ORIGINAL ARTICLES

# The Use of *Sargassum Sp.* Extract as a Bio-Fertilizer

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**Abstract**

The study examined the effects of *Sargassum sp.* (seaweed) extract on the growth of chickpea plants (*Cicer arietinum*). The seaweed extract was applied to the chickpea plant either as a foliar spray or as a soil conditioner. Results indicated that foliar application of the extract significantly enhanced germination rates, achieving 100% compared to 70% for soil conditioner, 90% for synthetic fertilizer, and 80% for control. Conversely, applying the seaweed extract to the soil as soil conditioner increased the biomass and height of the chickpea plants. This increase in biomass and height was ascribed to the decrease in soil salinity. Additionally, the seaweed extract improved nitrate and phosphorus uptake which contributed to plant growth. Together, these results suggest that seaweed extract can be used as an alternative to synthetic fertilizers, especially in the Bahamian context. It also suggests that applying seaweed as an extract does not increase soil salinity as previously observed when the seaweed itself was used as a soil conditioner.

## Introduction

Soil health is a major concern within the Bahamian agricultural sector. Recent studies on Bahamian soils revealed that, while nitrogen levels in Bahamian soils were adequate, potassium, phosphorus, pH, and organic carbon were suboptimal (Chambers et al., 2023). Most notably, due to the limestone nature of Bahamian soil (Moebius-Clune et al., 2016), the pH exceeded the optimal range of 6.4–7.3, based on the Cornell Assessment of Soil Health framework.

Seaweeds, classified as macroalgae, include Phaeophyta (brown), Rhodophyta (red), and Chlorophyll (green) algae (Guimaraens et al., 2006). Globally, over 11,017 macroalgal species have been identified (Stiger-Pouvreau & Zubia, 2020) with brown macroalgae being the most common species found in coastal areas. *Sargassum sp.* (seaweed) has shown significant increases in growth due to rising global temperatures (Short & Neckles, 1999). Given this rise in the seaweed abundance and potential benefit to agriculture, numerous studies have explored its applications. Studies have shown that seaweed extract supplies plants with valuable nutrients such as growth hormones (ethylene, auxins, gibberellins), carbohydrates, and essential nutrients. Furthermore, seaweed-based fertilizers are biodegradable and non-toxic, making them an eco-friendly alternative to synthetic fertilizers (Sasikala et al., 2016).

While synthetic fertilizers have improved crop yields and made food production more affordable, they also contribute to significant environmental, economic, and social issues (Altieri, 1998). Furthermore, the cost for synthetic fertilizers is particularly burdensome for smallholder farmers who cannot afford to apply them at large scales. Moreover, the use of synthetic fertilizers has negatively affected soil health since it leads to soil degradation through heavy metal contamination, acidification, and increased soil salinity.

The abuse of fertilizers can also have detrimental impact on crop health and production. The improper application of fertilizer leads to increase soil salinity, which dehydrates plant roots and limit nutrient uptake (Hygrozyme, 2021). Studies have also shown that overfertilization can results in stunted growth, excessive foliage with fewer blooms, halted reproduction, and leaf rusting (Hygrozyme, 2021; Shershen et al., 2016). Similar negative effects have also been observed when using unprocessed or "unwashed" seaweed as a soil conditioner as the salt content in the seaweed was directly deposited into the soil, leading to plant death (Thompson et al., 2020; Adderley et al., 2023).

Recent studies have shown that seaweed extract applied as a foliar spray is a more effective fertilization method than soil conditioning (Sutharsan et al., 2014). Although small traces of salt have been detected in soils treated with seaweed extract foliar spray, the effects are far less severe than those observed when using unprocessed seaweed as a soil conditioner. However, limited research exists on the impact of seaweed extract on soils with high pH, low nutrient levels, and low organic carbon content. Thus this study aims to evaluate the effects of seaweed extract applied both as a foliar spray and as a soil conditioner on soil health and plant growth in Bahamian soils characterized by high pH and nutrient deficiencies. The objective of this study is to assess soil and chickpea plants' (*Cicer arietinum*) health with and without the application of seaweed extract as a foliar application and as a soil conditioner. It is hypothesized that seaweed extract foliar application will yield the most favorable plant growth and soil quality outcomes compared to other treatments.

