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GROWTH EVALUATION OF RED MERANTI SPECIES IN RESTORATION AREA OF GUNUNG DAHU RESEARCH FOREST, BOGOR

(Evaluasi Pertumbuhan Jenis Meranti Merah di Areal Restorasi Hutan Gunung Dahu, Bogor)

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ABSTRACT

The use of local species for revegetation activities is expected to accelerate the natural regeneration to increase the biodiversity in restoration efforts of disturbed areas. This study used several parameters to observe the growth of 20-years old stand *S. pinanga* and *S. platyclados*, including diameter, total tree height, Mean Annual Increment (MAI), % of fruiting trees, Leaf Area Index (LAI), altitude, and slope. The study results were analyzed using one-way variance analysis (ANOVA) and Duncan test with a 95% confidence level. The results showed that *S. platyclados* significantly had a higher diameter (32.7 cm), height (19.1 m), and mean volume (0.43 m^3) compared to *S. pinanga*. The growth of *S. platyclados*, which locally known as *meranti bukit* is strongly supported by conditions in Gunung Dahu Research Forest, which has an altitude of about 800 m.asl. On the other hand, *S. pinanga*, as lowland species, showed lower growth compared to *S. platyclados*.

I. INTRODUCTION

Meranti is a commercial tree species widely known with its various commercial names. One of them is *Shorea* red *meranti*. It has a high economic value in global trade since the commercialization of natural forest in the 1970s was begun (Sukendro & Sugiarto, 2012; Juniarti, Herawatiningsih, & Burhanuddin, 2017; Chotimah, Wasis, & Rachmat, 2020). *Shorea pinanga* and *Shorea platyclados* were grouped into *Shorea* red *meranti* based on their timber characteristic. Its timber has multiple purposes, and the seed of *S. pinanga* is also known for the source of tengkawang or illipe nut (Purwaningsih, 2004; Wardani & Susilo, 2017). Both species' high economic values have been triggered by massive exploitation and utilization, which may risk their natural occurrence in the future. Reducing population size, increasing inbreeding rate, and lowering genetic diversity are among the threats that may alter the species' existence.

In their natural habitat, *S. platyclados* grows at an altitude ranging from 700–1,300 masl and sometimes grows at the bottom of the mountain valley, starting from 200 masl. In comparison, *S. pinanga* grows best at ridges below 700 m asl (Cao, Gailing, Siregar, Siregar, & Finkeldey, 2009; Ng, Lee, Lee, Tnah, & Ng, 2013; Hardiwinoto et al., 2016). The Shorea species' natural habitat has been facing serious problems, including forest fires, encroachment, and illegal loggings (Fiani, 2014). According to the International Union for

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Conservation of Nature (IUCN), *Shorea pinanga* was listed as Least Concern (LC), while *Shorea platyclados* was listed as Endangered (EN) (Ashton, 1998; Robiansyah et al., 2019). The conservation status was generated by the assessment result for the risk of a population decline of at least 50% in the last ten years. Population decline without any effort in conservation activities could end in extinction status.

Forest conversion and exploitation were among the significant causes for population declining in many *Shorea* species (Cao et al., 2009), including *S. platyclados* and *S. pinanga*. Following their high risk of extinction, native species for rehabilitation programs have gained more popularity today. Selecting the best local species with high economic value as a candidate for the degraded land revegetation effort is in line with improving land productivity and conserving native genetic resources. Local species' use will increase the success rate of revegetation activity since local species are more adaptive to their environment. Hopefully, it will ensure the genetic integrity of the species (Nugroho & Yassir, 2017). Compared to the potentially invasive exotic species, utilizing and planting local species will bring more benefit to the ecosystem sustainability (Simmons, Hallett, Sonti, Auyeung, & Lu, 2016; Lu et al., 2017; Sattler, Raedig, Hebner, & Wesenberg, 2018; Anggana, Cahyono, & Lastiantoro, 2019; Ratanapongsai, 2020).

