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Leaf Growth of Angsana Plants on Reclaimed Land After Coal Mining

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Abstract: The majority of coal mining is done using open pit mining techniques which have an effect and present a challenge to changes in the chemical, physical, and biological characteristics of the soil. Restoration of ecosystems damaged by mining activities is prioritized through revegetation of reclaimed land. This study aims to evaluate how well Angsana plants develop faster in coal mining reclamation zones when planted directly. Field data and observations are utilized to assess the growth of plants that are directly planted methods in land reclaimed after mining activities. The growth parameters that are observed involve counting the number of leaves of Angsana plants using both seedlings and stem-cutting planting. The results showed that the average leaf growth in seedlings treated with bokashi fertilizer showed normal growth and showed more leaf characteristics compared to the control treatment. The increase in the number of leaves on seedling planting material was seen from 6 weeks after planting until the end of the study. Meanwhile, the average leaf growth in cuttings occurred from 4 weeks after planting to 12 weeks after planting.
Keywords: Reclamation, Angsana plant, leaf growth

1. Introduction

One of Indonesia's most important industries is coal mining. The main problem that often appears after mining activities is the issue of environmental change and landscape alteration [1]. Coal mining activities, especially in open mining systems have led to severe ecological damage, primarily due to land clearing and the removal of topsoil and subsoil in large volumes [2]. Various problems such as loss of vegetation, damage to soil structure, extreme soil pH, low availability of soil organic matter and nutrients, high heavy metal content, and increased susceptibility to erosion, water, and air pollution can occur [3].

Post-coal mine reclamation was performed on the land that has experienced damage and degradation of soil quality due to coal mining activities. Post-coal mine reclamation aimed to restore the function of damaged land and make it productive again [4]. Plant growth on post-coal mine reclamation land is important to ensure the success of land reclamation. One of the plants that can grow on post-coal mine reclamation land is the Angsana. The Angsana can thrive on less fertile land and have good adaptability [5].

One of the major challenges in the reclamation process is restoring the function and productivity of previously damaged land to a healthy and sustainable condition. The productivity of ex-mining land can be improved through revegetation with appropriate plant species. Revegetation is an effort to repair and restore damaged vegetation through planting and maintenance activities on formerly used forest land. Revegetation is generally carried out in three stages. The first stage starts with planting vegetation cover crops, then fast-growing species, and finally insertion of plants with climax species [4].

Plant growth on post-coal mine reclamation land is important to ensure the success of land reclamation. Several plants have been reported to be used for revegetation on post-mining land, including *Gliricidia sepium*, *Senna siamea*, *Leucaena leucocephala*, and *Acacia magnum* [6][7], *Ipomoea* sp, and *Limnocharis flava*, *Mikania cordata* and *Azolla* [4], *Terminalia catapa*, *Swetenia Mahagoni*, *Cassia siamea*, *Anthocephalus chinensis*, *Vitex pubescens*, *Gmelina arborea*, *Paraserianthus falcataria*, and *Pterocarpus indicus* [8]. Sonokembang, another name for the *Pterocarpus indicus* tree, is a member of the legume family, Fabaceae (*Leguminosae*). This plant is a type of deciduous tree that grows tall, with a trunk diameter of over 2 meters and heights of 30 to 40 meters. The adaptable *Pterocarpus indicus* thrives in open spaces with direct sunlight and well-drained soil. The two most prevalent propagation methods are seeds and stem and branch cuts. However, because it is straightforward and generally results in rapid growth, cutting propagation is frequently favored[5].

The Angsana plant (*Pterocarpus indicus*) is one of the tree species often used in post-coal mine land reclamation efforts because it has good adaptability and the ability to grow quickly. Leaf growth in angsana plants plays an important role in evaluating the quality of development and the success of land reclamation efforts. Leaves play a vital role in photosynthesis where plants produce food and oxygen. In addition, leaves also serve as indicators of plant and environmental health. An optimal number of leaves indicates that the plant can absorb nutrients well, has sufficient access to sunlight, and is in overall good health. However, reclaiming post-coal mine land poses several challenges to the growth of Angsana plants, such as poor soil quality, a lack of organic matter, a lack of water, and limited available nutrients.

