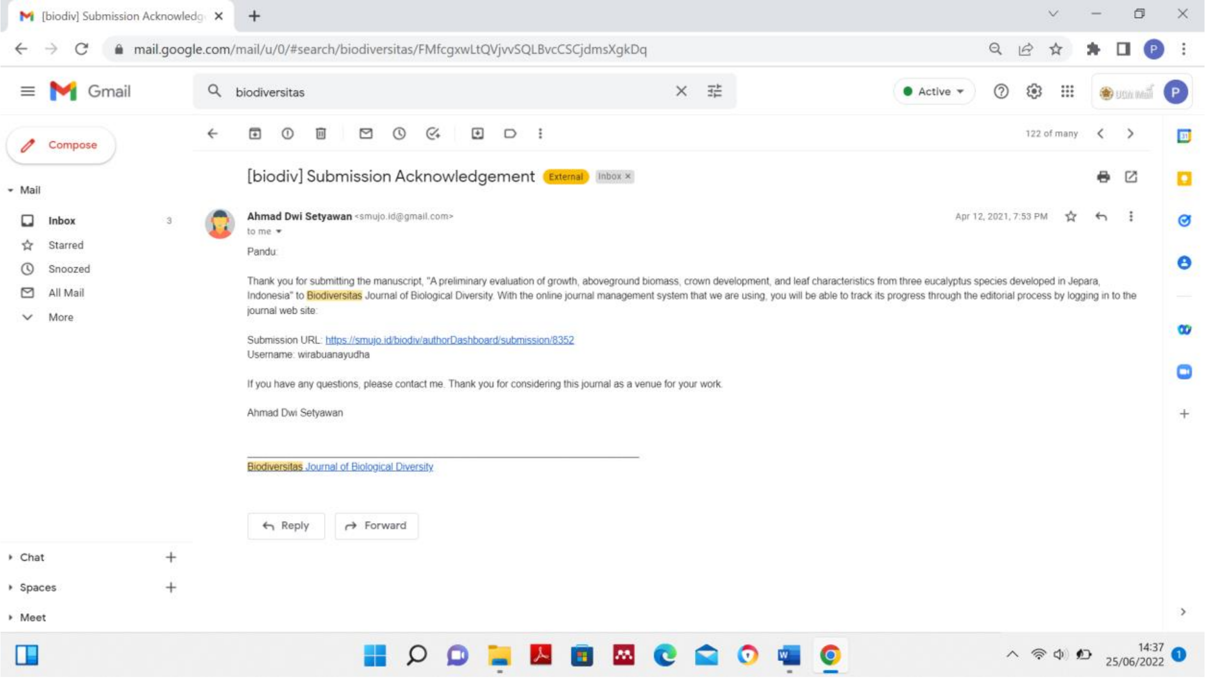
BUKTI KORESPONDENSI
ARTIKEL JURNAL INTERNASIONAL BEREPUTASI

Judul Artikel	:	The growth, aboveground biomass, crown development, and leaf characteristics of three Eucalyptus species at initial stage of planting in Jepara, Indonesia
Link	:	https://doi.org/10.13057/biodiv/d220550
Jurnal	:	Biodiversitas Journal of Biological Diversity
Volume	:	22
Issue	:	5
Halaman	:	2859-2869
Penulis	:	Pandu Yudha Adi Putra Wirabuana, Syamsu Alam, Jeriels Matatula, Moehar Maraghiy Harahap, Yusanto Nugroho, Fahmi Idris, Alnus Meinata, Dewa Ayu Sekar

No.	Perihal	Tanggal
1.	Bukti konfirmasi submit artikel dan draft artikel yang disubmit	12 April 2021
2.	Bukti keputusan editor, artikel hasil review, dan artikel perbaikan tahap 1	22 April 2021
3.	Bukti accepted	24 April 2021

BUKTI SUBMIT MANUSCRIPT 12 APRIL 2021



[biodiv] Submission Acknowledgement

Ahmad Dwi Setyawan <smujo.id@gmail.com>
to me

Apr 12, 2021, 7:53 PM

Pandu:

Thank you for submitting the manuscript, "A preliminary evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia" to Biodiversitas Journal of Biological Diversity. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Submission URL: https://smujo.id/biodiv/authorDashboard/submission/8352
Username: wirabuanayudha

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

COVERING LETTER

Dear **Editor-in-Chief,**

I herewith enclosed a research article,

Title:

A preliminary evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia

Author(s) name:

Pandu Yudha Adi Putra Wirabuana, Syamsu Alam, Jeriels Matatula, Moehar Maraghiy Harahap, Yusanto Nugroho, Fahmi Idris, Alnus Meinata, Dewa Ayu Sekar Pratiwi

Address

(Fill in your institution's name and address, your personal cellular phone and email)

Department of Forest Management, Faculty of Forestry, Universitas Gadjah Mada, Jln. Agro No.1 Bulaksumur, Yogyakarta, Indonesia. Phone. +6281-2268-87738 Email. pandu.yudha.a.p@ugm.ac.id

For possibility publication on the journal:

(fill in *Biodiversitas* or *Nusantara Bioscience* or *mention the others*)

Biodiversitas

Novelty:

(state your claimed novelty of the findings versus current knowledge)

This study aimed to evaluate the growth, biomass accumulation, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia. Sixteen parameters were used to assess the performance of eucalyptus, including survival, height, diameter, biomass distribution (stem, branches, and foliage), total aboveground biomass, crown radius, crown length, crown ratio, crown projection area, individual leaf area, individual leaf dry weight, specific leaf area, leaf mass area, and leaf area index. Results found all measured parameters demonstrated a significant difference, exception for survival, foliage biomass, and crown ratio. Among those species, the initial performance of *E. pellita* was substantially better than others even though it had the lowest value for foliage biomass, individual leaf area, individual leaf dry weight, and specific leaf area. It exhibited the highest height, diameter, and total aboverground biomass. Higher performance of *E. pellita* was supported by more effective photosynthesis process in this species which indicated by bigger leaf area index. Moreover, compared to *E. alba* and *E. urophylla*, the environmental condition in the study area, especially related to altitude and slope, was more suitable for *E. pellita*. Nevertheless, a continuous monitoring was still required to assess the consistent performance of those species.

Statements:

This manuscript has not been published and is not under consideration for publication to any other journal or any other type of publication (including web hosting) either by me or any of my co-authors.
Author(s) has been read and agree to the Ethical Guidelines.

List of five potential reviewers

(Fill in names of five potential reviewers **that agree to review your manuscpt** and their **email** addresses. He/she should have Scopus ID and come from different institution with the authors; and from at least three different countries)

1. Joko Ridho Witono / Indonesian Institute of Science / Scopus ID 19436718100 / jrwitono@yahoo.com
2. Aah Ahmad Almulqu / Politeknik Pertanian Negeri Kupang / Scopus ID 57200964657/ ahmadalmulqu@yahoo.com
3. Mamoru Kanzaki / Kyoto University / Scopus ID 7006880712 / mkanzaki@kais.kyoto-u.ac.jp
4. Sapit Diloksumpun / Kasetsart University / Scopus ID 13407859400 / sapit.d@ku.ac.th
5. Mohammad Basyuni / Universitas Sumatra Utara / Scopus ID 15055287200 / m.basyuni@usu.ac.id

Place and date:

Yogyakarta, 5 April 2021

Sincerely yours,

(fill in your name, no need scanned autograph)

Pandu Yudha Adi Putra Wirabuana

A preliminary evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia

PANDU YUDHA ADI PUTRA WIRABUANA[1,♥], SYAMSU ALAM[2], JERIELS MATATULA[3], MOEHAR MARGHIY HARAHAP[4], YUSANTO NUGROHO[5], FAHMI IDRIS[6], ALNUS MEINATA[6], DEWA AYU SEKAR[6]
[1]Department of Forest Management, Faculty of Forestry, Universitas Gadjah Mada, Jln. Agro No. 1 Bulaksumur, Sleman 55281, Yogyakarta, Indonesia.
Tel./Fax.: +62-274-548815, ♥email: pandu.yudha.a.p@ugm.ac.id
[2]Department of Soil Science, Faculty of Agriculture, Universitas Halu Oleo, Jl. HEA Mokodompit, Kendari 93231, Southeast Sulawesi, Indonesia
[3]Forestry Field Program, Politeknik Pertanian Negeri Kupang, Jl. Prof. Herman Johanes, Lasiana, Kupang 85011, East Nusa Tenggara, Indonesia
[4]Department of Forest Conservation, Faculty of Forestry, Universitas Sumatera Utara, Medan Baru, Medan 20155, North Sumatra, Indonesia
[5]Faculty of Forestry, Universitas Lambung Mangkurat, South Banjarbaru, Banjarbaru 70714, South Kalimantan, Indonesia
[6]Department of Research and Development, Trofsit Institute, Banguntapan, Bantul 55798, Indonesia

Manuscript received: 05 04 2021. Revision accepted: .... 2021.

Abstract. Industry development, climate change mitigation and renewable energy currently become the most essential challenge in tropical forest management, primarily in Indonesia. The existence of tropical forests is not only managed to maintain the stability of wood supply for commercial industries but also to reduce greenhouse gas emissions in the atmosphere and to generate energy alternatives from tree biomass. To answer this challenge, the development of fast-growing species like eucalyptus can become a good solution. However, the productivity of eucalyptus depends on its adaptability to the site condition. Therefore, understanding site-species interaction becomes the fundamental requirement before planted on a large scale. This study aimed to evaluate the initial performance of eucalyptus species developed in Jepara. An experiment consisted of three different eucalyptus species, i.e. *E. alba*, *E. pellita*, and *E. urophylla*, was established using a randomized complete block design. Sixteen parameters were selected to assess the eucalyptus performance, including survival, height, diameter, biomass accumulation (stem, branches, foliage, and total aboveground), crown length, crown radius, crown projection area, crown ratio, individual leaf area, individual leaf dry weight, specific leaf area, leaf mass area, and leaf area index. Comparison mean of tree attributes from each species was examined using ANOVA, followed by HSD Tukey. Results showed all measured parameters indicated a significant difference among the three species ($p<0.05$), except for survival, foliage biomass, and crown ratio ($p>0.05$). The preliminary performance of *E. pellita* was relatively better than other species, mainly related to height (3.00±0.21 m), total aboveground biomass (49.86±3.60 kg ha^{-1}), crown projection area (2.68±0.27 m^2), and leaf area index (5.76±0.44). Our study concluded the initial performance of *E. pellita* in Jepara was substantially superior to *E. alba* and *E. urophylla*. Nevertheless, continuous evaluation was need to monitor the consistent performance those species in the study area.

Key words: Crown projection area, eucalyptus, leaf area index, leaf mass area, specific leaf area

Running title: Preliminary evaluation of eucalyptus species

INTRODUCTION

Integration of industry development, climate change mitigation, and renewable energy diversification currently become the most important challenge in tropical forest management (Sadono et al. 2021a), including in Indonesia. The existence of tropical forests is not only managed to stabilize wood supply for commercial industries but also to minimize carbon emissions in the atmosphere (Sasaki et al. 2016) and to generate energy alternatives from tree biomass (Ferreira et al. 2017). To tackle this challenge, the development of fast-growing species can become a realistic solution for supporting the fundamental role of tropical forest in maintaining industry viability, reducing carbon emissions, and resulting bioenergy (González-García et al. 2016). During last periods, there are several fast-growing species that planted in plantation forests at the tropics, one of which is eucalyptus.

The establishment of eucalyptus as a primary species in plantation forests has been widely conducted in many tropical countries, such as Brazil, Chile, Colombia, Mexico, Thailand, Vietnam, and Indonesia (Aggangan et al. 2013, Hakamada et al. 2017, Acuña et al. 2018, Amezquita et al. 2018, Van Bich et al. 2019, Wirabuana et al. 2020a). Besides having a short rotation by approximately 5-8 years (Little et al. 2018), The quality of eucalyptus wood is also suitable as raw materials for industries, like construction, pulp and paper, plywood, veneer, and furniture (Forrester 2013, Hii et al. 2017, Nambiar et al. 2018). In addition, the majority of eucalyptus species also have rapid growth due to the more efficient photosynthesis process (Lewis et al. 2011, Lima et al. 2019). It indicates the carbon absorption in eucalyptus is relatively faster than slow-growing species (Kaul et al. 2010). Therefore, the previous studies also report that the existence of eucalyptus plantations provides a significant contribution to encouraging climate change mitigation (Magalhães et al. 2020). Furthermore, a study explains the eucalyptus wood can become a source of renewable energy since it has a high calorific value of 4,532-4,661 kcal kg^{-1} (Simetti et al. 2018). The use of eucalyptus wood for bioenergy has been conducted in some foreign countries, like Brazil, Spain, and Portugal, wherein the development of biomass power plants has been intensively managed (Barreiro & Tomé 2012, González-García et al. 2016, Cavalett et al. 2018). A study confirms the use of plant biomass, mainly from eucalyptus, results in lower carbon emissions to the atmosphere than fossil fuels like coal as well as oil and gas (Cavalett et al. 2018). This fact demonstrates this species is highly potential developed as a strategy to tackle the integration of industry development, climate change mitigation, renewable energy diversification in tropical countries, particularly in Indonesia.

The cultivation of eucalyptus in Indonesia is prospective because it is a native species from this country. Some studies explain there are several eucalyptus species that naturally distributed in the eastern of Indonesia, such as *E. pellita*, *E. alba*, and *E. urophylla* (Stanturf et al. 2013, Prasetyo et al. 2017). However, the existence of eucalyptus plantation in Indonesia is still limited wherein most eucalyptus estates are located in Sumatra (Nambiar et al. 2018). Moreover, the objective of eucalyptus management in Indonesia still focuses on supplying raw materials for pulp and paper industry (Prasetyo et al. 2017). This circumstance is quite different from other countries like Brazil, China, and Vietnam in which the presence of eucalyptus plantation becomes the most important plantation forests in those countries and has many processing industries for eucalyptus wood. It indicates there is a wide opportunity to develop eucalyptus plantations in Indonesia by expanding its area nor improving its downstream industries. However, to obtain high productivity of eucalyptus stand, understanding about site-species interaction is basically required before doing the planting activities on a large scale. It is commonly done by establishing an experiment for species trial in several sites which become the priority area for eucalyptus development. In this context, the best species is selected by considering its superior performance to other eucalyptus species.

This study examined the adaptability of three different eucalyptus species planted in the Jepara District. A preliminary evaluation was undertaken to monitor the growth, aboveground biomass, crown development, and leaf characteristics of those three species at six months after planting. It is a critical period to assess the suitability of species to survive in the site condition (Van Bich et al. 2019, Stuepp et al. 2020, Wirabuana et al. 2020a) since every eucalyptus species has a habitat preference to support its growth and development. if site condition is not suitable, the species will demonstrate a high mortality rate and low growth performance (Thompson 2013, Maimunah et al. 2018, Aguilos et al. 2020). The species trial of eucalyptus was built in Jepara because this town has a number of wood processing industries, especially for furniture. Moreover, there are several other forestry industries located near this town such as pulp and paper, plywood, veneer, and construction that require a continuous supply for wood demand. Interestingly, Jepara has also a power plant that faces a problem related to the coal deficit. This situation provides an opportunity to maximize the potential of eucalyptus for bioenergy. On another side, the development of eucalyptus plantation in Jepara is still not be conducted until now, even though this species offers a lot of advantages. Most importantly, the effort of eucalyptus establishment in Jepara is not only directed to support the integration of industry development, climate change mitigation, and renewable energy but also to facilitate the program of Ex situ conservation and to optimize the potential of native species from Indonesia.

MATERIALS AND METHODS

Study area

A species trial was established in community forests located at Srobyong, Jepara District. It had geographic position in S6°31'35"-6°31'37" and E110°41'39"-110°43'22" (Figure 1). The species trial was set up in private land of farmers with a large area of 2 ha. Altitude reached 70 m above sea level. Topography was flat with a slope level of 3-8%. The average daily temperature was 29°C with a minimum of 22°C and a maximum of 34°C. Annual rainfall varied from 2,246 to 2,446 mm $year^{-1}$ during the last five years from 2016 to 2020. The majority of rainfall was recorded in February around 33.82% of total rainfall in a year. Dry periods occurred for 5 months from May to September. The mean air humidity reached 84%. Soil type was predominantly by alfisol with having acidity level of 5.5 to 6.0. Before becoming a site for species trial, the vegetation cover consisted of uneven-aged mixed species with irregular distribution and high variation in growth.

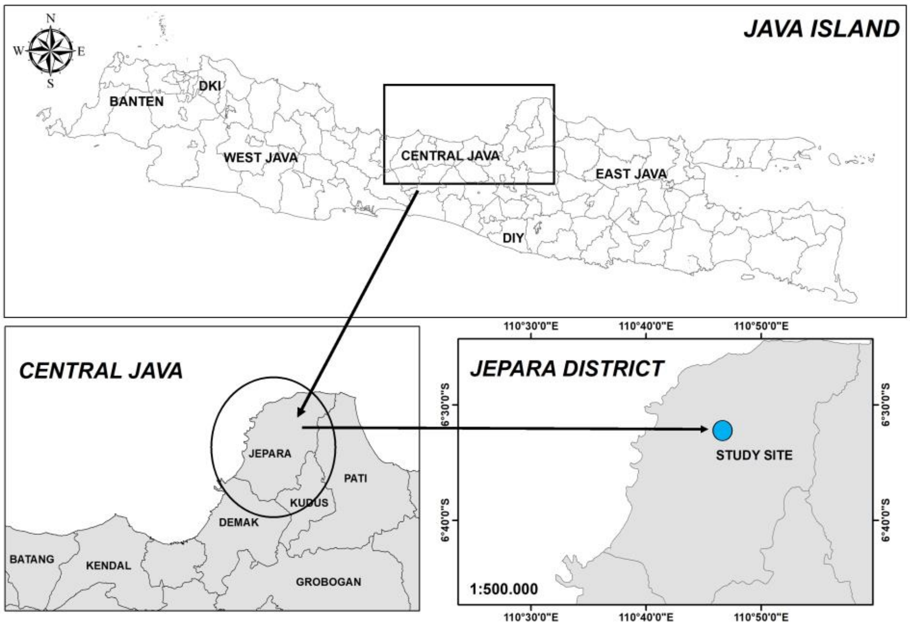
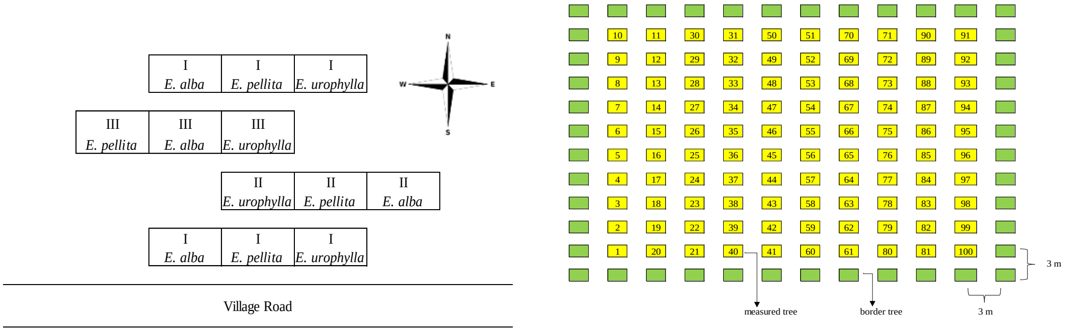


Figure 1. Study area of species trial for eucalyptus development in Jepara District. The blue symbol indicated site for trial establishment

Experimental design

The species trial was established in a randomized complete block design (RBCD) with four blocks, consisting of three blocks for continuous monitoring and one block for destructive measurement in specific periods, namely 6, 12, 24, 36, 48, and 60 months. This design was selected to minimize the influence of environmental gradient on eucalyptus performance (Thompson 2013). It was importantly conducted to avoid the biased result due to the impact of site condition, particularly related to soil quality. There were three different eucalyptus species examined in this study, i.e. *E. alba*, *E. urophylla*, and *E. pellita*. Each species was planted in a square plot of 0.1 ha comprising 100 measured trees and 44 border trees (Figure 2). The principal function of border trees was to indicate the clear boundaries among treatments in every block. Moreover, to support the activity of monitoring, a nameplate was placed in each treatment plot using a specific code. Every measured tree was also marked by a number identity.



(a) (b)

Figure 2. The layout of experimental design in the study area for evaluating the performance of eucalyptus stand from three different species established in Jepara District. (a) the position of every treatment in each block and (b) the position of measured and border trees in every treatment plot.

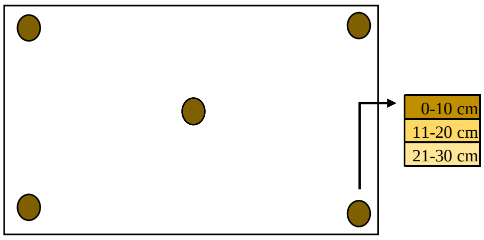


Figure 3. The distribution of five sample points for collecting soil sample in the site experiment. The brown circle indicated the sampling location for taking soil sample..

This trial was established in August 2020. The site preparation was implemented to identify the variation of environmental gradient before determining the layout of experimental design. It was exceptionally required to create a homogeneous condition in each block for minimizing the influence of environmental gradient on treatment plots (Gonçalves et al. 2010). The activity of site preparation consisted of several stages, like measuring slope variation, observing waterlog, identifying wind disturbance, and assessing soil quality (Wirabuana et al. 2020a). To facilitate the soil quality assessment, soil sampling was collected in five different points at three depth layers of 0-10 cm, 11-20 cm, and 21-30 cm (Li et al. 2018, Wirabuana et al. 2019, Sadono et al. 2021b) (Figure 3). Then, the sample was composited and brought to the laboratory for quantifying its characteristics, namely soil acidity, soil organic carbon, total nitrogen, available phosphorus, total potassium, and cation exchange capacity (Table 1). Soil acidity was measured using pH meter. The quantification of soil organic carbon was conducted using Walkey and Black method. Total nitrogen was estimated by Kjeldahl method. The analysis of available phosphorus was executed using Olsen method. The method of flame photometry was utilized to calculate the total potassium. The use of ammonium acetate method was applied to quantify the content of cation exchange capacity. The protocol of soil analysis was conducted referring to the guide for methods of soil, plant, and water analysis published by Estefan et al. (2013).

Table 1. Soil characteristics in the site experiment quantified by soil acidity, soil organic carbon, total nitrogen, available phosphorus, total potassium, and cation exchange capacity. Data were presented in mean±standard deviation

Soil parameters	Symbol	Units	Value	Categories
Soil acidity	pH	-	6.00±0.86	Slightly acid
Soil organic carbon	SOC	%	2.97±0.37	Moderate
Total nitrogen	N-tot	%	0.17±0.01	Low
Available phosphorus	Av-P	ppm	2.79±1.54	Very low
Total potassium	K-tot	cmolc kg^{-1}	0.21±0.12	Very low
Cation exchange capacity	CEC	cmolc kg^{-1}	10.11±3.14	Low

Note: the classification of soil quality was determined following the soil quality categories reported by (Nandini & Narendra 2017)

The plant material of *E. alba*, *E. urophylla*, and *E. pellita* used in this study was from different provenance since every species has different natural distribution. *E. alba* and *E. urophylla* were from provenance Timor, East Nusa Tenggara. Meanwhile, *E. pellita* was from provenance Muting, Papua. The seed was sown in the nursery for 90 days. In parallel, soil tillage was conducted to improve soil structure at 2 weeks before field planting. A week before establishment, the grading activity was undertaken to determine the quality of seedlings from each species. In this case, only seedlings with a height of 30 cm and having healhty condition were used as plant materials for planting. Seedlings were planted by initial spacing 3 m x 3 m. The addition of fertilizer (NPK 15:15:15) was also provided for every seedling with a dose of 100 g. It was applied to increase the availability of nutrients for eucalyptus because the site experiment had a low content of nitrogen, phosphorus, and potassium in the soil. Moreover, several studies reported eucalyptus is highly responsive to phosphorus availability since it was a macronutrient exceptionally required by this plant (Amezquita et al. 2018, Bassaco et al. 2018, Sadono et al. 2021b). To support the early growth of eucalyptus, the application of weed control was also implemented by slashing and chemical spraying at 3 and 6 months after planting.

