EARLY GROWTH AND STAND VOLUME PRODUCTIVITY OF SELECTED CLONES OF *Eucalyptus pellita*

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EARLY GROWTH AND STAND VOLUME PRODUCTIVITY OF SELECTED CLONES OF *Eucalyptus pellita*. Using current technologies, several forest plantation companies in Indonesia are pursuing clonal forestry program with *E. pellita* to increase plantation productivity using selected clones. This paper evaluates the early growth and stand volume productivity of selected clones of *E. pellita* as part of a breeding program for pulpwood. Two clonal trials of *E. pellita* were established in Central Java with two different plot configurations: single tree-plot and multiple tree-plot. Trial evaluation was done at two years age involving tree height, diameter, stem volume and stand volume. Result show that among the clones there were significant differences for all traits assessed. All of the tested clones exceeded the control seedling of F-1 generation by 9-50% for height, 10-36% for diameter and 22-137% for stem volume, respectively. Clonal repeatability ranged from 0.7-0.9, with corresponding individual ramet repeatability ranged from 0.2-0.4. Overall stand volume productivity at given age reached 15 m³/ha.

Keywords: Clonal forestry, clone, *Eucalyptus pellita*, growth, stand volume

PERTUMBUHAN AWAL DAN PRODUKTIVITAS VOLUME TEGAKAN KLON Eucalyptus pellita *TERPILIH. Dengan menggunakan teknologi terkini, beberapa perusahaan HTI di Indonesia mengedepankan program perhutanan klon* E.pellita *untuk meningkatkan produktivitas tanaman melalui penggunaan klon-klon terpilih. Tulisan ini mengevaluasi pertumbuhan awal dan produktivitas volume tegakan klon* E. pellita *terpilih sebagai bagian dari program pemuliaan kayu pulp. Dua uji klon* E. pellita *telah dibangun di Jawa Tengah dengan konfigurasi plot yang berbeda: plot dengan pohon tunggal dan plot dengan banyak pohon. Evaluasi dilakukan pada umur dua tahun pada sifat tinggi pohon, diameter, volume batang dan volume tegakan. Penelitian menunjukkan adanya perbedaan yang signifikan diantara klon yang diuji pada seluruh sifat yang diamati. Seluruh klon yang diuji lebih baik dibanding kontrol yang berupa tanaman yang berasal dari benih F-1, dengan peningkatan 9-50% pada tinggi, 10-36% pada diameter dan 22-137% pada volume batang. Repeatabilitas klonal berkisar 0,7-0,9 dengan repeatabilitas ramet individual berkisar 0,2-0,4. Secara keseluruhan produktivitas volume tegakan pada umur tersebut mencapai 15 m³/ha.*

Kata kunci: Perhutanan klonal, klon, Eucalyptus pellita*, pertumbuhan, volume tegakan*

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I. INTRODUCTION

Eucalyptus pellita F. Muell. is a fast-growing tree species that are widely developed for plantation forest in Indonesia. About 83.000 hectares of *E. pellita* plantations have been established to supply raw material for the pulp and paper industries (Hardiyanto, 2010b). The Ministry of Forestry has set a target of 5 million hectares for industrial forest plantation development (Rufi'ie, Prihatini, Subarudi, & Fatmawati, 2005).

The conventional breeding (open pollination) of E. pellita was not able to provide optimum results to increase the productivity because of high variations in stand growth (Sachs, Lee, Ripperda, & Woodward, 1988). The advanced breeding through clonal development can further improve the productivity of *E. pellita* by using the best clones, the plantation productivity (yield) can increase and it can produce a relatively uniform stand growth. Some countries have successfully developed and proven that Eucalyptus clones produced genetically good plantations with relatively uniform stands which are more economical compared to seedlings (Libby & Ahuja, 1992).

In 2011, in order to improve the productivity of *E. pellita* through advanced breeding strategy, the Center for Forest Biotechnology and Tree Improvement, Yogyakarta has developed a clonal test in Wonogiri, Central Java. An evaluation of the trial was conducted with the main objective to determine growth and stand volume productivity at the age of 2 years.

II. MATERIAL AND METHOD

A. Clonal Propagation

Clones were collected from first generation of Seedling Seed Orchard (SSO F-1) in Wonogiri (Central Java), which was established in 1996. Clonal propagation was done by rejuvenating the 11 years old plus trees and propagated using cuttings of shoots (Kartikaningtyas & Yuliastuti, 2011). There were 7 clones to be tested that were selected based on the rooting ability. In addition, there were 2 additional clones that were collected from the 11 years old bulkseed plantation. The information of all clones tested in the trials is presented in Table 1.

