Application of planting hole sizes, seedling sizes of meranti (Shorea johorensis) and planting media for the rehabilitation of skidding road

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Abstract. Timber harvesting in natural forest caused damage along the skidding roads. This research studied the effects of planting hole sizes, seedling sizes and culture media on the growth of Meranti (Shorea johorensis) at skidding roads. This study used factorial in completely randomized block design 3 x 2 x 2 in three replicates. The first factor was planting hole sizes (A1 : A2 : 40 x 40 x 40 cm, A3: 40 x 40 x 50 cm), second was seedling size (B1 : decapitated seedlings for 10 cm, B2 : non-decapitated seedlings) and third was culture media (C1 : C2: soil and wood charcoal). The results showed that the growth of Shorea johorensis plantation coming from 10 cm decapitated seedlings at 3-year-old after planting grew well and better than non-decapitated one. The appropriate planting hole size and culture media for planting Shorea johorensis were 40 x 40 x 30 cm and soil and top soil. The success of seedling regrowth is one of solutions to overcome seedling damage during seedling transportation.

1. Introduction
Timber harvesting, generally, caused negative impacts such as decrease of forest timber stock, soil compaction and biodiversity. Soil compaction and erosion are closely related due to the use of heavy transportation vehicles for skidding and transportation from the forest, skidding road, temporary log-yard and industry.

The log-over areas and skidding roads must be rehabilitated by using commercial tree species for sustainable forest management in the future, although need longer time. Therefore, a suitable technology to increase timber production in unused skidding roads in shorter time period is very urgent. In addition, selection of commercial fast-growing tree species, good seedling quality in sufficient needed quantity is the priority. These efforts must be backed by correct planting hole size, culture media and size of seedling.

Actually, during seedling transportation, some seedlings are found broken or death, while the seedling cost production is already paid. In principle the broken seedling stem is still live as far as their root systems are not damaged. For that reason, it is important to study the re-growth ability of broken-stem seedlings through improving the size of planting hole and also culture media to support the growth of root.

The development root is inhibited when the soil bulk density > 1.3 g/cm³ [1]. Soil bulk density will decrease in line with the increase of soil permeability and porosity. However, the decrease of
bulk density can be accelerated through adding the organic material e.g. litter, compost and charcoal. Those organic materials will improve the soil environment health as a result of increasing of microbial activity in the soil. Micro pore will be established by the mycorrhizal fungi, degradating fungi, bacteria as well as other soil fauna. Those micro-pores will increase the water and nutrient infiltration, and in turn will affect tree growth.

Shorea leprosula, S. parvifolia and S.johorensis were able to grow well in skidding roads and temporary log-yard according to [2]. Combination treatments of planting hole size, seedling size and culture media may increase the growth of S. johorensis seedlings planted in un-used skidding roads. The aim of this research was to study the effects of planting hole sizes, seedling sizes and planting media on the growth of Shorea johorensis in skidding roads.

2. Materials and Method

Research was carried out at natural production forest at PT. Suka Jaya Makmur Forest Concession Holder, Ketapang District, West Kalimantan, about 159 km from Ketapang. It is located at 110° 27'E – 111° 25' E and 01°00'S – 01°55'S, at an altitude of 700 m above sea level (a.s.l.).

Data was collected from plantation of S. johorensis of 3-year-old planted at unused skidding roads. Tree seedlings were planted at the right and left side of skidding roads, with 3 x 3 m planting distance. Seedlings of Meranti (Shorea johorensis) 6-month-old, 50-60 cm in height, and 0.5-0.6 cm in diameter were planted in unused skidding roads. After planting, soil surface was covered with mulch as thick as 5 cm to conserve the humidity of soil. Mulches were collected from the forests nearby the skidding roads.

Weeding was carried out every three months up to one year after planting, then weeding was carried out for every year until 3 years after planting.

