Root development in mangrove plant *Rhizophora mucronata* under different shade intensities

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**Abstract.** The reduced area of mangrove forests due to various pressures required rehabilitation activities throughout the damaged area of mangrove forests. *Rhizophora mucronata* is one of the plants in the mangrove ecosystem that has stilted roots to stand the ocean waves. It is necessary to provide *R. mucronata* seedlings in mangrove rehabilitation. This study aims to determine the best shade intensity for root growth of *R. mucronata* seedlings. This research was conducted in the nursery of Jaring Halus Village, Langkat, North Sumatra, during three months cultivation. This research used the utterly random design with five treatments, namely 0%, 25%, 50%, 75% and 100% of shading, for ten replications. The results showed that 0% shade intensity had a better growing number of primary and secondary roots and root length than the others of shade intensity. In this study, it is also estimated that the spacing planting of *R. mucronata* seedlings was better at 3 x 2 meters for rehabilitation activity.

1. Introduction

The decreasing extent of mangrove forests due to various pressures that exist requires that rehabilitation activities be carried out throughout the damaged mangrove forest areas [1]. Proper planning and use of good seeds can increase success in mangrove forest rehabilitation activities [2]. *Rhizophora mucronata* is one species of interest in rehabilitation activities because of its ability to adapt in conditions of high salinity [3].

Growing plant space is divided into two parts, namely space above ground and space below ground. Arrangement of space above the ground is intended so that the crown develops optimally, and aims to reduce competition for sunlight intensity [4]. The appropriate silvicultural measurements are pruning and thinning. Arrangement of below-ground space is intended in order to roots develop optimally and reduce competition for nutrients and water and provide space for spreading roots in the soil [5]. The appropriate silvicultural action is setting the width of the planting distance and the shape of the planting hole. The width of the spacing is determined based on the speed of root lengthening, while the shape of the planting hole is determined based on the root structure [5].
The root is the entry point for nutrients absorbed by plants including *R. mucronata*. The roots absorb nutrients and channel them to the leaves for processing into energy through photosynthesis [6]. Study on roots in mangrove plants, especially root growth in *R. mucronata* species is still limited. We previously reported the effect of salinity on the development roots in several mangrove seedlings [7]. With the root growth data, a possibility estimation of spacing can be made to avoid the scrambling for nutrients and can make room for root growth. Thus the present study aims to determine the best shade intensity in the growth of *R. mucronata* seedling roots.

2. Materials and Method

2.1. Preparation of planting media

This research was conducted at the Mangrove Nursery for the Mangrove Forest Rehabilitation Program at Jaring Halus Village, Secanggang District, Langkat Regency, North Sumatra. The nursery location chosen was cultivated on a full and flat. The nursery location chosen is attempted to get the tide more or less 20 times/month.

2.2. Propagule selection and planting

The media used for the growth of *R. mucronata* is mud around the nursery that has been compiled. Ten propagules of *R. mucronata* are selected from around the nursery then 2-20 cm deep soil is taken as much as 2 kg. The collected soil is stirred together to be used on 50 polybags measuring for 10 cm x 15 cm. Propagules that have fallen were collected from the Jaring Halus Village and were selected for healthy, fresh, no pests and diseases and not rooted [7]. Planting was done when the seawater receded, making it easier to mark. The holes made using 7 cm deep bamboo and inserted selected propagule [8].

2.3. Observation of shading tolerance response

Calculation of the number of roots is done manually using a counter that was carried out after harvesting *R. mucronata* seedlings for three months. The number of roots is calculated based on the position of the roots in the root system (branching level) according to a previous report [7].

3. Results and Discussion

Seedling survival percentage is calculated by comparing the number of life seedlings and the number of seedlings planted at the beginning of the study (Table 1). Data were collected at the end of the observation after three months of cultivations.

| No | Parameter          | Survival percentage (%) |
|----|--------------------|-------------------------|
| 1  | Shade Intensity 0% | 100                     |
| 2  | Shade Intensity 25%| 100                     |
| 3  | Shade Intensity 50%| 100                     |
| 4  | Shade Intensity 75%| 100                     |
| 5  | Shade Intensity 100%| 100                    |