Data Collection

Data were collected at 6 months after planting. This period was frequently used by most plantation forests company in Indonesia to conduct the first evaluation of species trials (Wirabuana et al. 2019). It was also supported by the previous studies reported that the period was a critical moment to assess the adaptability of species to environmental conditions outside their natural habitat (Stuepp et al. 2020). The process of data collection was conducted from March to April 2021. It consisted of several activities, i.e. stand measurement, destructive sampling, and laboratory analysis. Sixteen parameters were selected to evaluate the eucalyptus performance from three different species, including survival, height, diameter, biomass production (stem, branches, foliage, and total aboveground), crown length, crown radius, crown projection area, crown ration, individual leaf area, individual leaf dry weight, specific leaf area, leaf mass area, and leaf area index.

Survival was defined as the ratio of actual density and initial planting density. Height was measured from aboveground to top crown using a measuring pole (Halomoan et al. 2015). Diameter was measured at 0.3 m aboveground by a caliper (Wirabuana et al. 2019). The crown length was quantified from crown base to top crown while crown ratio was calculated as the ratio between crown length and tree height. Crown radius was computed as the quadratic mean crown radius at eight directions (eq.1) (Wirabuana et al. 2019). The transition from crown radius to crown projection area was determined by the occupation area of every tree (eq.2) (Pretzsch et al. 2015).

$$CR = \left(\left(R_N^2 + R_{NE}^2 + \ldots + R_{NW}^2\right) / 8\right)^{1/2} \qquad (1)$$

$$CPA = \pi \times CR^2 \qquad (2)$$

wherein *CR* was a quadratic mean crown radius every tree (m), *R* represented crown radius in certain direction (m), and *CPA* described crown projection area of each tree (m^2).

To quantify biomass accumulation and leaf characteristics of each species, destructive sampling was conducted step by step in a chronological manner. Each species was represented by five sample trees. Those sample trees were determined by considering the distribution of diameter. It aimed to obtain the balance growth dimension from small to big trees (Sadono et al. 2021a). In this study, the diameter was classified into three classes, including small (1.0-1.9 cm), medium (2.0-2.9 cm), and big (3.0-3.9 cm). After the sample tree was felled, the tree component was separated into stem, branches, and foliage. For part of foliage, the sample also stratified into three layers based on leaves position, i.e. base, middle, and top. It was conducted to facilitate the measurement of leaf characteristics. From every layer, ten leaf samples were taken randomly. Thereby, the number of sample for determining leaf attributes in each sample tree was 30 samples.

The fresh weight of each component was measured in the field using a hanging balance. Afterward, approximately 500 g subsample from each part was taken and brought to the laboratory for dried. Before starting the drying process, the area of selected leaf samples was measured using a planimeter. Then, the subsample of each component (including the selected leaf samples) was dried using an oven for 48 hours at 70°C before measuring their dry weight (Hakamada et al. 2017). The biomass accumulation in each component was calculated by multiplying the ratio of dry-fresh weight from subsample with the total fresh weight of each part from field measurement (eq.3) (Altanzagas et al. 2019) while total aboveground biomass for each individual tree was calculated by summing the biomass distribution in stem, branches, and foliage (eq.4) (Rance et al. 2017).

$$W_c = (DW_s / FW_s) \times FW_c \tag{3}$$

$$W_t = W_{stem} + W_{branches} + W_{foliage} \tag{4}$$

wherein W_c was biomass from every tree component like stem, branches, or foliage (kg), DW_s described the dry weight of subsample (kg), FW_s indicated the fresh weight of sub sample (kg), FW_c was the total fresh weight of tree component (kg), and W_t signified total aboveground biomass of individual tree (kg). Then, the result of destructive sampling was converted to estimate the biomass production of eucalyptus stand from every species in treatment plots.

To measure the leaf characteristics, the dry weight of each selected leaf sample was determined using a digital analytic scale. The specific leaf area was calculated based on the ratio of leaf area and leaf dry weight (eq.5) (Hakamada et al. 2016). In opposite condition, leaf mass area was computed by dividing leaf dry weight and leaf area (eq.6) (De La Riva et al. 2016). Leaf area index from each sample tree was quantified following this equation (eq. 7) (Wirabuana et al. 2019).

$$SLA = LA / LW \tag{5}$$

$$LMA = LW / LA \tag{6}$$

$$LAI = (W_{foliage} \times SLA) / CPA \tag{7}$$

wherein SLA was specific leaf area (m^2 kg^{-1}), LMA represented leaf mass area (kg m^{-2}), LA described individual leaf area (cm^2), LW was individual leaf dry weight (g), and LAI indicated leaf area index.

Data Analysis

Statistical analysis was processed using software R version 4.0.2 with a significant level of 5%. The package agricolae was used to facilitate the process of data analysis. Descriptive test was applied to identify the data characteristics, primarily related to minimum, maximum, mean, standard deviation, and coefficient of variation. It aimed to assess the accuracy and precision of data collected from stand measurement, destructive sampling, and laboratory analysis. The normality of data was evaluated using Shapiro-Wilk test. Homogeneity variance among treatments were examined using Bartlett's test. The comparison means eucalyptus performance among three species for each parameter was tested using ANOVA followed by HSD Tukey. The analysis of correlation using a pallete matrix was also done to evaluate the relationship between observed parameters.

RESULTS AND DISCUSSION

Growth Performance

The survival among species did not significantly differ ($p>0.05$) (Table 2). Each species had a survival more than 80%. It indicated every species had a good tolerance to the environmental condition in the study area. The highest survival was recorded in *E. alba* (90.4±2.19%), followed by *E. pellita* (89.6±3.57%) and *E. urophylla* (88.8±5.21%). In the context of plantation forest management, survival was an essential indicator to evaluate the species performance since it determined the number of trees that could be harvested at the end of the rotation (Truax et al. 2018). This parameter also directly affected land cover and tree competition at the stand level (Kweon & Comeau 2019). Moreover, the plant survival also had a strong relationship to the efficiency of planting cost for establishing plantation forests. The development of species in the plantation forest required a high survival to obtain an optimum stand productivity because it become a multiplier factor to estimate the wood volume and biomass production in hectare unit.

Table 2. Comparison means growth, aboveground biomass, crown development, and leaf characteristics of three different eucalyptus species established in Jepara District. Data were demonstrated in mean ± standard deviation

Group variables	Measured parameters	Units	Species			*p-value*
			E. alba	*E. pellita*	*E. urophylla*	
Growth	Survival	%	90.4±2.19a	89.6±3.57a	88.8±5.21a	0.958^{ns}
	Height	m	2.82±0.25a	3.00±0.21a	1.87±0.29b	$<0.001^{*}$
	Diameter	cm	2.31±0.19a	2.39±0.19a	1.62±0.15b	$<0.001^{*}$

Aboveground biomass	Stem biomass	kg ha^{-1}	16.58±2.75ab	17.25±3.12a	12.01±2.56b	0.024^{*}
	Branches biomass	kg ha^{-1}	11.15±1.90a	12.10±1.91a	6.78±1.11b	$<0.001^{*}$
	Foliage biomass	kg ha^{-1}	21.40±2.24a	20.50±2.40a	24.16±2.33a	0.069^{ns}
	Total Aboveground biomass	kg ha^{-1}	49.14±2.80a	49.86±3.60a	42.96±3.30b	0.010^{*}
Crown development	Crown radius	m	0.86±0.05a	0.90±0.04a	0.64±0.06b	$<0.001^{*}$
	Crown length	M	2.15±0.16a	2.27±0.14a	1.52±0.19b	$<0.001^{*}$
	Crown projection area	m^{2}	2.47±0.29a	2.68±0.27a	1.42±0.28b	$<0.001^{*}$
	Crown ratio	-	0.93±0.02a	0.95±0.04a	0.93±0.04a	0.763^{ns}
Leaf characteristics	Individual Leaf area	cm^{2}	64.27±2.91b	63.30±3.67b	78.52±8.66a	0.001^{*}
	Individual Leaf dry weight	g	0.80±0.02b	0.79±0.04b	0.92±0.08a	0.007^{*}
	Specific leaf area	m^{2} kg^{-1}	7.93±0.13b	7.91±0.17b	8.41±0.14a	$<0.001^{*}$
	Leaf mass area	kg m^{-2}	0.12±0.002a	0.12±0.002a	0.11±0.002b	$<0.001^{*}$
	Leaf area index	-	5.39±0.52a	5.76±0.44a	3.40±0.61b	$<0.001^{*}$

Note: the symbol * indicated a significant different among species based on ANOVA test while the symbol ^{ns} showed a non significant different among species referring to ANOVA test. A similar letter in row indicated the parameter between species was not significantly different according to HSD Tukey test.

Even though survival was not significantly different among species, this study found there was a significant difference in height and diameter from three eucalyptus species ($p<0.05$) (Table 2). *E. pellita* showed higher height and diameter than *E. alba* and *E. urophylla*. This finding verified the land characteristics in the study site were more suitable to *E. pellita* than other species. It was also supported by the previous studies explained that *E. pellita* was a species naturally distributed in the lowland area with a range altitude of 0-700 m above sea level (Hung et al. 2015). This species preferred a soil acidity in the range of 5.0-6.0 (Harwood et al. 1997). According to the site description, the study area was classified as a lowland area because it had an altitude of 70 m above sea level. Moreover, the soil acidity of study area was also categorized into slightly acid with pH of 6.00±0.86 (Table 1). This biophysical condition principally supported the site requirement for *E. pellita* development.

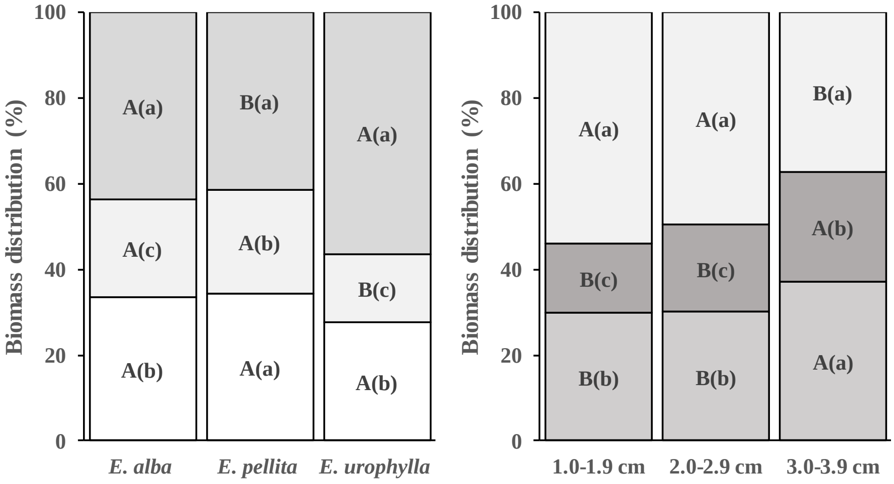
Biomass Accumulation

Biomass production from three species relatively varied (Table 2). Our study recorded the accumulation of biomass in stem, branches, and total aboveground differed significantly ($p<0.05$). In opposite conditions, the biomass distribution in the foliage component was not significantly different ($p>0.05$). The greatest total aboveground biomass was observed in *E. pellita* (49.86±3.60 kg ha^{-1}), followed by *E. alba* (49.14±2.80 kg ha^{-1}), and *E. urophylla* (42.96±3.30 kg ha^{-1}). The similar pattern was also found in stem and branches biomass. Interestingly, *E. pellita* had a lower accumulation of foliage biomass (20.50±2.40 kg ha^{-1}) than *E. alba* (21.40±2.24 kg ha^{-1}) and *E. urophylla* (24.16±2.33 kg ha^{-1}). It was caused by the lower value of leaf area and leaf dry weight in this species (Table 2).

This study found that the largest biomass distribution for all species at 6 months after field planting was observed in the foliage (41-56%), followed by stem (28-34%) and branches (16-24%) (Table 3). In general, the biomass allocation in each tree component from every species differed significantly (Figure 4). However, the relative contribution of stem biomass to total biomass among three species was statistically equal. In contrast, the percentage contribution of foliage and branches biomass to total biomass was highly different among those species. Suprisingly, our study also demonstrated that biomass proportion in stem and branches gradually improved along with the increasing of diameter classes while the distribution of biomass in foliage progressively declined with the increment of diameter classes.

Table 3. Ratio of the biomass of stem, branches, and foliage to the total aboveground biomass from sample tree. Data were presented in mean, standard deviation, range.

Species	Stem biomass/AGB			Branches biomass/AGB			Foliage Biomass/AGB		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
E. alba	0.34	0.04	0.28-0.38	0.23	0.03	0.18-0.25	0.44	0.07	0.37-0.54
E. pellita	0.34	0.04	0.30-0.40	0.24	0.02	0.21-0.28	0.41	0.07	0.33-0.49
E. urophylla	0.28	0.04	0.25-0.33	0.16	0.02	0.13-0.19	0.56	0.06	0.50-0.62
Total	0.32	0.05	0.25-0.40	0.21	0.04	0.13-0.28	0.47	0.09	0.33-0.62



(a) (b)

Figure 4. (a) Comparison of biomass distribution in every tree component from different eucalyptus species; (b) Relative contribution of biomass in every tree component to total aboveground biomass across diameter classes. A similar big letter demonstrated there was not significantly difference in biomass accumulation in the same component at different species and diameter classes. The similar small letter indicated that there was not a significant difference of biomass proportion among tree components at the same species and diameter classes.

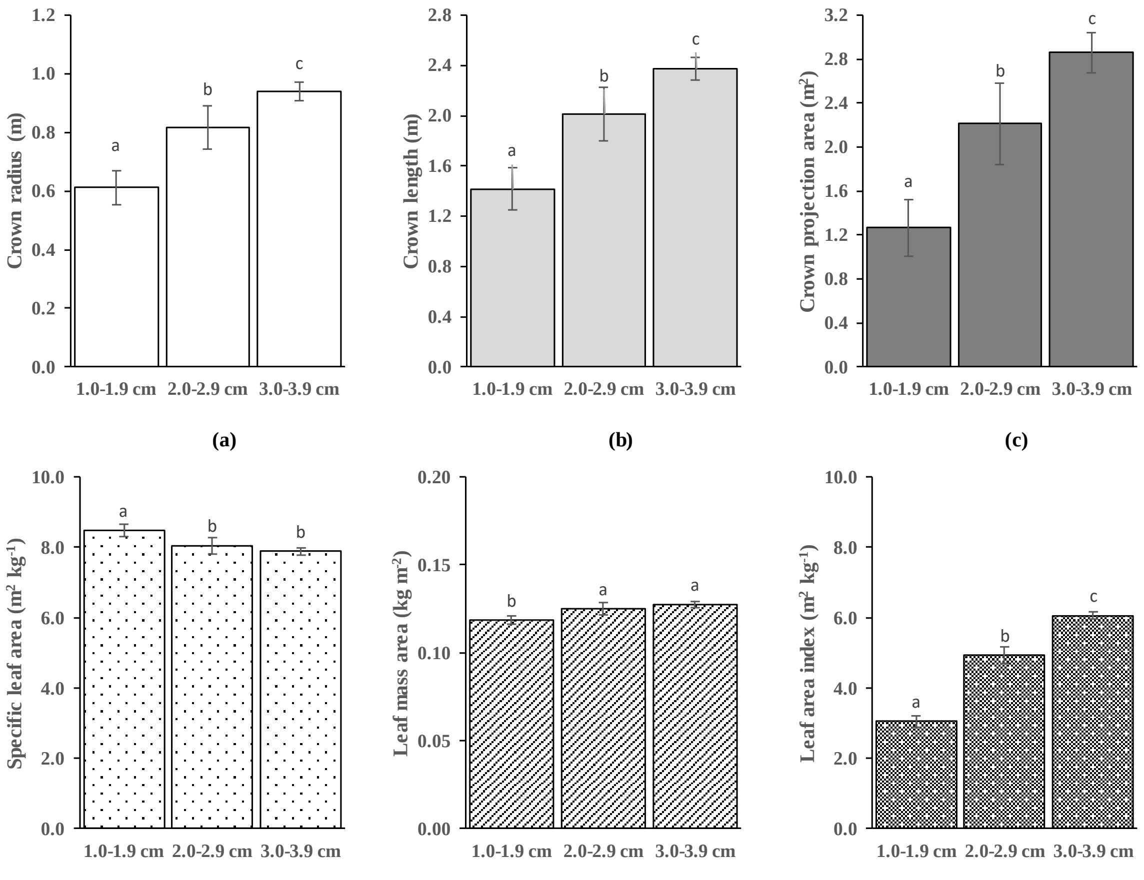
The biomass allocation within tree was principally affected by its physiological process (Poorter et al. 2012). At the early growth periods, trees generally accumulated more biomass to foliage for accelerating the photosynthesis process (Kohl et al. 2017). When the trees became bigger and older, the accumulation of foliage biomass slowly declined since trees provided more photosynthate to stem for improving growth and accelerating translocation process (Dong et al. 2018, Altanzagas et al. 2019, Wirabuana et al. 2020b). Moreover, the occurrence of leaves shedding by trees also reduced the biomass accumulation in foliage. Some previous studies reported the leaves shedding occurred more intensively with the increasing tree competition, drought stress, and age of tree (Gutiérrez-Soto et al. 2008, Xie et al. 2015, Nguyen et al. 2019).

Biomass was an attribute of tree that had important role in biogeochemical cycle (Houghton et al. 2009). Higher biomass indicated greater carbon storage since around 50% biomass was composed of carbon (Latifah et al. 2018, Viera & Rodríguez-Soalleiro 2019, Wirabuana et al. 2020a). Moreover, the biomass was also source of nutrients to maintain the soil fertility. In this case, when the litter was decomposed amount of nutrient would be returned to soil. In fact, the majority of plantation forests in other countries had utilized the biomass residue from harvesting activities as an additional fertilizer to minimize the fertilization cost (Versini et al. 2014, Ferreira et al. 2016, Van Bich et al. 2019).

Besides having a lot of benefits related to ecological functions, biomass was also used as a measurement unit to determine the commercial value of wood, mainly in the pulp and paper, fuelwood, and pellets industries (Visser et al. 2020). However, the commercial value of biomass was only applied for stem components because it was the primary product of woody species like eucalyptus. Referring to the results, *E. pellita* showed higher potential stem biomass (17.25±3.12 kg ha^{-1}) than *E. alba* (16.58±2.75 kg ha^{-1}) and *E. urophylla* (12.01±2.56 kg ha^{-1}) (Table 2).

Crown Development

Crown characteristics among three species were significantly different for all parameters except in crown ratio (Table 4). The largest mean crown projection area was observed in *E. pellita* (2.68±0.27 m^2), followed by *E. alba* (2.47±0.29 m^2) and *E. urophylla* (1.42±0.28 m^2). Greater crown dimension commonly indicated more biomass production because crown was the main tree component that played important role in photosynthesis process (Binkley et al. 2013). It was also evidenced by the outcomes of correlation analysis verified there was a strong correlation between crown radius, crown length, and crown projection area with total aboveground biomass of eucalyptus species (Figure 6). Trees with a big dimension of crown commonly had better growth performance than trees with a small crown size. It was also confirmed by the study results wherein the size of crown dimension significantly improved along with the increasing diameter class (Figure 5).



(a) **(b)** **(c)**

(d) (e) (f)

Figure 5. Crown development and leaf characteristics of eucalyptus species across diameter classes. (a) crown radius; (b) crown length; (c) crown projection area; (d) specific leaf area; (e) leaf mass area; and (f) leaf area index. Data were presented in trend for all species.

The development of crown dimensions in every tree was commonly affected by environmental conditions, primarily related to site quality and space availability. A study reported the size of crown dimension was relatively bigger at good site than poor site (DeRose & Seymour 2009). Meanwhile, Larger space availability would stimulate better crown development since the growth of the crown was highly responsive to the growing space (Pretzsch et al. 2015). The information about crown development was also important to identify the level of tree competition because it was necessary as a basic consideration to formulate the best silviculture treatment, such as thinning and pruning (McTague & Weiskittel 2016). In this study, the site quality and space availability of every species were principally equal since each species was planted by spacing 3 m x 3 m. Therefore, the dimension of crown from three species was naturally affected by its suitability to the site characteristics. At the end of 6 months after planting, *E. pellita* showed better crown dimension than other species (Table 2).

Leaf Characteristics

Leaf characteristics from three species significantly differed for all parameters ($p<0.05$) (Table 2). *E. urophylla* showed greater average individual leaf area, individual leaf dry weight, and specific leaf area than other species. Nevertheless, the highest mean leaf area index (LAI) was found in *E. pellita* (5.76±0.44), followed by *E. alba* (5.39±0.52) and *E. urophylla* (3.40±0.61). LAI was an important parameter to describe the effectiveness of nutrients absorption and photosynthesis (Bréda 2008). This parameter was generally used as one of the criteria to evaluate the application of silviculture treatment in plantation forests primarily related to fertilization and spacing management (Laclau et al. 2009, Forrester et al. 2012, Van Bich et al. 2019). Higher LAI generated better growth performance and greater biomass since the nutrients uptake and photosynthesis occurred more optimum. It explained the primary reason why *E. pellita* resulted in a greater average of tree dimensions and bigger total biomass than *E. alba* and *E. urophylla*.

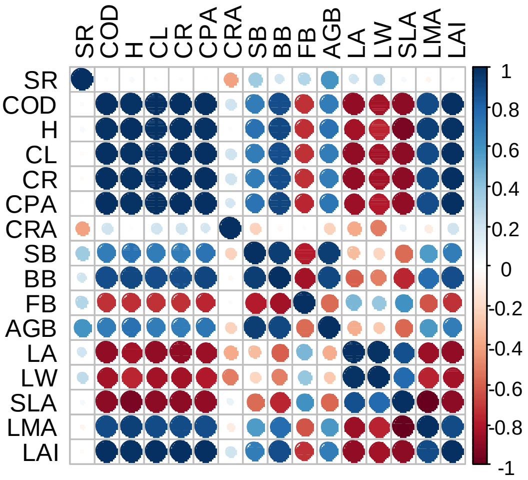


Figure 6. A pallete diagram demonstrated correlation among measured parameters. SR (survival); COD (diameter); H (height); CL (crown length); CR (crown radius); CPA (crown projection area); CRA (crown ratio); SB (stem biomass); BB (branches biomass); FB (foliage biomass); AGB (total aboveground biomass); LA (individual leaf area); LW (individual leaf dry weight); SLA (specific leaf area); LMA (leaf mass area); LAI (leaf area index).

Based on the results, the value of LAI and leaf mass area significantly increased with the increment of diameter classes (Figure 6). A different trend was noted in specific leaf area in which this parameter gradually declined with the increase of diameter classes. The specific leaf area in each species relatively varied depending on its adaptability to the environment (Rosbakh et al. 2015). The previous studies reported that the specific leaf area would declined along with the bigger tree dimension because it had a negative correlation to the age of tree (Xiao et al. 2006, Karavin 2013, Dwyer et al. 2014). Bigger tree dimension indicated an older tree. However, this trend was not commonly discovered in every species due to the impact of several factors, such as seasonal variation, tree competition, and maintenance activities (Zhu et al. 2016).

Finally, this study concluded the initial performance of *E. pellita* in Jepara was substantially superior to *E. alba* and *E. urophylla* since it demonstrated the highest mean in diameter, height, total biomass, and leaf area index at the 6 months after field establishment. However, continuous evaluation was still required to monitor the consistent performance of three species in th site experiment.

