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GROWTH ANALYSES OF DIPTEROCARPACEAE STAND ON SELECTIVE CUTTING AND LINE PLANTING SILVICULTURAL SYSTEM WITH DIFFERENT PLANTING LINE DIRECTION IN NORTH KALIMANTAN

(*Analisis Pertumbuhan Jenis Dipterocarpaceae pada Sistem Silvikultur Tebang Pilih dan Tanam Jalur dengan Arah JalurTanam Berbeda di Kalimantan Utara*)

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ABSTRACT

The potency of the Indonesian Tropical Forest, particularly in Kalimantan, has been shrinkage year by year. Selective Cutting and Line Planting System (SCLP) is expected to increase the productivity of the tropical forest. This study aims to analyze the growth and diameter increment of Dipterocarpaceae stand planted in West-East (W-E) and North-South (N-S) planting direction on SCLP at concession area of PT. Intracawood Manufacturing, Bulungan District, North Kalimantan, Indonesia. Growth and diameter increment data of Dipterocarpaceae was obtained by field measurement in 4 (four) permanent plots sized 100 m x 100 m with W-E and N-S directions. The study revealed that the largest growth and average diameter increment on a five-year-old stand is Shorea parvifolia with planting direction of W-E about 8,5 cm and 1,92 cm/yr. In contrast, the smallest is Dryobalanops lanceolata with N-S planting direction about 4,6 cm and 0,99 cm/yr. Planting line direction does not influence diameter increment. It is due to the stand position in the spacing line as an ex-cutting area or the right and left-hand sides of the planting line with low density and low average stand height (17,62 m). Therefore, the light intensity on the N-S planting line direction has no barrier of spacing line stand.

Keywords: Increment, Light Intensity, Planting Line Direction

ABSTRAK

Potensi Hutan Tropis Indonesia, khususnya di Kalimantan, dari tahun ke tahun terus menyusut. Sistem Tebang Pilih dan Tanam Jalur (TPTJ) diharapkan dapat meningkatkan produktivitas hutan tropis. Penelitian ini bertujuan untuk menganalisis pertumbuhan dan riap diameter tegakan Dipterocarpaceae yang ditanam pada arah tanam Barat-Timur (B-T) dan Utara-Selatan (U-S) pada Sistem TPTJ di areal konsesi PT. Intracawood Manufacturing, Kabupaten Bulungan, Kalimantan Utara, Indonesia. Data pertumbuhan dan riap diameter Dipterocarpaceae diperoleh berdasarkan pengukuran lapangan pada 4 (empat) plot permanen berukuran 100 m x 100 m dengan arah B-T dan U-S. Hasil penelitian menunjukkan bahwa pertumbuhan dan riap diameter rata-rata terbesar pada tegakan berumur lima tahun adalah *Shorea parvifolia* dengan arah tanam B-T sebesar 8,5 cm dan 1,92 cm/tahun. Sedangkan yang terkecil adalah *Dryobalanops lanceolata* dengan arah tanam U-S sebesar 4,6 cm dan 0,99 cm/th. Arah jalur tanam tidak mempengaruhi pertambahan diameter. Hal ini disebabkan posisi tegakan pada jalur antara merupakan areal bekas tebangan, yang berada pada sisi kanan dan kiri jalur tanam dengan kerapatan yang rendah dan tinggi tegakan rata-rata yang rendah (17,62 m). Dengan demikian, intensitas cahaya pada arah jalur tanam U-S pada tegakan di jalur antar tidak terhambat.

Kata kunci: Arah jalur tanam, intensitas cahaya, riap.

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INTRODUCTION

Indonesia has the third-largest tropical rainforest after Brazil and Congo. However, tropical forest area and potency in Indonesia, particularly in Kalimantan, continue to decrease and be degraded by years due to technical, socio-economic factors, including changes in a functional area, improper forest management practices, illegal logging, and other unsustainable forest management supporting factors. On the other hand, soil compaction is a major determinant of plant growth and mortality. Tropical rainforests in Southeast Asia have been degraded by commercial logging, and the use of heavy equipment in these operations has increased soil compaction (Hattori *et al.* 2013).

The large forest area of Indonesia has high potency to enhance community prosperity. Forestry may be the solution for big problems; Indonesian people face by knowing and proving that planting trees has good prospects in the future (Widodo 2014). However, some forest areas are currently degraded due to no management nor ownership. The tropical rain forest of Kalimantan, particularly in North Kalimantan, has been decreased in the area and their potency and productivity in the logged-over area. One of the sustainable forest management factors related to economic and forest productivity aspects is knowledge of increment on how to optimize increment and its analyses for forest management.

The Government of Indonesia has strengthened their efforts to maintain the remaining tropical rainforest area and increase forest productivity by revising policies and the proper forest management system. The sustainability of tropical forest is one of the Government concerns that can be reached through the implementation of the three silvicultural systems, namely Indonesian Selective Cutting System (TPI), Indonesian Selective Cutting and Replanting System (TPTI), and Selective Cutting and Line Planting System (TPTJ) (Na'iem *et al.* 2013).

