

# Combination of Organic, Chemical and Biological Fertilizers to Accelerate Mangrove Growth on the East Coast of Sumatra, Indonesia

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**Abstract:** Efforts to rehabilitate mangroves often do not yield satisfactory planting results. Low maintenance measures due to the tidal situation of the area make it difficult for rehabilitation actors to carry out fertilization and insertion. This study aims to increase the growth of *Rhizophora mucronata* with fertilization treatment during planting with various biological fertilizers. The study was designed using a completely randomized non-factorial design with 6 treatments. The results of the study for 5 months showed that the provision of treatment resulted in different plant growth. The biological fertilizer given significantly increased growth in all parameters measured. Trichoderma and mycorrhiza increased plant growth. However, the addition of manure produced a better response both without biological fertilizer and in combination with biological fertilizer. The best response was obtained in the treatment of manure combined with M21 microbes and chemical NPK fertilizers for all parameters measured.

**Keywords:** R. Mucronata, Growth, Biological Fertilizer, Manure, Chemical, Combination

## Introduction

The Indonesian Archipelago has a very long coastline. This condition allows Indonesia to have extensive mangrove forests. The Indonesian mangrove community is recorded as the largest area in the world, the total area of Indonesian mangroves is currently 3,364,076 Ha. However, this area is only 2% compared to the total land area of Indonesia (Eddy *et al.*, 2019).

Asahan Regency is one of the areas in North Sumatra Province that has a mangrove forest area of around 4,624.41 km<sup>2</sup>. Silo Baru Village is a village that has a Mangrove ecosystem area which is administratively located in Silo Laut District, Asahan Regency, North Sumatra with an area of around 84.6758 km<sup>2</sup>.

The pressure on mangrove forests is now increasing considering that the land area that can be used for land conversion is increasingly limited. Rapid population growth has forced a significant increase in land use. Among the various types of land use, the highest conversion of mangrove forests is conversion into oil palm plantations. In this condition, flooded and muddy mangrove land will be drained using drainage ditches and embankments will be built so that seawater does not

inundate the plant area again. The mud in the mangrove land will actually be very beneficial for the growth of oil palm because it means that this mud contains nutrients that are ready to be absorbed by oil palm roots which are known to be greedy for nutrients. This basic idea is what then encourages investors to penetrate mangrove forests.

Law enforcement related to land conversion into oil palm plantations is now starting to be enforced. Areas that previously had the status of mangrove forests must be returned to forests. However, rehabilitation efforts are not easy due to various aspects such as environmental changes to land, decreasing soil fertility, and genetic causes of the mangrove species itself.

Therefore, to increase the ability to grow and develop, mangrove seedlings must receive environmental support that supports their growth. One of them is by providing sufficient nutrients through increasing biological activity in the root environment of this plant. The seedling period is a very critical growth period with a mortality rate of up to 70% if environmental conditions are not supportive (Jiang *et al.*, 2019). Therefore, this study was conducted to create a rhizosphere atmosphere that can support the growth of mangrove roots. In this case, researchers used several types of biological

fertilizers to increase the decomposition of minerals and litter that were previously in an unavailable condition so that they can be absorbed by plant roots and support optimal plant growth (Qiong *et al.* 2016)

One type of mangrove that is known to have benefits for the socio-economy of the community is *Rhizophora mucronata*. This type of plant habitus is a tree that can reach a height of up to 20 m with a trunk diameter of 50 cm at the age of 20 years (Mulyani *et al.*, 2020). This is what makes *R. mucronata* wood very popular in the market because in addition to having longer heat resistance, its large diameter makes it charcoal with the highest economic value (Setyawan *et al.*, 2019). The fruit can also be used as processed flour which can be made into various types of processed foods. This plant is very suitable to be developed as a rehabilitation plant that has the potential to produce multi-purpose non-wood economic benefits (Kurniati *et al.*, 2022).

