BIODIVERSITAS
Volume 24, Number 6, June 2023
Pages: 3114-3119

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240603

The growth of *sengon* (*Parasarienthes falcataria*) and citronella (*Cymbopogon nardus*) productivity performance in agroforestry system

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Manuscript received: 15 November 2022. Revision accepted: 5 May 2023.

Abstract. *Rahmah H, Wijayanto N, Wulandari AS. 2023. The growth of* sengon (Parasarienthes falcataria) *and citronella* (Cymbopogon nardus) *productivity performance in agroforestry system. Biodiversitas 24: 3114-3119. Sengon* is a fast-growing plant species widely planted in community forests. *Sengon* is widely cultivated in agroforestry systems with seasonal crops. The main obstacle to cultivation in agroforestry systems is low growth due to competition for nutrients and low absorption of sunlight. This study aims to analyze the growth of *sengon* varieties and citronella varieties. The research was conducted for six months in the Cikabayan field, Faculty of Forestry, IPB University, Bogor, West Java. This study consisted of two activities: (i) analyzing the effect of the two-year-old *sengon* variety on the growth of tree height, diameter, crown, and volume, (ii) analyzing the effect of the citronella variety on the growth and yield of citronella oil. The experiment was designed with three factors, a completely randomized design with three replications. The results showed that *Sengon* Solomon had higher growth than *Sengon* Kendal. *Sengon* Solomon F2 had better growth than *Sengon* Solomon F1 and Kendal locale. Citronella plants grown under the local stands of *Sengon* Kendal had the best productivity. Lemongrass variety G1 had better growth than the Sitrona 2 Agribun variety in the shaded condition of *sengon* stands. However, the Sitrona 2 Agribun variety's yield has a higher value than the G1 citronella variety.

Keywords: Agroforestry, citronella productivity, citronella variety, *sengon* provenance

INTRODUCTION

Agroforestry is a land use system that combines woody plants with agricultural or livestock crops in which there are ecological, economic and social interactions (Alao and Shuaibu 2013). Land management using the agroforestry system is carried out to optimize land use that can benefit the community. This provides interest for the community to plant the land with an agroforestry system economically and environmentally. One tree species in great demand and can be applied in agroforestry systems is *sengon* (*Falcataria moluccana* (Miq.) Barneby & J.W.Grimes).

Sengon (*Falcataria moluccana* (Miq.) Barneby & J.W. Grimes) is a potential plant to be cultivated by the community. *Sengon* is a fast-growing tree with a height of up to 26-37 m and a diameter of 20-100 cm. This plant is widely used as carpentry wood and pulp raw material (Krisnawati et al. 2011; Priadi and Hartati 2015). The selection of *sengon* species can increase the productivity of community forests. In addition to local *sengon*, Solomon *sengon* is a superior type of *sengon*. Solomon *sengon* has faster growth than local *sengon*. *Sengon* can grow in various environmental soil conditions and is resistant to pests and diseases (Susanto and Baskorowati 2018; Ikhfan and Wijayanto 2019).

Sengon has an open crown and light leaves so that light can penetrate the soil. The low canopy space can be used for planting or seasonal crops (Wijayanto and Pratiwi 2011; Azizah et al. 2019). Utilization of growing space under *sengon* stands is used through an agroforestry system. Agroforestry is a land use system that combines woody plants and agricultural crops on the same land. Agroforestry land management can form ecological, economic, and social interactions. (Alao and Shuaibu 2013; Kaur et al. 2017; Prayogo et al. 2020). One of the efforts to support the development of sustainable forest areas and provide economic benefits is the selection of plant species (Japarudin et al. 2020). One of the essential plants that have high export value is citronella.

Lemongrass is an annual plant that has the potential to produce essential oils. Lemongrass can be harvested three times a year. At the first harvest of citronella aged six months, then harvesting is carried out every three months (Sulaswatty et al. 2019). This plant is very prospective because it can produce good essential oil products and meet domestic and export needs. The citronella oil pit in Indonesia increases annually by more than 2000 tons and only reaches about 8% (Anwar et al. 2016; Harianingsih et al. 2017). The price of citronella oil is quite high, ranging from Rp. 215,000/kg - Rp. 225,000/kg (Sulaswatty et al. 2019). The world's demand for citronella oil is an opportunity for Indonesia to meet the needs of the international market (Sujianto et al. 2012). The land under the stand is expected to increase the production of citronella without opening new lands.

