An evaluation of an agroforestry system with 2-year-old *sengon* (*Paraserianthes falcataria*) and shade-tolerant upland rice

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Abstract. *Tsaniya SH, Wijayanto N, Wirnas D. 2022. An evaluation of an agroforestry system with 2-year-old sengon* (Paraserianthes falcataria) *and shade-tolerant upland rice. Biodiversitas 23: 1159-1166. Sengon* is tree species that is often cultivated with upland rice in agroforestry systems. The main obstacle of rice development in agroforestry systems are competition between plants for sunlight and nutrients. 2-year-old *sengon* has a wider canopy and longer roots, increasing competition between *sengon* and rice. Planting upland rice in this condition requires strategies, such as selecting shade-tolerant rice varieties and rice plantations inside bamboo. This study aimed to evaluate the agroforestry system of *sengon* and shade-tolerant upland rice when the *sengon* plants were two years old and evaluate the effectiveness of using bamboo to reduce the competition between *sengon* and upland rice. This research was conducted from November 2020 to April 2021 in the Cikabayan Forest, IPB University, Bogor, West Java. This study used one-factor completely randomized design to analyze the growth of sengon provenances and a three-factor completely randomized design with three replications to analyze the growth and yield of rice. The first factor was the cultivation system (Solomon F1 agroforestry, Solomon F2 agroforestry, local *sengon* agroforestry, and rice monoculture), the second factor was the planting method (using bamboo and without bamboo), and the third factor was rice varieties (Rindang 1 Agritan and Rindang 2 Agritan). The results showed that Solomon and local *sengon* in this study had a growth that was not significantly different and had low diversity. The results also showed that 2-year-old *sengon* spacing 3 m x 1.5 m caused great shade and high competition, leading to low rice yields.

Keywords: Agroforestry, light intensity, rice growth, Solomon *sengon*

INTRODUCTION

Agroforestry is a sustainable land-use system combining woody and non-woody plants on the same land. Agroforestry systems can form ecological and economic interactions between their components to increase land-use efficiency (Huxley 1999; Nair 1993). This system improves soil condition by leaf litter decomposition that increases microbial activity (Dewi et al. 2017). One of the agroforestry systems is growing upland rice (*Oryza sativa* L.) under a *sengon* (*Paraserianthes falcataria* (L.) Nielsen) stand to increase national food production. Agroforestry systems can increase land productivity both economically and ecologically. This system also allows synchronizing between producing crops and natural resource protection (Ngongo and Marcus 2020).

Sengon is a tree species that many people choose to plant on community forest land in an agroforestry system for several reasons. It has a short lifespan and an open canopy enabling sunlight to reach the forest floor, and it is a legume that can fix nitrogen (Nugroho et al. 2018; Senjaya 2017). Increasing community forest productivity can be done by cultivating superior *sengon* varieties (Azizah et al. 2019; Ikhfan and Wijayanto 2019), such as Solomon *sengon*, which has higher productivity than the local variety (Setiadi et al. 2014).

Upland rice, cultivated on dry land, is a common food crop grown in agroforestry systems. According to Tarigan et al. (2019), upland rice is one of the important crops in the agricultural system in Indonesia as a source of staple food. However, research on the agroforestry system of *sengon* and upland rice when *sengon* is still young, and the crown is not yet dense has been carried out (Azizah et al. 2019; Ningrum et al. 2019; Senjaya 2017).

Sopacua et al. (2021) have reported the growth of 16-month-old of *sengon* from various provenances (Solomon F1, Solomon F2, and local) and various varieties of upland rice (Inpago lipigo 1, Inpago lipigo 2, IPB 3S, and IPB 9S) in an agroforestry system. The results showed that only IPB 3S and IPB 9G varieties produced seeds. Our present research was conducted with the same *sengon* plants when they were two years old with a wider canopy, which had a higher shade level than young *sengon* (Rahmawathi et al. 2017; Suci and Heddy 2018). Planting upland rice on land with limited light requires strategies, one of which is the selection of shade-tolerant rice varieties (Caron et al. 2019; Wang et al. 2015). Therefore, in this study, Rindang 1 Agritan and Rindang 2 Agritan, upland rice varieties developed with superior shade tolerance, were selected for planting under 2-year-old *sengon* stands (Balitbangtan 2019).

