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THE USAGE OF MARINE PLANT-BASED BIO-FERTILIZER FOR TOMATO GROWING IN MOGADISHU, SOMALIA

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Abstract: Seaweed and seagrass contain plant growth hormones and mineral nutrients such as proteins, lipids, amino acids, phytohormones, carbohydrates, antimicrobial compounds and osmoprotectants. Hence, the present work was undertaken to assess the potential of marine plant-based bio-fertilizer, prepared as a mixture of six seaweed species and three seagrass species, in comparison with goat manure fertilizer, mixed fertilizer, conventional and no-fertilizer (control) applications on the growth and yield of tomato (*Solanum lycopersicum*) under greenhouse conditions. The experiment was designed in a split plot with a randomized complete block design. Fifteen biological replications were used from each treatment for measuring plant height, number of fruits and fruit weight. In this study, treatment of conventional, marine plant bio-fertilizer, goat manure, mixed fertilizer and control was applied. This study revealed that tomato plants supplied with a mix of traditional fertilizers had the highest plant height (178 cm) and the highest number of fruits (150 fruits/plant), while the plants treated with marine plant bio-fertilizer produced fruits of the highest weight (3132 grams/15 fruits). This is the first study on the utility of marine plant as bio-stimulants for agricultural production in Somalia. The application of eco-friendly and user-friendly marine bio-fertilizers can be suggested to farmers in getting higher yields and better growth of tomato plants.

Keywords: Traditional fertilizers, Seaweed, Seagrass, Tomato, Marine, Bio-fertilizer

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1. Introduction

Marine plant bio-fertilizers have been traditionally utilized in stimulating agricultural production since ancient times (Zafar et al., 2022). Seaweeds have been traditionally used as bio-fertilizers in farming practices in the Roman Empire, China, France, Japan, Spain, Britain, and others. Seaweeds are reported to be a potential source of plant-growth-promoting hormones and nutrients necessary for crop plant growth. Additionally, the seaweeds comprise various chemical constituents such as carbohydrates, proteins, amino acids, lipids, and antimicrobial compounds (Jayasinghe et al., 2016; Nabti et al., 2017; Vinoth et al., 2017; Pramanick et al., 2017; Raghunandan et al., 2019). Today, there is an increasing need for eco-friendly agricultural output of healthy and quality food to feed the rising population of the globe. In this context, marine plants possess many benefits for crop production, including enhancement of seed germination, improvement of growth and health, enhanced absorption of water and nutrients, stress tolerance to saline and frost, bioremediation of pollutants, and resistance to phytopathogens (Nabti et al., 2017; Raghunandan et al., 2019).

Seaweed and seagrass extracts are available as fertilizers in the forms of powder, Seaweed Liquid Fertilizers (SLF), and Seagrass liquid fertilizer (SGLF) (Patel et al., 2017; Dineshkumar et al., 2018; Sheeja, 2019; Dineshkumar et al., 2019a). Seaweed extracts are efficient for improving soil fertility and the quality of crop yield (El-Din, 2015; Patel et al., 2017). The effectiveness of the SLF is experimentally evaluated at various concentrations as 1%, 0.8%, 0.6%, 0.4% and 0.2%, applied to tomato plants by foliar spray, seed and soil treatments and recorded the highest yield and growth of the tomato at 0.6% concentration (Sasikala et al., 2016). The combined SLF and SGLF are reported to be highly effective on seed germination at 10% concentration compared to SGLF and SLF used individually (Sheeja, 2019). Recently, several studies showed that seaweed extracts enhance seed germination, plant nutrient uptake, and shelf life of horticultural products (El-Din, 2015; Ghaderiardakani et al., 2019; Ahmed et al., 2021). Nevertheless, a higher concentration of SLF may inhibit growth and yield, as reported in tomato, wheat and eggplants (El-Din, 2015; Ramya et al., 2015; Sasikala et al., 2016).