The utilization of native and local species for revegetation could restore the ecosystem environments near its original condition. Revegetation using local species has been established successfully in Kalimantan and several mining sites across Indonesia (Lampela, Jauhiainen, Sarkkola, & Vasander, 2017; Setyowati, Amala & Aini, 2017; Sasmita, Komara, & Purba, 2020). However, *S. platyclados* and *S. pinanga* for the revegetation purpose have not gained much attention. Therefore, previous revegetation efforts were incorporated into more exotic species. This study aimed to assess the growth performance of two red meranti species having different habitat niche in Gunung Dahu Research Forest as a landscape revegetation effort conducted by the Center of Forest Research and Development.

II. METHODOLOGY

A. Research Time and Location

This study was conducted at Gunung Dahu Research Forest (GDRF) in Bogor, West Java. GDRF have a 2,500–2,700 mm/year rainfall, which located between 106° 34'00" –106° 35'30" E and 06° 36'30" –06° 37'00" S.

GDRF has a mountainous topography with an altitude ranging from 550 - 800 masl with a red-yellow latosol soil type. At the beginning of the restoration, the landscape was dominated by shrubs, e.g., ferns, melastomas, and bamboos. Only a few trees remain at the site, which consisted of several old pinus stands (Subiakto, Rachmat, & Sakai, 2016).

Plots were chosen using a purposive sampling method on *S. pinanga* planting site at plots 5 and 24, while *S. platyclados* at plot 4 and 15. Planting distance for each plot was 4 m x 4 m. The plot location for both species is shown in Figure 1.

B. Tools and Material

The tools used in this study were a map, phi band, haga hypsometer, plastic bag, thumbtack, sketch board, measuring tape, soil drill, clinometer, tally sheet, Global Positioning System (GPS), SLR camera, Fisheye lens, hoe, ruler, camera, label, writing tools, and a laptop equipped with Hemiview 2.1 software, Statistical Product and Service Solutions (SPSS) 25, Microsoft Office 2010, and Microsoft Excel 2010. Materials used in this study were *S. platyclados* and *S. pinanga* stands.

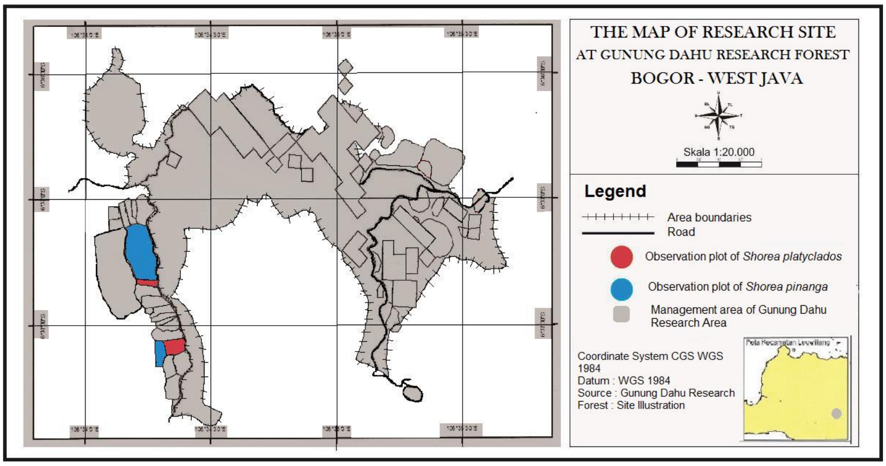

Figure 1. Research Location in Gunung Dahu Research Forest, Bogor

C. Research Method

1. Diameter, Total Tree Height, and Number of Fruiting Trees/Fruiting Tree Count

Tree diameter measured at breast height of 1.30 m above ground using a phi band, while tree height was measured using a haga hypsometer (Widiyatno, Soekotjo, Naiem, Hardiwinoto, & Purnomo, 2011). Mean Annual Increment (MAI) was measured using the equation MAI D = $\frac{D}{T}$ and MAI H = $\frac{H}{T}$; in which D = diameter at breast height (cm), H = total height (m), and T = tree age (years old) (Prodan, 1968). Data regarding numbers of fruiting trees were obtained from direct observation in the field. The fruiting tree percentage was the division between the fruiting tree's number and the total potential number of mother trees in the experimental plot.