Table 2 the measurement of the primary root diameter of the *R. mucronata* seedlings obtained the largest average primary root diameter at a shade intensity of 0% (4.56 cm), and the lowest average was 25% shade intensity of 3.50 cm. Whereas on the lateral root the largest root diameter was at 100% shade intensity of 2.47 cm and the smallest at 50% shade intensity was 2.28 cm. From the length and diameter parameters of the roots have different growth stimuli in the treatment provided. Length and diameter measurements could also be used as a standard measurement of root surface area and root length density where the whole root also shows different biomass weight gain [9].
Table 2. Growth of root diameter

| Treatment            | Main root (cm) | Lateral root (cm) |
|----------------------|----------------|-------------------|
| Shade Intensity 0%   | 4.56           | 2.42              |
| Shade Intensity 25%  | 3.50           | 2.34              |
| Shade Intensity 50%  | 3.56           | 2.28              |
| Shade Intensity 75%  | 3.57           | 2.30              |
| Shade Intensity 100% | 3.73           | 2.47              |

Table 3. Biomass, root surface area and root length density of *R. mucronata* seedlings

| Treatment            | Root biomass (g) | Root Surface Area (cm²) | Root length density (cm) |
|----------------------|------------------|-------------------------|--------------------------|
| Shade Intensity 0%   | 11.65            | 189.45                  | 133.42                   |
| Shade Intensity 25%  | 13.10            | 202.28                  | 147.87                   |
| Shade Intensity 50%  | 10.78            | 202.81                  | 155.24                   |
| Shade Intensity 75%  | 9.79             | 206.06                  | 161.18                   |
| Shade Intensity 100% | 12.67            | 300.25                  | 169.57                   |

Table 3 shows the root biomass of *R. mucronata* seedlings had the highest value at 25% shade intensity that was equal to 13.10 g. The lowest biomass is at 75% shade intensity which was equal to 9.79 g. Calculation results for the root surface area of *R. mucronata* seedlings obtained 100% shade intensity has the highest average value of 300.25 cm² and 0% shade intensity has the smallest average value. While the calculation results for root length density in *R. mucronata* seedlings obtained 100%, shade intensity has the highest average value of 169.57 cm and 0% shade intensity has the smallest average value of 133.42 cm. Root length density can also be used as one of the standards in estimating plant spacing at planting.

Table 4. The estimated spacing of *R. mucronata* seedlings

| Root length density | Growth for three months (cm) | Growth for one year (cm) |
|---------------------|-------------------------------|-------------------------|
| 133.42              | 44.47                         | 533.68                  |
| 147.87              | 49.29                         | 591.48                  |
| 155.24              | 51.75                         | 620.96                  |
| 161.18              | 53.73                         | 644.72                  |
| 169.57              | 56.52                         | 678.28                  |
| **Average**         | **613.82**                    | **613.82**              |
| **Estimated planting distance (m)** | **2 x 3**                   |                         |

In the calculation results of estimated planting distances on *R.mucronata* seedlings obtained a distance of 3 x 2 meters for a minimum distance in planting. This distance estimate is obtained from the root length density value per month and is estimated within one year. Root development at the bottom of the *R. mucronata* seedlings should be positively correlated with the growth of the upper seedlings where good root growth will increase the growth of the upper part of the plant. However, in this study, different results were obtained where the growth of the top seedlings had the best growth at 50% shade intensity.

From the observations of the percentage of survival and mortality in *R. mucronata* seedlings have a significant difference where the percentage of the life of *R. mucronata* seedlings reaches 100% with a mortality of 0%. This illustrates that the high resilience of *R. mucronata* seedlings to various shading intensities [7]. *R. mucronata* seedlings can survive and grow well in each shade intensity treatment even
though there is a difference in light entering the shade for 12 weeks cultivations. The place to grow the of \textit{R. mucronata} which is often found in high tides in the interior of mangrove forests makes it difficult for light to enter the forest floor, but \textit{R.mucronata} still grows well [3].

Growth of the number of roots in each treatment obtained different results both from main and the lateral roots. However, the real difference to the influence given to the average value of the number of lateral and primary roots is not significant, or the intensity of the shade provided does not provide a stimulatory effect on the growth of the number of roots to grow. Insignificant growth in the number of lateral and main roots can occur due to the presence of food reserves in each propagule when planted. This is supported by the study of [10] that the success of a plant’s growth is strongly influenced by the food reserves that exist in the plant cell tissue. At 12 weeks after planting growth, the number of lateral roots began to show a response to light entering the shade to carry out photosynthesis. This data is consistent with [11] report that light influences the growth and development of seedlings in a nursery.