The increasing age of *sengon* also expands root systems

horizontally and vertically, thereby increasing competition among plant roots (Ikhfan and Wijayanto 2019) in absorbing water and nutrients from the soil. Sopacua et al. (2021) reported that *sengon* roots indirectly absorb the nutrients provided to rice. Therefore, in this study, a trial of rice planting in bamboo was conducted by penetrating bamboo vertically in the soil to minimize the competition. The presence of bamboo was expected to reduce the interaction of rice roots and *sengon* roots so that rice can absorb nutrients optimally.

The purposes of this study were to evaluate the agroforestry system of *sengon* and shade-tolerant upland rice when the *sengon* plants were two years old and to evaluate the effectiveness of using bamboo to reduce the competition between *sengon* and upland rice.

MATERIALS AND METHODS

Study area

The research was conducted from November 2020 to April 2021 in Cikabayan Forest, IPB University, Bogor, West Java, Indonesia (06º32'48.8"S 06º43'02.4"E) (Figure 1). In the research area, stands of 2-year-old *sengon* with different varieties, i.e., Solomon F1, Solomon F2, and local (Kendal), were planted on Latosol soil with a spacing of 3 m x 1.5 m. The research area was located at an altitude of 162 meters, with a slope of 0%. The air temperature, relative humidity, and average rainfall during the research were 26.8-28.7 ºC, 67.7-84%, and 242.52 mm/month, respectively (BMKG 2021).

Procedures
The growth of various provenances of 2-year-old sengon

The design used was a one-factor completely randomized design, namely the provenances of *sengon* (Solomon F1, Solomon F2, and Kendal as the local *sengon*). A total of 20 trees from each provenance were observed as replication so

that there were 20 replicates. Variables observed were the increase in total plant height and stem diameter, and plant canopy area. Data on the increase in total plant height and stem diameter were obtained by measuring the total plant height and stem diameter every month during the observation. Plant height was measured using a Hagameter, while stem diameter at breast height (DBH) and crown length were measured using a tape measure. The increase in total plant height and stem diameter was the average difference in the measurement results each month.

The *sengon* growth data obtained were analyzed using analysis of variance (ANOVA) at the significance level of 5% and continued with the estimation of diversity based on the genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), and heritability (h^2) calculated with the following formulas:

$$\text{Genotypic variance } (\sigma^2 g) = \frac{KTg - KTe}{r}$$

$$\text{Environmental variance } (\sigma^2 e) = KTe$$

$$\text{Phenotypic variance } (\sigma^2 f) = \sigma^2 g + \sigma^2 e$$

$$GCV = \frac{\sqrt{\sigma^2 g}}{x} \times 100\%, \text{ where x is the general mean of the character}$$

$$PCV = \frac{\sqrt{\sigma^2 f}}{x} \times 100\%, \text{ where x is the general mean of the character}$$

