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ROLE OF ALGAE AND SEAWEED EXTRACT AS BIO-FERTILIZER IN IMPROVING GROWTH, YIELD, AND YIELD COMPONENTS OF ROSELLE (*Hibiscus sabdariffa* L.)

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ABSTRACT:

Universal climate change causes to think about applying bio-fertilizers as an alternative way of using synthetic fertilizers, since more uses of artificial fertilizers are contaminating the soil, water, and air, and also it is the major contributor to raise greenhouse gas (GHG) emissions and lastly, harming the earth. During this current study, green algae and seaweed were used as a bio-fertilizer to provide soil nutrients resulting in higher roselle (*Hibiscus sabdariffa* L.) crop productivity. Different levels of algae (0.0, 0.5 and 1.0 t ha^{-1}) and also seaweed (0.0 and 0.5 t ha^{-1}), were applied to the soil. Seeds of roselle were sowed in the summer season of 2024. Results presented that applying 0.5 t ha^{-1} of algae was superior on other levels and also on seaweed for most of the growth and yield parameters of roselle plant, such as stem diameter, number of branches per plant, number of fruits per plant, and calyx dry weight (23.3mm, 9.7, 84.3, and 20.0 g $plant^{-1}$), respectively. While, the longest fruit length was recorded for algae at the level of 1.0 t ha^{-1} by (31.5mm). Generally, green algae were better than seaweed for all productivity characteristics. This makes us pay more attention to protect the environment and sustainable agriculture through applying algae.

KEYWORDS: Roselle, Algae, Seaweed, Water Waste Management, Improve Crop Productivity.

1. INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is a tropical annual shrub belonging to the Malvaceae family, which is one of the most important medicinal crops. Additionally, it is known as Roselle, Rozelle hemp, Rosella, Jamaican sorrel, red sorrel, Indian sorrel, and natal sorrel. Researchers believed that India was native of roselle, which was later introduced to Malaysia where it is commonly sown and said to have been planted previously in Africa (Asfaw & Gebremedin, 2017). Moreover, Kays (2011) reported that in Japanese it is named Rohzelu. Sepals are a commercially valuable part of the roselle plant, and their quality depend on the color. Sepals also have several medicinal uses and food preparation in sauces, jams, juices, jellies, syrups, and also it is using for flavoring and coloring food and drinks (Hanafy *et al.,* 2022).

If we want success and development of agriculture the soil must be fertile. Organic farming systems are also the foundation of soil health. So, for that purpose we have to consider the type of fertilizers, whether it is organic or artificial. Generally, the present study focused on using bio-fertilizers as an alternative to synthetic fertilizers, which were to prevent environmental pollution of soil, water, and air, and lastly, to reduce greenhouse gas (GHG) emissions. Improved water management, the use of renewable energy, organic fertilizers, etc., are essential components for providing a successful clean climate and adaptation strategies. Ritika and Utpal (2014) reported that bio-fertilizers are live microorganisms that enhance chemical and biological properties of soils, restore soil fertility, and additionally improves plant growth. Bio-fertilization is a sustainable agricultural practice that includes applying bio-fertilizers to improve the nutrient content of the soil and then increase crop productivity (Suleiman *et al.,* 2020). On the other hand, algae are the most distinctive organisms on the planet which are found in most of terrestrial environments. It is applied in agriculture as bio-fertilizers and also as soil conditioning agents for the improvement of soil fertility and plant productivity (Chapman 2013; Duarte *et al.,* 2018). Both micro and macroalgae are correct environmentally friendly bio-based fertilizers for pollution-free agricultural applies (Ammar *et al.,* 2022).

Acid significantly affected the growth and yield components of the roselle plant (Hanafy *et al.,* 2022). AL-Ajili and Almosawy

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(2024) found that marine algae extract has a significant effect on the vegetative growth, quality, and vitamin C content of the roselle plant.