These environmental factors can affect leaf number growth in angsana plants and ultimately impact the success of reclaimed land rehabilitation. Although many previous studies have been conducted on plant growth on post-mining reclamation land, research specifically examining the influence of environmental factors on leaf number growth in angsana plants is limited. Therefore, This study aims to determine the growth of the number of leaves in Angsana plants influenced by environmental factors such as soil quality, lighting, and nutrient availability in post-coal mine reclamation land using the direct planting method for 12 weeks using bokashi fertilizer and coal fertilizer.

2. Material and Methods

2.1. Study Site

The study was carried out on lahan reklamasi pasca tambang di Sumatera Selatan (Figure 1-2). The sampling location is in the finalized reclaimed area in Pit 3 Barat IUP Banko Barat Barat PT. Bukit Asam, Tbk, Tanjung Enim, Sumatera Selatan, Indonesia, with a research site area of ± 630 m^2. Open-pit mining is used by the coal mining company PT. Bukit Asam, Tbk to produce coal. The initial mining procedure entails removing the soil from the overburden and clearing the concession land that will be mined. The soil is layered individually to protect its quality. After it has been reshaped to restore and improve the former mining land for its environmental function, the exposed land can also be dispersed directly in the mine reclamation area.

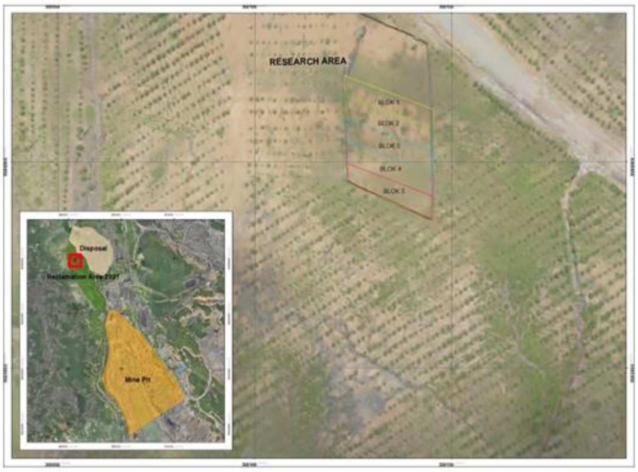

Figure 1. Location of study

The topography of West Banko is hilly and undulating, with an altitude ranging from 70 to 80 meters above sea level. The former mine excavation area is a basin with the lowest elevation ranging from -130 meters, covering an area of 540.3 hectares. However, after PIT mining, the total area was reduced to 468 hectares. The research area encompasses several soil types, including Grumosol, Mediterranean, Podzolic, reddish-yellow Regosol, and Organosol. The soil in this region has a pH range of 6.0 to 8.2, with alkalinity increasing with soil depth. Grumosol soil contains Ca and Mg and exhibits characteristics of moist saturation. The vegetation area is dominated by an ecologically unstable secondary natural forest. Some notable species found in this forest include *Oplismenus burmannii*, *Leea indica*, *Pithecelobium jiringa*, *Havea brasiliensis*, *Eurya acuminata*, *Melastoma walichii*, *Schima walichii*, and *Scleria sumatrana*.

2.2. Soil sampling and analysis

The soil samples were taken using an aerator and ring soil sampler at 0-30 cm depth. After being air-dried and combined with a 0.5' x 0.5' wire mesh, the obtained soil samples were extensively mixed by hand to homogenize the merged samples. Finer soil particles, stones, and other waste were eliminated in harvesting. Chemical properties of the soil analysis include pH, organic carbon (C-organic), total nitrogen (N-total), available phosphorus, and K-dd.

