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DIRECT SEEDING AND SEEDBALL AS ALTERNATIVE PLANTING METHOD FOR RECLAMATION IN POST MINING AREA

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1. INTRODUCTION

1.1 Background

Mining business according to UU RI no. 3 Tahun 2020 is an activity in the context of mineral or coal exploitation which includes the stages of activities for general investigation, exploration, feasibility study, construction, mining, processing, refining, transportation, sales, and management ex-mining activities. The existance of the mining process of limestone, both on an industrial scale and traditional, causes ecological imbalance in the environment (Okafitria 2018) due to loss of vegetation, damage to soil horizons, soil compaction, damage to soil structure and texture (Ikbal et al. 2016). The ex-mining land cannot be reused because of a decrease in soil organic matter, a decrease in soil nutrient content, loss of top soil, soil compaction, decrease in microbial diversity, increased soil temperature and pH (Ekawati et al. 2016) so it is necessary to rehabilitate the ex-mining land.

In accordance of Environmental and Mineral Resources (ESDM) Ministry regulation No. 1829/2018, good mining engineering principles include the implementation of aspects of environmental management of mining, reclamation, and post-mining, as well as post-operation. Reclamation and rehabilitation activities are carried out to restore the carrying capacity of the land in order to function according to its purpose. Furthermore, the success of reclamation is described in P.60/Menhut-II/2009 which decides that post-mining land reclamation is said to be good if the success is more than 80%, so rehabilitation techniques and suitable types of plants are needed.

One of the ways to carry out post-mining land reclamation is by direct seeding. Direct seeding is an alternative method to support reforestation and rehabilitation of forests and land in tropical areas (Tuheteru 2011). The planting technique in the direct seeding method is by sowing or planting seeds in the field without going through the nursery stage (Beyer 2008). Direct seeding has the advantage of reducing the cost of forest development because there is no cost for producing seedlings in the nursery, so the total cost of planting can be significantly reduced (Schmidt 2007). However, direct seeding has weaknesses, which are the seeds may be eaten by insects and birds (Jawahar and Umarani 2019), the seeds are less protected because environmental factors that can affect germination are difficult to control, limited species that grow in extreme conditions, and are less effective on land with high slopes (Schmidt 2008) so a method was developed to make plant seeds more adaptive and reduce the possibility of being eaten by insects and birds, namely by wrapping the seeds (seedballs). Seed wrapping aims to provide the seeds with a nutritious formula so that they are able to survive to the conditions that will allow them to germinate, increase the mass of seeds so they will fall on the target location for rehabilitation (Priadi 2010), and can act as a seed bank for a while, as well as prolong the dormation period of seeds (Jawahar and Umarani 2019).

The clay content of seedballs can reduce water deficiency by increasing water potency and helping to prevent the seeds from being eaten by insects and birds. In recent years, many parties have prepared and used seedballs for direct seeding on stretches of land to increase land cover. The concept of the seedball itself is very relevant and has enormous potential not only to increase land cover, but also to increase community awareness for nature conservation by participating in planting (Jawahar and Umarani 2019). Another advantage of seed wrapping is that it can be planted immediately regardless of the type and shape of the seed. This wrapper is very thin, allowing multiple coatings with only 1-10% weight of the seed (Tekrony 2006).

1.2 Objective

The purpose of this study is:

1. Comparing and analysing seedball formulation
2. Analyzing the effectiveness of direct seeding and seedball techniques for recalcitrant, orthodox and cover crop seeds
3. Analysing survival rate and germination rate of the plants with direct seeding and seedball planting method
4. Analysing factor that influence the succesfull of direct seeding and seedball planting method at post mining area.
5. Analysing the influence of manure to germination rate which plants with direct seeding planting method.

1.3 Expected Output

The results of this studies are expected to be used as material in determining the post-mining land reclamation method and determining the suitable and effective plant species through direct seeding and seedball methods. Planting with direct seeding and seedball methods is expected to reduce planting costs and accelerate the reclamation program for ex-mining land in Indonesia, especially limestone mining.

2. STATE OF THE ART OF THE RESEARCH

Direct seeding technique is a technique of planting using seeds directly in the field without going through the nursery stage. This method can be applied to temporary reclamation areas and by small-scale mining companies because of the low cost (Nugroho 2013). According to Beyer (2008) the advantages of applying direct seeding techniques are:

1. Reducing planting costs because seeds are planted directly in the field without going through the nursery stage
2. Able to reach areas with difficult accessibility because seeds are easier to carry than seeds
3. Plant root growth and development tends to be better because it does not experience stress after planting and has the opportunity to adapt earlier
4. More plant growth in general can be better because it is protected from damage to seedlings due to transportation
5. In general, trees produce seeds, but seedlings may not be available.
6. Direct seeding technique can be done in every season, provided that the soil moisture is sufficient.

The application of planting using the direct seeding technique also has several drawbacks (Schmidt 2008), the seeds are less protected because environmental factors that affect germination are difficult to control, in contrast to the optimal environmental conditions regulated in the nursery, it is less effective to do on land with high slopes because there is a possibility of seeds. will be lost due to erosion, and it is necessary to control the predators of seeds and weeds, so that the use of seedballs in direct seeding practice is believed to be able to improve the weaknesses of the direct seeding techniques above, especially in increasing the biological control capacity (Choong et al. 2006), increasing power and seed germination rate (Podlaski and Wyszkowska 2003) and increased drought resistance (Sudrajat et al. 2015).

Several types that are suitable and have been widely used in the seedball method in Indonesia are Gmelina arborea, Enterolobium cyclocarpum and Callophyllum inophyllum (Sudrajat et al. 2019). There are no publications regarding the use of recalcitrant, orthodox, and cover crop types using direct seeding or seedball methods to rehabilitate post-mining land, especially limestone mining for the cement industry, so this research is important.

According to P.60/Menhut-II/2009 criteria and indicators of success in forest reclamation in revegetation, it is necessary to plant local types of long-cycle forest plants. Based on these regulations, suitable plant types are those that are liked by the community and have certain advantages such as wood products, fruit and sap and their products have high economic value, for example teak, rasamala, mahogany, cempaka, meranti, lime, ironwood and / or MPTS plants for example. durian, mango, rambutan, banana, jengkol, breadfruit, jackfruit. The research that will be carried out utilizes several of the above species to reclaim land after lime mining in accordance with government regulations and has not been widely carried out in Indonesia using the seedball method. The use of this method has been used in land rehabilitation, especially vacant land and other degraded lands, but there has not been much report in Indonesia regarding the rehabilitation of land after lime mining for the cement industry, so this research is necessary.

