SEVERAL PHYSICAL PROPERTIES OF *Eucalyptus pellita* F. Muell FROM DIFFERENT PROVENANCES AND SAMPLING POSITION ON TREE

(Beberapa Sifat Fisik Eucalyptus pellita F. Muell dari Provenan dan Posisi Pengambilan Sampel pada Pohon yang Berbeda)

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Article Info	**ABSTRACT**
	Eucalyptus pellita F. Muell is one of the species selected for the development of the plantation forest in Indonesia. In order to obtain a superior plant for the continuity of the plantation forest program, various tree breeding techniques are often applied, one of which is through best provenance selection. Conventional or advanced tree breeding program generally aims to obtain a fast-growing plant with good physical appearance. The program rarely gives attention to the properties/characteristics of timber produced. This aspect becomes the main background of this particular study which aims to investigate the effect of four provenances and also to examine the effect of sampling position on the trees on several physical properties of *E. pellita*. The result showed that the highest moisture content (97.34 $\pm$ 15.67%) was found in the bottom part of trees from Indonesia provenance. While, the highest air-dry moisture content (15.15 $\pm$ 0.20%) was observed in the top-part samples from Provenance North Kiriwo PNG. Samples from Provenance Serisa Village PNG have the highest density ranges, approximately 590 $\pm$ 90 kg/m³ and 630 $\pm$ 80 kg/m³ in the bottom-part samples and in the top-part samples, respectively. The highest T/R ratio, approximately 1.91 $\pm$ 0.26, was observed in the bottom-part samples from Provenance South Kiriwa, PNG. The T/R ratio values of all provenances were less than 2, indicating the lumber will be possibly stable during its uses or further processing. Further result showed provenance factor significantly affect initial moisture content and density. Sampling position on trees only affect affects the initial moisture content. Based on the results, the timber of *E. pellita* being examined can be further used for light-to-medium construction purpose.
	ABSTRAK
	Eucalyptus pellita F. Muell merupakan salah satu jenis tanaman terpilih untuk program pembangunan hutan tanaman di Indonesia. Untuk memperoleh bibit tanaman unggul yang dapat mendukung kelangsungan program hutan tanaman, aneka teknik program pemuliaan tanaman dapat dilakukan, salah satunya melalui melalui seleksi provenan unggul. Pada umumnya, program pemuliaan tanaman yang dilakukan secara konvensional maupun modern bertujuan untuk memperoleh bibit tanaman yang cepat tumbuh dan memiliki penampilan fisik yang bagus. Sifat atau karakteristik kayu yang dihasilkan biasanya jarang diperhatikan sebagai tujuan program tersebut. Aspek tersebut yang melatar belakangi penelitian ini yang bertujuan untuk mengetahui pengaruh dari perbedaan 4 kelompok provenan dan posisi sampel pada batang pohon terhadap beberapa sifat fisik E. pellita. Hasil yang diperoleh menunjukkan bahwa bagian pangkal pohon contoh dari Provenan Indonesia memiliki kadar air awal tertinggi (97,34 $\pm$ 15,67%). Sampel dari bagian ujung pohon yang berasal dari provenan Kiriwa Utara PNG mengandung kadar air kering udara tertinggi (15,15 $\pm$ 0,20%). Sampel dari Provenan Serisa Village PNG memiliki kerapatan tertinggi, 590 $\pm$ 90 kg/m³ untuk bagian pangkal dan 630 $\pm$ 80 kg/m³ untuk bagian ujung. Bagian pangkal pohon contoh asal Provenan Kiriwa Selatan PNG memiliki rasio T/R tertinggi yaitu 1,91 $\pm$ 0,26. Nilai T/R yang kurang dari 2 untuk semua provenan mengindikasikan kayu akan stabil selama pemakaian atau pengolahan lanjutan. Hasil lebih lanjut menunjukkan provenan memiliki pengaruh nyata terhadap kadar air awal dan kerapatan kayu E. pellita. Faktor posisi sampel pada batang pohon hanya mempengaruhi nilai kadar air awal. Berdasarkan hasil penelitian ini, kayu E. pellita yang diperiksa dapat digunakan untuk keperluan konstruksi ringan hingga sedang.

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I. INTRODUCTION

Eucalyptus pellita is naturally distributed in North Queensland, Papua New Guinea, and Irian Jaya (Bristow, 2008). This species is one of those selected for the establishment of plantation forest in Indonesia and across South East Asia (Lukmandaru *et al.,* 2016; Setyaji *et al.,* 2016; Hii *et al.,* 2017). The reasons for selecting this species include its fast growth, short rotation, straight stem, high tolerance to various types of soil and location, and high resistance to pest and diseases (Nadalia, 2013; Lukmandaru *et al.,* 2016; Sulichantini, 2016).

Besides to fulfill the need of pulp and paper industry, this hardwood species has been considered as well as potential raw material for construction purposes and veneer and/or plywood production in Malaysia (Hii *et al.,* 2017). Hopewell *et al.* (2008) reported that *E. pellita* will be ready as pulp and paper material at harvesting age of 8 years and 10 years up for other purposes. Due to its popularity in the market, Indonesia has also established the average selling price of sawn timber made of this species for export purpose is approximately US$ 300 per m³ (Direktur Jenderal Perdagangan Luar Negeri, 2017).

To support the success of plantation forest program, sufficient quality seed is required. Conventional breeding or open pollination is no longer reliable to meet this need (Setyaji *et al.,* 2016). In order to obtain adequate quality seed to grow superior plants, an advanced breeding strategy should be adopted to replace the conventional one. Various advanced breeding strategies that can be applied include clonal test, plus tree selection, best provenance selection, tissue culture or genetic engineering (Nirsatmanto *et al.,* 2015; Haggman *et al.,* 2016; Leksono, 2016). For *E. pellita* case, the breeding program has been initiated since the early 1990s by Center for Forest Biotechnology and Tree Improvement (CFBTI) in Yogyakarta collaborated with Japan International Cooperation Agency (JICA). The establishment of the 1st generation (F1) of *E. pellita* in several sites used genetic material from the best provenances from Queensland, Papua New Guinea, and Indonesia. This phase resulted in the production of superior seed of *E. pellita* which was further released for commercial purpose on 11th October 2004 (Leksono, 2016). In 2003, the 2nd progeny trial plots (F2) were developed in Wonogiri (Central Java Province) and Pelaihari (South Borneo Province) using the superior seed obtained from the F1 generation (Leksono, 2016; Lukmandaru *et al.,* 2016).

