Efficacy of Soil Treated with Seaweed Extract on the Growth and Yield of Indian mustard [*Brassica juncea* (L.) Czernjaew]

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DECLARATION

I hereby declare that the work embodied in here is the result of my own research except for the excerpt as cited in the references.

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ABSTRACT

Fertilizer application technique should be a fundamental part of Fertilizer Best Management Practices (BFMPs) to achieve optimum nutrient additions in soil to maximize growth and yield, while minimizing environmental impact. Though chemical fertilizers play a significant role in boosting crop productivity, the application of natural plant extract to increase the crop production, maximize the soil nutrient efficiency, and soil fertility need to be explored towards achieving BFMPs. Therefore, a study was carried out at Agro-Techno Park, Universiti Malaysia Kelantan, Jeli Campus, Malaysia to determine the efficacy of soil treated with different rates of seaweed extract on the growth and yield of Indian mustard [*Brassica juncea* (L.) Czernjaew]. The plants were treated with a series of application rates of seaweed extract at 0.0 ml/g (control; **T0**), 0.5 ml/g (**T1**), 1.0 ml/g (**T2**), and 2.0 ml/g (**T3**) under shelter house. Seaweed extract at **T2** and **T3** significantly increased in the plant height, fresh weight, dry weight, and leaf diameter of Indian mustard. However, at these two concentrations, it was found that there is no significant increase in chlorophyll content, where the effect was likely similar to control plants. This study showed that **T3** was the optimum application rate in increase the growth and yield of Indian mustard, thus suggesting that the application of seaweed extract at the correct rate in vegetable cultivation could be a promising approach in relation to precision application of fertilizer and other agriculture inputs.

Keywords: Indian mustard [*Brassica juncea* (L.) Czernjaew], Seaweed extract, Growth, Yield

Keberkesanan Tanah yang Dirawat dengan Ekstrak Rumpai Laut terhadap Pertumbuhan dan Hasil Sawi India [*Brassica juncea* (L.) Czernjaew]

ABSTRAK

Teknik penggunaan baja harus menjadi sebahagian asas Amalan Pengurusan Baja Terbaik (BFMPs) untuk mencapai penambahan nutrien yang optimum dalam tanah untuk memaksimumkan pertumbuhan dan hasil, serta meminimumkan kesan alam sekitar. Walaupun baja kimia memainkan peranan penting dalam meningkatkan produktiviti tanaman, penggunaan ekstrak tumbuhan semulajadi dalam meningkatkan pengeluaran tanaman, memaksimumkan kecekapan nutrien tanah dan kesuburan tanah perlu diterokai ke arah mencapai BFMPs. Oleh itu, satu kajian telah dijalankan di Agro-Techno Park, Universiti Malaysia Kelantan, Kampus Jeli, Malaysia untuk menentukan keberkesanan tanah yang dirawat dengan kadar ekstrak rumpai laut yang berbeza terhadap pertumbuhan dan hasil sawi India [*Brassica juncea* (L.) Czernjaew]. Tumbuhan telah dirawat dengan satu siri kadar penggunaan ekstrak rumpai laut pada 0.0 ml/g (kawalan; **T0**), 0.5 ml/g (**T1**), 1.0 ml/g (**T2**), dan 2.0 ml/g (**T3**) di bawah rumah lindungan. Ekstrak rumpai laut pada **T2** dan **T3** meningkat ketinggian tumbuhan, berat segar, berat kering, dan diameter daun sawi India dengan signifikan. Walau bagaimanapun, pada kedua-dua kepekatan ini, didapati tiada peningkatan signifikan dalam kandungan klorofil, di mana kesannya seakan sama dengan tumbuhan kawalan. Oleh itu, kajian ini menunjukkan bahawa **T3** adalah kadar aplikasi optimum dalam meningkatkan pertumbuhan dan hasil sawi India, seterusnya mencadangkan bahawa penggunaan ekstrak rumpai laut pada kadar yang betul dalam penanaman sayur-sayuran menjadikannya satu pendekatan yang berpotensi yang berhubung dengan aplikasi baja dan input pertanian lain secara jitu.

Kata kunci: Sawi India [*Brassica juncea* (L.) Czernjaew], Ekstrak rumpai laut, Pertumbuhan, Hasil

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL	MEANING
%	percent
µl	microliter
ml/g	millimeter per gram
m	meter
˚C	degree Celcius
cm	centimeter
ha	hectare
g	gram
kg	kilogram
N	Nitrogen
ANOVA	Analysis of Variance
DOA	Department of Agriculture
CRD	Completely Randomized Design
BFMPs	Fertilizer Best Management Practices

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Indian mustard [*Brassica juncea* (L.) Czernjaew] is one of central Asia, particularly Malaysia's, major leafy vegetable crops. Indian mustard belongs to the Brassicaceae family, also known as vegetable mustard. The plant is around 1m higher in height, typically cultivated annually or biennially (James, 1983). This vegetable was also rich in Vitamin A and C and cool-season vegetable which is an average temperature of 15 to 18˚C. Depending on the weather conditions and variety, the harvest takes between 40 - 60 days in the month for an increasing cycle of Indian mustard. While it is commonly cultivated as a vegetable, it is more cultivated for the seeds that produce a condiment and basic olive oil and is frequently used in a salad on young tender leaves. Indian mustard is one of the principal plants produced in Malaysia for the last five years (DOA, 2017) and Indian mustard contributes to the export market and generates revenue for the country, (DOA, 2013).

Bad impacts on land and violent farming activities have occurred in Malaysia over the past 50 years. Today's activities in agriculture exhaust soils with organic matter and plant nutrients. One of the new agricultural scheme methods is the excessive use of inorganic fertilizers. This current trend has raised new sustainability issues in agriculture (Han, 2016). Before inorganic fertilizers, farmers used organic products to help soil quality and growth, primarily as the sole source (Asghar, Ishaq, Zahir, Khalid & Arshad, 2006). Organic fertilizer is also a second choice for soil fertility farmers to preserve. Some of the origins of organic fertilizer are organic waste and animal manure. Organically, organic manure or animal manure has been used in China for decades as the key ingredient for rice production (Hao, Liu, Wu, Hu, Tong, & Su, 2008).

