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Growth of *Ensideroxylon zwageri* seedlings and Silvicultural Changes in Logged-Over and Burned Forests of Bukit Soeharto, East Kalimantan, Indonesia

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Abstract

Ulin (*Eusideroxylon zwageri*) is an ironwood species whose growing stock has decreased due to overexploitation. *Ulin* trees occur in lowland forests as scattered individuals in Kalimantan and naturally regenerated seedlings are usually restricted in the area near seed parents. They are recruited almost every year although the recruitment rates fluctuate. Seedlings of *ulin* in a closed rain forest seldom die. However, as they grow slowly, natural regeneration appears to be poor in terms of timber production. Canopy opening and weeding (release cutting) accelerate the seedling growth by improving the light conditions. Release cutting applied to seedling about 5 years old and 92 ± 36 cm tall in this study enabled to increase seedling growth rates and possibly decrease the time required for the *ulin* stem to reach 10 cm in dbh (diameter at breast height) from 78 to 26 years. However, sudden felling caused an increase in the death rate of the seedlings. Since seedlings less than 3 years old are sometimes more sensitive to sunlight and dry weather conditions than older seedlings, release cutting should be carried out in the case of 3-year-old seedlings or older. *Ulin* is fire-resistant after becoming large. However, it is still sensitive during small seedling stages. Appropriate release cutting should thus shorten the time required for *ulin* to become fire-resistant.

Discipline: Forestry and forest products
Additional key words: ironwood, endangered species, regeneration, fire, Borneo

Introduction

Ulin (Borneo ironwood, *Eusideroxylon zwageri*) is a species of Lauraceae that grows up to 40 m tall. Natural trees are found in South Sumatra, Kalimantan, and on the nearby small islands. In Kalimantan, *ulin* is common along rivers and adjacent hills, sometimes forming pure stands in primary and secondary forests, up to 500 m altitude, on sandy well-drained soils[6]. In South Sumatra, it forms pure stands on clay-rich soils[14] unlike in East Kalimantan[15].

Since the wood is strong and extremely durable, it is in great demand for heavy construction, roofing, agricultural uses, and others. In Kalimantan, *ulin* is originally a common species occurring in lowland areas. The original areas of *ulin* forests in Borneo have been estimated to cover 1,440 km^2 but presently only about 40% of these areas remains[8]. Along roadways near Bukit Soeharto in East Kalimantan, farmers settled and started pepper farming using *ulin* support stakes mostly in the 1970s[7]. By the late 1990s, *ulin* trees with a large diameter were seldom observed in the region. In parts of Kalimantan, this species is already considered to be endangered[9]. The decrease in growing stock is due to exploitation beyond the growth.

In natural forests, *ulin* grows slowly when its stem diameter at breast height (dbh) is below 10 cm (Fig. 1). The growth markedly accelerates when the dbh ranges between 10 and 30 cm. Growth is then reduced to a level intermediate between that of the former stages, and remains steady until the dbh reaches 1 m or more. By following the method of Brown[1], the time required for the *ulin* stem to reach 30 cm in dbh is estimated at 120 years, and for 120 cm, at 403 years (Fig. 2). It is very easy to accelerate the growth at the initial stages silviculturally. Actually, one individual with a dbh of 6.85 cm (closed circle in Fig. 1) under a canopy gap grew faster

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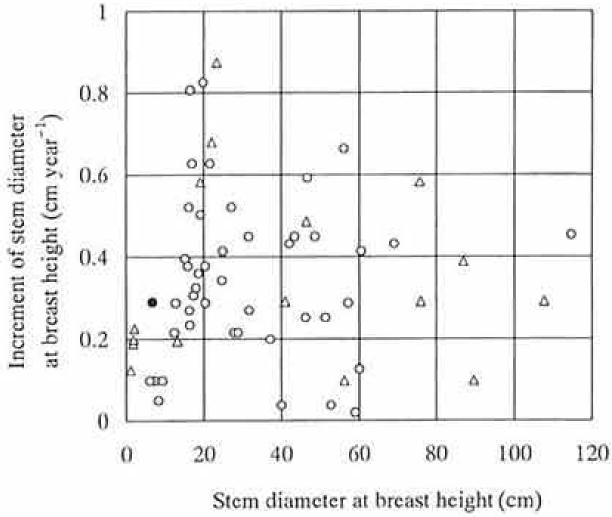

Fig. 1. Stem growth at various stages of development of *Eusideroxylon zwageri* in logged-over and burned lowland forests
(modified from Hastaniah and Kiyono, 1995[4])
○ : Trees at Bukit Soeharto.
● : A tree at Bukit Soeharto, located in an open area in the forest.
△ : Trees at Lempake.