Mangrove species rarely receive fertilization because frequent flooding washes away the applied fertilizer. This is what causes the mangrove rehabilitation program to be limited to planting seedlings or propagules. The effect of fertilizer on *Rhizophora mucronata*, *Trichoderma* can reduce root disease attacks and increase the efficiency of water and nutrient use from the soil, Mycorrhiza can increase root growth, resistance to abiotic stress, and increase the availability of water and nutrients in the soil. Application of manure to *Rhizophora mucronata* can improve soil texture and provide a sustainable source of nutrients, which supports better plant growth, especially in swampy or coastal land conditions. The use of M21 microbes can accelerate the decomposition of organic matter in the soil, increase nutrient availability, and increase plant resistance to disease or environmental stress. Application of NPK fertilizer can increase leaf growth, roots, and overall plant biomass, especially if the soil is less rich in nutrients. Overall, the growth of *Rhizophora mucronata* is influenced by the balance between these factors. Warm temperatures, high humidity, moderate salinity, and sufficient rainfall are optimal conditions for its growth. These fertilizers are very affordable and easily available to local people. However, extreme conditions such as temperatures that are too hot or cold, very high salinity, or unbalanced rainfall (too little or too much) can inhibit or damage the growth of this plant. Therefore, the existence of a healthy mangrove ecosystem is highly dependent on stable environmental conditions. In fact, the baby plant stage is a very critical stage that determines the development of seedlings to be able to grow optimally until the generative period. Therefore, there must be a modification of the root environment that supports optimum growth of mangrove roots to the adult phase so that it can be ensured that at the age of 7 years they can reach a diameter of 30 cm. In this case, researchers made efforts to increase growth using several biological fertilizers because of their nature that lasts longer in the rhizosphere area. The purpose of this study

was to determine the effect of *Trichoderma* sp., mycorrhiza organic fertilizer, M<sub>21</sub> microbes and manure on their interactions with soil biological microbes to increase the growth of *R. mucronata* plants.

## Materials and Methods

The study's instruments were analytical scales, Shuntoo caliper, ovens, Nikon DSLR cameras, and Lenovo laptops with Windows i7 specifications equipped with ArcGis software version 8.0 and Autocad version 8.0. The materials used in this study were *R. mucronata* seedlings, *Trichoderma* biological fertilizer, mycorrhiza, chicken manure, M<sub>21</sub> microbes, NPK 16-16-16 fertilizer, name labels, plastic ropes, sample envelopes, millimetre paper

The study was conducted on the East Coast of Silo Laut Village, Air Joman District, Asahan Regency, North Sumatra, Indonesia situated at 03°12'79.20"E, 99°77'42.62"N and at the Forest Silviculture Laboratory, Faculty of Forestry, Universitas Sumatera Utara. The research was conducted for 6 months starting in August 2023 until completion. The research location map can be seen in Figure 1.

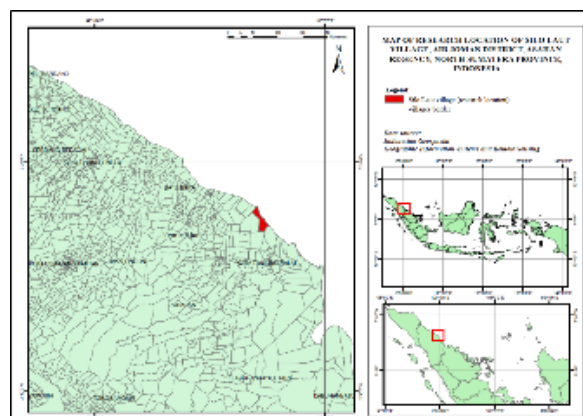


Fig. 1: Map of research location

The study used a Non-Factorial Completely Randomized Design consisting of 6 treatments and 10 replications, so that there were 60 experimental units, namely:

- P<sub>0</sub> = control
- P<sub>1</sub> = *Trichoderma* 10 g/plant
- P<sub>2</sub> = Mycorrhiza 10 g/plant
- P<sub>3</sub> = Pure manure 500 g/plant
- P<sub>4</sub> = Manure + M<sub>21</sub> microbes 100 ml
- P<sub>5</sub> = Manure 500 g + M<sub>21</sub> microbes 50 ml + NPK fertilizer 50 g

The doses used in this study refer to the recommended doses for each microorganism (Rokhminarsi and Utami, 2019; Fiodor *et al.*, 2021). The determination of the dose used is the recommended dose stated on the product packaging. The Linear Model of the Non-Factorial Completely Randomized Design is as follows:

$$Y_{ij} = \mu + \tau_i + \sum j$$

Before starting the experiment, the site must be cleared of weeds, debris, and other materials that may hinder plant growth. This ensures that the research environment is clean.

