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Short Communication: The survival rate and one-year growth of *Shorea javanica, Shorea macrobalanos* and *Hopea mengarawan* in coal mined land in Central Bengkulu, Indonesia

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[1]Department of Forestry, Faculty of Agriculture, Universitas Bengkulu. Jl. WR Supratman, Bengkulu 38371A, Indonesia. Tel./Fax. +62-736-21170, [♥]email: wiryonogood@yahoo.com, wiryonogood@unib.ac.id

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Abstract. *Wiryono, Suhartoyo H, Munawar A. 2016. Short Communication: The survival rate and one-year growth of* Shorea javanica, Shorea macrobalanos *and* Hopea mengarawan *in coal mined land in Central Bengkulu, Indonesia. Biodiversitas 17: 741-745.* Dipterocarp trees used to dominate the lowland forest of Sumatra and Kalimantan. Currently, however, dipterocarp trees are rare due to deforestation of natural forest. One major cause of deforestation in Sumatra and Kalimantan is coal mining. Rehabilitation of coal mined soil is usually done using fast-growing alien species. We tried to restore a piece of mined land in Central Bengkulu, using commercially valuable species of Dipterocarpaceae, namely *Shorea javanica* Koord. & Valet., *Shorea macrobalanos* Ashton and *Hopea mengarawan* Miq. In this article, we presented the survival rate and growth of the one year old seedlings of these three species within one year of observation. Of the three species, *S. macrobalanos* had the highest survival rate (93%), followed by *S. javanica* (80%) and *H. mengarawan* (77%). Within a year, the one year old seedlings of *S. macrobalanos* grew 452% in height, significantly higher than that of *S. javanica* (221%) and of *H. mengarawan* (119%). *Shorea macrobalanos* also had the highest growth in diameter within a year, namely 337%, followed by *S. javanica* (145%) and *H. mengarawan* (135%). It can be concluded that within a year of observation, the three species of dipterocarps could grow relatively well in mined land. It is therefore recommended that in the restoration of mined land in Sumatra economically valuable native species of dipterocarps should be used instead of fast-growing alien species.

Keywords: Coal mined soil, Dipterocarpaceae, restoration

INTRODUCTION

Trees of the Dipterocarpaceae family used to dominate the lowland forest of Indonesia (Whitmore 1984), but most of them are now threatened with the disappearing of lowland forest in Indonesia. One of industries contributing to the deforestation is mining. Between 2000 and 2010, mining industries caused 0.3 million hectares of forest loss, resulting in 3.6-4.4 Mega ton of carbon emission (Abood et al. 2015). Mining activities not only remove the vegetation, but also drastically destroy the ecosystem. Topsoil was removed and the materials previously buried deep underground were brought to surface. Mine soil, is generally unfavorable for plant growth and must be amended before revegetation (Bradshaw 1997; Lottermoser 2010).

The Indonesian government regulations require that the mining companies rehabilitate the mined land in order to restore the ecosystem functions. Usually, exotic fast growing species, such *Acacia mangium* (Suhartoyo et al. 2012), *Paraserianthes falcataria*, *Sesbania grandiflora* (Munawar et al. 2011) are used for the revegetation of mined land. While these species can restore some ecosystem functions of the degraded forest, the establishment of these species changes the species composition of the forest. According to the Society of Ecological Restoration (SER) one of nine ecosystem attributes as the criteria of restoration success is that indigenous species must be present in the area (Clewel and Aronson 2007). Several researchers have tried to use local fast growing species for revegetation of mined land in Kalimantan (Adman et al. 2012) and found that some local fast growing species were able to survive and grow in mined land. Those species, however, had low economical value.

Considering the lack of study of coal mined land restoration using Dipterocarpaceae, we tried to plant three species of Dipterocarpaceae in coal mined land in Central Bengkulu District where raintree (*Samanea saman*) had already been planted. The three species were *Shorea javanica* Koord. & Valet, *Shorea macrobalanos* Ashton and *Hopea mengarawan* Miq. In some literature *H. mengarawan* is written as *H. mengarawan* Miq. *Shorea javanica* is naturally found in primary and secondary forest in Sumatra and Central Java, but it has been planted in many countries of Southeast Asia (Orwa et al. 2009). *Shorea macrobalanos* used to be endemic to Sarawak and East Kalimantan, and it is categorized as critically endangered species in IUCN Redlist (Ashton 1998a; IUCN 2016). *Hopea mengarawan* is native to Indonesia and Malaysia (Fern 2016) and it is also categorized as critically endangered in IUCN Redlist (IUCN 2016). The objective

of this study was to report the survival rate and the growth of one year old seedlings of the three species within a year of observation.