The general target for implementing any breeding strategy is to obtain a fast-growing plant with a good physical appearance in a short time. The strategy rarely gives attention to the properties/characteristics of the timber produced. On the other hand, information on the wood characteristics is often required especially when the wood is being used for furniture or building purpose. Quang *et al.* (2010) reported that progeny trial could significantly influence some physical and chemical properties of the wood such as density, cellulose and lignin contents. Nevertheless, no information has been found for the effect of progeny trials on the wood properties of *E. pellita*. Considering the discrepancy in the existing information, this study then aims to investigate any significant influence of different provenances on several physical properties of *E. pellita* such as initial moisture content, density, and tangential-radial (T/R) shrinkage ratio. Physical properties, in particular density, are often questioned by users who will further utilize the timber for construction purposes. T/R shrinkage ratio indicates the dimensional stability of a particular wood species during its use. Any wood with a value of T/R shrinkage ratio of less than 2 will usually have a stable dimension during its service. In addition, together with density, T/R shrinkage ratio can also affect the wood during its drying process (Basri *et al.,* 2009; Cáceres *et al.,* 2017). Therefore, T/R shrinkage ratio is one of the parameters that can or should be considered during the selection of provenances for construction timber production (Cáceres *et al.,* 2017).

II. RESEARCH METHOD

A. Material and Equipment

The main material used for this research was 10-year old *E. pellita* from the research forest area in Wonogiri, Central Java; one of many research plantation areas owned by the Ministry of Environment and Forestry of Indonesia. The Wonogiri's research forest is currently managed by the Center for Forest Biotechnology and Tree Improvement (CFBTI) in Yogyakarta. The *E. pellita* collected consisted of 4 provenances (i.e. S. Kiriwo PNG; N. Kiriwo PNG; Serisa Village PNG; and Bupul-Muting Indonesia).

Six trees for each provenance, approximately at a height of 100 mm above the ground, were collected from two planting blocks in the same area. Each tree was sawn into several 4000 mm-long small logs. Those small logs were coded to mark the bottom (A), middle (B), and top (C) parts of the trees. A total of 72 logs were produced and further transported to the Center for Research and Development on Forest Products (CRDFP). These logs were stored outside nearby the sawing laboratory.
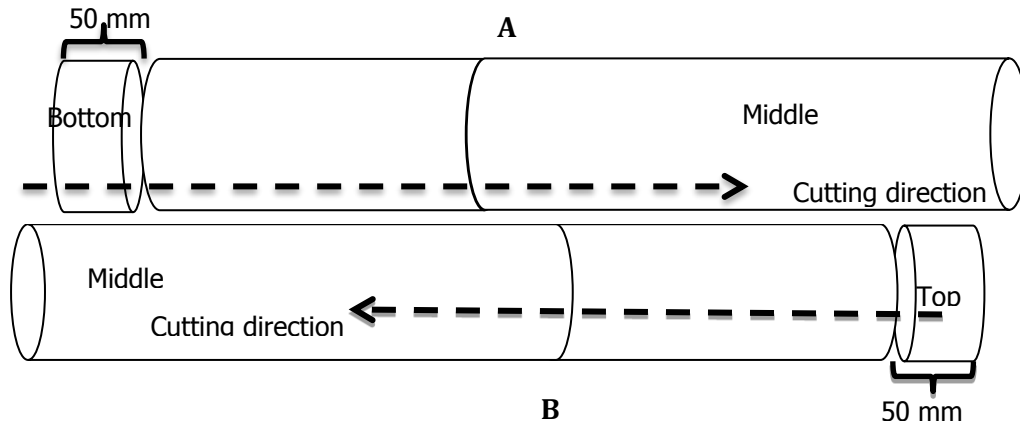
Figure 1. The cutting pattern for 50-mm thick disk from the bottom part (A) and the top part (B) of the logs of *E. pellita*
Gambar 1. *Pola pengambilan disket dengan ketebalan 50 mm dari bagian pangkal (A) dan ujung (B) dolok E. Pellita*

Other supporting materials used included sealant, spray gun, aluminum foil, plastic film (clingwrap), plastic spatula, vape, binder clips bulldog, writing tools, notebooks, etc. The equipment used included sawing machine, small band-saw, oven, fridge, caliper, moisture meter, ruler, measuring tape, and scale.

B. Time and Place

The field trips to select the trees in the plantation area and the trees collection were executed from mid to late of October 2016. The whole experiment started from November 2016 to February 2017. All sawing and drying processes were carried out in the sawing and drying facilities of CFPRD.

C. Research Procedures

1. Time and the purposes of the activity

The activity was carried out from mid-November 2016 to February 2017. The measurements of density, tangential-radial (T/R) shrinkage ratio, and initial moisture content (M) were carried out for all 4 provenances of *E. pellita*.

2. Sample preparation

The bottom and the top logs of 2 trees from the 6 trees collected for each provenance of *E. pellita* were randomly selected, resulted in 4 logs for each group. The disks, measuring 50 mm in thickness, were sawn from the end-part of each log with the largest diameter for the bottom-logs or the smallest diameter for the top-logs (Figure 1). These disks were then cut following the specific pattern (Figure 2). The number of samples obtained from each disk could be different depending on the disk diameter.

3. Experiment method

British Standard 373-1957 was used to examine the physical properties (BSI, 1957). A modification was applied to sample dimension due to the limitation in the log diameter and this practice has been previously used by another study (Basri, 2011). The dimension sample was 20 mm (width) x 20 mm (length) x 20 mm (thickness). Tangential and radial directions were marked for each sample (Figure 3).

Initial weight and dimension of each sample were measured. Samples were then placed at room
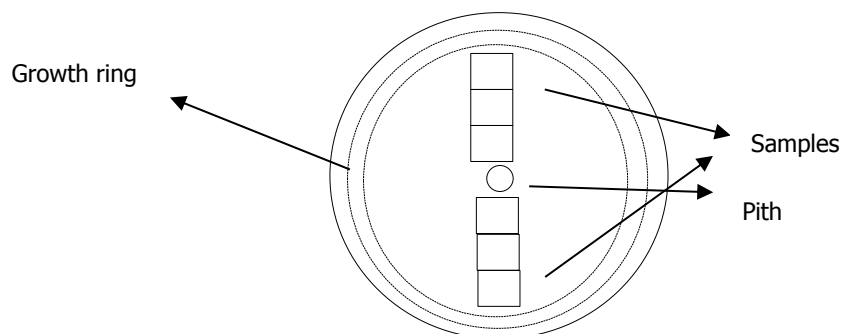