Under these intensive silvicultural regimes, biomass carbon stocks also recover to primary forests levels, but with increased representation of commercial species. Although silviculturally successful, the financial consequences of these approaches to intensive management remain to be scrutinized (Putz *et al*. 2017). Productivity problems in forest plantation development may be encountered by 'Prospective Forest', which has high productivity, efficient utilization, effective management, a stable ecosystem, and high biodiversity. Intensive Silviculture is one of the techniques for prospective forests (Na'iem 2014).

A modification of the selective cutting and line planting system (TPTJ), called SILIN (Intensive Silviculture) has been considered a new approach in increasing tropical forest productivity. Intensive Silviculture (SILIN) is a technique for increasing productivity by planting selected species, such as *Shorea leprosula* in line planting, with some element of growth, such as selected species and good seed sources, optimum environmental manipulations (good land preparation, appropriate fertilization, and appropriate light intensity), and eradicating forest product loss due to pests and diseases. Land preparation of SILIN was initiated by making a strip planting three meters wide, free from tall trees so the sunshine can enter directly to forest floor optimally (Na'iem *et al.* 2013).

Pilot projects of SILIN using meranti have been conducted in six forest concession areas in Indonesia since 2005. Preliminary results showed that target species were expected to have an increment of about 10 m3/ha/yr. The examples of the target species were *Shorea leprosula, S. parvifolia* and S. Johorensis (Soekotjo 2009). Those species and S. Platyclados are suitable for enrichment planting in selective cutting with line replanting silvicultural system. Without enrichment planting with appropriate species, the tropical rainforest will experience degradation and fragmentation (de Lacerd *et al*. 2012).

To boost the productivity of tropical forests, further study on a combination of selected dipterocarp species and specific silvicultural treatment would be required (Widyatno *et al.* 2013 and Subiakto *et al*. 2016). PT. Intracawood Manufacturing, as one company whose owned business license for utilization of timber forest products (IUPHHK) at North Kalimantan, has been appointed by the Ministry of Environment and Forestry (MoEF) to implement SILIN or TPTJ covering the management area of 654 ha at Bulungan District since 2008. The superior trees planted in the area including *Shorea leprosula*, *Shorea parvifolia*, *Shorea pinanga*, *Dryobalanops* sp., *Shorea macrophylla*, *Shorea dasyphylla*, *Shorea parvistipulata*, *Shorea johorensis*, *Shorea gibosa*, and *Shorea agami*.

Therefore, it is necessary to study the implementation of the TPTJ system carefully as it is not expected to have great economic losses and ecological risk when implemented on a large scale. Knowledge on how far the influence of planting line direction on stand increment of Dipterocarpaceae in TPTJ system is required to develop sustainable yield forest management plan.

This study aims to analyse the growth and diameter increment of Dipterocarpaceae stand planted in West-East (W-E) and North-South (N-S) planting direction on TPTJ at concession area of PT. Intracawood Manufacturing, Bulungan District, North Kalimantan, Indonesia. Various tree species of the Dipterocarpaceae family, including *S. leprosula*, *S. parvifolia*, *S. dasyphylla* dan *D. lanceolata* planted on different planting lines. It is expected that the research resulted in optimum planting line direction to increase forest productivity with species of the Dipterocarpaceae family.

MATERIAL AND METHOD

Study Area

This research was carried out at the TPTJ block of PT. Intracawood Manufacturing (PT. IWM) in Bulungan District, North Kalimantan Province (3^o15'40.7" N, 117^o02'15.8" E) (Figure 1).

Selective cutting and line planting system (TPTJ) was utilized to manage forest land, with a DBH limit of 40 cm allowed to be harvested (MoF 2009). The artificial regeneration should be undertaken using selected dipterocarps in line planting system (Nguyen *et al*. 1998 and MoF 2009). The location has a type A climate (Schmidt and Ferguson) with a mean annual rainfall of 2,316 mm year-1 and rainy days of 125 days year-1. Materials used in this research were *S. leprosula, S. parvifolia, S. dasyphylla* dan *D. lanceolata* saplings and trees, 1-5 years old, at the planting lines in the TPTJ block in the concession area of PT IWM (Figure 2.). This study's equipment includes working map, phi-band, Suunto clinometer, and measuring tapes.

Methods

To determine the growth of *S. leprosula, S. parvifolia, S. dasyphylla* dan *D. lanceolata*, 1-5-year-old saplings and trees planted at the planting lines on the TPTJ block with two-line directions, namely West-East (W-E) and North-South (N-S) directions. The tree growing parameters of diameter, diameter increment, and basal area were measured at the 4 PUPs (permanent sample plots) sized 100m x 100m (1 ha) each and had 5 planting lines as replication (Figure 2-3).