2. Altitude and Slope

Altitude data were taken from GPS by tagging a position based on observation plots' location, taken at five spots for every observation. Meanwhile, slope data were obtained with a clinometer. Slope data were obtained from five spots for each observation, which data then categorized into five classes consisted of flat (0-8 %), gentle slope (8-15 %), slightly steep (15-25 %), steep (25-45 %), and very steep (≥ 45 %) (Syah & Hariyanto, 2013).

3. Leaf Area Index (LAI)

LAI data were obtained by taking a picture using a Fisheye lens with a hemispherical canopy photograph technique. Pictures were taken on each plot in five different spots.

D. Data analysis

The analysis of variance (ANOVA) at the 5% level was applied to observe the variation between plots. Further analysis using Duncan multiple range test at 5% level was performed if there was a significant difference in observed variables (Mattjik & Sumertajaya, 2002). Afterward, data distributions were performed by using boxplot analysis to show diameter and total height distribution.

III. RESULTS AND DISCUSSION

A. Diameter Growth of *S. pinanga* and *S. platyclados*

The revegetation success is characterized by several categories, one of them is an increase in area coverage by vegetation that also showed the success of restoring its ecosystem environment (Filho, Costa, Sousa, & Junqueira, 2013; Lee, Seo, Seo, Joong, & Kim, 2013; Adams, 2015; Correa, Teza, Balduino, & Baptista, 2018). Growth parameters that were observed in this study were diameter and total tree height. Diameter growth of

S. pinanga and *S. platyclados* are presented in Table 1.

Table 1 shows the average diameter of *S. pinanga* and *S. platyclados* were significantly different according to Duncan's result at a 5% level. The largest average diameter was observed at Spt (04) stand measured at 34.0 cm, while the least diameter average was observed at Spn (24) stand, which measured at 20.0 cm. This result indicated a faster diameter growth of *S. platyclados* stands compared to *S. pinanga*. A similar result was also observed in maximum diameter, as the maximum diameter in *S. platyclados* was higher compared to *S. pinanga*.

Higher average diameter *S. platyclados* indicated a better adaptation and higher compatibility of this species with the habitat in highlands of about 800 masl. *S. platyclados* grows at an altitude ranging from 700–1,300 masl and sometimes grows at the bottom of the mountain valley, starting from 200 masl. *S. platyclados* can be found in the Malay Peninsula at an altitude of 300–1,200 mdpl with optimal growing altitude ranging from 750–1,000 masl. On the contrary, *S. pinanga* grows better at its habitat in the ridge below 700 masl. It explains its lower growth than *S. platyclados* (Cao et al., 2009; Ng et al., 2013; Hardiwinoto et al., 2016).

A study conducted by Subiakto et al. (2016) in Gunung Dahu Research Forest revealed *S. leprosula* growth at 17 years of age, with a spacing of 4 m x 4 m yields an average diameter value of 24.9 cm. This value was lower than *S. platyclados* that yields an average diameter of 34.0 cm but higher than *S. pinanga* that diameter value was averaging at 22.0 cm.

Mean Annual Increment (MAI) value or highest diameter increment also showed a significantly different result between *S. platyclados* and *S. pinanga* stands according to Duncan test results at a 5% level. Results also showed that *S. platyclados* has a respectably rapid growth. The highest MAI value was observed in *S. platyclados* stand at plot numbers 04 and 15, with each MAI value measured at 1.6 cm/year, while *S. pinanga* stand had a lower MAI value measured at 1.0 and 1.1 cm/year.

Based on the classification from Mindawati & Tiryana (2002), *S. platyclados* growth was categorized as very fast (increment > 1.4 cm/year) while *S. pinanga* was categorized as normal (increment = 0.79 – 1.19 cm/year). This showed that the average MAI of *S. platyclados* stands were higher than *S. pinanga*. MAI value of *S. platyclados* at Spt (15) and Spt (04) showed an insignificant difference, similar results shown in *S. pinanga* stands at Spn (24) and Spn (05). Diameter increment of *S. platyclados* in this study was much lower compared to Widiyatno, Soekotjo, Naiem, Purnomo, & Setiyanto (2014) conducted in Logged Over Area (LOA), which MAI reached 2.56 cm/year at 6.5 years of age.