The experiment design of Completely randomized block design in factorial 3x2x2 was used. First factor was 3 sizes of planting holes namely 40 x 40 x 30 cm, 40 x 40 x 40 cm, and 40 x 40 x 50 cm. The second factor was 2 types of seedling size (B1: decapitated 10 cm from the top, and B2: non-decapitated seedlings) and the third factor was 2 types of culture media (C1: soil + top soil and C2: soil + charcoal). The experiment was replicated in 3 skidding road locations.

Data was analyzed using analysis of variance followed by Duncan test (DMRT, Duncan Multiple Range Test) to find out the best treatment [3]. Obtained data were then analyzed with analyses of variance. If the results show significantly different at the level of α = 0.05, then further tests are performed with Duncan Multiple Range Test (DMRT) [3].

3. Result and discussion

3.1. Properties of Soil Chemical and Physical

Properties of soil chemical at skidding road were analyzed and was presented in Table 1. The soil properties at three different skidding roads were not so different. Soil pH, C-organic content, N total, P available, CEC were categorized as low and very low, except in content of Potassium (K). Soil pH belong to acid soil (4.2 – 4.7). This condition will affect to the nutrient mobility in the soil, it was proven by the value of P HCl 25%, amounted to 47.90 – 56.40%, while the P available was 4.9-5.9 % only. The soil pH also affected to the value of AL³⁺ that belong to high (5.94-6.72). The existence of Al³⁺ in high concentration will affect the mobility of Fe²⁺ and Fe³⁺ to be absorbed by the plants. The soil fertility in skidding roads was categorized as low fertility with CEC ranging from 8.79 to 11.08. In this case, additional of organic material component would rise the soil fertility for better growth of seedlings planted in skidding roads. On the other hand, soil fertility will decrease very fast if nutrient leaching in the soil increase sharply caused by soil structure, especially if it is dominated by sand fraction. Soil texture in skidding roads was classified as sandy-clay. This texture affected to water-soil percolation, causing increase of nutrient leaching.
Table 1. Soil chemical properties in the skidding roads at PT. Suka Jaya Makmur Forest Concession Holder, West Kalimantan

| No | Parameters                  | Skidding road 1 | Skidding road 2 | Skidding road 3 |
|----|-----------------------------|-----------------|-----------------|-----------------|
| 1  | pH H2O                      | 4.20            | 4.70            | 4.2             |
| 2  | pH KCl                      | 3.30            | 3.80            | 3.20            |
| 3  | C -Organic (%)              | 2.45            | 2.61            | 1.88            |
| 4  | N Total (%)                 | 0.17            | 0.18            | 0.13            |
| 5  | C/N ratio                   | 14.41           | 14.5            | 14.46           |
| 6  | P -available Bray I (ppm)   | 5.90            | 5.40            | 4.90            |
| 7  | P HCL 25 %                  | 56.40           | 53.50           | 47.90           |
| 8  | Ca (meq/100 gr)             | 0.20            | 0.28            | 0.33            |
| 9  | Mg (meq/100 gr)             | 0.27            | 0.17            | 0.16            |
| 10 | K (meq/100 gr)              | 0.16            | 0.13            | 0.11            |
| 11 | Na (meq/100 gr)             | 0.18            | 0.15            | 0.14            |
| 12 | CEC (meq/100 gr)            | 11.08           | 10.31           | 8.79            |
| 13 | Base saturation (%)         | 7.31            | 7.08            | 8.42            |
| 14 | Al 3+ exchangeable          | 6.35            | 5.94            | 6.72            |
| 15 | H+ exchangeable             | 0.54            | 0.48            | 0.56            |
| 16 | Fe (ppm)                    | 83.74           | 119.13          | 123.08          |

Texture:

|        | Sand   | Silt   | Loam   |
|--------|--------|--------|--------|
| 17     | 62.81  | 23.82  | 13.37  |
| 18     | 58.59  | 15.65  | 25.76  |
| 19     | 60.92  | 18.82  | 20.26  |

When observed the results of the C / N ratio parameters in this study, they are smaller than 20 and based on the assessment of soil fertility criteria according to the Soil Research Institute [4] that the C / N ratio in natural forests after one year is high (14.46). If the C / N ratio is too small, the nutrient cycle is slow because organic matter is difficult to decompose and N mineralization increases [5].