### Seed Preparation and Fertilization

This stage is the most crucial stage in determining plant growth in the field. So in this period, seed handling is the most important thing to consider. *Trichoderma* is a type of fungus that is widely used as a biocontrol agent. They are saprophytic and mycorrhizal (can interact with plant roots). *Trichoderma* plays a role in overcoming plant pathogens by competing for space, producing enzymes, or breaking down pathogen cell walls. *Trichoderma* also plays a role in improving soil health and supporting plant growth. Mycorrhizal fungi can increase the efficiency of water and nutrient absorption, especially phosphorus, for plants, which is very important for plants in mangrove habitats that tend to be poor in nutrients. *R. mucronata* seedlings were obtained

from measurements around the planting location (Usman *et al.*, 2022). Seeds were selected that were physically uniform, had the same number of leaves, namely 2 strands and were 3 months old (Widayanti and Firmansyah, 2022). The selected seeds were then planted with a spacing of 0.5 m x 0.5 m. To avoid contamination between treatments, treatments were given at every 10 plants. Likewise, the placement of the replications was also carried out at a distance between 20 plants. After planting, the plants were marked according to the treatment. To reduce data errors, the same treatment was repeated 10 times.

After the plants were marked, fertilizer treatment was given to each treatment plant. Fertilizer is given when the sea water is receding to ensure that the fertilizer can be completely immersed in the rhizosphere area. In the manure treatment, the manure with microbes and NPK fertilizer is mixed evenly before being immersed in the soil to ensure its homogeneity in the manure. Fertilization is only done once in 5 months of observation. Harvesting is done after the 20<sup>th</sup> observation and then manually removed.



**Fig. 2:** Stages of planting, fertilization, and field observations

### Parameters and Data Analysis

In this research activity, observations were carried out once every two weeks for 5 months. Data collection was carried out 20 times by observing several parameters, namely: plant height and stem diameter which were observed every 2 weeks. Meanwhile, data on the number of leaves, leaf area, and crown area were calculated at the end of the observation period (Kim *et al.*, 2019).

Observations in the laboratory were continued by harvesting the treatment plants and weighing the wet and dry weight of the crown and roots of the plants. Furthermore, the plant parts were oven-dried for 3 x 24 hours at a temperature of 80°C to obtain the dry weight

of the crown and roots and the shoot root ratio for each treatment was calculated. To ensure that plant growth is only determined by the treatment factors without any other factors, measurements of temperature, humidity, salinity, rainfall, and physical and chemical properties of the soil were carried out at the research location. The data obtained from the research results were then analyzed using analysis of variance and if the treatment had a significant effect ( $P < 0.05$ ), then a further Duncan Multiple Range Test was carried out.

### Results and Discussion

To obtain a comprehensive picture of soil conditions, before conducting the research, tests were carried out on

the physical and chemical properties of the soil at the research location. The test results are presented in Table 1 below.

**Table 1:** Physical and chemical properties of soil at the research location indicate low chemical properties of soil

| Physical and chemical properties of soil | Test value result |
|------------------------------------------|-------------------|
| pH                                       |                   |
| H <sub>2</sub> O                         | 6.93              |
| KCL                                      | 6.04              |
| Exchangeable cations (me/100g)           |                   |
| K <sup>+</sup>                           | 159.43            |
| Na <sup>+</sup>                          | 9.01              |
| Ca <sub>2</sub> <sup>+</sup>             | 16.17             |
| Mg <sub>2</sub> <sup>+</sup>             | 10.6              |
| Al <sub>3</sub> <sup>+</sup>             | 0                 |
| H <sup>+</sup>                           | 2.5               |
| Number of base cation                    | 62.44             |
| Cation exchange capacity (me/100g):      |                   |
| Potential                                | 65.94             |
| Effective                                | 64.32             |
| Organic matter (%)                       |                   |
| a C                                      | 1.85              |
| b OM                                     | 3.56              |
| Availability (ppm)                       |                   |
| P                                        | 30.43             |
| K                                        | 158.15            |
| Total (mg/g)                             |                   |
| N                                        | 1.04              |
| P                                        | 0.65              |
| K                                        | 8.67              |
| Soil texture (%)                         |                   |
| Coarse sand                              | 18.01             |
| Medium sand                              | 12.86             |
| Fine sand                                | 25.94             |
| Dust                                     | 22.64             |
| Clay                                     | 20.55             |
| Texture class                            | silt clay loam    |