Table 1. Diameter growth of *S. pinanga* and *S. platyclados*

No.	Stands	Age	∑ sample	Diameter (cm)			
				Min	Max	Average	MAI (m/year)
1	Spt (04)	21	69	10.1	63.7	34.0a	1.6a
2	Spt (15)	20	107	11.1	66.9	32.7a	1.6a
3	Spn (05)	21	62	10.8	38.2	22.0b	1.0b
4	Spn (24)	19	151	10.0	39.4	20.0b	1.1b

Remarks: Spt= *S. platyclados*, Spn= *S. pinanga*, number in parenthesis shows plot number; number followed by the same letters shows the result is not significantly different at the level of 0.05

Another study by Widiyatno et al. (2011) with the same species of *S. platyclados* at five years of age Logged Over Area (LOA) had an average diameter of 9.06 cm and MAI of 1.94 cm/year. This MAI value is higher compared to the result gained from our study. The differences in MAI value are assumed to be caused by stands age difference at the observation time, which creates variations at the growing phase. *S. platyclados* at the age of 5 and 6.5 years yielded a higher increment, which presumably still underwent a juvenile period, characterized by its fast-growing increment (Pamoengkas, 2006). The use of selected superior planting stocks as required by intensive silviculture applied in the unit management of the study site may be one of the causes underlying the differences.

In their natural habitat, *S. platyclados* were found in clumped distribution on steep slopes of 10-45%, at the altitude 300-1,200 masl but has optimum growth at an altitude of 750-1,000 masl, yellow-red podzolic soil, 27 – 32 ^{o}C with moisture content range at 20 – 7-% and soil pH 5.9 – 6.8. In comparison, *S. pinanga* grows best at ridges below 700 m asl. The similar habitat characteristics of Gunung Dahu to that its natural habitat of *S. platyclados* provide a supportive environment for the optimum growth of *S. platyclados* at the study site. However, for *S. pinanga*, the habitat characteristics of Gunung Dahu is less supportive than that of *S. platyclados*. Regarding the marginal condition of habitat characteristic for *S. pinanga*, the species has shown good growth performance, marked by its vegetative growth performance and reproductive capabilities. Both species have shown their fruiting abilities at a different scale of intensities. Thus, both species are prospective to be planted and developed for various uses outside their natural habitat because of their high tolerance characteristics to different growing habitat. (Cao et al., 2009; Atmoko, Arifin, & Priyono, 2010; Ng et al., 2013; Hardiwinoto et al., 2016; Wardani & Susilo, 2017).

B. Total Height Growth of *S. pinanga* and *S. platyclados*

Plant growth is a transformation process in plant life, which increased both in numbers and dimensions. The increase may go upward (height) or lateral (diameter), which all would affect yield (Hardjana & Suastati, 2014). Total height growth is presented in Table 2.

Table 2 shows a significant difference between the total height of all stands based on the Duncan test results at a 5% level. The highest value on total height average was found at Spt (15) measured at 19.1 m, while the lowest observed on Spn (05) measured at 14.0 m. The total height average of *S. platyclados* is higher compared to *S. pinanga.*

Table 2. Total height growth of *S. pinanga* and *S. platyclados*

No.	Stands	Age	∑ sample	Total height (m)			
				Min	Max	Average	MAI (m/year)
1	Spt (15)	20	107	6.5	31.0	19.1a	1.0a
2	Spt (04)	21	69	8.5	25.0	18.0b	0.9b
3	Spn (24)	19	151	9.0	25.0	16.5c	0.9b
4	Spn (05)	21	62	7.0	20.4	14.0d	0.7c

Remarks: Spt= *S. platyclados*, Spn= *S. pinanga*, number in parenthesis shows plot number; number followed by the same letters shows the result is not significantly different at the level of 0.05

The higher diameter and total height value of *S. platyclados* are presumably related to habitat compatibility. *S. platyclados* is capable of living in the highlands of up to 300–1,500 masl with the best altitude range for optimal growth at 750 – 1,000 masl (Symington, 2004; Sasaki, 2008). Different from *S. platyclados*, *S. pinanga* prefers a habitat under 700 masl (Sidiyaksa 2015; Hardiwinoto et al., 2016).