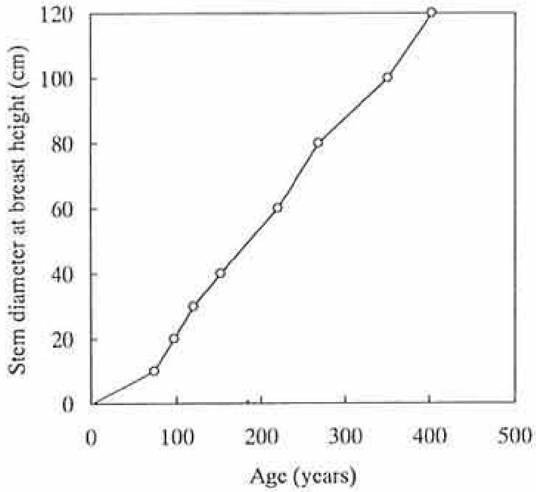

Fig. 2. Estimated stem growth rate of *Eusideroxylon zwageri* in logged-over and burned lowland forests
(modified from Hastaniah and Kiyono, 1995[4])

than the others in the same diameter class. Appropriate treatment such as release cutting could accelerate the growth of the seedlings and such a silvicultural practice may prevent a decrease in the growing stock of *ulin*.

In the present study, we analyzed the effects of the variations in growing environments such as light on the growth of *ulin* seedlings in Bukit Soeharto Education Forest (BSEF) in East Kalimantan. Such information could contribute to the improvement of silvicultural practices such as release cutting and enrichment planting to preserve *ulin* resources in Indonesian forests.

Seedling growth in contrasting light environments

1) Setting of study sites

The forests of BSEF underwent commercial logging followed by logging and slash-and-burn by local people in the 1970s, then experienced drought and fires in 1982–1983. In 1992, trees more than 50 m tall survived the fires in some areas and among them mostly secondary trees of *Macaranga gigantea* and *Macaranga triloba* were established after the fires[3]. Fertile trees of *ulin* partly remained in abundance. Seedlings are usually restricted to areas near seed trees because the fruit is heavy.

The effects of light environments on the seedling growth were examined in 2 experimental plots arranged in seedling banks on a slope with top soils consisting of sandy clay loam-sandy loam in July 1992 (Plots 1 and 2 in Table 1). Dominant overstory trees included *ulin*, *Endospermum diadenum*, *Dipterocarpus tempehes*, and other trees. Both plots contained 2 fertile *ulin* each. The 4 *ulin* trees, 30–60 cm in dbh, flowered almost every year during the period 1991–1996. Under them were 467 naturally regenerated seedlings in Plot 1 and 190 seedlings in Plot 2 in July 1992. The *ulin* seedlings were estimated to be mainly derived from the seeds from mast-fruiting around 1988 (Sopiyani, personal communication, 1996). For one plot (Plot 1), a canopy gap covering a 32×32 m land area was made and weeding was started in May 1993. Another plot (Plot 2) was used as the control. Based on the differences in the light environments, Plot 1 is referred to as gap site and Plot 2 as closed site.

All the seedlings including recruits in Plots 1 and 2 were labeled and their height, diameter at 0.3 m height, and other characteristics were measured in 1992, 1993, 1994, and 1996. The percentage of canopy opening was determined by hemisphere photographs 4 times in 1993–1996 in Plots 1 and 2. In each plot, top soils were sampled in 1995 and 5 seedlings were sampled in 1996 to determine the amounts of leaves, branches, stems, and roots. Since fresh fine roots of *ulin* are dumpy, 1.2–2.2 mm in diameter, their surface area was easily measured.