Data analyses

Growth parameters of diameter, diameter increment, and basal area of *S. leprosula, S. parvifolia, S. dasyphylla* and *D. lanceolata* trees were measured at the planting line. The growth parameters were calculated using the following formulas:

Figure 1. Research location at the TPTJ/SILIN block of PT. Intracawood Manufacturing (IWM) at Bulungan District, North Kalimantan Province, Indonesia.

a. The Basal Area of Tree

The Tree basal area was obtained from the circle area as the following equation:

$$g = \frac{1}{4}\pi d^2$$

where: g = basal area (cm²)
d = diameter of tree (cm)
π = 3,141592654

while the tree basal area obtained by the equation:

$$G_{(trees)} = \sum_{i=1}^{n} g$$

b. Mean Annual Increment (MAI)

The calculation of the mean annual increment based on the formula of (Ruchaemi 2016) as follows:

$$MAI\ Diameter = \frac{Dbh}{Age}(cm/year)/Age$$

$$MAI\ Basal\ Area = \frac{g}{Age}(m^2/year)/Age$$

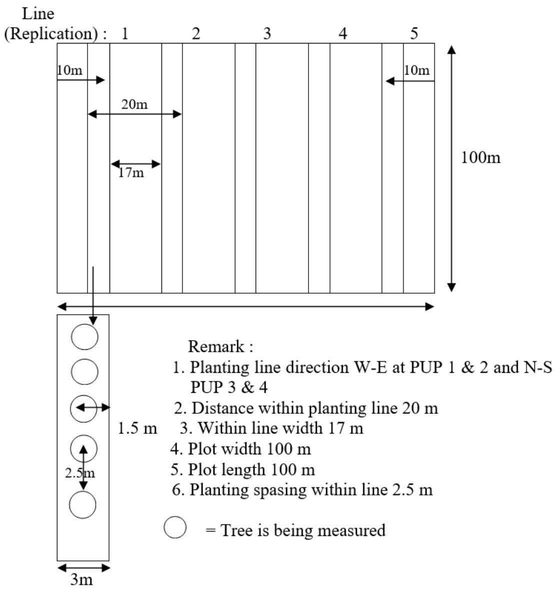

Figure 2. Research plots lay out

(a) (b) (c)

Figure 3. (a) Measurement of height of the tree using measurement stick, (b) and (c) Measurement of tree diameter using phi band.

c. Current Annual Increment (CAI)

The calculation of the current annual increment is based on the formula of (Prodan 1968) as follows:

$$CAI\ Diameter = \frac{Dn + 1 - Dn}{Tn + 1 - Tn} = \frac{\Delta D}{\Delta T}$$

$$CAI\ Basal\ Area = \frac{gn + 1 - gn}{n + 1 - Tn} = \frac{\Delta g}{\Delta T}$$

Next, statistical tests were carried out to determine the differences in diameter increment and basal area of the trees at the different planting line directions, using t-test as follows:

$$S^2 = \frac{(n_1 - 1)S_{1^2} + (n_2 - 1)S_{2^2}}{(n_1 - 1) + (n_2 - 1)}$$

$$Sd^2 = \frac{n_1 + n_2}{n_1 n_2} S^2$$

$$H0 :\ \mu_1 = \mu_2$$

$$H1 :\ \mu_1 \neq \mu_2$$

$$t_{hit} = \frac{\bar{x}_1 - \bar{x}_2}{Sd}$$

$$t_{hit} \begin{cases} \leq t_{\alpha/2}; (n_1 + n_2 - 2) \rightarrow accepted\ H0 \rightarrow \\ no\ significant\ difference\ between\ \mu_1 and\ \mu_2 \\ > t_{\alpha/2}; (n_1 + n_2 - 2) \rightarrow rejected\ H0 \rightarrow \\ there\ is\ significant\ difference\ between\ \mu_1 and\ \mu_2 \end{cases}$$

where:

μ 1 = mean diameter increment (cm/yr) and basal area population (m²/ha/yr) at the W-E planting line

μ 2 = mean diameter increment (cm/yr) and basal area population (m²/ ha/yr) at the N-S planting line

x1 = basal area of the sample (m²/ha) at plots the W-E planting line

x2 = basal area of the sample (m²/ha) at the plots N-S planting line

S1 = model's variance at W-E planting line

S2 = model's variance at N-S planting line

n1 = number of sample plots models at W-E planting line

n2 = number of sample plots models at N-S planting line

RESULTS AND DISCUSSIONS

The diameter data of trees for each planting line were analysed and summarized into data of diameter increment of tree resulted in forms of diameter growth and increment charts of *S. leprosula, S. Parvifolia, S. Dasyphylla, and D. Lanceolata* against some age variations in planting line directions of West-East (W-E) and of North-South N-S).

Comparison of four tree species bylines

Data analyses show that in the 5 years, *S. parvifolia* has the highest diameter increment followed by *S. leprosula*, *S. dasiphylla* and the smallest of *D. lanceolata* on W-E N-S planting lines. The figures indicate that growth and diameter