Soliman *et al.* (2020) reported that bio-stimulants have the important role, especially seaweed extract as a bioactive stimulant in improving growth, yield and quality properties of roselle plant. Spraying amino acids and seaweeds extract gave the highest values for plant growth characteristics of roselle (Mahmoud *et al.,* 2021). Ismael and Sarhan (2025) recommended that the foliar application of humic acid and seaweed extract were really necessary for production the organic broccoli cultivar (Agassirz).

The hypothesis of our study is that bio-fertilizers are effective alternatives to chemical fertilizers especially under organic farming system. The current paper aims to enhance growth and yield characteristics of roselle plant via applying green algae and seaweed.

2. MATERIALS AND METHODS

Study Site:

This study was carried on in Grdarasha Research Station at the Department of Field Crops and Medicinal Plants, College of Agricultural Engineering Sciences, Salahaddin University-Erbil. It is situated in the governorate of Erbil, Kurdistan Region, Iraq (Latitude 36° 0016 N and Longitude 44° 01 24 E), at an elevation of 398 meters above sea level (Figure 1).

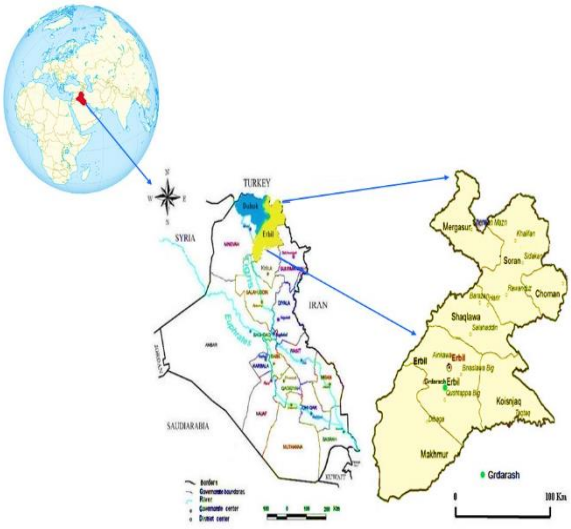

Figure 1: Geographical location of the study. *Source:* (Salih *et al.,* 2022).

Materials:

Seed of roselle (*Hibiscus sabdariffa* L *Var.* Americana), was sowed during the summer season, 2023-2024. Different levels of green algae (0.0, 0.5 and 1.0 t ha^{-1}) and seaweed (0.0 and 0.5 t ha^{-1}) were used, which were symbolized as A0, A1, A2 and A3 respectively. Green algae were collected in the Malakan River, Erbil, Kurdistan Region. Then, it was dried under the sun for several days. Lastly, all the dried algae were grinded and sieved (Figure 2). Furthermore, green algae and seaweed were added to the soil as a powder.

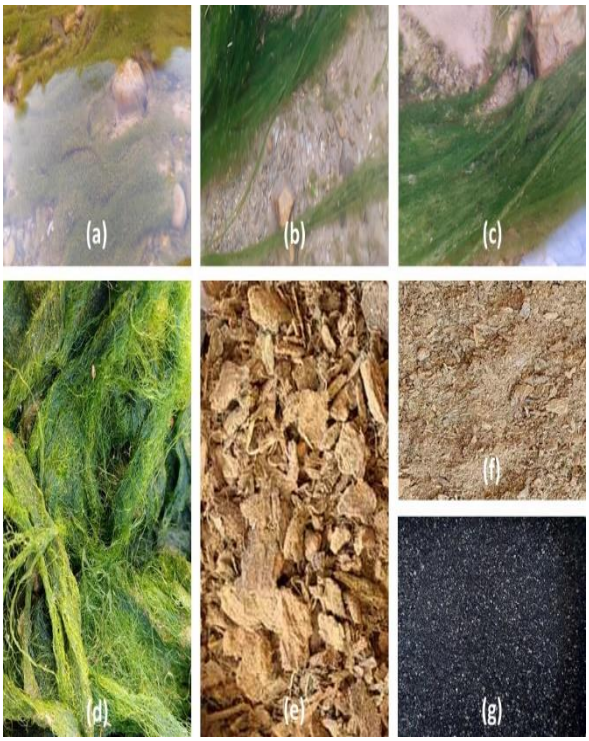

Figure 2: Green Algae: (a-c) Green Algae in the Malakan River, Erbil, Kurdistan; (d) Algae Collection; (e) Dried Algae; (f) Grinding and Powdering of Algae; (G) Seaweed.

