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The usage of various fungi species has allowed the *Avicennia marina* to develop more swiftly in Belawan and Pulau Sembilan

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ABSTRACT
Mangroves are a unique ecology that resides in places with salinity, which are inundated at low tide when there is no flooding and at high tide. Mangrove forests that are increasingly damaged cause the quality and quantity to decrease. Using different species of fungi that can accelerate the growth of mangroves is one attempt to increase and get high-quality mangrove seeds. This study aims to shed light on the fungi that can dramatically improve the growth of *Avicennia marina* seedlings. Mangroves can absorb organic and non-organic materials produced by decomposing microorganisms, which come from leaf litter or other decomposed materials. In this experiment, several fungal species were used, including *Aspergillus niger*, *Aspergillus* sp. 2, and *Aspergillus* sp. 1. The findings demonstrated that the fungus might speed up *A. marina* seedling growth. The plant's height, diameter, leaf width, and total dry weight were all altered as a result. Based on the study's findings, it can be said that *Aspergillus niger* provided the best growth for *A. marina* seedlings.
Keyword*: Avicennia marina*, Fungi, Aspergillus

1. Introduction

Mangrove forests are typically found near rivers or beaches where the tides affect the area. One of the most productive ecosystems on the planet is mangroves [1]. Mangroves are also spawning grounds because mangrove habitat provides food and protection from predation [2]-[5]. By producing 3,035 g/m^2 of litter annually (in the form of bark, leaves, twigs, fruit, blooms, etc.), mangrove trees provide a considerable food source [5]. Mangrove habitats rapidly disappear due to direct anthropogenic effects and broader climatic changes. [6] Benthic ecosystems, biodiversity in meiofauna (as a proxy for benthic biodiversity), benthic biomass, and prokaryotic heterotrophic production (as a proxy for ecosystem function) are all impacted by mangrove habitat destruction.

The results of the study [7,8] found the fungus *Aspergillus niger* and several species of *Aspergillus* sp. in mangrove litter, and it was discovered that decanter solid waste contains a lot of microbiology, including *Aspergillus niger*, *Aspergillus fumigatus*, *Cellvibrio* sp., and *Pseudomonas* sp. These microorganisms will contribute to the supply of nutrients that plants require, like nitrogen (N), phosphorous (P), potassium (K), and organic carbon (C). Two species of *Aspergillus* spp. demonstrated the efficacy of disease control. These results indicate that the antifungal compounds produced by Aspergillus can help develop new natural

biofertilizers and fungicides [9]. *A. niger*, *Penicillium* sp., and *Trichoderma viride* are just a few examples of soil fungi that can flourish in salty soils. This fungus can break down lignocellulosic materials, dissolve phosphate, and make hormones [10]. The isolated fungi included *Penicillium* sp., *Eupenicillium* sp., *Talaromyces* sp., *Aspergillus* sp., *Trichoderma* sp., and sterile fungi, i.e., fungi that do not produce conidium on PDA media [11]. Biological fertilizers are fungi that have the activity of providing nutrients in the soil, namely *A.niger* PS1.4, *Penicillium* sp. R7.5 and *Trichoderma viride*. *A. niger* PS1.4 can decompose cellulose; its cellulase activity is 0.127 units/ml. The results of [12] showed that species of antagonistic fungi were successfully isolated in his research, namely *Trichoderma harzianum*, *A. niger*, and *Paecilomyces lilacinus*. These three antagonistic fungi showed hostile activity against the growth of *Fusarium* sp. In addition to producing IAA, this fungus may dissolve inorganic phosphate [13].

Aspergillus, Colletotrichum, Fusarium, Guignardia, Penicillium, Pestalotiopsis, Phomopsis, Talaromyces, and Trichoderma are among the groups represented by the isolated endophytic fungus. It can be said that endophytic fungi have colonized the mangrove trees growing on North Sulawesi's Bunaken Island and Sampiran Beach [14]. The fungus *A. niger* van Tieghem, 1867 is a type of soil microorganism capable of producing indoleacetic acid (IAA) and gibberellins (GA3) [15]. Cellulose is available in the soil as an organic component. The cellulose mineralization process supports the availability of nutrients for fungi to reproduce. Fungal populations support the availability of growth hormones that plants can utilize. Based on this phenomenon, the role of cellulase in the soil is related to the availability of growth hormone as a guarantor of the natural symbiotic mechanism between microorganisms and plants [16].