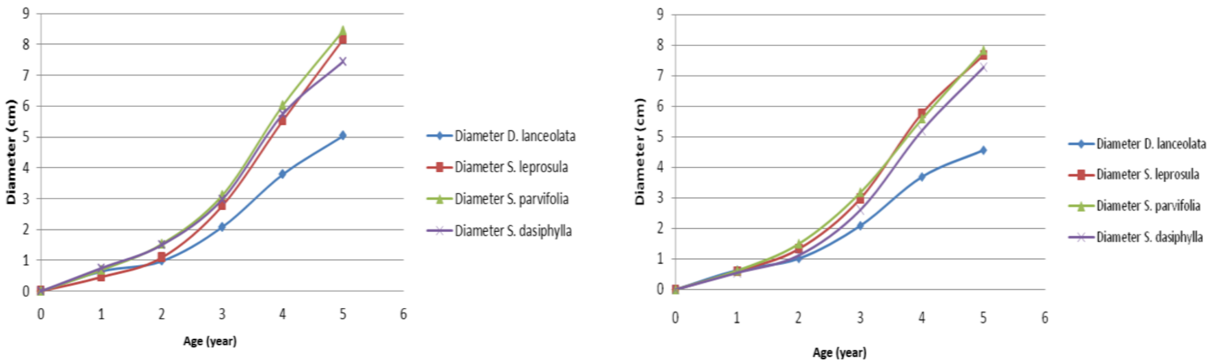

Figure 4. Diameter growth of *D. lanceolata, S. leprosula, S.parvifolia* dan *S. dasiphylla* species at various age (a) and at various increment level (b) on W-E planting line.

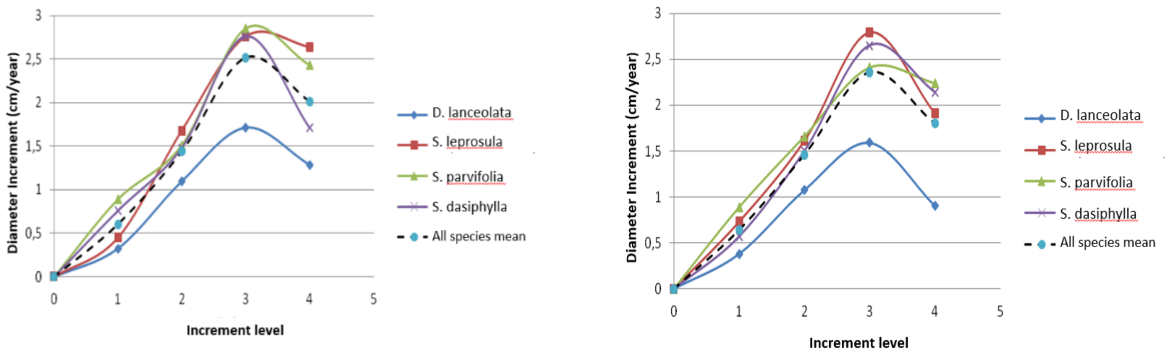

Figure 5. Diameter growth of D. *lanceolata*, *S. leprosula*, *S. parvifolia*, and *S. dasiphylla* at various age (a) and at various increment level (b) on N-S planting line.

increment of Shorea group has better adaptability to the planting site when compared to *D. lanceolata*.

Among the five young Dipterocarpaceae aged 5 years stand, the largest diameter average (Figure 4) and diameter increment (Figure 5) is *S. Parvifolia* on W-E planting line direction with 8,45 cm and 1,92 cm/yr consecutively. In contrast, the smallest is *D. lanceolata* on the N-S planting line direction of about 4,57 cm and 0,99 cm/yr consecutively (Figure 6-7). The largest diameter average and increment for all directions (W-E and N-S planting lines) found in *S. Parvifolia* of about 8,14 cm and 1,86 cm/yr consecutively. It is followed by *S. leprosula* of about 7,93 cm and 1,82 cm/yr; *S. dasiphylla* of about 7,37 cm and 1,70 cm/yr; and the smallest is *D. lanceolata* of about 4,81cm and 1,05 cm/yr, respectively.

In general, the study results at PT IWM at Bulungan District, North Kalimantan Province has no difference from the study results of (Tirkaamiana 2014) at PT Balikpapan Forest Industries, Penajam Paser Utara District, North Kalimantan Province. The study revealed that the average diameter increment of *D. lanceolata* on the 3 m line was 0. 74 cm/year, and on the 6 m line was 1,14 cm/year. At the same time, that of *S. leprosula* was higher than *D. lanceolata*, which was 1,47 cm/year on the 3 m line and 2,09 cm/ year on the 6 m line.

On the other hand, the study of (Kiswanto 2008) found that *D. lanceolata* had a diameter increment of 2,61 cm/year, where *D. lanceolata* had a larger diameter increment in the first year than that of *S. leprosula* and *S. parvifolia*. The seedling size of *D. lanceolata* planted in this study site was bigger than the other sites, enabling them to grow better and be more adaptive to the site.

Basically, the Dipterocarpaceae family has large variation average growth. The seedling and sapling stages show tolerant characteristics with fast-growing in unfull light conditions (Ashton 1982). Species of the Dipterocarpaceae family are dominant in tropical rainforests of Borneo, so they become the characteristic of Borneo's tropical rainforests. Shorea, better known as meranti (Eni *et al.* 2018), is one of the genera of the Dipterocarpaceae family which has the highest species diversity. One of the Dipterocarpaceae which is often exploited is *Dryobalanops lanceolata* as an endemic species of Borneo (Chung *et al.* 2013).

Shorea leprosula known as 'Meranti tembaga' is tolerant to water stress and is also known as light-demanding species in the early growth stage. This species also has a wide range of geographical distribution (Appanah *et al.* 1993 and Kiswanto 2008). *S.johorensis dan S. leprosula* can be recommended as the main species for enrichment planting in tropical rainforest using line planting (Widyatno *et al.* 2013). Moreover, *Shorea leprosula, S. Platyclados, S. Parvifolia dan S. Johorensis* are appropriate as enrichment planting species in selective cutting systems and line planting silvicultural systems. Without enrichment planting with appropriate planting species, tropical rain forests will enter degradation and fragmentation stages.