Figure 2. Sampling process from the 50-mm thick disk for physical properties test
Gambar 2. *Pengambilan sampel dari disket dengan ketebalan 50 mm untuk uji sifat fisis*
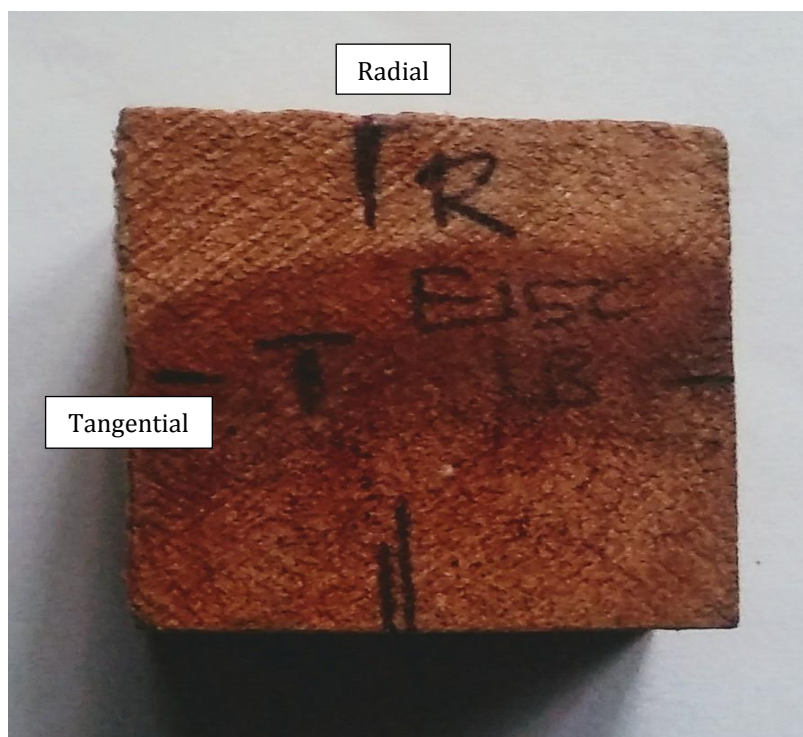
Figure 3. Tangential and radial directions were marked for each sample
Gambar 3. *Penandaan arah tangensial dan radial untuk setiap sampel*

temperature (at a range of 20-22°C) and humidity (at a range of 70-88%). Weight and dimension change of each sample were recorded daily. When the samples reached air-dry condition, in 54-56 days averagely and indicated by constant weight or no weight change, the samples were dried in an oven at a temperature of 60°C. When the samples reached constant weight under this condition (within 2 days averagely), the oven temperature was raised to 100°C. All samples were removed from the oven when their weight showed no change. The final weight and initial dimension of each sample were measured again.

4. Data collection and analysis

The data collected were the initial and final weight and dimension of the samples (post-oven drying condition at 100°C). The initial moisture content, the air-dry moisture content, density, and T/R ratio were calculated according to Formulas 1-4. The distribution of each physical property from bark to pith was further graphed separately.

$$\text{Initial moisture content} = \frac{\text{Green weight} - \text{oven dry weight}}{\text{Oven dry weight}} = \text{x } 100\% \quad (1)$$

$$\text{Air-dry moisture content} = \frac{\text{Green weight} - \text{air-dry weight}}{\text{Air dry weight}} = \text{x } 100\% \quad (2)$$

$$\text{Density} = \frac{\text{Oven dry weight (kg)}}{\text{Green volume (m}^3\text{)}} = \text{x } 100\% \quad (3)$$

$$\text{T/R ratio} = \frac{\text{Shrinkage in tangential direction (Ts)}}{\text{Shrinkage in radial direction (Rs)}} \quad (4)$$

$$\text{Tangential/radial shrinkage} = \frac{\text{Initial dimension- oven dry dimension}}{\text{Initial dimension}} \quad (5)$$

Two-way analysis of variance (ANOVA) was used to examine the effect of different provenances, sampling position, and their interaction on each physical property. The replications used were 2 or 3, indicating the number of trees used. The value for each tree was the average of all samples produced from the same disk. A post-hoc Tukey test was carried out when the ANOVA result showed a significant result.

III. RESULTS AND DISCUSSION

A. Initial Moisture Content

The green or initial moisture content in samples from the bottom parts of the trees for all provenances was higher than that observed in the top-part samples (Table 1). According to Yuniarti (2017b), higher moisture content found in the bottom parts of the trees is an acceptable fact as this part is very close to the ground. The presence of roots in the plant base, hidden underground, facilitates the transport of moisture and any other nutrients from the soil into the plant. Therefore, the bottom parts of the trees could uptake moisture from the ground easily and in large amount. Another species from this genus, 4 to 17-year old *Eucalyptus regnans*, has also shown the same trend for its tendency of green moisture content (Frederick *et al.,* 1982).

Table 1. Average and standard deviation values of initial moisture content of *E. pellita* from 4 provenances

Tabel 1. *Nilai rata-rata dan standar deviasi kadar air awal E. pellita dari 4 provenan*

Provenance (*Provenan*)	Sample position on tree (*Posisi sampel pada pohon*)	Initial moisture content (%) (*Kadar air awal*)
1	Bottom	81.19 ± 20.40
(S. Kiriwo, PNG)	Top	69.19 ± 10.75
2	Bottom	84.04 ± 20.56
(N. Kiriwo PNG)	Top	70.59 ± 13.16
3	Bottom	76.00 ± 20.00
(Serisa Village, PNG)	Top	64.45 ± 14.01
4	Bottom	97.34 ± 15.67
(Bupul Muting, IND)	Top	89.21 ± 19.24

    E. pellita samples from the bottom and top part of trees of Provenance 4 (Bupul Muting Indonesia) have the highest initial moisture content (Table 1), reached 97.34 ± 15.67% and 89.21 ± 19.24%, respectively. The lowest initial moisture content was observed in samples from Provenance 3, reached 76.00 ± 20.00% for the bottom-part samples and 64.45 ± 14.01% for the top-part samples. Further ANOVA test confirmed the significant effect of provenance and sampling position on trees on the initial moisture content values, but not their interaction (Table 2). Subsequent Tukey tests showed the samples from Bupul Muting Indonesia (Provenance 4) have the highest moisture content and significantly different from the others except from N. Kiriwo, PNG (Table 3). The highest moisture content in Provenance 4 was possibly caused by its largest fiber diameter (21.95 μm) and widest lumen (14.36 μm) among all provenances (Yuniarti, 2017a).

