Assessing The Growth of Local Sengon and Solomon Sengon in Agroforestry System

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Abstract. Development of timber industry and demand for wood in Indonesia must be balanced with an enhancement of timber production. Utilization of fast growing species such as sengon (Falcataaria moluccana) may be done to increase the timber production. The optimal use of the land will be achieved by applying agroforestry system. This research aims to compare the growth between local sengon and solomon sengon in agroforestry system. The research showed that provenance is significantly influence the diameter. The interaction between provenance and planting technique do not affect the height, diameter, canopy area, depth of rooting system, root lenght, and root diameter horizontally. Solomon sengon F1 with opened polybag treatment revealed the highest average in diameter. The best average of depth and root diameter was found in closed polybag treatment, whereas the best average of root lenght was found in opened polybag treatment.

1. Introduction
The development of timber manufacturing and its demand in Indonesia which increase rapidly should be balanced with an effort in increasing timber production such as by planting fast growing species. The planting of fast-growing species usually applies monoculture system, but it may depend on the farmers’ willing for the side product such as short-term annual crops [1, 2].

Agroforestry is a system to optimize the land use with combination of forestry and agricultural plants in the same area. Agroforestry system is developed to increase community wealth inside and around the forest with maintaining sustainability of forest function [3]. Agroforestry system is also contributed in increasing farmers’ income, providing employment, increasing food production, and preserving cultural identity of the community or local institution [4]. One of agroforestry system developed to provide wood demand and national food needs is by combining sengon and upland rice [5].

Sengon (F. moluccana) is a fast-growing species that is widely cultivated by the community in the community forests or production forests. Sengon wood can be used for light construction wood, furniture and pulp raw materials [6]. One of the provenances of sengon which has faster growth compared to local provenance sengon is Solomon Sengon (F. moluccana (L.) Nielsen Solomon) [7] that originating from the Solomon Islands. The productivity of Solomon Sengon is three times higher than Local Sengon. Two-years old Solomon sengon may yield 16 cm diameter, whereas diameter of local sengon at the same age is 12 cm only [7]. In Indonesia, however, Solomon Sengon is still rarely cultivated by the community due to the high price of it seeds and constrained by the presence of rust tumors that commonly attack sengon plants [7]. Recently study on the growth of local sengon and solomon sengon seeds is still lacking, mainly in agroforestry system between sengon and upland rice. Therefore, the selection of suitable species and provenances, and appropriate planting techniques in the agroforestry system between sengon and upland rice are one of the keys to increase crop production.
2. Method

2.1. Sengon seedlings preparation
Sengon seedlings prepared in the greenhouse of the Department of Silviculture, Faculty of Forestry, IPB. Germination activities as well as weaning of the sengon seeds in a polybag of 15 cm × 10 cm are carried out for 2-4 months or until the height of the seeds reaches 20-25 cm, the roots develop well, and the stems are woody. The planting media used were soil, compost, and rice husk with a ratio of 1: 1: 1. Organic fertilizer is given once a week during the germination process. Such treatment can bound nitrogen from the air and spur the growth of seedlings [6].

2.2 Land preparation
Land preparation begins with land clearing from trees, bushes, and understorey vegetation. Land clearing is done at the end of the dry season. Basic fertilizers used are cow manure and organic fertilizer. Coarse dolomite added evenly on the entire study area.

2.3 Planting of sengon seedling and upland rice
Sengon seedling planted in the planting holes of 30 × 30 × 30 cm with a distance between planting holes of 1.5 × 1.5 m and 1.5 × 3 m. Twelve transects consisting of 20 planting holes established. One kg of cow manure added to each planting hole. The upland rice planted between the sengon transect when the sengon aged four months old. Planting was carried out using a shear technique with five upland rice seeds in each hole. The planting distance between upland rice and sengon plants is 50 cm, while the planting distance between upland rice is 25 × 25 cm [8].

2.4 Plant maintenance
Replanting is done 2-3 weeks after planting for seedlings that experience the abnormal growth. Watering is done twice every day in the morning and evening. Manure as a basic fertilizer added at the beginning of planting, followed by POH at three-month old sengon. An inorganic fertilizer is given to the upland rice 10 days after planting. Pruning carried out when the plants are 3-6 months old. Pruning is done periodically to maintain the quality of a straight stem and eliminating parts that are attacked by pests.

2.5 Pest and disease control
Pest and disease control activities are carried out mechanically by directly cutting the plant parts attacked by pests, to prevent a wider spread of disease from the pests. In addition, the use of chemical pesticides to control pests and diseases is carried out after the plants attacked badly by the pests.