Based on the data obtained in Table 1, it was found that the soil fertility conditions at the research location were relatively low, especially for the main elements of nutrients supporting plant growth. This can be seen from the nitrogen content of 1.04%, phosphorus 0.65% and potassium 8.67 in the low soil. Thus, this illustrates the ability of the soil to support the growth of plants growing on it. However, the neutral soil pH value indicates the nature of the soil that is not toxic to plants because the availability of microelements will be within the minimum threshold (Oyediran *et al.*, 2024). This is also supported by the absence of Al<sub>3</sub><sup>+</sup> ions in the soil. The soil texture class of silt clay loam shows that the soil is quite good at supporting good root growth. However, it has a weakness where when dry the soil will harden quickly and inhibit root development.

### Plant Growth

The results of the analysis of plant height variance showed that each treatment given had a very significant

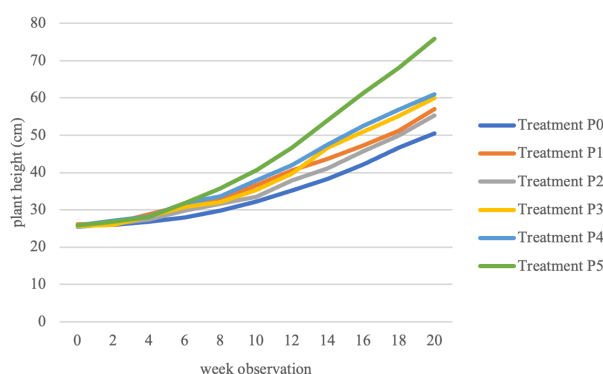
effect on the growth of *R. mucronata* plant height. Furthermore, the Duncan Multi Range Test further test showed the differences as shown in Table 2.

**Table 2:** Response of various treatments to various plant growth parameters in observations 20 weeks after planting in the field

| Parameter        | Treatment      |                |                |                |                |                |
|------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                  | P <sub>0</sub> | P <sub>1</sub> | P <sub>2</sub> | P <sub>3</sub> | P <sub>4</sub> | P <sub>5</sub> |
| Plant height     | 50.55a         | 56.98ab        | 55.32ab        | 60.03bc        | 61.04bc        | 75.87d         |
| Stem diameter    | 1.12a          | 1.2a           | 1.18a          | 1.31ab         | 1.34ab         | 1.98c          |
| Number of leaves | 5a             | 6a             | 5a             | 6a             | 6a             | 9b             |
| Leaves area      | 11.67a         | 12.18b         | 12.65b         | 13.66bc        | 14.21c         | 26.84d         |
| Crown area       | 345.55a        | 403.76b        | 432.51bc       | 501.03c        | 510.54c        | 784.65d        |

Note: Numbers followed by the same letter in the same column are not significantly different according to the duncan multi-range test at the 5 % level P<sub>0</sub> = Control; P<sub>1</sub> = Trichoderma sp; P<sub>2</sub> = Mycorrhiza; P<sub>3</sub> = manure; P<sub>4</sub> = manure + M 21 microbes; P<sub>5</sub> = manure + M 21 microbes + NPK fertilizer

Table 2 shows that all treatments given gave a significant effect in increasing plant growth parameters, namely: plant height, stem diameter, leaf area and plant crown area. The highest plant height growth response was obtained in treatment P<sub>5</sub>, namely manure + M<sub>21</sub> + NPK with an average of 75.87 cm. This is very different compared to the control which was only 50.55 cm. The combination of manure, M21, and NPK provides a double contribution in terms of soil quality and the availability of nutrients needed for plant growth. Manure improves soil quality and soil microbiology, M21 provides phosphorus and essential micronutrients, and NPK provides the main macronutrients (N, P, K). Thus, these three fertilizers support each other to achieve optimal growth results. Likewise for the parameters of stem diameter, number of leaves, leaf area and crown area. Overall there was a significant difference between treatment P<sub>5</sub> and control, as well as other treatments (P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>, P<sub>4</sub>). A description of the changes in plant height increase in all treatments during 20 weeks of observation can be seen in Figure 3 below.