3. METHOD

3.1 Research Period and Location

The research will be conducted on March till November 2021. Preliminary test which aims to determine the formulation of seedball will be carried out at IPB University and planting using direct seeding and seedball will be carried out in the post-mining land of PT Solusi Bangun Indonesia Tbk. Narogong Plant, Gunung Putri, Bogor, West Java.

PT Solusi Bangun Indonesia Tbk (PT SBI) was formerly known as PT Holcim Indonesia Tbk. Perseroan officially changed its company name on February 11, 2019 (SBI 2019). PT SBI is the largest cement producer in Indonesia and Southeast Asia. PT SBI operates an integrated business of cement, ready mix concrete, and aggregate production. The company operates four cement factories in Narogong (West Java), Cilacap (Central Java), Tuban (East Java), and Lhoknga (Aceh), with a total capacity of 14.8 million tons of cement per year, and employs more than 2,400 people. As a company with a mission to create environmental protection and sustainable social responsibility, PT SBI needs to manage the post mining area as its function (SBI 2019).

3.2 Variables Observed

The variables observed in this study are germination rate, seed viability, life percentage, seedling height, and seedling diameter.

3.3 Materials and Tools

The materials used in this study are divided into two part based on the planting method (seedball and direct seeding). Materials used for the seedball method include recalsitrant types such as jackfruit (*Artocarpus heterophyllus*), durian (*Durio zibethinus*), and bisbul (*Diospyros blancoi*) which is also a type of MPTS; orthodox types such as gmelina (*Gmelina arborea*) and merbau (*Intsia bijuga*); and cover crop seeds (LCC) with *Brachiaria decumbens* (BD grass) and *Crotalaria* sp., media for the seeds (clay, compost, and sand), media for the seedball (clay, compost, sawdust, insecticide, vermicompost, bone meal). Furthermore, the materials used for the direct seeding method are manure, merbau seeds (*Intsia bijuga*), jengkol (*Archidendron jiringa*), ketapang (*Terminalia catappa*), bisbul (*Diospyros blancoi*), and jackfruit (*Artocarpus heterophyllus*). The tools used include polybags, scissors, sprayer, buckets, pole, sandpaper, plastic bag, hoe, stationery, and documentation equipment.

3.4 Data Collection Procedure

3.4.1 Physical and Chemical Characteristic of soil at Post Limestone Mining Area

Soil samples will take at five points in an area to be planted using the direct seeding method. The location is determined based on the growth of plants that have a low success rate. These five points are in each corner and in the middle of the planting plot. Soil samples taken at the five points are at a depth of 0-60 cm. Illustration of soil sampling images can be seen in Figure 1.

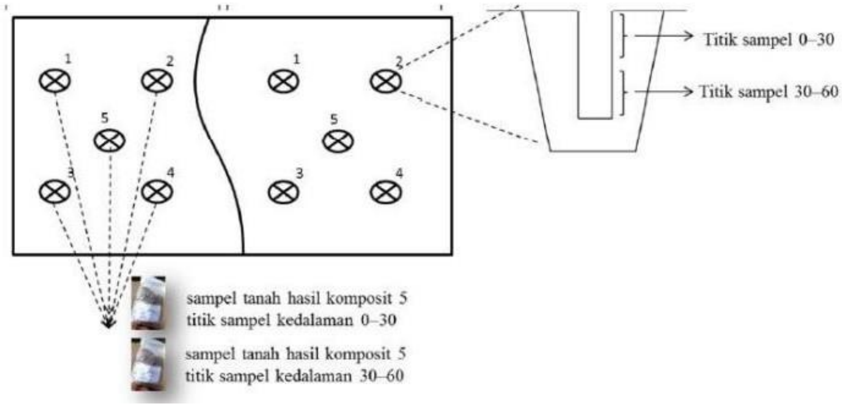

Figure 1. Soil sampling in planting plot.

Soil was taken at depth of 0-30 cm and 30-60 cm and then composited according to the depth, dried and then crushed. The composited soil that has been crushed then sieved through a 2 mm polyethylene sieve (Liu et al. 2017). All samples will analyze for field capacity, bulk density, pH, soil organic matter, N, P and K.

3.4.2 Seed Quality Test

Seed is one of the ways for plants to produce new individuals. In addition, seeds are now a traded commodity. The seeds that are planted are required to have prime quality so that seed quality testing needs to be done. Seed quality testing used in this research is physiological quality testing of seeds.

3.4.2.1 Physiological Quality Testing of Seeds

Physiological quality testing of seeds is done to get information about the quality of metabolic processes that occur in seeds. The testing activities are performed using standard seed germination methods. The basic steps of physiological quality testing of seeds :

1. Preparing germination media (topsoil) and put it into polybag. The number of seeds germinated is 10 seeds with three repetitions for each species.
2. Dormancy breaking performed before germination process. The dormancy breaking method adjusted to the dormancy characteristic of seed.

3.4.2.2 Seedball Formulation Test

The seedball formulation test will be carried out to determine the appropriate packaging formulation and give the best results when seed germination is carried out. The composition of the formulation was divided into three treatments in this study according to Table 1.

Table 1. Seedball formulation

Treatment	Material Composition
Formula 1	Clay + compost (1:1) (Hakim *et al.* 2015)
Formula 2	Clay + compost + insectiside (50:50:1) (Alimah *et al.* 2018)
Formula 3	Clay + sawdust + bone meal + vermicompost (8:8:2:1) (Jawahar dan Umarani 2019)

Tests is carried out by planting MPTS seeds such as jackfruit, durian, and bisbul in the form of seedballs in soil + compost + sand with a ratio 2: 1: 1 media. Jackfruit, durian and bisbul (Rohadi *et al.* 2005) are recalcitrant seeds so the seeds must be planted fresh and cannot be dried too long and the water content will decrease (Buharman *et al*. 2011).