2.6 Sengon seedlings measurement
Parameters measured in sengon seedlings for six months (September 2018-February 2019) are height, stem diameter, and dimensions of the roots measurement. Dimensions of the roots of the sengon seedlings are measured manually by digging the soil 10-30 cm or until the first primary root found perpendicular. The root dimensions observed include root depth, root length, and root horizontal diameter. Root length is measured from the primary root to the tertiary root, while the depth of the root is measured from the soil surface to the root neck (primary root).

2.7. Environmental Data
Light intensity measured using a lux-meter three days a week. Temperature and humidity measured three days in a month at the beginning, middle and at the end of the month using a thermo-hygrometer. Light intensity, temperature and humidity were measured three times a day in the morning, afternoon and evening. Daily rainfall data for August 2018-February 2019 derived from the Citeko Meteorological Station, Cisarua District, Bogor, West Java. Soil sampling was done by purposive sampling at five points to represent soil conditions at the study site [9]. Soil sampling was carried out at the beginning of land
preparation, after adding a dolomite and planting of sengon and upland rice, and after harvesting upland rice or completion of the study.

3. Result and discussion
Observation of growth of Local Sengon and Sengon Solomon seedlings carried out for six months using diameter, height, and canopy area parameters. Table 1 showed the effect of provenances, planting techniques, and their interactions to diameter, height, and crown area.

| Parameter          | Provenances | Planting Technique | Provenances x Planting Technique |
|--------------------|-------------|--------------------|---------------------------------|
| Diameter           | < 0.0001*   | 0.5650ns           | 0.3718ns                        |
| Height             | 0.1422ns    | 0.8071ns           | 0.7902ns                        |
| Canopy Area        | 0.4161ns    | 0.5194ns           | 0.0805ns                        |

*: treatments have significant effect on 95% confidence level with significant value (Pr>F) 0.05 (α), ns: treatments have no significant effect on 95% confidence level with significant value (Pr>F) 0.05 (α).

3.1 Growth of Diameter
The results of the average diameter growth of sengon seedlings (Table 2) showed that the sengon provenance of Solomon F1 with opened polybag treatment (F1T2) had the highest average diameter growth. The lowest average diameter growth found on local sengon provenance in the closed polybag (F0T1).

| Treatments | Average of diameter growth (cm) |
|------------|---------------------------------|
| F1T2       | 4.44 a                          |
| F1T1       | 4.18 ab                         |
| F2T1       | 3.50 b                          |
| F0T2       | 3.38 b                          |
| F2T2       | 3.30 b                          |
| F0T1       | 3.18 b                          |

Notes: Letter followed by the same alphabet showed no significant difference at 95 % confidence level.

Rapid growth of plant diameter can be used as an indicator of high production of a plant. Table 2 showed solomon sengon had the highest diameter growth, both in opened and closed polybags. This is in accordance with Setiadi [7] that stated the sengon provenance from Solomon Island has faster growth compared to local sengon. This difference can occur due to genetic diversity in each sengon provenance.

Sengon plant diameter can increase due to several factors, including soil and environmental conditions. Diameter of the sengon can increase due to adequate supply of nutrients and a supportive environment [10]. Land management which is more intensive in agroforestry systems compared to monoculture land will affect the condition of nutrient supply and better environment for plant growth. This is supported by the statement of Senjaya et al. [5], that land management in an agroforestry system can increase growth in height and diameter greater than monoculture land management, this is related to growing conditions that are more supportive for plant growth.
Figure 1. Growth of sengon seedlings average diameter in various treatments

Diameter of sengon seedlings at 1st – 4th week (Figure 1) showed that diameter growth for the three treatments did not provide a significant difference, but the growth of Sengon Solomon provenances F1 in the opened polybag treatment has a significant increase on diameter growth at the 5th – 12th week. This may due to the addition of organic fertilizer to sengon at the 3rd month. The application of inorganic fertilizers can stimulate overall plant growth and important assistance in the formation of leaf green [11].

Increasing the age of plants will increase the number of roots, diameter, and surface area of the roots, that in turn will affect to the greater nutrient uptake [12]. Inorganic fertilizers given to upland rice may absorb by the roots of the sengon, especially in the opened polybag treatment, thus increase the average diameter growth of the sengon seedlings. Opened polybags is suspected to have a smaller horizontal root penetration barrier than in closed polybags to find nutrients in the soil. These conditions may result to better horizontal growth of roots and thus optimize nutrient absorption in the soil.

The average diameter growth of local sengon seedlings with closed polybag treatment had the lowest growth compared to other treatments. This may occur due to suboptimal root growth causing from polybags that are still attached to the sengon seedling planting medium. Density of the planting media structure is very important to the growth rate of root penetration [12]. Denser rooting medium causes the root elongation area will be shorter, so that it affects the nutrients absorbed by plants.