MATERIALS AND METHODS

Study site

This study was conducted in the mining concession area of PT Inti Bara Perdana in Taba Penanjung Sub-district, Central Bengkulu District, Bengkulu, Indonesia (Figure 1). The site was approximately at 300 m altitude, with annual rainfall above 3000 mm. The site was revegetated with raintree (*Samanea saman*) four years earlier. The average canopy opening of the four-year old raintree stand was 40%, so there was some light reaching the forest floor. The light intensity on forest floor under the shade at noon varied between 800 to 3000 lux. The temperature at noon was 28-30^{o}C and the average relative humidity was 82%. During the driest month of 2015, namely October, the raintrees shed most of their leaves, so the canopy was open, and consequently the temperature and light intensity increased while the relative humidity dropped.

The land of this site was not leveled, but consisted of many mounds and depressions. The seedlings were planted on mounds in order to prevent water logging and to avoid compacted soil. Seedlings of three species of dipterocarps were planted, namely *Shorea macrobalanos* Ashton, *Shorea javanica* Koord. & Valet. and *Hopea mengarawan* Miq. The seedlings were approximately one year old. At the beginning of planting, a kilogram of compost was given for each planting hole. Afterward, every two months NPK fertilizer was given to each plant. During the months of July-September 2015, the seedlings were watered every two weeks, and during October they were watered every three days.

Every month, the height and diameter of seedlings were measured. Soil chemical and physical properties were analyzed in Soil Laboratory of the Faculty of Agriculture, Universitas Bengkulu, Indonesia.

Data analysis

The data of height growth and diameter growth were analyzed using ANOVA to know whether there were growth differences among species. If there were significant differences, further analyses were done using Least Square Differences (LSD) to know which species had higher growth than the others.

RESULTS AND DISCUSSION

Shorea macrobalanos had the highest survival rate among the three species (Table 1). Only two out of 30 plants died during the first year of planting. *Shorea javanica* and *Hopea mengarawan* had similar survival rate. *Shorea macrobalanos* also had the highest growth of diameter and height within a year of observation, and there was no statistically significant difference between *S. javanica* and *H. mengarawan* in diameter and height growth (Table 2). Within a year, *S. macrobalanos* grew 452% in height and 337% in diameter, while *S. javanica* 221% and 245%, and *H. mengarawan* 119% and 135%. In general, the results showed that the three dipterocarp species grew relatively well in the study site (Figures 2, 3 and 4).

The success of terrestrial ecosystem restoration is influenced by the plant-soil interactions (Eviner and Hawkes 2008). Plant growth in mined land is sometimes constrained by soil compaction (Sheoran et al. 2010). Soil compaction may impede root penetration, reduce aeration, slow down movement of nutrients and water, and cause the buildup of toxic gases in the rhizosphere (Brady and Weil. 2002). In the United States, the passing of Surface Mining Control and Reclamation Act, which requires the mined land to be returned to its original contour, had resulted in soil compaction due to the use of heavy equipment. As a result, the reclaimed mined land was mostly grown with grasses and herbaceous vegetation, while tree establishment was impeded by the high soil density (Fields-Johnson et al. 2014). To improve the establishment of trees, the soil compaction must be reduced, for example through ripping (Ashby 1997; Fields-Johnson et al. 2014). This problem of soil compaction, however, was not found in our study site, because the mining company did not level the soil. The dipterocarp seedlings were planted in piles of soil which were not compacted. The bulk density of the soil samples ranged between 1.49 and 1.60 g cm^{-3} and the soil particle density was 1.84-1.88 g cm^{-3} (Table 3). The bulk density in this study site was considered normal, because the mineral soil may have bulk density of 1.0-2.0 g cm^{-3} (Chapin et al. 2011) and the soil particle density was lower than the average particle density of mineral soil, which is 2.5-2.7 g cm^{-3}. With normal soil density, the roots of dipterocarp seedlings would not have problem in penetrating the soil. Also, because the seedlings were planted on the mounds, there was no problem of water saturation during rainy day.

The chemical properties of soil in mined land are in general unfavorable for plant growth. Mine soil which sometimes contains high concentration of sulfur can have a pH of 2.3-3.5 which lead to higher availability of toxic metal (Sheoran et al. 2010). In our study site, the chemical soil was very acidic with a pH of 4.0-4.2 (Table 4), but the pH was not extremely low. Even in primary tropical rain forest, the soil is usually also acidic. In Southwest China, Li et al. (2012) found the pH of primary tropical rain was 4.53.