Growth of *S. platyclados* at plots 15 and 04 showed the best results compared to *S. pinanga* at plots 24 and 05. This data was supported by a previously published study by Rachmat, Lisnawati, Fambayun, Denny, & Bintoro (2019), which stated that *S. platyclados* has the best growth performance with the highest volume valuation.

Total height MAI also showed a significant difference according to the Duncan test result at a 5% level. The highest MAI value was observed on plot Spt (15) with an increment of 1.0 m/year, while the lowest was found at Spn (05) with an increment of 0.7 m/year. MAI on Spt (04) and Spn (24) showed no significant difference. The height increment or MAI shows similar results at 0.9 m/year, eventhough the average total height yields significantly different in results.

Results of total height MAI of *S. platyclados* yields lower compared from the result of a prior study published by Widiyatno et al. (2011) in former Logged Over Area (LOA), which recorded total height MAI of *S. platyclados* at the age of five years reached 1.55 m/year. Similarly, Widiyatno et al. (2014) obtained a result of the total MAI value of *S. platyclados* that reached 1.33 m/year. Those stands were categorized in the juvenile period, which was characterized by their rapid increment growth (Pamoengkas, 2006).

C. Volume Of *S. pinanga* and *S. platyclados* Stands

Results of direct measurement from the trees' census at each stand are presented in Table 3. According to Table 3, the average volume of *S. pinanga* stand was significantly different from *S. platyclados* by Duncan's results at a 5% level. The highest average volume was observed at Spt (04), which yield 0.43 m^3, while the lowest volume was observed at Spn (24), which averaged at 0.20 m^3. This shows that *S. platyclados* stand has a more significant potential volume than *S. pinanga*. Similar to the total volume yield, the total volume of *S. platyclados* stand found in Spt (15) was higher compared to *S. pinanga* stand, which was measured at 46.18 m^3.

Table 3. Stand volume of *S. pinanga* and *S. platyclados*

No.	Stands	Number of individuals	Survival rate (%)	Mean volume* (m^3)	Volume per hectare* (m^3/ha)	Total volume (m^3)
1	Spt (15)	107	6.11	0.43a	16.49	46.18
2	Spt (04)	69	6.90	0.42a	18.60	29.22
3	Spn (24)	151	12.71	0.20b	15.87	30.15
4	Spn (05)	62	7.09	0.16b	7.19	10.07

Remarks: Spt= *S. platyclados*, Spn= *S. pinanga*, number in parenthesis shows plot number; number followed by the same letters shows the result is not significantly different at the level of 0.05. *= the calculated mean volume and total volume are for *S. pinanga* and *S. platyclados*.

In general, there were differences in survival rate compared to previous studies in the same location (Setiadi & Leksono, 2014; Subiakto et al., 2016). Several factors underlying the different results could be maintenance intensity, plot condition at the start of the planting period, plant spacing, and camp distance. Based on the primary interview with the field manager involved in the restoration activities since the beginning of GDRF development, no intensive maintenances performed on the observation plots. There were no activities of weeding and fertilizing, while replanting was conducted based on planting stock availability. The initial condition of observation plots was dominated by bushes growing at more than 1.5 meters in height. Row clearing was used when planting the stocks. Thus *Shorea* seedlings were faced high survival competition with the growing pressure of nearby bushes that increases the possibility of high mortality at the start of the planting period. In such competition, juveniles could not easily compete with bushes and weeds. Another study conducted by Rachmat & Subiakto (2019) reported the high mortality of meranti seedlings. In their study, high mortality rates at the start of the planting period of meranti and other peat swamp species were reported high at the early restoration activity in Tasik Besar Serkap of Riau Sumatra. Other studies also showed that high mortality in the early period of planting in rehabilitated land using Dipterocarp species (Daisuke, Tanaka, Jawa, Ikuo, & Katsutoshi 2013; Widiyatno et al., 2014; Tuck et al., 2016).