3.4.2.3 Data Analysis

a. Seeds Viability

Germination is the ability of seeds to germinate normally under optimum conditions measured as the percentage of normal sprouts to the number of seeds planted. The germination can be calculated using a formula;

$$\text{Seeds viability}=\frac{\text{normal sprouts}}{\text{Total planted seeds}}\times 100\%$$

b. Germination Rate

The germination rate is calculated to determine the number of days it takes for the radicle or plumule to appear. The germination rate can be calculated according to the formula;

$$\text{Germination rate}=\frac{n1t1+n2t2+\ldots+nxtx}{\text{Total germinated seeds}}$$

where;

n = The number of seeds that germinate

t = Days the seed takes to germinate

3.4.3 Adaptation of Selected Tree Species with Direct Seeding and Seedball Method

Direct seeding and seedball method using six tree specieses, namely Merbau (*Intsia bijuga* (Colebr.) O. Kuntze), Jengkol (*Archidendron jiringa*), Ketapang (*Terminalia catappa*), Bisbul (*Diospyros blancoi*), gmelina (*Gmelina arborea*) and Jackfruit (*Artocarpus heterophyllus*). Seedball method using 2 specieses of LCC, namely *Crotalaria* sp., and BD grass (*Brachiaria decumbens*). The seeds used must mature physiologically.

3.4.3.1 Experimental Steps

a. Field Preparation for Direct Seeding

The plantation plot is land that has finished the mining activity process, and has been restructured. Land preparation begins with dividing the area based on the research design using completely randomized design (CRD). Then, making a planting hole with a size of 30 x 30 x 30 cm with a spacing of 4 x 4 m and 15 repeatition for each species of trees.

b. Field Preparation for Seedball Planting Method

The research location has a flat to steep topography. Land preparation begins with planning the area of the object based on a randomized block design (RBD) research design. In accordance with the results of research by Narendra and Pratiwi (2014) which states that LCCs planted in row patterns have the ability to cover the soil higher than those of the scatter planting patterns. Then the land was cleared from weeds and boundary between plots which are differentiated based on recalcitrant, orthodox, and LCC types in the form of stumps and ropes.

c. Dormancy Breaking

The dormancy breaking method adjusted to the dormancy characteristic of seed for each species. The dormancy breaking technique used to accelerate the germination. Here is the treatment given to each seed :

1. Merbau and gmelina seeds is the scarification technique. Scarification is done by filing or sanding the strophile seeds. The seeds are then soaked in water for 24 hours (Tuheteru 2010). The sanded part of the seed is placed on top at the time of planting.
2. Jengkol, ketapang, jackfruit, and durian are not given dormancy breaking treatment. They are recalsitrant seeds. The recasitrant seeds that will be made into seeds must be immediately collected fresh (Buharman et al. 2011)
3. Bisbul seeds are rubbed using fine sandpaper.

d. Direct Seeding Method

The Direct seeding method in this research is done by planting seeds in a 30 x 30 x 30 cm plant hole. Every plant site planted seeds at a depth of 0.5 cm. One plant hole filled with two seeds of plants without additional fertilizer. Repeatition every species of trees are 15. Each plant hole is marked with stake which is given a coloured tape according to the type planted.

e. Effect of Manure on Germination and Plant Growth Result of Direct Seeding Technique

The plantation plot is land that has finished the mining activity process, and has been restructured. Land preparation begins with dividing the area based on the research design using completely randomized design (CRD). Then, making a planting hole with a size of 30 x 30 x 30 cm with a spacing of 4 x 4 m and 15 repeatition for each species of trees. Treatment of 2 kg of manure is applied in each planting hole.

f. Seedball Method

Sowing of seeds in seedballs was carried out with a spacing of 4x4 m for recalcitrant and orthodox types, while for LCC types a line cropping pattern will be used. The seeds used are 3 recalcitrant species, 2 orthodox species, and 2 LCC species. The diameter of the seedballs was 2 cm in according to the research conducted by Hakim et al. (2015) the best growth was obtained when the seedball had a diameter of 2 cm. Each seed is planted at a depth of 1 cm. Each plant hole is marked with a stake which is given a colored ribbon according to the type planted.

g. Maintenance

Maintenance is done by keeping and observing the seeds planted from weeds. The weeds that grow around the planting hole are removed once a week. In addition, recording data of the percentage of seeds carried by erosion or out of planting holes and pests that attack plants after growing.

3.4.3.2 Growth Parameters

a. Seeds Viability

Germination is the ability of seeds to germinate normally under optimum conditions measured as the percentage of normal sprouts to the number of seeds planted. The germination can be calculated using a formula

$$\text{Seeds viability} = \frac{\text{normal sprouts}}{\text{Total planted seeds}} \times 100\%$$

b. Germination Rate

The germination rate is calculated to determine the number of days it takes for the radicle or plumule to appear. The germination rate can be calculated according to the formula;

$$\text{Germination rate} = \frac{n1t1+n2t2+\ldots+nxtx}{\text{Total germinated seeds}}$$

where;

n = The number of seeds that germinate

t = Days the seed takes to germinate

c. Life Percentage

The percentage of life is obtained by calculating the number of seeds that live compared to the total number of seeds that are observed in each hole. This data was taken at the end of the observation. The formula is:

$$\text{Life percentage} = \frac{\Sigma \text{ seeds that live}}{\Sigma \text{ seeds}} \text{ x } 100\%$$

d. Height (cm)

High measurements are made from one month after seeds has been planted, then measurements are made every two weeks. High measurements start from cotillion to peak.

e. Diameter (mm)

Measurements are made using calipers on the cotyledons every 4 weeks.

3.4.3.3 Experimental Design

a. Direct Seeding

The research design using completely randomized design (CRD) with five tree specieses and 15 repeatition for each species. Observation and measurement data are analyzed using a linear model:

$$Yik = \mu + \alpha\text{i} + \varepsilon\text{ik}$$

where:

Yik = Value / response from observations on the technical factor level-i and repetition k

μ = Average value

αi = Response from treatment i

εik = Random effect of treatment i and repetition k

b. Seedball

The experimental design used was a single factor randomized block design (RBD), with the influence variable of the type of seed which was divided into 3 blocks (orthodox seed block, recalcitrant, and LCC) and each block consisted of 15 experimental units. Observation and measurement data will analyze using a linear model:

$$Yik=\mu+\alpha i+\beta k+\varepsilon ik$$

where:

Yik = Value / response from observations on the technical factor level-i and block k

μ = Average value

αi = Response from treatment i

βk = Respons from block k

εik = Random effect of treatment i and block k

3.4.4 Data Analysis

Statistically tested using ANOVA. Data is processed using SAS 9.1.3 statistical software, with a determination:

a. Fhit>Ftabel, treatment has a real influence on the observed parameters

b. Fhit $\leq$ Ftabel, treatment does not give a real influence on the observed parameters.

