Effects of Goat Manure and NPK on the Growth of *Paraserianthes falcataria* (L.) Nielsen in Ex-limestone Mining Soil

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**Abstract.** Limestone mining is the kind of human activities producing negative impacts to the ecosystem stability. Revegetation is one of the efforts to improve the ecosystem of ex-limestone mining soil. Species selection that appropriates with the marginal soil is the key to reach the successfully revegetation. *Paraserianthes falcataria* (L.) Nielsen is a pioneer species, potential to be planted on ex-limestone mining soil. This research aims to analyze the effect of goat manure and NPK fertilizer to promote the growth of *P. falcataria* seedlings in ex-limestone mining soil and to find out the optimum dose of those combination treatments. The result showed that the combination of goat manure and NPK fertilizer did not significantly affect height, diameter, total wet weight, total dry weight, shoot-root ratio growth parameters. However, that treatment significantly affected the number of root nodules. These results indicated that *P. falcataria* is a pioneer species that may adapt quickly to grow in ex-limestone mining soil. The addition of goat manure and NPK fertilizer could improve that soil characteristic and *the P. falcataria* growth.

1. Introduction

Limestone mining is one of the form of exploitation and utilization of minerals from natural resources that affect the ecosystem stability. Generally, mining activities produce mining waste (tailing) with infertile (marginal) characteristics, and potentially reduce the ecosystem stability [1]. The mining waste decreases the soil quality as well as soil fertility [2]. Mining activities may resulted to several environmental problems, such as the loss of topsoil layer, low organic matter content, low nutrient content, soil compaction, pH problem, high soil temperature, and low microorganism activities [3]. The problem that must address to rehabilitate ex-lime mining.

Rehabilitation is an effort to recovery the function and structure of ecosystem through the soil characteristic improvement and revegetation. Revegetation is replanting process on the post-mining land to re-establishment the native vegetation sustainably [4]. Moreover, the revegetation aims on post-mining land are to controlling runoff and erosion, biodiversity improvement, as well as landscape esthetic value. Some important things to be considered for the success of revegetation are tree species selection, seed supply, as well as planting and plantation maintenance [5].

Species selection and soil property improvement are essential factors that are determining the success of revegetation process on post-mining lands, such as ex-limestone mining area. *P. falcataria* is a tree species that usually used on revegetation activities [6, 7]. *P. falcataria* has special characteristics, such as fast-growing species, pioneer tree species, and adaptive to marginal soil with...
less soil nutrition due to its mutualism association between nitrogen-fixing bacteria with the root system of this plant, called rhizobium. Soil properties improvement on the ex-limestone mining soil can be conducted in several ways, such as the fertilization. According to Wasis and Angraini [8], fertilization with goat manure and wood charcoal can improve the soil properties (physics, chemistry, and biology), as well as able to support the growth of *Gmelina arborea* seedlings on the tailing of Silica mining. Therefore, goat manure is potentially organic matter to be used for improving the properties of ex-limestone mining soil as well as to support the plant growth in this soil. Moreover, NPK fertilizer is expected to enrich the nutrient in ex-limestone mining soil to support plant growth.

This study aimed to analyze the effects of goat manure and NPK fertilizer to promote the growth of *P. falcataria* seedlings in ex-limestone mining soil, and to find out the optimal dose of those combination treatments.

2. Method

2.1. Materials

The tools used in this research were digital caliper, ruler, tally sheet, calculator, polybag (20 × 20 cm), shovel, digital scales, sprayer, camera, and oven. Materials needed being three-month *P. falcataria* seedlings, goat manure, NPK, water, and soil from ex-limestone mining in Gunung Kapur-Ciampea, Dramaga, Bogor, West Java.

2.2. Procedure

The research conducted in several steps, such as preparation, observation and data collection, and developed an experimental design.

2.2.1. Preparation

Soils from an ex-limestone mining area in air-dry conditions were weighed about 1 kg for each polybag). This soil as plant media mixed with goat manure and NPK fertilizer at an appropriate dose. The dose of goat manure was 0, 50, 100, 150 g/polybag) and NPK fertilizer was 0, 5, 10, 15 g/polybag) as a treatments. Healthy of *P. falcataria* seedlings and homogenous in diameter and height were planted in the potted culture media according to the combination of treatments.

