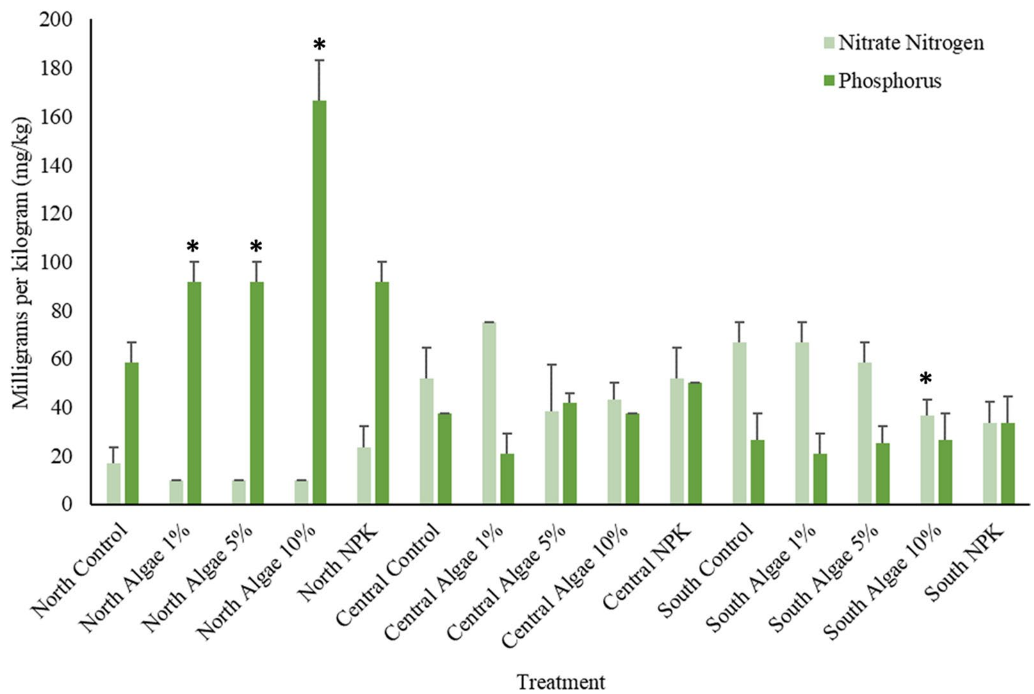


Fig. 3 Soil nutrient levels after the 60-day pot trial. Asterisks indicate significant differences when compared to the control groups ($p < 0.05$)

Table 1 Root and shoot dry weights and root-to-shoot ratios for each treatment

Treatment	Root dry weight (g)	Shoot dry weight (g)	Root-to-shoot ratio
North control	0.93 ± 0.19	4.29 ± 0.15	1:4.61
North algae 1%	0.12 ± 0.03	0.69 ± 0.21	1:5.75
North algae 5%	0.08 ± 0.03	0.41 ± 0.22	1:5.13
North algae 10%	0.02 ± 0.02	0.14 ± 0.08	1:7.00
North NPK	0.39 ± 0.08	2.68 ± 0.62	1:6.87
Central control	0.23 ± 0.13	1.53 ± 0.69	1:6.65
Central algae 1%	0.02	0.23	1:11.5
Central algae 5%	0.30 ± 0.20	1.63 ± 0.97	1:5.43
Central algae 10%	–	–	–
Central NPK	0.10 ± 0.09	0.57 ± 0.47	1:5.70
South control	0.04 ± 0.03	0.27 ± 0.12	1:6.75
South algae 1%	0.10 ± 0.10	0.47 ± 0.40	1:4.70
South algae 5%	0.01 ± 0.01	0.04 ± 0.02	1:4.00
South algae 10%	0.01 ± 0.01	0.06 ± 0.01	1:6.00
South NPK	0.26 ± 0.15	1.64 ± 1.02	1:6.31

NaCl (Guo et al. 2021). However, Tola et al. (2023) stated that tomatoes have a salinity threshold of 1600 mg kg^{-1}. Although this salinity threshold was not obtained in any of the soils treated with *Sargassum* treatments, there were treatments within soil from Central Long Island that surpassed 1000 mg kg^{-1} (Fig. 4). The incredibly high salinity concentration of soil collected from Central Long Island prior to the *Sargassum* treatments is attributable to the nearby brackish bodies of water. During previous hurricanes, this area has experienced storm surge and settlement of water. Wei et al. (2021) corroborated that nearby brackish water can induce an accumulation of salt in soil.

