Evaluation of two-year mangrove rehabilitation using *Rhizophora apiculata* propagules in Lubuk Kertang Village, North Sumatra

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Abstract. Mangrove forests in North Sumatera are rapidly threatened due to anthropogenic activities. The study site was former oil palm plantation, and the areas can be reforested. The present study describes a two-year evaluation on mangrove seedlings in Lubuk Kertang Village, Langkat, North Sumatra, Indonesia. The rehabilitation was carried out on December 2015 using direct planting of 6,000 *Rhizophora apiculata* propagules which were evaluated twice in September 2017 and January 2018. The evaluation was divided into four plots consisting of hundred seedlings each, and the criteria of mangrove rehabilitation consisted of seedling diameter and height, leaf thickness and number, and seedling growth rate. Results showed that the growth rate for a two-year evaluation of first and second observation was 89 and 92 %, respectively. Similarly, the height, diameter, and some leaves seedlings planting showed better performance in the second measurement. The data are likely to confirm relevant information on successful rehabilitation using recommended species for degraded areas and availability of mangrove propagules in the area.

1. Introduction

Mangrove forests in Lubuk Kertang Village, Brandan Barat District, Langkat, North Sumatra, Indonesia have suffered and continuously degraded since a decade [1]. This condition causes the mangrove area to become a serious concern. Increasing population and high economic needs are the reasons for greater land clearing to be converted into aquaculture and other land uses. Recently, the non-forest area turning from forest land has increased, especially mangrove forests [2, 3]. When the land is changed its function into a settlement, industry, aquaculture, and utilization of coastal resources without any restrictions or rules in the conversion of the land, the condition of the land definitely becomes worse and has an adverse effect on the survival of the surrounding area and community [3, 4].
The ways to restore the damaged mangrove forests can be done by employing restoration or rehabilitation or reforestation [5, 6]. Rehabilitation is defined as an effort to restore environmental conditions to their original condition naturally [1]. Thus, rehabilitation efforts should provide a way for nature to regulate itself. Humans as actors try to pave the means and opportunities and accelerate the recovery process of mangrove forests. However, with the many interests and the conversion of land use into settlements, it will be complicated for the mangrove areas to make their natural regeneration, besides the lack of significant efforts to rehabilitate damaged mangrove forests. The present study aimed to describe a two-year evaluation on mangrove plantations using direct seedlings (propagules) in Lubuk Kertang village, Langkat, North Sumatra, Indonesia.

2. Materials and method

2.1. Study area
The study area was in Lubuk Kertang village, Langkat, North Sumatra, Indonesia. The Lubuk Kertang village is situated at 04° 07' 39.71'' North latitudes, and 98° 30' 97.87'' East longitudes (figure 1). Lubuk Kertang is administratively in Langkat Regency and district of Brandan Barat. The rehabilitation activity in Lubuk Kertang village was carried out on May 2016 using propagules (direct planting) of 6,000 *Rhizophora apiculata*. Evaluations were done twice, on 29 September 2017 and 6 January 2018, to monitor and evaluate purposively 400 reforested seedlings.

![Figure 1. The study site (red circle) for the rehabilitation year 2015 in Lubuk Kertang.](image)

2.2. Growth measurement and rate
The growth of *R. apiculata* seedlings from propagules was chosen by the stem height and diameter of the seedlings as earlier described [1]. One cm ruler accuracy was applied to estimate stem heights from the bottom of the propagule to highest plant tip where the stem shoots grew. Plant diameter was measured by digital caliper. Thus, the stem heights and diameters of *R. apiculata* seedlings were the indices of growth in this work. The percentage of plant growth was estimated by associating the number of plants that exists in a plot with the number of plants that should be present in the assessing plot grid as hitherto described [5]. The evaluation of growth level denotes to the ruling of the Ministry of Forestry, Government of Indonesia number P.70/Menhut-II/2008.
3. Results and discussion

Direct planting was carried out in the rehabilitation program in December 2015. On direct planting using, *R. apiculata* propagules that are ready to be planted at rehabilitation sites, with planting holes were first made. Planting of propagules was recommended as thick as 1/3 the size of the seed length. In the 2015 rehabilitation program, 6000 propagules were planted. Mangrove reforestation in 2015 had a salinity level of 25 part per thousand (ppt) in the first observation (September 2017) and 24.3 ppt in the second observation (January 2018). The assessment parameters of mangrove reforestation comprised of seedling diameter, height, and growth rate. Results showed that the growth rate for indirect planting evaluations was 92.3 % (table 1 and 2), including the attacked pests. The growth was relatively lower, with the accounting of attacked pests was 86.8 %.

| No | Two-year evaluation | Seedling plots (%) |
|----|---------------------|--------------------|
|    |                     | Plot 1  | Plot 2  | Plot 3  | Plot 4  |
| 1  | Survival seedlings  | 96      | 83      | 94      | 86      |
|    | Healthy             | 86      | 81      | 89      | 82      |
|    | Attacked pests and diseases | 10 | 2 | 65 | 4 |
| 2  | Dead seedlings      | 4       | 17      | 6       | 14      |
|    | Total               | 400     |         |         |         |

| No | Two-year evaluation | Seedling plots (%) |
|----|---------------------|--------------------|
|    |                     | Plot 1  | Plot 2  | Plot 3  | Plot 4  |
| 1  | Survival seedlings  | 93      | 83      | 94      | 85      |
|    | Healthy             | 79      | 78      | 85      | 78      |
|    | Attacked pests and diseases | 14 | 5 | 9 | 7 |
| 2  | Dead seedlings      | 7       | 17      | 6       | 15      |
|    | Total               | 400     |         |         |         |