Experimental Design:

Seeds of roselle were planted at Field of Grdarasha, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, May 16, 2024. Plot size was 1.5×1.20 m, 4 rows in each plot, distance between rows just about 50 cm, while between plants 40 cm. Additionally, 1m was a distance between replicates, while 1.30 m was between plot to plot. As mentioned previously, green algae in three different levels were added to the plants (0,0, 0.5 and 1.0 t ha^{-1}), while one level only of seaweed was used (0.5 t ha^{-1}), which were symbolized as A0, A1, A2 and A3 respectively. Randomized Complete Block Design (RCBD) in split-split plot with three replicates were applied as experimental design during this current study. Three plants in each plot were selected to determine growth and yield parameters, while for fruit diameter, fruit length and calyx dry weight fifteen fruits were collected randomly. All parameters were studied during this present study symbolized as following:

PH= plant height, RL= root length, SD= stem diameter, NBP= number of branches per plant, NFP= number of fruits per plant, NDC %50= number of days to appear %50 calyx, NDF %50= number of days for %50 flowering, FD= fruit diameter, FL= fruit length and CDW= calyx dry weight.

Soil Analysis:

Soil samples were randomly taken in the depths of 0 to 30 cm from several places of the farm which was before divided into plots and sowing. The samples were transported to the laboratory, then they were air dried and sieved through a 2 mm pore size

sieve. Table 1 displays the physical and chemical characteristics of the soil of the study site (Grdarasha Filed).

Table 1: Physicochemical properties of the soil at the study site (Grdarasha Filed).

	Soil Properties	
Chemical Properties	Nitrogen (mg Kg^{-1})	72.0
	Phosphorous (mg Kg^{-1})	5.12
	Potassium (mg Kg^{-1})	15.2
	$Caco_3$ (%)	15.7
	Organic Matter (%)	1.73
Physical Properties	Bulk Density (g cm^3)	1.03
	CEC (meq 100 g $soil^{-1}$)	22.39
	EC (dS m^{-1})	0.19
	pH	8.04
	Soil Texture	Silty clay loam
	Sand (%)	16.28
	Silt (%)	49.24
	Clay (%)	34.47

Data Analysis:

All field characteristics, yield and its components were repeated for at least three times. The analysis of variance (ANOVA) of the data were performed using IBM SPSS statistical software program (version 20) as well as Duncan's test. Differences were considered statistically significant with a p-value less than 0.05.

3. RESULS AND DISCUSSION

Effect of Algae and Seaweed on Plant Height, Root Length and Stem Diameter:

Algae and seaweed were added to the treatments which were to know their effects on the roselle plant. Non-significant effect was noted for each of plant height and root length, while stem diameter was significantly increased with adding algae at the level of (0.5 t ha^{-1}), by (23.3mm) followed by (21.0mm), when seaweed added at the same level; whereas, in the control treatment it was approximately about (18.4mm) (Figure 3). As mentioned earlier, plant height and root length did not significantly change but they were increased (159.9 and 38.8 cm), respectively, by adding seaweed. Recent results were in harmony with the investigation of Hanafy *et al*. (2022) and AL-Ajili and Almosawy (2024). Additionally, seaweed extract gave the best results for each of plant height and plant diameter of roselle plant compared to control treatment (Hassanein *et al.,* 2021). Similar results were also found by Soliman *et al.* (2020), who stated that plant height and brunch diameter were significantly improved through adding seaweed extract. Dried algae had the significant effected on plant height of sun hemp (*Crotalaria juncea* L.) (Rey *et al.,* 2024). On the other hand, the highest average of root length was recorded in the seaweed treatment by (38.8cm), while in the control treatment just (34.0cm). Atteya and Amer (2018) obtained similar results about affecting seaweed of root length of roselle plant.