The application of 0.5 g of seaweed biomass is reported to increase plant growth rates, rooting ability, 100% survival rates, higher number of leaves, longer shoots, higher stem thickness and total chlorophyll content. Additionally, the seaweed increases the levels of total phosphorus, nitrogen and potassium in the treated soil as compared to chemical fertilizer (Saadaoui et al., 2019). The combination of seaweed extract and chemical fertilizer was also examined. *Kappaphycus* extract at 7.5% along with 100% of the recommended dose of chemical fertilizers, are reported to improve the growth, yield and quality of potatoes (Pramanick et al., 2017). Moreover, the efficacy of the organic palm leaf, seaweed extract, rice residuals and conventional was evaluated on the growth of Broccoli (*Brassica oleracea var. italica L.*) and recorded higher growth rates, enhanced head produce and good quality at six ml/l of seaweed extract and rice residual (Manea and Abbas, 2017).

Seaweeds are reported to be a potential source of polysaccharides with a good effect on plant biomass, chlorophyll content and seed germination (Chbani et al., 2015; Dineshkumar et al., 2017; Mzibra et al., 2018). *Turbinaria murayana* (TM) was proven to be a bio-stimulant in tomato plants. The TM extract at 4% considerably increased vegetative growth, plant height, shoot branches, and leaf number (Sunarpi et al., 2020).

The lady's finger (*Abelmoschus esculentus*) seeds were treated with seagrass extract in the form of foliar spray (FS) and soil drench (SD), recorded increased pods and number of flowers by FS, whereas enhanced weight and length of pods by SD, and suggested the marine plants as an alternate source of bio-stimulants for organic farming (Muniswami et al., 2021). Foliar sprays of seaweed mixtures are known to substantially increase growth and biochemical parameters in *Ocimum sanctum* when treated with a combination of *Turbinaria ornata, Sargassum wightii* and *Caulerpa racemosa* (Uthirapandi et al., 2018). The treatment of seaweed mixture was also proven to reduce heavy metal pollutants. The application of a combination of *Ulva fasciata* and *Sargassum lacerifolium* appeared to decrease the levels of Cu, Pb, Ni and Zn to their normal rates in the soil samples and to reduce the levels of Cr, Cd, Mn and Fe to tolerable limits (Ahmed et al., 2021). To sum up, there has never been any previous research done on the application of marine plant bio-fertilizer in agricultural production in Somalia. Hence, the present work was undertaken to investigate the potential of marine plant-based bio-fertilizer, in comparison with organic and inorganic fertilizers for the growth and yield of tomato.

2. Material and Methods

This experiment was performed at the greenhouse of the Department of Agriculture, City University of Mogadishu, Somalia. Before the beginning of the trial, soil samples were randomly collected and analyzed at the Filson Somali Labs to identify soil chemical and physical properties (Table 1).

Table 1. Physical and chemical features of the soil of the experimental site

Parameter	Unit	Value
pH	-	6.87
Electrical conductivity	$ds.m^{-1}$	0.25
Total N	$mg.kg^{-1}$	120
Exchangeable K	$mg.kg^{-1}$	80
Available P	$mg.kg^{-1}$	0.08
Available S	$mg.kg^{-1}$	0.05
Organic matter	$mg.kg^{-1}$	0.96
Soil texture:		
Clay	%	57.1
Sand		14.3
Silt		28.6
Calcium as $Ca(OH)_2$	g/kg of soil	15.35

Note that pH refers potential of hydrogen, N refers to nitrogen, K refers to kalium, the Mediaeval Latin word for potassium, P refers to phosphorus, and S refers to sulfur.