2.3. *The Angsana (Pterocarpus indicus) Plant sample preparation and data collection with the direct planting method*

The study was performed on reclaimed land over three months with 630 m^2 of research site area. The evaluation and measurement of plant growth were done using a vegetation inventory. Square plots of 22.5 m × 28 m were made to collect data for five plots. Using bokashi and coal fertilizer, the planted seeds (generative and vegetative) were randomly distributed and determined in the plots. The quantity of coal fertilizer utilized varied from 1-3 kg/planting hole, and three different dosages of the bokashi fertilizer 3, 5, and 7 kg/planting hole were available (the fertilizer would undergo incubation before use). The distance between plots was 5 m, with a planting distance of 3 m × 3 m. Observed variables include the number of seeds sown (generative or vegetative), the amount of fertilizer dosage, and the growth rate of leaves. For both Pterocarpus indicus seedlings and cuttings, leaf count observations were made over three months with 33 observation intervals. The leaf count is calculated in individual leaf units. Each sample henceforth named and abbreviated as control seedlings (CS), seedlings bokashi fertilizer 3 kg (CBF 3), seedlings bokashi fertilizer 5 kg (CBF 5), seedlings bokashi 7 kg (CBF 7), seedlings coal fertilizer 1 kg (SCF), seedlings coal fertilizer 2 kg (SCF 2), seedlings coal fertilizer 3 kg (SCF 3), cuttings control (CC), cuttings coal fertilizer 1 kg (CCF 1), cuttings coal fertilizer 2 kg (CCF 2), cuttings coal fertilizer 3 kg (CCF 3), cuttings bokashi fertilizer 3 kg (CBF 3), cuttings bokashi fertilizer 5 kg (CBF 5), and cuttings bokashi fertilizer 7 kg (CBF 7).

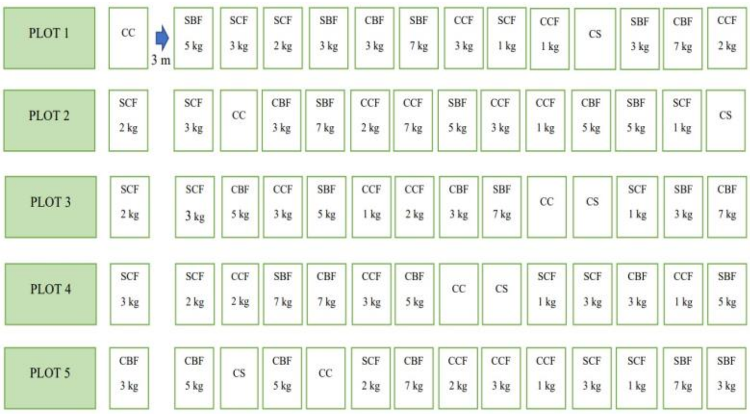

Figure 2. Angsana Planting Pattern on Post-Mining Reclamation Land

2.4. *Analysis of rainfall intensity*

Rain intensity is the height or depth of rainwater per unit of time. In other words, the intensity of rainfall expresses the amount of rainfall in the short term, giving an overview of the amount of rain per hour. To get the value of rain intensity in a place, the rain gauge used must be able to record the amount of rain volume and the time it lasts until the rain stops. The Van Breen method can be used to convert rainfall into rain intensity. Van Breen is based on the assumption that the duration of rain on the island of Java is concentrated for 4 hours with an effective rain of 90% of the total rainfall for 24 hours, according to Equation 1.

$$I = \frac{90\%\ R24}{4}$$

Where:

I = Intensity

R= Rainfall

3. Results and Discussion

3.1. *Characteristic of soil from coal post-mining*

The analysis of soil chemical properties is conducted to determine the fertility level of the planting medium through soil chemical parameters, thus serving as a reference to assess the potential of adding coal and bokashi fertilizers to improve the nutrient content of post-coal mining reclamation soil.