Table 3. Tukey test results to investigate the differences in initial moisture content between provenances
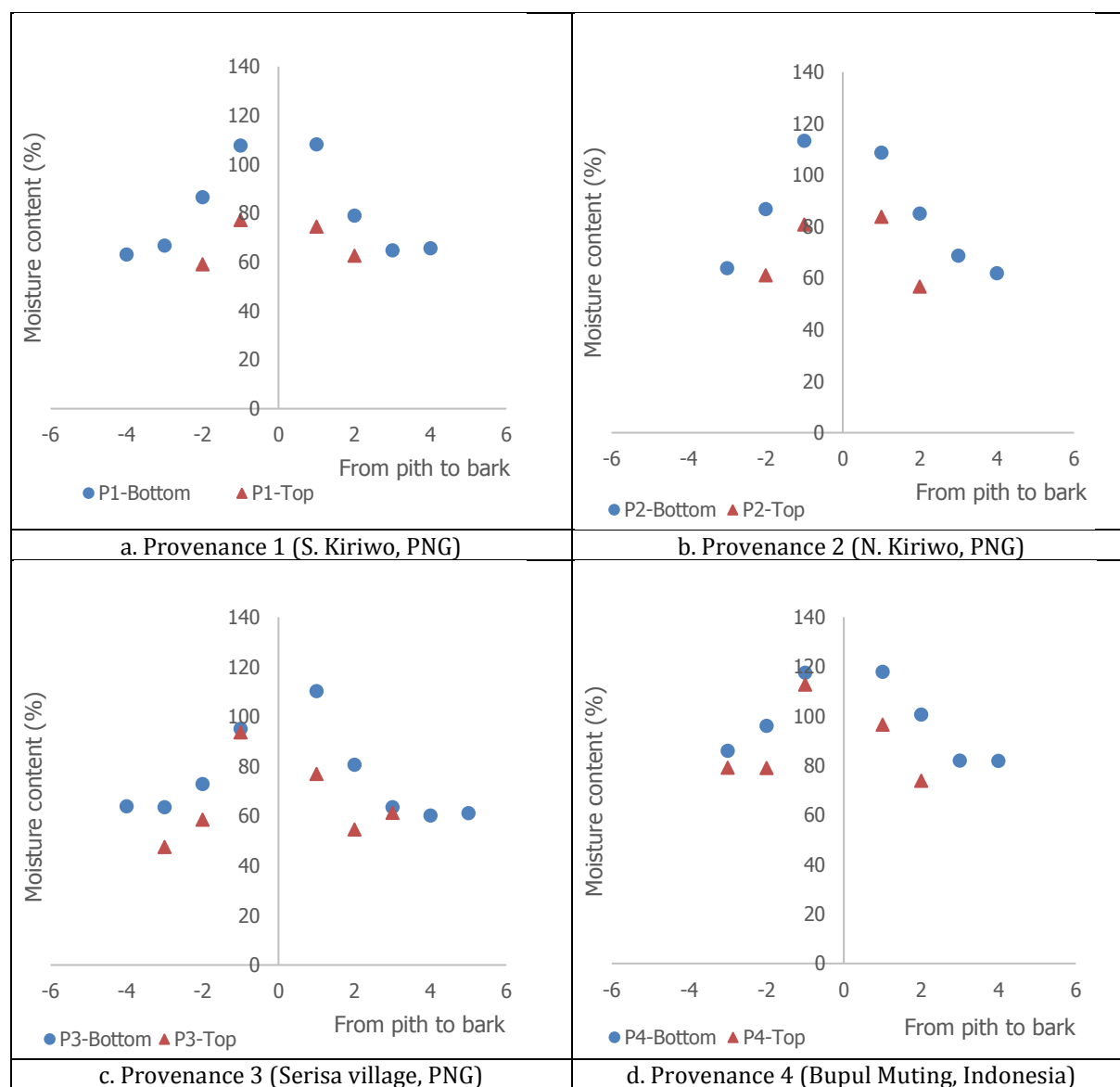
Tabel 3. *Hasil uji Tukey untuk menyelidiki perbedaan nilai kadar air awal antar provenan*

Provenance (*Provenan*)	Samples (*Contoh uji*)	Mean (*Nilai tengah*)
1 S. Kiriwo, PNG	5	75.2b
2 N. Kiriwo, PNG	4	77.3ab
3 Serisa Village, PNG	4	70.5b
4 Bupul Muting, Indonesia	4	92.8a

Remarks: Similar letter shows the factor means are not significantly different.
Keterangan: Huruf yang sama menunjukkan nilai tengah faktor tidak berbeda nyata.

    The initial moisture content tended to decrease toward the barks in all samples (Figure 4). Possibly because the outer part of the wood, which is close to the bark, consists of younger cells than the inner part, thus it is easier to evaporate moisture than the inner part. High initial moisture content should be taken into attention when the wood is further dried. The combination of high initial moisture content and the presence of deposits in wood cells, such as tyloses, minerals or others, could cause the development of drying defects, such as an initial check, deformation or even collapse, during the initial stage of drying. It is observed that the vessels of this species contain tyloses (Yuniarti, 2017a). Therefore, careful attention during its drying process will be required to prevent or minimize the development of serious defects.

Table 2. ANOVA test result to investigate the factors affecting the initial moisture content of *Eucalyptus pellita*

Tabel 2. *Hasil uji ANOVA untuk memeriksa faktor-faktor yang mempengaruhi kadar air awal Eucalyptus pellita*

Source of variation (*Sumber keragaman*)	Degree of freedom (*Derajat bebas*)	Seq sum square (*Jumlah kuadrat*)	Adj sum square (*Jumlah kuadrat disesuaikan*)	Adj mean square (*Kuadrat tengah disesuaikan*)	F-value (*Nilai F*)	P-value (*Nilai P*)
Provenance (*Provenan*)	3	1177.11	1129.15	376.38	6.82	0.011
Sampling (*Pengambilan sampel*)	1	529.51	525.20	525.20	9.52	0.013
Provenance * sampling (*Provenan*penga mbilan sampel*)	3	9.77	9.77	3.26	0.06	0.980
Error (*Galat*)	9	496.54	496.54	55.17		
Total (*Total*)	16	2212.94				

Remarks (*Keterangan*): S = 7.42769   R-Sq = 77.56%   R-Sq(adj) = 60.11%

a. Provenance 1 (S. Kiriwo, PNG)

b. Provenance 2 (N. Kiriwo, PNG)

c. Provenance 3 (Serisa village, PNG)

d. Provenance 4 (Bupul Muting, Indonesia)

Remarks: 0 at X-axis indicates pith; (-) sign at X-axis indicates opposite direction from the pith; Number 2 at X-axis indicates 40 mm distance from pith; 4 indicates 80 mm distance from pith; 6 indicates 100 mm distance from pith

Keterangan: 0 pada sumbu X mencirikan empulur; tanda (-) pada sumbu X mencirikan arah yang berlawanan dari empulur; Angka 2 pada sumbu X mencirikan jarak 40 mm dari empulur; 4 mencirikan jarak 80 mm dari empulur; 6 mencirikan jarak 100 mmdari empulur

Figure 4. Initial moisture content distribution from pith to bark for samples from each provenance of E. pellita