**Fig. 3:** The growth rate of *Rhizophora mucronata* plants in the field at a planting age of 20 weeks (5 months) observed every 2 weeks

Basically, *Trichoderma* sp. and mycorrhiza have a positive effect on increasing plant growth. *Trichoderma* sp. has the ability to compete with pathogens in the soil, especially in terms of obtaining nitrogen and carbon. The biological genes of *Trichoderma* sp. are able to decompose lignin, cellulose, and chitin from organic matter into nutrients that are ready to be absorbed by plants (Krisdayani *et al.*, 2020). It's just that in the early stages of growth, *Trichoderma* sp. and mycorrhiza may still need to adjust first to their new environment, namely the location where these biological fertilizers are placed. These fungi must first adapt and develop themselves before working to mineralize nutrients and contribute them to the rhizosphere area (Ramirez-Viga *et al.*, 2020; Fall *et al.*, 2022). In order to grow and develop, these fungi require energy which is also estimated to be taken from the rhizosphere area of the plant or the field where *R. mucronata* is placed (Yusuf, 2021). This acclimatization process takes time so that the positive effects given to the plants are not as fast and powerful as if these fungi were combined with organic matter.

Kodikara *et al.* (2020) stated that the growth rate is directly proportional to the diameter of the xylem vessels. The increase in the number of leaves is also influenced by the diameter of the seedlings themselves, the wider the diameter of the plant, the wider the diameter of the xylem. Another factor that plays a role is the substrate, the plant substrate in places that are often disturbed has a harder structure, because it is more often disturbed, such as being stepped on. This affects the supply of oxygen, water, and other organic factors in the substrate (Habiba *et al.*, 2020).

In the pure manure treatment, plant growth parameters appeared to increase compared to *R. mucronata* which was only given *Trichoderma* and mycorrhiza fertilizers. This may be due to the improvement of the physical properties of the soil which is the main function of manure. Organic fertilizers are known to have high porosity, so they can increase the pores in the soil. As a result, plant roots become freer to develop and find nutrients in their growing areas. In addition, manure also contains macro and micro nutrients that can be directly absorbed by plant roots because of its low C/N ratio. Improvements in soil physical conditions plus the supply of various nutrients in manure will further increase nutrient absorption by plants (Yenny *et al.*, 2023).

In the P<sub>4</sub> treatment, namely the addition of manure with M<sub>21</sub> microbes, it resulted in better plant growth compared to the control or pure fungi treatment to the rhizosphere area (P<sub>1</sub> and P<sub>2</sub>). As with pure manure which has a good effect on plant roots due to changes in physical properties in the rhizosphere area, the addition of manure plus M<sub>21</sub> microbes has almost the same effect as the administration of pure manure (P<sub>1</sub>) until the plant is 5 months old. This may be due to the adaptation carried out by the M<sub>21</sub> microbes to their new growing

environment, before they can carry out their function of contributing nutrients to plants in the early stages of plant growth. Only after entering the 12<sup>th</sup> week (3 months) did the M<sub>21</sub> microbes begin to show their role in increasing plant growth. At this age, the M<sub>21</sub> microbes may have been able to grow and develop independently, mineralizing the nutrients in the soil and in the manure itself. In the P<sub>5</sub> treatment (manure + M<sub>21</sub> + NPK), plant growth reached maximum growth. This may be due to the adequacy of the main nutrients (N, P, K) given in the form of chemical fertilizers that can be directly dissolved in the soil and can be utilized by plants (Miah & Moula, 2019). Thus, since the early stages of *R. mucronata* being planted in the soil, these plants have obtained nutrients that become their energy to grow and develop before the nutrients from the manure can be mineralized by the M<sub>21</sub> microbes. Thus, the plants have obtained their booster energy since the beginning of being transferred to the field. The process of acclimatization of plant roots to a new environment may only take 2-5 weeks. With sufficient nutrition, plants never experience stress or obstacles to growth and development (Gamelasari *et al.*, 2023). On the other hand, the nutrients provided by NPK Fertilizer also become booster nutrients for M<sub>21</sub> microbes to be able to grow and develop easily, thus accelerating the growth of M<sub>21</sub> microbes which can immediately carry out their function of mineralizing nutrients in the soil. With sufficient nutrients, plants ultimately grow optimally at their age as indicated by the highest plant growth response (Ernawati *et al.*, 2018; Rattanaloeadnusorn, 2019). In addition to the plant height response, in terms of plant appearance as indicated by the difference in leaf area and crown area, it shows that the growth of *R. mucronata* which was given P<sub>5</sub> treatment was the highest, each at 26.84 cm compared to the control 11.67 cm for leaf area and 784.64 cm compared to 345.55 cm in the crown area of the control plant.