Lemongrass cultivated on land with limited light requires a strategy to achieve successful cultivation. Select varieties are expected to increase the success of cultivation in the shade. In 2015, the Research Institute for Spices and

Medicinal Plants (Balittro) released a select variety of Citronella 2 Agribun. The *sengon* stands used in this study were two years old, so they had developed a canopy and root cover. The tree canopy will expand as the plant ages, thereby reducing the intensity of light received by the plants beneath it (Sopacua et al. 2021). The increasing age of *sengon* causes its roots to develop horizontally and vertically, thereby increasing competition between plant roots (Ikhfan and Wijayanto 2019). Therefore, this study conducted a trial of planting citronella in bamboo immersed in the soil to minimize root competition. This study aimed to analyze the growth of *sengon* and citronella provenances in agroforestry systems and to evaluate the productivity of citronella planted using the bamboo planting method.

MATERIALS AND METHODS

Study area

The research was carried out from November 2020 to June 2021 in Cikabayan forest land, IPB University, Bogor, Indonesia (06°32'48.8"LS 106°43'02.4"E) (Figure 1). The research area is located at an altitude of ± 162 meters with a slope of 0%. The study site has air temperatures ranging from 26.8 - 28.7°C, relative humidity of 67.7-84%, and an average rainfall of 242.5 mm/month (BMKG 2021). The intensity of sunlight ranges from 6633-10430 lux in the measurement frequency. Light intensity was measured in the morning, afternoon, and evening three days during the week.

Procedures

Land preparation and plant material

This study used three types of *sengon*, namely Solomon F1 *sengon*, Solomon F2 *sengon*, and local Kendal. Kendal local *sengon* obtained from Kendal; Solomon F1 is a *sengon* from Solomon cultivated in Kendal District, Central Java; Solomon F2 is a Solomon type crossed with a local Kendal type. The citronella used were varieties G1 and Citrona 2 Agribun. Both varieties of citronella were obtained from Bandung, West Java. The type of soil at the research site is Latosol. The soil at the experimental site was prepared using general and planting techniques with bamboo. The standard technique is to clear the weeds and till the soil with a hoe to make the soil loose. Planting plots were made between *sengon* stands to plant citronella with a distance of 50 cm between *sengon* and citronella. The bamboo planting technique used bamboo measuring ± 20 cm long with a hole diameter of ± 3 cm. Bamboo planting was done by immersing it vertically until the bamboo was parallel to the ground. The spacing between citronella is 25 cm x 25 cm. Each planting hole was added with compost, manure, and husk charcoal for soil fertility. In addition, before planting, bio-organic fertilizer (POH) was given at a dose of 15 mL per planting hole.

The growth of three sengon *provenances*

This research was conducted by observing the growth of three provenances of *sengon*, namely *sengon* Solomon F1, *sengon* Solomon F2, and local Kendal. The seedlings were planted with 1.5 m x 1.5 m spacing. The design used a completely randomized design, with a single factor, namely the provenance of *sengon* with ten replications. The variables observed were the increase in total plant height, stem diameter, and canopy area. Data on the increase in total plant height and stem diameter were measured monthly during the observation. Plant height was measured using a Hagameter, while stem height (DBH) and crown were measured using a meter. The increase in total plant height and stem diameter is the average difference in the measurement results each month.