ACKNOWLEDGEMENTS

Authors deliver our gratitude to Mr. Tarmuji Muh Suwarno as a farmer who provided land for supporting this research. We are also very grateful to reviewers for suggestions to improve this article.

REFERENCES

Acuña E, Cancino J, Rubilar R, Sandoval S. 2018. Aboveground biomass growth and yield of first rotation cutting cycle of acacia and eucalyptus short rotation dendroenergy crops. Revista Árvore. 41: 1–10. DOI: 10.1590/1806-90882017000600008

Aggangan NS, Moon HK, Han SH. 2013. Growth and nutrient accumulation of *Eucalyptus pellita* F. Muell. in response to inoculation with edible ectomycorrhizal mushrooms. Asia Life Sciences. 22: 95–112.

Aguilos R, Marquez C, Adornado H, Aguilos M. 2020. Domesticating commercially important native tree species in the Philippines: early growth performance level. Forests. 11: 1–15. DOI: 10.3390/f11080885

Altanzagas B, Luo Y, Altansukh B, Dorjsuren C, Fang J, Hu H. 2019. Allometric equations for estimating the above-ground biomass of five forest tree species in Khangai, Mongolia. Forests. 10: 1–17. DOI: 10.3390/f10080661

Amezquita PSM, Rubiano JAM, Filho NFDB, Cipriani HN. 2018. Fertilization effects on *Eucalyptus pellita* F. Muell productivity in the Colombian Orinoco Region. Revista Arvore. 42: 1–8. DOI: 10.1590/1806-9088201800050002

Barreiro S, Tomé M. 2012. Analysis of the impact of the use of eucalyptus biomass for energy on wood availability for eucalyptus forest in Portugal: a simulation study. Ecology and Society. 17. DOI: 10.5751/ES-04642-170214

Bassaco MVM, Motta ACV, Pauletti V, Prior SA, Nisgoski S, Ferreira CF. 2018. Nitrogen, phosphorus, and potassium requirements for *Eucalyptus urograndis* plantations in southern Brazil. New Forests. 49: 681–697. DOI: 10.1007/s11056-018-9658-0

Binkley D, Campoe OC, Gspaltl M, Forrester DI. 2013. Light absorption and use efficiency in forests: Why patterns differ for trees and stands. Forest Ecology and Management. 288: 5–13. DOI: 10.1016/j.foreco.2011.11.002

Bréda NJJ. 2008. Leaf area index. In: Encyclopedia of Ecology. DOI: 10.1016/B978-0-444-63768-0.00849-0

Cavalett O, Slettmo SN, Cherubini F. 2018. Energy and environmental aspects of using eucalyptus from Brazil for energy and transportation services in Europe. Sustainability. 10: 1–18. DOI: 10.3390/su10114068

De La Riva EG, Olmo M, Poorter H, Ubera JL, Villar R. 2016. Leaf mass per area (LMA) and its relationship with leaf structure and anatomy in 34 mediterranean woody species along a water availability gradient. PLoS ONE. 11: 1–18. DOI: 10.1371/journal.pone.0148788

DeRose RJ, Seymour RS. 2009. The effect of site quality on growth efficiency of upper crown class *Picea rubens* and *Abies balsamea* in Maine, USA. Canadian Journal of Forest Research. 39: 777–784. DOI: 10.1139/X09-012

Dong L, Zhang L, Li F. 2018. Additive biomass equations based on different dendrometric variables for two dominant species (*Larix gmelini* Rupr. and *Betula platyphylla* Suk.) in natural forests in the Eastern Daxing'an Mountains, Northeast China. Forests. 9: 1–24. DOI: 10.3390/f9050261

Dwyer JM, Hobbs RJ, Mayfield MM. 2014. Specific leaf area responses to environmental gradients through space and time. Ecology. 95: 399–410. DOI: 10.1890/13-0412.1

Estefan G, Sommer R, Ryan J. 2013. Methods of soil, plant, and water analysis. International Center for Agriculture Research in the Dry Areas, pp. 1–243. Retrieved from https://www.gob.mx/siap/articulos/cierre-estadistico-de-la-produccion-ganadera-2017?idiom=es

Ferreira GWD, Soares EMB, Oliveira FCC, Silva IR, Dungait JAJ, Souza IF, Vergütz L. 2016. Nutrient release from decomposing eucalyptus harvest residues following simulated management practices in multiple sites in Brazil. Forest Ecology and Management. 370: 1–11. DOI: 10.1016/j.foreco.2016.03.047

Ferreira MC, Santos RC dos, Castro RVO, Carneiro A de CO, Silva GGC da, Castro AFNM, Costa SE de L, Pimenta AS. 2017. Biomass and energy production at short rotation eucalyptus clonal plantations deployed in Rio Grande Do Norte1. Revista Árvore. 41: 1–7. DOI: 10.1590/1806-90882017000500004

Forrester DI. 2013. Growth responses to thinning, pruning and fertiliser application in Eucalyptus plantations: A review of their production ecology and interactions. Forest Ecology and Management. 310: 336–347. DOI: 10.1016/j.foreco.2013.08.047

Forrester DI, Collopy JJ, Beadle CL, Baker TG. 2012. Interactive effects of simultaneously applied thinning, pruning and fertiliser application treatments on growth, biomass production and crown architecture in a young *Eucalyptus nitens* plantation. Forest Ecology and Management. 267: 104–116. -DOI: 10.1016/j.foreco.2011.11.039

Gonçalves JLM, Wichert MCP, Gava JL, Masetto A V, Junior AJC, Serrano MIP, Mello SLM. 2010. Soil fertility and growth of *Eucalyptus grandis* in Brazil under different residue management practices. Southern Forests . 69: 95–102. DOI: 10.2989/SHFJ.2007.69.2.4.289

González-García M, Hevia A, Majada J, Rubiera F, Barrio-Anta M. 2016. Nutritional, carbon and energy evaluation of *Eucalyptus nitens* short rotation bioenergy plantations in northwestern Spain. IForest. 9: 303–310. DOI: 10.3832/ifor1505-008

Gutiérrez-Soto M V., Pacheco A, Holbrook NM. 2008. Leaf age and the timing of leaf abscission in two tropical dry forest trees. Trees. 22: 393–401. DOI: 10.1007/s00468-007-0200-9

Hakamada R, Giunti Neto C, de Lemos CCZ, Silva SR, Otto MSG, Hall KB, Stape JL. 2016. Validation of an efficient visual method for estimating leaf area index in clonal Eucalyptus plantations. Southern Forests. 78: 275–281. DOI: 10.2989/20702620.2016.1201641

Hakamada R, Hubbard RM, Ferraz S, Stape JL. 2017. Biomass production and potential water stress increase with planting density in four highly productive clonal Eucalyptus genotypes. Southern Forests. 79: 251–257. DOI: 10.2989/20702620.2016.1256041

Halomoan SST, Wawan, Adiwirman. 2015. Effect of fertilization on the growth and biomass of *Acacia mangium* and Eucalyptus hybrid (*E . grandis x E . pellita*). Journal of Tropical Soils. 20: 157–166. DOI: 10.5400/jts.2015.20.3.157

Harwood CE, Alloysius D, Pomroy P, Robson KW, Haines MW. 1997. Early growth and survival of *Eucalyptus pellita* provenances in a range of tropical environments , compared with *E. grandis* , *E. urophylla* and *Acacia mangium*. New Forests. 14: 203–219.

Hii SY, Ha KS, Ngui ML, Ak Penguang S, Duju A, Teng XY, Meder R. 2017. Assessment of plantation-grown *Eucalyptus pellita* in Borneo, Malaysia for solid wood utilisation. Australian Forestry. 80: 26–33. DOI: 10.1080/00049158.2016.1272526

Houghton RA, Hall F, Goetz SJ. 2009. Importance of biomass in the global carbon cycle. Journal of Geophysical Research: 114: 1–13. DOI: 10.1029/2009JG000935

Hung TD, Brawner JT, Meder R. 2015. Estimates of genetic parameters for growth and wood properties in *Eucalyptus pellita* F . Muell . to support tree breeding in Vietnam. Annals of Forest Science. 72: 205–217. DOI: 10.1007/s13595-014-0426-9

Karavin N. 2013. Effects of leaf and plant age on specific leaf area in deciduous tree species *Quercus cerris* L. var. cerris. Bangladesh Journal of Botany. 42: 301–306. DOI: 10.3329/bjb.v42i2.18034

Kaul M, Mohren GMJ, Dadhwal VK. 2010. Carbon storage and sequestration potential of selected tree species in India. Mitigation and Adaptation Strategies for Global Change. 15: 489–510. DOI: 10.1007/s11027-010-9230-5

Kohl M, Neupane PR, Lotfiomran N. 2017. The impact of tree age on biomass growth and carbon accumulation capacity : a retrospective analysis using tree ring data of three tropical tree species grown in natural forests of Suriname. PLoS ONE. 12: 1–17.

Kweon D, Comeau PG. 2019. Relationships between tree survival, stand structure and age in trembling aspen dominated stands. Forest Ecology and Management. 438: 114–122. DOI: 10.1016/j.foreco.2019.02.003

Laclau JP, Almeida JCR, Gonalves JLM, Saint-Andr L, Ventura M, Ranger J, Moreira RM, Nouvellon Y. 2009) Influence of nitrogen and potassium fertilization on leaf lifespan and allocation of above-ground growth in Eucalyptus plantations. Tree Physiology. 29: 111–124. DOI: 10.1093/treephys/tpn010

Latifah S, Muhdi M, Purwoko A, Tanjung E. 2018. Estimation of aboveground tree biomass *Toona sureni* and *Coffea arabica* in agroforestry system of Simalungun, North Sumatra, Indonesia. Biodiversitas. 19: 620–625. DOI: 10.13057/biodiv/d190239

Lewis JD, Phillips NG, Logan BA, Hricko CR, Tissue DT. 2011. Leaf photosynthesis, respiration and stomatal conductance in six Eucalyptus species native to mesic and xeric environments growing in a common garden. Tree Physiology. 31: 997–1006. DOI: 10.1093/treephys/tpr087

Li G, Zhang Z, Shi L, Zhou Y, Yang M, Cao J (2018). Effects of different grazing intensities on soil C , N , and P in an Alpine Meadow on the Qinghai — Tibetan. International Journal of Environmental Research and Public Health. 15: 1–16. DOI: 10.3390/ijerph15112584

Lima PR, Malavasi UC, Battistus AG, Dranski JAL, De Matos Malavasi M. 2019. Photosynthetic responses of eucalyptus seedlings submitted to chemical and mechanical stimulus. Ciencia Florestal. 29: 740–753. DOI: 10.5902/1980509830685

Little KM, Ahtikoski A, Morris AR, Little KM, Ahtikoski A, Rotation-end ARM, Little KM, Ahtikoski A, Morris AR. 2018. Rotation-end financial performance of vegetation control on *Eucalyptus smithii* in South Africa smithii in South Africa. Southern Forests. 80: 241–250. DOI: 10.2989/20702620.2017.1341114

Magalhães TM, Cossa VN, Guedes BS, Fanheiro ASM. 2020. Species-specific biomass allometric models and expansion factors for indigenous and planted forests of the Mozambique highlands. Journal of Forestry Research. DOI: 10.1007/s11676-020-01156-0

Maimunah S, Rahman SA, Samsudin YB, Artati Y, Simamora TI, Andini S, Lee SM, Baral H. 2018. Assessment of suitability of tree species for bioenergy production on burned and degraded peatlands in Central Kalimantan, Indonesia. Land. 7: 1–14. DOI: 10.3390/land7040115

McTague JP, Weiskittel AR. 2016. Individual-tree competition indices and improved compatibility with stand-level estimates of stem density and long-term production. Forests. 7: 1–16. DOI: 10.3390/f7100238

Nambiar EKS, Harwood CE, Mendham DS. 2018. Paths to sustainable wood supply to the pulp and paper industry in Indonesia after diseases have forced a change of species from acacia to eucalypts. Australian Forestry. 81: 148–161. DOI: 10.1080/00049158.2018.1482798

Nandini R, Narendra BH. 2017. Critical land characteristics of former eruption of Batur Mount in Bangli District, Bali. Jurnal Penelitian Hutan dan Konservasi Alam. 9: 199–211. DOI: 10.20886/jphka.2012.9.3.199-211

Nguyen TT, Arndt SK, Baker PJ. 2019. Leaf physiological responses to drought stress and community assembly in an Asian Savanna. Forests. 10: 15–17. DOI: 10.3390/f10121119

Poorter H, Niklas KJ, Reich PB, Oleksyn J, Poot P, Mommer L. 2012. Biomass allocation to leaves, stems and roots: meta-analyses of interspecific variation and environmental control. New Phytologist. 193: 30–50. DOI: 10.1111/j.1469-8137.2011.03952.x

Prasetyo A, Aiso H, Ishiguri F, Wahyudi I, Wijaya IPG, Ohshima J, Yokota S. 2017. Variations on growth characteristics and wood properties of three *Eucalyptus* species planted for pulpwood in Indonesia. Tropics. 26: 59–69. DOI: 10.3759/tropics.ms16-15

Pretzsch H, Biber P, Uhl E, Dahlhausen J, Rötzer T, Caldentey J, Koike T, van Con T, Chavanne A, Seifert T, Toit B du, Farnden C, Pauleit S. 2015.

Crown size and growing space requirement of common tree species in urban centres, parks, and forests. Urban Forestry and Urban Greening. 14: 466–479. DOI: 10.1016/j.ufug.2015.04.006

Rance SJ, Mendham DS, Cameron DM. 2017. Assessment of crown woody biomass in Eucalyptus grandis and E. globulus plantations. New Forests. 48: 381–396. DOI: 10.1007/s11056-016-9563-3

Rosbakh S, Römermann C, Poschlod P (2015). Specific leaf area correlates with temperature: new evidence of trait variation at the population, species and community levels. Alpine Botany. 125: 79–86. DOI: 10.1007/s00035-015-0150-6

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021a. Allometric equations for estimating aboveground biomass of Eucalytpus urophylla S.T. Blake in East Nusa Tenggara. Journal of Tropical Forest Management. 27: 24–31. DOI: 10.7226/jtfm.27.1.24

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021b. Soil chemical properties influences on the growth performance of Eucalyptus urophylla planted in dryland ecosystems, East Nusa Tenggara. Journal of Degraded and Mining Lands Management. 8: 2635–2642. DOI: 10.15243/jdmlm.2021.082.2635

Sasaki N, Asner GP, Pan Y, Knorr W, Durst PB, Ma HO, Abe I, Lowe AJ, Koh LP, Putz FE. 2016. Sustainable management of tropical forests can reduce carbon emissions and stabilize timber production. Frontiers in Environmental Science. 4: 1–13. DOI: 10.3389/fenvs.2016.00050

Simetti R, Bonduelle GM, Silva DA da, Mayer SLS, Souza HP, Muniz GIB de. 2018. Production of biomass and energy stock for five Eucalyptus species. Revista Ciência Da Madeira - RCM. 9: 30–36. DOI: 10.12953/2177-6830/rcm.v9n1p30-36

Stanturf JA, Vance ED, Fox TR, Kirst M. 2013. Eucalyptus beyond its native range: environmental issues in exotic bioenergy plantations. International Journal of Forestry Research. 2013: 1–5. DOI: 10.1155/2013/463030

Stuepp CA, Kratz D, Gabira MM, Wendling I. 2020. Survival and initial growth in the field of eucalyptus seedlings produced in different substrates. Pesquisa Agropecuaria Brasileira. 55: 1–12. DOI: 10.1590/S1678-3921.pab2020.v55.01587

Thompson IM. 2013. Early growth results of three *Eucalyptus grandis* × *Eucalyptus nitens* hybrid clonal trials and their response to snow events. Southern Forests. 75: 185–188. DOI: 10.2989/20702620.2013.820446

Truax B, Fortier J, Gagnon D, Lambert F. 2018. Planting density and site effects on stem dimensions, stand productivity, biomass partitioning, carbon stocks and soil nutrient supply in hybrid poplar plantations. Forests. 9: 1–21. DOI: 10.3390/f9060293

Van Bich N, Mendham D, Evans KJ, Dong TL, Hai VD, Van Thanh H, Mohammed CL. 2019. Effect of residue management and fertiliser application on the productivity of a Eucalyptus hybrid and *Acacia mangium* planted on sloping terrain in northern Vietnam. Southern Forests. 81: 201–212. DOI: 10.2989/20702620.2018.1555940

Versini A, Zeller B, Derrien D, Mazoumbou J, Laclau J. 2014. The role of harvest residues to sustain tree growth and soil nitrogen stocks in a tropical Eucalyptus plantation. 245–260. DOI: 10.1007/s11104-013-1963-y

Viera M, Rodríguez-Soalleiro R. 2019. A complete assessment of carbon stocks in above and belowground biomass components of a hybrid eucalyptus plantation in Southern Brazil. Forests. 10: 1–12. DOI: 10.3390/f10070536

Visser L, Hoefnagels R, Junginger M. 2020. The potential contribution of imported biomass to renewable energy targets in the EU-the trade-off between ambitious greenhouse gas emission reduction targets and cost thresholds. Energies. 13: 1–30. DOI: 10.3390/en13071761

Wirabuana PYAP, Sadono R, Juniarso S, Idris F. 2020a. Interaction of fertilization and weed control influences on growth , biomass , and carbon in eucalyptus hybrid (*E. pellita* × *E. brassiana*). Journal of Tropical Forest Management. 26: 144–154. DOI: 10.7226/jtfm.26.2.144

Wirabuana PYAP, Sadono R, Jurniarso S. 2019. Fertilization effects on early growth, aboveground biomass, carbon storage, and leaf characteristics of Eucalyptus pellita F.Muell. in South Sumatra. ournal of Tropical Forest Management. 25: 154–163. DOI: 10.7226/jtfm.25.3.154

Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS, Matatula J. 2020b. Allometric equations for estimating biomass of community forest tree species in Madiun , Indonesia. Biodiversitas. 21: 4291–4300. DOI: 10.13057/biodiv/d210947

Xiao CW, Janssens IA, Curiel Yuste J, Ceulemans R. 2006. Variation of specific leaf area and upscaling to leaf area index in mature Scots pine. Trees. 20: 304–310. DOI: 10.1007/s00468-005-0039-x

Xie Y, Wang X, Silander JA. 2015. Deciduous forest responses to temperature, precipitation, and drought imply complex climate change impacts. Proceedings of the National Academy of Sciences of the United States of America. 112: 13585–13590. DOI: 10.1073/pnas.1509991112

Zhu W, Xiang W, Pan Q, Zeng Y, Ouyang S, Lei P, Deng X, Fang X, Peng C. 2016. Spatial and seasonal variations of leaf area index (LAI) in subtropical secondary forests related to floristic composition and stand characters. Biogeosciences. 13: 3819–3831. DOI: 10.5194/bg-13-3819-2016

SUBMISSION CHECKLIST

Ensure that the following items are present:

The first corresponding author must be accompanied with contact details:	**Give mark (X)**
• E-mail address	x
• Full postal address (incl street name and number (location), city, postal code, state/province, country)	x
• Phone and facsimile numbers (incl country phone code)	x

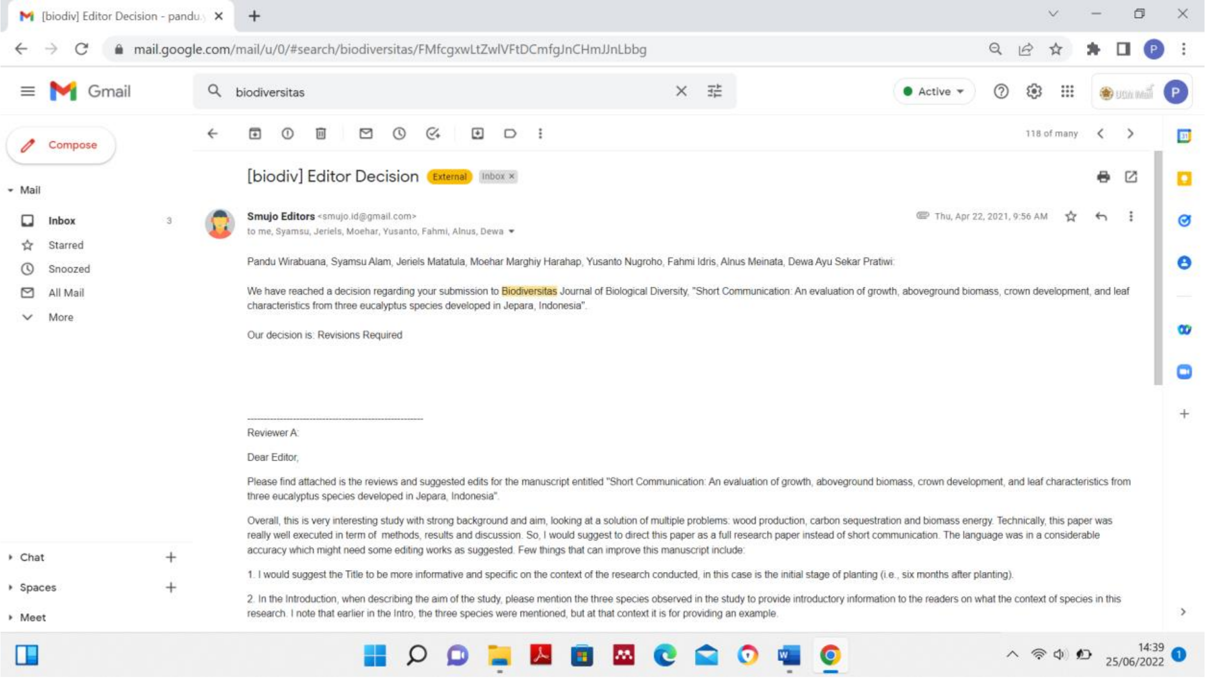
All necessary files have been uploaded, and contain:

• Keywords	x
• Running titles	x
• All figure captions	x
• All tables (incl title and note/description)	x

Further considerations

• Manuscript has been “spell & grammar-checked” Better, if it is revised by a professional science editor or a native English speaker	x
• References are in the correct format for this journal	x
• All references mentioned in the Reference list are cited in the text, and vice versa	x
• Colored figures are only used if the information in the text may be losing without those images	x
• Charts (graphs and diagrams) are drawn in black and white images; use shading to differentiate	x

KEPUTUSAN EDITOR 22 APRIL 2021 – REVISION



[biodiv] Editor Decision

Smujo Editors <smujo.id@gmail.com>
to me, Syamsu, Jeriels, Moehar, Yusanto, Fahmi, Alnus, Dewa

Thu, Apr 22, 2021, 9:56 AM

Pandu Wirabuana, Syamsu Alam, Jeriels Matatula, Moehar Marghiy Harahap, Yusanto Nugroho, Fahmi Idris, Alnus Meinata, Dewa Ayu Sekar Pratiwi:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Short Communication: An evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia".

Our decision is: Revisions Required

Reviewer A:

Dear Editor,

Please find attached is the reviews and suggested edits for the manuscript entitled "Short Communication: An evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia".

Overall, this is very interesting study with strong background and aim, looking at a solution of multiple problems: wood production, carbon sequestration and biomass energy. Technically, this paper was really well executed in term of methods, results and discussion. So, I would suggest to direct this paper as a full research paper instead of short communication. The language was in a considerable accuracy which might need some editing works as suggested. Few things that can improve this manuscript include:

1. I would suggest the Title to be more informative and specific on the context of the research conducted, in this case is the initial stage of planting (i.e., six months after planting).

2. In the Introduction, when describing the aim of the study, please mention the three species observed in the study to provide introductory information to the readers on what the context of species in this research. I note that earlier in the Intro, the three species were mentioned, but at that context it is for providing an example.