The dense planting distance affected plants' survivability, resulting in a high survival percentage at the early periods compared to vast planting distance. It is why the general scheme of monoculture forest employs a dense planting distance at the start of their cycle followed by periodical roguing until optimum species density is achieved at a particular time (Rocha et al., 2016; Subiakto et al., 2016; Simic, Gendvilas, O'Reilly, Nieuwenhuis, & Harte, 2017)

Another factor that potentially affects the survival rate was the distance from the camp, which directly connected with monitoring and growth evaluation intensity. The observation plot that is located far and difficult to access from camp will have more constraints for intensive evaluation and monitoring. The availability of limited field personnel will put the nearer plot to have easier monitoring and evaluation, giving more advantages than those which far from the camp. Nearer plots to camp mean easier access both in terms of plot security and growth monitoring. Besides, the accessibility at the beginning of research forest development was difficult. Main roads that connect the site with the nearest town were still comprised of heavily damaged stone roads that hinder the monitoring activities, especially for several remote plots. Accessibility was started to improve seven to eight years ago gradually.

D. Distribution of *S. pinanga* and *S. platyclados* Diameter

A deeper understanding of stand structure may be overlooked by understanding its diameter distribution. According to Pamoengkas & Prayogi (2011), stand structure can be represented by age distribution, diameter class, or crown class.

Based on Figure 2 Spt (15) and Spt (04) stand have a higher box position compared to Spn (24) and Spn (05) stands. This showed that Spt (15) and Spt (04) stands had more growth stage at diameter ±20-40 cm, while Spn (24) and Spn (05) stands had more growth stage at diameter ±15-25 cm.

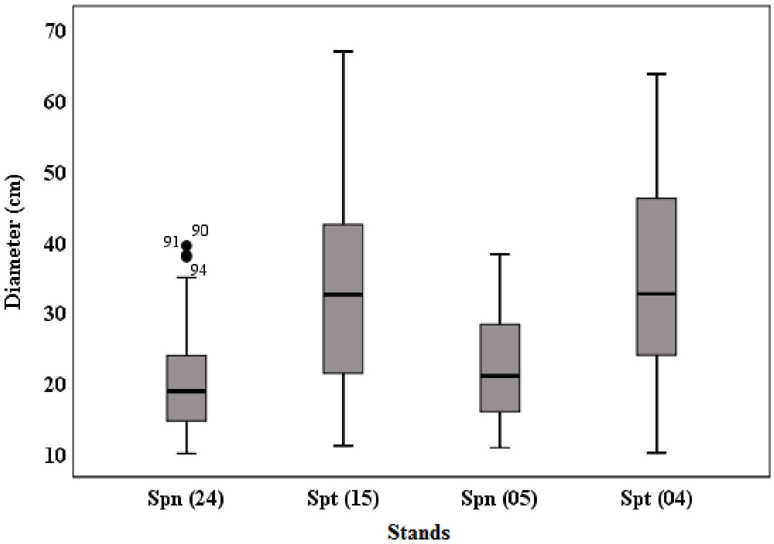

Figure 2. Boxplot diagram of *S. pinanga* and *S. platyclados* diameter distribution

Spt (15) and Spt (04) stands have a more extended box size compared to Spn (24) and Spn (05). Box length showed the distribution or variation/diversity of data (Junaidi, 2014). Spt (15) and Spt (04) had relatively similar diameter diversity, while the diameter diversity of those stands are higher compared to Spn (24) and Spn (05) stands.

The distribution of diameter data on all stands was considered an abnormal distribution, indicating the diameter's uneven distribution. The high variation of diameter data reflected the significant difference among individual's growth. This may be caused by the presence of survival competition between individuals in obtaining nutrients, water, and light. The competitions between plants were very high those making the number of small-diameter plants were available in numerous sizes (Nambiar & Sands, 2011; Caine & Dybzinski, 2013; Looney, D'Amato, Fraver, Palik, & Reinikainen, 2016). Considering the condition, support on tree growth can be achieved by practicing silvicultural treatment is a need to perform (e.i horizontal/vertical roguing) to ensure more growing spaces and maximize the light intensity (Pamoengkas & Prasetia, 2014; Siswadi, Umroni, Pamungkas, & Manurung, 2015; Panjaitan, 2016).