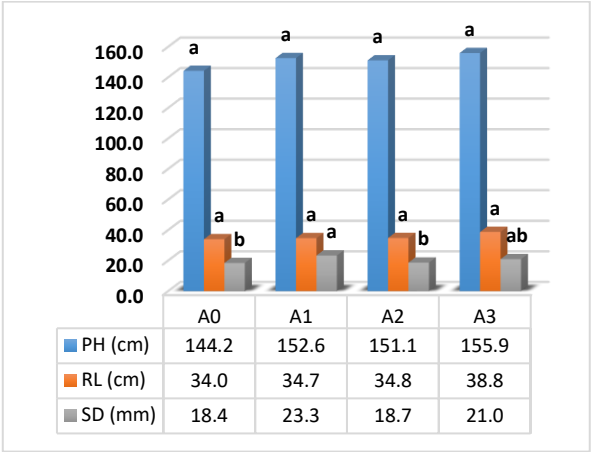

Figure 3: Effect of algae and seaweed on plant height, root length and stem diameter of roselle.

Effect of Algae and Seaweed on Number of Branches and Fruits Per Plant:

Number of branches and fruits per plant are two important characteristics directly affecting yield parameters. Figure 4 shows the effect of algae and seaweed on both mentioned characteristics above, so the biggest number of branches and fruits per plant were found when green algae was used at the level of A1, which were (9.7 and 84.3), respectively but (6.2 and 53.3), which were noted in the control treatment. Seaweed was also improved number of fruits per plant by (75.7). On the other hand, the soil elements (nitrogen, phosphorus and potassium) that have been accumulated in the studied site with algae and seaweed were used in this present study may be caused to that change (Table 1). Results from the current study were supported by previous researches such as Atteya and Amer (2018), who reported that spraying roselle plant by 30% seaweed provided the highest value of number of branches per plant. Seaweed extract caused to increase number of branches of roselle plant (Soliman *et al.,* 2020). Additionally, Hassanein *et al.* (2021) stated that the number of branches per plant raised to 12 branches when nano zinc mixed to seaweed extract. Spraying roselle plants with marine algae extract could increase number of mean branches per plant (Ajili & Almosawy, 2024). However, the highest value of number of fruits per plant was recorded when algae was added at the level of (0.5 t ha^{-1}) by (84.3), followed by (75.7) which was by adding seaweed at the level of (0.5 t ha^{-1}). Similar results were reported by Atteya and Amer (2018), who claimed that the largest significant number of fruits per plant was found when seaweed added to the roselle plants. Nazzal and Al-Nuaymi (2019) reported that seaweed extract caused to increase number of fruits

per plant of roselle. The biggest value was recorded when plants spraying by seaweed extract at (2 ml.$^{-1}$), which was (182.7 fruits plant^{-1}), while in the control treatment just about (67.3 fruits plant^{-1}). These are attributed to the function of algae as mentioned by Choudhary *et al.* (2024), who stated that algae are used as bio-fertilizers, which are sources for nutrients, especially blue-green algae able to fix atmospheric nitrogen, and then it has a vital role in plant growth and motivation.