B. Trial Design and Measurement

The trials were established in 2011 at Wonogiri Central Java by using single tree plot and multiple tree plot model (Sunarti, Setyaji, Nirsatmanto, & Kartikaningtyas, 2011). The single tree plot model was used to obtain information on genetic parameter values, while the multiple tree plot was arranged to assess the productivity. The trials were built in a completely randomized block design (RCBD), 9 clones, spacing 3 m x 2 m and 16 blocks of replication. For the multiple tree plot model, 16 ramets (4 x 4) was used for each clone. Seedlings were taken from SSO F-1 *E. pellita* Wonogiri, Central Java and were also planted in the trials as control. Measurement was conducted 2 years after planting regarding height, diameter at breast height (dbh) and stem volume. The

Table 1. Information of the tested clones.

Clone	Seedlot	Origin Provenance	Plantation
1	495	18199-CG 1903 Serisa Village WP, PNG	SSO
2	-	-	Bulkseed
3	519	18200-BVG 2214 Keru To Nata WP,PNG	SSO
4	498	18199-CG 1090 Serisa Village WP, PNG	SSO
5	430	18197-CG 1882 South of Kiriwo, PNG	SSO
7	-	-	Bulkseed
8	518	18200-BVG 2213 Keru To Nata WP,PNG	SSO
9	502	18199-CG1912 Serisa Village WP, PNG	SSO
14	464	18197-BVG 2171 North of Kiriwo, PNG	SSO

Table 2. Site description of *E. pellita* clonal test

Item	Information
Administration	Wonogiri, Central Java
Geographic position	7º80' S and 110º93'E
Climate (Schmidt-Fergusson)	Type D
Rain fall (mm/year)	1878
Temperature (min – max)	21 - 32°C
Soil Order	Vertisol
Elevation (m asl)	141
Slope (%)	10

Source: Sunarti, Setyaji, Nirsatmanto, and Kartikaningtyas (2011)

traits were recorded in quantitative scale: meter (m), centimeter (cm) and meter cubic (m^3) for height, diameter and stem volume respectively. Detailed information of the two locations is shown in Table 2.

C. Data Analysis

1. Analysis of variance

Analysis of variance was done of individual data with a linear model according to Hardiyanto (2010 b) as follows (Equation 1):

$$Y_{ij} = \mu + R_i + C_j + E_{ij} \quad (1)$$

where :

Y_{ij} : individual observation of the j^{-th} clone in the i^{-th} replication

μ : mean of population

R_i : an effect of the i^{-th} replication

C_j : an effect of the j^{-th} clone

E_{ij} : error associated with Y_{ij}

2. Repeatability values

The estimation of repeatability was calculated for clone (heritability of mean clone) and ramet (individual heritability) using formula of Gonçales et al., (2006) as shown in Equations 2 and 3 as follows:

Clone Repeatability :

$$H_c^2 = \frac{\sigma_c^2}{\sigma_c^2 + (\sigma_e^2 / b)} \quad (2)$$

Ramet Repeatability :

$$h_r^2 = \frac{\sigma_c^2}{\sigma_c^2 + \sigma_e^2} \quad (3)$$

where :

H^2c : clone repeatability

h^2r : ramet repeatability

σ^2c : clone variance component

σ^2e : error variance component

b : replication

3. Ranking of clones and productivity

The clones were ranked using DMRT (Duncan Multiple Range Test) to find the best clone. The productivity of clone at each trait was calculated using the formula according to Sunarti (2013) as follows:

$$\text{Productivity} = \frac{\text{clone - control}}{\text{control}} \times 100\% \quad (4)$$

III. RESULT AND DISCUSSION

A. Variance Components and Clone Repeatability

The result of analysis of variance for each test as well as across test are shown in Table 3. The differences among clones on all traits in the site were highly significant. The differences reflected the influence of genetic factors on the growth indicating that selection of clones for increasing the productivity of *E. pellita* stands is justified. Table 3 also shows that the variance components of clones were 0.70932, 0.16850, 5.72419E-6, for height, diameter and stem volume, respectively. Clone and ramet repeatability for height were 0.89 and 0.41, respectivelly. While repeatability for diameter were 0.68 for clone mean and 0.16 for ramet. According to Falconer (1989) the values were categorized as moderate to high.

Table 3. Estimation of variance component and family heritability by single and across test

	Traits		
	Height (m)	Diameter (cm)	Stem Volume (m^3)
Mean	7.05	5.86	0.0109
Clone variance component (σ^2_c)	0.70932**	0.16850**	5.72419E-6**
Clone repeatibility (H^2_c)	0.89	0.68	-
Ramet repeatibility (h^2_r)	0.41	0.16	-
Control	5.64	4.66	0.0063