In the tropical area, the diameter of broadleaf trees grows all year long. The growth of trees' diameter is influenced by its position within the stand. The suppressed trees start and end their growth generally faster than the dominant trees. The highest point of diameter increment on

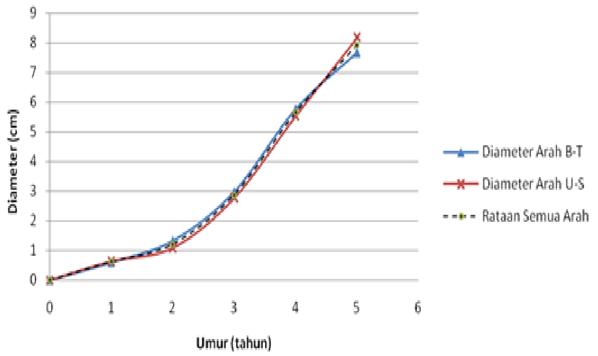

Figure 8. Diameter growth of *D. lanceolata* at various age on W-E and N-S planting line directions.

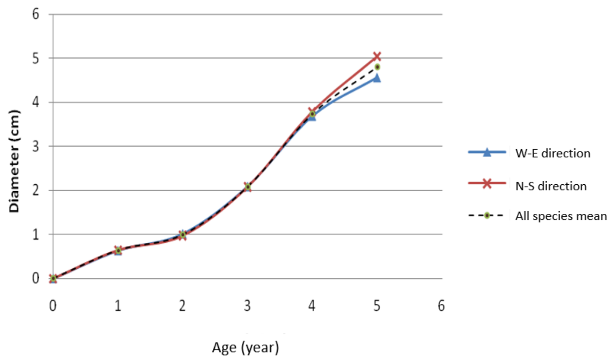

Figure 9. Diameter growth of *S. leprosula* at various age on W-E and N-S planting line directions

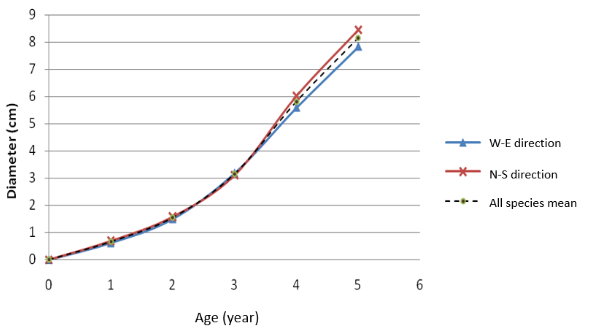

Figure 10. Diameter growth of *S. parvifolia* at various age on W-E and N-S planting line directions

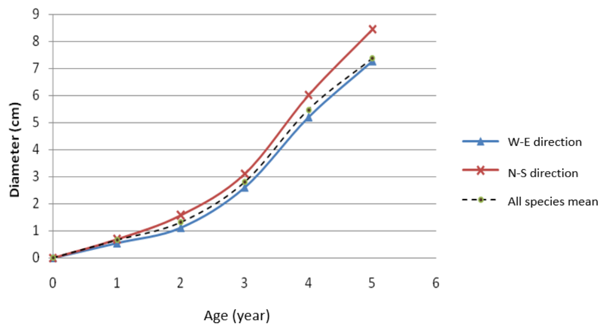

Figure 11. Diameter growth of *S. dasiphylla* at various age on W-E and N-S planting line directions

stand lifetime occurs faster than that of height increment. Through the arrangement of growing space and fertilization, the highest point can be slowed or even stopped. The diameter increments on the trunk close to the ground is greater than that of the upper parts (Ruchaemi 2013).

Comparison of line planting direction by species

When comparing diameter growth (Figure 8–11) and diameter increment (Figure 12–15) by two planting line directions, all meranti and 'kapur' species show no significant response to changes in planting line directions of W–E and N–S. The diameter growth of the four species appears to be stacked one on top of the other, implying that planting line orientations play no important influence. Similarly, there is no significant differences for diameter increment and basal area of all species at the first increment to the second increment on W – E and N - S planting line directions.

Meanwhile, there is a difference in diameter growth and the basal area between the second and fourth increments, though it is statistically insignificant. It is due to the presence of logged over space line along the planting line, which has potency, density and low average stand height of 17,62 m allowing sunlight to enter the N-S planting lines. These data indicate that Shorea and *Dryobalanops* are tolerant to the availability of sunlight. Hence, they can be easily established in an open planting area with high-temperature stress in the early plantation stage (Pedraza *et al.* 2003). The relationship of light intensity reception to the forest floor will affect the process of photosynthesis in trees. *S. leprosula*, especially has been known as 'Meranti Tembaga' is tolerant to water stress and also known as light-demanding species in the early stage of growth. The species also has a wide range of site distribution (Na'iem *et al.* 2013). The estimated optimum RLIs for seedling growth did not differ between the species; 26,9% and 31,8% for *D. aromatica* and *D. lanceolata*, respectively. But seedling allometry showed significant interspecific differences. *Dryobalanops aromatica* allocated more above-ground biomass to stem and made taller seedlings than *D. lanceolata*. This allometric difference seems to be related to the differences in gap regimes of the sites where they are distributed in the study forest (Itoh *et al.* 1999).