Gambar 4. *Distribusi kadar air awal dari empulur ke kulit kayu E. pellita dari setiap provenan*
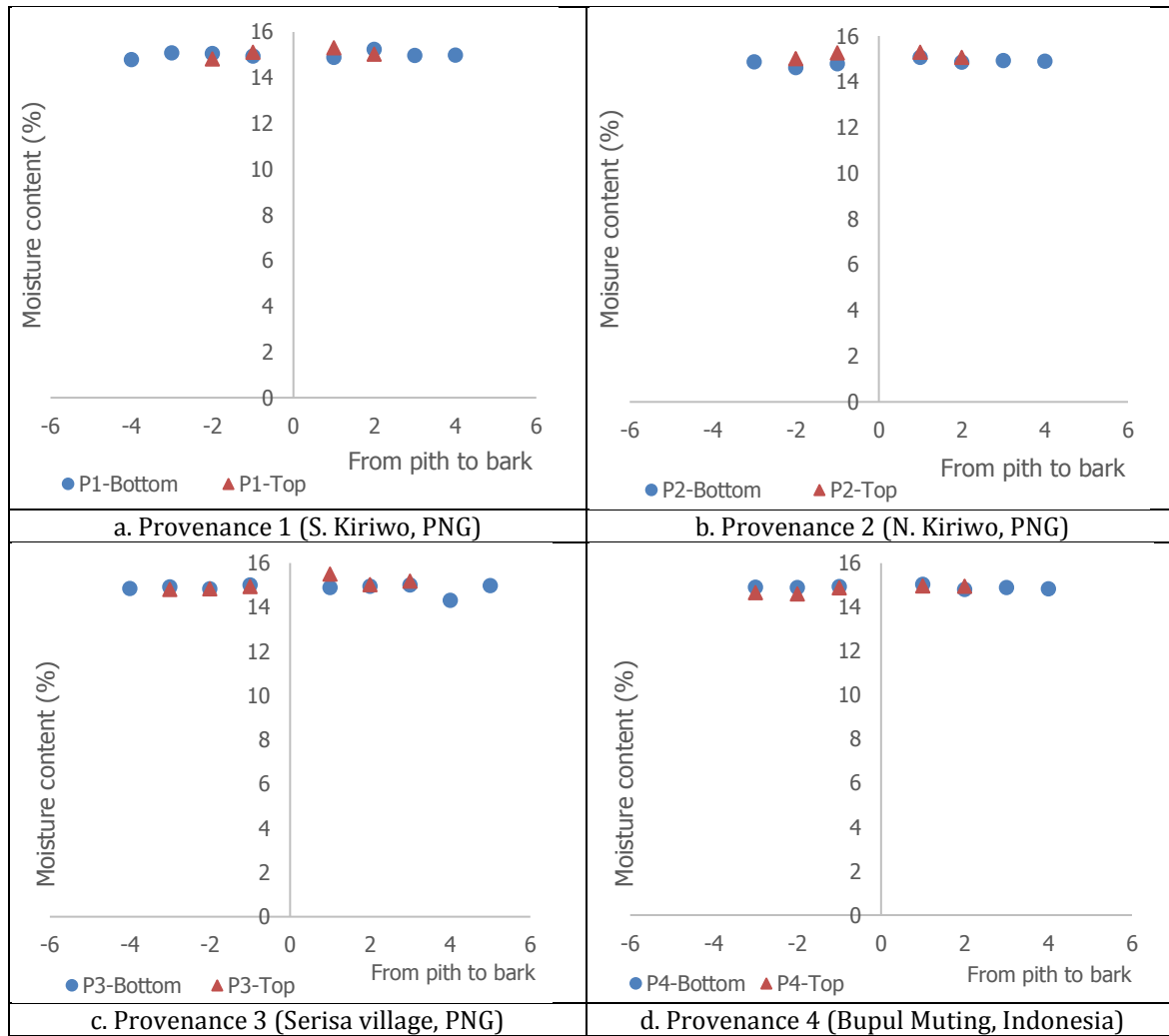
B. Air-Dry Moisture Content

The bottom-part samples from all PNG provenances were found to have lower air-dry moisture content than their top-part counterparts (Table 4). The lowest air-dry moisture content was observed in the top-part samples from Provenance 4 (14.83 $\pm$ 0.20%), whilst the highest one was observed in the top-part samples from Provenance 2 (15.15 $\pm$ 0.20%). Nevertheless, the air-dry moisture content was actually not affected significantly by provenance, sample position on the tree, and the combination of both factors (Table 5).

Table 4. Average air-dry moisture content for *E. pellita* from 4 provenances

Tabel 4. *Nilai rata-rata kadar air kering udara pada kayu E. pellita dari 4 provenan*

Provenance (Provenan)	Sample position on tree (Posisi sampel pada pohon)	Air-dry moisture content (%) (Kadar air kering udara (%))
1 (S. Kiriwo, PNG)	Bottom	15.00 $\pm$ 0.25
	Top	15.09 $\pm$ 0.20
2 (N. Kiriwo, PNG)	Bottom	14.86 $\pm$ 0.22
	Top	15.15 $\pm$ 0.20
3 (Serisa Village, PNG)	Bottom	14.85 $\pm$ 0.48
	Top	15.12 $\pm$ 0.31
4 (Bupul Muting, IND)	Bottom	14.90 $\pm$ 0.31
	Top	14.83 $\pm$ 0.20

a. Provenance 1 (S. Kiriwo, PNG)

b. Provenance 2 (N. Kiriwo, PNG)

c. Provenance 3 (Serisa village, PNG)

d. Provenance 4 (Bupul Muting, Indonesia)

Remarks: 0 at X-axis indicates pith; (-) sign at X-axis indicates opposite direction from the pith; Number 2 at X-axis indicates 40 mm distance from pith; 4 indicates 80 mm distance from pith; 6 indicates 100 mm distance from pith

*Keterangan: 0 pada sumbu X mencirikan empulur; tanda (-) pada sumbu X mencirikan arah yang berlawanan dari empulur; Angka 2 pada sumbu X mencirikan jarak 40 mm dar*i empulur; 4 mencirikan jarak 80 mm dari empulur; 6 mencirikan jarak 100 mm dari empulur.

Figure 5. *Air-dry moisture content distribution from pith to bark in trees from each provenance of E. pellita*
Gambar 5. *Distribusi kadar air kering udara dari empulur ke kulit kayu E. pellita dari setiap provenan*

Table 5. ANOVA test result to investigate the factors affecting the air-dry moisture content of *E. pellita*
Tabel 5. *Hasil uji ANOVA untuk memeriksa faktor-faktor yang mempengaruhi kadar air kering udara E. pellita*