3.1.1. pH value of soil

The average pH value of the soil after bokashi and coal fertilizer treatments in post-mining soil remains low, which is < 4.5 or categorized as highly acidic (Table 1). Generally, the average pH value of coal mining soil is pH 2–3. Soil reaction (pH) significantly influences soil chemical behavior, nutrient availability, and microbiological activity (Figure 3). This condition is commonly found in post-mining areas, which are environments with high acidity levels. This is in line with Neina's [9] opinion, which states that the leaching rate and the lack of microbial activity in the soil can lead to a decrease in soil pH.

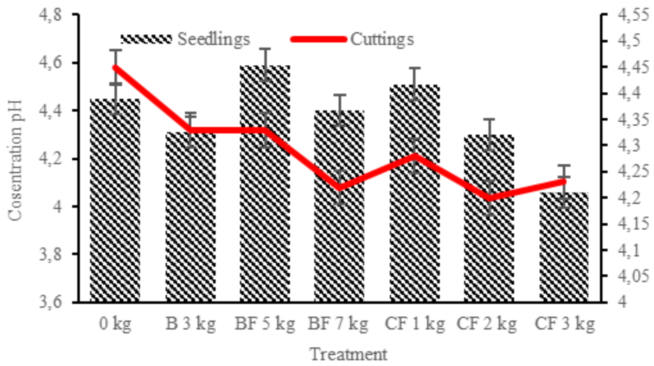

Figure 3. Soil pH of treatment

Adding coal fertilizer and bokashi fertilizer did not significantly increase the soil pH in post-mining areas. This is due to the initially very low soil acidity level and the fact that the fertilizers were added relatively short, which is insufficient to improve the soil condition comprehensively. Unfavorable environmental conditions can also influence the success of increasing soil pH, causing fertilizers not to work optimally[10].

The process of plant growth, soil reaction, or soil pH reflects the availability of macro and micronutrients as it is influenced by the ion exchange mechanisms in soil colloids and soil solution, which are affected by soil pH (Tabel 1). Generally, a soil pH close to neutral (pH 6–8) is considered an ideal range for optimal plant nutrient availability. Within this pH range, the ion exchange mechanisms on soil colloids and soil solution function effectively, soil microorganisms play a role in nitrogen (N) mineralization, and the symbiotic uptake of free nitrogen from the air can operate efficiently [11].

3.1.2. Chemical properties of coal mining

The analysis of organic C-content and total N-content in the soil treated with coal and bokashi fertilizers showed a higher percentage than in untreated soil study (SC and CC). Applying coal and bokashi fertilizers can enhance the organic carbon and nitrogen status of post-coal mining soil, although it remains relatively low. Using different doses of bokashi fertilizer, it was observed that the optimal amount for increasing the organic C-status and total N of the soil after 12 weeks of planting is 5 kg of bokashi per planting hole, combined with 3 kg of coal fertilizer per planting hole. This means that applying both fertilizer materials has not been able to increase the organic C status or total N in the soil [12]. Organic C and total N increase with the increasing age of reclamation. Organic C in the soil can stimulate microbial activity, which, in turn, enhances soil decomposition rate, P dissolution, N fixation, and microbial reactions [13]. The application of coal and bokashi fertilizers can increase the percentage of organic C and total N content in the soil [14].

The potassium (K), dispersed aluminum (Al), phosphorus (P), and cation exchange capacity (CEC) content of post-coal mining reclamation soil after treatment remains low. This is likely due to the relatively low concentrations of K, Al, P, and CEC in the bokashi and coal fertilizers, resulting in both fertilizers not providing a significant contribution to the increase in dispersed concentration in the soil. The presence of rapid decomposition processes and competition between fertilizers and soil colloids in the retention and ion exchange processes can influence nutrient availability and uptake by plants [15]. However, environmental factors such as soil pH, moisture, and temperature can also affect the availability and uptake of nutrients by plants [16].