In the TPTJ system with W – E line planting direction, the intensity and duration of light entering the lines from morning to afternoon seem to be higher than that of N – S planting direction. According to the study results, the average diameter growth and increment of the four Dipterocarpaceae species on W – E line planting direction are greater than that of N – S planting line direction. Nevertheless, statistical analyses using t-test shows no significant influence of planting lines on diameter growth and increment. Light is an essential factor of the photosynthesis process as the key to other metabolic processes in plants. Photosynthesis is a basic process in plants to produce food and energy source for growth. Photosynthetic performance, growth and light availability showed a strong correlation across environments. Disparities in tree growth and survival are more obviously attributable to the two species' different carbon allocation patterns than interspecific differences in photosynthesis. *D. lanceolata* showed an increasing allometric, *S. leprosula* maximizes

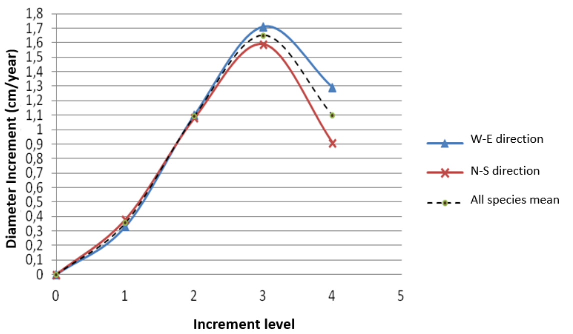

Figure 12. Diameter increment of *D. lanceolata* at various age on W-E and N-S planting line directions

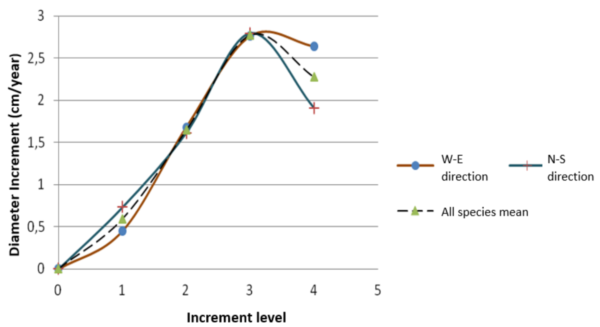

Figure 13. Diameter increment of *S. leprosula* at various age on W-E and N-S planting line directions

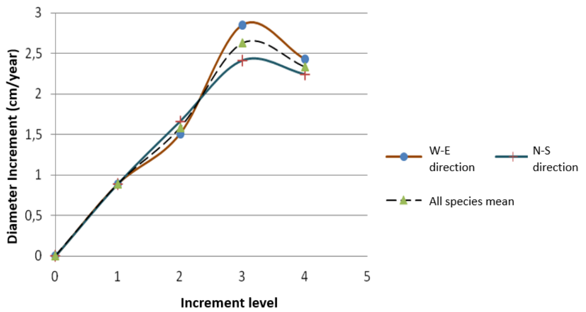

Figure 14. Diameter increment of *S. parvifolia* at various age on W-E and N-S planting line directions

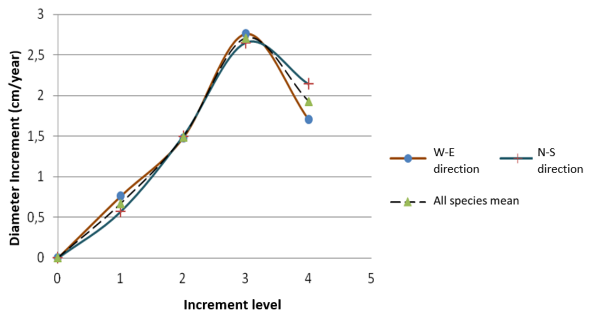

Figure 15. Diameter increment of *S. dasiphylla* at various age on W-E and N-S planting line directions

height growth and thus has a competitive advantage in more open sites. Although photosynthetic performance mirrored growth, we conclude that in the absence of information on photosynthetic allocation, rates of carbon dioxide fixation alone cannot describe a species' seedling ecology (Zipperlen *et al*. 1996).

The increase of light for *Shorea parvifolia* will gradually increase the photosynthesis process to reach light compensation level. The light level at CO_2 intake is similar to at CO_2 produce when the light continuously increases photosynthesis to reach the saturated light level (Daniel *et al.* 1995). Field observation shows that *dipterocarps* require partial shade with the best growth at full sunlight.

Light intensity received by the forest floor will affect the photosynthesis process in trees. Optimum light intensity acceptance on leaves may accelerate transpiration rate, stomata opening, which influence photosynthesis rate process and hence accelerate diameter and height growth of plants. Crown cover opening is important for successful regeneration. Study on shading level indicated that *Dipterocarpaceae* require partial sun radiation higher compared to that of direct sun radiation (Mori 1980; Sasaki 1980; and Ashton 1982) whereas diameter growth rates were linearly correlated with LI (mean per species r^2 = 0,45; excluding substantially damaged and vine-covered trees) and highly correlated with LI/wood density in Dipterocarp Forest in Malaysia (King *et al*. 2005).