2. Method

2.1. Time and location

The research was carried out from July to November 2022. The two locations used for the sampling process were the mangrove forests of Kampung Nelayan-Belawan District, Medan City, which represent areas with high contamination, and the Pulau Sembilan mangrove forest in Pangkalan Susu District, Langkat Regency, which is an example of an uncontaminated region. The Forest Sylviculture Laboratory, Faculty of Forestry, Universitas Sumatera Utara, conducted the laboratory analysis.

2.2. Materials

Isolates of various fungal species, including *Aspergillus niger*, *Aspergillus* sp. 2, and *Aspergillus* sp. 1, from previous investigations [7] were used as material in this study. 30 days old *A. marina* mangrove seedlings with four leaves are prepared for planting in the field.

2.3. Research procedure

2.3.1. Fungal cultivation

The fungal isolate was placed in a petri dish containing sterilized Potato Dextrose Agar (PDA) media. The fungus takes about 3-4 days to grow and mature. After one week, the mushrooms will grow to their maximum size.

2.3.2. Planting seeds

Planting of *A. marina* seeds was carried out in planting plots in the field. Forty planting holes with dimensions of 10 cm by 10 cm by 15 cm were constructed in each plot. The holes were created, and *A. marina* seeds were placed inside.

2.3.3. Application of mushrooms to planting media.

Fungal isolates grown on PDA media were cut into 1 cm by 2 mm dimensions. This piece of media was then put into a test tube containing 2.5 ml of sterile water, which was used as a suspension. 2.5 ml of fungal suspension is spread evenly over all plant roots.

2.3.4. Measurement of growth parameters

Observations were carried out periodically every 15 days until it reached 90 days (12 weeks), so the total observations were six times. The growth parameters of *A. marina* seedlings included stem height, stem diameter, number of leaves, and widest leaf width. Dry weight parameters were determined at the end of observation (12th week).

3. Result and Discussion

Observations and measurements of *A. marina* seedlings over twelve weeks showed variances in height, leaf diameter and width, and total dry weight gains. The observation data of *A. marina* seedlings subjected to various species of fungi in Pulau Sembilan and Belawan are displayed in Table 1 and 2.

Table 1.The average value of observations of *A. marina* seedlings from Pulau Sembilan

Parameter	Treatment			
	Control	*A. niger*	*Aspergillus* sp. 2	*Aspergillus* sp. 1
Height (cm)	19.45	21.95	23.42	22.75
Diameter (cm)	0.36	0.42	0.39	0.39
Leaf width (cm)	4.99	6.25	6	5.57
Total dry weight (g)	4.71	6.93	6.25	7.73
Number of leaves (sheet)	8	8	12	9

Table 2.The average value of observations of *A. marina* seedlings from Belawan

Parameter	Treatment			
	Control	*A. niger*	*Aspergillus* sp. 2	*Aspergillus* sp. 1
Height (cm)	15.75	21.23	19.12	19.45
Diameter (cm)	0.37	0.44	0.34	0.41
Leaf width (cm)	4.69	6.11	4.70	4.97
Total dry weight (cm)	3.99	6.33	5.13	5.2
Number of leaves (cm)	8	10	8	9

3.1. Height of A. marina seedlings

Based on the measurements carried out for 12 weeks, as shown in Figures 1 and 2, *A. marina* seedlings treated with the fungus showed better height growth than the control. A similar research trend regarding the influence of the Aspergillus fungus on the height growth response of *Rhizopora mucronata* seedlings also occurred in *A. flavus* and *A. terreus* [17]. *A. marina* seedlings from Pulau Sembilan showed better height growth than those from Belawan. The trend in Figure 1 shows that the treatment using the fungus *Aspergillus* sp. 2 gave the best height parameter response for *A. marina* seeds originating from Pulau Sembilan, while *Aspergillus niger* provided the best response for seeds originating from Belawan.