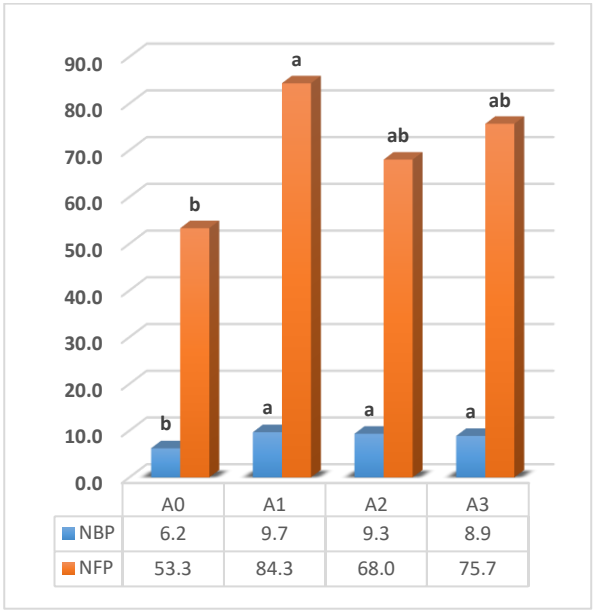

Figure 4: Effect of algae and seaweed on number of branches and fruits per plant of roselle.

Effect of Algae and Seaweed on Number of Days to Appear %50 Calyx and %50 Flowering:

Number of days to appear %50 calyx and number of days for %50 flowering were significantly changed between control and other treatments (Figure 5). Plants with algae at the level of (0.5 t ha-1), A1 needed the minimum days for each of %50 calyx appearing and %50 flowering (111.3 and 128.7 days), respectively while in the control treatment A0 plants needed more days for appearing both parameters (122.7 and 136.0 days), respectively. Green algae at the level of A1 was not only superior in control treatment but also in others, indicating the respect and impact of green algae for improving growth parameters of roselle plants may also correct for another crops. Since, green algae improve soil fertility and may also cause to increase nutrient availability, it encourages plants to grow earlier. The results of this study demonstrated the importance of algae on early flowering of roselle plants. These results were similar to the findings obtained by Vieira *et al.* (2025), who stated that microalgae application meaningfully encouraged the earlier flowering of marigold plants.

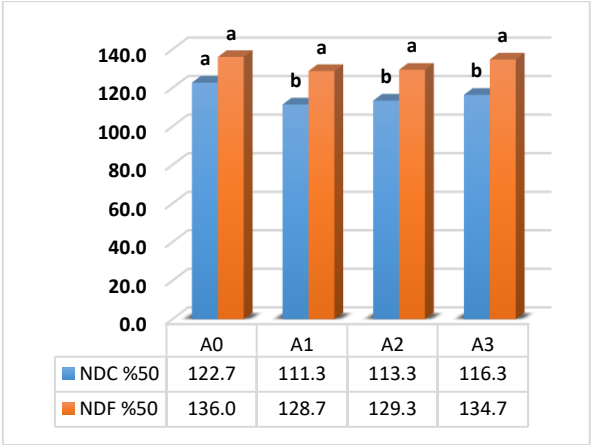

Figure 5: Effect of algae and seaweed on number of days %50 for calyx appearing and flowering of roselle.

Effect of Algae and Seaweed on Fruit Diameter and Fruit Length:

Fruit diameter was not affected significantly when algae and seaweed were added to the plants, however, the fruit length significantly improved (Figure 6). The longest fruit length was found when algae was added to the plants at the level of (1.0 t ha^{-1}), (31.5mm), followed by (29.4mm) in the seaweed treatment; whereas, in the control treatment it was about (27.9mm). Foliar application of algae extract caused to enhance fruit length and fruit width of Citrus aurantium L. tress (Al-Musawi, 2018). In the present study, the biggest fruit diameter was recorded (19.6mm), in the (A2) treatment, by adding algae at the level of (1.0 t ha^{-1}). Algae was also significantly improved fruit diameter of olive trees (Hussein & Gad El-Kareem, 2021).