[6] and [7] stated that the main causes of soil acidity are high rainfall that cause basal leaching, aluminum – silica in releasing Al ion as the main contributor through hydrolysis process, degradation of organic material and nitrate from fertilizer. Table 1 showed also that the soil fertility condition in skidding roads were in low fertility which need to be improved for optimal growth of the seedlings. Therefore, culture media need to be improved through addition of organic materials.

[8] suggested to improve soil fertility through amendment of organic material in the soil as culture media. In species selection level, selected species must be adaptable to soil that has low fertility and low nutrient availability which is dominated by loamy and silty texture. In fact, bulk density also play important role in root development. [6] said that the critical bulk density for root development is 1.3 gram/cm³.

Table 2. Bulk density (BD) and permeability in skidding road in different soil depths

| Location         | Soil depth (cm) | BD (g/cm³) | Permeability (cm/hour) |
|------------------|-----------------|------------|------------------------|
| Branch skidding  | 0-10            | 0.92       | 14.41                  |
|                  | 10-20           | 0.83       | 21.03                  |
Table 2 showed that bulk density in main skidding roads was higher (0.82 – 1.09 g/cm³) than in branch skidding roads (1.00 – 1.15 g/cm³) according to soil depths. It was caused by the transported log volume and frequency in main skidding road was higher than in branching skidding roads.

These bulk densities were still intolerable value for root growth. Those bulk densities impacted also to the soil permeability. Permeability of soil in branching skidding roads (8.63 – 21.03 cm/hour) was higher than in main skidding roads (3.67 – 13.81 cm/hour). Permeability of good soil will facilitate the root growth and oxygen supply in the soil.

The use of mulching in skidding road could reduce the soil bulk density until 50%. More and more tractor pass, more and more the bulk density increase, however the use of mulching in skidding roads decreases the bulk density. Generally, the increase of bulk density takes place until 30 cm depth, and it will be constant after 50 cm depth [9].

3.2. Growth of plantation in skidding roads

The growth response of *S. johorensis* at three years after planting in skidding roads is presented in Figure 1 and figure 2, as an effect of size of planting holes, seedling size and culture media treatments. To obtain the seedling in different size, seedling decapitation was done at 10 cm from the top. This treatment was done to anticipate the seedling damage such as broken stem during transportation from nursery to field planting. Figure 1 and figure 2 showed that the growth of decapitated seedlings grew better than non-decapitated seedlings. It is expected that damaged seedlings from *S. johorensis* seedlings could grow well in the field if the seedling handling was not properly done during transportation.

![Figure 1. Growth of Shorea johorensis Non-decapitated](image1)

![Figure 2. Growth of Shorea johorensis decapitated](image2)
The effect of growth media on seedling height growth showed that the best growth was found in mixture culture media consisted of soil and top soil compared to the seedlings planted in culture media consisting of soil and charcoal. On the other hand, in deeper planting hole, the height growth of *S.johorensis* seedlings was less satisfactory. It is possible that the root growth of *S.johorensis* was limited due to insufficient oxygen supply.

![Figure 3](image-url). Effect of planting hole size, seedling size and culture media on height growth of meranti (*S. johorensis*) plantation at 3 years after planting

Duncan test (Figure 2) showed that at 3 years after planting the best growth of *S.johorensis* was found in the planting hole size of 40 x 40 x 30 cm, using culture media a mixture of soil and top soil and using decapitated seedlings at 10 cm from the top (A1B1C1) treatment namely 183.289 cm, while the lowest height growth was found in the treatment planting hole size of 40x40x50 cm, non-decapitated seedlings and using culture media soil and top soil (A3B2C1) namely 117.44 cm.