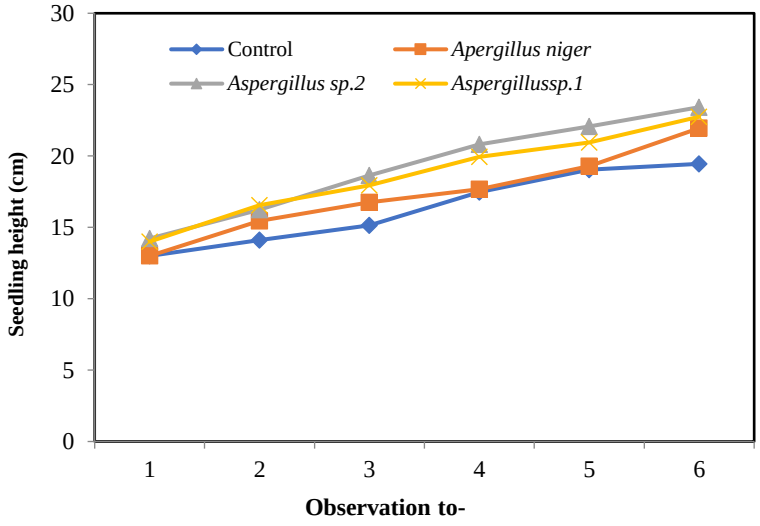

Figure 1. Trends in height growth of *A. marina* seedlings from Pulau Sembilan

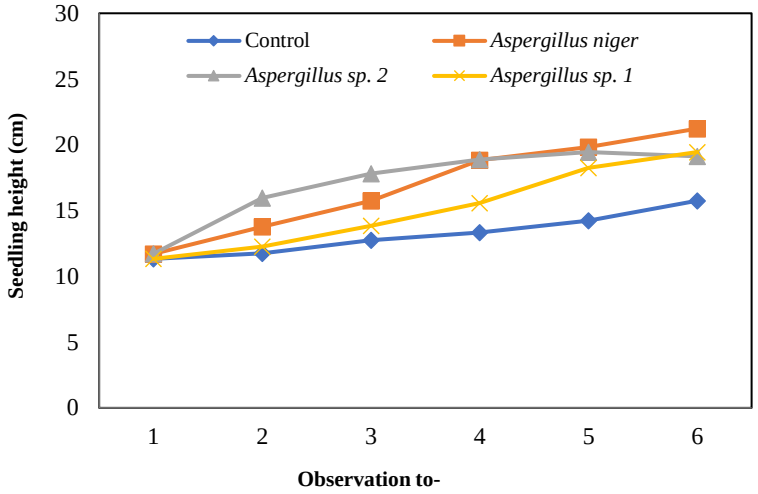

Figure 2. Trends in height growth of *A. marina* seedlings from Belawan

Trends in height growth of *A. marina* seedlings from Pulau Sembilan, the application of the Aspergillus fungus gave a better response than the control. It was due to the role of the fungus as a decomposer of organic material so that it can produce nutrients for plants. The presence of Aspergillus is likely to suppress the life of fungi or other bacteria around the roots of *A. marina* plants so that the application of Aspergillus fungi can accelerate the development of *A. marina* plant roots. According to [18], *Aspergillus* spp. fungi produced from litter decomposition can dissolve P (Phosphor), producing phosphate ions as H_2PO_4. Plants need phosphorus to stimulate growth, for example, height growth, and to increase sturdiness so that they are resistant to waves and wind. This compound is a secondary metabolite that functions as a hormone that plants need for root, stem, and leaf growth. In other systems, the cellulase enzyme is secreted by fungi as a natural mechanism for obtaining carbon sources from cellulose in the soil as a metabolic source [19]. The high level of *A. marina* in the two locations that used *A. niger* treatment was due to this fungus growing faster than *Aspergillus* sp.2 and *Aspergillus* sp.1. According to [7] that compared to *Aspergillus* sp.2 and *Aspergillus* sp.1, *A. niger* has a higher colony growth rate. This factor causes the application of *A. niger* to *A. marina* seedlings to increase plant height growth.