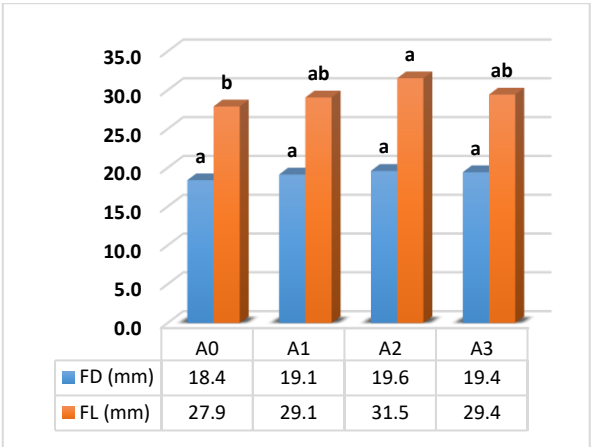

Figure 6: Effect of algae and seaweed on fruit diameter and fruit length of roselle.

Effect of Algae and Seaweed on Calyx Dry weight :

Calyx of roselle plant has healthy effects for consumers, thereby improving and increasing are required. During conducting the current study, calyx dry weight was dramatically increased by almost double as can be seen in Figure 7, treatments (A1 and A0), respectively (20.0 and 13.0 g plant^{-1}). Hence, it can be said that adding green algae to the roselle plant did not only

improve growth parameters but also it was really beneficial for increasing yield (calyx). Having the adequate number of algae activates the nutrients in the soil, which are then absorbed by the plants for better yields. Alobwede *et al.* (2019) stated that algae had a significant impact on farms, through the addition of soil nutrients. Calyx dry weight was increased over control treatment, which was through adding algae (Hanafy *et al.,* 2022). Also, total yield of the calyx was significantly increased when roselle plants were sprayed with different concentrations of marine algae (Al-Hamidi, 2023; AL-Ajili & Almosawy, 2024).

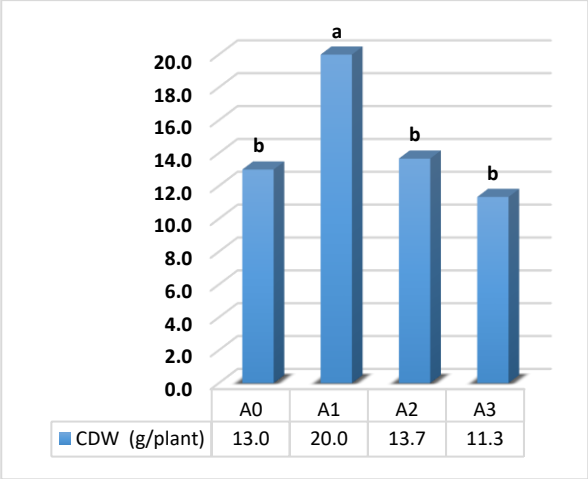

Figure 7: Effect of algae and seaweed on calyx dry weight of roselle.

CONCLUSION

To give high crop productivity, the soil should be completely fertile. For this purpose, green algae and seaweed were used as bio-fertilizers and were added as a powder to the soil, since both of micro and macro algae are exact environmental friendly bio-based fertilizers for pollution-free agricultural applies. Additionally, they cause to increase the nutrient content of the soil, organic matters and microorganism activity. For reminding, during the current study, different levels of algae with a level of seaweed were applied; (0.0, 0.5, 1.0 and 0.5 t ha^{-1}), respectively. Generally, both algae and seaweed positively affected growth and yield parameters of roselle plant, but green algae at the level of 0.5 t ha^{-1} (A1) was so much better compared to others. Stem diameter, number of branches and fruits per plant, number of days to appear %50 calyx, number of days to %50 flowering and calyx dry weight were improved when algae was added to the plants as (A1). These results encourage researchers to do more research on algae as bio-fertilizer which is not only a fertilizer but also it will be suggested as an organizer to prevent soil pollution.

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Author Contributions:

The conception and design of the study was carried out by the author. He also collected, analysed the data, and drafted the manuscript.

Ethical statement:

Ethical approval was not required for this study, as it did not involve any human participants, animal subjects, or sensitive personal data.

Declaration:

Author confirms that has no conflict of interest to declare.

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