### Wet Weight and Dry Weight of Plants

The dry weight of the plant is separated into 2 separate parts, namely the crown weight which is the weight of the upper part of the plant including leaves and stems. The next part is the root weight starting from the root neck to the entire root.

In the 20<sup>th</sup> week of observation, the sample plants were harvested and oven-dried at 80°C for 3 x 24 hours. This was intended to remove the water content in the plant tissue. The wet weight of the plant seemed to be in line with its dry weight which was only distinguished by its water content ranging from 50-65%. Therefore, the most appropriate parameter to measure the role of the fertilizer treatment given is the observation of the dry weight of the plant which is the result of net photosynthesis of the plant. The dry weight of the crown seemed to be higher than the dry weight of the roots (Table 3). The results of the analysis of variance showed that the fertilizer treatment had a significant effect on

increasing the dry weight of the plant, both for the dry weight of the crown and the roots. The highest dry weight was obtained in the P<sub>5</sub> treatment which produced an average dry weight of the plant of 55.62 g. While the control treatment which was not given anything produced the lowest dry weight of 24.6 g.

**Table 3:** Wet and Dry Weight of *R. mucronata* Seedlings after 20 weeks after planting

| Parameter                  | Treatment      |                |                |                |                |                |
|----------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                            | P <sub>0</sub> | P <sub>1</sub> | P <sub>2</sub> | P <sub>3</sub> | P <sub>4</sub> | P <sub>5</sub> |
| Wet weight of plant crown  | 35.68          | 40.06          | 39.43          | 42.09          | 43.55          | 96.65          |
| Wet weight of roots        | 21.43          | 25.98          | 26.26          | 27.12          | 27.98          | 51.07          |
| Total wet weight of plants | 57.11          | 66.04          | 65.69          | 69.21          | 71.53          | 147.72         |
| Dry weight of plant crown  | 15.31          | 15.88          | 15.21          | 17.23          | 17.54          | 29.74          |
| Dry weight of roots        | 9.29           | 11.62          | 11.71          | 13.83          | 13.65          | 25.88          |
| Total dry weight of plants | 24.6           | 27.5           | 26.92          | 31.06          | 31.19          | 55.62          |
| Shoot-root ratio           | 1.65           | 1.37           | 1.30           | 1.25           | 1.28           | 1.15           |

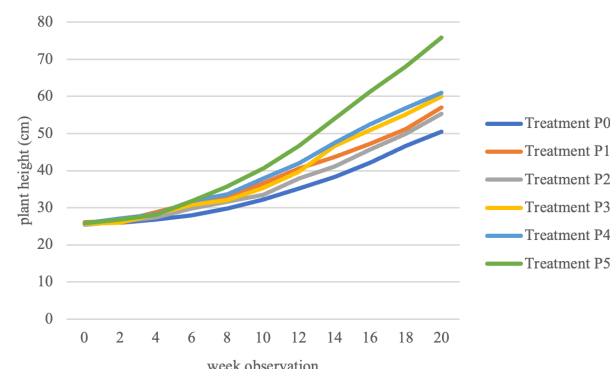
Note: Numbers followed by the same letter in the same column are not significantly different according to the duncan multi-range test at the 5 % level P<sub>0</sub> = Control; P<sub>1</sub> = *Trichoderma* sp; P<sub>2</sub> = *Mycorrhiza*; P<sub>3</sub> = manure; P<sub>4</sub> = manure + M 21 microbes; P<sub>5</sub> manure + M 21 microbes + NPK fertilizer

The treatment of biological fertilizers alone, namely *Trichoderma* and mycorrhiza, did not seem to produce significant plant growth when compared to the control. This is because the biological fertilizers given in the form of *Trichoderma* and mycorrhiza fungi require energy to grow and develop in the root area of the plant. This results in competition for nutrients from soil minerals (Dong-dong *et al.*, 2018), before these fungi work to mineralize nutrients from the mud/soil where they grow. Thus, the role of these fungi may take longer to be able to provide a positive effect on plant growth. According to Gupta (2020) the addition of *Trichoderma* sp. to seedling media can increase plant height growth, this happens because this fungus is able to increase the distribution of nutrients which will cause an increase in root length and stem length. The administration of *Trichoderma harzianum*, *Trichoderma koningii* and *Trichoderma viridae* can stimulate plants to produce IAA and gibberellin hormones that can support plant growth (Nieto-Jacobo *et al.*, 2017).