Study at Surigao del Sur showed that seedling and sapling stages of dipterocarpa (dbh 5-20cm) might grow three times faster in the clean area as they can be prevented from other competitor growth. In line with the study, Bislig showed seedling and sapling grow faster 35 times in the managed land than that of unmanaged land (Revilla *et al.* 1976).

Line direction seems to have little influence on the survival and growth level of family Dipterocarpaceae. On the growth level, Southeast-Northwest seems to be the best planting direction for *S. johorensis*. Line width does not influence species survival but has a very strong influence on the growth, depends greatly on the overhead amount of light, which the line width can control. The growth of *S. johorensis* and *S. parvifolia* has benefitted from this line maintenance, where horizontal maintenance is better than vertical maintenance (Adjers *et al.* 1995). As a comparison, a study on forest dynamics in Dipterocarps rain forest in Malaysia indicates that gap size is unlikely to influence the composition of colonizing vegetation by controlling seed germination, but an effect operating through differential mortality cannot be discounted (Kennedy *et al.* 1992).

One of the physiographical factors that indirectly affect forest environment is an aspect or slope direction of an area. The slope aspect determines the amount of sunlight the slope receives in a site (Soekotjo 1984). The slope with pole direction will be more humid and cooler than the slope with equator line direction. The aspect may influence forest growth, particularly by its effect on temperature and soil water. East slope may be hit by morning sunlight; the sun effect protects the sites during the hottest afternoon. Although the east slope's N–S planting direction may have better tree growth than W–E, the west slope has a relatively hotter and dryer. Light intensity seems to have a very important influence on the growth of Dipterocarps. Therefore, variability of tree growth rates, both within and among species, is proportional to light interception/wood density (King *et al.* 2005).

Growth and diameter increment average of 1 year to 5 years old of Shorea group (*S. leprosula, S. parvifolia, S. dasyphylla)* shows almost similar growth curve and far bigger compared to ‘kapur’species (*D. Lanceolata*). The largest diameter increment is *S. parvifolia* on the W-E planting line direction of about 1,92 cm/yr. In contrast, the smallest is *D. lanceolata* on the N-S planting line direction of about 0,99 cm/yr. It indicates that the Shorea group has better site adaptability compared to *D. lanceolata.*

Field observation shows that the growth and diameter increment on the W – E planting line direction are larger than that of the N – S planting line direction. It is due to the intensity and duration of solar radiation being larger from morning to afternoon in the W – E planting line than that of N – S planting line direction. However, statistical analyses using t-test shows no significant influence of the line planting directions on the growth and diameter increment. It seems that spacing line stands with low density and low height average and aspect or slope direction determining solar radiation acceptance by the sites.

CONCLUSIONS

Planting line direction does not influence diameter increment. It is due to stand position in spacing line as ex-cutting area or the right and left-hand sides of planting line which has a low density and low average stand height. Therefore, the light intensity on the N-S planting line direction has no barrier of spacing line stand.

REFERENCES

Adjers GA, Hadengganan S, Kuusipalo J, Nuryanto K, and Vesa L. 1995. Enrichment planting of dipterocarps in logged-over secondary forests: effect of width, direction and maintenance method of planting line on selected Shorea species. *Forest ecology and management*, *73*(1), pp.259-270.

Appanah S, Weinland G. 1993. Planting quality timber trees in Peninsular Malaysia. Forest Research Institute Malaysia. Kepong. Malayan Forest Record. No. 38.

Ashton PS. 1982. *Flora Indo-Malayana. Seri I*. 9 (2): 237-552. [Indonesian].

Chung AYC, Maycock CR, Khoo E, Hastie A, Nilus R, Majapun R, Kimjus K, Chey VK. 2013. New records of insect associated with Borneo endemic dipterocarp seedlings J Trop Forest Sci 25 (1): 5-11.

Daniel TW, Helms JA, Bakers FS. 1995. *Prinsip-prinsip Silvikultur*. Marsono D, penerjemah; Soseno OH, editor. Yogyakarta: Gadjah mada University Press. Terjemahan dari: Principle of Silviculture. [Indonesian].

de Lacerd AEB, Junior FWA, Scolforo JRS, de Mello JM, de Oliveira AD, de Carvalho LMT, Calegário A, Filho, ACF. 2012. Sustainable Forest management of native vegetation remnants in Brazil. In: Martín-García J, Diez JJ (eds.). *Sustainable Forest Management Case Studies*. InTech, Rijecka, Croatia.

Eni A, Dewantara I, Sisillia L. 2018. Identification of tengkawang (Shorea spp) species as natural days of tenun ikat Kapuas Hulu Regency West Borneo. *J Hutan Lestari.* 6 (1): 7-15 [Indonesian].

Hattori D, Kenzo T, Irino KO, Kendawang JJ, Ninomiya I, and Sakurai K. 2013. Effects of soil compaction on the growth and mortality of planted dipterocarp seedlings in a logged-over tropical rainforest in Sarawak, Malaysia. *Forest ecology and management*, *310*, pp.770-776.