The monthly rainfall at the research station of Bukit Soeharto Education Forest in 1988–1997 averaged 163 ± 94 mm year^{-1}. After July 1992, low monthly rainfall of below 70 mm was observed in July–September and November 1993, in July–September 1994, in June and August–October 1997, and in January–April 1998 at the research station near the plots.

In March 1998, forest fires occurred in BSEF.

Table 1. General description of the research plots

Plot	Land area (m^2)	Overstory	Canopy openness[a] (%) May 1993	Dec. 1993	Aug. 1994	Nov. 1996	Weeding (times)
1	484	Canopy gap	9.6	19.3	14.2	11.0	5[b]
2	484	Closed	2.6	6.0	0.8	0.8	0

a): By hemisphere photographs. b): In 1993–1996.

Although almost all the seedlings were green before the fires, they burned to death, except for some seedlings in Plot 1. In October 1998, all the living seedlings in Plot 1 and some dead seedlings in each plot were selected and their height, diameter, and other characteristics were measured. Since the seedlings that had burned to death were standing with branches and leaves in perfect shape, their height and diameter were considered to correspond to the values recorded in March 1998. For the living seedlings, height and diameter in March 1998 were estimated from the values recorded in March 1996 and October 1998.

2) Growth of seedlings depending on changes of light conditions

The death rate of the seedlings at the closed site was 2.8% year^{-1} (Table 2). This value is lower than that of red meranti-*Shorea* seedlings of almost the same age recorded in a similar rain forest in Sabah, Borneo (9.8–16.0% year^{-1})[12] and shows that *ulin* is a shade-tolerant species[13].

Sudden canopy opening resulted in an increase in the seedling death rate. The death rate at the gap site was about twice as high as the death rate at the closed site (Table 2). For the first 5 months after canopy opening, the highest death rate (12.2% year^{-1}) was recorded (Table 3). One month after canopy opening, a low rainfall period occurred during 5 months. It is likely that the very high death rate was due to the drought and sun exposure.

The death rate after sudden canopy opening depended on the differences in seedling age. During the low rainfall period of 1994, some cohorts of below-3-year-old seedlings exhibited higher death rates than the older seedlings (Table 3). Jong[5], Endert[2], and Tuyt[11] also reported that 3- to 8-year-old seedlings grew well when the canopy was open.

Although *ulin* is considered to be a shade-tolerant species, the seedlings require appropriate canopy opening to growth faster. The seedlings at the gap site displayed higher relative growth rates for height and diameter than the seedlings at the closed site (Table 2). The diameter growth of the tallest 10 seedlings at the gap site averaged 0.389 cm year^{-1}, while that at the closed site was 0.123 cm year^{-1}. Assuming that these diameter growth rates remained unchanged, canopy opening and weeding at the gap site decreased the time required for the *ulin* stem to reach 10 cm in dbh from 78 to 26 years.

The seedlings grown under strong light conditions developed thick leaves and large root systems. Canopy opening apparently resulted in low humid conditions on the forest floor. At 42 months after gap formation, the total dry mass of the seedlings at the gap site was 5.9 times higher than that at the closed site (Table 4). The thick roots at the gap site were 2.5 times longer horizontally and 1.7 times deeper than at the closed site. The total leaf area (LA)/fine-root mass ratios of individual seedlings were smaller (0.85 times) at the gap site than at the closed site. On the other hand, the leaf mass/fine-root mass ratios were 1.23 times larger at the gap site than at the closed site. Such morphological characteristics seem to be common for various tree seedlings grown under different light conditions[10].

Table 2. Growth of *Eusideroxylon zwageri* seedlings in 1993 – 1996

Plot	Age[a] (years)	Mean height[a] (cm)	Height growth rate (cm cm^{-1} year^{-1})	Diameter growth rate (cm cm^{-1} year^{-1})	Death rate (% year^{-1})
1 (gap site)	About 5	92 ± 36	1.210	1.228	5.7
2 (closed site)	About 5	85 ± 30	1.080	1.084	2.8

a): In 1993.