Short Communication:
~~An evaluation of~~ The growth, aboveground biomass, crown development, and leaf characteristics ~~from~~ of three eucalyptus species at initial stage of planting~~developed~~ in Jepara, Indonesia

Abstract. Industry development, climate change mitigation and renewable energy currently become the most essential challenge in tropical forest management, primarily in Indonesia. The existence of tropical forests is not only managed to maintain the stability of wood supply for commercial industries but also to reduce greenhouse gas emissions in the atmosphere and to generate energy alternatives from tree biomass. To answer this challenge, the development of fast-growing species like eucalyptus can become a good solution. However, the productivity of eucalyptus depends on its adaptability to the site condition. Therefore, understanding site-species interaction becomes the fundamental requirement before planted on a large scale. This study aimed to evaluate the initial performance of eucalyptus species developed in Jepara. An experiment consisted of three different eucalyptus species, i.e., *E. alba*, *E. pellita*, and *E. urophylla*, was established using a randomized complete block design. Sixteen parameters were selected to assess the eucalyptus performance, including survival, height, diameter, biomass accumulation (stem, branches, foliage, and total aboveground), crown length, crown radius, crown projection area, crown ratio, individual leaf area, individual leaf dry weight, specific leaf area, leaf mass area, and leaf area index. The ~~C~~comparison of the mean of tree attributes from each species was examined using ANOVA, followed by HSD Tukey. Results showed that all measured parameters indicated a significant difference among the three species (p<0.05), except for survival, foliage biomass, and crown ratio (p>0.05). The preliminary performance of *E. pellita* was relatively better than the other two species, mainly related to height (3.00±0.21 m), total aboveground biomass (49.86±3.60 kg ha^{-1}), crown projection area (2.68±0.27 m^2), and leaf area index (5.76±0.44). Our study concluded the initial performance of *E. pellita* in Jepara was substantially superior to *E. alba* and *E. urophylla*. Nevertheless, continuous evaluation is~~was~~ needed to monitor the consistent performance those species in the study area.

Key words: Crown projection area, eucalyptus, leaf area index, leaf mass area, specific leaf area

Running title: Preliminary evaluation of eucalyptus species

INTRODUCTION

Integration of industry development, climate change mitigation, and renewable energy diversification currently becomes the most important challenge in sustainable ~~tropical~~ forest management in tropical region (Sadono et al. 2021a), including in Indonesia. In the tropics, ~~T~~the existence of ~~tropical~~ forests is not only managed to ~~stabilize~~supply wood ~~supply~~demands for commercial industries, but also to reduce~~minimize~~ carbon emissions in the atmosphere (Sasaki et al. 2016) and to generate energy alternatives from tree biomass (Ferreira et al. 2017). To tackle this challenge, the development of fast-growing tree species can become a ~~realistic~~ win-win solution ~~for supporting the fundamental role of tropical forest in~~to achieve triple objectives of maintaining industry viability, reducing carbon emissions, and ~~resulting~~ producing bioenergy (González-García et al. 2016).

~~During last periods~~In several decades, there are ~~several~~ a number of fast-growing tree species ~~that planted in~~developed as plantation forest~~s at~~ in the tropics, one of which is eucalyptus.

The ~~establishment~~ development of eucalyptus as a ~~primary~~ major species in plantation forests has been widely conducted in many tropical countries, such as Brazil, Chile, Colombia, Mexico, Thailand, Vietnam, and Indonesia (Aggangan et al. 2013, Hakamada et al. 2017, Acuña et al. 2018, Amezquita et al. 2018, Van Bich et al. 2019, Wirabuana et al. 2020a). Besides having a short rotation period ~~by~~of approximately 5-8 years (Little et al. 2018), t~~T~~he quality of eucalyptus wood ~~is also suitable as raw materials~~ suits ~~for~~the requirements of industries, such as for~~like~~ construction materials, pulp and paper, plywood, veneer, and furniture (Forrester 2013, Hii et al. 2017, Nambiar et al. 2018). In addition, the majority of eucalyptus species also have rapid growth due to the more efficient photosynthesis process (Lewis et al. 2011, Lima et al. 2019), suggesting ~~. It indicates~~that the carbon ~~absorption~~sequestration in eucalyptus is relatively

Commented [A1]: This paper was well executed in term of background, aim, methods, results and discussion. So, I would suggest to direct this paper as a full research paper instead of short communication.

Commented [A2]: I would suggest the title to be more informative and specific on the context of the research conducted, in this case is the initial stage of planting (i.e., six months after planting).

faster than slow-growing species (Kaul et al. 2010). Therefore, the previous studies also report that the existence of eucalyptus plantations provides a significant contribution to ~~encouraging~~ climate change mitigation (Magalhães et al. 2020). Furthermore, a study explains that ~~he~~ eucalyptus wood can become a potential source of renewable energy since it has a high calorific value of 4,532-4,661 kcal kg^{-1} (Simetti et al. 2018). The use of eucalyptus wood for bioenergy has been conducted in some foreign countries, including~~like~~ Brazil, Spain, and Portugal, wherein the development of biomass power plants has been intensively managed (Barreiro & Tomé 2012, González-García et al. 2016, Cavalett et al. 2018). A study confirms that the use of plant biomass, mainly sourced from eucalyptus wood, results in lower carbon emissions to the atmosphere than fossil fuels like coal as well as oil and gas (Cavalett et al. 2018). All of those evidences provide justification that eucalyptus ~~This fact demonstrates this species~~ is highly potential to be developed ~~as a strategy~~ as plantation forest to simultaneously integrating~~to tackle the integration of~~ the goals of industry development, climate change mitigation and~~,~~ renewable energy ~~diversification~~ sources in tropical countries, particularly in Indonesia.

~~The~~Developing ~~cultivation of~~ eucalyptus plantations in Indonesia is prospective because it is a native species from this country. Some studies state that~~explain~~ there are several eucalyptus species that have natural~~ly~~ distribution~~ed~~ in the eastern of Indonesia, such as *Eucalyptus*~~.~~ *pellita*, *E. alba*, and *E. urophylla* (Stanturf et al. 2013, Prasetyo et al. 2017). However, the existence of eucalyptus plantations in Indonesia ~~is~~ is still limited wherein most eucalyptus estates are located in Sumatra (Nambiar et al. 2018). Moreover, the objective of eucalyptus management in Indonesia still focuses on supplying raw materials for pulp and paper industry (Prasetyo et al. 2017). This circumstance is quite different from other countries like Brazil, China, and Vietnam in which the presence of eucalyptus plantation becomes the most important plantation forests ~~in those countries~~ along in such countries with the development of ~~and has~~ many processing industries for eucalyptus wood. Those facts ~~It~~ indicate~~s~~ that there is a wide opportunity to develop eucalyptus plantations in Indonesia by expanding its area nor improving its downstream industries. However, to develop large scale eucalyptus plantations, there is a need to enhance the understanding about site-species interaction of eucalyptus stand with its environment in order to obtain high productivity~~ of eucalyptus stand, understanding about site-species interaction is basically required before doing the planting activities on a large scale~~. It is commonly done by establishing an experiment for species trial in several sites which become the priority area for eucalyptus development. In this context, the best species is selected by considering its superior performance to other eucalyptus species.

This study examined the adaptability of three different eucalyptus species planted in the Jepara District, Central Java Province, Indonesia. A preliminary evaluation was undertaken to monitor the growth, aboveground biomass, crown development, and leaf characteristics of those three species at six months after planting. It is a critical period to assess the suitability of species to survive in the site condition (Van Bich et al. 2019, Stuepp et al. 2020, Wirabuana et al. 2020a) since every eucalyptus species has a habitat preference to support its growth and development. I~~i~~f site condition is not suitable, the species will demonstrate a high mortality rate and low growth performance (Thompson 2013, Maimunah et al. 2018, Aguilos et al. 2020). The species trial of eucalyptus ~~was built~~ in Jepara was based on the rationale that ~~because~~ Jepara~~this town~~ has a number of wood processing industries, especially for furniture. Moreover, there are several other forestry industries located near this ~~town~~area, such as pulp and paper, plywood, veneer, and construction, that require a continuous supply for wood ~~demand~~raw materials. Interestingly, Jepara has also a power plant that faces a problem related to the coal deficit. This situation provides an opportunity to maximize the potential of eucalyptus for bioenergy. On another side, the development of eucalyptus plantation in Jepara ~~is~~has ~~still~~ not yet be conducted until now, even though this species offers a lot of advantages. Most importantly, ~~the effort of~~developing eucalyptus ~~establishment~~plantations in Jepara is not only directed to support the integration of industry development, climate change mitigation, and renewable energy but also to facilitate the program of *e*~~*E*~~*x*~~–~~*-situ* conservation and to optimize the potential of native species from Indonesia.

Commented [A3]: Please mention here the three species observed in the study to provide introductory information to the readers on what the context of species in this research.

Formatted: Font: Italic

MATERIALS AND METHODS

Study area

Formatted: English (United States)

A planting~~A species~~ trial was established in community forests located at Srobyong, Jepara District~~. It had~~ with geographic position in S6°31'35"-6°31'37" and E110°41'39"-110°43'22" (Figure 1). The ~~species~~planting trial was set up in private land of farmers with an extent ~~large area~~ of 2 ha.

The research site has an ~~A~~altitude of~~reached~~ 70 m above sea level,~~.~~ flat ~~T~~topography ~~was flat~~ with a slope level of 3-8%, ~~. T~~the average daily temperature of~~was~~ 29°C with a minimum of 22°C and a maximum of 34°C, and the mean air humidity of 84%. It has ~~. A~~annual rainfall ~~varied~~ from 2,246 to 2,446 mm year $^{-1}$ during the last five years from 2016 to 2020 with~~. T~~ the majority of rainfall is~~was~~ recorded in February around 33.82% of total rainfall in a year. Dry periods occur~~red~~ for five~~5~~ months from May to September~~. The mean air humidity reached 84%~~. Soil type ~~was predominantly~~is dominated by alfisol with ~~having acidity level~~pH of 5.5 to 6.0. ~~Before becoming a site for species trial~~Previously, the vegetation cover consisted of uneven-aged mixed species with irregular distribution and high variation in growth.

Figure 1. Study area of planting~~species~~ trial of ~~for~~ eucalyptus ~~development~~ in Jepara District (blue ~~. The blue~~ symbol) ~~indicated site for trial establishment.~~

Commented [A4]: Please note that not all the readers are familiar with the study site. I would suggest to add an inset map showing the regional context of the study site (e.g. Java Island or Indonesia).

Experimental design

Three different eucalyptus species were examined in this study, i.e., *E. alba*, *E. urophylla*, and *E. pellita*. The planting~~species~~ trial was established in a randomized complete block design (RBCD) with four blocks (i.e., ~~consisting of~~ three blocks for continuous monitoring and one block for destructive measurement in specific periods, namely 6, 12, 24, 36, 48, and 60 months). This design was selected to minimize the influence of environmental gradient on eucalyptus performance (Thompson 2013). It was importantly conducted to avoid the biased result due to the impact of site condition, particularly related to soil quality.

~~There were three different eucalyptus species examined in this study, i.e. *E. alba, E. urophylla*, and *E. pellita*.~~ Each species was planted in a square plot of 0.1 ha comprising 100 measured trees and 44 border trees (Figure 2). The ~~principal~~ main function of border trees was to indicate the clear boundaries among treatments in every block. Moreover, to support the activity of monitoring, a nameplate was placed in each treatment plot using a specific code. Every measured tree was also marked by ~~a~~individual identity number ~~identity~~.

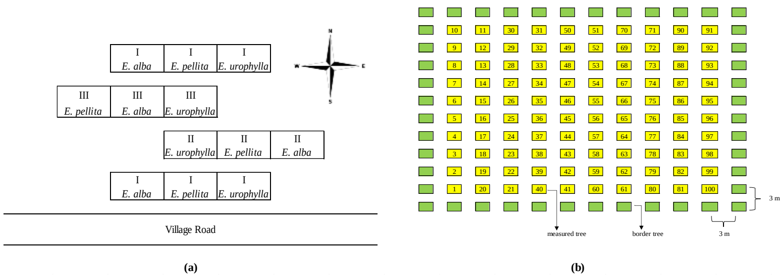


Figure 2. The layout of experimental design in the study area for evaluating the performance of eucalyptus stand ~~from~~ of three different species established in Jepara District. (a) the position of every treatment in each block and (b) the position of measured and border trees in every treatment plot.

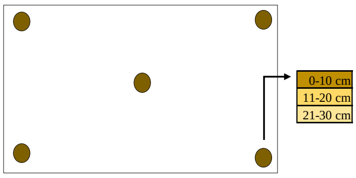


Figure 3. The distribution of five sample points for collecting soil sample in the site experiment (~~. The~~ brown circle). ~~indicated the sampling location for taking soil sample.~~.

This trial was established in August 2020. ~~The s~~Site preparation was ~~implemented~~ conducted to identify the variation of environmental gradient before determining the layout of experimental design. It was~~was~~ ~~exceptionally~~ required to create a homogeneous condition in each block to~~for~~ minimize~~ing~~ the influence of environmental gradient on treatment plots (Gonçalves et al. 2010). The ~~activity of~~ site preparation consisted of several stages, including~~like~~ measuring slope variation, observing waterlog, identifying wind disturbance, and assessing soil quality (Wirabuana et al. 2020a). ~~To facilitate the s~~Soil quality assessment was conducted by collecting ~~,~~ soil samples ~~ing was collected~~ in five different points at three depth layers of 0-10 cm, 11-20 cm, and 21-30 cm (Li et al. 2018, Wirabuana et al. 2019, Sadono et al. 2021b) (Figure 3). Then, the samples were~~was~~ ~~composited~~packed and brought to the laboratory for quantifying its characteristics, namely soil acidity, soil organic carbon, total nitrogen, available phosphorus, total potassium, and cation exchange capacity (Table 1). Soil acidity was measured using pH meter. The quantification of soil organic carbon was conducted using Walkey and Black method. Total nitrogen was estimated by Kjeldahl method. The analysis of available phosphorus was executed using Olsen method. The method of flame photometry was utilized to calculate the total potassium. The use of ammonium acetate method was applied to quantify the content of cation exchange capacity. The protocol of soil analysis was conducted referring to the guide for methods of soil, plant, and water analysis published by Estefan et al. (2013).

Table 1. Soil characteristics at ~~in~~ the research sit~~e experiment quantified by soil acidity, soil organic carbon, total nitrogen, available phosphorus, total potassium, and cation exchange capacity~~e. Data are~~were~~ presented in mean±standard deviation

Soil parameter~~s~~	**Symbol**	**Units**	**Value**	**Categories**
Soil acidity	pH	-	6.00±0.86	Slightly acid
Soil organic carbon	SOC	%	2.97±0.37	Moderate
Total nitrogen	N-tot	%	0.17±0.01	Low
Available phosphorus	Av-P	ppm	2.79±1.54	Very low
Total potassium	K-tot	cmolc kg^{-1}	0.21±0.12	Very low
Cation exchange capacity	CEC	cmolc kg^{-1}	10.11±3.14	Low

Note: the classification of soil quality was determined following the soil quality categories reported by (Nandini & Narendra 2017)

The plant materials of *E. alba*, *E. urophylla*, and *E. pellita* used in this study were obtained~~as~~ from different provenance sources since every species has different natural distribution. *E. alba* and *E. urophylla* were from provenance Timor, East Nusa Tenggara, ~~. Mean~~while~~,~~ *E. pellita* was from provenance Muting, Papua. The seeds of such species ~~was~~were sown in the nursery for 90 days. In parallel, soil tillage was conducted to improve soil structure at two~~2~~ weeks before field planting. A week before ~~establishment~~planting the seedlings, ~~the~~ grading activity was undertaken to determine the quality of seedlings from each species. In this case, only seedlings with a height of 30 cm and~~ having~~ ~~healhty~~healthy condition were used as plant materials for planting. Seedlings were planted by initial spacing of 3 m x 3 m. F~~The addition of f~~ertilizer ~~(~~NPK with concentration of 15:15:15~~)~~ was also added ~~provided for~~to ~~every~~each seedling with a dose of 100 g~~.~~ ~~It was applied~~ to increase the availability of nutrients for eucalyptus because the site experiment had a low content of nitrogen, phosphorus, and potassium in the soil. Moreover, several studies reported eucalyptus is highly responsive to phosphorus availability since it was a macronutrient exceptionally required by this plant (Amezquita et al. 2018, Bassaco et al. 2018, Sadono et al. 2021b). To support the early growth of eucalyptus, the application of weed control was also implemented by slashing and chemical spraying at three~~3~~ and six~~6~~ months after planting.

Data ~~C~~collection

Data were collected at 6 months after planting. This period was frequently used by most plantation forests company in Indonesia to conduct the first evaluation of planting~~species~~ trials (Wirabuana et al. 2019). ~~It was also supported by the previous studies reported that t~~The period was a critical moment to assess the adaptability of species to environmental conditions outside their natural habitat (Stuepp et al. 2020). The process of data collection was conducted from March to April 2021, ~~. It~~ consisting~~ed~~ of several activities, i.e., stand measurement, destructive sampling, and laboratory analysis. Sixteen parameters were selected to evaluate the performance of the three eucalyptus ~~performance from three different~~ species, including survival rate, height, diameter, biomass production (stem, branches, foliage, and total aboveground), crown length, crown radius, crown projection area, crown ration, individual leaf area, individual leaf dry weight, specific leaf area, leaf mass area, and leaf area index.

Survival rate was defined as the ratio of actual density and initial planting density. Height was measured from aboveground to top crown using a measuring pole (Halomoan et al. 2015). Diameter was measured at 0.3 m aboveground by a caliper (Wirabuana et al. 2019). The crown length was quantified from crown base to top crown while crown ratio was calculated as the ratio between crown length and tree height. Crown radius was computed as the quadratic mean crown radius at eight directions (eq.1) (Wirabuana et al. 2019). The transition from crown radius to crown projection area was determined by the occupation area of every tree (eq.2) (Pretzsch et al. 2015).

$$CR = \left(\left(R_N^2 + R_{NE}^2 + \ldots + R_{NW}^2\right) / 8\right)^{1/2} \quad (1)$$

$$CPA = \pi \times CR^2 \quad (2)$$

wherein *CR* was a quadratic mean crown radius every tree (m), *R* represented crown radius in certain direction (m), and *CPA* described crown projection area of each tree (m^2).

To quantify biomass accumulation and leaf characteristics of each species, destructive sampling was conducted step by step in a chronological manner. Each species was represented by five sample trees. Those sample trees were determined by considering the distribution of diameter ~~. It aimed~~ to obtain the balance growth dimension from small to big trees (Sadono et al. 2021a). In this study, the diameter was classified into three classes, including small (1.0-1.9 cm), medium (2.0-2.9 cm), and big (3.0-3.9 cm). After the sample tree was felled, the tree component was separated into stem, branches, and foliage. For part of foliage, the sample was also stratified into three layers based on leaves position, i.e., base, middle, and top. It was conducted to facilitate the measurement of leaf characteristics. From every layer, ten leaf samples were taken randomly. Thereby, the number of samples for determining leaf attributes in each sample tree was 30 samples.

The fresh weight of each component was measured in the field using a hanging balance. Afterward, approximately 500 g subsample from each part was taken and brought to the laboratory for dried. Before starting the drying process, the area of selected leaf samples was measured using a planimeter. Then, the subsample of each component (including the selected leaf samples) was dried using an oven for 48 hours at 70°C before measuring their dry weight (Hakamada et al. 2017). The biomass accumulation in each component was calculated by multiplying the ratio of dry-fresh weight from subsample with the total fresh weight of each part from field measurement (eq.3) (Altanzagas et al. 2019) while total aboveground biomass for each individual tree was calculated by summing the biomass distribution in stem, branches, and foliage (eq.4) (Rance et al. 2017).

$$W_c = (DW_s / FW_s) \times FW_c \qquad (3)$$

$$W_t = W_{stem} + W_{branches} + W_{foliage} \qquad (4)$$

wherein W_c was biomass from every tree component like stem, branches, or foliage (kg), DW_s described the dry weight of subsample (kg), FW_s indicated the fresh weight of sub sample (kg), FW_c was the total fresh weight of tree component (kg), and W_t signified total aboveground biomass of individual tree (kg). Then, the result of destructive sampling was converted to estimate the biomass production of eucalyptus stand from every species in treatment plots.

To measure the leaf characteristics, the dry weight of each selected leaf sample was determined using a digital analytic scale. The specific leaf area was calculated based on the ratio of leaf area and leaf dry weight (eq.5) (Hakamada et al. 2016). In opposite condition, leaf mass area was computed by dividing leaf dry weight and leaf area (eq.6) (De La Riva et al. 2016). Leaf area index from each sample tree was quantified following this equation (eq. 7) (Wirabuana et al. 2019).

$$SLA = LA / LW \qquad (5)$$

$$LMA = LW / LA \qquad (6)$$

$$LAI = (W_{foliage} \times SLA) / CPA \qquad (7)$$

wherein SLA was specific leaf area (m^2 kg^{-1}), LMA represented leaf mass area (kg m^{-2}), LA described individual leaf area (cm^2), LW was individual leaf dry weight (g), and LAI indicated leaf area index.

Data a~~A~~nalysis

Statistical analysis was processed using software R version 4.0.2 with a significant level of 5%. The package agricolae was used to facilitate the process of data analysis. Descriptive test was applied to identify the data characteristics, primarily related to minimum, maximum, mean, standard deviation, and coefficient of variation. It aimed to assess the accuracy and precision of data collected from stand measurement, destructive sampling, and laboratory analysis. The normality of data was evaluated using Shapiro-Wilk test. Homogeneity variance among treatments were examined using Bartlett's test. The comparison means eucalyptus performance among three species for each parameter was tested using ANOVA followed by HSD Tukey. The analysis of correlation using a pallete matrix was also done to evaluate the relationship between observed parameters.

RESULTS AND DISCUSSION

Growth p~~P~~erformance

The survival rate among species did not significantly differ ($p>0.05$) (Table 2). Each species had a survival rate of more than 80%,~~.~~ ~~It~~ indicating that~~ed~~ every species had a good tolerance to the environmental condition in the study area. The highest survival rate was recorded in *E. alba* (90.4±2.19%), followed by *E. pellita* (89.6±3.57%) and *E. urophylla* (88.8±5.21%). In the context of plantation forest management, survival is~~was~~ an essential indicator to evaluate the species performance since it determines ~~d~~ the number of trees that could be harvested at the end of the rotation (Truax et al. 2018). This parameter also directly affects~~ed~~ land cover and tree competition at the stand level (Kweon & Comeau 2019). Moreover, the plant survival also has~~d~~ a strong relationship to the efficiency of planting cost for establishing plantation forests. The development of a species in ~~the~~ plantation forest requires~~d~~ a high survival to obtain an optimum stand productivity because it becomes a multiplier factor to estimate the wood volume and biomass production in hectare unit.