Cow dung is the largest source of organic fertilizer and is used for energy production in many developed countries. It is an ideal solution to chemical fertilizers since the soil is preserved and microbial species improve production in the long term (Raj, Jhariya, Toppo, 2014). Cow dung manure and vermicomposting enhance the soil's organic matter, which improves water infiltration and water resistance as well as the potential for cation exchange. It replaces reliance on firewood, firewood and fossil, and coal, and so on, through renewable and sustainable energies through biogas or plywood (Raj, Jhariya, Toppo, 2014). Furthermore, the proper and safe use of cow dung not only improves productivity but can also limit potential pathogenic diseases of bacteria and fungi. The illegal use of cow dung should then be avoided and used to support an agricultural operation as an organic fertilizer.

Seaweed is a rich, cheap resource, and has a huge potential for commercial exploitation along with coastal agricultural areas. Seaweed isolated that form seaweed extract, a broad variety of macronutrients, microelement nutrients, and organic components such as sterols, cytokinins, betaines, vitamins, amino acids, and growth hormones that play a major role in the production of the planting mechanism for the ecosystem (Yuanyuan Yao, 2020). The plants require balanced and optimal growth in many building blocks of life and cannot develop to their whole potential without these nutrients. Therefore, seaweed can stimulate plants for development (Darren, 2019).

Many studies have reported that the application of seaweed extract can enhance plant growth and yields (Rama Rao, 1991), develop tolerance to environmental stress (Zhang and Schmidt, 2000; Zhang et al., 2003), increase nutrient uptake from soil (Verkleij, 1992; Turan and Köse, 2004) and enhance antioxidant properties (Verkleij, 1992). However, most of these studies only focus on the application of seaweed extract as a foliar spray. The incorporation of seaweed extract as a soil-applied biostimulant would help to increase the efficiency of nutrients released from the organic and inorganic fertilizers in the soil medium besides enhancing the nutrients uptake by the plants.

1.2 Problem Statement

The slow release of nutrients during plant cultivation occurs due to the granular or powder form of the organic and inorganic fertilizer. This problem has contributed to the slow nutrient uptake by the plants and eventually will lead to the poor yield and quality of the harvested plants. Previous studies have demonstrated that seaweed extract improves root growth and plant development, increases crop yield and quality and enhances microbial proliferation (Rathore et al., 2009). Natural source of micro and macronutrients, amino acids and carbohydrates contained in seaweed extract had increased the quality, yield and strength of crops (Mooney and Van Staden, 1986). The efficacy of seaweed extract application onto the soil has not been fully studied in the literature. In addition, there are no reports on the relationship of soil treated with seaweed extract with the nutrient released from organic and inorganic fertilizers in Indian mustard cultivation. Thus, this study was conducted to determine the efficacy of soil treated with different rates of seaweed extract on the growth and yield of Indian mustard [*Brassica juncea* (L.) Czernjaew].

1.3 Hypothesis

H0: There was no significant increase on the growth and yield of Indian mustard [*Brassica juncea* (L.) Czernjaew] grown under soil treated seaweed extract.

H1: There was a significant increase on the growth and yield of Indian mustard [*Brassica juncea* (L.) Czernjaew] grown under soil treated seaweed extract.

1.4 Research Objective

The objective of this study is to determine the efficacy of soil treated with different rates of seaweed extract on the growth and yield of Indian mustard [*Brassica juncea* (L.) Czernjaew].

1.5 Scope of Study

This study focusses on the preparation of treatment; soil treated with different rates of seaweed extract to measure the growth (plant height, root length, number of leaves, leaf diameter, chlorophyll content) and yield parameters, (fresh and dry weight) of Indian mustard after 40 days of plant cultivation. From the study output, the relationship between soil treated with seaweed extract and fertilizer nutrients released also were discussed.

1.6 Significant of Study

Fertilization and soil management are important farming practices in agriculture. To achieve a balance between the cost of farm maintenance and crop yield loss, farmers/ growers need to understand the responses of targeted crops species to inorganic or organic fertilizer as well as their growing medium. In this study, the incorporation of seaweed extract onto the soil sustainably improved the growth and yield of Indian mustard. In addition, the application of seaweed extract as a soil-applied biostimulant were offer an efficient method to trigger optimum nutrient release from the fertilizers inside the soil**.**

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Indian Mustard [*Brassica juncea* (L.) Czernjaew]

2.1.1 Origin, taxonomy and distribution

Figure 2.1: Indian mustard [*Brassica juncea* (L.) Czernjaew]

Indian mustard has various forms of names widely used, including Chinese mustard, Oriental mustard or Brown mustard, belonging to the Brassicaceae family or mustard family. The annual herb of the cruciferous family is *Brassica juncea*. The family *Brassica* includes species that are of significant economic significance such as foodstuffs, ornamental, vegetable plants and used in place of rapeseed oil as a special lubricant. In dry season and on the market all year round, the average yield of mustard green is about 12 tons/ha (James A., 1983). Roots, stems, buds, flowers, leaves, and seeds have been produced to edible almost a part of the mustard plants (AVRDC, 2020). The obovate or ovate leaves are petiol and simple in the meantime, the flowers of the raceme are bisexual with four petals and four sepals and two shorter and two longer stamens. *B. juncea* is a self-pollinating, insect pest and disease less vulnerable. Even if it is common in Asia, North America, Africa and Europe, some researchers feel that Eastern India, China, and the Caucasus are the largest *B. juncea* genetic centres (Reka, 2020). The agriculture zone now encompasses southern and central China, and even countries in South Asia, including Malaysia, Vietnam and Indonesia (Dixon, 2006).

<u>Taxonomy of Indian Mustard:</u>

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Capparales

Family: Brassicaceae

Genus: Brassica L.

Species: *Brassica juncea* (L.) Czern

2.1.2 Morphological characteristics

Brassica juncea foliage is pale green, with some fur on the first leaf and leaf blades on the leaf stem. *Brassica juncea* has matured from a height of one to two meters. The top of the leaves is thin and intact so that the bottom leaves vibrate very well. *Brassica napus* and *Brassica rapa* differ from *B. juncea* as upper leaves are not seized. The inflorescence is an elongated raceme, with pale yellow flowers and open gradually up to the base. Sowing of 2.5 to 5 cm long excluding the beak is mildly depressed. The beak length is between 0.5 and 1 cm. The seeds can be yellow or brown and are round. (CFIA, 2008).

2.1.3 Ecological requirements

In soils with a minimum pH level of between 5.5 and 6.8, Indian mustard grows well. Indian mustard grows in the best conditions as a rained crop but grows well in some dry parts and average temperature between 15 to 18˚C (James, 1983). Indian mustard will tolerate soil acidity in moderation, which prefers a pH level. It can also grow with or without semi-shade and favours moist soil. The cool seasonal cultivation that is Indian mustard loves the uniqueness, low humidity and fair sunlight. It grows in areas with hot and cold days and is moderately drought-resistant like well-drained soil, when the season is not too intense, it can also be growing.