2.2.2. Observation and data collection.

Observation and data collection on height, diameter, biomass (wet and dry weight), root nodules, as well as shoot-root ratio were done.

2.2.3. Experiment design

Factorial in completely randomized design and three replicates used the combination of treatments.

| Manure | Replicates | NPK     |
|--------|------------|---------|
|        |            | N0      | N5      | N10     | N15     |
| P0     | 1          | P0N0-1  | P0N5-1  | P0N10-1 | P0N15-1 |
|        | 2          | P0N0-2  | P0N5-2  | P0N10-2 | P0N15-2 |
|        | 3          | P0N0-3  | P0N5-3  | P0N10-3 | P0N15-3 |
|        | 1          | P1N0-1  | P1N5-1  | P1N10-1 | P1N15-1 |
| P1     | 2          | P1N0-2  | P1N5-2  | P1N10-2 | P1N15-2 |
|        | 3          | P1N0-3  | P1N5-3  | P1N10-3 | P1N15-3 |
| P2     | 1          | P2N0-1  | P2N5-1  | P2N10-1 | P2N15-1 |
|        | 2          | P2N0-2  | P2N5-2  | P2N10-2 | P2N15-2 |
Table 1. Combinations of treatments of goat manure and NPK fertilizer (continuation)

|   | P2N0-3 | P2N5-3 | P2N10-3 | P2N15-3 |
|---|--------|--------|---------|---------|
| P3 | P3N0-1 | P3N5-1 | P3N10-1 | P3N15-1 |
| P3 | P3N0-2 | P3N5-2 | P3N10-2 | P3N15-2 |
| P3 | P3N0-3 | P3N5-3 | P3N10-3 | P3N15-3 |

Factors for NPK (N)
- N0: 0 g (NPK) + 1000 g (ex-limestone mining soil)
- N5: 5 g (NPK) + 1000 g (ex-limestone mining soil)
- N10: 10 g (NPK) + 1000 g (ex-limestone mining soil)
- N15: 15 g (NPK) + 1000 g (ex-limestone mining soil)

Factors for goat manure (P)
- P0: 0 g (goat manure) + 1000 g (ex-limestone mining soil)
- P1: 50 g (goat manure) + 1000 g (ex-limestone mining soil)
- P2: 100 g (goat manure) + 1000 g (ex-limestone mining soil)
- P3: 150 g (goat manure) + 1000 g (ex-limestone mining soil)

3. Result and discussion

Plant growth was the most important indicator to be observed in order to study the adaptability of a type of plant to its growing media [9, 10]. Plant growth was the process of increasing the mass and volume of a plant. Growth in the form of mass plant growth illustrated by the growth of plant biomass, both total weight wet (TWW) and total dry weight (TDW). The growth in volume increment described by growth in height and diameter [11]. The plant growth was irreversible because it could not return to its initial condition. The growth of a type of plant influenced by two factors, namely internal factors (genetic) and external factors (environment).

Table 2 showed the results of the analysis of variance of treatment in the form of goat manure and NPK to the growth of *P. falcataria* seedlings. Analysis of variance showed that the combination treatments of goat manure and NPK had a significant effect on the number of nodules. Height and diameter growth, TWW, TDW, and shoot-root ratio (SRR) were not significantly affected by the treatments.

Table 2. Recapitulation of variance analysis on the effects of goat manure and NPK fertilizer on the growth of *P. falcataria* seedlings in ex-limestone mining soil

| Parameter   | Manure | NPK   | Manure X NPK |
|-------------|--------|-------|--------------|
| High        | 0.1371  | 0.6495 | 0.2819       |
| Diameter    | 0.7138  | 0.6128 | 0.2439       |
| TWW         | 0.0335  | 0.2525 | 0.6989       |
| TDW         | 0.0591  | 0.3844 | 0.3068       |
| SRR         | 0.0883  | 0.5459 | 0.5066       |
| Root nodules| 0.1145  | 0.4696 | 0.0031       |

* = treatment had a significant effect on the confidence level of 95% with a significant value (P-value) < 0.05 (α), ns = treatment had no a significant effect on the confidence level of 95% with a significant value (P-value) > 0.05 (α).