The crop plant selected for this experiment was tomato (*Solanum lycopersicum*). Seeds in uniform size, weight and colour were used for raising seedlings in trays with dimensions of 28 × 53 cm and 200 cells containing coco peat. The seedlings were applied NPK fertilizers and watered daily with 1 litre during their growing period. The trays were kept in the greenhouse, maintained with a temperature of 29-38 °C, relative humidity of 60 to 40 %, and a photoperiod of 12 hours. The greenhouse had a total area of 320 square meters with 40 m length and 8 m width, and there were six rows of 39 m in length and 30 cm in width each. Each row had two irrigation lines with 60 cm between plants and spaced 30 cm between irrigation lines. When seedlings were 8–12 cm in height, they were transplanted at a distance of 60 cm between plants, and there were 120 plants in each row. The seaweeds used in this study were *Sargassum sp., Ulva lactuca, Codium fragile, Asparagopsis sp., Corallina sp. and Chondrus sp.* (Table 2).

Table 2. The different types of seaweeds/seagrasses available in Lido area, Mogadishu, Somalia

Scientific Name	Common Name	Local Name
Seaweeds		
Sargassum sp.	Japanes Wireweed	Teli
Ulva lactuca	Sea Lettuce	Cowsbaded
Codium fragile	Dead man's Fingers	Cowska Badda
Asparacgopsis sp.	Red seaweed	Cowsbadeed
Corallina sp.	Red alga	Cowsbadeed
Chondrus sp.	Irish Man	Cowsbadeed
Seagrasses		
Enhalus sp.	Eelgrass	Teli
Zostera Marina	Common eelgrass	Teli
Syringodium sp.	Noodle seagrass	Teli

They were freshly collected from the coastal area of the Indian Ocean, Lido (2° 2' 48.9624'' N-45° 19' 5.3796'' E) in Mogadishu, Somalia. The seagrasses used in this study were *Enhalus, Zostera Marina* and *Syringodium*, collected from the same coastal area. The plant samples were collected during low tide, washed thoroughly to remove sand particles and epiphytes, and transported in bags to the laboratory.

The marine plant samples were dried at room temperature. After drying, they were mixed and allowed to decompose in a pit with a length of 2.3 m, width of 1.7 meters and depth of 1 m. After three months, the decomposed marine plants were removed from the pit. Five of the six rows of soil beds in the greenhouse were used for fertilizer treatment in the amount of 14 kg per 0.08 decares as a soil drench, and the sixth row was maintained as control without any treatment. Each row was applied with one of these five fertilizer treatments: decomposed marine plant bio-fertilizer, goat manure, DAP fertilizers (conventional), and a mixture of fertilizers. The last row was used as a control. 15 plants were selected from each row for analysis. The trial was designed in a split plot with a randomized complete block design. Fifteen biological replications were used from each row for measuring plant height, number of fruits and fruit weight. The data collection continued for 17 weeks.

3. Results

Growth performance was assessed for the number of fruits, fruit weight and plant height of tomatoes under the treatment of marine plant bio-fertilizer, goat manure, chemical fertilizer, mixed fertilizer, and control (Tables 3-5). The growth performance was analyzed under five developmental stages (31, 62, 92, 123, 153) for five months.

3.1. Plant Height

The plant height steadily increased under the five growth stages in four fertilizer treatments (Table 3). The plant height was recorded to be the highest for conventional, followed by marine plant bio-fertilizer, mixed fertilizer and goat manure, with an increase of 19.9%, 13.4, 7.5% and 1% over control, respectively.

3.2. Number of Fruits Harvested

The fruit yield was analyzed every 30 days on 92 days, 123 days and 153 days of plant growth (Table 4). A total of 571 fruits were collected from the experimental and control plants.

Table 3. Impact of basal fertilizer application of marine plant bio-fertilizer, goat manure, mixed fertilizer, traditional fertilizer (DAP) and control on growth parameters (plant height (cm)) of tomato plant (*Solanum lycopersicum*)

	Plant Height (cm) under different days of growth				
Fertilizer Treatment	31	62	92	123	153
Marine plant	26.09	86.7	132.0	173.0	178.0
Goat manure	21.4	71.0	115.3	151.0	158.5
Mixed fertilizer	22.0	94.1	115.5	163.6	168.7
Conventional	31.6	114.7	139.3	174.6	188.3
Control	20.5	74	115.5	151	157