2.1.4 Production and economic important

Department of Agriculture Peninsular Malaysia (DOA, 2016) has shown that *Brassica* production is the highest year-round. The planted area for *Brassica* is approximately 14, 443 hectares, the cultivated area is 14, 098 hectares and the area are 224, 126 metric tons. Based on the hectare and vegetable production of Malaysia, *Brassica* became the first of ten highest-hectare vegetable types and cash crops in 2016 with the production amount RM542, 385. In Kelantan, the production for *Brassica* is also high since the vegetables are locally consumed by most of the residents here. The *Brassica* production in Kelantan is 2.086,92 metric tons per year with 157,65 hectares of the planted area. And it adds up to RM 5050.34 output volume (DOA, 2016).

2.2 Nutrient release from fertilizer

Fertilizers are soils or crops of natural or synthetic origin for soil and plant tissues but are normally added in leaves to provide one or more plant nutrients that are necessary for plant growth. Fertilizers come from the shape and material of liquid, gaseous, or solid compounds that contain one or more plant nutrients (Heng, 2016). The purpose of fertilizer is to naturally replenish the supply of nutrients to the soil, create soil fertility to satisfy crop requirements with high yield potential and offset nutrients taken up by harvested or missing goods due to eventual environmental leaking and to ensure that soil conditions that are ideal for planting are maintained. Usually, fertilizers release nutrients at a slower pace and over a longer period, while they participate in a breakdown and releasing mechanism called mineralization (Crouse, 2018). This nutrient which, because of the complex chemical structure of the fertilizer, contains some nutrients or nutrients slowly released into the soil is normally N. Mineralization effect of moisture, temperature, microbial organisms and plant communities.

2.3 Seaweed extract

Seaweed extract is an organic fertilizer provided as the primary raw material by precise processing of marine plant seaweed. The primary ingredient is the organic natural active substance derived from kelp (Darren, 2019). The successful seaweed extract includes a huge number of organic materials containing non-nitrogen, including 40 types of minerals, such as iodine, zinc, copper, magnesium, calcium and potassium, and plenty of terrestrial plants, in particular, seaweed polysaccharides, which are unmatchable to seaweed. The development of non-specific active factors in crops will stimulate alginic acid, highly unsaturated fatty acids and other natural plant growth, regulators. The benefits of this seaweed extract are as follows; improved post-harvest durability increased resilience to biotic and abiotic stress, improved crop production and yield, and premature seed germination and establishment. Seaweed extract is used as a biofertilizer or biostimulant and nutrient addition to enhancing crop yield and growth (Khan, 2009).

Table 2.1: List of the effect of seaweed extract on the plant growth

Plant species	Seaweed extract concentration	Effect	References
Potato (*Solanum tuberosum L.*)	200, 325 and 558 mg/ha (foliar spraying)	Enhancement of tuber size	(Falcón-Rodríguez, Costales, Gónzalez-Peña, Morales, Mederos, Jerez, & Cabrera, 2017)
10 species of rice plant	200, 300 and 500 mg/ha (foliar spraying)	Enhancement of number of tillers	Sunarpi, J.A. & Kurnianingsih, Rina & Julisaniah, Nur & Nikmatullah, Aluh. (2010).
Soybean (*Glycine max*)	250, 500, 750, 1000 mg/ha (foliar spraying)	Enhancement of growth, yield and nutrient uptake	(S. S. Rathore, D. R. Chaudhary, G.N. Boricha, A. Ghosh, B.P. Bhatt, S.T. Zodape, J.S. Patolia, 2008).
Petunia	0, 2.5, 5, 10, 20 ml/L (foliar spraying)	Post-production life	Yuqi. L., Neil. S. M. (2015).
Tomato (*Solanum lycopersicum* Mill.)	200, 300, 600, 900 mg/ha (foliar spraying)	Enhancement of leaf photosynthesis, ripening time.	Yuanyuan. Y., Xiaoqi. W., Baocheng. C., Min. Z., Jinzhao. M. (2020).

2.4 Animal manure

Animals can either negatively or positively lead to deforestation in a most forested environment in terms of energy-providing or via the container manures of fuel through manure or biogas, replacing charcoal, wood fuel, firewood and other sources. Animals have a significant role in the energy supply. Cow dung is a major source of bio-fertilizer but can be used for efficient bio-fertilizer with cow urine, cow horn and cow carcass. Cow dung is a great source of soil productivity and a growing number of microbial populations. The fertilizer includes three main plant nutrients which are nitrogen, phosphorus, and potassium (NPK), and other nutrients such as carbon, magnesium, sulphur, zinc, copper, and so on as per Fulhage (2000). In addition to the supply of plants with nutrients, fertilizers usually improved the slope, aeration and resistance to soil water. The use of cow dung manure and vermicomposting increases the organic content of the soil and contributes to more water, water resistance and cation exchange.

Due to a long-lasting role for sustainable agriculture, rising prices of chemical and inefficient fertilizers, it is essential to use organic fertilizers, like cow dung, to maintain full efficiency with greater soil health. It can also be used as a basis for energy, fertilizer, biogas, and electricity, with a significant socio-economic component. Effective manure usage would further improve the safety of energy and reduce environmental and greenhouse gas damages (Raipur, 2014).

2.5 Effect of organic and inorganic fertilizer on leafy vegetables

2.5.1 Physiological growth response

To improve crop yield, Chen (2006) noted that it depends in great part on the form of fertilizers used to provide the plants with essential nutrients. Since adequate and balanced nutrients have to be available for optimal crop development, fertilizers have also been engineered to add nutrients that are already present in the soil. Inorganic fertilizers and organic manure impact plant growth and land both positively and negatively (Han, An, Hwang, Kim & Park, 2016). Inorganic fertilizer nutrients are soluble and available immediately to the plants so they typically work directly and quickly, while organic fertilisers have a more balanced nutrient supply which will help to maintain the plant healthy (Chen, 2006).

Slower releases of organic fertilizer nutrients into the soil transform into plants with high productivity of nutrient usage. Nutrient loss by liquidation, depletion and volatilization is reduced (Rauton, 2007). The increase in CO2 concentration, Smith (2004) said, is a function of the increase in soil organic carbon (SOC) thus enhancing soil productivity for cultivation. Mbatha (2008) indicates that good soil aeration is more favourable for deeper roots to ensure strong stems and larger plants particularly on sandy soils or in degraded areas with high nutrients. Adding animal manure, for example, will boost carrot root growth to 10 cm deep. Mbatha (2008) also noted that despite having a good crop, roots emerge into deeper soil layers and permit plants to extract more water and nutrients. Increased plant growth rates including height, stem diameter, sheet and leaf numbers.