Mostly, the goat manure and NPK fertilizer did not significantly affect the growth of *P. falcataria* seedlings, except the root nodules. This fact indicated that *P. falcataria* was a tree species with excellent performance (adaptability) to planted on the ex-limestone mining soil.
3.1 Height and diameter

Plant height was the simplest parameter to be observed and could help to a better understanding of the effect of the environmental factors on the plant growth [12]. Figure 1 showed the average growth of *P. falcataria* seedlings height for three months in several treatments.

![Figure 1](image1.jpg)

**Figure 1.** The average of height growth of *P. falcataria* seedlings in several treatments of goat manure and NPK fertilizer in ex-limestone mining soil.

*P. falcataria* seedlings showed the highest growth (17.47 cm) in treatment P1N10 (50 g goat manure + 10 g NPK). The lowest growth (6.93 cm) showed by P1N5 treatment (50 g goat manure + 5 g NPK). These facts showed that the planting media with the addition of 50 g goat manure and 10 g NPK could give a positive impact on the nutrient availability in the ex-limestone mining soil and increased the growth of *P. falcataria* seedlings compared to other treatments. Increasing dosage of fertilizer not always followed by a plant with excellent performance and could even trigger plant poisoning [13].

According to Dwijoseputro [14], plant diameter growth was secondary growth, resulting from cambium (lateral meristem) activity that formed the xylem and phloem.

![Figure 2](image2.jpg)

**Figure 2.** The average growth of *P. falcataria* seedlings diameter in several treatments of goat manure and NPK fertilizer in ex-limestone mining soil.

Figure 2 showed the average diameter growth of *P. falcataria* seedlings in several treatments. The treatment of P2N5 (100 g goat manure + 5 g NPK) resulted in the highest diameter growth reaching to 4.8 mm. The lowest diameter growth obtained from P2N15 treatment (100 g manure + 15 g NPK).
The average diameter growth of *P. falcataria* seedlings ranged from 0.9 - 1.87 mm. According to Faizin *et al.* [15], determining the right planting media would produce the optimal plant growth.

### 3.2 Biomass (TWW and TDW)

TWW and TDW of plants could describe biomass. TWW described a physiological activity because it related to water content, nutrients, and yields of plant metabolism [16]. TDW was a parameter that could be used to determine the response of plants in utilizing available nutrients on the growth medium [17].

![Figure 3](image)

**Figure 3.** Average TWW and TDW at growth with several treatments of goat manure and NPK addition on the ex-limestone mining soil

Based on Figure 3, it is known that treatment P0N10 (0 g goat manure + 10 g NPK) produced the highest TWW and TDW, 22.2 g and 5.0 g, respectively. The treatment of P3N5 (150 g goat manure + 5 g NPK) produced the lowest TWW (8.2 g), while treatment of P1N5 (50 g goat manure + 5 g NPK) produced the lowest TDW (1.2 g). However, the treatments were not significantly affected by the TWW and TDW of *P. falcataria*. These facts showed that *P. falcataria* still could grow in control media (ex-limestone mining soil without goat manure and NPK) as well as treatment media. According to Heriyanto and Siregar [18], TWW had a fundamental relationship with TDW, because it is related to the accumulation of the synthesis of metabolic results used by plant growth. TDW could describe the accumulation of nutrient content in plants [18].

### 3.3 Shoot-root ratio (SRR) and root nodules

SRR could describe nutrient and water conditions in the media (soil) that affect the ability of roots to absorb water and nutrients. Large SRR showed that the availability of water and nutrients for plants was relatively optimal as a result, the growth of shoots would be more dominant [19]. Seedlings could be said to be good if they have a root apex ratio ranging from 1-3, but the best was that which approaches the value of 1 [20].