$$\text{Heritability } (h^2) = \frac{\sigma^2 g}{\sigma^2 f}$$

According to Moedjiono and Mejaya (1994), the coefficients of genetic and phenotype diversity that have been obtained can be classified into four criteria, i.e., low (0-25%), moderately low (25-50%), moderately high (50-75%), and high (75-100%). Heritability criteria were classified into low ($h^2 < 0.2$), moderate ($0.2 < h^2 < 0.5$) and high ($h^2 > 0.5$) (Stansfield 1991).
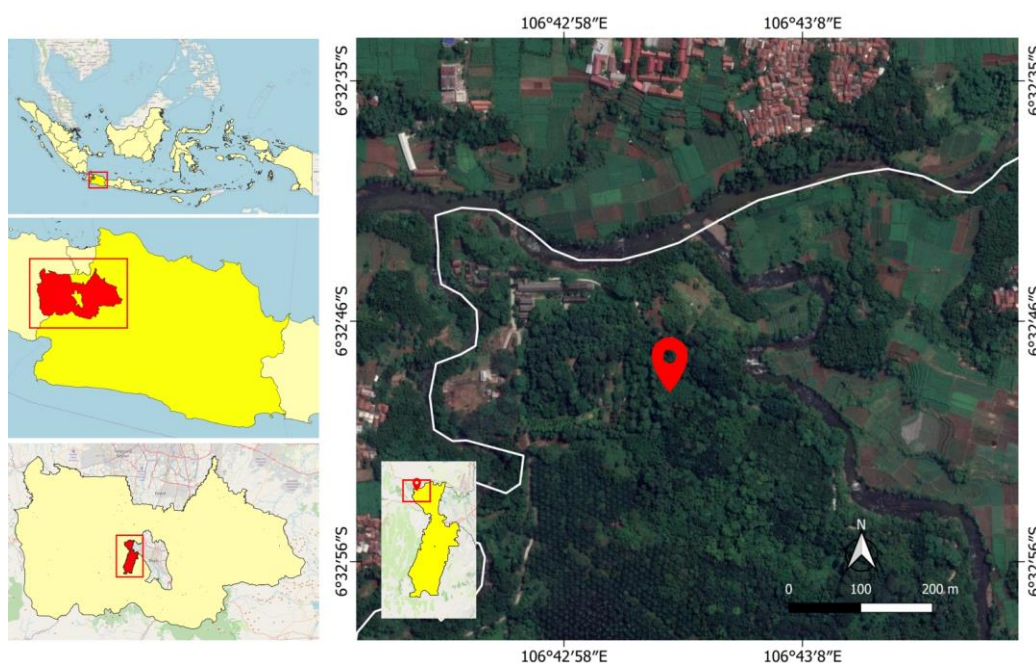
Figure 1. The research location in Cikabayan Forest, IPB University, Bogor, Indonesia (Google map)

Rice growth and yield

The experimental design used in this study was a completely randomized design with three treatments and three replications. The treatments used were cultivation systems (Solomon F1 agroforestry, Solomon F2 agroforestry, local *sengon* agroforestry, and rice monoculture), planting methods (using bamboo and without bamboo), and rice varieties (Rindang 1 Agritan and Rindang 2 Agritan). Rice planting was carried out when the *sengon* was two years old, and rice was planted at a spacing of 25 cm x 25 cm in each experimental unit of 1.5 m x 1.5 m with a total of 25 planting holes.

The bamboo used was 20 cm long. Planting in bamboo was done by penetrating the bamboo vertically until the top surface of the bamboo was in line with the soil surface. Before planting, the rice seeds were soaked in water for 24 hours then wrapped in a wet cloth for 48 hours to break their dormancy.

Rice maintenance was carried out according to plant conditions. The fertilizers given for rice were biological organic fertilizers and inorganic fertilizers, i.e., urea, SP36 and KCL. Urea was given at 3 WAP (weeks after planting) and 6 WAP at a dose of 100 kg/ha each time of fertilization, while SP36 and KCL were given at 3 WAP with a dose of 100 kg/ha each. Insecticides with the active ingredient of fipronil were given when the rice panicles started to grow to eradicate the pest bug. Rice harvesting was done when 85% of the rice grains were physiologically mature.

Variables measured to determine the growth and production of rice were plant height, number of tillers, number of productive tillers, panicle length, the weight of filled grain, and productivity. Rice productivity was calculated by considering the area of land that can be used for rice cultivation, which was 83% of the total land area. The rice data obtained were analyzed using analysis of variance (ANOVA) at the significance level of 5%. If the ANOVA results showed a significant effect of treatments on the observed variables, then the Duncan's Multiple Range Test was carried out at the significance level of 5%. Data analysis was carried out using SPSS version 25 software. In addition, the light intensity in the four cultivation systems was measured using a lux meter once a week.

RESULTS AND DISCUSSION

The growth and diversity of *sengon*

Sengon is one of the most frequently found tree species in community forests, especially in Java. Besides local *sengon*, the Solomon *sengon* from the Solomon Islands has also grown in Indonesia, known as Solomon F1 and Solomon F2. The results of variance analysis showed that the growth of *sengon* since the age of 2 years was not influenced by its provenance (Table 1). Sopacua et al. (2021) reported that 16-month-old Solomon F1, Solomon F2, and local Kendal had no significant plant height and stem diameter difference.