2.5.2 Yield

Various studies compare organic and inorganic fertilizer to yielding plants. Gontcharenko (1974) and Haraldsen et al. (2000), where vegetables such as cucumber, tomatoes and cabbage treated with inorganic fertilizer produced better returns than organic fertilizers, also showed a beneficial impact of inorganic fertilizer application on plant production and yield changes. The results were higher. However, other findings suggest that organic fertilizer leafy vegetables such as lettuce have more dry weight than those inorganically fertilized (Mbatha, 2008).

Furthermore, a mixture of organic and inorganic fertilizers has also shown a beneficial impact for different experiments. Bandyopadhyay (2010) has significant changes in plant growth parameters, including root length density, root mass density, and leaf span, as well as in the prescribed usage of farmyards and inorganic fertilizer dosage. Organic manure and sawdust have been reported to not only encourage yellow poplar growth but to improve soil conditions as well (Han et al., 2016). The use of combined organic or inorganic nutrient sources can be more production-oriented, and soil fertility and productivity will continue, according to Ullah (2018). The development and production of radish were also improved with the integrated application of recycled and inorganic-organic waste (Asghar et al., 2006).

CHAPTER 3

METHODOLOGY

3.1 Materials

3.1.1 Plant materials

Seed of bioassay species, Indian mustard [*Brassica juncea* (L.) Czernjaew] was brought from WLS Mart located at Kok Lanas, Kelantan, Malaysia. Meanwhile, cow dung manure and seaweed extract were purchased from Nutrigrow 123 at Johor Bharu, Johor, Malaysia.

3.1.2 Apparatus/Equipment

In this study, there are several apparatus and equipments that was used as in Table 3.1 below:

Table 3.1: Apparatus and Equipments

Activity	Apparatus/ Equipments
1. Treatment preparation	- Micropipette - Beaker - Petri dish - Cotton Pad
2. Crop cultivation	- Seedling tray - Polybag 15x14 - Watering can - Silver shine - Hoe - Shovel - Gardening fork
3. Data collection	- Digital scale (dry weight/fresh weight) - Oven (dry weight/fresh weight) - Ruler/ measuring tape (plant height/ root length) - Calipers (leaf diameter) - SPAD meter (chlorophyll content)
4. Data analysis	SPSS SOFWARE

3.2 Methods

3.2.1 Treatment preparation

The seaweed extract was prepared by dissolving 5.0 g of seaweed extract in 1000 ml of distilled water to get the stock solution of 5.0 ml/g. Then, the stock solution was diluted to a series of application rates as below:

Table 3.2: List of treatments

Treatment	Application Rate
T0 (Control)	Soil + Seaweed extract (0.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
Treatment 1	Soil + Seaweed extract (0.5 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
Treatment 2	Soil + Seaweed extract (1.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
Treatment 3	Soil + Seaweed extract (2.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)

Note: Cow manure recommended rate (20t/ha) –Source: (Usman, 2015)

NPK recommended rate (2t/ha) – Source: (Usman, 2015)

Seedling growth experiment

The study on the activity of soil treated with seaweed extract on the growth and yield of Indian mustard was conducted at the Agro TechnoPark of Universiti Malaysia Kelantan (UMK), Jeli Campus, Kelantan, Malaysia. A total of 4 kg of topsoil together with coco peat was filled in a polybag with a diameter of 15 cm x 14 cm. Five Indian mustard seeds were planted in each polybag after proper seed selection and moistened daily with water. At one week after planting, the Indian mustard plants were thinned to one plant per polybag using garden scope leaving the most vigorous and healthier plant. On weeks two, four and five, the cow manure and NPK 15:15:15 fertilizer were applied at the recommended rate of 20 tan/ha (15.71 g/polybag) and 2 tan/ha (1.571 g/polybag) for all polybags, respectively. After one day of fertilizers application, the seaweed extract was treated onto the soil surface at different application rates of 0.0 ml/g (T0), 0.5 ml/g (T1), 1.0 ml/g (T2) and 2.0 ml/g (T3) with the spraying volume of 500 L/ha (equivalent to 0.393 ml / 393 microliters (µl) per plant/polybag). All the treatments were in three replications. Non-treated Indian mustard plant was used as control. Next, the polybags were placed under a shelter house with temperatures ranging from 25ºC to 30ºC and maintained at 75% to 80% relative humidity. The seed was considered germinated upon plumule emergence. After 40 days of cultivation, the plant height, root length, leaf diameter, chlorophyll content and yield (fresh and dry weight) of Indian mustard were measured. Plant height and root length were measured by using the measuring tape. For leaf diameter, a Vernier caliper was used and the yield of Indian mustard was measured by using a weighing scale. The chlorophyll content of the plant further was measured by using the SPAD meter.

3.3 Statistical analysis

The experiment was arranged in a completely randomized design (CRD) with three replications. All data were subjected to one-way ANOVA analysis. The Tukey HSD was used to compare the mean among the treatments. Differences were regarded as significant the p-values were less than 0.05 ($p<0.05$).

CHAPTER 4

RESULTS AND DISCUSSION

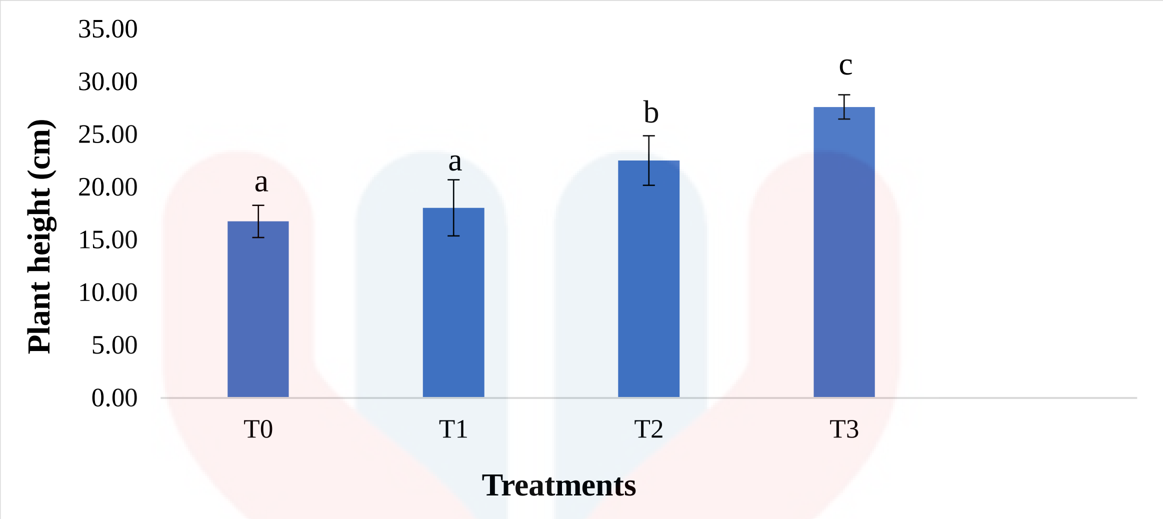
4.1 Effect of seaweed extract on plant height of Indian mustard [*Brassica juncea* (L.) Czernjaew]