Itoh A, Yamakura T, and Lee HS. 1999. Effects of light intensity on the growth and allometry of two Bornean *Dryobalanops* (Dipterocarpaceae) seedlings. *Journal of Tropical Forest Science*, pp.610-618.

Kennedy DN and Swaine MD. 1992. Germination and growth of colonizing species in artificial gaps of different sizes in dipterocarp rain forest. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *335*(1275), pp.357-367.

King DA, Davies SJ, Supardi MN, and Tan S. 2005. Tree growth is related to light interception and wood density in two mixed dipterocarp forests of Malaysia. *Functional ecology*, *19*(3), pp.445-453.

Kiswanto. 2008. Natural Youth Growth and Crops in the Test Area of the Intensive TPTI System. [Thesis]. Faculty of Forestry, Mulawarman University, Samarinda. [Indonesian].

Ministry of Forestry. 2009. The Guidance of Silviculture System in The Forest Production Area to Manage Forest Product: No. P.9/VI/BPHA/2009. Ministry of Forestry. Jakarta.

Mori T. 1980. Physiological studies on some dipterocarp species of Peninsular Malaysia as a basis for artificial regeneration: under the cooperative research program between Malaysia and Japan. *Physiological studies on some dipterocarp species of Peninsular Malaysia as a basis for artificial regeneration: under the cooperative research program between Malaysia and Japan.*, (78).

Na'iem M. 2014. Improved national forest productivity based on rehabilitation: efficient use of forest areas. 50 years of the Faculty of Forestry, Gajah Mada University: Indonesian Forest Emergency; Realizing Indonesia's New Forestry Architecture. Wana Aksara. Tangerang. [Indonesian]

Na'iem M, Widiyatmo M, Al-Fauzi Z. 2013. Progeny test of *Shorea leprosula* as key point to increase productivity of secondary forest in PT Balik Papan Forest Industries, East Kalimantan, Indonesia. Environmental Sciences Procedia. Elsevier, Netherland.

Nguyen-The N, Favrichon V, Sist P, Houde L, Bertault JG, Fauvet N. 1998. Growth and mortality patterns before and after logging. In: Bertault JG, Kadir K, editors. Silvicultural research in a lowland mixed dipterocarp forest of East Kalimantan. CIRAD-forest, Forda & PT. Inhutani I, Jakarta.

Pedraza RA, Williams-Linera G. 2003. Evaluation of native tree species for the rehabilitation of deforested areas in a Mexican cloud forest. New Forests 26: 83-99.

Prodan M. 1968. *Forest Biometrics*. Pergamon Press, Oxford, London.

Putz FE and Cropper WP. 2017. Effects of silvicultural intensification on timber yields, carbon dynamics, and tree species composition in a dipterocarp forest in Kalimantan, Indonesia: an individual-tree-based model simulation. *Forest ecology and management*.

Revilla Jr AV, Canonizado JA, Dalangin NB, and Paler RD. 1976. A growth and yield prediction model for the cut-over dipterocarp forests of PICOP in Surigao del Sur. *Unpublished Report. University of the Philippines at Los Banos*.

Ruchaemi A. 2013. The science of forest growth. Mulawarman University Press, Samarinda. [Indonesian].

Ruchaemi A. 2016. Forest Management. Growth and Increment Aspects in Forest Sustainability. Mulawarman University Press, Samarinda. [Indonesian].

Sasaki S. 1980. Growth and storageof bare-root planting stock of dipterocarps with special reference to Shorea talura. Malaysian Forester 43: 144-160.

Soekotjo W. 1984. Silvika. Departemen Manajemen Hutan Fakultas Kehutanan Institut Pertanian Bogor. Bogor.

Soekotjo. 2009. Intensive silviculture techniques (SILIN). Gajah Mada University Press, Yogyakarta. [Indonesian]

Subiakto A, Rachmat HH, Sakai C. 2016. Choosing native tree species for establishing man-made forest: A new perspective for sustainable forest management in changing world. Biodiversitas 17: 620-625.

Tirkaamiana MT. 2014. Analisis Dinamika Tegakan Hutan yang Dikelola Dengan Sistem Tebang Pilih Tanam Jalur Di Areal IUPHHK PT Balikpapan Forest Industries dan PT. Intracawood Manufacturingi. Disertasi Pada Program Pascasarjana Ilmu Kehutanan Universitas Mulawarman. Samarinda.

Widodo J. 2014. Forest for People's Prosperity. 50 Years of the Faculty of Forestry, Gajah Mada University: Indonesian Forest Emergency; Realizing Indonesia's New Forestry Architecture. Wana Aksara. Tangerang. [Indonesian].

Widyatno S, Purnomo, Soekotjo, Na'iem M, Hardiwinoto S. 2013. Growth of selected Shorea spp. in secondary tropical rainforests: the effect of silvicultural treatments to improve the quality of growth Shorea spp. J Penelitian Hutan Konservasi Alam 8 (4): 373-383 [Indonesian].

Zipperlen SW and Press MC. 1996. Photosynthesis in relation to growth and seedling ecology of two dipterocarp rain forest tree species. *Journal of Ecology*, pp.863-876.