3.2. Growth of Plant Height
Figure 2 showed the average height growth of sengon seedlings every two weeks in each treatment. The highest height growth found in provenance of Solomon F1 with opened polybags (F1T2), and the lowest in F0T2. All of the treatment has no significant effect on height parameters.

Sengon growth can be observed based on the growth of its dimensions, such as height, diameter, and roots. Based on Figure 2, the best average height growth is shown by sengon provenances solomon compared to local provenance. The different growth of average height in both provenances can occur due to genetic diversity of the difference in each provenance. Genetic diversity is related to adaptability of an individual in experiencing transformation as long as its development process and adapt in its habitat. The main cause of diversity can occur due to environmental variation and genetic variation [13].

Difference in growth of average height that is not too significant in each treatment may due to pruning done at the shoots of the sengon stem. Pruning the shoots of sengon stems can affect the overall growth rate of height.
3.3. Growth of Canopy Area

Sengon plant growth is strongly influenced by genetic diversity and environmental influences. Environmental factors that can affect the growth are soil fertility, water availability, and light intensity. The intensity of light that can be accepted by plants is very influential to the growth and plays an important role in the process of photosynthesis. Canopy area observed by measuring the length of canopies from four sides of the plant in the East-West direction. The length of the canopy from the four sides is then averaged to find the crown area [14]. The results of variance at 95% confidence interval showed that the canopy area were not significantly affected for sengon provenance, planting techniques, as well as the interaction between provenances and planting techniques used (Table 1).

The average crown area growth yield of the sengon seedlings every two weeks of observation in each treatment presented in Figure 3 are the widest, medium, and lowest canopy area growth.

**Figure 2.** Growth of sengon seedlings average height in various treatments

**Figure 3** Growth of sengon seedlings average canopy area in various treatments
Solomon Sengon F1 with opened polybag had the largest canopy area of 31109.0 cm², while Local Sengon with opened polybag had the lowest (16755.4 cm²). Canopy size of a plant may describe competition between plants. This is related to the space competition to get light that will affect the shape, crown area, and growth of the plant.

Canopy area growth is an important component influencing the growth of height and diameter, as it directly affects the photosynthesis process and positively correlates to the reach of roots to obtain minerals in the soil. The wider canopy will enlarge the process of photosynthesis, causing plant growth to be faster [14]. Based on the results, the canopy area of the Sengon Solomon has a greater value than Local Sengon. These results are proportional to the greater growth of diameter and height of Sengon Solomon than Local Sengon.

### 3.4. Dimension of Sengon Roots

Development of roots of sengon and upland rice as intercropping in the application of agroforestry systems should be well-considered to minimize root competition between sengon and the upland rice. The root dimensions observed in this study include horizontal root depth, horizontal root length, and horizontal root diameter. Effects of provenance, planting techniques, and their interaction to the root dimensions of the sengon seedling illustrated in Table 3. The provenance treatment and planting technique used and the interaction between the two did not significantly influence the root depth parameters, root length, and root horizontal diameter.

| Parameter      | Treatments | Provenances | Planting Technique | Provenances x Planting Technique |
|----------------|------------|-------------|--------------------|----------------------------------|
| Depth of root  |            | 0.9246<sup>ns</sup> | 0.1667<sup>ns</sup> | 0.2640<sup>ns</sup>               |
| Length of root |            | 0.0631<sup>ns</sup> | 0.4122<sup>ns</sup> | 0.7781<sup>ns</sup>               |
| Diameter of root|           | 0.7256<sup>ns</sup> | 0.8739<sup>ns</sup> | 0.9807<sup>ns</sup>               |

Notes: *: treatments have significant effect on 95% confidence level with significant value (Pr<F) 0.05 (α), ns: treatments have no significant effect on 95% confidence level with significant value (Pr>F) 0.05 (α).

The results of analysis of variance (Table 3) show that the provenance treatment, planting technique, and interaction between the two did not significantly affect the root depth parameters, root length, and root horizontal diameter. Root growth is strongly influenced by physical and chemical soil conditions [14]. The more fertile the soil the better the root development and the higher the root penetration [15].