The treatments of seaweed extract had a positive impact on the plant height of Indian mustard cultivated in polybags. The increased application rate of seaweed extract from 0.5 ml/g (**T1**) to 2.0 ml/g (**T3**) significantly enhanced the plant height with the values ranging from 18.04 cm to 27.62 cm (Appendix B). However, it was found that there is no significant increase on plant height when the Indian mustard was treated with control, **T0** (0.0 ml/g) and **T1** (0.5 ml/g) of seaweed extract.

According to Blunden (1991), bioactive compounds extracted from marine algae have a variety of favourable benefits in terms of productivity and quality enhancement in crop cultivation. A study conducted by Rathore et al. (2008) investigated that the increased application of seaweed extract resulted in a progressive rise of plant height of soybean crops [*Glycine max* (L.) Merr.] grown in the field. They also reported the plant height was significantly increased by 46% and 57% as compared to the control at a concentration of 12500 ml/g and 15000 ml/g seaweed extract, respectively. Later on, Dogra (2012) documented that seaweed extract at concentrations of 2500 ml/g and 3000 ml/g significantly improved the plant height of onions [*Allium Cepal* (var.) Ascalonicum] by 120.8% and 102.5%, respectively as compared to the control**.**

Referring to Prajapati et al. (2016), foliar applications of seaweed extract at 2.5 ml/g – 10.0 ml/g substantially altered the vegetative development characteristics of growth and yield of potato (*Solanum tuberosum*) in terms of plant height. The most stimulatory impact was recorded on plant height in plants treated with 10.0 ml/g seaweed extract, with 65.48 cm as compared to the control plant, with a plant height of 30.3 cm.

However, the results in this current study showed that the application of seaweed extract at a concentration as low as 1.0 mg/ml (**T2**) to 2.0 mg/ml (**T3**) significantly increased the plant height of Indian mustard, suggesting that the seaweed extract application exhibit different effect with a various concentration on crops and plants.



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Legend:

T0 (Control)	Soil + Seaweed extract (0.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T1	Soil + Seaweed extract (0.5 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T2	Soil + Seaweed extract (1.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T3	Soil + Seaweed extract (2.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)

Figure 4.1 Plant height of Indian mustard [*Brassica juncea* (L.) Czernjaew], 40 days after treatment with different rates of seaweed extract. Vertical bars represent the standard deviation (SD) of the mean.

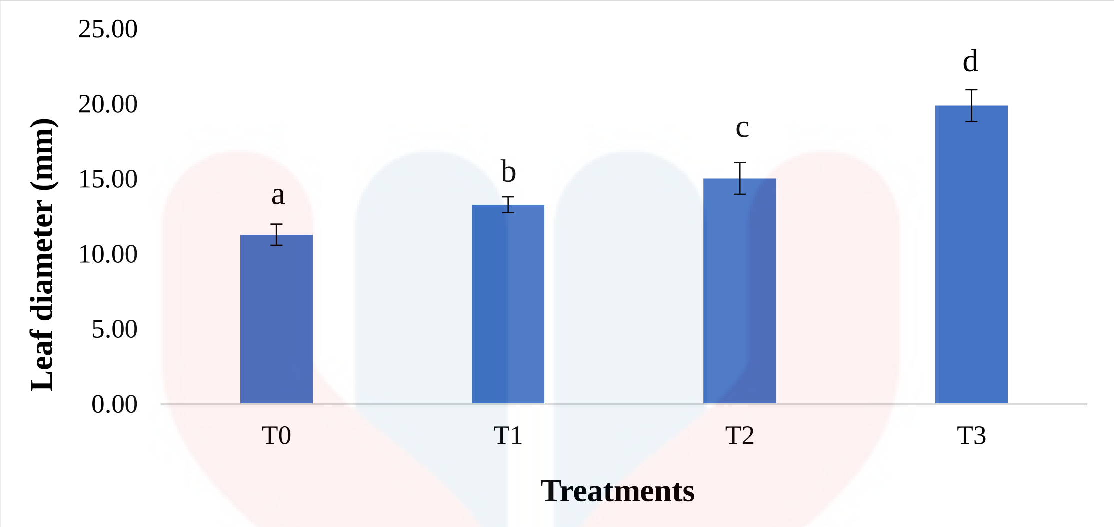
4.2 Effect of seaweed extract on leaf diameter of Indian mustard [*Brassica juncea* (L.) Czernjaew]

Figure 4.2 shows the effect of the seaweed extract at different concentrations towards the leaf's diameter of Indian mustard. It is interesting to note that all seaweed treatments significantly increased ($P \leq 0.05$) the leaf diameter of bioassay species (Appendix C). Seaweed extract at an application rate of 2.0 ml/g (**T3**) showed the biggest leaf diameter with the mean value of 20 mm (43.0% increment over control). Conversely, for the Indian mustard that were treated with 0.5 ml/g (**T1**) and 1.0 ml/g (**T2**) of seaweed extract, the leaf diameter of plants showed 22.33% and 25.27% increment as compared to control (**T0**), respectively.

Kingman and Moore (1982) reported that seaweed contains all of the trace minerals and hormones for the plant growth and development. According to Rao et al. (2014), seaweed extract through soil application influences seed germination, growth, and fruit development of several vegetable crops including brinjal (*Solanum melongena*), tomato (*Solanum lycopersicum*), and chilli (*Capsicum frutescens*). They found that a higher concentration of seaweed extract at 15000 ml/g had increased the leaf diameter of brinjal, tomato and chilli by 23 mm, 15 mm, and 17 mm, respectively.

The potential of other plant extract in increased the leaf diameter of plants also has been reported in many studies. Recently, Hasibuan (2020) observed that the bamboo shoot extract was found to increase leaf diameter of binahong plant (*Anredera cordifolia* (Ten.) Steenis.) with the mean value of 30.5 mm, at highest concentration of 40000 ml/g.