3.2. Diameter of A. marina seedlings

Based on the measurements carried out for 12 weeks, as shown in Figures 3 and 4, *A. marina* seedlings treated with the fungus showed better diameter growth than the control.

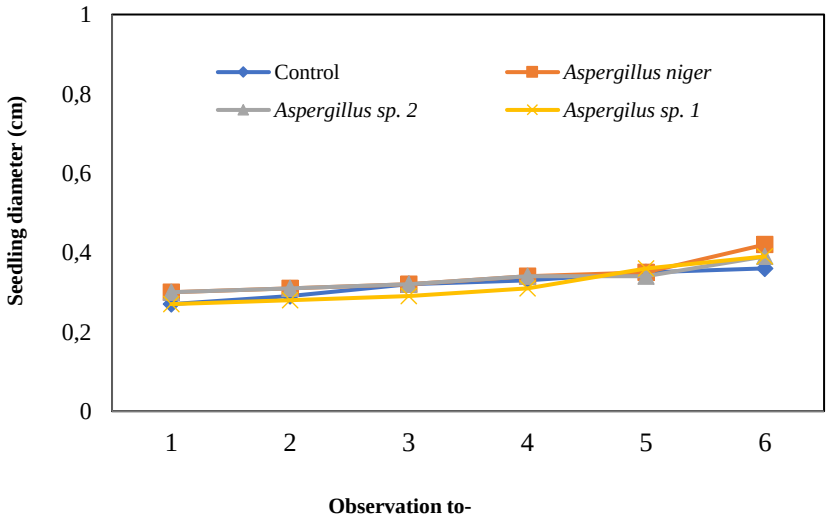

Figure 3.Trends in diameter growth of *A. marina* seedlings from Pulau Sembilan

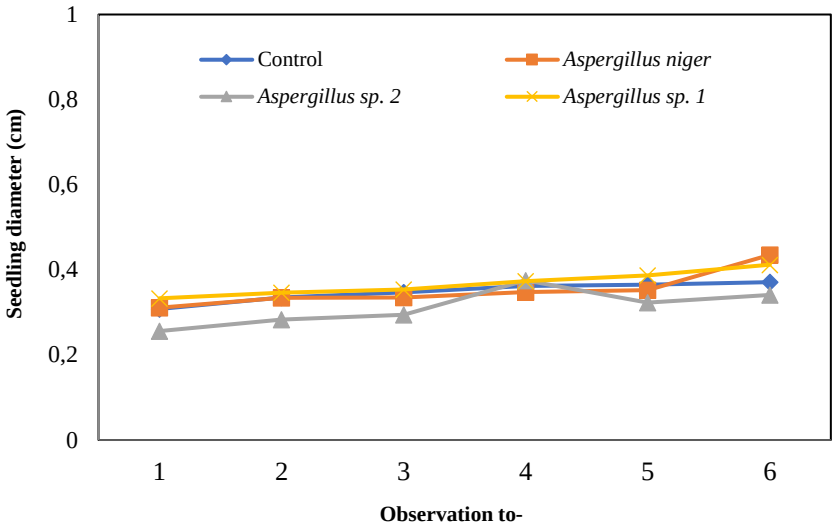

Figure 4. Trends in diameter growth of *A. marina* seedlings from Belawan

Overall, seedlings treated with fungus had better growth compared to controls. According to [20], *Aspergillus* sp. is a fungus that can convert organic material into nutrients, so it is helpful for seeds to meet their nutritional needs. *Aspergillus* sp. is a species of fungus that can provide the phosphorus nutrients that plants need for growth and cell division. So, increasing the rate of cell division can increase the diameter of the stem of the plant seed. In the Belawan mangrove area, which represents an area with high pollution conditions, *Aspergillus* sp. can convert unavailable soil phosphorus into available. This is by the statement [21] that the use of fungi such as *Aspergillus* sp. can dissolve phosphorus ions in the soil and minimize alumunium (Al) toxicity so that it can encourage the growth of *A. marina*. Phosphorus ions are an element that plants need to increase the growth of plant stems and roots. Aspergillus fungi can play a role in decomposing organic material around the roots of *A. marina* plants.