Table 4. Impact of basal fertilizer applications of marine plant bio-fertilizer, goat manure, mixed fertilizer and traditional fertilizer (DAP) on growth parameters (fruit number) of tomato plant (*Solanum lycopersicum*)

	Number of fruits harvested			
Fertilizer treatment	92	123	153	Total
Marine plant	81	39	14	134
Goat manure	44	16	17	77
Mixed fertilizer	77	44	14	135
Conventional	99	39	12	150
Control	36	28	11	75

Table 5. Impact of basal fertilizer applications of marine plant bio-fertilizer, goat manure, mixed fertilizer, Traditional fertilizer (DAP) and control on growth parameters (fruit weight) of tomato plant (*Solanum lycopersicum*)

	Fruit weight (gram)		
Fertilizer treatment	92 DAT	123 DAT	153 DAT
Marine plant	3132	1450	579.1
Goat manure	1825	525.5	717.9
Mixed fertilizer	2482	1086.5	471.9
Conventional	3210	1337.4	421.3
Control	1255	836	258.6

The total number of fruits harvested was recorded to be the highest for conventional, followed by mixed fertilizer, marine plant bio-fertilizer and goat manure, with an increase of 100%, 80%, 79% and 3% over control, respectively. The total harvest of fruits was 337, 166 and 68 on 93, 123,153 days of growth, respectively. Thus, the yield reduced with the increment of plant growth.

3.3. Fruit Weight

The fruit weight was analyzed every 30 days from 92,123 and 153 days of plant growth (Table 5). The average fruit weight was the highest for marine plant bio-fertilizer, followed by conventional, mixed fertilizer and goat manure, with increases of 120%, 112%, 72% and 31% over control, respectively. The total harvest of fruit weight was 2381, 1047, and 490 g on 93, 123 and 153 days of growth, respectively. Therefore, the fruit weight is reduced with the increase of plant growth.

4. Discussion

In general, agricultural soil is affected by indiscriminate application of chemicals such as pesticides and synthetic fertilizers, and intensive cropping practice reduces soil nutrients. However, there is an upsurge in practicing organic farming without using inorganic fertilizers. Hence, seaweeds are cut into pieces and boiled with 1 Liter of distilled water for 1 h. After cooling, the extract is filtered through what man No: 1 Paper and Stored at 4 °C for future analysis (Vijayakumar et al. 2018). The filtrate is considered a 100% concentration of the seaweed liquid fertilizer (SLF) to boost the growth of crops, seed germination, number of leaves, shoot length, root length and number of lateral roots (Zodape et al., 2010; Haider et al., 2012; Singh et al., 2016). The seaweed extracts are reported for better seed germination and growth performance in green gram (Ashok-Kumar et al., 2012), tomato (Sasikala et al., 2016) and black gram (Kalaivanan and Venkatesalu, 2012). A recent study has successfully attempted to use the extract of *Gracilaria sap* and *Kappaphycus alvarezii* with or without a conventional (Pramanick et al., 2014). The present study observed a similar effect in tomato plants. The marine plant-based bio-fertilizer increased tomato fruit by 120%, the number of fruits by 79% and plant height by 13% over plants without fertilizer treatment (Tables 3-5). This finding is similar to an earlier report that seaweed extract induces tomato plants to produce fruits of larger size (Hussain et al., 2021).

The seaweeds are rich in macro-nutrients (Ca, K, P), particularly *Caulerpa sertlatioides; Caulerpa cf. brachypus; Undaria pinnatifida* and *Ulva lactuca* (van Ginneken and de Vries, 2018). Liquid seaweed fertilizers contain potassium, an essential element for meristematic growth, translocation of photosynthesis, and disease resistance. Seaweed extracts have a role in activating enzymes, elongating cells, and stabilizing cell structures. Plant hormones known to induce physiological responses, are also found in seaweed extracts (Pramanick et al., 2013). Moreover, brown and green seaweed extracts are known to contain several betaines and betaine-like elements (MacKinnon et al., 2010). Betaines contain an osmolyte at higher concentrations, which induces stress tolerance to drought and salinity. They also serve as a nitrogen source at lower concentrations (Zecher et al., 2020).