These previous findings showed that the application of the seaweed extract was very high to give the effect to the selected crops. However, in the present study, the seaweed extract that is treated in the soil only need small concentrations ranging from 0.5 ml/g - 2.0 ml/g to increase the leaf diameter of Indian mustard. This result suggests that seaweed extract act as a stimulant to increase the efficiency of fertilizer uptake by the plant.



Legend:

T0 (Control)	Soil + Seaweed extract (0.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T1	Soil + Seaweed extract (0.5 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T2	Soil + Seaweed extract (1.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T3	Soil + Seaweed extract (2.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)

Figure 4.2 Leaf diameter of Indian mustard [*Brassica juncea* (L.) Czernjaew], 40 days after treatment with different rates of seaweed extract. Vertical bars represent the standard deviation (SD) of the mean.

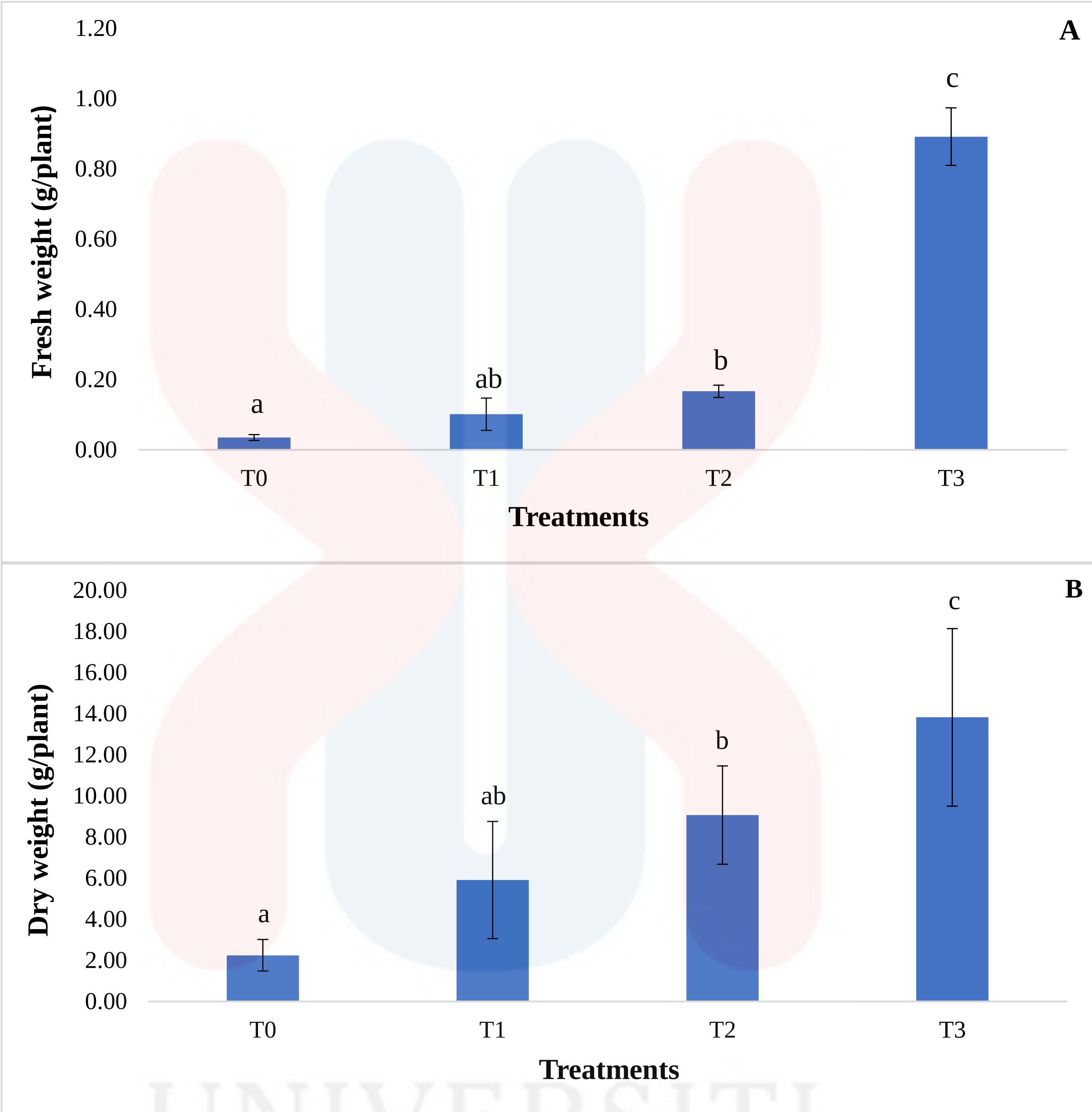
4.3 Effect of seaweed extract on fresh weight and dry weight of Indian mustard [*Brassica juncea* (L.) Czernjaew]

The fresh weights and dry weight of Indian mustard are affected by the treatment of seaweed extract. Figure 4.3A shows there is significant increase in term of plant fresh weight at an application rate of 1.0 ml/g (**T2**) and 2.0 ml/g (**T3**) as compared to the control (**T0**) with the mean value ranging from 0.17 g/plant (76.5% increment) to 0.89 g/plant (95.5% increment), respectively (Appendix D). However, there is no significant increase in fresh weight of Indian mustard that treated with **T0** and lowest application rate of seaweed extract at (**T1**) 0.5 ml/g. A similar pattern was also observed for plant dry weight where **T2** and **T3** significantly increased the dry weight of Indian mustard (Figure 4.3B). It was found that the plant dry weight was increased by 75.2% and 83.7% at **T2** and **T3**, respectively as compared to the control (Appendix E).

These results were in line with the study conducted by Nelson (1984) where the seaweed extract was found to enrich the soil. Furthermore, the seaweed extract also shows the increase in growth and yield of selected terrestrial plants even under harsh environmental circumstances. Thirumaran et al. (2009) reported that the seaweed extract with a concentration ranging from 0.5 – 2.0 ml/g had increased the growth and yield of cluster pea [*Cyamopsis tetragonoloba* (L) Taub]. They demonstrated that the fresh weight and dry weight of cluster pea at a concentration of 2.0 ml/g seaweed extract was 6.76 g and 6.46g, respectively. Meanwhile, the seaweed extract had a minimum fresh weight and dry weight with 3.97g and 3.92g, respectively at a low concentration of 0.5 ml/g seaweed extract.