If there is a significant difference, continued test performed using the Duncan`s Multiple Range Test (DMRT).

3.4.5 Cost Analysis

Cost analysis is done by reviewing the costs incurred for planting using the direct seeding method and comparing it with the costs when planting using seedlings. Some things that are considered in this cost analysis are the need for seeds and seedlings, prices for seeds and seedlings, spacing, planting and maintenance components. The need for seeds of each species is estimated by the percentage of plant life from direct seeding that lasts until the end of the observation, converted into units of area (hectares) according to the spacing used in field experiments. The result is then multiplied by the price of the seed. The stake requirement is also calculated for each unit area (hectare) and multiplied by the stake price. Planting and maintenance components such as tracking, staking, making planting holes, transporting, planting, maintaning, are calculated in People Working Days (HOK) and multiplied by the worker's daily wage. The final result of the cost by direct seeding compared to the cost of planting using seeds in monetary units.

4. RESULT AND DISCUSSION

4.1 Physical and Chemical Characteristic of soil at Post Limestone Mining Area

The location of the planting area is on ex-lime mining land which has a soil type according to the USDA classification is Rendol. This type of soil has a shallow depth and its use is quite limited. This soil, if it is too dry, cannot absorb water, so if there is rain, the organic matter has the potential to be carried away by surface runoff. This soil is prone to drought due to rapid percolation, and is not recommended for agriculture, because it will interfere with roots due to a lot of rocks. The description of the results of the physical and chemical properties of the soil at the two soil extraction locations can be seen in Appendix 1.

4.1.1 Soil Physical Analysis

Soil texture is the relative ratio between the fractions of sand, silt and clay in the soil mass. Soil texture shows the coarseness of the soil from the fine soil fraction (Hardjowigeno 2010). Soil texture at both locations of sandy clay loam which is dominated by high sand content. Soil texture also greatly affects the ability of the soil to hold water. This type of Rendoll soil usually has a relatively good Bulk density (BD), but a low Particle density (PD) value.

4.1.2 Soil Chemical Analysis

Organic C content in direct seeding land is higher than seedball planting land. However, the organic C content in both locations was low. The pH values of H_2O and KCl in both fields were classified as slightly alkaline. Meanwhile, the total N value, C/N ratio in both locations is very low. The available P is both low, while the potential K in the direct seedling area is very high compared to the seedball experimental area.

On the other hand, the soil at each study site contains very low-low Na^+ and K^+ exchangeable cations, and high-very high Mg^{2+} and Ca^{2+}. The cation exchange capacity is low-medium and the base saturation content is very high. Meanwhile Al^{3+} which can be exchanged is classified as very low, while Fe is classified as high.

4.2. Seed Viabilities and Germination

Seed is functionally seen as planting material, in the context of agronomy it is expected to achieve maximum productivity, and in the context of seed technology it is expected to be able to maintain genetic identity (Susilastuti, 2016). Plant seeds in the forestry sector have an important role in forestry development, especially in ex-mining areas located in forest areas. Knowing the quality of plant seeds is very important to support the success of revegetation on ex-mining reclamation land. Seeds are classified into two categories based on their storage capacity, namely recalcitrant seeds and orthodox seeds. Orthodox seeds can be stored for a long time at a temperature of 4 – 18°C with an air humidity of about 40 – 50% and a moisture content of 4 – 8%. Meanwhile, recalcitrant seeds can be stored for a relatively short time, usually 1-4 weeks at a moisture content of 20-50%, humidity of 50-60%, and a temperature of 18-20°C (Buharman et al, 2011). Seeds are classified into two categories based on their storage capability namely recalcitrant and orthodox seeds. Orthodox seeds can be stored for a long time at a temperature of 4 – 18°C with an air humidity of around 40 – 50% and a moisture content of 4 – 8%. While recalcitrant seeds may be kept for a relatively short period, usually 1-4 weeks at a moisture content of 20-50%, a humidity of 50-60%, and a temperature of 18-20°C (Buharman et al, 2011).

A physiological quality test of seeds is performed to determine the potential seed growth of the species tested. The tests are carried out in the nursery so that environmental factors can be controlled and growth can occur more regularly. The parameters observed in this test were seed viability and germination rate. In this observation, seed viability is defined as the proportion of normal germination based on an examination of seeds that develop into seedlings with a normal structure (Sutopo, 2002). The rate at which seeds germinate is represented by the germination rate.

4.2.1 Seedball Formulation Test

Testing the composition of seedball ingredients on the seeds of jackfruit, durian, bisbul, gmelina and merbau plants to find out the best formula. Prior to seedball making and planting, dormancy was broken through filing and soaking for 24 hours on merbau and gmelina seeds. The test was carried out by planting seedballs in polybags with a diameter of 20cm with a composition of soil/compost/sand with a ratio of 2:1:1. The seedball is planted at a depth of 2 cm, so that half the ball is immersed in the medium. Furthermore, polybags are arranged according to the arrangement that has been made using a completely randomized design (CRD) (**Figure 2**).

Figure 2. Seedball planting with various compositions of seed ball ingredients

The best presentation of germination in durian, jackfruit, and gmelina seeds was found in the third formula, while in bisbul seeds it was found in the first formula, and merbau germination was found to be the same between the first and third formulas. From the observations in Table 2, it is shown that the best composition is found in Formula 3 which consists of clay: sawdust: bone meal: vermicompost with a ratio of 8: 8: 2:1 by looking at the germination of the seeds (**Figure 3**).

Table 2. Seed germination based on the composition of seedball

	Germination (%)					
	Durian	Nangka	Bisbul	Merbau	Gmelina	**Total**
Composition 1	25,00	16,67	33,33	8,33	8,33	**55**
Composition 2	25,00	25,00	16,67	-	-	**40**
Composition 3	33,33	33,33	25,00	8,33	16,67	**70**

Figure 3. Observation of seed ball germination

4.2.2. Seed ball Viability Test

Viability testing for seedball seeds was carried out on 25 seeds using sand growing media for 40 days (**Figure 4**). Seed viability parameters observed were germination rate and seed germination. The results of observations of germination and germination rate of seeds used for the seedball method can be seen in **Table 3**.