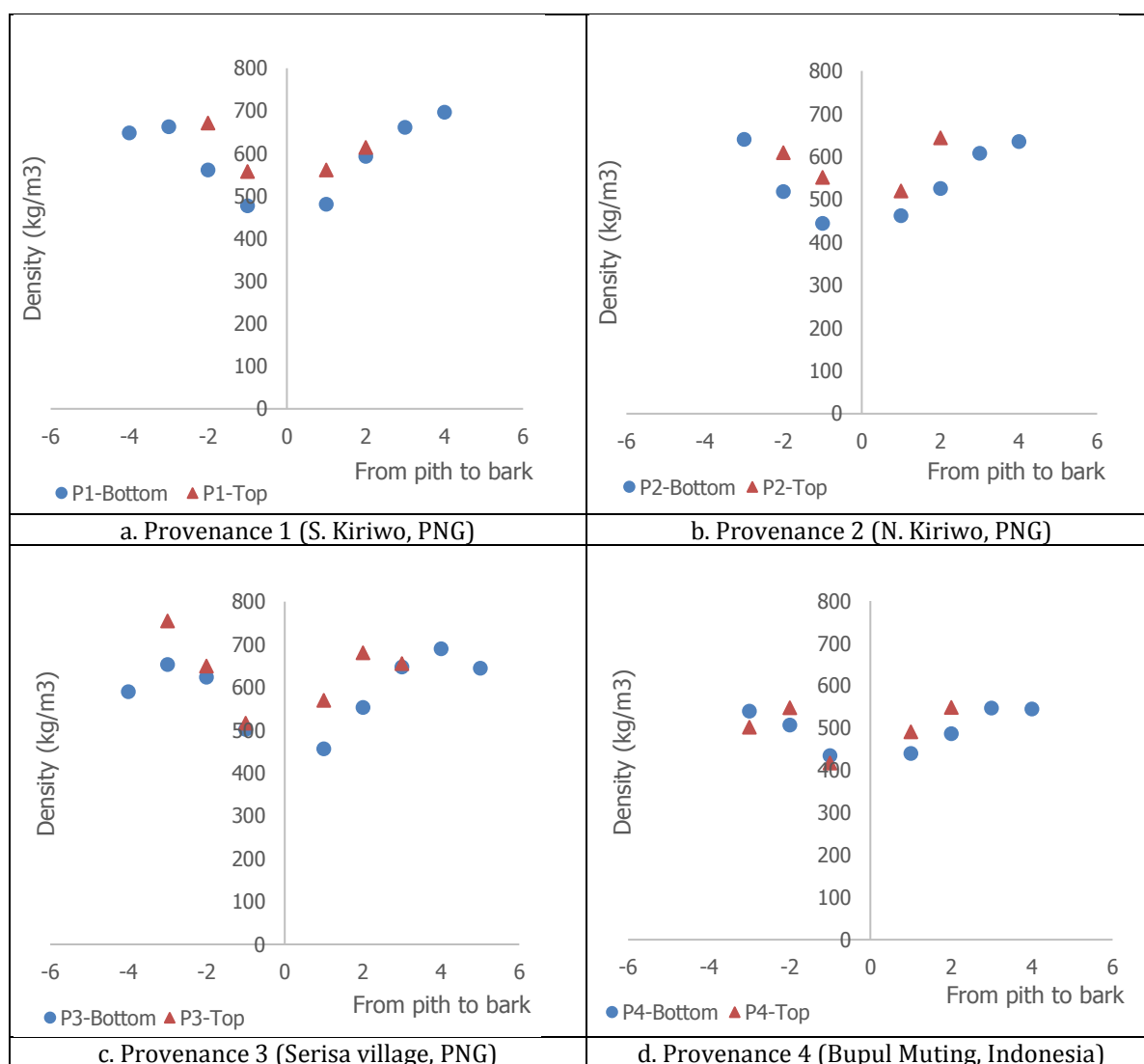| Source of variation *(Sumber keragaman)*	Degree of freedom *(Derajat bebas)*	Seq sum square *(Jumlah kuadrat)*	Adj sum square *(Jumlah kuadrat disesuaikan)*	Adj mean square *(Kuadrat tengah disesuaikan)*	F-value *(Nilai F)*	P-value *(Nilai P)*
Provenance *(Provenan)*	3	0.08463	0.07572	0.02524	0.41	0.747
Sampling *(Pengambilan sampel)*	1	0.10391	0.10597	0.10597	1.74	0.220
Provenance * sampling *(Provenan*pengambilan sampel)*	3	0.08367	0.08367	0.02789	0.46	0.719
Error *(Galat)*	9	0.54924	0.054924	0.06103		
Total *(Total)*	16	0.82145				

Remarks *(Keterangan)*: S = 0.247035 R-Sq = 33.14% R-Sq(adj) = 0.00%

Both bottom- and top-part samples from all provenances generally showed the same trend (Figure 5). The moisture content at air-dry condition was found to be distributed evenly from the pith to bark. This result indicates that under a natural air-drying condition, the species is possibly permeable thus the liquid can flow easily from the inner part of the wood to its outer part. Further study is required to determine the exact value of the permeability of this species to confirm the assumption.

C. Density

The average density of the samples from both the top and bottom parts of the trees was not much different (Table 6). Between provenances, the differences in density were also not that large. Samples from Provenance 4 (Bupul Muting, Indonesia) have the lowest density ranges, approximately 500 ± 50 kg/m³ for the bottom-part samples and 500 ± 70 kg/m³ for the top-part samples. On the other hand, samples from Provenance 3 have the highest density ranges, approximately 590 ± 90 kg/m³ for the bottom-part samples and 630 ± 80 kg/m³ for the top-part samples. Provenance 3 was found to have thicker cell wall than Provenance 2 or 4 (approximately 4.04 μm), but still lower than that observed in Provenance 1 (4.23 μm) (Yuniarti, 2017a). Therefore, the densest structure of Provenance 3 is possibly contributed by other components which will need further study.

a. Provenance 1 (S. Kiriwo, PNG)

b. Provenance 2 (N. Kiriwo, PNG)

c. Provenance 3 (Serisa village, PNG)

d. Provenance 4 (Bupul Muting, Indonesia)

Remarks: 0 at X-axis indicates pith; (-) sign at X-axis indicates opposite direction from the pith; Number 2 at X-axis indicates 40 mm distance from pith; 4 indicates 80 mm distance from pith; 6 indicates 100 mm distance from pith.
Keterangan: 0 pada sumbu X mencirikan empulur; tanda (-) pada sumbu X mencirikan arah yang berlawanan dari empulur; Angka 2 pada sumbu X mencirikan jarak 40 mm dari empulur; 4 mencirikan jarak 80 mm dari empulur; 6 mencirikan jarak 100 mm dari empulur.

Figure 6. Density distribution from pith to bark in trees from each provenance of *E. pellita*
Gambar 6. *Distribusi kerapatan dari empulur ke kulit kayu E. pellita dari setiap provenan*

Table 6. The average and standard deviation values of density of *E. pellita* from 4 provenances
Tabel 6. *Nilai rata-rata dan standar deviasi kerapatan E. pellita dari 4 provenan*

Provenance (Provenan)	Sample position on the tree (Posisi sampel pada pohon)	Density (kg/m³) (Kerapatan)
1 (S. Kiriwo, PNG)	Bottom	590 ± 80
	Top	590 ± 70
2 (N. Kiriwo, PNG)	Bottom	550 ± 80
	Top	580 ± 60
3 (Serisa Village, PNG)	Bottom	590 ± 90
	Top	630 ± 80
4 (Bupul Muting, IND)	Bottom	500 ± 50
	Top	500 ± 70

The density values for all provenances studied can be classified into strength class II-III according to the classification proposed by Den Berger in 1923 (Martawijaya *et al.,* 2005). Nevertheless, their values are still lower than those of *E. pellita* from Australia, which was approximately 748 kg/m³ (McGavin *et al.,* 2015). The difference is possibly due to the age difference between the samples used, where the trees sampled in Australia was 1 year older than that sampled in Indonesia. Further, the density values were significantly affected by the provenance factor, but not by the sampling position on trees or interaction between the 2 main factors (Table 7). The mean density value of the Bupul Muting provenance was found significantly lower than that of the Serisa Village (Table 8).