## Materials and Methods

### *Seaweed Extract Soil Conditioner*

The *sargassum sp.* (seaweed) extract was obtained from Bari Farms, a local seaweed biofertilizer manufacturer. The seaweed extract (30 ml) was diluted with 3785 ml of non-chlorinated water, following the manufacturer's instructions. During the germination stage of the chickpea seeds, 100 ml of the mixture was applied every other day. In the seedling stage, the plants continued to receive 100 ml of the mixture every other day. After the seedling stage, the extract concentration was increased to 240 ml and diluted with the same volume of non-chlorinated water (3785 ml) following the manufacturer's instructions. The soil conditioner solution contained 700 ± 73.60 mg/kg of potassium, 168.75 ± 6.25 mg/kg of phosphorus, and 162.50 ± 23.94 mg/kg of nitrate nitrogen.

### *Seaweed Extract Foliar Spray*

The seaweed extract (5 ml) was diluted with 1000 ml (one liter) of non-chlorinated water. During the germination stage, 100 ml of the solution was applied every other day. The same irrigation schedule was maintained in the seedling stage. After the seedling stage, the concentration of the extract was increased to 15 ml, again diluted with 1000 ml of non-chlorinated water following the manufacturer's instructions. The foliar spray had a potassium level of 2262.50 ± 322.34 mg/kg, a phosphorus level of 787.50 ± 23.94

mg/kg, and a nitrate nitrogen level of 450 ± 125.83 mg/kg.

### *Synthetic Fertilizer*

Miracle-Gro™ was used as the synthetic fertilizer in this study. It has potassium-phosphorus -nitrate ratio of 24-8-16. A 10 ml portion of the fertilizer was diluted with 3785 ml of non-chlorinated water, according to the manufacturer's instructions. During the germination stage, 100 ml of the fertilizer mixture was applied weekly, with non-chlorinated water used on the remaining days. This irrigation schedule was maintained throughout the seedling and plant growth cycle.

### *Experimental Design*

A 48-day pot experiment was conducted to assess the effect of the seaweed extract (as a soil conditioner and foliar spray) and synthetic fertilizer on chickpea plants' germination speed and growth. The germination success and pot comparative analyses were conducted separately. For the germination success experiment, seeds were placed in sterile containers indoors to minimize contamination. The seeds were disinfected with 3% hydrogen peroxide at 60 °C for five minutes (see Suslow, 2004). Ten seeds were placed in a separate container for each treatment.

The pot analysis was conducted outdoors in a shaded area to control light exposure. The pots were arranged randomly to eliminate positional bias. The seeds were grown in Bahamian sandy-loam soil to simulate challenging conditions and assess whether the soil influenced crop growth.

In the experiment, twenty-four one-gallon pots were filled with 1497 g of soil. Six replicates were used for each treatment within the experiment. The seaweed extract foliar spray, soil conditioner and synthetic fertilizer were prepared following the respective manufacturer's instructions. On February 14, 2024, before planting, the soil in each pot was treated with 100 ml of the respective mixtures, and four seedlings were planted per pot, spaced evenly to promote adequate growth.

### *Soil Collection and Analysis*

The soil was air dried prior to analysis. The soil's nitrogen, potassium, and phosphorus levels were measured before and after the experiment using a LaMotte Agricultural Combination Soil Kit (Model STH – 14 Outfit) as was reported in previous studies (Adderley et al., 2023; Chambers et al., 2023; Jacobo et al., 2021). Soil salinity and pH were measured with the use of a 5-in-1 TDS/ EC/ pH/ Salinity/ Temperature meter (Brand RRMY-Digital).

### *Data Collection and Analysis*

The germination success rate was obtained by recording the ratio of seeds that germinated against the total number of seeds (Sasikala et al., 2016). The growth parameters of the chickpea plants were recorded every second day starting on February 14, 2024. Growth parameters, including the number of leaves and plant height, were recorded every other day starting on February 14, 2024. Plant height was measured from the soil surface to the tip of the leaves. Fresh weights of roots and shoots were recorded after plants were gently extracted, rinsed, and separated into roots and shoots. Dry weights were measured after the plants were oven-dried at 60 °C for 72 hours in a Fischer Scientific Isotemp Oven. The soil analysis data, recorded before treatment application, represent the means and standard errors (means ± SE) of six replicates.