Table 2. The ~~C~~comparison of the ~~means~~ growth, aboveground biomass, crown development, and leaf characteristics of three different eucalyptus species ~~established~~ trialed in Jepara District. Data are presented~~were demonstrated~~ in mean ± standard deviation

Group variable~~s~~	Measured parameter~~s~~	Unit~~s~~	Species			*p-value*
			E. alba	*E. pellita*	*E. urophylla*	
Growth	Survival	%	90.4±2.19a	89.6±3.57a	88.8±5.21a	0.958^{ns}
	Height	m	2.82±0.25a	3.00±0.21a	1.87±0.29b	$<0.001^{*}$
	Diameter	cm	2.31±0.19a	2.39±0.19a	1.62±0.15b	$<0.001^{*}$
Aboveground biomass	Stem biomass	kg ha^{-1}	16.58±2.75ab	17.25±3.12a	12.01±2.56b	0.024^{*}
	Branches biomass	kg ha^{-1}	11.15±1.90a	12.10±1.91a	6.78±1.11b	$<0.001^{*}$

	Foliage biomass	kg ha^{-1}	21.40±2.24a	20.50±2.40a	24.16±2.33a	0.069^{ns}
	Total Aboveground biomass	kg ha^{-1}	49.14±2.80a	49.86±3.60a	42.96±3.30b	0.010*
Crown development	Crown radius	m	0.86±0.05a	0.90±0.04a	0.64±0.06b	<0.001*
	Crown length	M	2.15±0.16a	2.27±0.14a	1.52±0.19b	<0.001*
	Crown projection area	m^{2}	2.47±0.29a	2.68±0.27a	1.42±0.28b	<0.001*
	Crown ratio	-	0.93±0.02a	0.95±0.04a	0.93±0.04a	0.763^{ns}
Leaf characteristics	Individual Leaf area	cm^{2}	64.27±2.91b	63.30±3.67b	78.52±8.66a	0.001*
	Individual Leaf dry weight	g	0.80±0.02b	0.79±0.04b	0.92±0.08a	0.007*
	Specific leaf area	m^{2} kg^{-1}	7.93±0.13b	7.91±0.17b	8.41±0.14a	<0.001*
	Leaf mass area	kg m^{-2}	0.12±0.002a	0.12±0.002a	0.11±0.002b	<0.001*
	Leaf area index	-	5.39±0.52a	5.76±0.44a	3.40±0.61b	<0.001*

Note: the symbol * indicated a significant difference~~t~~ among species based on ANOVA test while the symbol ^{ns} showed a non-~~n~~ significant difference~~t~~ among species referring to ANOVA test. A similar letter in row indicates~~d~~ the parameter between species is~~was~~ not significantly different according to HSD Tukey test.

Even though the survival rate was not significantly different among species, this study found there was a significant difference in height and diameter growth from the three eucalyptus species (p<0.05) (Table 2). *E. pellita* showed higher height and diameter than those of *E. alba* and *E. urophylla*. This finding verified the land characteristics in the study site ~~were~~ are more suitable to *E. pellita* than other species. It is~~was~~ also supported by the previous studies explained that *E. pellita* is~~was~~ a species naturally distributed in the lowland area with a range altitude of 0-700 m above sea level (Hung et al. 2015). This species prefers~~red~~ a soil acidity in the range of 5.0-6.0 (Harwood et al. 1997). According to the site description, the study area ~~was~~ is classified as a lowland area because it has~~d~~ an altitude of 70 m above sea level. Moreover, the soil acidity of study area ~~was~~ is also categorized into slightly acid with pH of 6.00±0.86 (Table 1). The~~is~~ biophysical conditions at the study site principally support~~ed~~ the site requirement for *E. pellita* development.

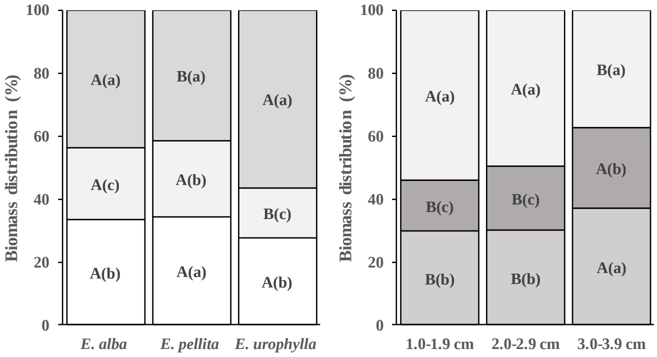
Biomass a~~A~~ccumulation

Biomass production from the three species relatively varied (Table 2). Our study recorded the accumulation of biomass in stem, branches, and total aboveground differed significantly (p<0.05). In ~~opposite conditions~~contrast, the biomass distribution in the foliage component was not significantly different (p>0.05). The greatest total aboveground biomass was observed in *E. pellita* (49.86±3.60 kg ha^{-1}), followed by *E. alba* (49.14±2.80 kg ha^{-1}), and *E. urophylla* (42.96±3.30 kg ha^{-1}). The similar pattern was also found in stem and branches biomass. Interestingly, *E. pellita* had a lower accumulation of foliage biomass (20.50±2.40 kg ha^{-1}) than *E. alba* (21.40±2.24 kg ha^{-1}) and *E. urophylla* (24.16±2.33 kg ha^{-1}). It was caused by the lower value of leaf area and leaf dry weight in this species (Table 2).

This study found that the largest biomass distribution for all species at 6 months after field planting was observed in the foliage (41-56%), followed by stem (28-34%) and branches (16-24%) (Table 3). In general, the biomass allocation in each tree component ~~from every~~among the three species differed significantly (Figure 4). However, the relative contribution of stem biomass to total biomass among the three species was statistically equal. In contrast, the percentage contribution of foliage and branches biomass to total biomass was highly different among those species. ~~Suprisingly~~Surprisingly, our study also demonstrated that biomass proportion in stem and branches gradually improved along with the increasing of diameter classes while the distribution of biomass in foliage progressively declined with the increment of diameter classes.

Table 3. Ratio of the biomass of stem, branches, and foliage to the total aboveground biomass from sample tree. Data are~~were~~ presented in mean, standard deviation~~,~~, and range.

Species	Stem biomass/AGB			Branches biomass/AGB			Foliage b~~B~~iomass/AGB		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
E. alba	0.34	0.04	0.28-0.38	0.23	0.03	0.18-0.25	0.44	0.07	0.37-0.54
E. pellita	0.34	0.04	0.30-0.40	0.24	0.02	0.21-0.28	0.41	0.07	0.33-0.49
E. urophylla	0.28	0.04	0.25-0.33	0.16	0.02	0.13-0.19	0.56	0.06	0.50-0.62
Total	0.32	0.05	0.25-0.40	0.21	0.04	0.13-0.28	0.47	0.09	0.33-0.62



(a) **(b)**

Figure 4. (a) Comparison of biomass distribution in each~~every~~ tree component ~~from different~~among the three eucalyptus species; (b) Relative contribution of biomass in each~~every~~ tree component to total aboveground biomass across diameter classes. A similar big letter demonstrated there was not significantly difference in biomass accumulation in the same component at different species and diameter classes. The similar small letter indicated that there was not a significant difference of biomass proportion among tree components at the same species and diameter classes.

The biomass allocation within tree is~~was~~ principally affected by its physiological process (Poorter et al. 2012). At the early growth periods, trees generally accumulate~~d~~ more biomass to foliage ~~for~~to accelerate~~ing~~ ~~the~~ photosynthesis process (Kohl et al. 2017). When the trees beco~~a~~me bigger and older, the accumulation of foliage biomass slowly declines~~d~~ since trees provide~~d~~ more photosynthate to stem to~~for~~ improve~~ing~~ growth and accelerate~~ing~~ translocation process (Dong et al. 2018, Altanzagas et al. 2019, Wirabuana et al. 2020b). Moreover, the occurrence of leaves shedding by trees also reduces~~d~~ the biomass accumulation in foliage. Some previous studies reported the leaves shedding ~~occurr~~occurs~~ed~~ more intensively with the increasing tree competition, drought stress, and age of tree (Gutiérrez-Soto et al. 2008, Xie et al. 2015, Nguyen et al. 2019).

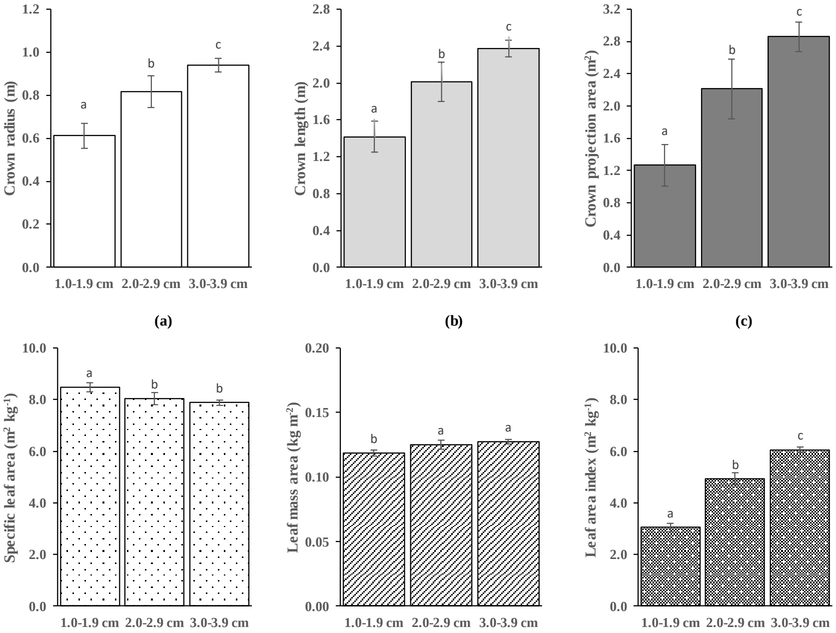
Biomass is~~was~~ an attribute of tree that has an~~d~~ important role in biogeochemical cycle (Houghton et al. 2009). Higher biomass indicates~~d~~ greater carbon storage since around 50% biomass is~~was~~ composed of carbon (Latifah et al. 2018, Viera & Rodríguez-Soalleiro 2019, Wirabuana et al. 2020a). Moreover, ~~the~~ biomass is ~~was~~ also a source of nutrients to maintain the soil fertility. In this case, when ~~the~~ litter is~~was~~ decomposed, some amounts of nutrient would be returned to soil. In fact, ~~the~~ majority of plantation forests in other countries have~~d~~ utilized the biomass residue from harvesting activities as an additional fertilizer to minimize the fertilization cost (Versini et al. 2014, Ferreira et al. 2016, Van Bich et al. 2019).

Besides having a lot of benefits related to ecological functions, biomass is~~was~~ also used as a measurement unit to determine the commercial value of wood, mainly in the pulp and paper, fuelwood, and pellets industries (Visser et al. 2020). However, the commercial value of biomass is~~was~~ only applied for stem components because it is~~was~~ the primary product of woody species like eucalyptus. Referring to the results, *E. pellita* showed higher potential stem biomass (17.25±3.12 kg ha^{-1}) than *E. alba* (16.58±2.75 kg ha^{-1}) and *E. urophylla* (12.01±2.56 kg ha^{-1}) (Table 2).

Formatted: Font: 10 pt

Crown d~~D~~evelopment

Crown characteristics among the three species were significantly different for all parameters except in crown ratio (Table 4). The largest average~~mean~~ crown projection area was observed in *E. pellita* (2.68±0.27 m^2), followed by *E. alba* (2.47±0.29 m^2) and *E. urophylla* (1.42±0.28 m^2). Greater crown dimension commonly indicates~~d~~ more biomass production because crown is~~was~~ the main tree component that plays an~~ed~~ important role in photosynthesis process (Binkley et al. 2013). It was also ~~evidenced~~ strengthened by the ~~outcomes~~results of correlation analysis that ~~verified~~ there was a strong correlation between crown radius, crown length, and crown projection area with total aboveground biomass of eucalyptus species (Figure 6). Trees with a big dimension of crown commonly have~~d~~ better growth performance than trees with a small crown size. It was also confirmed by the study results wherein the size of crown dimension significantly improved along with the increasing diameter class (Figure 5).



(d) (e) (f)

Figure 5. Crown development and leaf characteristics of eucalyptus species across diameter classes. (a) crown radius; (b) crown length; (c) crown projection area; (d) specific leaf area; (e) leaf mass area; and (f) leaf area index. Data are~~were~~ presented in trend for all species.

The development of crown dimensions in every tree is~~was~~ commonly affected by environmental conditions, primarily related to site quality and space availability. A study reported the size of crown dimension is~~was~~ relatively bigger at good site than poor site (DeRose & Seymour 2009). Meanwhile, l~~L~~arger space availability would stimulate better crown development since the growth of the crown is~~was~~ highly responsive to the growing space (Pretzsch et al. 2015). The information about crown development is~~was~~ also important to identify the level of tree competition because it is~~was~~ necessary as a basic consideration to formulate the best silviculture treatment, such as thinning and pruning (McTague & Weiskittel 2016). In this study, the site quality and space availability of every species were principally equal since each species was planted by spacing 3 m x 3 m. Therefore, the dimension of crown from three species was naturally affected by its suitability to the site characteristics. At the end of 6 months after planting, *E. pellita* showed better crown dimension than other species (Table 2).

Leaf c~~C~~haracteristics

Leaf characteristics from the three species significantly differed for all parameters ($p<0.05$) (Table 2). *E. urophylla* showed greater average individual leaf area, individual leaf dry weight, and specific leaf area than other species. Nevertheless, the highest mean leaf area index (LAI) was found in *E. pellita* (5.76±0.44), followed by *E. alba* (5.39±0.52) and *E. urophylla* (3.40±0.61). LAI is ~~was~~ an important parameter to describe the effectiveness of nutrients absorption and photosynthesis (Bréda 2008). This parameter is~~was~~ generally used as one of the criteria to evaluate the application of silviculture treatment in plantation forests primarily related to fertilization and spacing management (Laclau et al. 2009, Forrester et al. 2012, Van Bich et al. 2019). Higher LAI generates~~d~~ better growth performance and greater biomass since the nutrients uptake and photosynthesis occurred more optimum. It explains~~ed~~ the primary reason why *E. pellita* resulted in a greater average of tree dimensions and bigger total biomass than those of *E. alba* and *E. urophylla*.

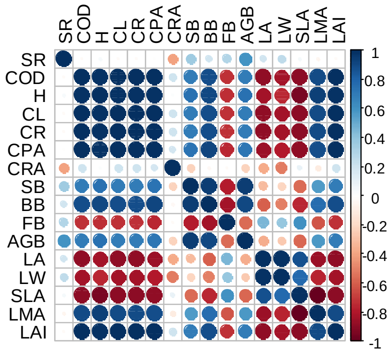


Figure 6. A pallete diagram demonstrating the~~ed~~ correlations among measured parameters. SR (survival); COD (diameter); H (height); CL (crown length); CR (crown radius); CPA (crown projection area); CRA (crown ratio); SB (stem biomass); BB (branches biomass); FB (foliage biomass); AGB (total aboveground biomass); LA (individual leaf area); LW (individual leaf dry weight); SLA (specific leaf area); LMA (leaf mass area); LAI (leaf area index).

Based on the results, the value of LAI and leaf mass area significantly increased with the increment of diameter classes (Figure 6). A different trend was noted in specific leaf area in which this parameter gradually declined with the increase of diameter classes. The specific leaf area in each species relatively varies~~ed~~ depending on its adaptability to the environment (Rosbakh et al. 2015). The previous studies reported that the specific leaf area would decline~~d~~ along with the bigger tree dimension because it has~~d~~ a negative correlation to the age of tree (Xiao et al. 2006, Karavin 2013, Dwyer et al. 2014). Bigger tree dimension indicates~~d~~ an older tree. However, this trend is~~was~~ not commonly discovered in every species due to the impact of several factors, such as seasonal variation, tree competition, and maintenance activities (Zhu et al. 2016).

Finally, this study concluded that in general the ~~initial~~ performance of *E. pellita* at the initial period of planting in Jepara was substantially superior to *E. alba* and *E. urophylla* since it demonstrated the highest mean in diameter, height, total biomass, and leaf area index at the 6 months after field establishment. However, continuous evaluation is~~was~~ still required to monitor the consistent performance of three species in the site experiment.

ACKNOWLEDGEMENTS

Authors deliver our gratitude to Mr. Tarmuji Muh Suwarno as a farmer who provided land for supporting this research. We are also very grateful to reviewers for suggestions to improve this article.

REFERENCES

Acuña E, Cancino J, Rubilar R, Sandoval S. 2018. Aboveground biomass growth and yield of first rotation cutting cycle of acacia and eucalyptus short rotation dendroenergy crops. Revista Árvore. 41: 1–10. DOI: 10.1590/1806-90882017000600008

Aggangan NS, Moon HK, Han SH. 2013. Growth and nutrient accumulation of *Eucalyptus pellita* F. Muell. in response to inoculation with edible ectomycorrhizal mushrooms. Asia Life Sciences. 22: 95–112.

Aguilos R, Marquez C, Adornado H, Aguilos M. 2020. Domesticating commercially important native tree species in the Philippines: early growth performance level. Forests. 11: 1–15. DOI: 10.3390/f11080885

Altanzagas B, Luo Y, Altansukh B, Dorjsuren C, Fang J, Hu H. 2019. Allometric equations for estimating the above-ground biomass of five forest tree species in Khangai, Mongolia. Forests. 10: 1–17. DOI: 10.3390/f10080661

Amezquita PSM, Rubiano JAM, Filho NFDB, Cipriani HN. 2018. Fertilization effects on *Eucalyptus pellita* F. Muell productivity in the Colombian Orinoco Region. Revista Arvore. 42: 1–8. DOI: 10.1590/1806-9088201800050002

Barreiro S, Tomé M. 2012. Analysis of the impact of the use of eucalyptus biomass for energy on wood availability for eucalyptus forest in Portugal: a simulation study. Ecology and Society. 17. DOI: 10.5751/ES-04642-170214

Bassaco MVM, Motta ACV, Pauletti V, Prior SA, Nisgoski S, Ferreira CF. 2018. Nitrogen, phosphorus, and potassium requirements for *Eucalyptus urograndis* plantations in southern Brazil. New Forests. 49: 681–697. DOI: 10.1007/s11056-018-9658-0

Binkley D, Campoe OC, Gspaltl M, Forrester DI. 2013. Light absorption and use efficiency in forests: Why patterns differ for trees and stands. Forest Ecology and Management. 288: 5–13. DOI: 10.1016/j.foreco.2011.11.002

Bréda NJJ. 2008. Leaf area index. In: Encyclopedia of Ecology. DOI: 10.1016/B978-0-444-63768-0.00849-0

Cavalett O, Slettmo SN, Cherubini F. 2018. Energy and environmental aspects of using eucalyptus from Brazil for energy and transportation services in Europe. Sustainability. 10: 1–18. DOI: 10.3390/su10114068

De La Riva EG, Olmo M, Poorter H, Ubera JL, Villar R. 2016. Leaf mass per area (LMA) and its relationship with leaf structure and anatomy in 34 mediterranean woody species along a water availability gradient. PLoS ONE. 11: 1–18. DOI: 10.1371/journal.pone.0148788

DeRose RJ, Seymour RS. 2009. The effect of site quality on growth efficiency of upper crown class *Picea rubens* and *Abies balsamea* in Maine, USA. Canadian Journal of Forest Research. 39: 777–784. DOI: 10.1139/X09-012

Dong L, Zhang L, Li F. 2018. Additive biomass equations based on different dendrometric variables for two dominant species (*Larix gmelini* Rupr. and *Betula platyphylla* Suk.) in natural forests in the Eastern Daxing'an Mountains, Northeast China. Forests. 9: 1–24. DOI: 10.3390/f9050261

Dwyer JM, Hobbs RJ, Mayfield MM. 2014. Specific leaf area responses to environmental gradients through space and time. Ecology. 95: 399–410. DOI: 10.1890/13-0412.1

Estefan G, Sommer R, Ryan J. 2013. Methods of soil, plant, and water analysis. International Center for Agriculture Research in the Dry Areas, pp. 1–243. Retrieved from https://www.gob.mx/siap/articulos/cierre-estadistico-de-la-produccion-ganadera-2017?idiom=es

Ferreira GWD, Soares EMB, Oliveira FCC, Silva IR, Dungait JAJ, Souza IF, Vergütz L. 2016. Nutrient release from decomposing eucalyptus harvest residues following simulated management practices in multiple sites in Brazil. Forest Ecology and Management. 370: 1–11. DOI: 10.1016/j.foreco.2016.03.047

Ferreira MC, Santos RC dos, Castro RVO, Carneiro A de CO, Silva GGC da, Castro AFNM, Costa SE de L, Pimenta AS. 2017. Biomass and energy production at short rotation eucalyptus clonal plantations deployed in Rio Grande Do Norte1. Revista Árvore. 41: 1–7. DOI: 10.1590/1806-90882017000500004

Forrester DI. 2013. Growth responses to thinning, pruning and fertiliser application in Eucalyptus plantations: A review of their production ecology and interactions. Forest Ecology and Management. 310: 336–347. DOI: 10.1016/j.foreco.2013.08.047

Forrester DI, Collopy JJ, Beadle CL, Baker TG. 2012. Interactive effects of simultaneously applied thinning, pruning and fertiliser application treatments on growth, biomass production and crown architecture in a young *Eucalyptus nitens* plantation. Forest Ecology and Management. 267: 104–116. - DOI: 10.1016/j.foreco.2011.11.039

Gonçalves JLM, Wichert MCP, Gava JL, Masetto A V, Junior AJC, Serrano MIP, Mello SLM. 2010. Soil fertility and growth of *Eucalyptus grandis* in Brazil under different residue management practices. Southern Forests . 69: 95–102. DOI: 10.2989/SHFJ.2007.69.2.4.289

González-García M, Hevia A, Majada J, Rubiera F, Barrio-Anta M. 2016. Nutritional, carbon and energy evaluation of *Eucalyptus nitens* short rotation bioenergy plantations in northwestern Spain. IForest. 9: 303–310. DOI: 10.3832/ifor1505-008

Gutiérrez-Soto M V., Pacheco A, Holbrook NM. 2008. Leaf age and the timing of leaf abscission in two tropical dry forest trees. Trees. 22: 393–401. DOI: 10.1007/s00468-007-0200-9

Hakamada R, Giunti Neto C, de Lemos CCZ, Silva SR, Otto MSG, Hall KB, Stape JL. 2016. Validation of an efficient visual method for estimating leaf area index in clonal Eucalyptus plantations. Southern Forests. 78: 275–281. DOI: 10.2989/20702620.2016.1201641

Hakamada R, Hubbard RM, Ferraz S, Stape JL. 2017. Biomass production and potential water stress increase with planting density in four highly productive clonal Eucalyptus genotypes. Southern Forests. 79: 251–257. DOI: 10.2989/20702620.2016.1256041

Halomoan SST, Wawan, Adiwirman. 2015. Effect of fertilization on the growth and biomass of *Acacia mangium* and Eucalyptus hybrid (*E . grandis x E . pellita*). Journal of Tropical Soils. 20: 157–166. DOI: 10.5400/jts.2015.20.3.157

Harwood CE, Alloysius D, Pomroy P, Robson KW, Haines MW. 1997. Early growth and survival of *Eucalyptus pellita* provenances in a range of tropical environments , compared with *E. grandis* , *E. urophylla* and *Acacia mangium*. New Forests. 14: 203–219.

Hii SY, Ha KS, Ngui ML, Ak Penguang S, Duju A, Teng XY, Meder R. 2017. Assessment of plantation-grown *Eucalyptus pellita* in Borneo, Malaysia for solid wood utilisation. Australian Forestry. 80: 26–33. DOI: 10.1080/00049158.2016.1272526

Houghton RA, Hall F, Goetz SJ. 2009. Importance of biomass in the global carbon cycle. Journal of Geophysical Research: 114: 1–13. DOI: 10.1029/2009JG000935

Hung TD, Brawner JT, Meder R. 2015. Estimates of genetic parameters for growth and wood properties in *Eucalyptus pellita* F . Muell . to support tree breeding in Vietnam. Annals of Forest Science. 72: 205–217. DOI: 10.1007/s13595-014-0426-9

Karavin N. 2013. Effects of leaf and plant age on specific leaf area in deciduous tree species *Quercus cerris* L. var. cerris. Bangladesh Journal of Botany. 42: 301–306. DOI: 10.3329/bjb.v42i2.18034

Kaul M, Mohren GMJ, Dadhwal VK. 2010. Carbon storage and sequestration potential of selected tree species in India. Mitigation and Adaptation Strategies for Global Change. 15: 489–510. DOI: 10.1007/s11027-010-9230-5

Kohl M, Neupane PR, Lotfiomran N. 2017. The impact of tree age on biomass growth and carbon accumulation capacity : a retrospective analysis using tree ring data of three tropical tree species grown in natural forests of Suriname. PLoS ONE. 12: 1–17.