Liquid seaweed fertilizers play a role to control the water status of plants by stomatal regulation and photosynthesis-related processes. The seaweed-extract-treated plants were reported to have more flowers than control plants (Dookie et al., 2021). The number of flowers and their maturity determine the crop yield. The flowering is influenced by phytohormones such as cytokinins (Bartrina et al., 2017), auxins (Ke et al., 2018), gibberellins (Moeller et al., 2013) and ethylene (Iqbal et al., 2017) and also the physiological age of plants determines initiation and development of flowers. The phytohormones found in seaweed extracts are reported to promote flowering by stimulating more rapid plant growth (Pramanick et al., 2013). Early flowering produces early fruiting and ripening, which usually bring better market prices for the farmers.

The micro-algal fertilizers play a role in releasing crucial chemicals needed for producing high-quality fruits and preventing leaching and excessive nutrient losses. The plants provided with micro-algal bio-fertilizers lead to enhanced fruit quality attributes due to the abundance of nutrients at the top of the plant when compared with the use of conventional (Dineshkumar et al., 2018; Dineshkumar et al., 2019b; Dineshkumar et al., 2020a; Dineshkumar et al., 2020b). The micro-algal extracts were used as a foliar spray (Supraja et al., 2020) and dry biomass as a soil drench (Dineshkumar et al., 2018) for energizing plant growth. Application of Chlorella vulgaris as foliar spray, soil drench and mixture of *C. vulgaris* bio-fertilizer + cow dung treatments have shown to improve soil quality, plant growth and greater yield of maize, paddy, black gram and onion (Dineshkumar et al., 2017; Dineshkumar et al., 2018). Furthermore, application of a mixture of *C. vulgaris* and Cow dung has increased the release of plant nutrients and their availability for improving yield attributes. The positive effect of *C. vulgaris* bio-fertilizer on the chemical composition and quality of tomato fruits was also reported (Suchithra et al., 2021). Similarly, tomato plants treated with dried *Acutodesmus dimorphus* biomass showed to improve the number of flowers and shoot branches of tomatoes (Garcia-Gonzalez and Sommerfeld, 2016). In addition to growth, the microalgal and organic fertilizer treatments influence the chemical constituents of tomatoes (Pangaribuan and Monica, 2016). Thus, the beneficial impacts of algal extracts are agronomically substantial for incrementing tomato fruit quality and output. This is in agreement with the present results and other published papers.

5. Conclusion

Seagrass and seaweed contain phytohormones and macro- and micronutrients required for plant growth. In this study, conventional treatment showed the highest increment in the number of fruits and plant height, whereas marine plant-based bio-fertilizers exhibited the highest fruit weight. The existence of inorganic elements in seaweed and seagrass fertilizers makes them a potential choice for organic fertilizers. The areas where conventional are not abundantly available, seaweed/seagrass bio-fertilizers might give an eco-friendly alternative to plant nutrient management. The use of marine plant-based bio-fertilizer is cheaper and cost-effective for agricultural applications due to the abundant availability of seaweeds and seagrasses along the coastal areas of Somalia. The application of eco-friendly and user-friendly marine bio-fertilizers can be suggested to farmers in getting higher yields and better growth of tomato plants. Future studies are required on using seaweed/seagrass liquid extracts as soil drenches and foliar spray.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	M.M.S.	M.H.A.	M.A.	M.A.K.	A.S.
C	20	20	20	20	20
D	20	20	20	20	20
S	20	20	20	20	20
DCP	20	20	20	20	20
DAI	20	20	20	20	20
L	20	20	20	20	20
W	20	20	20	20	20
CR	20	20	20	20	20
SR	20	20	20	20	20
PM	20	20	20	20	20

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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