Table 1. Chemical Properties of Post-Coal Mining Reclamation Soil After Treatment

Sample	Organic C	Total N	exch K	CEC	Al saturation	P
	%			Cmol.kg^{-1}		mg/kg^{-1}
CS	0,24	0,02	0,28	8,70	1,17	0,65
CC	0,34	0,13	0,49	8,70	1,46	1,20
SBF3	0,67	0,06	0,51	10,15	0,71	2,00
SBF5	0,71	0,06	0,38	10,88	1,15	2,15
SBF7	0,53	0,04	0,22	10,88	1,16	2,15
SCF 1	0,49	0,04	0,47	10,88	0,69	1,45
SCF2	0,42	0,03	0,19	10,88	1,28	2,15
SCF3	0,79	0,05	0,30	14,50	0,92	1,85
CBF3	0,39	0,03	0,26	13,78	1,15	1,95
CBF5	0,51	0,04	0,41	13,78	1,09	2,43
CBF7	0,59	0,04	0,45	13,78	1,25	2,75
CCF1	0,63	0,05	0,39	13,05	0,67	2,20
CCF2	0,71	0,05	0,32	15,23	1,21	2,25
CCF3	0,64	0,05	0,24	13,78	1,16	3,00
Note	< 1,00	< 0,10	0,1-0,3	< 5.00	< 10	< 10
	Very low	Very low	Very low	low	Very low	Very low

3.2. *Growth of leaf count in angsana plants*

Leaves are essential organs for plants, as they can synthesize food through the process of photosynthesis. Leaves also play a role in storing food reserves in the form of starch or sugar in leaf tissues. The morphology of Angsana leaves shows adaptations that are suitable for their environment and physiological functions. The large and reticulate shape, opposite leaf composition, and efficient venation enable Angsana to perform photosynthesis and transfer the photosynthesis products, such as glucose and oxygen, to other plant organs.

Based on the data in Table 2, it shows that in the seedling planting material, the average leaf growth of Angsana plants treated with bokashi fertilizer looks normal, with more leaf characteristics than the control treatment. However, the average leaf growth is *absisi* at 2 to 4 weeks of mass after planting. The increase in the number of leaves of seedling planting material was seen from the age of 6 weeks after planting until the end of the study. The number of new leaves formed exceeded the number of fallen leaves. This condition was seen when the intensity of rainfall increased slightly due to the transition from the dry season to the rainy season thus plants were seen forming new shoots. The growth in the number of leaves on Angsana seedlings is influenced by several factors, such as a better-developed root system that allows for more efficient absorption of water and nutrients, thus providing the basis for optimal vegetative growth. Seedlings have higher genetic potential because they come from seeds or tissue cultures that inherit the desired traits from the parent plant. Seedlings also have sufficient energy reserves in the seeds or tissue culture used at the beginning of growth. Another factor that can trigger leaf growth is that genetic diversity in seedlings provides adaptability to environmental changes and resistance to pests and diseases [5].

The average leaf growth on the planting material of cuttings occurs from 4 to 12 weeks after planting. However, slow leaf growth was observed in the cuttings' planting material treated with coal fertilizer at a dose of 1 kg per planting hole. Leaf growth occurred 11 weeks after planting, but during that period, the average leaves on the cuttings' planting material experienced chlorosis and black spots, and many leaves fell off. Leaf loss is a natural process in the life cycle of plants, where some leaves are shed to make way for new leaves to grow. Chlorosis is when the leaves lose their normal green color and appear yellow or pale. In this context, chlorosis on the leaves of the cuttings' planting material can be caused by nutrient deficiencies in nitrogen (N) and phosphorus (P). Both nutrients are essential for plant growth and chlorophyll synthesis, affecting the leaves' green color. A lack of nitrogen and phosphorus can disrupt photosynthesis and cause chlorosis in the leaves

[17]. Furthermore, in the treatment with 2 kg per planting hole, leaf growth did not occur until the end of the study. Upon observation of the physical condition of the stem of the cuttings' planting material, there was a change in color from green to blackish-brown, and blackish spots were also present.