Kweon D, Comeau PG. 2019. Relationships between tree survival, stand structure and age in trembling aspen dominated stands. Forest Ecology and Management. 438: 114–122. DOI: 10.1016/j.foreco.2019.02.003

Laclau JP, Almeida JCR, Gonalves JLM, Saint-Andr L, Ventura M, Ranger J, Moreira RM, Nouvellon Y. 2009) Influence of nitrogen and potassium fertilization on leaf lifespan and allocation of above-ground growth in Eucalyptus plantations. Tree Physiology. 29: 111–124. DOI: 10.1093/treephys/tpn010

Latifah S, Muhdi M, Purwoko A, Tanjung E. 2018. Estimation of aboveground tree biomass *Toona sureni* and *Coffea arabica* in agroforestry system of Simalungun, North Sumatra, Indonesia. Biodiversitas. 19: 620–625. DOI: 10.13057/biodiv/d190239

Lewis JD, Phillips NG, Logan BA, Hricko CR, Tissue DT. 2011. Leaf photosynthesis, respiration and stomatal conductance in six Eucalyptus species native to mesic and xeric environments growing in a common garden. Tree Physiology. 31: 997–1006. DOI: 10.1093/treephys/tpr087

Li G, Zhang Z, Shi L, Zhou Y, Yang M, Cao J (2018). Effects of different grazing intensities on soil C , N , and P in an Alpine Meadow on the Qinghai — Tibetan. International Journal of Environmental Research and Public Health. 15: 1–16. DOI: 10.3390/ijerph15112584

Lima PR, Malavasi UC, Battistus AG, Dranski JAL, De Matos Malavasi M. 2019. Photosynthetic responses of eucalyptus seedlings submitted to chemical and mechanical stimulus. Ciencia Florestal. 29: 740–753. DOI: 10.5902/1980509830685

Little KM, Ahtikoski A, Morris AR, Little KM, Ahtikoski A, Rotation-end ARM, Little KM, Ahtikoski A, Morris AR. 2018. Rotation-end financial performance of vegetation control on *Eucalyptus smithii* in South Africa smithii in South Africa. Southern Forests. 80: 241–250. DOI: 10.2989/20702620.2017.1341114

Magalhães TM, Cossa VN, Guedes BS, Fanheiro ASM. 2020. Species-specific biomass allometric models and expansion factors for indigenous and planted forests of the Mozambique highlands. Journal of Forestry Research. DOI: 10.1007/s11676-020-01156-0

Maimunah S, Rahman SA, Samsudin YB, Artati Y, Simamora TI, Andini S, Lee SM, Baral H. 2018. Assessment of suitability of tree species for bioenergy production on burned and degraded peatlands in Central Kalimantan, Indonesia. Land. 7: 1–14. DOI: 10.3390/land7040115

McTague JP, Weiskittel AR. 2016. Individual-tree competition indices and improved compatibility with stand-level estimates of stem density and long-term production. Forests. 7: 1–16. DOI: 10.3390/f7100238

Nambiar EKS, Harwood CE, Mendham DS. 2018. Paths to sustainable wood supply to the pulp and paper industry in Indonesia after diseases have forced a change of species from acacia to eucalypts. Australian Forestry. 81: 148–161. DOI: 10.1080/00049158.2018.1482798

Nandini R, Narendra BH. 2017. Critical land characteristics of former eruption of Batur Mount in Bangli District, Bali. Jurnal Penelitian Hutan dan Konservasi Alam. 9: 199–211. DOI: 10.20886/jphka.2012.9.3.199-211

Nguyen TT, Arndt SK, Baker PJ. 2019. Leaf physiological responses to drought stress and community assembly in an Asian Savanna. Forests. 10: 15–17. DOI: 10.3390/f10121119

Poorter H, Niklas KJ, Reich PB, Oleksyn J, Poot P, Mommer L. 2012. Biomass allocation to leaves, stems and roots: meta-analyses of interspecific variation and environmental control. New Phytologist. 193: 30–50. DOI: 10.1111/j.1469-8137.2011.03952.x

Prasetyo A, Aiso H, Ishiguri F, Wahyudi I, Wijaya IPG, Ohshima J, Yokota S. 2017. Variations on growth characteristics and wood properties of three *Eucalyptus* species planted for pulpwood in Indonesia. Tropics. 26: 59–69. DOI: 10.3759/tropics.ms16-15

Pretzsch H, Biber P, Uhl E, Dahlhausen J, Rötzer T, Caldentey J, Koike T, van Con T, Chavanne A, Seifert T, Toit B du, Farnden C, Pauleit S. 2015. Crown size and growing space requirement of common tree species in urban centres, parks, and forests. Urban Forestry and Urban Greening. 14: 466–479. DOI: 10.1016/j.ufug.2015.04.006

Rance SJ, Mendham DS, Cameron DM. 2017. Assessment of crown woody biomass in Eucalyptus grandis and E. globulus plantations. New Forests. 48: 381–396. DOI: 10.1007/s11056-016-9563-3

Rosbakh S, Römermann C, Poschlod P (2015). Specific leaf area correlates with temperature: new evidence of trait variation at the population, species and community levels. Alpine Botany. 125: 79–86. DOI: 10.1007/s00035-015-0150-6

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021a. Allometric equations for estimating aboveground biomass of Eucalytpus urophylla S.T. Blake in East Nusa Tenggara. Journal of Tropical Forest Management. 27: 24–31. DOI: 10.7226/jtfm.27.1.24

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021b. Soil chemical properties influences on the growth performance of Eucalyptus urophylla planted in dryland ecosystems, East Nusa Tenggara. Journal of Degraded and Mining Lands Management. 8: 2635–2642. DOI: 10.15243/jdmlm.2021.082.2635

Sasaki N, Asner GP, Pan Y, Knorr W, Durst PB, Ma HO, Abe I, Lowe AJ, Koh LP, Putz FE. 2016. Sustainable management of tropical forests can reduce carbon emissions and stabilize timber production. Frontiers in Environmental Science. 4: 1–13. DOI: 10.3389/fenvs.2016.00050

Simetti R, Bonduelle GM, Silva DA da, Mayer SLS, Souza HP, Muniz GIB de. 2018. Production of biomass and energy stock for five Eucalyptus species. Revista Ciência Da Madeira - RCM. 9: 30–36. DOI: 10.12953/2177-6830/rcm.v9n1p30-36

Stanturf JA, Vance ED, Fox TR, Kirst M. 2013. Eucalyptus beyond its native range: environmental issues in exotic bioenergy plantations. International Journal of Forestry Research. 2013: 1–5. DOI: 10.1155/2013/463030

Stuepp CA, Kratz D, Gabira MM, Wendling I. 2020. Survival and initial growth in the field of eucalyptus seedlings produced in different substrates. Pesquisa Agropecuaria Brasileira. 55: 1–12. DOI: 10.1590/S1678-3921.pab2020.v55.01587

Thompson IM. 2013. Early growth results of three *Eucalyptus grandis* × *Eucalyptus nitens* hybrid clonal trials and their response to snow events. Southern Forests. 75: 185–188. DOI: 10.2989/20702620.2013.820446

Truax B, Fortier J, Gagnon D, Lambert F. 2018. Planting density and site effects on stem dimensions, stand productivity, biomass partitioning, carbon stocks and soil nutrient supply in hybrid poplar plantations. Forests. 9: 1–21. DOI: 10.3390/f9060293

Van Bich N, Mendham D, Evans KJ, Dong TL, Hai VD, Van Thanh H, Mohammed CL. 2019. Effect of residue management and fertiliser application on the productivity of a Eucalyptus hybrid and *Acacia mangium* planted on sloping terrain in northern Vietnam. Southern Forests. 81: 201–212. DOI: 10.2989/20702620.2018.1555940

Versini A, Zeller B, Derrien D, Mazoumbou J, Laclau J. 2014. The role of harvest residues to sustain tree growth and soil nitrogen stocks in a tropical Eucalyptus plantation. 245–260. DOI: 10.1007/s11104-013-1963-y

Viera M, Rodríguez-Soalleiro R. 2019. A complete assessment of carbon stocks in above and belowground biomass components of a hybrid eucalyptus plantation in Southern Brazil. Forests. 10: 1–12. DOI: 10.3390/f10070536

Visser L, Hoefnagels R, Junginger M. 2020. The potential contribution of imported biomass to renewable energy targets in the EU-the trade-off between ambitious greenhouse gas emission reduction targets and cost thresholds. Energies. 13: 1–30. DOI: 10.3390/en13071761

Wirabuana PYAP, Sadono R, Juniarso S, Idris F. 2020a. Interaction of fertilization and weed control influences on growth , biomass , and carbon in eucalyptus hybrid (*E. pellita* × *E. brassiana*). Journal of Tropical Forest Management. 26: 144–154. DOI: 10.7226/jtfm.26.2.144

Wirabuana PYAP, Sadono R, Jurniarso S. 2019. Fertilization effects on early growth, aboveground biomass, carbon storage, and leaf characteristics of Eucalyptus pellita F.Muell. in South Sumatra. ournal of Tropical Forest Management. 25: 154–163. DOI: 10.7226/jtfm.25.3.154

Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS, Matatula J. 2020b. Allometric equations for estimating biomass of community forest tree species in Madiun , Indonesia. Biodiversitas. 21: 4291–4300. DOI: 10.13057/biodiv/d210947

Xiao CW, Janssens IA, Curiel Yuste J, Ceulemans R. 2006. Variation of specific leaf area and upscaling to leaf area index in mature Scots pine. Trees. 20: 304–310. DOI: 10.1007/s00468-005-0039-x

Xie Y, Wang X, Silander JA. 2015. Deciduous forest responses to temperature, precipitation, and drought imply complex climate change impacts. Proceedings of the National Academy of Sciences of the United States of America. 112: 13585–13590. DOI: 10.1073/pnas.1509991112

Zhu W, Xiang W, Pan Q, Zeng Y, Ouyang S, Lei P, Deng X, Fang X, Peng C. 2016. Spatial and seasonal variations of leaf area index (LAI) in subtropical secondary forests related to floristic composition and stand characters. Biogeosciences. 13: 3819–3831. DOI: 10.5194/bg-13-3819-2016

525

Short Communication:
The growth, aboveground biomass, crown development, and leaf characteristics of three eucalyptus species at initial stage of planting in Jepara, Indonesia

Commented [A1]: This paper was well executed in term of background, aim, methods, results and discussion. So, I would suggest to direct this paper as a full research paper instead of short communication.

Commented [AS2R1]: Thank you for your recommendation. To be honest, authors also hopeful this paper can be published as a full research article. However, the final decision depends on the editorial board of Biodiversitas Journal of Biological Diversity

Commented [A3]: I would suggest the title to be more informative and specific on the context of the research conducted, in this case is the initial stage of planting (i.e., six months after planting).

Commented [AS4R3]: The title have been revised following the reviewers' suggestions

Abstract. Industry development, climate change mitigation and renewable energy currently become the most essential challenge in tropical forest management, primarily in Indonesia. The existence of tropical forests is not only managed to maintain the stability of wood supply for commercial industries but also to reduce greenhouse gas emissions in the atmosphere and to generate energy alternatives from tree biomass. To answer this challenge, the development of fast-growing species like eucalyptus can become a good solution. However, the productivity of eucalyptus depends on its adaptability to the site condition. Therefore, understanding site-species interaction becomes the fundamental requirement before planted on a large scale. This study aimed to evaluate the initial performance of eucalyptus species developed in Jepara. An experiment consisted of three different eucalyptus species, i.e., *E. alba*, *E. pellita*, and *E. urophylla*, was established using a randomized complete block design. Sixteen parameters were selected to assess the eucalyptus performance, including survival, height, diameter, biomass accumulation (stem, branches, foliage, and total aboveground), crown length, crown radius, crown projection area, crown ratio, individual leaf area, individual leaf dry weight, specific leaf area, leaf mass area, and leaf area index. The comparison of the mean of tree attributes from each species was examined using ANOVA, followed by HSD Tukey. Results showed that all measured parameters indicated a significant difference among the three species ($p<0.05$), except for survival, foliage biomass, and crown ratio ($p>0.05$). The preliminary performance of *E. pellita* was relatively better than the other two species, mainly related to height (3.00±0.21 m), total aboveground biomass (49.86±3.60 kg ha^{-1}), crown projection area (2.68±0.27 m^2), and leaf area index (5.76±0.44). Our study concluded the initial performance of *E. pellita* in Jepara was substantially superior to *E. alba* and *E. urophylla*. Nevertheless, continuous evaluation is needed to monitor the consistent performance those species in the study area.

Key words: Crown projection area, eucalyptus, leaf area index, leaf mass area, specific leaf area

Running title: Preliminary evaluation of eucalyptus species

INTRODUCTION

Integration of industry development, climate change mitigation, and renewable energy diversification currently becomes the most important challenge in sustainable forest management in tropical region (Sadono et al. 2021a), including in Indonesia. In the tropics, the existence of forests is not only managed to supply wood demands for commercial industries, but also to reduce carbon emissions in the atmosphere (Sasaki et al. 2016) and to generate energy alternatives from tree biomass (Ferreira et al. 2017). To tackle this challenge, the development of fast-growing tree species can become a win-win solution to achieve triple objectives of maintaining industry viability, reducing carbon emissions, and producing bioenergy (González-García et al. 2016).

In several decades, there are a number of fast-growing tree species developed as plantation forest in the tropics, one of which is eucalyptus. The development of eucalyptus as a major species in plantation forests has been widely conducted in many tropical countries, such as Brazil, Chile, Colombia, Mexico, Thailand, Vietnam, and Indonesia (Aggangan et al. 2013, Hakamada et al. 2017, Acuña et al. 2018, Amezquita et al. 2018, Van Bich et al. 2019, Wirabuana et al. 2020a). Besides having a short rotation period of approximately 5-8 years (Little et al. 2018), the quality of eucalyptus wood suits the requirements of industries, such as for construction materials, pulp and paper, plywood, veneer, and furniture (Forrester 2013, Hii et al. 2017, Nambiar et al. 2018). In addition, the majority of eucalyptus species also have rapid growth due to the more efficient photosynthesis process (Lewis et al. 2011, Lima et al. 2019), suggesting that the carbon sequestration in eucalyptus is relatively faster than slow-growing species (Kaul et al. 2010). Therefore, the previous studies also report that the existence of eucalyptus plantations provides a significant contribution to climate change mitigation (Magalhães et al. 2020). Furthermore, a study explains that eucalyptus wood can become a potential source of renewable energy since it has a high calorific value of 4,532-4,661 kcal kg^{-1} (Simetti et al. 2018). The use of eucalyptus wood for bioenergy has been conducted in some foreign countries, including Brazil, Spain, and Portugal, wherein the development of biomass power plants has been intensively managed (Barreiro & Tomé 2012, González-García et al. 2016, Cavalett et al. 2018). A study confirms that the use of plant biomass, mainly sourced from eucalyptus wood, results in lower carbon emissions to the atmosphere than fossil fuels like coal as well as oil and gas (Cavalett et al. 2018). All of those evidences provide justification that eucalyptus is highly potential to be developed as plantation forest to simultaneously integrating the goals of industry development, climate change mitigation and renewable energy sources in tropical countries, particularly in Indonesia.

Developing eucalyptus plantations in Indonesia is prospective because it is a native species from this country. Some studies state that there are several eucalyptus species that have natural distribution in the eastern of Indonesia, such as *Eucalyptus pellita*, *E. alba*, and *E. urophylla* (Stanturf et al. 2013, Prasetyo et al. 2017). However, the existence of eucalyptus plantations in Indonesia is still limited wherein most eucalyptus estates are located in Sumatra (Nambiar et al. 2018). Moreover, the objective of eucalyptus management in Indonesia still focuses on supplying raw materials for pulp and paper industry (Prasetyo et al. 2017). This circumstance is quite different from other countries like Brazil, China, and Vietnam in which the presence of eucalyptus plantation becomes the most important plantation forests along in such countries with the development of many processing industries for eucalyptus wood. Those facts indicate that there is a wide opportunity to develop eucalyptus plantations in Indonesia by expanding its area nor improving its downstream industries. However, to develop large scale eucalyptus plantations, there is a need to enhance the understanding about site-species interaction of eucalyptus stand with its environment in order to obtain high productivity. It is commonly done by establishing an experiment for species trial in several sites which become the priority area for eucalyptus development. In this context, the best species is selected by considering its superior performance to other eucalyptus species.

This study examined the adaptability of three different eucalyptus species, namely *E. alba*, *E. pellita*, and *E. urophylla* planted in the Jepara District, Central Java Province, Indonesia. A preliminary evaluation was undertaken to monitor the growth, aboveground biomass, crown development, and leaf characteristics of those three species at six months after planting. It is a critical period to assess the suitability of species to survive in the site condition (Van Bich et al. 2019, Stuepp et al. 2020, Wirabuana et al. 2020a) since every eucalyptus species has a habitat preference to support its growth and development. If site condition is not suitable, the species will demonstrate a high mortality rate and low growth performance (Thompson 2013, Maimunah et al. 2018, Aguilos et al. 2020). The species trial of eucalyptus in Jepara was based on the rationale that Jepara has a number of wood processing industries, especially for furniture. Moreover, there are several other forestry industries located near this area, such as pulp and paper, plywood, veneer, and construction, that require a continuous supply for wood raw materials. Interestingly, Jepara has also a power plant that faces a problem related to the coal deficit. This situation provides an opportunity to maximize the potential of eucalyptus for bioenergy. On another side, the development of eucalyptus plantation in Jepara has not yet be conducted until now, even though this species offers a lot of advantages. Most importantly, developing eucalyptus plantations in Jepara is not only directed to support the integration of industry development, climate change mitigation, and renewable energy but also to facilitate the program of *ex-situ* conservation and to optimize the potential of native species from Indonesia.

Commented [A5]: Please mention here the three species observed in the study to provide introductory information to the readers on what the context of species in this research.

Commented [AS6R5]: The details of species used for this trial have been added

MATERIALS AND METHODS

Study area

A planting trial was established in community forests located at Srobyong, Jepara District with geographic position in S6°31'35''-6°31'37'' and E110°41'39''-110°43'22'' (Figure 1). The planting trial was set up in private land of farmers with an extent of 2 ha. The research site has an altitude of 70 m above sea level, flat topography was flat with a slope level of 3-8%, the average daily temperature of 29°C with a minimum of 22°C and a maximum of 34°C, and the mean air humidity of 84%. It has annual rainfall from 2,246 to 2,446 mm year $^{-1}$ during the last five years from 2016 to 2020 with the majority of rainfall is recorded in February around 33.82% of total rainfall in a year. Dry periods occur for five months from May to September. Soil type is dominated by alfisol with pH of 5.5 to 6.0. Previously, the vegetation cover consisted of uneven-aged mixed species with irregular distribution and high variation in growth.

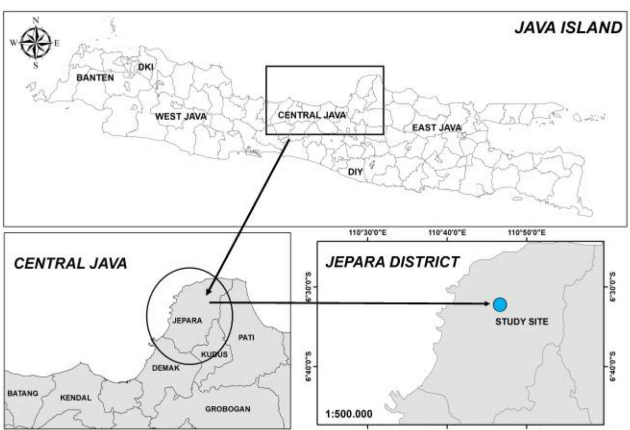


Figure 1. Study area of planting trial of eucalyptus in Jepara District (blue symbol).

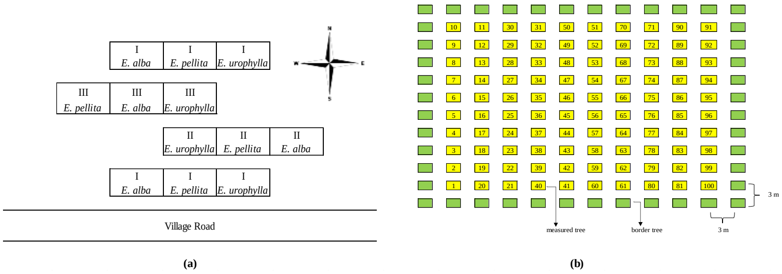
Commented [A7]: Please note that not all the readers are familiar with the study site. I would suggest to add an inset map showing the regional context of the study site (e.g. Java Island or Indonesia).

Commented [AS8R7]: The map have been revised

Experimental design

Three different eucalyptus species were examined in this study, i.e., *E. alba*, *E. urophylla*, and *E. pellita*. The planting trial was established in a randomized complete block design (RBCD) with four blocks (i.e., three blocks for continuous monitoring and one block for destructive measurement in specific periods, namely 6, 12, 24, 36, 48, and 60 months). This design was selected to minimize the influence of environmental gradient on eucalyptus performance (Thompson 2013). It was importantly conducted to avoid the biased result due to the impact of site condition, particularly related to soil quality.

Each species was planted in a square plot of 0.1 ha comprising 100 measured trees and 44 border trees (Figure 2). The main function of border trees was to indicate the clear boundaries among treatments in every block. Moreover, to support the activity of monitoring, a nameplate was placed in each treatment plot using a specific code. Every measured tree was also marked by individual identity number.



(a) (b)

Figure 2. The layout of experimental design in the study area for evaluating the performance of eucalyptus stand of three different species established in Jepara District. (a) the position of every treatment in each block and (b) the position of measured and border trees in every treatment plot.

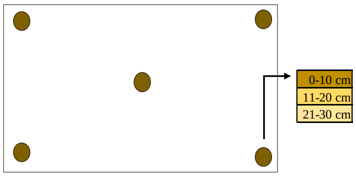


Figure 3. The distribution of five sample points for collecting soil sample in the site experiment (brown circle).

This trial was established in August 2020. Site preparation was conducted to identify the variation of environmental gradient before determining the layout of experimental design. It was required to create a homogeneous condition in each block to minimize the influence of environmental gradient on treatment plots (Gonçalves et al. 2010). The site preparation consisted of several stages, including measuring slope variation, observing waterlog, identifying wind disturbance, and assessing soil quality (Wirabuana et al. 2020a). Soil quality assessment was conducted by collecting soil samples in five different points at three depth layers of 0-10 cm, 11-20 cm, and 21-30 cm (Li et al. 2018, Wirabuana et al. 2019, Sadono et al. 2021b) (Figure 3). Then, the samples were packed and brought to the laboratory for quantifying its characteristics, namely soil acidity, soil organic carbon, total nitrogen, available phosphorus, total potassium, and cation exchange capacity (Table 1). Soil acidity was measured using pH meter. The quantification of soil organic carbon was conducted using Walkey and Black method. Total nitrogen was estimated by Kjeldahl method. The analysis of available phosphorus was executed using Olsen method. The method of flame photometry was utilized to calculate the total potassium. The use of ammonium acetate method was applied to quantify the content of cation exchange capacity. The protocol of soil analysis was conducted referring to the guide for methods of soil, plant, and water analysis published by Estefan et al. (2013).