## Results and Discussion

### *Soil Salinity and Nutrients*

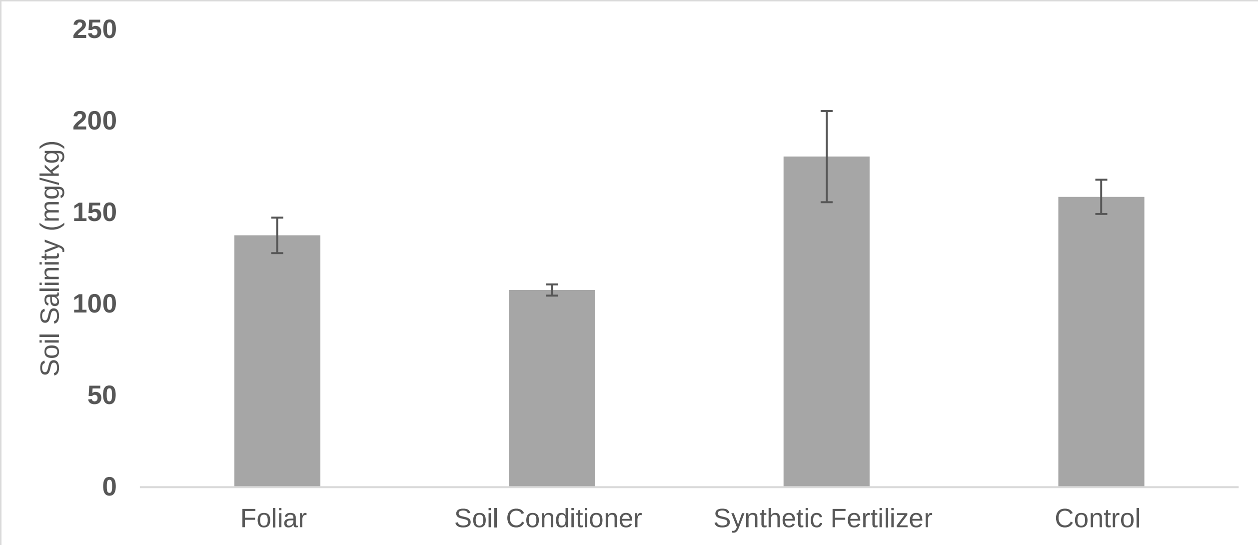
The present study was conducted to evaluate the effects of seaweed extract on chickpea plant growth and soil health. Our results showed that soil pH ranged from 8.33 to 8.63 across all treatments. The initial soil pH before treatment application was 8.4. After the addition of the seaweed extract as a foliar spray and soil conditioner, the pH values were 8.42 and 8.63, respectively. The synthetic fertilizer and control treatments had pH values of 8.33 and 8.57, respectively. Studies have shown that soil pH plays an important role in nutrient availability. Soils within a pH range of 6.4 to 7.3 have the highest nutrient availability (Moebius-Clune et al., 2016). As soil pH increases, the solubility of iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) decreases significantly (Westerman, 2015). When soil pH exceeds 8.0, plants may suffer from Fe chlorosis due to reduced chlorophyll production, which causes leaves to turn yellow (Chakraborty et al., 2015). In our study, some crops appeared to exhibit symptoms of Fe chlorosis before they withered. The number of viable plants used in the experiment for the seaweed extract foliar spray, soil conditioner, synthetic fertilizer, and control groups were 13, 12, 3, and 8, at the end of the study.

The addition of the seaweed extract did not increase soil salinity compared to the control and synthetic fertilizer treatments (Figure 1). This suggests that using a seaweed extract instead of directly adding whole seaweed to the soil as an amendment could mitigate the negative impacts previously reported when seaweed was used as a bio-fertilizer. Our previous study showed that using whole seaweed as a soil amendment can increase soil salinity (Adderley et al., 2023). In this study, the salinity levels in the seaweed soil conditioner treatment were lower than in the other treatments, with values of 107.75 ± 3.07 mg/kg compared to 180.67 ± 24.92 mg/kg for the synthetic fertilizer, 158.67 ± 9.35 mg/kg for the control, and 137.60 ± 9.69 mg/kg for the foliar spray (Figure 1). The optimal salinity threshold that plants can tolerate is no more than 230 mg/kg (WateReuse Foundation, 2007). Maintaining soil salinity within the optimal range is important, as elevated salinity can negatively affect seed germination and seedling survival, which, in turn, can reduce crop production and yield (Aymen et al., 2014; Abdel Latef et al., 2017). These findings are consistent with our results, as plants grown under the soil conditioner treatment exhibited the best growth and shoot-to-root biomass ratio.