*Trichoderma* spp. in addition to protecting against disease, has also been proven to support plant growth such as increasing the length of plant roots, fruit weight, and dry seed weight while endomycorrhiza can increase plant length, number of leaves, fresh root weight, dry root weight, and total dry weight of plants.

In the treatment of pure manure and manure given M<sub>21</sub> microbes, the dry weight of plants appeared higher than the *Trichoderma* sp and mycorrhiza treatments. The physical properties of manure which is crumbly, soft and easily penetrated by roots provide a more porous physical environment for plant growth so that roots can easily grow and develop in the place where the plants are planted. However, manure contains low nutrients

compared to chemical fertilizers so that *R. mucronata*, even though it lives in a good root environment, its growth is still limited by these limited nutrients (Mesta *et al.*, 2018).



**Fig. 4:** Visual depiction of the differences between several treatments and the control at 20 weeks of plant age

In the treatment of manure plus M<sub>21</sub> microbes and given NPK fertilizer, the dry weight of the plant appeared to be the highest. This is the result of rapid plant growth because it grows in a non-dense soil environment due to the effects of the manure given. In addition, the nutrients from NPK fertilizer seem to be a booster at the beginning of growth so that the plants do not have time to experience nutritional stress (Yuniantika *et al.*, 2023). As a result, the plants grow thick and healthy. This results in the dry weight of the plants in this treatment being the highest among the other treatments. The application of manure, M21, and NPK can produce excellent plant growth, both in the short and long term, if managed properly. Manure provides sustainable benefits for soil quality, while M21 and NPK provide fast nutrients for plant growth. However, the use of these fertilizers must be done carefully, paying attention to the balance of nutrients, to prevent long-term problems such as soil quality decline or environmental pollution.

### Shoot Root Ratio

The shoot root ratio can be a benchmark for the health of a plant. A good shoot root ratio is usually close to 1.0. This number means that the development of the crown is in line with the development of the roots in the soil. Plant growth is inhibited with a high shoot root ratio. This means that the roots are unable to catch up with the development of the crown growth, which means that the roots are hampered in growing in the soil. This can be caused by dense soil or soil infertility (Ameen & Al-Homaidan, 2020).

Table 2 shows the highest shoot root ratio obtained in the control treatment, indicating that the roots were unable to develop due to limited nutrients and higher soil density. The provision of manure treatment significantly reduced the shoot root ratio because the porous nature of the manure helped root development. The lowest shoot

root ratio was obtained in the P<sub>5</sub> treatment. This is because in addition to the physical environment of the plant roots being good, the roots can move freely in the soil, the roots also get enough nutrients for their growth (Gupta, 2016). The presence of microbes that were given did not cause competition in obtaining nutrients until the age of 20 weeks after the plants were planted in the field. This shows that the baby plant stage is very susceptible to nutrient availability. Plants that are supported by sufficient nutrients will be able to grow and develop optimally in the soil (Gawas & Yogamoorthi, 2016). With the increasingly healthy plants at the baby plant stage, of course, it will increase plant growth until they reach adulthood. Environmental Conditions (Temperature, Humidity, Salinity, and Rainfall).

The temperature at the planting location during 5 months of observation is shown in Table 4. The data presented shows that the air temperature is quite normal for the conditions in the research area, which is around 27-34°C. With relatively good humidity ranging from 67-83%. This condition describes a normal environmental situation during the research period (Aboulsoud and Elkhoully, 2022). There are no extreme environmental changes considering that the temperature and humidity figures are within normal limits.