Based on Figure 4, it can be said that the highest of SRR parameters showed by P3N10 treatment (150 g goat manure + 10 g NPK), and the lowest was in the control treatment P0N0 (0 g goat manure + 0 g NPK). According to Winata [10], nutrient and water conditions in plant growth media could also be seen by the magnitude of the SRR value. The results found in this study that the condition of the limestone mining soil media with its characteristic improvement through the provision of goat manure and NPK was able to improve *P. falcataria* seedlings growth.
Figure 4. The average SRR at growth with several treatments of goat manure and NPK addition on the ex-limestone mining soil

The control of treatment (P0N0) had low nutrient content. Besides that, the texture was dominated by a coarse fraction (sand) (Table 3) so that the media of the ex-limestone mining was relatively not optimal in providing water and nutrients needed by plants. It was different from the media ex-limestone mining with the treatment of P3N10, which was capable of producing P. falcataria seedlings with the highest SRR, which was 28.86. This condition indicates that the provision of goat manure and NPK was able to provide characteristic soil improvement so that it could support plant growth, in this case, P. falcataria seedlings.

P. falcataria was a legume plant which was generally associated with nitrogen-fixing bacteria in its root area so that it could produce root nodules. According to Purnomo [21], root nodules contain rhizobium which could bind free nitrogen from the air and convert it to ammonia (NH₃) and could be used by some nitrogen sources for plants so that it quickly grows on nutrient-poor soils. Table 2 showed the results of the Duncan test treatment for the development of the number of P. falcataria root nodules in ex-limestone mining media.

Based on the results of the study that the highest number of root nodules produced at P1N10 treatment (50 g goat manure + 10 g NPK) which was not significantly different from P1N15 (50 g goat manure + 10 g NPK) and P2N0 (100 g goat manure + 0 g NPK) at a 95% confidence interval. According to Óscar et al. [22], fertilization could provide nutrients that were not available in the soil for plant growth.

In addition, the administration of fertilizers both goat manure and NPK could stimulate the development of root nodules in P. falcataria seedlings. Based on the results of the study, it found that the treatment of P1N10, P2N10, and P1N15 was the best because it had a percentage increase in the number of root nodules to the control of 170.03%. The indicates if the three treatments could increase the number of root nodules in sengon seedlings planted in the media of former limestone quarries.

On the other hand, the response to the formation of the lowest root nodules obtained in the control treatment, namely P0N0 (0 g goat manure + 0 g NPK). This is presumably because the treatment of P0N0 did not support the availability of nutrients that support the growth of rhizobium bacteria in root nodules [23]. This condition further indicates that the administration of fertilizers, such as goat manure and NPK, could improve soil characteristics in terms of providing nutrients needed by plants. The stimulating the development of root nodules on the roots of P. falcaaria, to increase P. falcataria seedling growth in soil media ex-limestone mining.
Table 3. The effect of the goat manure and NPK addition to the number of *P. falcata*ria seedlings root nodules

| Treatment | Average of root nodules | % Increasing to the control |
|-----------|-------------------------|-----------------------------|
| P1N10     | 9.000a                  | 170.03                      |
| P2N0      | 9.000a                  | 170.03                      |
| P1N15     | 9.000a                  | 170.03                      |
| P0N15     | 8.667ab                 | 160.04                      |
| P1N5      | 8.333ab                 | 150.02                      |
| P3N0      | 8.333ab                 | 150.02                      |
| P2N15     | 8.333ab                 | 150.02                      |
| P0N5      | 8.000ab                 | 140.02                      |
| P3N10     | 7.333abc                | 120.01                      |
| P2N5      | 7.333abc                | 120.01                      |
| P1N0      | 7.333abc                | 120.01                      |
| P3N5      | 7.333abc                | 120.01                      |
| P0N10     | 7.000abc                | 110.02                      |
| P3N15     | 5.333bcd                | 60.01                       |
| P2N10     | 4.667cd                 | 40.02                       |
| P0N0      | 3.333d                  | 0                           |

* The number followed by the same letter indicated that the treatment was not significantly different at the 95% confidence level.