Although the growth was not significantly different among provenances, Solomon F1 had a relatively higher increase in total plant height and stem diameter than the other provenances. Solomon F2 ranked second and local Kendal *sengon* the last. Solomon F2 had a relatively larger canopy area than the other provenances. The results of Azizah et al. (2019) in various provenances of 6-month-old *sengon* showed that Solomon F1 had better growth than Solomon F2 and local Kendal. Hardiyanto (2010) and Setiadi et al. (2014) reported that the growth of Solomon *sengon* was better than the local *sengon* provenance. Solomon *sengon* has high adaptability to various environmental factors (Azizah et al. 2019; Sopacua et al. 2021; Susanto and Baskorowati 2018) and has a higher growth rate, which can be related to genetic factors (Ikhfan and Wijayanto 2019; Susanto and Baskorowati 2018).

The phenotypic and genetic diversity of the *sengon* population in this study is shown in Table 2. Genetic diversity shows differences in performance between populations caused by genetic factors (Susilowati et al. 2018). Therefore, the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are parameters that can be used to determine the level of diversity among trees in one *sengon* provenance, while the heritability value reflects the diversity among *sengon* provenances.

Based on the grouping of GCV and PCV by Moedjiono and Mejaya (1994), the results of data analysis showed that the three *sengon* provenances had low GCV values for all observed characters. Meanwhile, the PCV values of the three *sengon* provenances varied from moderately low to moderately high (Table 2). The characteristic with a moderately low PCV value was canopy area, while the moderately high GCV value was found in the increase in total plant height and stem diameter. Low GCV and PCV values indicate that the diversity among individuals in each provenance is low, while high GCV and PCV values indicate wide diversity and varied appearance of individuals in each provenance.

The heritability value was estimated to determine the influence of genetic factors on the diversity among provenances of *sengon* tested in this study. The analysis results showed that all of the characteristics tested had low heritability values, ranging from 0.05 to 0.16 (Table 2). This low heritability value indicates that all growth variables of the three *sengon* provenances are more influenced by environmental than genetic factors (Roy and Shil 2020; Sadimantara et al. 2021).

Table 1. The comparison of growth of various *sengon* provenances in agroforestry systems

Variable	F test	Provenance		
		Solomon F1	Solomon F2	Kendal
Increase in total plant height (m)	ns	0.825	0.713	0.425
Increase in stem diameter (cm)	ns	0.245	0.233	0.155
Canopy area (m^2)	ns	11.550	12.130	11.000

Note: ns: the treatment had no significant effect at the 5% level

Upland rice growth and yield

In the agroforestry system of *sengon* and upland rice, there is competition between the main plant and other plants in obtaining sunlight, nutrients, and water (Dewi et al. 2017; Senjaya 2017). The competition will be stronger with the increasing age of the *sengon* trees.

Sengon trees at the research site were two years old, so they already had large crowns and extensive roots. Table 3 shows the effect of the cultivation system (rice-*sengon* agroforestry system and rice monoculture), planting method (using bamboo and without bamboo), and rice varieties (Rindang 1 Agritan and Rindang 2 Agritan) on the growth and yield of rice. The cultivation system and planting method had a significant effect on plant height, number of productive tillers, and panicle length of rice, while rice varieties had a significant effect on plant height, number of tillers, number of productive tillers, the weight of filled grain, and rice productivity. The interaction between treatments did not significantly affect all observation variables, except for the number of productive tillers.

The cultivation system in this study, which consisted of *sengon*-rice agroforestry and rice monoculture, had a significant effect on several observed variables. The agroforestry system has the effect of reducing light intensity for plants so that the sunlight from rice plants in the agroforestry system is lower than in the monoculture system (Table 4). The average light intensity received by rice plants in agroforestry systems only reaches 60% of rice grown in monoculture systems.