E. Total Height Distribution of *S. pinanga* and *S. platyclados*

The distribution data total height for *S. pinanga* and *S. platyclados* in this study were presented as boxplot in Figure 3. According to Figure 3, Spt (15) and Spt (04) stands have a higher box position compared to Spn (24) and Spn (05). This means that Spt (15) and Spt (04) stands had more growth stage at a total height of ±15-22 m, while Spn (24) and Spn (05) had more growth stage at the total height of ±13-20 m. Spt (15), Spt (05) and Spn (24) stands have a similar box, and that was more extended than Spn (05). This data showed that the three stands have relatively similar total height diversity, which is higher than Spn (05).

That boxplot diagram also showed abnormal data distribution in all total height for all stands. Abnormal data distribution of total height data was also presumably caused by competition between individuals. The presence of competition between individuals to obtain water and nutrients will reduce the number of individuals who survive on each growing stage (Bowman, Brienen, Gloor, Phillips, & Prior, 2013; Putra, 2015; Erkan & Aydin, 2016).

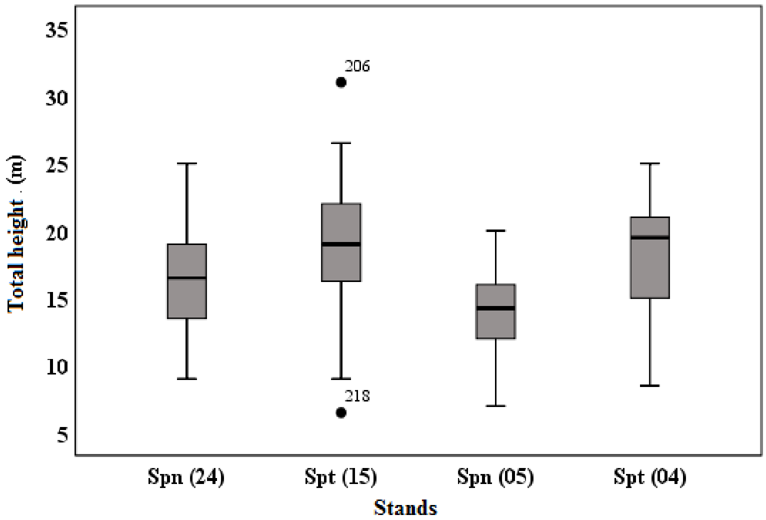

Figure 3. Boxplot diagram of *S. pinanga* and *S. platyclados* total height distribution

F. Growth Supporting Factors of *S. pinanga* and *S. platyclados*

Assessment on growth indicator for both *S. platyclados* and *S. pinanga* also be represented through several factors such as stand density, Leaf Area Index (LAI), and the percentage of fruiting trees as shown in Table 4. Other species were also found in all plots, such as bamboo (*Bambuseae* sp.), kayu afrika (*Maesopsis eminii*), pine (*Pinus merkusii*), pasang (*Quercus sundaica*) and puspa (*Schima wallichii*). Spn (24) has the highest density value compared to the others. This could be due to species adaptation that resulted in a lower individual mortality rate. Variation in density value of each species may also be caused by differences in seed-source mother tree availability, reproduction capabilities, dispersions, and environmental adaptability (Gunawan, Basuni, Indrawan, Prasetyo, & Soedjito, 2011; Mawazin & Suhaendi, 2012; Heriyanto, 2017; Pertiwi, Safitri, & Azahro, 2019).

At the time of observation, *S. pinanga* stand has a higher percentage of fruiting trees compared to *S. platyclados* stand. The highest percentage of fruiting trees were observed at Spn (05) and Spn (24) stands, which measured at 75.8% and 68.2%, while the lowest percentage of fruiting trees were found at Spt (04), which measured at 14.7%.