The nitrate levels in soil samples treated with the seaweed extract were lower than those observed in the synthetic fertilizer and control treatments. Soil nitrate levels in the foliar spray and soil conditioner treatments were 36.50 ± 16.48 mg/kg and 82.50 ± 10.16 mg/kg, respectively, compared to 133.33 ± 4.17 mg/kg for the synthetic fertilizer and 96.67 ± 23.51 mg/kg for the control (Figure 2). Studies have shown that an accumulation of nitrate in the soil can be a sign of plant stress, as stressed plants are less able to metabolize nitrate into proteins efficiently. These results are consistent with our findings, as plant growth and biomass in the foliar spray and soil conditioner treatments were better than those in the control and synthetic fertilizer treatments (Dechorgnat et al., 2011; Zayed et al., 2023).

**Figure 1**

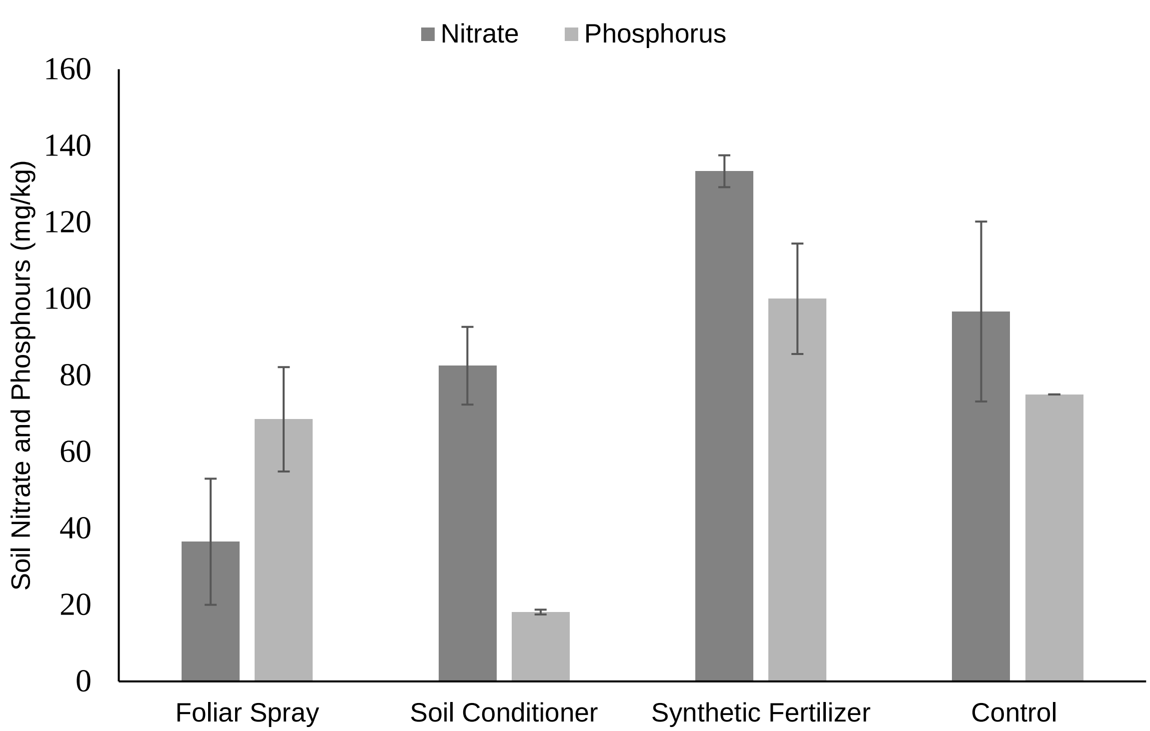
*Soil Salinity for Each Treatment on Day 48, when the plants were harvested.*




*Note:* Data represent mean ± SE

**Figure 2**

*Soil Nitrate and Phosphorus for Each Treatment on Day 48, when the plants were harvested.*




*Note:* Data represent mean ± SE

The soil conditioner treatment had the lowest phosphorus level, measuring 18.13 ± 0.63 mg/kg. This may have occurred due to lower salinity levels and potentially higher phosphorus uptake by the plants in those samples. Previous research has demonstrated a negative correlation between soil salinity and phosphorus availability (Duan & Kaushal, 2015; Xie et al., 2022). Our study observed a similar relationship, where high salinity levels negatively affected phosphorus uptake, resulting in excess phosphorus accumulation in the soil. The optimal phosphorus levels for plant growth are between 3.5 and 21.5 mg/kg (Moebius-Clune et al., 2016). Excess phosphorus can induce deficiencies of Fe and Zn, leading to symptoms such as stunted growth and leaf yellowing (Smith et al., 2019). The synthetic fertilizer treatment had the highest phosphorus level at 100 ± 14.43 mg/kg, along with a salinity level of 158.67 ± 9.35 mg/kg (Figure 1). A similar trend was observed in the control and foliar spray soil samples, which also had elevated phosphorus levels. In contrast, the soil conditioner treatment exhibited the lowest phosphorus levels, which can be attributed to the reduced salinity, allowing plants in these pots to absorb more phosphorus from the soil.