Sunlight has an important role in plant growth and development because it is one of the main components in photosynthesis and energy formation (Salisbury and Ross 1985). The intensity of sunlight received by rice will affect its growth and yield (Nuraida et al. 2020; Wang et al. 2015). Low light intensity inhibits the works of enzymes that play a role in photosynthesis, reducing the amount of assimilation for the growth and filling of rice grains (Liu et al. 2014). Ningrum et al. (2019) reported that the shade reduced the number of leaves, number of tillers, grain weight, and panicle length. Liu et al. (2014) explained that low light intensity during the panicle formation and grain filling process could decrease rice yields substantially.

Table 2. Population diversity and heritability of various provenances

Characteristics	GCV	Criteria	PCV	Criteria	h^2	Criteria
Increase in total plant height	20.64	low	51.87	moderately high	0.16	low
Increase in stem diameter	21.82	low	57.75	moderately high	0.14	low
Canopy area	8.93	low	40.49	moderately low	0.05	low

Table 3. ANOVA results on the effect of cultivation systems, planting methods, and rice varieties on rice performance

Variable	Treatment						
				Interaction			
	Cultivation system	Planting method	Rice variety	Cultivation system and planting method	Cultivation system and rice variety	Planting method and rice variety	Cultivation system, planting method, and rice variety
Plant height (cm)	*	*	*	ns	ns	ns	ns
Number of tillers (tillers)	ns	ns	*	ns	ns	ns	ns
Number of productive tillers (tillers)	*	*	*	ns	ns	*	ns
Panicle length (cm)	*	*	ns	ns	ns	ns	ns
Weight of filled grain (g)	ns	ns	*	ns	ns	ns	ns
Productivity (ton/ha)	ns	ns	*	ns	ns	ns	ns

Note: *: the treatment had a significant impact at the 5% significance level; ns: the treatment had no significant effect at the 5% significance level

Table 4. Light intensity on each cultivation system

	Agroforestry				Rice monoculture
	Solomon F1	Solomon F2	Kendal	Average	
Light intensity (lux)	7369.333	6942.389	7850.889	7387.537	12116.778

Rice plants cultivated in monoculture have better plant height, a number of productive tillers, and panicle length than those grown in agroforestry systems because they receive more light than those grown in agroforestry systems. The same result was also reported by Lestari et al. (2020), Azizah et al. (2019), Ningrum et al. (2019), and Juliarti et al. (2021). Rice growth in a monoculture system is better than in the agroforestry system because competition for nutrients, water, and sunlight in monoculture systems is almost non-existent or very low. The agroforestry cultivation system provides a higher plant density than the monoculture cultivation system, so the competition among plants is higher (Sopacua et al. 2021). Neither et al. (2020) reported that soil in agroforestry cultivation has a lower water content than monoculture.

The growth and yield performance of rice in agroforestry and monoculture systems are shown in Table 5. Rice grown under local *sengon* stands had the highest yields. Meanwhile, the lowest growth and yield of rice was found under Solomon F2 stands. This result is in accordance with Azizah's research (2019) which showed that rice in local *sengon* had the highest productivity, followed by Solomon F1, and the lowest was Solomon F2. Rice productivity in agroforestry cultivation systems is thought to be related to the growth of *sengon.* Solomon *sengon* in this study grew relatively faster than local *sengon*, resulting in greater absorption of nutrients and consequently greater competition between *sengon* and upland rice in obtaining nutrients in the soil (Azizah 2019; Ikhfan and Wijayanto 2019; Sopacua et al. 2021). In this study, Solomon F1 and Solomon F2 had almost the same growth rate, but rice under the shade of Solomon F2 received lower light intensity, causing lower productivity (Dutta et al. 2018; Panda et al. 2019; Ganguly et al. 2020).