Figure 2 shows the average observations of September 2017 on 2015 plantation with the highest average height in plot 1 was 102.95 cm, and the smallest average height in plot 3 was 81.41 cm. While of the observation in January 2018, the highest average height in plot 1 was 115.95 cm, and the smallest average height was in plot 3, which was 99.25 cm. Plot 1 occupies the highest value in the observations of September 2017 and January 2018 compared to plot 3, and this is due to the light received in plot 1, sufficient light intensity and excellent light quality compared from plot 3 so that the plant grew positively.

Light is an essential factor for photosynthesis. Photosynthesis is a key process of other metabolic processes in plants [7]. Light is one of the most important environmental factors because of its role in the photosynthesis; light directly affects the growth of propagule through intensity, quality, and duration of irradiation. Besides, light also plays a significant role in the metabolic activity of newly planted propagule tissue because propagules do not have leaves [8].

A tight spacing will create competition for growing space for plants. If this competition occurs, then a fast planting distance of plant height growth will be higher than the non-dense spacing. This view is also supported by [5, 6] that a tight spacing will produce a higher plant height than narrow plant spacing. It also reflects that at close spacing, competition occurs in taking light, nutrients, and other essential water elements.
Figure 2. Growth parameters, diameter (A), height (B), leaf thickness (C), and the number of leaves (D) of *R. apiculata* in the assessment in September 2017-January 2018.

From figure 2, it is shown that the average yield of leaf observations in September 2017 for the most massive planting was found in plot 1, which was 0.70 mm and the lowest was in plot 4, which was 0.58 mm. For the average of leaf thickness in January 2018, the largest was in plot 4, which was 0.86 mm, and the smallest was in plot 2 and plot 3, which was 0.83 mm. Plot 4 had the highest level of leaf thickness increase compared to the other plots in the observation of September 2017 and January 2018. This result supported the previous finding that the leaf thickness has a drastic decrease in high salinity concentrations; this plant will affect nutrient absorption and reduce water at a high level of salinity [8].

The first observation in the 2015 plantation area was conducted on September 29, 2017. Figure 3 depicts the condition of the first observation evaluation, which the result was planting activity using *R. apiculata* propagules. The mortality rate at the second observation indirect plant was slightly increased that it might be influenced by the local community activities making the crab trap at the planting site (table 2, figure 3). However, the rehabilitation program in this study is positively considered in line with the forestry minister's regulation number 70 the year 2008, where the percentage of plant growth was more than 70%.
Table 1 shows that the highest percentage of *R. apiculata* seedlings was found in plot 1, which was 96% seedlings survival, while the plants died as 4%, 86% healthy seedlings, and 10% plants attacked by pests and diseases. The lowest percentage of *R. apiculata* growth was found in plot 2, which it was 83% survived, consisting of 81% healthy, 2% attacked by pests and diseases and 17% the plants died (Table 1). Of the four plots, plot 2 has the lowest percentage of life with the highest mortality rate. This circumstance is caused by low or lousy propagule conditions that make many plants die compared to others. These points were supported by Belkheiri and Mulas [9] stating that one result of low growth in propagules is caused by physiological conditions in propagules that can cause low growing plants or lack of maturity propagules at the collection time.

The second observation in the 2015 plantation site was carried out on January 6, 2018. In Table 2 and Figure 4, the condition of the second observation was evaluated, this was the result of the planting activity using propagules *R. apiculata* planted in 2005. Table 2 shows that the highest percentage of *R. apiculata* seedlings was found in plot 3, which was 94% survival, 85% healthy seedlings, then the plants died 6%, 9% seedlings were attacked by pests and diseases. The lowest percentage of *R. apiculata* seedlings was found in plot 2, which was 83%, comprising of 78% healthy plants, 17% the plants died 17% and 5% seedlings were attacked by pests and diseases (table 2). Plot 2 still had the lowest percentage of survival with the highest mortality rate of the other four plots, but from the second observation and the first application, plot 2 had a different death rate (table 1 and table 2). When two plants are observed, they can survive and adapt to the surrounding environment so that the plant remains thriving [10, 11]. The death rate of other plots was not very significant too. The average percentage of survival in the second observation in 2015 was 89% (Table 2), this meant that the rehabilitation program of 2015 was successful following the forestry minister's regulation number 70 of 2008, with the percentage of plant growth after second-year rehabilitation was ≥ 70%.
Figure 4. Layout assessment rehabilitation year 2015 for the second observation.

4. Conclusions
The success and failure rate of mangrove rehabilitation in the second year assessment was 90.5 and 9.5%, respectively. In this case, reforestation activity is considered successfully according to the regulation of the Minister of Forestry number P.70/Menhut-II/2008. The data is expected to afford significant data for mangrove reforestation works in North Sumatra, Indonesia.

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