3.3. Leaf width of A. marina seedlings

Based on the measurements carried out for 12 weeks, as shown in Figures 5 and 6, *A. marina* seedlings treated with the fungus showed better leaf width growth than the control.

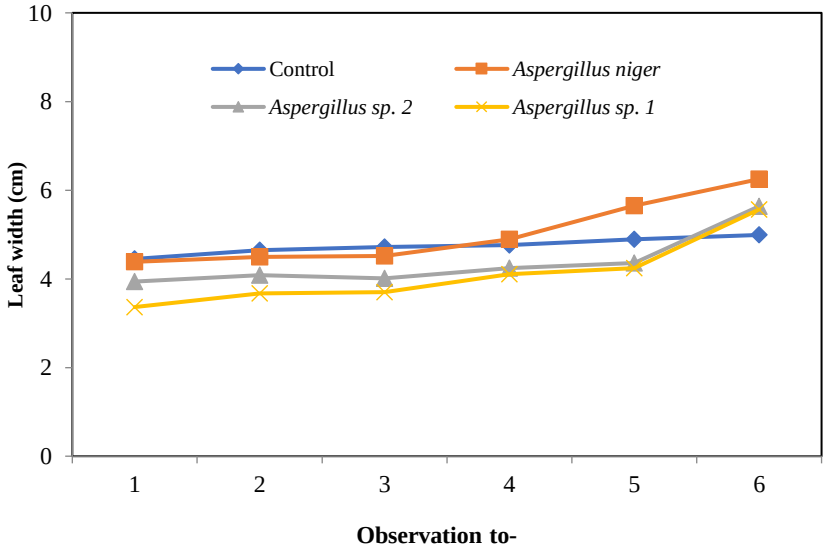

Figure 5. Trends in leaf width of *A. marina* seedlings from Pulau Sembilan

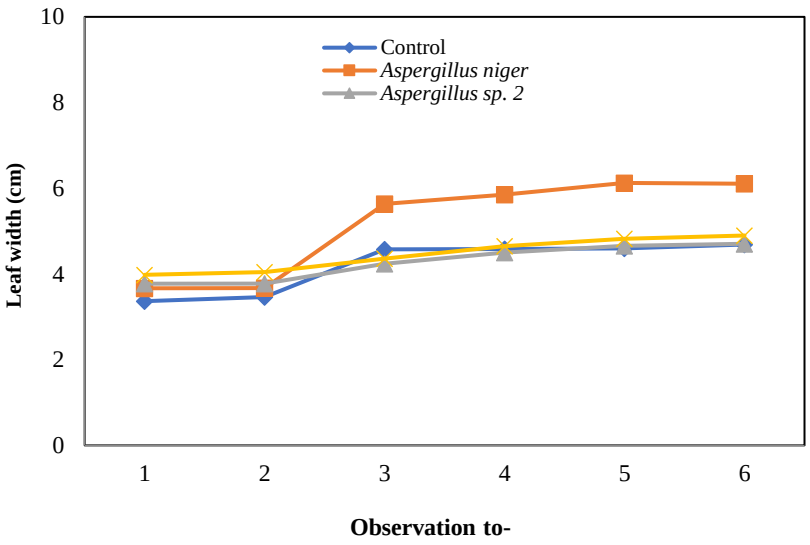

Figure 6. Trends in leaf width of *A. marina* seedlings from Belawan

Treatment of Aspergillus sp. can be used to improve plant growth by dissolving phosphate and increasing the availability of nutrients that plants need to thrive. Leaf width is one of the plant growth parameters that requires nutrients to increase cell division caused by irreversible or irreversible vegetative growth [22].With the aid of *Aspergillus* sp., more cell division will result from meeting the requirement for phosphorus components, increasing leaf breadth. According to [23], the application of *A. niger* fungus resulted in better leaf width growth compared to the control.