Table 1. Soil characteristics at the research site. Data are presented in mean±standard deviation

Soil parameter	**Symbol**	**Units**	**Value**	**Categories**
Soil acidity	pH	-	6.00±0.86	Slightly acid
Soil organic carbon	SOC	%	2.97±0.37	Moderate
Total nitrogen	N-tot	%	0.17±0.01	Low
Available phosphorus	Av-P	ppm	2.79±1.54	Very low
Total potassium	K-tot	cmolc kg^{-1}	0.21±0.12	Very low
Cation exchange capacity	CEC	cmolc kg^{-1}	10.11±3.14	Low

Note: the classification of soil quality was determined following the soil quality categories reported by (Nandini & Narendra 2017)

The plant materials of *E. alba*, *E. urophylla*, and *E. pellita* used in this study were obtained from different provenance sources since every species has different natural distribution. *E. alba* and *E. urophylla* were from provenance Timor, East Nusa Tenggara, while *E. pellita* was from provenance Muting, Papua. The seeds of such species were sown in the nursery for 90 days. In parallel, soil tillage was conducted to improve soil structure at two weeks before field planting. A week before planting the seedlings, grading activity was undertaken to determine the quality of seedlings from each species. In this case, only seedlings with a height of 30 cm and healthy condition were used as plant materials for planting. Seedlings were planted by initial spacing of 3 m x 3 m. Fertilizer NPK with concentration of 15:15:15 was also added to each seedling with a dose of 100 g to increase the availability of nutrients for eucalyptus because the site experiment had a low content of nitrogen, phosphorus, and potassium in the soil. Moreover, several studies reported eucalyptus is highly responsive to phosphorus availability since it was a macronutrient exceptionally required by this plant (Amezquita et al. 2018, Bassaco et al. 2018, Sadono et al. 2021b). To support the early growth of eucalyptus, the application of weed control was also implemented by slashing and chemical spraying at three and six months after planting.

Data collection

Data were collected at 6 months after planting. This period was frequently used by most plantation forests company in Indonesia to conduct the first evaluation of planting trials (Wirabuana et al. 2019). The period was a critical moment to assess the adaptability of species to environmental conditions outside their natural habitat (Stuepp et al. 2020). The process of data collection was conducted from March to April 2021, consisting of several activities, i.e., stand measurement, destructive sampling, and laboratory analysis. Sixteen parameters were selected to evaluate the performance of the three eucalyptus species, including survival rate, height, diameter, biomass production (stem, branches, foliage, and total aboveground), crown length, crown radius, crown projection area, crown ration, individual leaf area, individual leaf dry weight, specific leaf area, leaf mass area, and leaf area index.

Survival rate was defined as the ratio of actual density and initial planting density. Height was measured from aboveground to top crown using a measuring pole (Halomoan et al. 2015). Diameter was measured at 0.3 m aboveground by a caliper (Wirabuana et al. 2019). The crown length was quantified from crown base to top crown while crown ratio was calculated as the ratio between crown length and tree height. Crown radius was computed as the quadratic mean crown radius at eight directions (eq.1) (Wirabuana et al. 2019). The transition from crown radius to crown projection area was determined by the occupation area of every tree (eq.2) (Pretzsch et al. 2015).

$$CR = \left((R_N^2 + R_{NE}^2 + \ldots + R_{NW}^2) / 8 \right)^{1/2} \quad (1)$$

$$CPA = \pi \times CR^2 \quad (2)$$

wherein *CR* was a quadratic mean crown radius every tree (m), *R* represented crown radius in certain direction (m), and *CPA* described crown projection area of each tree (m^2).

To quantify biomass accumulation and leaf characteristics of each species, destructive sampling was conducted step by step in a chronological manner. Each species was represented by five sample trees. Those sample trees were determined by considering the distribution of diameter to obtain the balance growth dimension from small to big trees (Sadono et al. 2021a). In this study, the diameter was classified into three classes, including small (1.0-1.9 cm), medium (2.0-2.9 cm), and big (3.0-3.9 cm). After the sample tree was felled, the tree component was separated into stem, branches, and foliage. For part of foliage, the sample was also stratified into three layers based on leaves position, i.e., base, middle, and top. It was conducted to facilitate the measurement of leaf characteristics. From every layer, ten leaf samples were taken randomly. Thereby, the number of samples for determining leaf attributes in each sample tree was 30 samples.

The fresh weight of each component was measured in the field using a hanging balance. Afterward, approximately 500 g subsample from each part was taken and brought to the laboratory for dried. Before starting the drying process, the area of selected leaf samples was measured using a planimeter. Then, the subsample of each component (including the selected leaf samples) was dried using an oven for 48 hours at 70°C before measuring their dry weight (Hakamada et al. 2017). The biomass accumulation in each component was calculated by multiplying the ratio of dry-fresh weight from subsample with the total fresh weight of each part from field measurement (eq.3) (Altanzagas et al. 2019) while total aboveground biomass for each individual tree was calculated by summing the biomass distribution in stem, branches, and foliage (eq.4) (Rance et al. 2017).

$$W_c = (DW_s / FW_s) \times FW_c \qquad (3)$$

$$W_t = W_{stem} + W_{branches} + W_{foliage} \qquad (4)$$

wherein W_c was biomass from every tree component like stem, branches, or foliage (kg), DW_s described the dry weight of subsample (kg), FW_s indicated the fresh weight of sub sample (kg), FW_c was the total fresh weight of tree component (kg), and W_t signified total aboveground biomass of individual tree (kg). Then, the result of destructive sampling was converted to estimate the biomass production of eucalyptus stand from every species in treatment plots.

To measure the leaf characteristics, the dry weight of each selected leaf sample was determined using a digital analytic scale. The specific leaf area was calculated based on the ratio of leaf area and leaf dry weight (eq.5) (Hakamada et al. 2016). In opposite condition, leaf mass area was computed by dividing leaf dry weight and leaf area (eq.6) (De La Riva et al. 2016). Leaf area index from each sample tree was quantified following this equation (eq. 7) (Wirabuana et al. 2019).

$$SLA = LA / LW \qquad (5)$$

$$LMA = LW / LA \qquad (6)$$

$$LAI = (W_{foliage} \times SLA) / CPA \qquad (7)$$

wherein SLA was specific leaf area (m^2 kg^{-1}), LMA represented leaf mass area (kg m^{-2}), LA described individual leaf area (cm^2), LW was individual leaf dry weight (g), and LAI indicated leaf area index.

Data analysis

Statistical analysis was processed using software R version 4.0.2 with a significant level of 5%. The package agricolae was used to facilitate the process of data analysis. Descriptive test was applied to identify the data characteristics, primarily related to minimum, maximum, mean, standard deviation, and coefficient of variation. It aimed to assess the accuracy and precision of data collected from stand measurement, destructive sampling, and laboratory analysis. The normality of data was evaluated using Shapiro-Wilk test. Homogeneity variance among treatments were examined using Bartlett's test. The comparison means eucalyptus performance among three species for each parameter was tested using ANOVA followed by HSD Tukey. The analysis of correlation using a pallete matrix was also done to evaluate the relationship between observed parameters.

RESULTS AND DISCUSSION

Growth performance

The survival rate among species did not significantly differ (p>0.05) (Table 2). Each species had a survival rate of more than 80%, indicating that every species had a good tolerance to the environmental condition in the study area. The highest survival rate was recorded in *E. alba* (90.4±2.19%), followed by *E. pellita* (89.6±3.57%) and *E. urophylla* (88.8±5.21%). In the context of plantation forest management, survival is an essential indicator to evaluate the species performance since it determines the number of trees that could be harvested at the end of the rotation (Truax et al. 2018). This parameter also directly affects land cover and tree competition at the stand level (Kweon & Comeau 2019). Moreover, the plant survival also has a strong relationship to the efficiency of planting cost for establishing plantation forests. The development of a species in plantation forest requires a high survival to obtain an optimum stand productivity because it becomes a multiplier factor to estimate the wood volume and biomass production in hectare unit.

Table 2. The comparison of the growth, aboveground biomass, crown development, and leaf characteristics of three different eucalyptus species trialed in Jepara District. Data are presented in mean ± standard deviation

Group variable	Measured parameter	Unit	Species			*p-value*
			E. alba	*E. pellita*	*E. urophylla*	
Growth	Survival	%	90.4±2.19a	89.6±3.57a	88.8±5.21a	0.958^{ns}
	Height	m	2.82±0.25a	3.00±0.21a	1.87±0.29b	<0.001*
	Diameter	cm	2.31±0.19a	2.39±0.19a	1.62±0.15b	<0.001*
Aboveground biomass	Stem biomass	kg ha^{-1}	16.58±2.75ab	17.25±3.12a	12.01±2.56b	0.024*

	Branches biomass	kg ha^{-1}	11.15±1.90a	12.10±1.91a	6.78±1.11b	<0.001*
	Foliage biomass	kg ha^{-1}	21.40±2.24a	20.50±2.40a	24.16±2.33a	0.069^{ns}
	Total Aboveground biomass	kg ha^{-1}	49.14±2.80a	49.86±3.60a	42.96±3.30b	0.010*
Crown development	Crown radius	m	0.86±0.05a	0.90±0.04a	0.64±0.06b	<0.001*
	Crown length	M	2.15±0.16a	2.27±0.14a	1.52±0.19b	<0.001*
	Crown projection area	m^{2}	2.47±0.29a	2.68±0.27a	1.42±0.28b	<0.001*
	Crown ratio	-	0.93±0.02a	0.95±0.04a	0.93±0.04a	0.763^{ns}
Leaf characteristics	Individual Leaf area	cm^{2}	64.27±2.91b	63.30±3.67b	78.52±8.66a	0.001*
	Individual Leaf dry weight	g	0.80±0.02b	0.79±0.04b	0.92±0.08a	0.007*
	Specific leaf area	m^{2} kg^{-1}	7.93±0.13b	7.91±0.17b	8.41±0.14a	<0.001*
	Leaf mass area	kg m^{-2}	0.12±0.002a	0.12±0.002a	0.11±0.002b	<0.001*
	Leaf area index	-	5.39±0.52a	5.76±0.44a	3.40±0.61b	<0.001*

Note: the symbol * indicated a significant difference among species based on ANOVA test while the symbol ^{ns} showed a non-significant difference among species referring to ANOVA test. A similar letter in row indicates the parameter between species is not significantly different according to HSD Tukey test.

Even though the survival rate was not significantly different among species, this study found there was a significant difference in height and diameter growth from the three eucalyptus species ($p<0.05$) (Table 2). *E. pellita* showed higher height and diameter than those of *E. alba* and *E. urophylla*. This finding verified the land characteristics in the study site are more suitable to *E. pellita* than other species. It is also supported by the previous studies explained that *E. pellita* is a species naturally distributed in the lowland area with a range altitude of 0-700 m above sea level (Hung et al. 2015). This species prefers a soil acidity in the range of 5.0-6.0 (Harwood et al. 1997). According to the site description, the study area is classified as a lowland area because it has an altitude of 70 m above sea level. Moreover, the soil acidity of study area is also categorized into slightly acid with pH of 6.00±0.86 (Table 1). The biophysical conditions at the study site principally support the site requirement for *E. pellita* development.

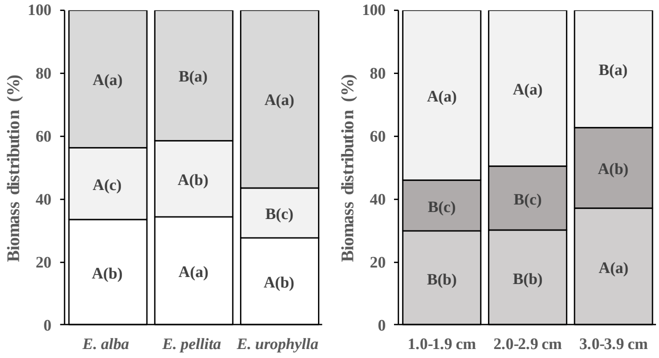
Biomass accumulation

Biomass production from the three species relatively varied (Table 2). Our study recorded the accumulation of biomass in stem, branches, and total aboveground differed significantly ($p<0.05$). In contrast, the biomass distribution in the foliage component was not significantly different ($p>0.05$). The greatest total aboveground biomass was observed in *E. pellita* (49.86±3.60 kg ha^{-1}), followed by *E. alba* (49.14±2.80 kg ha^{-1}), and *E. urophylla* (42.96±3.30 kg ha^{-1}). The similar pattern was also found in stem and branches biomass. Interestingly, *E. pellita* had a lower accumulation of foliage biomass (20.50±2.40 kg ha^{-1}) than *E. alba* (21.40±2.24 kg ha^{-1}) and *E. urophylla* (24.16±2.33 kg ha^{-1}). It was caused by the lower value of leaf area and leaf dry weight in this species (Table 2).

This study found that the largest biomass distribution for all species at 6 months after field planting was observed in the foliage (41-56%), followed by stem (28-34%) and branches (16-24%) (Table 3). In general, the biomass allocation in each tree component among the three species differed significantly (Figure 4). However, the relative contribution of stem biomass to total biomass among the three species was statistically equal. In contrast, the percentage contribution of foliage and branches biomass to total biomass was highly different among those species. Surprisingly, our study also demonstrated that biomass proportion in stem and branches gradually improved along with the increasing of diameter classes while the distribution of biomass in foliage progressively declined with the increment of diameter classes.

Table 3. Ratio of the biomass of stem, branches, and foliage to the total aboveground biomass from sample tree. Data are presented in mean, standard deviation, and range.

Species	Stem biomass/AGB			Branches biomass/AGB			Foliage biomass/AGB		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
E. alba	0.34	0.04	0.28-0.38	0.23	0.03	0.18-0.25	0.44	0.07	0.37-0.54
E. pellita	0.34	0.04	0.30-0.40	0.24	0.02	0.21-0.28	0.41	0.07	0.33-0.49
E. urophylla	0.28	0.04	0.25-0.33	0.16	0.02	0.13-0.19	0.56	0.06	0.50-0.62
Total	0.32	0.05	0.25-0.40	0.21	0.04	0.13-0.28	0.47	0.09	0.33-0.62



(a) **(b)**

Figure 4. (a) Comparison of biomass distribution in each tree component among the three eucalyptus species; (b) Relative contribution of biomass in each tree component to total aboveground biomass across diameter classes. A similar big letter demonstrated there was not significantly difference in biomass accumulation in the same component at different species and diameter classes. The similar small letter indicated that there was not a significant difference of biomass proportion among tree components at the same species and diameter classes.

The biomass allocation within tree is principally affected by its physiological process (Poorter et al. 2012). At the early growth periods, trees generally accumulate more biomass to foliage to accelerate photosynthesis process (Kohl et al. 2017). When the trees become bigger and older, the accumulation of foliage biomass slowly declines since trees provide more photosynthate to stem to improve growth and accelerate translocation process (Dong et al. 2018, Altanzagas et al. 2019, Wirabuana et al. 2020b). Moreover, the occurrence of leaves shedding by trees also reduces the biomass accumulation in foliage. Some previous studies reported the leaves shedding occurs more intensively with the increasing tree competition, drought stress, and age of tree (Gutiérrez-Soto et al. 2008, Xie et al. 2015, Nguyen et al. 2019).

Biomass is an attribute of tree that has an important role in biogeochemical cycle (Houghton et al. 2009). Higher biomass indicates greater carbon storage since around 50% biomass is composed of carbon (Latifah et al. 2018, Viera & Rodríguez-Soalleiro 2019, Wirabuana et al. 2020a). Moreover, biomass is also a source of nutrients to maintain the soil fertility. In this case, when litter is decomposed, some amounts of nutrient would be returned to soil. In fact, majority of plantation forests in other countries have utilized the biomass residue from harvesting activities as an additional fertilizer to minimize the fertilization cost (Versini et al. 2014, Ferreira et al. 2016, Van Bich et al. 2019).

Besides having a lot of benefits related to ecological functions, biomass is also used as a measurement unit to determine the commercial value of wood, mainly in the pulp and paper, fuelwood, and pellets industries (Visser et al. 2020). However, the commercial value of biomass is only applied for stem components because it is the primary product of woody species like eucalyptus. Referring to the results, *E. pellita* showed higher potential stem biomass (17.25±3.12 kg ha^{-1}) than *E. alba* (16.58±2.75 kg ha^{-1}) and *E. urophylla* (12.01±2.56 kg ha^{-1}) (Table 2).

Crown development

Crown characteristics among the three species were significantly different for all parameters except in crown ratio (Table 4). The largest average crown projection area was observed in *E. pellita* (2.68±0.27 m^2), followed by *E. alba* (2.47±0.29 m^2) and *E. urophylla* (1.42±0.28 m^2). Greater crown dimension commonly indicates more biomass production because crown is the main tree component that plays an important role in photosynthesis process (Binkley et al. 2013). It was also strengthened by the results of correlation analysis that there was a strong correlation between crown radius, crown length, and crown projection area with total aboveground biomass of eucalyptus species (Figure 6). Trees with a big dimension of crown commonly have better growth performance than trees with a small crown size. It was also confirmed by the study results wherein the size of crown dimension significantly improved along with the increasing diameter class (Figure 5).

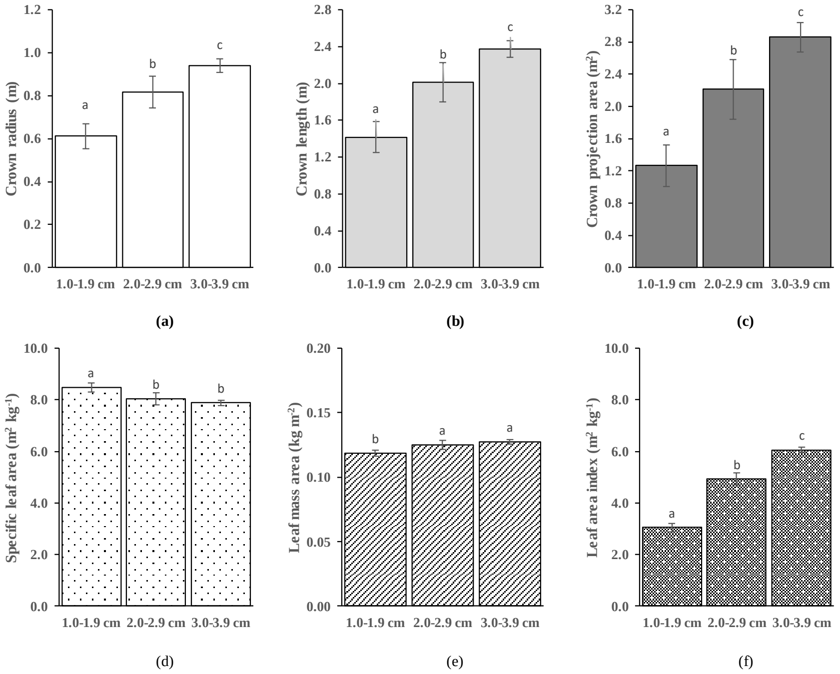


Figure 5. Crown development and leaf characteristics of eucalyptus species across diameter classes. (a) crown radius; (b) crown length; (c) crown projection area; (d) specific leaf area; (e) leaf mass area; and (f) leaf area index. Data are presented in trend for all species.

The development of crown dimensions in every tree is commonly affected by environmental conditions, primarily related to site quality and space availability. A study reported the size of crown dimension is relatively bigger at good site than poor site (DeRose & Seymour 2009). Meanwhile, larger space availability would stimulate better crown development since the growth of the crown is highly responsive to the growing space (Pretzsch et al. 2015). The information about crown development is also important to identify the level of tree competition because it is necessary as a basic consideration to formulate the best silviculture treatment, such as thinning and pruning (McTague & Weiskittel 2016). In this study, the site quality and space availability of every species were principally equal since each species was planted by spacing 3 m x 3 m. Therefore, the dimension of crown from three species was naturally affected by its suitability to the site characteristics. At the end of 6 months after planting, *E. pellita* showed better crown dimension than other species (Table 2).

Leaf characteristics

Leaf characteristics from the three species significantly differed for all parameters ($p<0.05$) (Table 2). *E. urophylla* showed greater average individual leaf area, individual leaf dry weight, and specific leaf area than other species. Nevertheless, the highest mean leaf area index (LAI) was found in *E. pellita* (5.76±0.44), followed by *E. alba* (5.39±0.52) and *E. urophylla* (3.40±0.61). LAI is an important parameter to describe the effectiveness of nutrients absorption and photosynthesis (Bréda 2008). This parameter is generally used as one of the criteria to evaluate the application of silviculture treatment in plantation forests primarily related to fertilization and spacing management (Laclau et al. 2009, Forrester et al. 2012, Van Bich et al. 2019). Higher LAI generates better growth performance and greater biomass since the nutrients uptake and photosynthesis occurred more optimum. It explains the primary reason why *E. pellita* resulted in a greater average of tree dimensions and bigger total biomass than those of *E. alba* and *E. urophylla*.

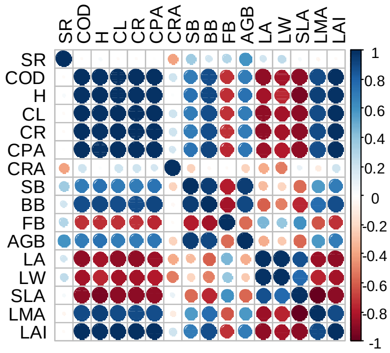


Figure 6. A pallete diagram demonstrating the correlations among measured parameters. SR (survival); COD (diameter); H (height); CL (crown length); CR (crown radius); CPA (crown projection area); CRA (crown ratio); SB (stem biomass); BB (branches biomass); FB (foliage biomass); AGB (total aboveground biomass); LA (individual leaf area); LW (individual leaf dry weight); SLA (specific leaf area); LMA (leaf mass area); LAI (leaf area index).

Based on the results, the value of LAI and leaf mass area significantly increased with the increment of diameter classes (Figure 6). A different trend was noted in specific leaf area in which this parameter gradually declined with the increase of diameter classes. The specific leaf area in each species relatively varies depending on its adaptability to the environment (Rosbakh et al. 2015). The previous studies reported that the specific leaf area would decline along with the bigger tree dimension because it has a negative correlation to the age of tree (Xiao et al. 2006, Karavin 2013, Dwyer et al. 2014). Bigger tree dimension indicates an older tree. However, this trend is not commonly discovered in every species due to the impact of several factors, such as seasonal variation, tree competition, and maintenance activities (Zhu et al. 2016).

Finally, this study concluded that in general the performance of *E. pellita* at the initial period of planting in Jepara was substantially superior to *E. alba* and *E. urophylla* since it demonstrated the highest mean in diameter, height, total biomass, and leaf area index at the 6 months after field establishment. However, continuous evaluation is still required to monitor the consistent performance of three species in the site experiment.

ACKNOWLEDGEMENTS

Authors deliver our gratitude to farmers who provided land for supporting this research. We are also very grateful to reviewers for suggestions to improve this article.

REFERENCES

Acuña E, Cancino J, Rubilar R, Sandoval S. 2018. Aboveground biomass growth and yield of first rotation cutting cycle of acacia and eucalyptus short rotation dendroenergy crops. Revista Árvore. 41: 1–10. DOI: 10.1590/1806-90882017000600008

Aggangan NS, Moon HK, Han SH. 2013. Growth and nutrient accumulation of *Eucalyptus pellita* F. Muell. in response to inoculation with edible ectomycorrhizal mushrooms. Asia Life Sciences. 22: 95–112.