Figure 4. Seed viability test

Table 3. Seed viability test results for seedball

Species	Germination (%)	Germination rate (days)
Durian (*Durio zibethinus*)	92	3
Nangka (*Artocarpus heterophyllus*)	96	5,29
Bisbul (*Diospyros blancoi*)	56	6
Merbau (*Intsia bijuga*)	96	4,46
Gamelina (*Gmelina arborea*)	48	16,17

4.2.3. Direct Seeding Viability Test

Viability test of seeds to be planted using direct seeding technique was also carried out. The relatively large size of the seeds made the viability test ineffective using a germination tank, so 20 cm polybags were used (**Figure 5**). Planting media using topsoil around the nursery. The seeds used in this study were merbau, ketapang, bisbul, jengkol and jackfruit seeds. The treatment of breaking physical dormancy by scarification was carried out for merbau and ketapang seeds. The scarified seeds were then soaked in water at room temperature for 24 hours.

Figure 5. Testing the viability of direct seeding seeds in polybags

Seed viability test germination observation. Parameters observed were germination rate and daily germination rate. The results of observations of germination and germination rate can be seen in **Table 4**.

Table 4. Germination and germination rate of direct seeding seeds

Species	Germination (%)	Germination rate
Ketapang (*Terminalia catappa*)	83%	20
Merbau (*Intsia bijuga*)	87%	3
Bisbul (*Diospiros blancoi*)	97%	7
Nangka (*Artocarpus heterophyllus*)	80%	8
Jengkol (*Archidendron jiringa*)	50%	3

Diospiros blancoi had the highest germination rate (97%). The percentage value of D. blancoi sprouts in this research was identical to the value obtained in Putri and Popi's research

(2002), which was 96.67 percent without special treatment. D. blancoi germinates easily and does not require any special treatment. *I. bijuga* had the second-highest germination percentage after D. blancoi, at 87%. The germination percentage of *I. bijuga* obtained in this research was greater than in Nugroho's (2013) study, which used a combination of mechanical and chemical scarification of dormancy breaking methods and had a germination rate of 78.67%. However, the results of germination in this study were lower when compared to Tuheteru (2009) which got a germination percentage of *I. bijuga* of 92 – 96%. The lower viability compared to previous studies was due to some germinating seeds that did not develop properly according to the complete seed structure criteria. Abnormal germination conditions can be caused by damage to germ cells that are currently germinating and severe damage to certain areas so that growth is inhibited (Copeland et al, 2001). It indicates that probably these seeds were stored for a long time and reducing their viability. However, the germination percentage of *I. bijuga* in this research is still acceptable. According to Sudrajat (2017), *I. bijuga* with a germination percentage of about 80-90% are included in the number two seed quality criteria.

Terminalia catappa germination had an 83% success rate. Masilamani et al (2013) achieved comparable germination values, germinating T. catappa with a germination percentage of 80 – 98 percent. The germination percentage of T. catappa with a value more than or equal to 60% is included in the number one seed quality criteria (Sudrajat et al, 2017). A. heterophyllus had an 80 percent seedling percentage. Under optimal conditions, A. heterophyllus can have a germination percentage varying from 80% to 100% (Rukmana, 2003). The species with the lowest germination rate was A. jiringa, which had a germination rate of 50%. The attack of microorganisms that cause rot and damage to the seeds even after radicles have developed is one of the problems leading A. jiringa germination to be disrupted. The seeds of A. jiringa are recalcitrant, which means they have a short lifetime and are difficult to store since their high water content makes them vulnerable to microbial infection and regresses more quickly. A. jiringa's low germination percentage can be attributed to seed quality. The seeds were purchased on the market and might have been harvested from parent trees in a variety of locations. They were also might have been contaminated by micro bacteria that causes rot.

The germination rate is the time required for seeds to germinate. The species with the quickest germination rates were I. bijuga and A. jiringa, which germinate in three days, while the species with the slowest germination rate were T. catappa, which germinate in 20 days. The daily germination rate was determined by observing the development of radicles from the planted seeds. The development of sprout components that emerge from the seed coat and then extend downward to create a root system is referred to as a radicle (Edmond et al, 1975). **Figure 6** shows the daily germination chart.

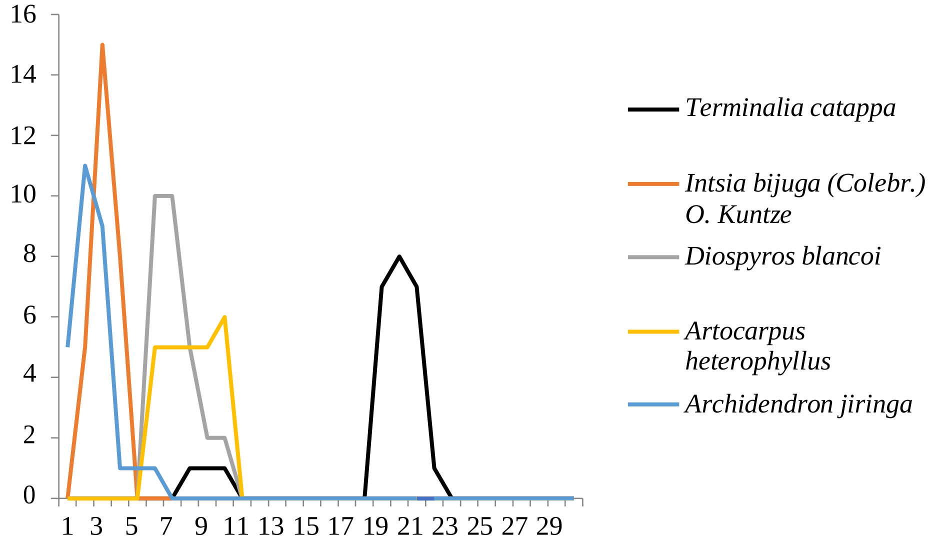

Figure 6. Daily germination chart.