Rice productivity in this study is very low. Azizah (2019) stated that rice grown under 6-month-old *sengon* has productivity of 1.40 tons/ha on local Kendal, 1.26 tons/ha on Solomon F1, and 0.97 tons/ha on Solomon F2. Meanwhile, rice productivity understands of 2-year-old *sengon* only reached 0.013, 0.008, and 0.006 tons/ha, respectively, under local Kendal, Solomon F1, and Solomon F2 stands. The decline in rice productivity under

2-year-old *sengon* stands was more than 90%. The results of this study are in line with those of Senjaya (2017), showing that rice grown in agroforestry with 3-month-old *sengon* had a productivity of 63.68 g/plot, while at 2-year-old *sengon* its productivity decreased by more than 90% to 6.19 g/plot. The 3-month-old *sengon* in Senjaya's research (2017) and 6-month-old in Azizah's research (2019) had a light canopy so that sunlight could easily reach the forest floor, while the 2-year-old *sengon* had a larger and denser canopy. In addition, *sengon* aged two years old had longer roots than *sengon* aged 3 and 6 months old, increasing competition between rice's and *sengon*'s roots. Thus, it can be stated that rice cultivation under 2-year-old *sengon* stands is no longer feasible. The development of 2-year-old *sengon* agroforestry systems needs to be supported with plant species resistant to heavy shade levels.

The results showed that in addition to low light intensity, the growth of *sengon* also reduced rice production. *Sengon* at the research site had roots that had reached the rice planting area. Hartoyo et al. (2014) reported that *sengon* roots that grow horizontally were mostly found in cultivation with agroforestry systems. According to Senjaya (2017), a 2-year-old *sengon* had an average root length of 104.25 cm. There is competition between *sengon* and rice grown in the same area.

Table 6. Comparison of upland rice performance in two planting methods

Variable	Planting method	
	With bamboo	Without bamboo
Plant height (cm)	63.438b	74.283a
Number of tillers (tillers)	4.313	4.3540
Number of productive tillers (tillers)	2.225b	4.058a
Panicle length (cm)	8.002b	11.406a
Weight of filled grain (g)	1.106	2.215
Productivity (ton/ha)	0.006	0.012

Note: numbers followed by different letters in the same row are significantly different according to Duncan's test with the significance level of 5%

Table 5. Comparison of upland rice performance understands of various *sengon* provenances and monocultures

Variable	Agroforestry				Rice monoculture
	Solomon F1	Solomon F2	Kendal	Average	
Plant height (cm)	63.116b	61.816b	74.542a	66.491	75.967a
Number of tillers (tillers)	4.433	4.100	4.258	4.264	4.542
Number of productive tillers (tillers)	2.908ab	1.925b	3.842a	2.892	3.892a
Panicle length (cm)	9.183b	6.668c	11.218ab	9.023	11.743a
Weight of filled grain (g)	1.586	1.168	2.353	1.702	1.535
Productivity (ton/ha)	0.008	0.006	0.013	0.009	0.010

Note: numbers followed by different letters in the same row are significantly different according to Duncan's test at the significance level of 5%

Table 7. The comparison of upland rice performance (Rindang 1 Agritan and Rindang 2 Agritan) in agroforestry systems

Variable	Upland rice varieties	
	Rindang 1 Agritan	**Rindang 2 Agritan**
Plant height (cm)	72.929a	64.792b
Numbers of tillers (tillers)	4.838a	3.829b
Numbers of productive tillers (tillers)	4.479a	1.804b
Panicle length (cm)	10.381	9.026
Weight of filled grain (g)	2.972a	0.350b
Productivity (ton/ha)	0.016a	0.002b

Note: numbers followed by different letters in the same row are significantly different according to Duncan's test with the significance level of 5%

Rice planting in bamboo in this study was carried out to reduce competition between rice and *sengon* so that rice can obtain more optimal nutrients. However, the results of the study presented in Table 5 show that rice grown using the bamboo method had lower plant height, fewer productive tillers, and shorter panicle length. The rice can only get the water and nutrients available in a narrow bamboo, the same as planting plants in small pots. Poorter et al. (2012) stated that planting plants in small pots can reduce water and nutrients. The lack of nitrogen and phosphorus elements will reduce the rate of photosynthesis of plants (Guo et al. 2021; Poorter et al. 2012; Ya-wei et al. 2019), causing stunted growth. In addition, rice grown without using bamboo is thought to benefit from *sengon* roots. *Sengon* can fix nitrogen in root nodules so that the soil contains high nitrogen nutrients (Nugroho et al. 2018). Thus, the rice cultivation in bamboo cannot reduce the competition between *sengon* and rice.