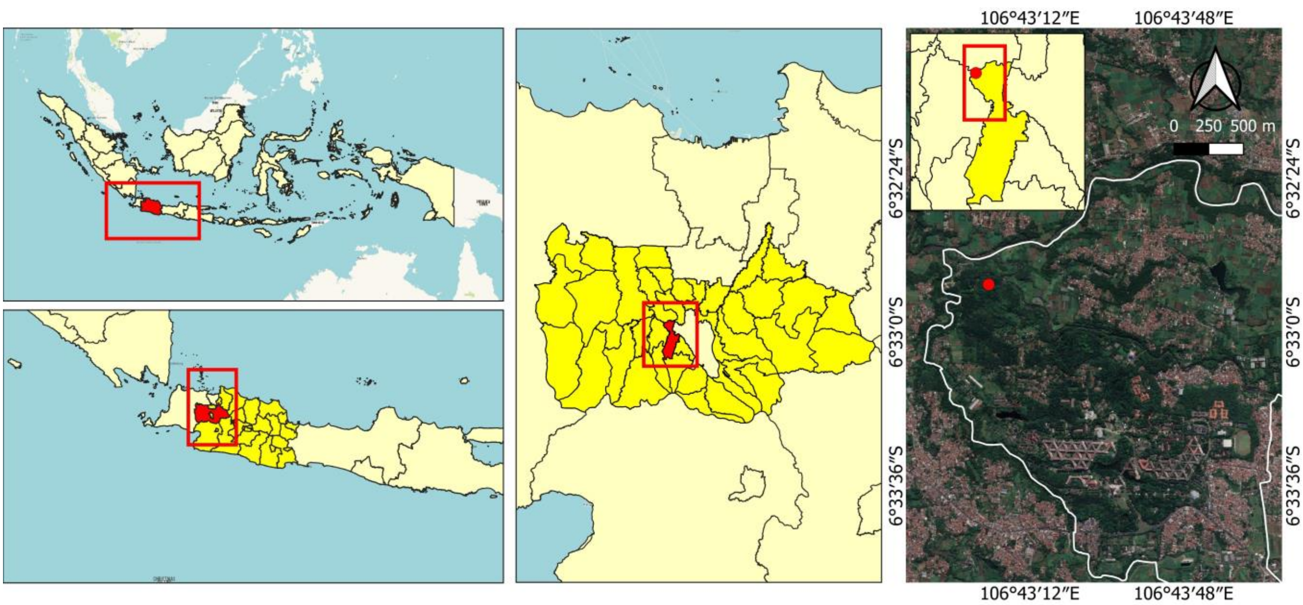

Figure 1. Research location of Cikabayan Forest, IPB University, Bogor District, West Java Province, Indonesia

The growth of citronella in agroforestry systems

This research was conducted by observing the growth of two varieties of citronella, namely varieties G1 and Citrona 2 Agribun, in agroforestry systems. The design was completely randomized, with three treatments and three replications. The treatments used were agroforestry systems (Solomon F1 + Citronella G1 and Citrona 2 Agribun, Solomon F2 + Citronella G1 and Citrona 2 Agribun, local *sengon* + Citronella G1 and Citrona 2 Agribun, and citronella monoculture), planting methods (using and without bamboo). Citronella was planted under a two-year-old *sengon* tree with a spacing of 25 cm x 25 cm for each planting hole. The bamboo planting method used bamboo measuring ± 20 cm long with a hole diameter of ± 3 cm; then, it was vertically immersed until it was parallel to the ground. The maintenance of citronella was carried out by giving biological organic fertilizers and inorganic fertilizers, namely urea, SP 36 and KCL. Urea was given 3 WAP (Weeks After Planting) with a dose of urea 100 kg/ha, SP36 25 kg/ha, and KCL 125 kg/ha. Harvesting was done when the citronella was six months old. The stems were cut at least 5 cm above the lower ligule (the boundary between the midrib and the leaf blade). Steam distillation was carried out by drying the stalks of citronella and then boiling them for 4 hours. The variables observed were plant height, number of tillers per clump, biomass, oil volume, and yield. In addition, the light intensity in the four cultivation systems was measured once a week using a lux meter.

Data analysis

Sengon and citronella growth data obtained were analyzed using Analysis of Variance (ANOVA) at a significance level of 5%. If the results showed a significant effect of the treatments on the variables, Duncan's Multiple Range Test was performed at a significance level of 5%. Data analysis was done using SPSS version 25.

RESULTS AND DISCUSSION

The growth of Solomon and local *sengon*

Each provenance of *sengon* has different growth abilities. Dwiyanti et al. (2021) state that plant provenance affects its ability to deal with interactions and the quality of its genes. *Sengon* developed in agroforestry systems has better growth than monoculture cultivation (Susanto et al. 2019). Based on the analysis of variance, the provenance of *sengon* gave significant differences in the variables of canopy area and tree volume (Table 1).

The variance results showed that the *sengon* provenance had a significantly different effect on the canopy area and tree volume. Meanwhile, the increase in diameter and height did not show a significant effect. Based on the growth variable, the highest value was found in Solomon F2 *sengon*, followed by Solomon F1, and the lowest growth was in Kendal local *sengon*. Ikhfan and Wijayanto (2019) stated that the ability of Solomon *sengon* to grow was three times higher than that of the local *sengon* provenance.

Measurement of the canopy area of *sengon* showed significantly different results in Solomon F2 *sengon*. Sopacua (2021) stated that the canopy of *sengon* F2 at the age of 16 months had the highest value, so the *sengon* canopy's growth could affect the shade plants. Wijayanto and Pratiwi (2011) explained that sunlight entering the stand would affect photosynthesis. The effect of shade in agroforestry patterns can increase plant growth with a shade level of 30%. Dendang and Sudomo (2020) explained that the *sengon* agroforestry cropping pattern could increase canopy competition. The results of measuring the volume of the *sengon* tree showed significantly different results in Solomon F2 *sengon*. Sopacua et al. (2021) explained that the volume of Solomon F2 trees aged 16 months experienced faster growth than the Solomon F1 *sengon* and Kendal local *sengon*. Factors that affect tree volume are stand density, quality of growing location, and maintenance techniques (Rahman et al. 2018; Mulyadi et al. 2022; Aldafiana and Murniayati 2021).