Table 4. Result of stands density, LAI, *S. pinanga* and *S. platyclados* fruiting

No.	Stands	Stands density (ind/ha)	Species density (ind/ha)	LAI (Leaf Area Index)	Fruiting tree percentage* (%)
1	Spn (24)	79.5	411	1.4	68.2
2	Spn (05)	38.2	282	1.0	75.8
3	Spt (15)	44.3	291	1.5	34.6
4	Spt (04)	43.1	354	1.3	14.7

Remarks: Spt= *S. platyclados,* Spn= *S. pinanga*, number in parenthesis shows the number of plot; *During observation

The primary interview with the field manager determined that *S. platyclados* bear fruits almost every year for more than these ten consecutive years. However, the fruiting intensity varied from only a few trees to mass fruiting trees. Unlike *S. platyclados*, *S. pinanga* has only been recorded four times fruiting and, at the time of observation, was the only record that the species experiencing mass fruiting. Shorea species generally flowers every 4-7 years in which *S. pinanga* tends to flower during July – September and bears fruits in December – March. Meanwhile, *S. platyclados* tend to flower in April – July (Tata, Wibawa, & Joshi, 2010). Based on previous observation and study conducted by Soekotjo (2009); Fitriasari (2011); and Winarni, Kurniasari, Hartiningsih, Nusalawo, & Sakuntaladewi (2016). Genus *Shorea* can bear fruits after reaching six years old, and species from the Dipterocarpaceae family have been well known for its irregular fruiting time.

According to Table 4, it is determined that LAI has a different value on each stand. The highest LAI value was found at Spt (15), while the lowest LAI was found at Spn (05). A higher LAI value usually means a denser canopy cover within the stand. Based on the study conducted by Setiawan (2006), higher LAI indicated a more significant solar radiation that can be intercepted for plant use.

Figure 4 showed a series of photos to illustrate the comparison of the canopy cover of all stands. All stands have a varying canopy cover according to their LAI value. Spt (15) (Figure 4B), has a greater LAI value compared to Spn (24) (Figure 4A), indicated by its denser canopy cover.

Canopy cover in Spn (05) was shown to be more sparse compared to the condition observed in Spt (04), which resulted in a lower LAI value in Spn (05) and Spt (04). Canopy cover of *S. platyclados* stands has a higher density, compared to *S. pinanga* stands, caused by the wider crown shape of *S. platyclados* supported with its greater tree density.

IV. CONCLUSION

Shorea platyclados had a greater diameter and total height growth and also significantly different from that of *Shorea pinanga*. The highest growth of *S. platyclados* was found on plot 15, with an average diameter and a total height of 32.7 cm and 19.1 m, respectively. The average diameter and total height increment (MAI) were measured at 1.6 cm/year and 1.0 m/year, respectively. Highland areas such as Gunung Dahu (up to 800 masl) supported hill species' growth as *S. platyclados* known as meranti bukit.

S. platyclados is suitable to be planted in the altitude's highland area ranging from 800-1,500 masl, while *S. pinanga* is known as lowland species that can be planted below 700 masl. However, both species showed good vegetative and reproductive growth capabilities in the Gunung Dahu forest, making them prospective species to be planted and established for various uses outside their natural habitat. Frequent evaluation of growth parameters and the fruiting season is essential to understand their growth and productivity rate.

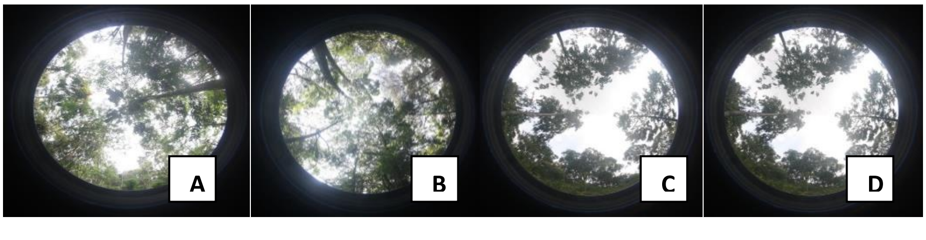

Figure 4. Canopy cover condition of *S. pinanga* plot 24, LAI 1.4 (A), *S. platyclados* plot 15, LAI 1.5 (B), *S. pinanga* plot 05, LAI 1.0 (C), *S. pinanga* plot 04, LAI 1.3 (D).

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