The daily germination rate represented the number of germinated seeds every day, as indicated by the development of radicles. The daily germination rate of I. bijuga which was treated with scarification as the dormancy breaking method resulted in three days of germination rate. This result is faster than Dodo et al (2009), who performed a dormancy breaking technique on I. bijuga by immersing it in concentrated H_2SO4 (95%) for 40 minutes, resulting in an average germination rate of 9 days. Mechanical scarification has a higher germination rate than the chemical method of using sulfuric acid (H_2SO4). In addition, mechanical scarification is less harmful to the environment than chemical scarification. Mechanical scarification has a time effectiveness disadvantage because the time required to scarify seeds one by one is significantly longer and relies on the speed and labor employed, while the use of chemicals as a dormancy breaking technique requires less time (Musyarofah et al, 2016).

Artocarpus heterophyllus, *Archidendron jiringa*, and *Diospiros blancoi* which were included in recalcitrant seeds did not have a dormancy period. Recalcitrant seeds have a fast life span and germinate quickly. The germination rate of A. jiringa was three days, and daily germination began on the first day after planting. Meanwhile, A. heterophyllus had an eight-day germination rate and daily germination began on the fifth day. This is in line with the statement of Purnomosidhi et al (2013) which stated that A. jiringa will germinate and sprout within one week after planting, while A. heterophyllus takes one to two weeks after planting. D. blancoi germination took seven days and began on the fifth day. The species that take the longest time to germinate is T. catappa which took 21 days to germinate.

4.3. Seedball and Direct Seeding Planting on Ex-Limestone Mining Land

4.2.3. Seedball Planting

Seedball seeds were planted based on the RAK design. Planting distances of 2x2 m are marked with stakes and raffia rope with different colors (**Figure 7**). Planting using the best seedball composition in accordance with the results of testing the composition of the seedball material. Observations on plant growth using the seedball method in post-lime mining land were carried out after 40 days starting by measuring growth parameters such as seedling height, seedling diameter, and number of leaves (**Figure 8**).

Figure 7. Planting seedball seeds in ex limestone mining

Figure 8. Observation of seedball seed growth in ex limstone mining

One of the parameters of plant growth that can be observed is seedling height. Growth is defined as the increase in the number and dimensions of trees, both height and diameter in a stand. Upward growth in plants (height) is primary growth while lateral growth (diameter) is called secondary growth.

The difference in seedling height is due to differences in the speed of growth or the emergence of seedlings to the seed ball surface. The slower the speed of sprouting on the surface of the seed ball, the lower the seedling height. According to the average increased in seedling height based on the seed ball formulation, the best formulation was found in the formula C with an average of 17.98 cm (Gambar 9).

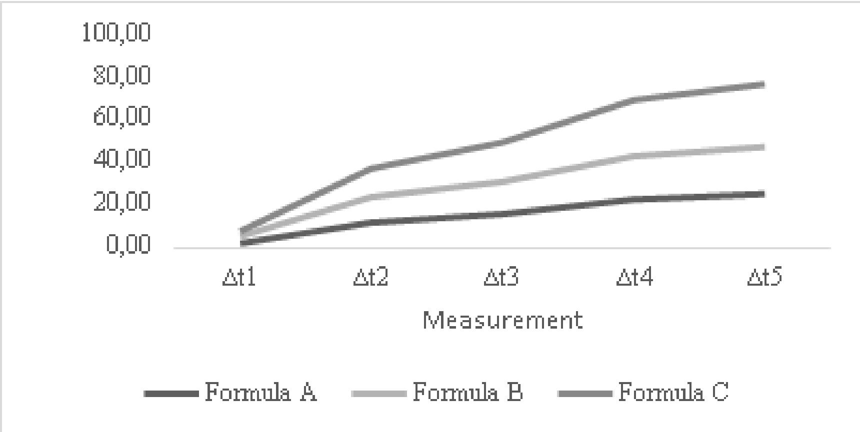

Figure 9. Average increase in seedling height

The forming materials used in formula C consisted of clay as an adhesive and retaining water content, sawdust as organic material to maintain drainage, and bonemeal and vermicompost as fertilizer. The use of sawdust as a medium is very potential because it can improve soil structure, maintain drainage, and stabilize humidity and temperature, so that the benefits of sawdust in seedball are to maintain drainage and water content is not excessive so that the seeds do not rot easily.

Vermicompost is compost obtained from the decomposition of organic matter carried out by worms. Vermicompost contains organic nutrients C, N, and K that plants need, so that after the seeds grow into seedlings and the seedballs begin to crack and decompose, the forming materials will become additional fertilizer and affect seedling growth, such as seedling height. In accordance with previous studies, the increase in seedling height was influenced by the nutrients contained in vermicompost such as nitrogen, phosphorus, potassium, and magnesium.

Bone meal contains 10% of N nutrients with 2.1% P and 1% K. Bone meal is produced by washing the bones and then boiling them, soaking them in hydrochloric acid, steaming them to soften the bones, then drying the bones in an oven, and grinding them to produce finer bone meal. Bone meal can be used as a source of phosphorus (P) and calcium (Ca) which are needed for plant growth. Bone meal is able to release P slowly as compared to rock phosphate, or in some soils has the same effectiveness as superphosphate fertilizer so that in this study the seed ball formula affected the average increase in seedling height.

Table 5. ANOVA test results the effect of seedball formula on the average increase in plant height

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	231.420	2	115.710	12.810	0.000
Within Groups	162.594	18	9.033		
Total	394.014	20			

The results of variance in Table 5 show that the seed ball formulation had a significant effect on the average increase in seedling height. There was a difference in height increase in all treatments due to differences in nutrient absorption. Plant growth influenced by genetic factors, and environmental factors such as growth media and nutrient availability, which in this study the availability of nutrients sourced from seed balls.

4.3.2. Direct Seeding Planting

Some of the activities carried out in preparation for planting were placing stakes, placing markers on the markers in the form of ribbons as treatment markers and making planting holes measuring 30 cm x 30 cm x 30 cm (**Figure 10**). The marking uses a yellow ribbon for jackfruit, red for merbau, pink for jengkol, blue for merbau and orange for ketapang.

Figure 10. Planting direct seeding in ex limestone mining

The direct seeding method is a technique for planting plant seeds directly in the field without going through the nursery stage. Table 6 shows the result of the Least Significance Difference (LSD) analysis value on the germination of the five species planted using direct seeding techniques.

Table 6. The significant value of the least significant difference test result.