Table 2. The average growth of Angsana leaves a week after planting

Treatment /Dosage	The average growth of Angsana leaves											
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
CC	0	0	0	8,8	15,6	9,8	15,4	12,6	16,6	21,5	23,8	24,6
CBF 3 kg	0	0	0	4,8	3,4	6,4	3,6	4,8	14,8	18	22	30,8
CBF 5 kg	0	0	0	2,4	1	1,4	3,4	4,2	3,6	5,8	7,6	8
CBF 7 kg	0	0	0	9,2	10,4	9	6,4	7,2	15,4	18,8	23	20,4
CCF 1 kg	0	0	0	0	0	0	0	0	0	0	0,6	7,2
CCF 2 kg	0	0	0	0	0	0	0	0	0	0	0	0
CCF 3 kg	0	0	0	4,2	3,4	3,6	3,2	4	3,2	0,2	1	14,6
CS	32,2	18,2	9	11,2	25	38,2	48,8	55,8	65,4	77,4	90	104,4
CBF 3kg	41,8	27,8	21	25,8	38	46,8	57,2	67	79,8	90,6	103,4	105,8
CBF 5 kg	35,6	25,6	7,4	8,8	19,2	32,6	42,2	52	64,6	76	89,8	123,6
CBF 7 kg	29	18	6,4	7,6	19,6	35	41,2	52,2	67,4	78,8	94	109
SCF 1 kg	37,8	19,6	5,8	12,2	21	31	39,6	48,8	58,6	69	80,2	94
SCF 2 kg	28,6	18	6,2	8,6	23,6	32,8	38,8	48,2	60,4	72,2	86,8	100,8
SCF 3 kg	28,8	20,2	6,8	5,2	19,6	30	39,4	48,8	62,6	73,4	87,4	101,8

Note : WAP (A week after planting)

3.3. The influence of the microclimate on the growth of Angsana in land reclamation post-coal mining

The Angsana plant (*Pterocarpus indicus*) is a pioneer plant that thrives in open areas. Several factors are essential for its growth, including specific climatic conditions. Angsana plants require temperatures ranging from 20 to 30 °C (68 to 86 °F), falling under warm to moderate temperatures for optimal growth. An annual rainfall intensity of approximately 1000–2000 mm and sunlight intensity ranging from 2,000 to 10,000 lux is necessary [18]. The climatic conditions in the study area of "post-coal mine reclamation land" during the direct planting period met the growth requirements of Angsana plants. Recorded temperatures ranged from 24 to 32 °C, while sunlight intensity ranged from 1000 to 6000 lux. The rainfall intensity during May, June, July, and August was recorded at 357.90 mm, 454.00 mm, 63.00 mm, and 352.50 mm, respectively

.

Table 3. Rainfall intensity measured directly

Month	Rainfall (mm)	Rainy day	Temperature °C	Light intensity (Lux)
Jan	438.50	22	27.5	2894.55
Feb	158.00	15	30.8	3524.48
Mar	179.00	15	30.6	3851.88
Apr	213.00	20	29.7	3386.93
May	357.90	19	30	3229,67
Jun	454.00	24	27,5	3745,2
Jul	63.00	12	31,8	6087,9
Aug	352.50	23	30,3	3856,9
Sept	117.50	10	31.6	3325.24
Oct	260.50	13	29.6	3152.44
Nov	295.00	19	28.9	3586.27
Dec	585.00	27	28.6	3248.71

4. Conclusion

The results showed that the average growth of leaves planted by direct planting on seedling planting material treated with bokashi fertilizer showed normal growth with more leaf characteristics compared to the control treatment. However, in the period 2 to 4 weeks after planting, there was *absisi* in leaf growth. The growth of the number of leaves on the seedling planting material was observed starting from 6 weeks after planting until the end of the study. Meanwhile, the average leaf growth on the cuttings planting material occurred from 4 to 12 weeks after planting. However, slow leaf growth occurred in the planting material of cuttings treated with coal fertilizer at a dose of 1 kg/planting hole, where leaf growth only occurred 11 weeks after planting.

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