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The prevalence of *Rhizoctonia* sp. and its impacts on growth and yields of upland paddy (*Oryza sativa*) planted under sengon (*Paraserianthes falcataria*) agroforestry

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Abstract. *Firmansyah MA, Hartoyo APP, Wijayanto N, Erfiani, Jayanegara A, Purnama TJ. 2025. The prevalence of* Rhizoctonia *sp. and its impacts on growth and yields of upland paddy (*Oryza sativa*) planted under sengon (*Paraserianthes falcataria*) agroforestry. Biodiversitas 26: 2746-2753.* Agroforestry is a land management system that integrates trees and agricultural crops to optimize land use for generating socio-economic and ecosystem functions. Sengon (*Paraserianthes falcataria*), a fast-growing species, can be effectively combined with upland paddy (*Oryza sativa*) under agroforestry system to enhance land productivity and environmental sustainability, but this system is not free from pests and diseases. This study aimed to analyze the prevalence of disease caused by *Rhizoctonia* sp. on upland paddy and its impacts on the paddy growth and yields as well as the total biomass of sengon in an agroforestry system. The research employed a completely randomized factorial design with repeated measurements, consisting of two factors: Planting system (monoculture and agroforestry) and paddy varieties (Situpatenggang and IR64); each treatment with three replications. The findings indicated that paddy growth was broadly similar across all treatments, though the disease attack and intensity levels were pervasive and nearly uniform. The agroforestry system, particularly with a planting distance of 2 × 2 meters, increased 23.2% paddy grain weight, although it did not prevent the spread of the inoculated disease. The total sengon biomass was 16.95 Mg/ha, with a total carbon stock of 7.80 MgC/ha, highlighting the potential of agroforestry systems for carbon sequestration. These results suggest that agroforestry systems offer significant benefits for paddy yield and carbon stock; yet they require careful management of disease risks to optimize outcomes. Therefore, integrating sengon and paddy in agroforestry systems positively impacts paddy yields and contributes to environmental sustainability. These findings underscore the importance of agroforestry systems in balancing agricultural productivity with ecological sustainability despite the challenges posed by disease and shading.

Keywords: Carbon stock, food production, food security, land management, plantation disease

INTRODUCTION

Agroforestry, a land management system that integrates forestry and agricultural practices, has the potential to enhance land productivity and economic profitability while maintaining environmental sustainability. This approach is desirable for optimizing land use, promoting biodiversity, and supporting rural livelihoods (Bettles et al. 2021). Agroforestry systems offer multiple benefits, including food production for improving household income and ensuring food security. Moreover, these systems provide critical ecosystem services such as improving soil fertility, mitigating erosion, and enhancing resilience to climate change (Torralba et al. 2016). Thus, agroforestry addresses ecological concerns and supports socio-economic well-being. By enhancing biodiversity, agroforestry systems can create more resilient agricultural environments. For example, incorporating nitrogen-fixing trees can improve soil fertility, reduce reliance on synthetic fertilizers, and enhance the sustainability of land use (Sari and Prayudyaningsih 2019). Furthermore, agroforestry systems can improve the long-term availability of food resources by fostering a more sustainable agricultural environment (Sher et al. 2018). Agroforestry has thus emerged as a viable strategy for poverty alleviation, increasing crop yields, diversifying income streams, and reducing reliance on external agricultural inputs (Bettles et al. 2021).

One of the critical aspects of agroforestry is the selection of tree species that can complement crops. The species-specific traits of the trees, such as their growth rate, canopy structure, and root system, play a significant role in determining the effectiveness of the agroforestry system (Sher et al. 2018). *Paraserianthes falcataria* (L.) I.C.Nielsen, locally known as sengon in Indonesia, a fast-growing leguminous tree, has been identified as an ideal species for agroforestry systems due to its light crown and nitrogen-fixing ability (Nuroniah et al. 2021). Sengon's capacity to form root nodules through symbiosis with

Rhizobium bacteria helps maintain soil nutrient availability, particularly nitrogen, which is vital for the productivity of crops (Sari and Prayudyaningsih 2019). Its adaptability to well-drained soils makes it suitable for integrating various crops, including upland paddy (*Oryza sativa* L.). A study by Azizah (2019) found that upland paddy cultivated under 6-month-old sengon achieved productive yields of 1.40 tons/ha for local Kendal sengon variety, 1.26 tons/ha for Solomon F1, and 0.97 tons/ha for Solomon F2. In contrast, research conducted by Tasinya et al. (2022) indicated that the productivity of upland paddy under 2-year-old sengon was considerably lower, with yields of only 0.013 tons/ha for local Kendal, 0.008 tons/ha for Solomon F1, and 0.006 tons/ha for Solomon F2 stands.