Salinity is an abiotic stress that affects the growth of tomato plants at all stages and ultimately restricts fruit production. It interferes with the uptake of nitrogen, thus minimizing plant growth, development, and reproduction (Devkar et al. 2020). Salinity reduces plant uptake of phosphate as it causes phosphate ions to precipitate with calcium ions, thus limiting water uptake (Shrivastava and Kumar 2015). In addition, high soil sodium (Na) levels increase water lost as stomatal closure is affected (Msimbira and Smith 2020). This aggregation of sodium imposes osmotic stress, ion toxicity, and nutrient deficiency (of N, P, K, Ca, Fe, and Zn). Oxidative stress, resulting in reactive oxygen species, is also a consequence of sodium accumulation within the plant (Shrivastava and Kumar 2015).

Root and shoot weights are also affected by soil alkalinity and salinity. Carbohydrates produced during the process of photosynthesis are allocated by plants to support growth, maintenance, development, and reproduction (Hartmann et al. 2020). The dry biomass, including root and shoot dry weights, shows carbon allocation.

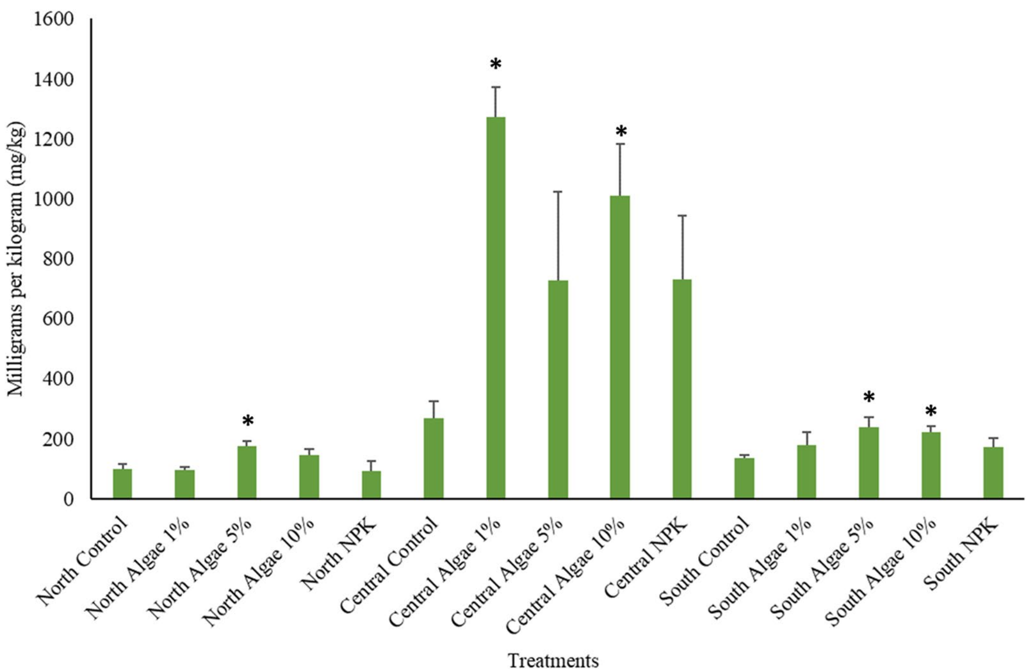


Fig. 4 Soil salinity levels after the 60-day pot trial. Asterisks indicate significant differences when compared to the control groups ($p < 0.05$)