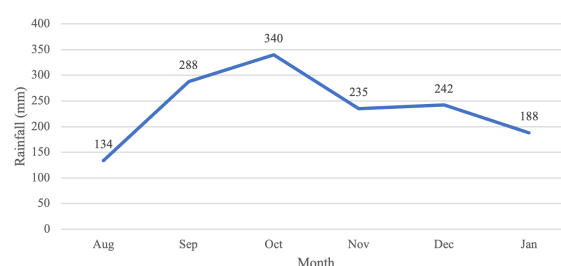
**Table 4:** Temperature, Humidity, and Salinity of Research Locations

| Observation time (week) | Temperature (°C) | Humidity (%) | Salinity (ppt) |
|-------------------------|------------------|--------------|----------------|
| 0                       | 32°/29°          | 82           | 24             |
| 2                       | 31°/29°          | 72           | 24             |
| 4                       | 33°/31°          | 79           | 24             |
| 6                       | 30°/27°          | 70           | 24             |
| 8                       | 32°/29°          | 71           | 22             |
| 10                      | 30°/27°          | 83           | 23             |
| 12                      | 32°/28°          | 80           | 24             |
| 14                      | 34°/30°          | 76           | 24             |
| 16                      | 34°/30°          | 72           | 23             |
| 18                      | 32°/28°          | 67           | 24             |
| 20                      | 30°/27°          | 82           | 24             |

Mangrove vegetation is plant vegetation that is resistant to soil conditions containing salt (salt-resistant plants) that are able to maintain growth under osmotic stress conditions (Yunasfi *et al.*, 2024). Salinity at the research location on the east coast of Silo Laut, Asahan Regency is 22-24 ppt where seedlings can grow and experience good growth, while according to Silva *et al.* (2023) salinity of 1-22 ppt in the mangrove vegetation area can grow well at these locations, especially those dominated by *Rhizophora* species. The decrease in plant height is also caused by limited water supply and organic matter in the tissue due to the influence of salinity (Kodikara *et al.*, 2017). Changes in salinity occur due to high and long sea currents or high rainfall at the research location at the time of observation. Mangroves can grow well in saltwater salinity and reach 2-3%. Differences in salinity can determine which can divide mangrove

forests into several forest zones (Silva & Amarasinghe, 2021).

Rainfall is the amount of water that falls to the earth's surface in a certain period measured in units of height (mm) above the ground surface where evaporation, runoff and infiltration do not occur. According to Yue *et al.*, (2016) the rainfall measured is rainfall that does not experience evaporation, infiltration and does not flow which is measured above the ground surface. The monthly rainfall that occurs on the East Coast of Silo Laut Village, Asahan Regency varies with rainfall that is quite high. The highest rainfall occurs in October, which is 340 mm. Complete monthly rainfall data during the research period at the research location is presented in Figure 5.



**Fig. 5:** Image of rainfall data during a period of 5 months at the research location

The environmental data presented in Table 4 and Figure 4 show that during the 5-month research period, the environmental factors at the research location were normal. Weather, rainfall, humidity, air temperature and salinity appear constant without much fluctuation. With this data, it can be assumed that the difference in plant growth during the research period is purely due to differences in treatment.

## Conclusion

The administration of *Trichoderma* sp. and mycorrhiza tends to show better plant growth compared to the control as indicated by the results of statistical tests that are very significantly different. However, it has not been able to show maximum growth of *R. mucronata*. Maximum growth is shown by the treatment of manure given M<sub>21</sub> microbes combined with NPK chemical fertilizers. This applies to all parameters tested.

Fertilization with manure, M21, and NPK on a large scale can provide benefits for mangrove growth if done properly. However, to avoid negative impacts on the ecosystem, fertilization must be done carefully, considering environmental balance, and following appropriate guidelines. Good monitoring and management are essential to ensure that fertilization does not damage the sensitive mangrove ecosystem system.

## Author's Contributions

**Budi Utomo:** Create concept and designed, monitor the progress of research from start to finished and ensure

that the entire research process goes according to plane

**Yuda Ilham Ramadan:** Mad a mayor contribution to the conduct of the research and data acquisition.

**Yunasfi:** Contributed in drafted the article or reviewed it critically for significant intellectual content.

**Anita Zaitunah:** Contributed in drafted the article or reviewed it critically for significant intellectual content.

**Afifuddin Dalimunthe:** assist with initial data processing and revising the manuscript.

**Mohammad Basyuni:** Gave final approval of the version to be submitted and revised version.

**Rizky Wahyudi:** Coordinate the data analysis and contributed to written of the manuscript.

## Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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## Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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