Upland paddy, a variety of paddy that thrives on dry land, can boost food security, particularly in Indonesia, where paddy is a staple food (Das et al. 2022). Integrating upland paddy with sengon in agroforestry systems not only enhances the productivity of the land but also contributes to meeting the growing demand for paddy in the country. However, paddy cultivation faces significant challenges in lowland or upland systems, including vulnerability to diseases such as sheath blight caused by the fungus *Rhizoctonia* sp. (Tsaniya et al. 2022). Sheath blight can reduce paddy yields by affecting the plant's root, leaves, shoots, seedling vigor index, and germination by up to 26.71% in under-field conditions, compromising productivity (Firmansyah et al. 2018; Tooray et al. 2019).

While offering potential benefits, integrating sengon and upland paddy in agroforestry systems poses certain risks. The proximity of different species in the same system can increase the likelihood of disease transmission. *Rhizoctonia* sp., a fungus that can infect both sengon and paddy, may spread more easily in such systems due to shared hosts. This pathogen typically attacks the tips of plant leaves, reducing photosynthetic capacity and leading to decreased crop yields (Firmansyah et al. 2018). The wounds caused by the disease can also exacerbate infection rates, further threatening plant health and productivity.

Given the potential for increased disease transmission in agroforestry systems, careful management is required to optimize crop yield and environmental benefits. This study, therefore, aimed to evaluate the incidence of disease caused by *Rhizoctonia* sp. in an agroforestry system that combines sengon and upland paddy. The research will also assess the yields of upland paddy and the total biomass of sengon to determine this system's overall productivity and sustainability. By exploring these factors, the study seeks to provide insights into how agroforestry can be effectively managed to enhance food security, promote environmental sustainability, and mitigate disease risks.

MATERIALS AND METHODS

Study area and period

The research was carried out on two different lands, namely agroforestry land (sengon and upland paddy) and upland paddy monoculture land in Ciapus, Bogor, West Java, Indonesia (6°35'45.6"S 106°44'53.8"E) from April-August 2017. The study area is situated at an altitude of 700 m asl, with a flat slope of 0%. The soil is categorized as Andosol. The average air temperature, relative humidity, and rainfall during the study period were between 21-29°C, 80-95%, and 271.65 mm per month.

Research design

This study was designed with a Completely Randomized Factorial (CRF). The treatment consisted of two factors; each factor had three replications. The first factor was planting system, which consisted of agroforestry of sengon and paddy, and paddy monoculture. The second factor was paddy varieties, namely IR 64 and Situpatenggang. This experiment had four combinations with three repetitions, resulted in 12 experimental units. The plot area used was 11 × 21 meters.

Land preparation and planting

Land preparation was conducted a week before planting. This activity aims to clear and prepare the forest floor for paddy planting. The next activity was the establishment of paddy plots. Then, cow manure at 1000 kg/ha was added to increase soil fertility. Paddy was planted by digging a hole 3-4 cm deep and placing it between two-year-old sengon trees, which were planted at a distance of 2 × 2 m (Figure 1). For paddy monoculture, the planting distance was 1 × 1 m.

Fungi sample preparation and pathogenicity test

Isolate of *Rhizoctonia* sp. was obtained from isolate collection of Pathology Laboratory, Department of Silviculture, Faculty of Forestry, IPB University. The seedlings of sengon were observed to be in healthy condition. Fungal isolation was conducted by selecting symptomatic tissues from diseased sengon plants, followed by surface sterilization using 90% ethanol. The sterilized leaf segments were transferred onto Petri dishes containing Potato Dextrose Agar (PDA) and Potato Dextrose Broth (PDB) media. Samples were incubated at ambient room temperature for approximately seven days to promote the development of homogeneous fungal cultures. Throughout the incubation period, environmental parameters, including temperature and relative humidity, were monitored daily at three-time intervals: morning (07:00-08:00), midday (12:00-13:00), and evening (16:00-17:00) using a standard thermometer and hygrothermometer. The morphological and molecular technique has identified isolated species in Firmansyah et al. (2018).

Rhizoctonia sp. was inoculated into paddy based on the method of Firmansyah et al. (2018). Observation of disease attacks was conducted every three days. A pathogenicity test was conducted on the fungus generating dieback disease symptoms. Pathogenicity test parameters were disease incidence and dieback fungus attack intensity to the sengon seedlings and paddy. The disease severity scale and the numeric value of the disease, followed by Chiang et al. (2017), can be seen in Table 1.