Senthuran et al. (2019) discovered the influence of seaweed extract as a foliar spray at 5000 ml/g and 10000 ml/g on the growth and development of a common leafy vegetable crop (*Amaranthus polygamous*). It was reported that at the maximum concentration of 10000 ml/g seaweed extract, the fresh weight and dry weight of *A. polygamous* was increase by 28.6 g and 27.4 g, respectively. Conversely, the fresh weight and dry weight of the plant only increased by 22.8 g and 20.1g, respectively at the lowest concentration of 5000 ml/g seaweed extract.

Plant extracts from some trees, as well as existing plant residues, can affect crop development and production (Farooq et al., 2008). Mahmood (2020) discovered that increasing the availability of NPK by adding organic fertiliser to the soil and spraying with 5ml/g of garlic extract had increased the dry weight (157 g) and fresh weight (177 g) of tomato (*Solanum lycopersicum*). Similar to this study, seaweed extract at various concentration shows synergistic effect with the fertilizer that available in the soil, thus enhance the India mustard yields in term of fresh weight and dry weight.


A
Fresh weight (g/plant)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
a
ab
b
c
T0
T1
T2
T3
Treatments
B
Dry weight (g/plant)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
a
ab
b
c
T0
T1
T2
T3
Treatments

Legend:

T0 (Control)	Soil + Seaweed extract (0.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T1	Soil + Seaweed extract (0.5 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T2	Soil + Seaweed extract (1.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T3	Soil + Seaweed extract (2.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)

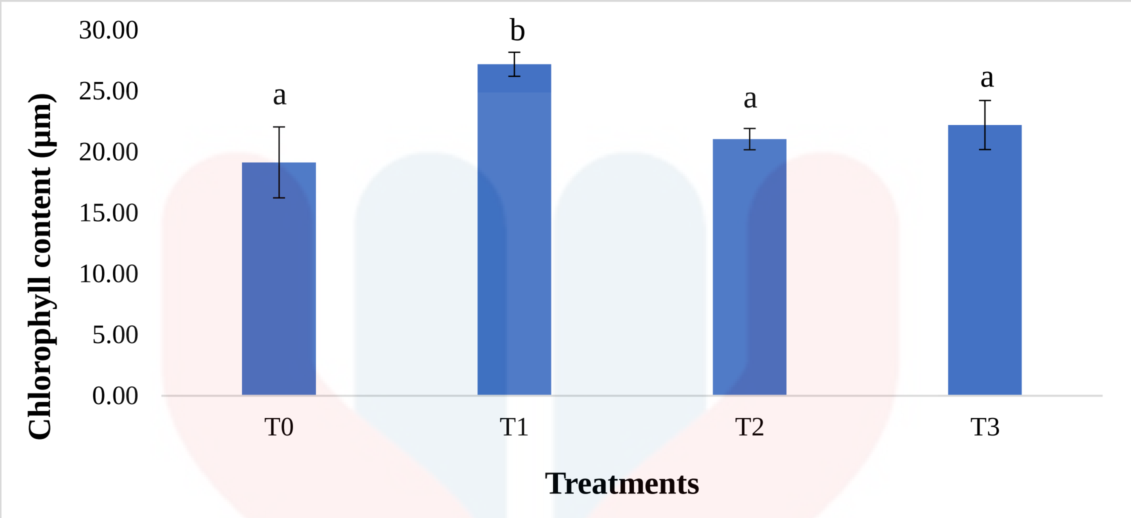
Figure 4.3 Fresh weight (A) and dry weight (B) of Indian mustard [*Brassica juncea* (L.) Czernjaew], 40 days after treatment with different rates of seaweed extract. Vertical bars represent the standard deviation (SD) of the mean.

4.4 Effect of seaweed extract on chlorophyll content of Indian mustard [*Brassica juncea* (L.) Czernjaew]

Figure 4.4 showed the chlorophyll content of the Indian mustard against the treatments applied. It was found that there is no significant increase in chlorophyll content for all seaweed extract treatment ($P \geq 0.05$), except **T1** (0.5 mg/l). The chlorophyll content of Indian mustard in **T1** increased almost 30% (27.2µm) from **T0** (19.2µm).

According to Chapman (1980), seaweeds are a group of plants that live either in brackish water environments or in the sea. Seaweed, like terrestrial plants, has photosynthetic pigment that can photosynthesize and create food with the assistance of sunlight and nutrients available in seawater. A study conducted by Sathya et al. (2010) shows that seaweed extract at various concentrations of 1.0 ml/g, 2.0 ml/g, 3.0 ml/g, and 4.0 ml/g has affect the growth and biochemical composition of legume crops [*Cajanus charge* (L.) Mill sp]. They observed that seaweed extract at a concentration of 3.0 ml/g exhibit maximum chlorophyll content (18.6 µm) in legume crops and promoted maximal photosynthetic pigment.

Meanwhile, another study on plant extract conducted by Ahmad (2013) shows that garlic extract had increases the chlorophyll content of the pepper plant (*Piper nigrum*), which might be related to the increased of plant nutrient availability. The pepper plants' chlorophyll content was significantly affected by garlic extract at 1.0 ml/g, 1.5 ml/g, and 2.0 ml/g, resulting in an average increase of 29.3 µm as compare to the control plants (17.3 µm). Likewise, the soil treated with seaweed extract in this current study give synergistic effect in increased the nutrient availability in the soil medium for the Indian mustard growth.



Legend:

T0 (Control)	Soil + Seaweed extract (0.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T1	Soil + Seaweed extract (0.5 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
T2	Soil + Seaweed extract (1.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)
Tr3	Soil + Seaweed extract (2.0 ml/g)+ Cow manure (20 tan/ha) + NPK (2 tan/ha)

Figure 4.4 Chlorophyll content of Indian mustard [*Brassica juncea* (L.) Czernjaew], 40 days after treatment with different rates of seaweed extract. Vertical bars represent the standard deviation (SD) of the mean.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the seaweed extract improves the growth and yield of Indian mustard [*Brassica juncea* (L.) Czernjaew] by increasing plant height, leaf diameter, fresh and dry weight, and chlorophyll content. **T2** and **T3** at 1.0 ml/g and 2.0 ml/g of seaweed extract, respectively at had significantly increased in the plant height, fresh weight, dry weight and leaf diameter of Indian mustard. However, at these two concentrations it was found that there is no significant increase in chlorophyll content, where the effect was likely similar to control plants. These findings suggest that **T3** would be the optimum concentration which can be integrated in the soil to promote the growth and yield of Indian mustard.