*S.johorensis* growth in skid trails is influenced by soil conditions, nutrients, mycorrhizae and microclimate in skid trails after planting holes are made [10]. Plant height growth will be very responsive when planted on nutrient-poor soils that are treated with good nutrition [11][12].

It can be concluded that the treatment of A1B1C1 is that best treatment for planting *S.johorensis* in skidding roads. It also showed that interaction between planting hole size, seedling size, and culture media was directly affected to the growth of *S.johorensis*. This is because of texture modification caused by soil microbial activity that in turn will affect to soil properties physically and chemically, such as soil humidity, porosity, and nutrient availability. Those condition will also affect to root growth for supporting the plantation growth.

[2] and [13] showed that *Shorea leprosula*, *S. parvifolia* and *S.johorensis* were able to grow well in both skidding roads and temporary log-yard.

The growth of diameter of *S.johorensis* at 3 years after planting was also affected by interaction between planting hole size (A) and culture media (C) in skidding roads (Table 2) and the interaction between seedling size (B) and culture media (C), see Table 3.
Table 3. Duncan test on the interaction effects of planting hole size (A) and culture media (C) on diameter growth of *S.johorensis* plantation at 3 year after planting

| No | Planting hole size | Culture media (cm) |
|----|--------------------|--------------------|
|    |                    | Soil + top soil (C1) | Soil + charcoal (C2) |
| 1  | A1 (40×40×30 cm)   | 1.98 a              | 1.531 b              |
| 2  | A2 (40×40×40 cm)   | 1.603 b             | 1.522 b              |
| 3  | A3 (40×40×50 cm)   | 1.458 b             | 1.381 b              |

Note *: value followed by the same letter means not significantly different at P .05.

Table 3 showed that combination treatment of planting hole size (40x40x30 cm) and culture media A1C1 gave the best diameter growth of *S. johorensis* at 3 years after planting. Table 4 showed that the diameter growth was also affected by combination treatment of seedling size (B) and culture media (C). Treatment on decapitated seedling 10 cm from the top (C1) give the best diameter growth, 1.85 cm, at 3 years after planting. Based on Table 3 and 4, it can be said that the diameter growth of *S.johorensis* in the field is more related to planting hole size and culture media, or seedling size and culture media.

Table 4. Duncan test on the combination effects of seedling size (B) and culture media (C) on diameter growth of *S.johorensis* at 3 years after planting

| No | Seedling size | Culture media (cm) |
|----|---------------|--------------------|
|    | Seedling size | Soil + top soil (C1) | Soil + charcoal (C2) |
| 1  | Decapitated seedling at 10 cm from the top (B1) | 1.854 a | 1.543 b |
| 2  | Non-decapitated seedlings (B2) | 1.505 b | 1.415 b |

Note: *: Value followed with the same letter means not significantly different at P.05.

Interesting things in Table 5 is that diameter growth of decapitated seedling at 10 cm from the top was bigger than in non-decapitated seedlings. Treatment of A1B1C1 gives the best response on height growth. It is also possible that the planting hole size and culture media factors play important role in root growth that influencing to nutrient uptake and in turn improved the height and diameter growth of *S. johorensis*.

*S. johorensis* plants have the ability to adapt to subsoil soils, thus showing better growth. Therefore the use of soil and sub-soil, hole size and seed cutting is very necessary in order to control nutrient loss. The growth of *S.johorensis* for the coming years is very dependent on the development of root geometry growth and changes in soil bulk density around the planting hole in the skid trails.

4. Conclusion

Plantation of *Shorea johorensis* originating from decapitated seedlings at 10 cm from the top resulted the best growth at 3 years after planting. The best planting hole size and culture media was 40x40x30 cm.
cm and a mixture culture media of soil and top soil. The success of seedling regrowth is one of the solutions to overcome seedling damage during seedling transportation.

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