Remarks: ** : significant at 1%

Table 4. Rank and gain of clones in comparison with control

Rank	Traits								
	Height (m)			Diameter (cm)			Stem Volume (m^3)		
	clone	mean	gain(%)	clone	mean	gain (%)	clone	mean	gain (%)
1	1	8.49	50.42	2	6.33	35.94	1	0.01	136.51
2	2	8.23	45.85	14	6.29	34.96	2	0.01	122.22
3	3	7.70	36.59	1	6.28	34.69	14	0.01	103.17
4	14	7.39	31.03	8	6.04	29.59	3	0.01	76.19
5	4	6.86	21.59	4	6.04	29.55	4	0.01	74.60
6	7	6.60	17.09	3	5.74	23.30	8	0.01	57.14
7	9	6.31	11.89	5	5.39	15.67	7	0.01	41.27
8	5	6.15	9.11	7	5.21	11.81	5	0.01	25.40
9	8	6.13	8.66	9	5.13	10.13	9	0.01	22.22
Control		5.64			4.66			0.01	

Studies on clonal test of 2 years old *E. grandis* after planting in Portugal showed that clones repeatability was almost the same or about 0.87 to 0.91 (Borralho, Almeida, & Cotterill, 1992). The study in Vietnam of *E. camaldulensis* clone at 3 years age also showed the value of about 0.72 to 0.88 (Kien, 2009). The high repeatability estimation value indicates the high potential of clones to be vegetatively propagated.

B. Rank and productivity

The clone rank and gain in comparison with control in all traits are shown in Table 4. The same table shows that all of the clones tested proved superior to the control of seedling of F-1 generation. The clones superiority to control seedling *E. pellita* F-1 were 9 - 50% for height, 10 – 36% for diameter and 22 – 137% for stem volume, respectively.

The results of other studies also indicated that clones superiority to seedling was also found in hybrid clones of *E. grandis* x *E. camadulensis* in Africa (Quaile, 1988), hybrid of *E. pellita* x *E. urophylla* in Zimbabwe (Gwaze, Bridgwater, & Lowe, 2000) and the hybrid of *E. urophylla* x *E. grandis* in Kalimantan (Hardiyanto & Tridasa, 2000).

In this study, the best three clones for height growth were number 1, 2 and 3 with the superiority ranging from 37 - 50% compared with the control (Table 4) and ranging from 9 - 20 % compared with the average of total clones (Table 5). While for diameter, the best three clones were number 1, 2 and 14 with the superiority ranging from 35 - 36% compared with the control (Table 4) and ranging from 8 - 9 % above the average of the total clones (Table 5).

In case of stem volume, the best three clones were number 1, 2 and 14 with the superiority ranging from 103 - 137% compared with the control (Table 4) and ranging from 17 - 36 %

Table 5. Gain (compared with clones average) and estimation of stand volume of the best three clones

Rank	Traits									Stand Volume (m^3/ha)
	Height(m)			Diameter (cm)			Stem Volume(m^3)			
	clone	mean	gain(%)	clone	mean	gain (%)	clone	mean	gain (%)	
1	1	8.49	19.57	2	6.33	8.69	1	0.02	36.49	16.7
2	2	8.23	15.94	14	6.29	7.90	2	0.01	28.21	15.6
3	3	7.70	8.57	1	6.26	7.69	14	0.01	17.11	14.4
4	14	7.39	--	8	6.04	--	3	0.01	--	--
5	4	6.86	--	4	6.04	--	4	0.01	--	--
6	7	6.60	--	3	5.74	--	8	0.01	--	--
7	9	6.31	--	5	5.39	--	7	0.01	--	--
8	5	6.15	--	7	5.21	--	5	0.01	--	--
9	8	6.13	--	9	5.13	--	9	0.01	--	--
Clone average		7.05			5.87			0.01		

compared with the average of total clones (Table 5). The clones number 1 and 14 were the clones which originated from provenance of Papua New Guinea i.e: *Serisa* Village and North of Kiriwo. While clone number 2 was a clone collected from selected plus trees in bulkseed plantation with unknown origin. Table 5 shows that the projection of stand volume from the best selected three clones were 14.4, 15.6 and 16.7 m^3/ha, for clones 14, 2 and 1, respectively with the average of all three clones of 15 m^3/ha. These results indicate considerable opportunities in implementing the clonal forestry for increased productivity of *E. pellita* stands.

The use of clonal forests of eucalypts is currently widespread in Brazil that use Eucalyptus for industrial purposes.The total area planted with clones is over 1 million ha. Besides the expectation of higher productivity as expressed in the final product per hectare, the plantations also provide the incorporation of higher quality wood in the various end uses for which the breeding programs are being directed (de Assis, Rezende, & Aguiar, 2012). With the limited concessions area available in Indonesia, it is very important to increase yield of plantations to be able to supply adequate raw material to the industry. Significant improvement of wood production can be obtained by applying best silvicultural practices and through genetic improvement programs particularly through clonal forestry project such as with *E. pellita*.

IV. CONCLUSION

Although the evaluation was done using the data collected from relatively young plants, these results indicated considerable opportunities in implementing the clone selection for increased stand productivity of *E. pellita*. This clone test evaluation should be continued to determine the variation in growth and other properties.

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