3.4. Number of leaves of A. marina seedlings

Based on the measurements carried out for 12 weeks, as shown in Figures 7 and 8, almost all *A. marina* seedlings treated with the fungus showed better number of leaves than the control. Leaves are the most essential part of plants because leaves are a tool that plants use to carry out photosynthesis to produce food. So, the more leaves, the more food the plant has. Photosynthesis positively correlates with the number of leaves the more leaves, the better the plant's metabolic processes.

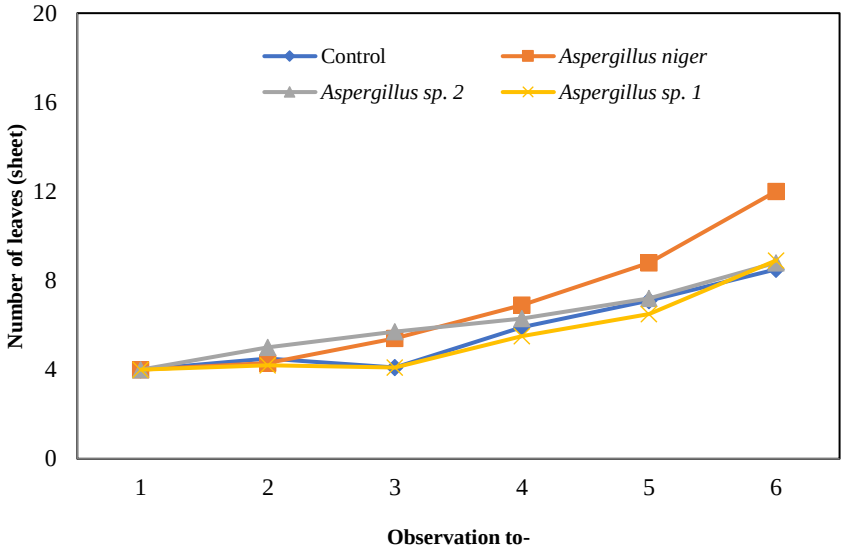

Figure 7. Trends in number of leaves of *A. marina* seedlings from Pulau Sembilan