### Table 4. Average root horizontal depth of sengon seedings for each treatment

| Planting Technique | Sengon provenances | Average root depth (cm) |
|--------------------|--------------------|-------------------------|
|                   | Local              | 21.33                   |
| Closed polybag    | Local              | 21.33                   |
|                   | Solomon F1         | 17.06                   |
|                   | Solomon F2         | 15.13                   |
| Average root depth of closed polybag |                   | 17.84                   |
| Opened polybag    | Local              | 11.67                   |
|                   | Solomon F1         | 13.31                   |
|                   | Solomon F2         | 16.76                   |
| Average root depth of opened polybag |                   | 13.91                   |

Root depth is one of the variables that can affect plant growth, because it is closely related to the activity of roots to find water and nutrients. The movement of plant roots will follow the location of water and nutrients in the soil [16]. Based on Table 4, the average root depth in the closed polybag treatment has a greater depth than the opened polybag. The value of the depth of the perpendicular root
of the largest array is the closed polybag treatment. According to Hidayat [15], root development is strongly influenced by temperature, oxygen, soil fertility, mechanical barriers, and applied cultivation techniques. The closed polybag treatment may be able to inhibit the horizontal root movement due to the presence of polybags that were still attached to the previous planting medium, so that these conditions resulted in more penetration of the roots into the soil.

The depth of the roots in the agroforestry system is closely related to the contested space, water and nutrition competition [36]. The deeper rooting of the sengon plant will affect the competition for water and nutrients with upland rice roots in the soil. According to Torey et al. [17], the average length of upland rice roots ranged from 6-15 cm. Under these conditions, the treatment of closed polybags on sengon seedlings can minimize the competition of sengon seedlings with upland rice which can affect the final yield of sengon wood production and productivity on upland rice.

| Table 5. Average root horizontal length of sengon seedlings for each treatment |
|-----------------------------------------------|
| Planting Technique                  | Sengon provenances | Average root length (cm) |
|-----------------------------------------------|
| Closed polybag                        | Local             | 118.25                   |
|                                       | Solomon F1        | 111.68                   |
|                                       | Solomon F2        | 36.53                    |
| Average root length of closed polybag     |                   | 88.74                    |
|-----------------------------------------------|
| Opened polybag                         | Local             | 119.00                   |
|                                       | Solomon F1        | 127.55                   |
|                                       | Solomon F2        | 77.55                    |
| Average root length of opened polybag     |                   | 108.03                   |

The development of roots is closely related to the growth of canopy staple plants. One variable in the root dimension that affects the growth of the sengon is root length. The average length of horizontal roots perpendicular to the array on the opened polybag treatment was 108.03 cm, while the closed polybag treatment was 88.74 cm (Table 5). According to the physiological concept, root growth is based on the morph genic balance between roots and canopy of plants, in other words the wider canopy distribution and tree height will determine the tree distribution. These conditions affect the length and the number of roots that are getting bigger which results in better canopy growth [18].

Based on the root length data obtained, these results are positively correlated with the height and canopy area data. The longer roots and the large number of roots result in higher plant height and greater canopy area. The variance of provenance, planting techniques, and the interaction of the two did not significantly affect the horizontal root diameter parameters. The measurement results for the diameter of the sengon seedlings (Table 6) show that the average diameter of the roots in the closed polybag treatment is greater than the opened polybag. The average diameter of the roots in the polybag is closed at 0.48 cm, while the polybag is opened at 0.46 cm.

| Table 6. Average root horizontal diameter of sengon seedlings for each treatment |
|-----------------------------------------------|
| Planting Technique                  | Sengon provenances | Average root diameter (cm) |
|-----------------------------------------------|
| Closed polybag                        | Local             | 0.44                      |
|                                       | Solomon F1        | 0.53                      |
|                                       | Solomon F2        | 0.46                      |
| Average root diameter of closed polybag  |                   | 0.48                      |
|-----------------------------------------------|
| Opened polybag                         | Local             | 0.45                      |
|                                       | Solomon F1        | 0.50                      |
|                                       | Solomon F2        | 0.44                      |
| Average root diameter of opened polybag  |                   | 0.46                      |
Knowledge in plants species, plants provenances, and planting technique is greatly needed for combining any plants in agroforestry system. The using of appropriate provenances and right combination of intercropped plants can increase production optimally. Knowledge in root system in applying agroforestry system is also needed to avoid the space competition of the root, competition for nutrients, and ground water. Main plants with deeper root system can be combined with shallower root system for the intercropped plants.

4. Conclusion
Provenances of local sengon and solomon sengon that was used only significantly affect to the diameter growth, whereas planting technique and interaction between provenances and planting technique not significantly affect to all parameters such as diameter, height, canopy area, root depth, root length, and horizontal root diameter. Solomon sengon F1 with opened polybag treatment has the highest average diameter of 4.44 cm. Closed polybag treatment has greater root length and root diameter than opened polybag, but opened polybag treatment has greater root length than closed polybag treatment.

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