The two upland rice varieties cultivated in this study are new high-yielding varieties developed with superior tolerance to low light intensity. However, Table 7 shows that Rindang 1 Agritan and Rindang 2 Agritan rice have low growth and yields. According to Balitbangtan (2019), Rindang 1 Agritan rice had an average plant height of 130 cm, and Rindang 2 Agritan's average plant height was 138 cm. Meanwhile, the average plant height of rice in this study was only 72.929 cm for Rindang 1 Agritan and 64.792 cm for Rindang 2 Agritan. Hairmansis et al. (2017) explained that planting rice in shaded conditions caused several genotypes of rice to have lower plant heights. All tested genotypes had lower tillers than those without shade, including the shade-tolerant rice variety named Jatiluhur. Low light intensity disrupts photosynthesis, so the photosynthate produced is not sufficient to meet the needs for plant growth (Lestari et al. 2020; Liu et al. 2014).

Rindang 1 Agritan rice can produce 4.64 tons/ha, and Rindang 2 Agritan 4.20 tons/ha (Balitbangtan 2019), while the productivity of rice in this study was only 0.016 tons/ha for Rindang 1 Agritan and 0.002 tons/ha for Rindang 2 Agritan (Table 7). The productivity of a plant can also be seen from the harvest index. Rice in this study had a low yield index (Asefa 2019; Horton 2000), namely 0.071 for Rindang 1 Agritan and 0.035 for Rindang 2 Agritan.

Although Rindang 1 Agritan and Rindang 2 Agritan are shade-tolerant rice varieties, 2-year-old *sengon* creates heavy shade for rice. The light intensity of 6942,389-12116,778 lux reduces rice yields. According to Hairmansis et al. (2017), the shade also reduces the yield of shade-tolerant rice varieties, but the decrease is lower than that of sensitive varieties. The low light intensity decreases the rate of photosynthesis due to the disruption of the activity of rubisco, which functions as a catalyst in CO_2 fixation, so the photosynthate is not sufficient for the formation and filling of rice grains (Chen et al. 2019; Ningrum et al. 2019; Pan et al. 2016). The results showed that planting rice under 2-year-old *sengon* stands also resulted in a longer rice harvest age than normal conditions, according to the research of Cai (2011) and Hairmansis et al. (2017). According to Balitbangtan (2019), under normal conditions, Rindang 1 Agritan and Rindang 2 Agritan rice can be harvested at the age of 113 days. Meanwhile, the rice in this study was ripe at the age of 150 days.

Based on results shown in Table 7, Rindang 1 Agritan had the highest growth and yield in this study, indicated by plant height, number of tillers, number of productive tillers, the weight of filled grain, and productivity. This result is thought to be related to each variety's tolerance to shade. Each plant variety will have a different response to light (Li et al. 2010; Polthanee et al. 2011; Wang et al. 2013). Balitbangtan (2019) stated that the Rindang 1 Agritan variety had a higher tolerance to shade than the Rindang 2 Agritan variety. Shade-tolerant varieties can increase the efficiency of capture and use of sunlight and reduce respiration, so they can grow and produce better in shade conditions than sensitive varieties (Wang et al. 2015). Shade-tolerant varieties adapt to light deficits by increasing the chlorophyll content to maximize photon absorption and increasing leaf area to expand the surface area for light absorption (Gommers et al. 2013; Li et al. 2015). Based on these results, it is known that in the shaded condition of two-year-old *sengon* stands, Rindang 1 Agritan rice had a better growth ability than Rindang 2 Agritan.

Based on this research, it can be concluded that Solomon *sengon* had relatively higher growth than local Kendal *sengon* in the agroforestry system. The low growth and yield of rice in this study indicated that upland rice cultivation under *sengon* stands aged two years old with a spacing of 3 m x 1.5 m was not effective because of great shade and high competition between rice and *sengon*, leading to low rice yields, even though those planted are shade-tolerant rice varieties.

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