**Table 1**

*Plant Height, Shoot, and Root Dry Weights for the Different tTeatments.*

| Treatment | Plant Height (cm) | Shoot Dry Weight (g) | Root Dry Weight (g) |
|---|---|---|---|
| Foliar Spray | 28.79 ± 1.30 | 1.48 ± 0.44 | 0.48 ± 0.16 |
| Soil Conditioner | 31.04 ± 1.33 | 2.38 ± 0.51 | 0.67 ± 0.16 |
| Synthetic Fertilizer | 28.5 ± 0.94 | 0.76 ± 0.26 | 0.16 ± 0.05 |
| Control | 28.58 ± 1.16 | 1.66 ± 0.21 | 0.45 ± 0.06 |

*Note:* Data are presented as mean ± SE

### *Seaweed Effects Chickpea Seed Germination*

The application of seaweed extract as a foliar spray improved the germination rate of chickpea seeds. When applied as a foliar spray, the germination rate was 100%. In contrast, when used as a soil conditioner, the germination rate was only 70%. The germination rates for the synthetic fertilizer and control treatments were 90% and 80%, respectively. We hypothesize that the differences in germination rates cannot be attributed to variations in salinity between the treatments, as both the foliar spray and synthetic fertilizer has higher salinity levels than other treatments since, the salinity level of the foliar spray was 2,573 ± 7.50 mg/kg, whereas that of the soil conditioner was 2,332.50 ± 4.79 mg/kg. On the contrary, studies have shown that high salinity can significantly affect seed germination and seedling survival due to the toxic effects of ions such as chloride and sodium (Aymen et al., 2014; Adilu & Gebre 2021). Furthermore, high salinity can also impact the seeds' ability to absorb water. This occurs because seeds and seedlings of non-halotolerant plants have a lower tolerance to high salinity, as they have not yet acclimatized to such conditions during the early stages of their growth cycle (Sasikala et al., 2016; Van Iersel, 2020; Adilu & Gebre, 2021). While it is unclear what specifically influenced the germination rates in the synthetic fertilizer and foliar spray, the higher concentrations of phosphorus and nitrate may have contributed to improved seed germination. Conversely, the lower germination rate observed in the soil conditioner treatment may be attributes to microbial contamination. All samples treated with the soil conditioner showed evidence of fungal contamination, which likely impacted the germination (Barreto et al., 2002).

### *Seaweed Effects Chickpea Plant Growth*

The soil conditioner treatment yielded a maximum shoot length of 31.04 ± 1.33 cm. The observed plant height was positively correlated with the root-to-shoot ratio, as shown in Table 1. The increase in plant height corresponded to a higher root-to-shoot ratio. Previous research has reported the negative effects of unprocessed seaweed on crop growth due to elevated salinity levels (Adderley et al., 2023). However, other studies have demonstrated the positive effects of seaweed extract, at various concentrations, on plant growth and germination rates (Sasikala et al., 2016). Similar positive effects were observed in this study, which can be attributed to the lower soil salinity and higher nutrient uptake (Figures 1 and 2). In contrast, the synthetic fertilizer treatment had the lowest root and shoot weights (Table 1). This may be due to increased soil salinity and higher nutrient accumulation in the soil. The elevated salinity could have stressed the plants, causing them to absorb less nitrate, which is essential for plant growth (Dechorgnat et al., 2011; Zayed et al., 2023). Similarly, the higher salinity levels may have reduced the bioavailability of phosphorus (Duan & Kaushal, 2015; Xie et al., 2022), further limiting plant growth.

## Conclusion

The present study is an integral step towards potentially utilizing the seaweed extract as a bio-fertilizer in the Bahamas. Its non-toxic nature and added nutrients make seaweed an excellent choice among organic fertilizers. The foliar spray achieved the best germination rate due to its lower salinity compared to the soil conditioner. Maximum growth and biomass of the chickpea plants were achieved with the use of the soil conditioner. This study concludes that seaweed extract as a soil conditioner is a promising form of biofertilier for chickpea plant cultivation in nutrient poor soils.

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