3.4 Soil characteristics

Based on the results of soil analysis, it was known that ex-limestone mining, which used as a planting medium had marginal or infertile characteristics. This could be seen in the treatment P0N0 (control), which presented in Table 4. In the control treatment, it is known that ex-limestone mining had low nutrient content. This indicated by the low number of elements such as C-organic, N, P-available, K, Na, and Mg. In addition, the soil texture in the control treatment dominated by the sand fraction (59.88%). The sand fraction could hold water low. It will be difficult for media ex-limestone mining soil to hold water in the soil, which is undoubtedly beneficial for plants. This was related to the condition of the fertility of ex-limestone mining to be relatively low.

According to Munawar [24], soil fertility as the status of land that shows the capacity of the soil in supplying sufficient quantities of essential elements for plant growth, without the poisoning concentration of any element. The provision of goat manure and NPK in this study was intended to improve the characteristics of the limestone mining so that it could optimally support *P. falcata*ria seedling growth.

Goat manure contains nutrients that are rich in nutrient compared to plant residues [24]. On the other hand, the addition of NPK has various benefits, including those related to the availability of N, P, and K elements in the soil media where plants grow. The N element can help the vegetative development of a plant, the content of P elements can help to stimulate root growth, the necessary ingredients of protein, and strengthen respiration. While for K elements could help in the formation of proteins and carbohydrates, strengthen plant tissue and resistance to disease and drought due to the presence of antibodies [2, 25, 26].
Table 4. Physical and chemical soil properties of study sites

| No | Treatments | Control | Criteria* | Goat manure dan NPK | Criteria* |
|----|------------|---------|-----------|---------------------|-----------|
| 1  | Texture (%) |         |           |                     |           |
|    | Sand       | 59.88   |           | 41.28               |           |
|    | Dust       | 22.59   |           | 33.57               |           |
|    | Clay       | 17.52   |           | 25.14               |           |
| 2  | C-Organic (%) | 0.08   | Very low  | 3.37                | High      |
| 3  | N-Total (%) | 0.03    | Very low  | 0.23                | Medium    |
| 4  | P-available (ppm) | 6.07     | Very low  | 138.93              | Very high |
| 5  | CEC (me/100g) | 24.22   | Medium    | 28.62               | High      |
| 6  | pH         | 7.25    | Neutral   | 7.16                | Neutral   |
| 7  | Cation arrangement: |       |           |                     |           |
|    | K (me/100g) | 0.22    | Low       | 4.03                | Very high |
|    | Na (mg/100g) | 0.25    | Low       | 1.11                | Very high |
|    | Mg (me/100g) | 0.48    | Low       | 3.85                | High      |
|    | Ca (me/100g) | 57.68   | Very high | 51.79               | Very high |

*criteria of soil characteristics by MOA [27]

The pH value of the original soil from ex-limestone mining (control media) was 7.25 (neutral), but after the amendment of goat manure and NPK, the pH became 7.16 (neutral). This indicated that the amendment of goat manure and NPK could reduce the pH in ex-limestone mining. The pH value affects nutrient uptake and plant growth, namely through its influence on nutrient availability and the presence of toxic elements [7].

C-organic showed the content of organic matter in the soil. C-organic had a crucial role in the soil, especially its effect on soil fertility [28]. The organic C-value in control was 0.08% (very low), whereas, after the addition of manure and NPK, organic C changed to 3.37% (high). According to Munawar [24], the amendment of soil organic matter increases the availability of soil fertility and plant nutrition.

Cation exchange capacity (CEC) showed the ability of the soil to hold cation and exchange this cation [26]. The results of the soil analysis showed high CEC values after being given the treatment of adding goat manure and NPK of 28.62 me / 100 g. The value of the results of soil analysis on N-total in the control treatment had a value of 0.03% (very low), while after the addition of goat manure and NPK had a value of 0.23% (medium). It was because bacteria that live around plant roots or rhizosphere that function as N fixator [24].

The P-available value in control had a value of 6.07 ppm (low) after the addition of goat manure, and NPK increased to 138.93 ppm (very high). This happens because phosphorus was an essential nutrient that makes up several key compounds and as a catalyst for essential biochemical reactions in plants [24].

The results of soil analysis at potassium showed that the control soil had a value of 0.22 me/ 100 g (low) after the contribution of goat manure and NPK to 4.03 me/100 g (very high). Potassium could be used to open stomata, transport and transport air, and activate, improve plant quality, protein synthesis, and photosynthesis [26].