Species name	*T. catappa*	*I. bijuga*	*D. blancoi*	*A. heterophyllus*	*A. jiringa*
T. catappa	-	0,159	0,027*	0,093	0,257
I. bijuga	0,159	-	0,393	0,775	0,014*
D. blancoi	0,027*	0,393	-	0,568	0,001*
A. heterophyllus	0,093	0,775	0,568	-	0,007*
A. jiringa	0,257	0,014*	0,001*	0,007*	-

*the mean difference is significant at the 0,05 level

Significant differences were found between *A. jiringa* and the other three species namely *I. bijuga*, *D. blancoi*, and *A. heterophyllus*. Apart from being statistically different from *A. jiringa*, only *D. blancoi* was statistically different from *T. catappa*. While *I. bijuga*, *D. blancoi*, and *A. heterophyllus* had germination rates that were not significantly different, *A. jiringa* and *T. catappa* were also not significantly different. This indicates that *I. bijuga*, *D. blancoi*, and *A. heterophyllus* had similar germination rates, as did *A. jiringa* and *T. catappa*. Table 7 shows the results of the viability and seed germination rate of the direct seeding method.

Table 7. Viability and germination rate of *T. catappa*, *I. bijuga*, *D. blancoi*, *A. heterophyllus*, and *A. jiringa* plants directly in the field.

Species name	Viability	Germination rate
T. catappa	55%	24
I. bijuga	85%	4
D. blancoi	100%	8
A. heterophyllus	80%	10
A. jiringa	40%	4

The results of the germination test using the direct seeding method showed that *D. blancoi* had a 100% germination percentage, which was the highest rate compared to other species. This species is relatively easy to germinate and does not require special treatment. *D. blancoi* germinates quickly but after the stem and leaves develop, the growth rate decreases, making this species rare. *D. blancoi* is distributed in primary and secondary forests in the low to medium lands, with an altitude of 0-800 meters above sea level on almost all soil types. *I. bijuga* had the second-highest germination percentage after *D. blancoi*, with a value of 85%. The percentage of germination obtained in the field differs by only 2% from the germination test in the nursery. Physical dormancy exists in the form of a hard seed coat in *I. bijuga*. The dormancy-breaking treatment given to this seed helps imbibition that occurs as an early phase in germination. In general, the genus *Intsia* grows on dry rocky soil, sometimes on sandy soil, clay, and moist soil that is not flooded, from lowlands to highlands with an elevation of 0–1000 meters above sea level. *Intsia bijuga* generally grows in sandy and rocky habitats, especially on sedimentary soils in lowland forests.

T. catappa is commonly found in coastal areas to lowland forests. This species native habitat is sandy soil conditions. *T. catappa* which is propagated generatively usually has a low percentage of germination, which is around 25%. Despite fairly high germination percentages (83%) obtained in the nursery test, the germination percentage of *T. catappa* planted using the direct seeding method in this study was 55%. This is because *T. catappa* seeds are attacked by soil mesofauna, particularly ants, who drill holes in the seed coat and destroy the inside of the seed. *T. catappa* is a species of host plant that ants prefer for nesting and feeding. Ants will build a nest on the ketapang leaves and feed on the ketapang seeds. The smallest germination rate is *A. jiringa* with a germination percentage of 40%. *A. jiringa* seeds are recalcitrant, which means the seeds do not have a dormancy period and will grow immediately even if stored. The low percentage of *A. jiringa* germination rate was caused by poor seed quality, which was line with the results of the nursery's germination test. Figure 11 shows the daily germination chart.

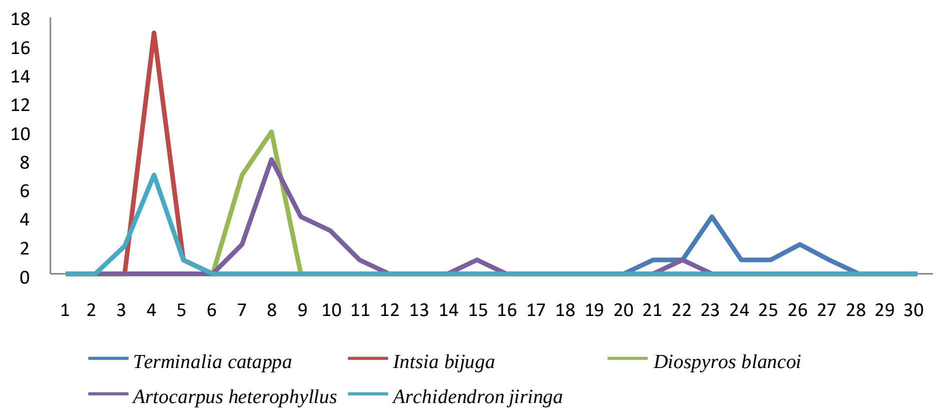

Figure 11. Daily germination chart of five species plants directly in the field.

The daily germination rate of seeds planted using the direct seeding technique had the same pattern as the nursery germination test. The difference between them is the starting point of germination. *I. bijuga* and *A. jiringa* germinated on the first day after planting, while in the field the germination of *I. bijuga* and *A. jiringa* started on the third and fourth days after planting. *D. blancoi* and *A. Heterophyllus* germinated 7 days after planting, which was two days longer than in the nursery. *T. catappa* had the longest germination time, taking 21 days to germinate.

Seed germination is affected by internal and external factors. Seed maturity, seed size, and dormancy are internal factors that affect germination. While external factors that affect germination are water, temperature, oxygen, and light. Physiologically, germination includes several important stages, such as water absorption, metabolism of decomposition of food reserve material, transport of decomposed material to actively growing parts, assimilation, respiration, and growth processes. Imbibition, the water absorption through the micropyle, is the first step that happens in the germination process. The availability of water and soil moisture affect the imbibition process. The sand fraction dominates the ex-limestone mining soil, which has low aggregation and macropores, resulting in a low water holding capacity. Because sandy soil cannot hold water and soil moisture is relatively low, it will delay the imbibition process, resulting in a slower germination rate than in a nursery with optimal conditions. In addition, the size of the seed also affects the germination process. The seeds used in this research have a large size. Large seeds are more difficult to germinate than small seeds because smaller seeds have thinner seed coats and absorb water more easily due to the larger ratio of area and volume in direct contact with soil.