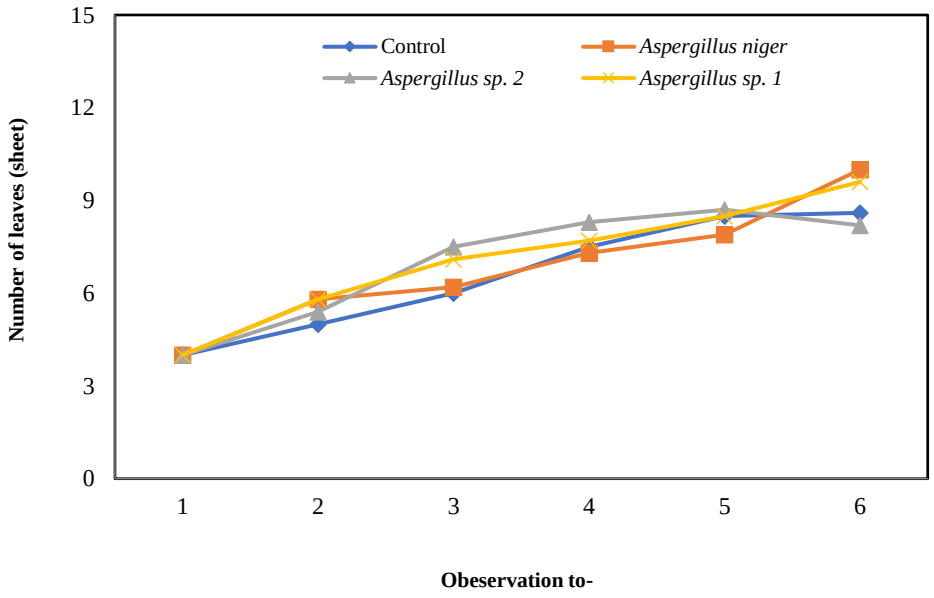

Figure 8. Trends in number of leaf of *A. marina* seedlings from Belawan

When comparing *A. marina* from Pulau Sembilan and Belawan, it can be seen that the fungal treatment of *A. marina* growing on Pulau Sembilan gave a better response compared to the Belawan area. This is likely caused by the influence of environmental pollution, which hurts the habitat/growing location of *A. marina* in the Belawan location. The Belawan area is thought to contain large amounts of heavy metals obtained from industrial activities or regional processing carried out by the community, so fungal treatment provides an increased growth response but is less than in Pulau Sembilan. The role of Aspergillus in increasing nutrients cannot be maximized due to the high influence of pollutants. Nitrogen, phosphorus, and potassium are nutrients that influence the growth of the number of leaves [25]. Microorganisms capable of dissolving phosphorus include *Aspergillus* sp., and *Penicillum* sp. Microorganisms that have a high ability to dissolve phosphorus can generally dissolve potassium well to support the growth of *A. marina* plants. This aligns with research conducted by [26] using the fungi *A. flavus* and *A. tereus*.

3.5. Dry weight of A. marina seedlings

Based on the measurements carried out for 12 weeks, as shown in Figures 9 and 10, *A. marina* seedlings treated with the fungus showed better dry weight than the control. The plant's dry weight is significantly impacted by the species of fungus used, as evidenced by the overall dry weight value. This trend occurred at both locations of origin of *A. marina* seeds used in this study. Increasing nutrient content contributes to accelerated mangrove growth and higher biomass growth rates [27].

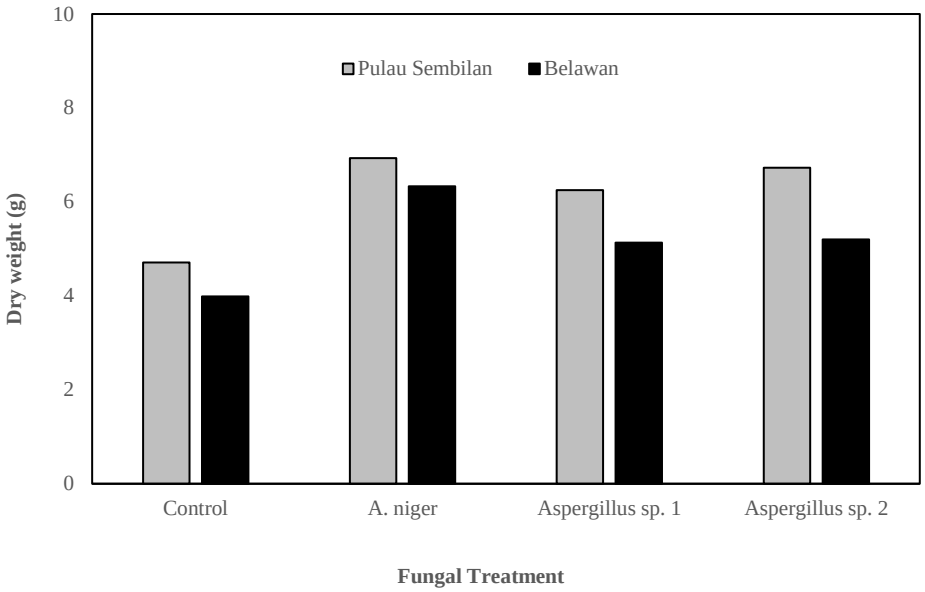

Figure 9. Dry weight of A. *marina* seedlings from Pulau Sembilan and Belawan

4. Conclusion

Overall, the treatment of *A. niger*, *Aspergillus* sp. 1, and *Aspergillus* sp. 2 has a positive effect on several growth parameters, such as diameter, leaf width, and dry weight of *A. marina* seedlings. Providing fungal treatment increased the growth of *A. marina* seedlings from both Pulau Sembilan and Belawan locations. However, *A. marina* seedlings from Pulau Sembilan had a better growth response. The performance of Aspergillus employed in this study is hampered by pollution conditions, which are believed to be high in the Belawan mangrove area.

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