Calcium values reached 51.79 me/100 g (very high) after the addition of goat manure and NPK compared to controls reached a value of 57.68%. The amendment of goat manure and NPK affected the decrease in Ca value of 5.89%. The high content of Ca elements in ex-limestone mining inhibits the growth of sengon seedlings. An increase in the element Magnesium (Mg) in the ex-limestone
mining media from 0.48 me/100 g (low) to 3.85 me/100 g (high). The role of Mg in plants as a component of chlorophyll molecules in all green plants and serves as a metabolic process and protein synthesis [24]. Microelements needed by plants in tiny amounts [24]. The change in Na value on soil analysis results from a value of 0.25 me/100g (low) to 1.11 me/100g (very high). The high Na content in a plant could cause health problems and soil productivity and affect soil salinity [29].

According to Hanafiah [25], the ideal proportion of soil fraction is 22.5-52.5% sand, 30-50% dust, and 10-30% clay, while the proportion control of soil fraction was 59.88% sand, 22.59% dust, and 17.52% clay. The results of the media added with goat manure and NPK had a proportion of soil fraction, namely 41.28% sand, 33.57% dust, and 25.14% clay. These facts showed that the controlled media dominated by a sand fraction, and the proportion of the dust fraction was insufficient for plant growth. However, the amendment of goat manure and NPK included in the ideal proposition for the growth of a plant. Healthy plant growth requires certain nutrients and must be in the optimum amount and concentration and be in a precise balance in the soil [25, 30].

4. Conclusion
The goat manure and NPK fertilizer amendment did not significantly affect almost all parameters of P. falcataria seedling growth on the ex-limestone mining soil media, such as high, diameter, TWW, TDW, and SRR. However, goat manure and NPK amendment gave a significant effect on the number of root nodules. The best treatment was P1N10 treatment, which was not significantly different with P1N15 and P2N0 with the increment of root nodules number to 170.03 % compared for the control.