5.2 Recommendation

The results of this preliminary study show that soil treated with seaweed extract can boost the growth and yield of Indian mustard. Therefore, further study on the physico-chemical of soil is very important because the soil productivity is affected by both its physical and chemical properties. The exploitation of seaweed extract in improve soil fertility as well as improving vegetables production will bring economic productivity for farmers and growers who engaged in agriculture.

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APPENDIX A

A. Indian mustard growth experiment

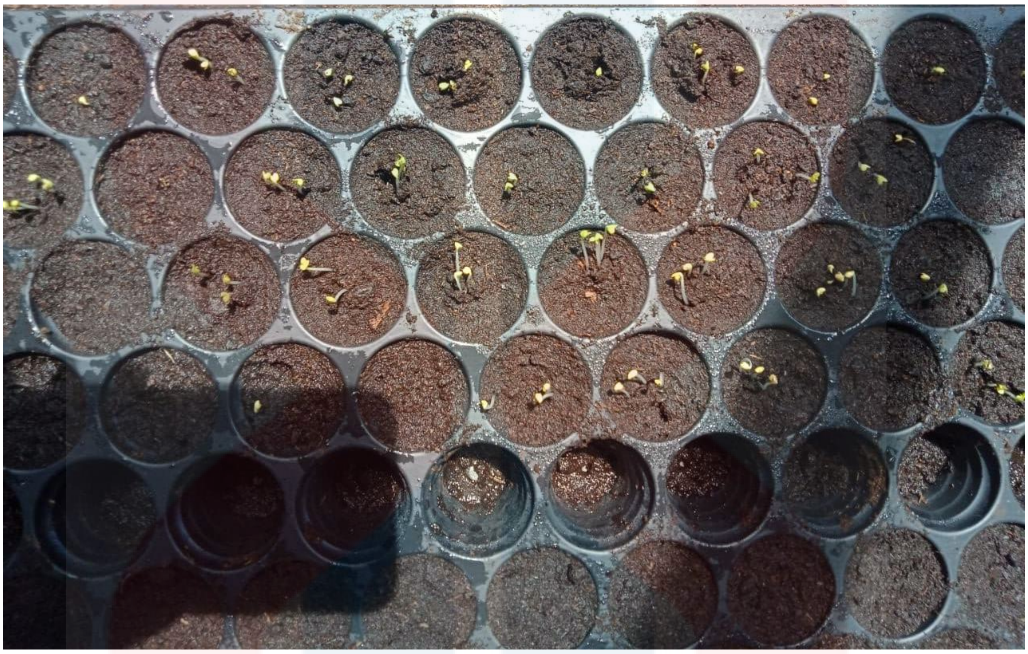

Figure A.1: Seedlings grow after 2 days of sowing into planting tray

Figure A.2: After 14 days of planting, seedlings were transferred into a polybag

Figure A.3: Indian mustard plant after transplanting into the polybag

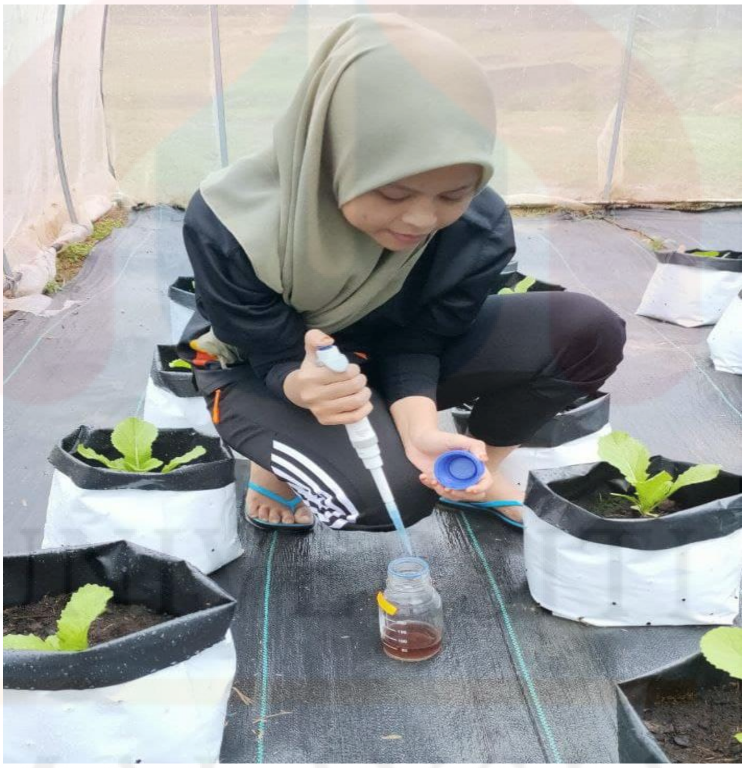

Figure A.4: The seaweed extract was treated onto the soil surface

Figure A.5: Indian mustard plant after application of seaweed extract

Figure A.6: Indian mustard plant after being harvested

APPENDIX B

Table B1: Plant height of Indian mustard 40 days after cultivation

Tukey HSD[a]

TREATMENTS	N	Subset for alpha = 0.05 1	2	3
T0(Control)	9	16.7556		
T1	9	18.0444		
T2	9		22.5333	
T3	9			27.6222
Sig.		.535	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

Table C1: Leaf diameter of Indian mustard 40 days after cultivation

Tukey HSD[a]

		Subset for alpha = 0.05			
TREATMENTS	N	1	2	3	4
T0 (Control)	6	11.3000			
T1	6		13.3000		
T2	6			15.0500	
T3	6				19.9000
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 6.000.

Table D1: Fresh weight of Indian mustard 40 days after cultivation

Tukey HSD[a,b]

TREATMENTS	N	Subset for alpha = 0.05 1	2	3
T0 (Control)	6	.0350		
T1	7	.1014	.1014	
T2	6		.1667	
T3	5			.8920
Sig.		.089	.097	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 5.915.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table E1: Dry weight of Indian mustard 40 days after cultivation

Tukey HSD[a]

TREATMENTS	N	Subset for alpha = 0.05		
		1	2	3
T0 (Control)	9	2.2480		
T1	9	5.9062	5.9062	
T2	9		9.0672	
T3	9			13.8181
Sig.		.051	.112	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

Table F1: Chlorophyll content of Indian mustard

Tukey HSD[a,b]

		Subset for alpha = 0.05	
TREATMENTS	N	1	2
T0 (Control)	6	19.1500	
T2	5	21.0600	
3	6	22.2167	
1	6		27.2000
Sig.		.064	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 5.714.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.