Productivity of citronella in the agroforestry system

In the agroforestry pattern, *sengon* can affect the growth and yield of citronella. The amount of light that enters the soil is blocked by the *sengon* canopy cover. Sharangi et al. (2022) explained that plant interactions in agroforestry systems could cause competition between plant components in obtaining sunlight and plant nutrients.

Sengon in the research area was two years old, so it had a larger developed canopy, creating a shade that affected the light intensity of the plants below. Table 2 shows that the highest light intensity was obtained under monoculture citronella cultivation conditions. In the agroforestry system, the light intensity under Solomon F2 *sengon* canopy was the lowest, while under Solomon F1 was the highest. Ansari et al. (2015) stated that the intensity of light received could affect the growth and productivity of citronella. Tsaniya et al. (2022) stated that the amount of sunlight intensity entering the forest floor was lower in agroforestry systems than in monoculture systems.

Table 1. The growth of various *sengon* provenances

Variable	F test	Treatment		
		Solomon F1	Solomon F2	Lokal Kendal
Plant height growth rate	ns	0.21a	0.34a	0.20a
Stem diameter growth rate	ns	1.26ab	2.44a	0.64b
Tree volume	*	0.07b	0.087a	0.067c
Canopy area	*	14.82b	22.28a	18.20b

Note: *: The treatment had a significant effect at the 5% level with a significant value (Pr>F) 0.05 (α), ns: the treatment had no significant effect at the 5% significance level with a significant value (Pr>F) 0.05 (α)

Table 2. Light intensity for each cropping pattern

Variable	Agroforestry			Monoculture
	Solomon F1	Solomon F2	Local Kendal	
Light intensity (lux)	8,007.39	6,551.72	6,633.56	10,430.78

The growth of citronella can affect the yield as indicated by plant height, number of tillers, essential oil, leaf production, and yield. The analysis of variance showed significant differences in the leaf production of citronella among cropping patterns (Table 3).

The results showed that the monoculture cropping pattern had higher growth, number of tillers, and better leaf production than the agroforestry cropping pattern, but the difference was not significant, except for leaf production. Citronella planted under the stands of *sengon* Solomon F2 had the lowest leaf production, which might be caused by the high growth of *sengon* resulting in competition for sunlight and nutrients. Sukarno (2022) stated that the monoculture cropping pattern had better growth and yield of citronella compared to the condition of the land under the shade because there is higher competition in agroforestry patterns in obtaining light intensity and nutrient content. According to Syakir and Gusmaini (2015), citronella with a high number of tillers and leaf production generally has a high growth rate.

The yield of G1 citronella in this study was higher than that of Sitrona 2 Agribun. Juliarti et al. (2020) stated that citronella planted between 1.5 years of eucalyptus with the G1 citronella variety had a growth of 0.99%, the Sitrona 2 Agribun citronella had a 1.5% yield, while the citronella planted monoculture the G1 variety had a yield of 1.5 Meanwhile, Table 4 shows that planting citronella under *sengon* stands can reduce yields by up to 90%. The amount of essential oil in agroforestry cropping patterns had the highest growth compared to monocultures. This is in accordance with the statement of Juliarti et al. (2021) that the essential oil content of citronella cultivated in agroforestry has a higher value than in monoculture. The amount of essential oil in Kendal's local *sengon* agroforestry system had the highest value due to the lowest Kendal local *sengon* growth. In the research of Ansari et al. (2015), the yield of citronella agroforestry cultivation on pigeon peas had the highest productivity. In addition, in Azizah research (2019), the growth of rice cultivated in agroforestry on local Kendal *sengon* has the highest productivity, followed by Solomon F1 *sengon* and the lowest productivity under Solomon F2 *sengon*.