Seeds sometimes have difficulty germinating, because they are in a dormant condition, which is a condition where living seeds do not germinate even the environmental conditions are ideal for germination [26]. There are two types of dormant conditions which are physical and physiological dormancy. Physical dormancy occurs as a result of structural limitations in the form of mechanical barriers that prevent water and gases from entering. Internal factors such as growth regulators, embryo immaturity, and other physiological reasons cause physiological dormancy. The seed's ability to absorb water and the embryo's ability to break the seed coat are both factors that affect the germination rate. *T.catappa* and *I. bijuga*, two plant species used in this research, have a form of physical dormancy. Both species feature a structural barrier in the form of a hard seed coat, which prevents the imbibition process. *T. catappa* has the longest germination rate compared to the other four species. The treatment of mechanical dormancy breaking by cracking the seed coat of *T. catappa* was done without breaking the seed coat. Cracking without breaking the entire seed coat enables *T. catappa* seeds to retain mechanical retention, causing the embryo to take a longer time to penetrate the seed coat.

5. CONCLUSION

The results of this study indicate that Merbau (Intsia bijuga), Ketapang (Terminalia catappa), and Jackfruit (Artocarpus heterophyllus) species are adaptive species to be planted in post-limestone mining areas using direct seeding method. Meanwhile, Jackfruit (Artocarpus heterophyllus), Gmelina (Gmelina arborea), and Merbau (Intsia bijuga) species are adaptive species to be planted in post-limestone mining areas using the seedball method.

The results of this study also indicate that direct sowing can be a viable alternative method of revegetation in ex-mining sites for certain recalcitrant and orthodox plant species. The most promising species for use are those that have at least one (but preferably more than one) of the following characteristics:

- Easily obtainable seeds (available in large quantities and for a long time);
- High seed viability and storage potential;
- Fast and consistent germination;
- Large seed size (>5 g) and large seedling size after germination for situations where there is significant weed growth;
- Deep root extension for situations where there is significant growth of shallow rooted weeds;
- High growth rate potential;
- Low sensitivity to competition;
- Wide tolerance to a wide range of light conditions—some shade tolerance may be advantageous in many situations.

However, that the characteristics of these species, where they should be sown directly and the most appropriate time for sowing must be considered, particularly in relation to the season at planting time and the conditions of land openness. This is to avoid environmental conditions that are too hot or scorching for plant growth and the need for water for plant growth. Experiments to assess the growth performance of recalcitrant and orthodox species under various conditions (especially different light environments) and different seasons can help in identifying species that are more adaptive to water stress and microenvironmental conditions (microclimate).

From the cost analysis, planting with direct seeding has a lower cost than using seedball. Optimal results can be obtained from a combination of low cost direct seeding and higher cost but more reliable seedling planting. The seedling success recorded in this trial basically indicates the minimum success that can be achieved using direct sowing. Maintenance in such a method must be very carefully considered, this is to increase the viability and growth of tree seedlings as a commitment to reforesting ex-mining land.

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APPENDIX

APPENDIX 1. Soil lab test results of the seed ball planting site (left) and direct seeding (right)

No.	No. Identifikasi Contoh Uji		Parameter																				
			pH		C-Organik	N-Total	C/N Ratio #	P_2O_5 Tersedia	P_2O_5 Potensial	K_2O Potensial	Kation Dapat Tukar				KTK	Kejenuhan Basa #	Kemasaman Dapat Tukar		Tekstur 3 Fraksi			Besi (Fe) #	Besi Tersedia (Fe) #
			H_2O	*N* KCl							K^+	Na^+	Ca^{2+}	Mg^{2+}			Al^{3+}	H^+	Pasir	Debu	Klei		
	PT BBI	Pelanggan	ICBB/MU/11.004.2 (Potensiometri)		ICBB/MU/11.004.14 (Walkley & Black)	ICBB/MU/11.004.12 (Kjeldahl)	Penghitungan	ICBB/MU/11.004.4 (Olsen)	ICBB/MU/11.004.8 (HCl 25 %)	ICBB/MU/11.004.9 (HCl 25 %)	ICBB/MU/11.004.13 (*N* NH_4OAc pH 7.0)				ICBB/MU/11.004.10 (*N* NH_4OAc pH 7.0)	Penghitungan	ICBB/MU/11.004.11 (*N* KCl)		ICBB/MU/11.004.3 (Pipet)			$HClO_4$ HNO_3 AAS	Morgan Wolf - AAS
			-		%	%	-	mg/Kg	mg/100g		cmol(+)/kg					%	cmol(+)/kg		%			mg/Kg	mg/Kg
1	2104.01918	Seed Ball 0-30 cm	8,33	7,88	1,40	0,06	23	21,05	43,64	48,04	0,29	0,06	84,22	1,42	22,05	100,00	< 0,05	0,17	50	25	25	25636,46	2,73

Keterangan :

#) Parameter tidak terakreditasi

No.	No. Identifikasi Contoh Uji		Parameter																				
			pH		C-Organik	N-Total	C/N Ratio #	P_2O_5 Tersedia	P_2O_5 Potensial	K_2O Potensial	Kation Dapat Tukar				KTK	Kejenuhan Basa #	Kemasaman Dapat Tukar		Tekstur 3 Fraksi			Besi (Fe) #	Besi Tersedia (Fe) #
			H_2O	*N* KCl							K^+	Na^+	Ca^{2+}	Mg^{2+}			Al^{3+}	H^+	Pasir	Debu	Klei		
	PT BBI	Pelanggan	ICBB/MU/11.004.2 (Potensiometri)		ICBB/MU/11.004.14 (Walkley & Black)	ICBB/MU/11.004.12 (Kjeldahl)	Penghitungan	ICBB/MU/11.004.4 (Olsen)	ICBB/MU/11.004.8 (HCl 25 %)	ICBB/MU/11.004.9 (HCl 25 %)	ICBB/MU/11.004.13 (*N* NH_4OAc pH 7.0)				ICBB/MU/11.004.10 (*N* NH_4OAc pH 7.0)	Penghitungan	ICBB/MU/11.004.11 (*N* KCl)		ICBB/MU/11.004.3 (Pipet)			$HClO_4$ HNO_3 AAS	Morgan Wolf - AAS
			-		%	%	-	mg/Kg	mg/100g		cmol(+)/kg					%	cmol(+)/kg		%			mg/Kg	mg/Kg
1	2104.01919	Blok Asem Timur 0-30 cm	8,93	8,34	1,82	0,08	23	17,51	57,72	112,55	1,04	0,10	63,91	2,00	18,22	100,00	< 0,05	0,08	82	15	3	22179,55	4,27

Keterangan :

#) Parameter tidak terakreditasi