Table 5. Parameters observed in \textit{R. mucronata} seedling intensity

| No | Parameter                        | Shade Intensity |
|----|----------------------------------|-----------------|
| 1  | Life                             | -               |
| 2  | Mortality                        | -               |
| 3  | Number of lateral roots          | -               |
| 4  | Number of primary roots          | -               |
| 5  | Number of secondary roots        | √               |
| 6  | Main root diameter               | -               |
| 7  | Root diameter                    | -               |
| 8  | Main root length                 | √               |
| 9  | Lateral root length              | -               |
| 10 | Primary root length              | √               |
| 11 | Root biomass                     | -               |
| 12 | Root Surface Area                | -               |
| 13 | Root length density              | -               |
| 14 | Seed diameter                    | -               |
| 15 | Seedling height                  | √               |

\(\sqrt{\text{: highest value, - : similar value}}\)

The growth of root diameter, both lateral and main root shows the light captured by \textit{R. mucronata} seedlings in the photosynthesis process has not affected the root diameter growth due to the propagule food reserves. The growth of the radicular part is like the root diameter at the beginning of the growth still depends on the existing food reserves. This is supported by research [3] that the size of \textit{R. mucronata} propagules with a length of 60 cm had many food reserves to support its growth, both for the growth of plumules and radicles. Existing food reserves can help the seeds in root growth until they are ready to carry out the nutrient absorption process. This condition can help the seeds of \textit{R. mucronata} to be easier to bind and stabilize the mud substrate so that it does not shake if hit by the waves and has more potential to get more nutrients for growth.

The highest root biomass was at 25% shade intensity with an average of biomass obtained at 13.10 grams, and the lowest was at 25% shade at 9.79 grams. The high root biomass at 25% shade intensity is due to the amount of light entering the optimal shade for photosynthesis so that the value of the root biomass increases. This result is supported by the study of [12] that the amount of light captured in the photosynthesis process illustrates the amount of biomass that is present, while the amount of biomass in plant tissue reflects dry weight.

The results of the calculation of the primary root surface area of \textit{R. mucronata} seedlings at 100% shade intensity had the highest average value of 300.25 cm$^2$ and 0% shade intensity had the smallest
The average value of 189.45 cm². The main root surface area at 100% shade intensity has a broad contact area with soil particles and the ability to absorb more water and nutrients than other *R. mucronata* seedlings. The ability to compete for nutrients becomes more significant because of the greater area of contact to land particles. *R. mucronata* seedlings at 100% shade intensity can be more competitive when planted in planting locations because it has a higher root surface area. Root surface area is critical to know because it deals in knowing how much the root absorbs water and nutrients. This result is supported by [13] that roots function to absorb water and nutrients from the soil around plants, a good root system is a key to producing right plants, the ratio of roots and shoots is a measurement method that helps us to record the level of fertility soil.

From the estimation results, it was found that the minimum distance of 3 x 2 m is the best where it was expected that competition between nutrients and water does not occur for one year to make the seeds of *R. mucronata* survive. In the measurement results of the height growth of *R. mucronata* seedlings with a 50% shade intensity resulted in a high growth value of 51.2% with an average of 19.17 cm from a shade intensity of 0% of 9.36 cm. Whereas for the measurement of *R. mucronata* seed diameter also has a value that is directly proportional to the length of the *R. mucronata* seedlings where the growth of diameter at 50% shade intensity produces a diameter of 19.6% with an average of 0.63 cm from 0% shade intensity of 0.50 cm.

This result was also supported by [14-15] studied that certain behaviors in growth can be considered as responses to various stimuli that affect plants. Stimulation can be external (environment in the form of the attraction of the earth, temperature, humidity, salt, and light) or internal (genetic) as a result of metabolic processes or processes for continuing heredity. Plant responses to stimuli are pointed out in two ways: the response to movement and the response to development.

4. Conclusions

The shade intensity of 0% produces the best root growth where the primary root length and number of secondary roots of *R. mucronata* seedlings.

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