The method of planting citronella with bamboo aims to reduce competition between *sengon* roots and citronella. The bamboo functions as a barrier to *sengon* roots so that it does not interfere with the absorption of citronella nutrients. Table 4 shows that the growth variables of citronella planted with bamboo and without bamboo methods were not significantly different. Lemongrass grown using the bamboo method had a high yield of essential oils. It is suspected that the citronella roots can find more water than those without bamboo. The citronella root only gets the water and nutrients contained in the bamboo; this is similar to the method of planting in a small pot. Muthahara et al. (2018) stated that planting plants in pots can affect the movement of roots in absorbing water and nutrients. The limited absorption of nutrients can reduce the rate of plant photosynthesis (Guo et al. 2021), which decreases leaf production and the level of citronella essential oil.

The planting method without bamboo provides a wider growing space for the citronella roots to obtain water and nutrients. Citronella plants benefit from *sengon* plants. *Sengon* is a legume that can fix nitrogen, which will increase the nitrogen content in the soil. Nitrogen is one of the macronutrients that increase plant cell growth (Barus et al. 2013; Nugroho et al. 2018; Zheljazkov et al. 2011). Citronella planted using the bamboo planting method had a higher root length than the non-bamboo planting method. The average length of citronella roots in the bamboo planting method was 32.78 cm, while the average length of citronella roots without bamboo was 18.47 cm.

Table 3. Comparison of the performance of citronella in various cropping patterns

Variable	F test	Agroforestry			Mono-culture
		Solomon F1	Solomon F2	Local Kendal	
Height (cm)	ns	89.20	76.98	100.55	124.65
Number of tillers (clump)	ns	1.50	1.75	2.67	2.67
Essential oil (mL)	ns	0.80	0.68	1.40	1.10
Leaf production (g/tree)	*	31.53c	15.52d	42.36b	52.53a
Yield (%)	ns	1×10^{-2}	5×10^{-3}	4×10^{-3}	7×10^{-3}

*: The treatment had a significant effect at the 5% level with a significant value (Pr>F) 0.05 (α), ns: the treatment had no significant effect at the 5% significance level with a significant value (Pr>F) 0.05 (α)

Table 4. The performance of citronella in various planting methods

Variable	F test	Method	
		Bamboo	Without bamboo
Height (cm)	ns	103.27	103.14
Number of tillers (clump)	ns	2.33	2.17
Essential oil (mL)	ns	0.99	1.70
Leaf production (g/tree)	ns	37.08	40.70
Yield (%)	ns	2.33	2.17

*: The treatment had a significant effect at the 5% level with a significant value (Pr>F) 0.05 (α), ns: the treatment had no significant effect at the 5% significance level with a significant value (Pr>F) 0.05 (α)

Table 5. Comparison of the performance of citronella in various varieties

Variable	F test	Variety	
		G1	Citrona 2 Agribun
Height (cm)	*	140.85a	65.57b
Number of tillers (clump)	*	3.23a	1.27b
Essential oil (mL)	ns	1.414	1.423
Leaf production (g/tree)	*	54.30a	23.49b
Yield (%)	*	0.002b	0.011a

Note: *: The treatment had a significant effect at the 5% level with a significant value (Pr>F) 0.05 (α), ns: the treatment had no significant effect at the 5% significance level with a significant value (Pr>F) 0.05 (α)

The two varieties of citronella cultivated in this study are shade-tolerant. Table 5 shows citronella G1 variety had higher growth, but the Sitrona 2 Agribun variety had higher yields. Based on Ballitro's (2015, in Sujianto et al. 2018) description, G1 citronella has a yield of 1.02%, while Sitrona 2 Agribun's citronella has a yield of 1.83%. In our study, the yield of citronella G1 was 0.002% and Sitrona 2 was 0.011%. This is in accordance with research by A'yun et al. (2020), which stated that the G1 variety had a yield of 0.92%, while the yield of Strona 2 Agribun was 1.8%. Citronella can grow in fertile soil, requiring a sufficient amount of light with an appropriate intensity of 75-100% (Rizal 2011; Rosman 2012).

Shade-tolerant varieties can increase capture efficiency and use of sunlight so that they can grow and produce better in shade conditions than sensitive varieties (Wang et al. 2015; Hafni et al. 2019). Chairudin et al. (2015) explained that under shaded conditions, tolerant genotypes would increase leaf area to expand the surface area for light absorption and reduce the number of leaves to compensate for the limited amount of light. In addition, tolerant genotypes increase the chlorophyll content to maximize absorption.

ACKNOWLEDGEMENTS

This research is one of the topics of Prof. Nurheni Wijayanto, funded by Ristekdikti, Indonesia. Therefore, we would like to take this opportunity to thank IPB University, Bogor, Indonesia, for allowing us to use the research site in the Cikabayan Forest. We also thank the field assistant, Adnani, who helped collect the necessary tools and materials and kindly helped to provide information.

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