Table 8. Tukey test results to investigate the differences in density between provenances
Tabel 8. *Hasil uji Tukey untuk menyelidiki perbedaan kerapatan antar provenan*

Provenance (Provenan)	Samples (Contoh uji)	Mean (Nilai tengah)
1 S. Kiriwo, PNG	5	590ab
2 N. Kiriwo, PNG	4	565ab
3 Serisa Village, PNG	4	660a
4 Bupul Muting, Indonesia	4	500b

Remarks: Similar letter shows the factor means are not significantly different.
Keterangan: Huruf yang sama menunjukkan nilai tengah faktor tidak berbeda nyata.

The density values tended to increase toward the bark for all provenances (Figure 6). Possible factors causing this trend are not clear yet. The presence of additional extractives in the cell lumen could be one of the factors. However, it will need further and more detail study to confirm the assumption. According to Panshin and De Zeeuw (1980), the density trend variation in hardwood was common. Based on this variation, the hardwood species can be divided into 3 groups, which are Group 1 for those with increasing density toward the bark; Group 2 for those with decreasing density from pith to the middle part and then increasing again toward the bark; and Group 3 for those with decreasing density toward the bark. The density variation is depending on the wood species studied. For example, an oak tree grown in Portugal has higher density in the part close to the pith than those close to the bark (Knapic *et al.,* 2008).

D. T/R Shrinkage Ratio

The T/R shrinkage ratio of the samples from the top parts of the trees was averagely lower than

Table 7. ANOVA test result to investigate the factors affecting the density of *Eucalyptus pellita*
Tabel 7. *Hasil uji ANOVA untuk memeriksa faktor-faktor yang mempengaruhi kerapatan Eucalyptus pellita*

Source of variation (Sumber keragaman)	Degree of freedom (Derajat bebas)	Seq sum square (Jumlah kuadrat)	Adj sum square (Jumlah kuadrat disesuaikan)	Adj mean square (Kuadrat tengah disesuaikan)	F-value (Nilai F)	P-value (Nilai P)
Provenance (Provenan)	3	0,026888	0,026817	0,008939	4,30	0,038
Sampling (Pengambilan sampel)	1	0,001384	0,001524	0,001524	0,73	0,414
Provenance * sampling (Provenan*pengambilan sampel)	3	0,001218	0,001218	0,000406	0,20	0,897
Error (Galat)	9	0,018708	0,018708	0,002079		
Total (Total)	16	0,048198				

Remarks *(Keterangan)*: S = 0,0455929   R-Sq = 61,18%   R-Sq(adj) = 30,99%

that in the bottom-part samples (Table 9). However, between provenances, the difference in T/R shrinkage ratio was not that large. The highest T/R ratio, approximately 1.91 ± 0.26, was found in the bottom-part samples from Provenance 1 (South Kiriwo, PNG). The lowest T/R ratio, approximately 1.31 ± 0.63, was observed for the top-part samples from Provenance 4 (Indonesia origin). Nevertheless, the values of T/R shrinkage ratio were not significantly affected by provenance, sampling position on trees, and interaction between both main factors (Table 10).

Table 9. Average and standard deviation values of tangential/radial shrinkage ratio (T/R ratio) of *E. pellita* from 4 provenances
Tabel 9. *Nilai rata-rata dan standar deviasi rasio penyusutan tangensial/radial kayu E. pellita dari 4 provenan*

Provenance (Provenan)	Sample position on tree (Posisi sampel pada pohon)	T/R ratio (Rasio T/R)
1	Bottom	1.91 ± 0.26
(S. Kiriwo, PNG)	Top	1.55 ± 0.34
2	Bottom	1.78 ± 0.42
(N. Kiriwo, PNG)	Top	1.67 ± 0.84
3	Bottom	1.77 ± 0.27
(Serisa Village, PNG)	Top	1.56 ± 0.26
4	Bottom	1.85 ± 0.80
(Bupul Muting, IND)	Top	1.31 ± 0.63

The trend of T/R ratio values for, in particular, the 3 provenances (PNG), were generally decreasing toward the barks, with values are less than or close to 2 (Figure 7). This trend, in general, starts from 400-mm distance from the pith. This finding indicates the samples dimension obtained, starting from that position, will be quite stable during the uses. As for samples from Provenance 4 (Bupul Muting, Indonesia), only the top-part samples show a decreasing trend toward the bark

and the bottom-part samples did not show the same trend. Possible factors causing this irregular pattern should be further studied. It is possible that the values of tangential or radial shrinkage obtained from each sample contribute to this irregular pattern. Nevertheless, this assumption needs further study to be confirmed.

The T/R shrinkage ratio values of samples from the top part of the trees from all provenances generally were less or close to 2, and lower than those for samples from bottom-part of the trees (Figure 7). This particular result indicates the dimension of samples from top-part of the trees will be possibly more stable during uses or drying process.