In mine soil, the nutrient availability is usually low, and so it was in our study site (Table 4). However, at the beginning of planting, manure was given for each seedling and subsequently, every two months, NPK fertilizer at the amount of 15 gram was given for each seedling. So, the nutrient content of the soil in the rhizosphere of the dipterocarp seedlings was certainly higher than that in the surrounding. Soil amendment could increase nutrient availability for plants in mine soil (Asensio et al. 2014).

Beside soil properties, light intensity also influences the establishment of plants in reclaimed mined land. Every species requires different need of light intensity for germination and establishment. Ashton (1998b) said that dipterocarps species could be broadly classified as shade-

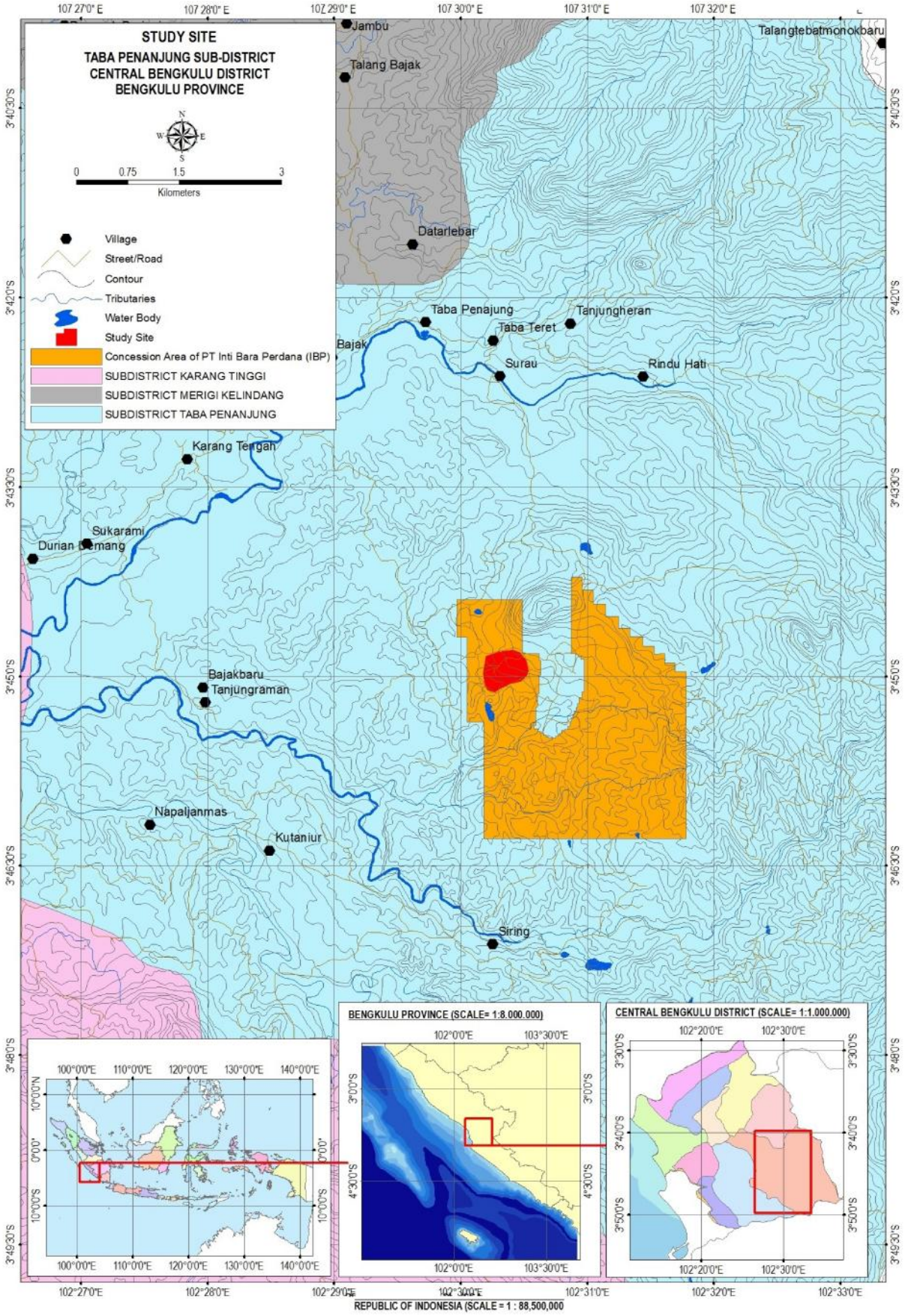

Figure 1. Study site in Taba Penanjung Sub-district, Central Bengkulu District, Bengkulu Province, Indonesia

intolerant, but some species were shade-tolerant. Generally, the seeds require partial shade for germination and early survival, but the seedlings require an increase in light for establishment and growth. Bawalsyah et al. (2015) in their study found in West Sumatra that there was no difference in the growth of *H. mengarawan* in different light intensity, which was 100% and 40%. In our study, the canopy of raintree was not fully closed. The light intensity on the forest floor, under the shade at noon varied between 800-3500 lux.