Leaf number assists in increasing shoot biomass. Therefore, the more the leaves, the higher the shoot biomass. Increased numbers of leaves allows for a greater surface area for photosynthesis to occur. Plants can detect changes in resources in the soil and respond accordingly by optimizing growth, development, and biomass allocation (Kudoyarova et al. 2015). In addition, carbon allocation to the roots is done in response to shortage of nutrients including nitrate and phosphorus (Kudoyarova et al. 2015). Larger shoot biomass, as compared to root biomass, is an indication that water and nutrients are readily available and more carbon is allocated to the shoot to allow for growth and development of leaves, fruits, etc. There are variations in the dry root to shoot biomass for the treatments of this study (Table 1). Increased salinity levels reduce root growth and development and result in a decline in the shoot biomass (Tang et al. 2021). Moreover, alkaline soils reduce root development by impairing the water supply to the plant (Msimbira and Smith 2020).

Consequently, the macroalgae treatments negatively impacted the growth performance parameters of the cherry tomato plants as the control groups produced plants with greater changes in plant height and number of leaves (from day 1 to day 60) and reduced their total biomass (Figs. 2 and 3; Table 1). Additionally, the first plants to start reproducing were those in the control groups. Although the addition of *Sargassum* increased nutrient content, the bioavailability of the nutrients did not increase due to the alkalinity of the soil. As a result of stress from soil salinity and alkalinity, the survivability rate for tomato plants varied among treatments (Additional file 1: Table S5).

To conclude, all the aims and objectives of this study were met. The soil quality of Long Island is poor as the soils lack sufficient concentrations of the basic macronutrients (nitrogen, phosphorus, and potassium). *Sargassum* sp. can be used as a biofertilizer for soils in Long Island with specific recommendations such as waiting on the soil to age, allowing decomposition and release of nutrients. *Sargassum* sp. has a positive effect on soil health and fertility as it increases nutrient concentration and organic matter; however, with the application rates used, it did not enhance growth performance. Lastly, based on results obtained, none of the application rates are ideal for tomato cultivation.

If this research was to be repeated, it is recommended that another species of algae be used, categorically a freshwater species, to prevent the increase in soil salinity, TDS and EC. However, if *Sargassum* sp. is used, the soil should be allowed to age so that nutrients can be released upon decomposition of the macroalgae and become more bioreadily available. Additionally, if time is limited, a halophyte can be used as these plants are tolerant to salt. Other recommendations include composting or biodigesting the *Sargassum*, using different application rates, and conducting a field experiment instead of utilizing a pot trial method to limit the 'pot effect'.

Conclusions

Although Bahamian soils are characterized by alkalinity and low fertility, the 60-day pot trial has provided data that will benefit Bahamians in the agricultural field, especially sustainable farmers. The addition of *Sargassum* sp. enhanced soil fertility by increasing organic matter content, nitrate nitrogen levels, and phosphorus levels. Prior research portrays that algae including various *Sargassum* species has improved soil health and increased plant growth performance parameters including plant height and number of leaves, buds, flowers, and fruits. However, the results obtained in this research show that *Sargassum* sp. treatments negatively affected plant growth performance parameters when compared to the control groups, and increased the soil salinity concentrations. For this primary reason, farmers should take caution when cultivating *Sargassum* sp. as a biofertilizer. Overall, this study provides significant insight into the effects of *Sargassum* sp. as a soil amendment for cultivating tomatoes in alkaline soil. How *Sargassum* sp. affects other species and different soil types is a question worthy of further investigation.

Abbreviations

Ca	Calcium
EC	Electrical conductivity
Fe	Iron
K	Potassium
Mg	Magnesium
NPK	Nitrogen, phosphorus, and potassium
P	Phosphorus
TDS	Total dissolved solids
Zn	Zinc

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42269-023-01087-w.

Additional file 1. Supplementary Information.

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Author contributions

AA, WG, and SW performed the measurements. CW, CB, and WG were involved in planning and supervised the work. AA, JF, and DS processed the experimental data and performed the analysis. AA, WG, and CW drafted the manuscript. AA, WG, SW, DS, CB, and CW discussed the results and commented on the manuscript. All authors have read and approved the manuscript.

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Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

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Competing interests

The authors report there are no competing interests to declare.

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