References
[1] Winata B, Wasis B, Setiadi Y 2016 JPSL 6, 211-216.
[2] Wasis B and Fathia N 2011 JMHT 17, 29-33.
[3] Prayudyaningsih R 2014 Wallacae Forestry Research Journal 3, 13-23.
[4] Setiadi Y 2006 Revegetation Techniques for Rehabilitation of Post-Mine Land National Seminar PKRLT Faculty of Agriculture [in Indonesian: Teknik Revegetasi untuk Merehabilitasi Lahan Pasca Tambang Seminar Nasional PKRLT] (Yogyakarta: Gadjah Mada University).
[5] Setiadi Y 2012 Land Improvement In Post-Mining Land [ in Indonesian: Pembenahan tanah di lahan pasca tambang]. Unpublished.
[6] Krisnawati H 2011 Paraserianthes falcataria (L.) Nielsen, Ecology, Silviculture, and Productivity [Paraserianthes falcataria (L.) Nielsen, Ekologi, Silvikultur dan Produktivitas] (Bogor: Center for International Forestry Research).
[7] Mindawati and Megawati 2013 Mahogany (Swietenia macrophylla King.) Cultivation Manual Research and development center for enhancing forest productivity [Manual budidaya mahoni (Swietenia macrophylla King.) Pusat penelitian dan pengembangan peningkatan produktivitas hutan] (Bogor: Forestry Research and Development Agency ).
[8] Wasis B and Angraini N 2017 Journal of Tropical Silviculture 8 203-207.
[9] Harjadi S 1993 Introduction to Agronomy [in Indonesian: Pengantar Agronomi] (Jakarta: Gramedia).
[10] Winata B 2014 Jabon (Anthocephalus cadamba) seedling growth on the former sand mining media with the addition of sub soil and coconut shell charcoal [in Indonesian: Pertumbuhan semai jabon (Anthocephalus cadamba) pada media bekas tambang pasir dengan penambahan sub soil dan arang tempurung kelapa] [thesis] (Bogor: IPB University).
[11] Darmawan J and Baharsjah J S 2010 Fundamentals of Plant Physiology [in Indonesian Dasar-Dasar Fisiologi Tanaman] (Jakarta: SITC).
[12] Noviani D 2010 The effect of NPK fertilizer and kompos on the growth of Jabon seedlings (Anthocephalus cadamba Roxb Miq) on the former gold mining soil media [Pengaruh pemberian pupuk NPK dan kompos terhadap pertumbuhan semai jabon (Anthocephalus cadamba Roxb Miq) pada media tanah bekas tambang emas] (Bogor: IPB University).
[13] Anayansi C, Fernandez C, Naeth M, Wilkinson S 2013 *Can. J. Soil. Sci.* 93, 555-566.
[14] Dwijoseputro 1984 *Introduction to Plant Physiology* [in Indonesian: *Pengantar Fisiologi Tumbuhan*] (Jakarta: PT Gramedia).
[15] Faizin N, Mardhiansyah M, Yoza D 2015 *JOM Faperta* 2 1-9.
[16] Sitompul S M and Guritno B 1995 Plant Growth Analysis [in Indonesian: *Analisis Pertumbuhan Tanaman*] (Yogyakarta: Gadjah Mada University Pr).
[17] Gusmailina and Pari G 2002 *Forest Products Research Bulletin* 23 217-229.
[18] Heriyanto N and Siregar C *Journal of Forest Products Research and Nature Conservation* 1 78-88.
[19] Santosa A, Harwati T, Siswadi 2013 *Journal of Agricultural Innovation* 12 53-66.
[20] Ramadani H 2007 Formulation of Arbuscular Mycorrhizal Fungus (AMF) inoculum and vermicompost in improving the quality of teak seedlings (*Tectona grandis* Linn.) [in Indonesian: *Formulasi inokulum Fungi Mikoriza Arbuskula (FMA) dan vermikompos dalam meningkatkan kualitas semai jati muna* (*Tectona grandis* Linn.)] (Bogor: IPB University).
[21] Purnomo A 2011 Growth of sengon seeds (*Paraserianthes falcatoria* (L.) Nielsen) developed from seed and tissue culture in a variety of planting media compositions [in Indonesian: *Pertumbuhan bibit sengon* (*Paraserianthes falcatoria* (L.) Nielsen) yang dikembangkan dari benih dan kultur jaringan pada berbagai komposisi media tanam] (Bogor: IPB University).
[22] Óscar J S, Diego A O, Sandra M 2017 *Waste Management* 69 136-153.
[23] Adrialin G, Wawan, Venita Y 2014 *Jom Faperta* 1 1-9.
[24] Munawar A 2011 *Soil Fertility and Plant Nutrition* [in Indonesian: *Kesuburan Tanah dan Nutrisi Tanaman*] (Bogor: IPB University Pr).
[25] Hanafiah K 2005 *Basics of Soil Science* [in Indonesian: *Dasar-Dasar Ilmu Tanah*] (Jakarta: Raja Grafindo Persada).
[26] Hardjowigeno S 2003 *Soil Science* [in Indonesian: *Ilmu Tanah*] (Jakarta: Akademika Pressindo).
[27] [MOA] Ministry of Agriculture 1983 Guidelines for Growing Rice, Palawija, Vegetables [*Pedoman Bercocok Tanam Padi, Palawija, Sayur-Sayuran*] (Jakarta: Ministry of Agriculture).
[28] Isminanda A 2012 Response of sengon buto seedling growth to PT Antam Pongkor's tailing media with the addition of coconut shell charcoal and bokashi manure [in Indonesian: *Respon pertumbuhan bibit sengon buto pada media tailing PT Antam Pongkor dengan penambahan arang tempurung kelapa dan bokashi pupuk kandang*] (Bogor: IPB University (Bogor Agricultural University)).
[29] Malvi U 2011 Interaction of micronutrients with major nutrient with special reference to potassium *J. Agric. Sci.* 42, 106-109.
[30] Nainggolan D 2011 Effect of Zn, Fe, and B spraying on the leaves of maize (*Zea mays* L) planted in the tailings deposition area [in Indonesian: *Pengaruh penyemprotan Zn, Fe, dan B pada daun tanaman jagung* (*Zea mays* L) yang ditanam di areal pengendapan tailing] (Papua: Papua University).