Aguilos R, Marquez C, Adornado H, Aguilos M. 2020. Domesticating commercially important native tree species in the Philippines: early growth performance level. Forests. 11: 1–15. DOI: 10.3390/f11080885

Altanzagas B, Luo Y, Altansukh B, Dorjsuren C, Fang J, Hu H. 2019. Allometric equations for estimating the above-ground biomass of five forest tree species in Khangai, Mongolia. Forests. 10: 1–17. DOI: 10.3390/f10080661

Amezquita PSM, Rubiano JAM, Filho NFDB, Cipriani HN. 2018. Fertilization effects on *Eucalyptus pellita* F. Muell productivity in the Colombian Orinoco Region. Revista Arvore. 42: 1–8. DOI: 10.1590/1806-9088201800050002

Barreiro S, Tomé M. 2012. Analysis of the impact of the use of eucalyptus biomass for energy on wood availability for eucalyptus forest in Portugal: a simulation study. Ecology and Society. 17. DOI: 10.5751/ES-04642-170214

Bassaco MVM, Motta ACV, Pauletti V, Prior SA, Nisgoski S, Ferreira CF. 2018. Nitrogen, phosphorus, and potassium requirements for *Eucalyptus urograndis* plantations in southern Brazil. New Forests. 49: 681–697. DOI: 10.1007/s11056-018-9658-0

Binkley D, Campoe OC, Gspaltl M, Forrester DI. 2013. Light absorption and use efficiency in forests: Why patterns differ for trees and stands. Forest Ecology and Management. 288: 5–13. DOI: 10.1016/j.foreco.2011.11.002

Bréda NJJ. 2008. Leaf area index. In: Encyclopedia of Ecology. DOI: 10.1016/B978-0-444-63768-0.00849-0

Cavalett O, Slettmo SN, Cherubini F. 2018. Energy and environmental aspects of using eucalyptus from Brazil for energy and transportation services in Europe. Sustainability. 10: 1–18. DOI: 10.3390/su10114068

De La Riva EG, Olmo M, Poorter H, Ubera JL, Villar R. 2016. Leaf mass per area (LMA) and its relationship with leaf structure and anatomy in 34 mediterranean woody species along a water availability gradient. PLoS ONE. 11: 1–18. DOI: 10.1371/journal.pone.0148788

DeRose RJ, Seymour RS. 2009. The effect of site quality on growth efficiency of upper crown class *Picea rubens* and *Abies balsamea* in Maine, USA. Canadian Journal of Forest Research. 39: 777–784. DOI: 10.1139/X09-012

Dong L, Zhang L, Li F. 2018. Additive biomass equations based on different dendrometric variables for two dominant species (*Larix gmelini* Rupr. and *Betula platyphylla* Suk.) in natural forests in the Eastern Daxing'an Mountains, Northeast China. Forests. 9: 1–24. DOI: 10.3390/f9050261

Dwyer JM, Hobbs RJ, Mayfield MM. 2014. Specific leaf area responses to environmental gradients through space and time. Ecology. 95: 399–410. DOI: 10.1890/13-0412.1

Estefan G, Sommer R, Ryan J. 2013. Methods of soil, plant, and water analysis. International Center for Agriculture Research in the Dry Areas, pp. 1–243. Retrieved from https://www.gob.mx/siap/articulos/cierre-estadistico-de-la-produccion-ganadera-2017?idiom=es

Ferreira GWD, Soares EMB, Oliveira FCC, Silva IR, Dungait JAJ, Souza IF, Vergütz L. 2016. Nutrient release from decomposing eucalyptus harvest residues following simulated management practices in multiple sites in Brazil. Forest Ecology and Management. 370: 1–11. DOI: 10.1016/j.foreco.2016.03.047

Ferreira MC, Santos RC dos, Castro RVO, Carneiro A de CO, Silva GGC da, Castro AFNM, Costa SE de L, Pimenta AS. 2017. Biomass and energy production at short rotation eucalyptus clonal plantations deployed in Rio Grande Do Norte1. Revista Árvore. 41: 1–7. DOI: 10.1590/1806-90882017000500004

Forrester DI. 2013. Growth responses to thinning, pruning and fertiliser application in Eucalyptus plantations: A review of their production ecology and interactions. Forest Ecology and Management. 310: 336–347. DOI: 10.1016/j.foreco.2013.08.047

Forrester DI, Collopy JJ, Beadle CL, Baker TG. 2012. Interactive effects of simultaneously applied thinning, pruning and fertiliser application treatments on growth, biomass production and crown architecture in a young *Eucalyptus nitens* plantation. Forest Ecology and Management. 267: 104–116. - DOI: 10.1016/j.foreco.2011.11.039

Gonçalves JLM, Wichert MCP, Gava JL, Masetto A V, Junior AJC, Serrano MIP, Mello SLM. 2010. Soil fertility and growth of *Eucalyptus grandis* in Brazil under different residue management practices. Southern Forests . 69: 95–102. DOI: 10.2989/SHFJ.2007.69.2.4.289

González-García M, Hevia A, Majada J, Rubiera F, Barrio-Anta M. 2016. Nutritional, carbon and energy evaluation of *Eucalyptus nitens* short rotation bioenergy plantations in northwestern Spain. IForest. 9: 303–310. DOI: 10.3832/ifor1505-008

Gutiérrez-Soto M V., Pacheco A, Holbrook NM. 2008. Leaf age and the timing of leaf abscission in two tropical dry forest trees. Trees. 22: 393–401. DOI: 10.1007/s00468-007-0200-9

Hakamada R, Giunti Neto C, de Lemos CCZ, Silva SR, Otto MSG, Hall KB, Stape JL. 2016. Validation of an efficient visual method for estimating leaf area index in clonal Eucalyptus plantations. Southern Forests. 78: 275–281. DOI: 10.2989/20702620.2016.1201641

Hakamada R, Hubbard RM, Ferraz S, Stape JL. 2017. Biomass production and potential water stress increase with planting density in four highly productive clonal Eucalyptus genotypes. Southern Forests. 79: 251–257. DOI: 10.2989/20702620.2016.1256041

Halomoan SST, Wawan, Adiwirman. 2015. Effect of fertilization on the growth and biomass of *Acacia mangium* and Eucalyptus hybrid (*E . grandis x E . pellita*). Journal of Tropical Soils. 20: 157–166. DOI: 10.5400/jts.2015.20.3.157

Harwood CE, Alloysius D, Pomroy P, Robson KW, Haines MW. 1997. Early growth and survival of *Eucalyptus pellita* provenances in a range of tropical environments , compared with *E. grandis* , *E. urophylla* and *Acacia mangium*. New Forests. 14: 203–219.

Hii SY, Ha KS, Ngui ML, Ak Penguang S, Duju A, Teng XY, Meder R. 2017. Assessment of plantation-grown *Eucalyptus pellita* in Borneo, Malaysia for solid wood utilisation. Australian Forestry. 80: 26–33. DOI: 10.1080/00049158.2016.1272526

Houghton RA, Hall F, Goetz SJ. 2009. Importance of biomass in the global carbon cycle. Journal of Geophysical Research: 114: 1–13. DOI: 10.1029/2009JG000935

Hung TD, Brawner JT, Meder R. 2015. Estimates of genetic parameters for growth and wood properties in *Eucalyptus pellita* F . Muell . to support tree breeding in Vietnam. Annals of Forest Science. 72: 205–217. DOI: 10.1007/s13595-014-0426-9

Karavin N. 2013. Effects of leaf and plant age on specific leaf area in deciduous tree species *Quercus cerris* L. var. cerris. Bangladesh Journal of Botany. 42: 301–306. DOI: 10.3329/bjb.v42i2.18034

Kaul M, Mohren GMJ, Dadhwal VK. 2010. Carbon storage and sequestration potential of selected tree species in India. Mitigation and Adaptation Strategies for Global Change. 15: 489–510. DOI: 10.1007/s11027-010-9230-5

Kohl M, Neupane PR, Lotfiomran N. 2017. The impact of tree age on biomass growth and carbon accumulation capacity : a retrospective analysis using tree ring data of three tropical tree species grown in natural forests of Suriname. PLoS ONE. 12: 1–17.

Kweon D, Comeau PG. 2019. Relationships between tree survival, stand structure and age in trembling aspen dominated stands. Forest Ecology and Management. 438: 114–122. DOI: 10.1016/j.foreco.2019.02.003

Laclau JP, Almeida JCR, Gonalves JLM, Saint-Andr L, Ventura M, Ranger J, Moreira RM, Nouvellon Y. 2009) Influence of nitrogen and potassium fertilization on leaf lifespan and allocation of above-ground growth in Eucalyptus plantations. Tree Physiology. 29: 111–124. DOI: 10.1093/treephys/tpn010

Latifah S, Muhdi M, Purwoko A, Tanjung E. 2018. Estimation of aboveground tree biomass *Toona sureni* and *Coffea arabica* in agroforestry system of Simalungun, North Sumatra, Indonesia. Biodiversitas. 19: 620–625. DOI: 10.13057/biodiv/d190239

Lewis JD, Phillips NG, Logan BA, Hricko CR, Tissue DT. 2011. Leaf photosynthesis, respiration and stomatal conductance in six Eucalyptus species native to mesic and xeric environments growing in a common garden. Tree Physiology. 31: 997–1006. DOI: 10.1093/treephys/tpr087

Li G, Zhang Z, Shi L, Zhou Y, Yang M, Cao J (2018). Effects of different grazing intensities on soil C , N , and P in an Alpine Meadow on the Qinghai — Tibetan. International Journal of Environmental Research and Public Health. 15: 1–16. DOI: 10.3390/ijerph15112584

Lima PR, Malavasi UC, Battistus AG, Dranski JAL, De Matos Malavasi M. 2019. Photosynthetic responses of eucalyptus seedlings submitted to chemical and mechanical stimulus. Ciencia Florestal. 29: 740–753. DOI: 10.5902/1980509830685

Little KM, Ahtikoski A, Morris AR, Little KM, Ahtikoski A, Rotation-end ARM, Little KM, Ahtikoski A, Morris AR. 2018. Rotation-end financial performance of vegetation control on *Eucalyptus smithii* in South Africa smithii in South Africa. Southern Forests. 80: 241–250. DOI: 10.2989/20702620.2017.1341114

Magalhães TM, Cossa VN, Guedes BS, Fanheiro ASM. 2020. Species-specific biomass allometric models and expansion factors for indigenous and planted forests of the Mozambique highlands. Journal of Forestry Research. DOI: 10.1007/s11676-020-01156-0

Maimunah S, Rahman SA, Samsudin YB, Artati Y, Simamora TI, Andini S, Lee SM, Baral H. 2018. Assessment of suitability of tree species for bioenergy production on burned and degraded peatlands in Central Kalimantan, Indonesia. Land. 7: 1–14. DOI: 10.3390/land7040115

McTague JP, Weiskittel AR. 2016. Individual-tree competition indices and improved compatibility with stand-level estimates of stem density and long-term production. Forests. 7: 1–16. DOI: 10.3390/f7100238

Nambiar EKS, Harwood CE, Mendham DS. 2018. Paths to sustainable wood supply to the pulp and paper industry in Indonesia after diseases have forced a change of species from acacia to eucalypts. Australian Forestry. 81: 148–161. DOI: 10.1080/00049158.2018.1482798

Nandini R, Narendra BH. 2017. Critical land characteristics of former eruption of Batur Mount in Bangli District, Bali. Jurnal Penelitian Hutan dan Konservasi Alam. 9: 199–211. DOI: 10.20886/jphka.2012.9.3.199-211

Nguyen TT, Arndt SK, Baker PJ. 2019. Leaf physiological responses to drought stress and community assembly in an Asian Savanna. Forests. 10: 15–17. DOI: 10.3390/f10121119

Poorter H, Niklas KJ, Reich PB, Oleksyn J, Poot P, Mommer L. 2012. Biomass allocation to leaves, stems and roots: meta-analyses of interspecific variation and environmental control. New Phytologist. 193: 30–50. DOI: 10.1111/j.1469-8137.2011.03952.x

Prasetyo A, Aiso H, Ishiguri F, Wahyudi I, Wijaya IPG, Ohshima J, Yokota S. 2017. Variations on growth characteristics and wood properties of three *Eucalyptus* species planted for pulpwood in Indonesia. Tropics. 26: 59–69. DOI: 10.3759/tropics.ms16-15

Pretzsch H, Biber P, Uhl E, Dahlhausen J, Rötzer T, Caldentey J, Koike T, van Con T, Chavanne A, Seifert T, Toit B du, Farnden C, Pauleit S. 2015. Crown size and growing space requirement of common tree species in urban centres, parks, and forests. Urban Forestry and Urban Greening. 14: 466–479. DOI: 10.1016/j.ufug.2015.04.006

Rance SJ, Mendham DS, Cameron DM. 2017. Assessment of crown woody biomass in Eucalyptus grandis and E. globulus plantations. New Forests. 48: 381–396. DOI: 10.1007/s11056-016-9563-3

Rosbakh S, Römermann C, Poschlod P (2015). Specific leaf area correlates with temperature: new evidence of trait variation at the population, species and community levels. Alpine Botany. 125: 79–86. DOI: 10.1007/s00035-015-0150-6

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021a. Allometric equations for estimating aboveground biomass of Eucalytpus urophylla S.T. Blake in East Nusa Tenggara. Journal of Tropical Forest Management. 27: 24–31. DOI: 10.7226/jtfm.27.1.24

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021b. Soil chemical properties influences on the growth performance of Eucalyptus urophylla planted in dryland ecosystems, East Nusa Tenggara. Journal of Degraded and Mining Lands Management. 8: 2635–2642. DOI: 10.15243/jdmlm.2021.082.2635

Sasaki N, Asner GP, Pan Y, Knorr W, Durst PB, Ma HO, Abe I, Lowe AJ, Koh LP, Putz FE. 2016. Sustainable management of tropical forests can reduce carbon emissions and stabilize timber production. Frontiers in Environmental Science. 4: 1–13. DOI: 10.3389/fenvs.2016.00050

Simetti R, Bonduelle GM, Silva DA da, Mayer SLS, Souza HP, Muniz GIB de. 2018. Production of biomass and energy stock for five Eucalyptus species. Revista Ciência Da Madeira - RCM. 9: 30–36. DOI: 10.12953/2177-6830/rcm.v9n1p30-36

Stanturf JA, Vance ED, Fox TR, Kirst M. 2013. Eucalyptus beyond its native range: environmental issues in exotic bioenergy plantations. International Journal of Forestry Research. 2013: 1–5. DOI: 10.1155/2013/463030

Stuepp CA, Kratz D, Gabira MM, Wendling I. 2020. Survival and initial growth in the field of eucalyptus seedlings produced in different substrates. Pesquisa Agropecuaria Brasileira. 55: 1–12. DOI: 10.1590/S1678-3921.pab2020.v55.01587

Thompson IM. 2013. Early growth results of three *Eucalyptus grandis* × *Eucalyptus nitens* hybrid clonal trials and their response to snow events. Southern Forests. 75: 185–188. DOI: 10.2989/20702620.2013.820446

Truax B, Fortier J, Gagnon D, Lambert F. 2018. Planting density and site effects on stem dimensions, stand productivity, biomass partitioning, carbon stocks and soil nutrient supply in hybrid poplar plantations. Forests. 9: 1–21. DOI: 10.3390/f9060293

Van Bich N, Mendham D, Evans KJ, Dong TL, Hai VD, Van Thanh H, Mohammed CL. 2019. Effect of residue management and fertiliser application on the productivity of a Eucalyptus hybrid and *Acacia mangium* planted on sloping terrain in northern Vietnam. Southern Forests. 81: 201–212. DOI: 10.2989/20702620.2018.1555940

Versini A, Zeller B, Derrien D, Mazoumbou J, Laclau J. 2014. The role of harvest residues to sustain tree growth and soil nitrogen stocks in a tropical Eucalyptus plantation. 245–260. DOI: 10.1007/s11104-013-1963-y

Viera M, Rodríguez-Soalleiro R. 2019. A complete assessment of carbon stocks in above and belowground biomass components of a hybrid eucalyptus plantation in Southern Brazil. Forests. 10: 1–12. DOI: 10.3390/f10070536

Visser L, Hoefnagels R, Junginger M. 2020. The potential contribution of imported biomass to renewable energy targets in the EU-the trade-off between ambitious greenhouse gas emission reduction targets and cost thresholds. Energies. 13: 1–30. DOI: 10.3390/en13071761

Wirabuana PYAP, Sadono R, Juniarso S, Idris F. 2020a. Interaction of fertilization and weed control influences on growth , biomass , and carbon in eucalyptus hybrid (*E. pellita* × *E. brassiana*). Journal of Tropical Forest Management. 26: 144–154. DOI: 10.7226/jtfm.26.2.144

Wirabuana PYAP, Sadono R, Jurniarso S. 2019. Fertilization effects on early growth, aboveground biomass, carbon storage, and leaf characteristics of Eucalyptus pellita F.Muell. in South Sumatra. ournal of Tropical Forest Management. 25: 154–163. DOI: 10.7226/jtfm.25.3.154

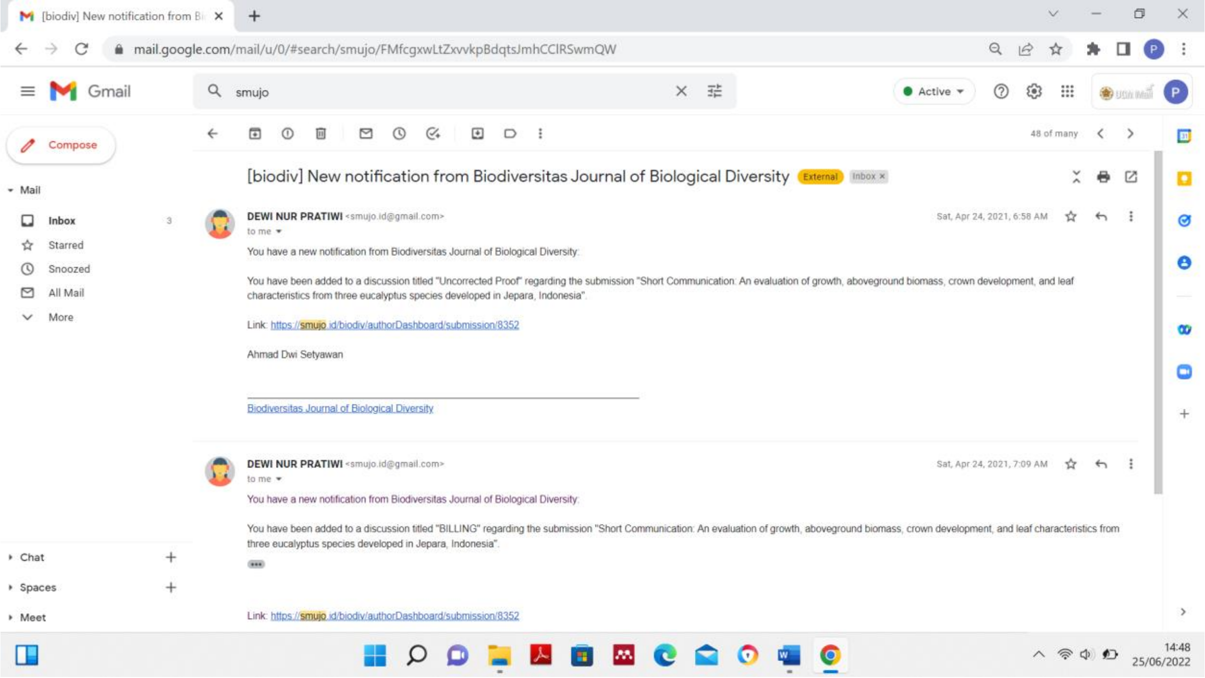
Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS, Matatula J. 2020b. Allometric equations for estimating biomass of community forest tree species in Madiun , Indonesia. Biodiversitas. 21: 4291–4300. DOI: 10.13057/biodiv/d210947

Xiao CW, Janssens IA, Curiel Yuste J, Ceulemans R. 2006. Variation of specific leaf area and upscaling to leaf area index in mature Scots pine. Trees. 20: 304–310. DOI: 10.1007/s00468-005-0039-x

Xie Y, Wang X, Silander JA. 2015. Deciduous forest responses to temperature, precipitation, and drought imply complex climate change impacts. Proceedings of the National Academy of Sciences of the United States of America. 112: 13585–13590. DOI: 10.1073/pnas.1509991112

Zhu W, Xiang W, Pan Q, Zeng Y, Ouyang S, Lei P, Deng X, Fang X, Peng C. 2016. Spatial and seasonal variations of leaf area index (LAI) in subtropical secondary forests related to floristic composition and stand characters. Biogeosciences. 13: 3819–3831. DOI: 10.5194/bg-13-3819-2016

EDITOR DECISION 24 APRIL 2021 - ACCEPTED



[biodiv] New notification from Biodiversitas Journal of Biological Diversity

DEWI NUR PRATIWI <smujo.id@gmail.com>
to me
Sat, Apr 24, 2021, 6:58 AM

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "Uncorrected Proof" regarding the submission "Short Communication: An evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia".

Link: https://smujo.id/biodiv/authorDashboard/submission/8352

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

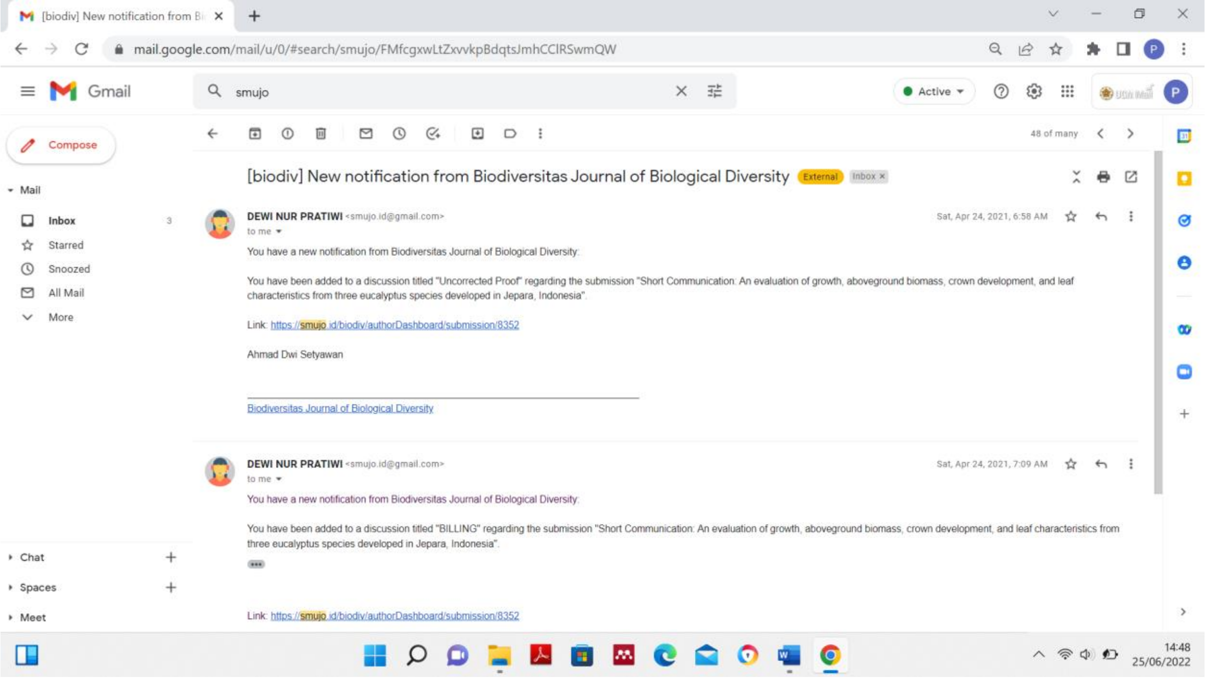
DEWI NUR PRATIWI <smujo.id@gmail.com>
to me
Sat, Apr 24, 2021, 7:09 AM

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "BILLING" regarding the submission "Short Communication: An evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia".

Link: https://smujo.id/biodiv/authorDashboard/submission/8352

KEPUTUSAN EDITOR 24 APRIL 2021 - ACCEPTED



[biodiv] New notification from Biodiversitas Journal of Biological Diversity

DEWI NUR PRATIWI <smujo.id@gmail.com>
to me
Sat, Apr 24, 2021, 6:58 AM

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "Uncorrected Proof" regarding the submission "Short Communication: An evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia".

Link: https://smujo.id/biodiv/authorDashboard/submission/8352

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

DEWI NUR PRATIWI <smujo.id@gmail.com>
to me
Sat, Apr 24, 2021, 7:09 AM

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "BILLING" regarding the submission "Short Communication: An evaluation of growth, aboveground biomass, crown development, and leaf characteristics from three eucalyptus species developed in Jepara, Indonesia".

Link: https://smujo.id/biodiv/authorDashboard/submission/8352