The tendency of top – part samples to have lower T/R values than their bottom – part samples is actually unforeseen previously. However, to recall, as shown in Figure 4 and Figure 6 previously, the top –part samples of all provenancos generally have lower moisture content and higher density than or similar to their bottom – part counterpart samples. Therefore, it can be understood why top-part samples have lower T/R shrinkage ratio than the bottom – part samples.
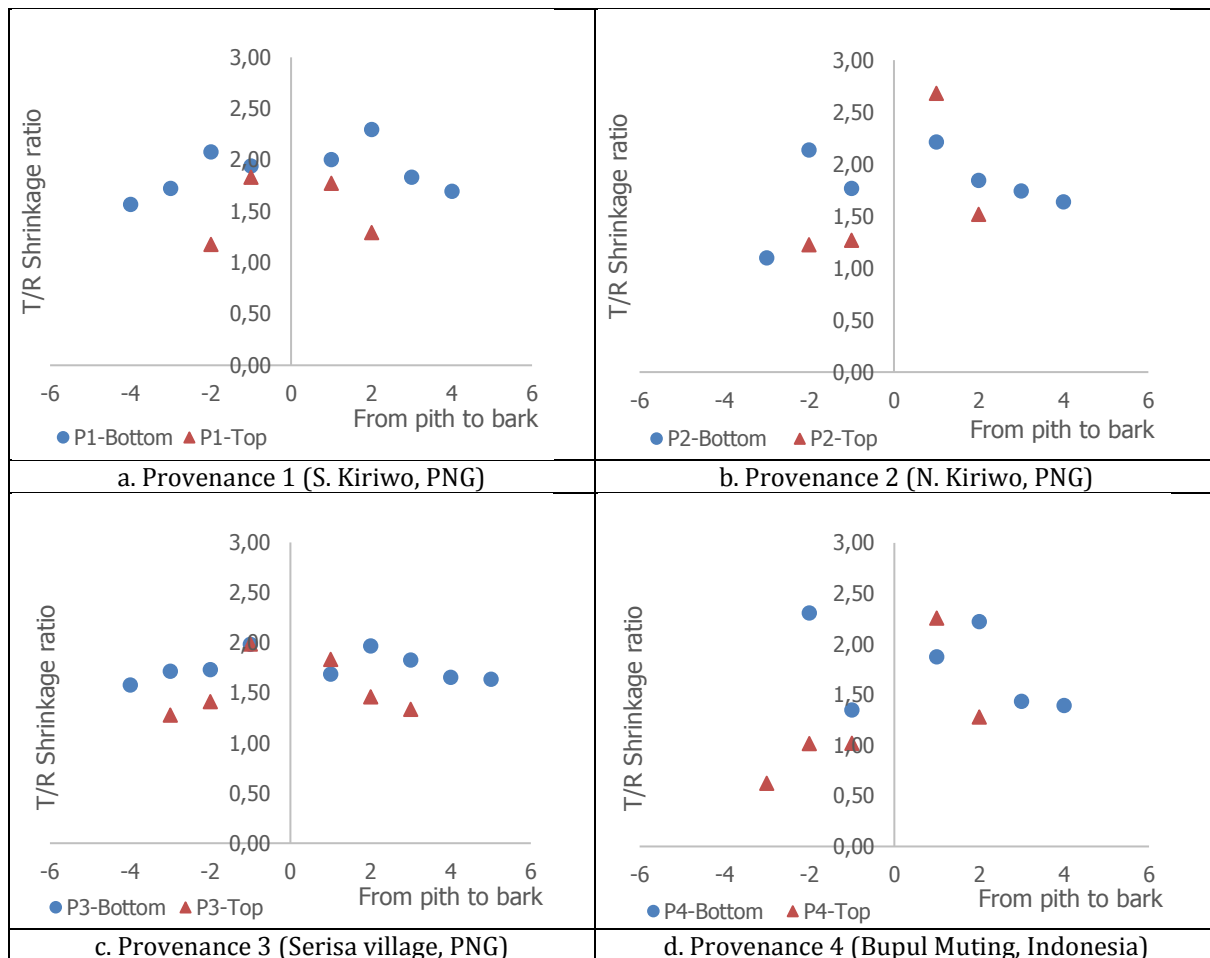
The T/R value, as well as density, is rarely being taken into formal, consideration when the suitability of a specific wood species for any construction purpose is being evaluated. Whilst the requirement for moisture content is often set up to 14% in any national standards related to the use of sawn timber, the same treatment is not given for density or T/R values. Considering the density of wood will affect its strength and T/R value will govern its dimensional stability, these 2 parameters should be given sufficient attention in any standards. As a matter of fact, these 2 parameters could act as a quick, initial estimator in deciding which wood species will be proper for heavy or light construction.

Table 10. ANOVA test result to investigate the factors affecting the T/R shrinkage ratio of *E. pellita.*
Tabel 10. *Hasil uji ANOVA untuk memeriksa faktor-faktor yang mempengaruhi rasio penyusutan T/R E. pellita.*

Source of variation (Sumber keragaman)	Degree of freedom (Derajat bebas)	Seq sum square (Jumlah kuadrat)	Adj sum square (Jumlah kuadrat disesuaikan)	Adj mean square (Kuadrat tengah disesuaikan)	F-value (Nilai F)	P-value (Nilai P)
Provenance (Provenan)	3	0,0481	0,0620	0,0207	0,20	0,897
Sampling (Pengambilan sampel)	1	0,3708	0,3641	0,3641	3,45	0,096
Provenance * sampling (Provenan*pengambilan sampel)	3	0,1017	0,1017	0,0339	0,32	0,810
Error (Galat)	9	0,9509	0,9509	0,1057		
Total (Total)	16	1,4715				

Remarks (Keterangan): S = 0,325049   R-Sq = 35,38%   R-Sq(adj) = 0,00%

a. Provenance 1 (S. Kiriwo, PNG)

b. Provenance 2 (N. Kiriwo, PNG)

c. Provenance 3 (Serisa village, PNG)

d. Provenance 4 (Bupul Muting, Indonesia)

Remarks: 0 at X-axis indicates pith; (-) sign at X-axis indicates opposite direction from the pith; Number 2 at X-axis indicates 40 mm distance from pith; 4 indicates 80 mm distance from pith; 6 indicates 100 mm distance from pith.
*Keterangan: 0 pada sumbu X mencirikan empulur; tanda (-) pada sumbu X mencirikan arah yang berlawanan dari empulur; Angka 2 pada sumbu X mencirikan jarak 40 mm dar*i *empulur; 4 mencirikan jarak 80 mm dari empulur; 6 mencirikan jarak 100 mm dari empulur*

Figure 7. T/R ratio distribution from pith to bark in trees from each provenance of *E. pellita*
Gambar 7. *Distribusi rasio T/R dari empulur ke kulit kayu E. pellita dari setiap provenan*

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

This study showed that the bottom-part of *E. pellita* samples from all provenances have higher green or initial moisture content but lower T/R ratio than the top-part samples. However, the density of both parts and all provenances is not significantly different.

Samples from provenance 4 (Bupul muting, Indonesia) have the highest initial moisture content ranges(97 – 34 ± 15,67% for the bottom – part samples and 89.21 ± 19.24% for the top – part sample), whilst the lowest range is observed in provenance 3 sample. The highest air – dry moisture content range (15.15 ± 0.20) is observed in the top – part samples of provenance 4.

Samples from provenance 3 (Village, PNG) have the highest density ranges (approximatply 590 ± 90 kg /m3 for the bottom – part samples 630 ± 80 kg /m3 for the top – part samples) and the lowes density range is found for provenance 4 samples. The highest T/R shrinkage ratio (1.91 ± 0.26) is obseved for the bottom – part samples of provenance1 (S.Kiriwo, PNG) and the lowest one is in the top – part samples from provenance 4.

Provenance factor significantly affects the initial moisture content and density of *E. pellita*. The sampling position on the tree only affects the initial moisture content but not other response variables.

B. Recommendation

Samples from all provenances have the average T/R ratio of less than 2, indicating it will be resistant to deformation or any dimensional change during the drying process. As a further consequence, those provenances are also potential for lumber production. Their density value ranges make *E. pellita* from the 4 provenances grouped

into strength class II-III and possibly suitable for light-to-medium-strength construction purpose. Further study to obtain information on proper drying schedule and process/technique for this species will be required in order to support its use for construction purposes.

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