The plant growth and survival are also influenced by its interaction with other organisms. Attack from pathogen to the dipterocarp seedlings was not found in our study, while minor herbivory was found but not lethal. Some plants died because they were uprooted by wild pigs. Fortunately, the leaves of the three dipterocarps were not palatable to large herbivore, so depredation from large herbivores was absent.

The most important threat came from competition with weeds, such as *Mikania micrantha*, *Synedrella nodiflora*, *Chromolaena odorata*, *Nephrolepis biserrata* and *Mimosa pudica*. These weeds can easily overgrow and enclose the dipterocarps seedlings, depriving the seedlings of the light. The worst weed was *Mikania micrantha*. Native to America (Holm et al. 1977), this twinning perennial weed would twin its stem around the seedlings' stem and branches. To ensure the establishment of the dipterocarps, every two weeks we manually removed the weeds surrounding the dipterocarps. In the US, Ashby (1997) found that the use of herbicide helped improve tree establishment in mined land.

It can be concluded that with proper care, *Shorea javanica*, *Shorea macrobalanos* and *Hopea mengarawan* could grow relatively well in coal mined under the rain tree stand in Central Bengkulu. It is recommended that dipterocarp trees be used to revegetate the mined land in Sumatra.

Table 1. The survival rate of three dipterocarp species in coal mined land during a year of observation

Species	Number of plants alive	Survival rate (%)
Shorea macrobalanos	28	93
Shorea javanica	24	80
Hopea mengarawan	23	77

Table 2. The growth of height and diameter of three dipterocarps species in coal mined land during a year of observation

Species	Height increase in a year (%)	Diameter increase in a year (%)
Shorea macrobalanos	452a	337a
Shorea javanica	221b	145b
Hopea mengarawan	119b	135b

Note: numbers followed by the same letter are not significantly different at p of 5% level

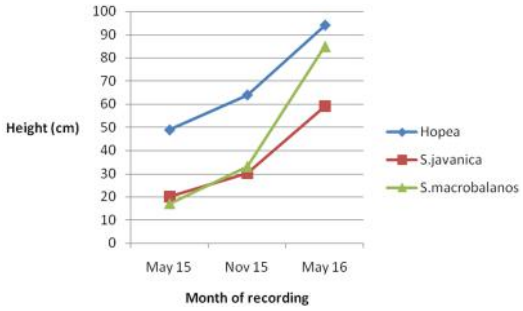

Figure 2. The plant height of three dipterocarps species in coal mined land during a year of observation

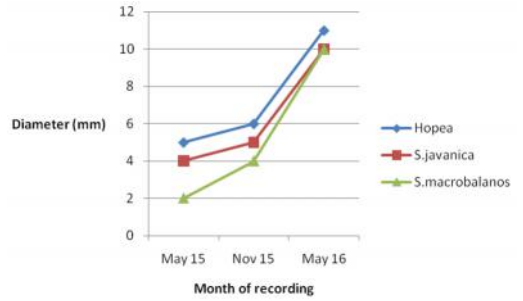

Figure 3. The plant diameter (in mm) of three dipterocarps species in coal mined land during a year of observation

Table 3. Physical properties of soil samples of coal mined land

	Particle density	Bulk density	Texture (hygrometer)			
		g cm^{-3}	Sand (%)	Silt (%)	Clay (%)	Class
Sample 1	1.84	1.49	45.51	24.36	30.13	Sandy clay loam-clay loam
Sample 2	1.88	1.60	76.24	8.68	15.08	Sandy loam

Table 4. The chemical properties of soil samples of mined land

Soil samples	pH (H_2O)	C	N	P_2O_5	K	Ca	Mg	CEC
			%	(mg.kg^{-1})		(cmol kg^{-1})		
Sample 1	4.0 (very acidic)	1.22 (low)	0.05 (very low)	Un-detected	0.35 (medium)	3.34 (low)	5.02 (low)	15.44 (low)
Sample 2	4.2 (very acidic)	1.52 (low)	0.07 (very low)	Un-detected	0.29 (medium)	2.14 (low)	5.13 (low)	14.92 (low)

Figure 4. *Hopea mengarawan*, A. 1 month old, B. 11 months old

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