Table 3. Changes in survival rates in each cohort of *Eusideroxylon zwageri* seedlings at (a) gap site (Plot 1), (b) closed site (Plot 2)

(a)

Period of recruitment			Before July 1992	July 1992–May 1993	May 1993–Dec. 1993	Dec. 1993 – Aug. 1994	Aug. 1994 – Jan. 1995	Jan. 1995 – Mar. 1996
Months				10	7	8	5	14
Number of recruits/484m²			476	6	3	14	2	4
	July 1992–May	1993	2.8(465)					
Death rate	May–Dec.	1993	12.2(431)	27(5)				
(% year⁻¹)	Dec. 1993–Aug.	1994	3.8(420)	54(3)	0(3)			
(Number of survivors	Aug. 1994–Jan.	1995	7.3(407)	62(2)	0(3)	55(10)		
at the end of each period)	Jan. 1995–Mar.	1996	2.7(394)	0(2)	0(3)	0(10)	0(2)	
	Mar. 1996–Oct.	1998[a]	63.1(30)	100(0)	100(0)	100(0)	100(0)	100(0)

(b)

Period of recruitment			Before July 1992	July 1992–May 1993	May 1993–Dec. 1993	Dec. 1993–Aug. 1994	Aug. 1994–Jan. 1995	Jan. 1995–Mar. 1996
Months				10	7	8	5	14
Number of recruits/484 m²			190	5	7	5	0	2
	July 1992–May	1993	2.5(186)					
Death rate	May–Dec.	1993	2.7(183)	0(5)				
(% year⁻¹)	Dec. 1993–Aug.	1994	4.1(178)	28(4)	40(5)			
(Number of survivors	Aug. 1994–Jan.	1995	1.3(177)	50(3)	42(4)	89(2)		
at the end of each period)	Jan. 1995–Mar.	1996	2.9(171)	0(3)	22(3)	0(2)		
	Mar. 1996–Oct.	1998[a]	100 (0)	100(0)	100(0)	100(0)		100(0)

a): The fires occurred in March 1998. Before the drought in 1997 – 1998, low monthly rainfall of below 70 mm was observed in July-September and November 1993 and in July-September 1994 at the research station near the plots.

Table 4. Organs of *Eusideroxylon zwageri* seedlings in November 1996

Plot	Mean height	Total mass	Leaves		Fine roots		LA/fine-root mass	Thick root ranges	
			SLA[a]	LA[b]	Mass	Surface area		Horizontal spread	Under-ground
	(cm)	(g)	($cm^2\ g^{-1}$)	(m^2)	(g)	(m^2)	($m^2\ g^{-1}$)	(cm)	(cm)
1 (gap site)	174	769	86.5	1.34	23.5	18.9	0.0570	116	77
2 (closed site)	110	130	126	0.265	3.95	2.70	0.0671	35	36

All data are mean values of 5 seedlings. a): Leaf area/mass. b): Total leaf area.

Influence of fire on seedling survival and regeneration

Relatively large *ulin* trees display a fire resistance capacity[3], and also are less vulnerable to cutting owing to effective sprouting. Of 26 *ulin* trees with a dbh of 44–92 cm, 24 (92%) sprouted new shoots from stumps in fallow land of slash-and-burn agriculture[7]. The ground fires in March 1998 burned the research sites. All of the 4 *ulin* mother trees (30–60 cm in dbh) at the closed and gap sites survived the fires, whereas, only 30 (7.6%) seedlings at the gap site survived the fires. The vulnerability to the fires was higher in the case of smaller seedlings than in larger ones at the gap site. After the fire events at the gap site, the survivors were 302 ± 90 cm tall with a diameter of 2.37 ± 0.83 cm at 0.3 m height, while the dead seedlings at the gap site were 208 ± 73 cm tall with a diameter of 1.52 ± 0.77 cm. Considering that all the seedlings (110 ± 55 cm tall with a diameter of 0.90 ± 0.40 cm) died at the closed site, release cutting prevented some *ulin* seedlings from burning to death.

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