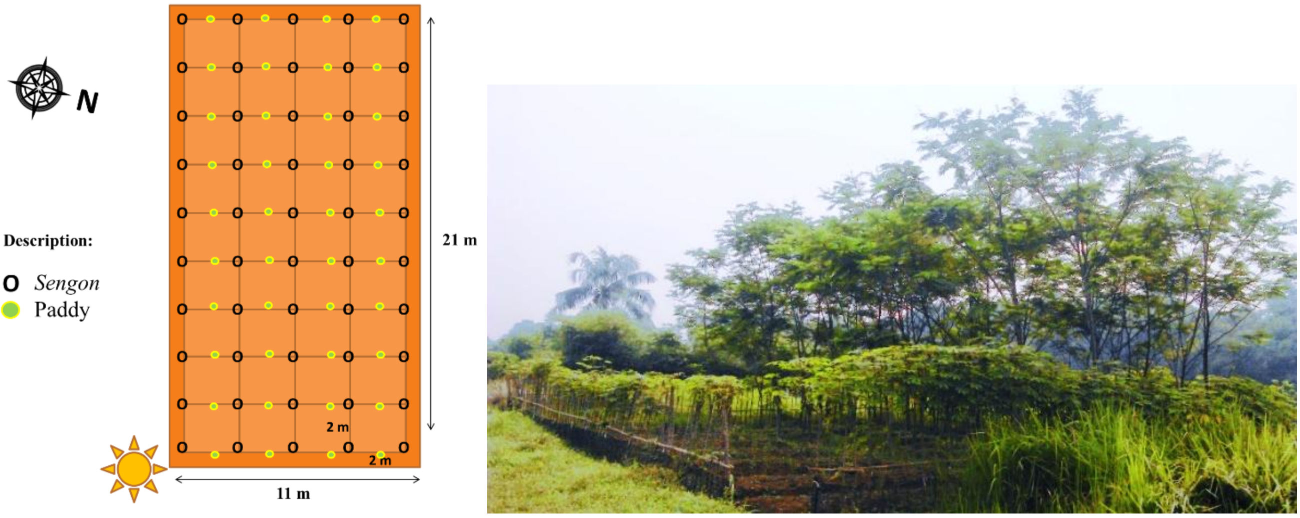

Figure 1. The planting design of agroforestry of sengon and paddy

Table 1. Disease severity and the numeric value of the disease

Score	Note
0	No symptom on leaves
1	Wilted leaves, or 25% of leaves, have necrosis
2	26-50% of leaves have necrosis
3	> 50% of leaves have necrosis
4	Plant dead

The incidence of disease was determined as in Equation (1) (Chiang et al. 2017; Bock et al. 2021):

$$\text{Disease Incidence (\%)} = \frac{\text{number of infected plant}}{\text{number of plant sample observed}} \times 100\% \quad (1)$$

Disease intensity was calculated by the following Equation (2) (Chiang et al. 2017):

$$DS = \frac{\Sigma\,(n.v)}{NZ} \times 100\% \quad (2)$$

Where:
DS : Disease Severity (%)
n : Number of leaves in every category
v : Numeric number of every attack category
N : Number of observed plants
Z : Numeric number of the highest attack category

Carbon stock measurement

Sengon productivity was measured as carbon stored in aboveground biomass. Biomass observation was started from paddy harvesting at three 3 months old and was only focused on the sengon trees. The allometric equation used diameter parameter (Wirabuana et al. 2020) to estimate tree biomass using Equation (3) following Hairiah et al. (2011):

B = 0.0272*D2.831 (3)

Where:
B : Tree biomass (kg/tree)
D : Tree Diameter at Breast Height (DBH) or 1.3 m (cm)

Tree biomass was converted into carbon stock value (kg/plot) and then multiplied by 0.46 (Hairiah et al. 2011).

Harvest parameters

Harvesting activities were conducted when the paddy began to mature physiologically. We observed the number of leaves, plant height, wet and dry plant weight, number of tillers per clump, and panicle length of the paddy (Sopacua et al. 2021). We also observed the dimension of sengon growth, namely Diameter at Breast Height (DBH) and the length and width of canopy dimensions (Hasan et al. 2020; Sopacua et al. 2021).

Data analysis

Data analysis used ANOVA at the 5% level to determine the differences between each treatment. Duncan's further test at a 5% level was carried out to see if there was a significant effect on the variables observed. Data were processed using the SAS 9.2 program.

RESULTS AND DISCUSSION

Paddy's growth and yield parameters

The data result showed that the performance of two upland paddy varieties, Situpatenggang and IR 64, under monoculture and agroforestry systems was assessed based on various agronomic and physiological parameters (Table 2). Both varieties exhibited a 100% germination rate under all conditions, indicating uniform seed viability across treatments. However, there were differences in plant survival rates, with monoculture Situpatenggang showing the lowest life percentage (61.20%), while all other treatments, including agroforestry systems, maintained a higher survival rate (83.40%) (Table 2). Despite a uniform disease incidence rate of 100% across all plots, notable differences were observed in plant growth and development. Paddy height was markedly reduced under agroforestry conditions, with Situpatenggang and IR 64 attaining heights of

63.16±3.81 cm and 62.83±1.04 cm, respectively, compared to 80.16±2.92 cm and 78±2.78 cm under monoculture. Panicle length followed a similar trend, where agroforestry cultivation led to significantly shorter panicles in both Situpatenggang (11.74±1.14 cm) and IR 64 (12.15±1.23 cm) than in monoculture (15.28±0.65 cm and 14.67±0.70 cm, respectively). Leaf greenness, an indicator of chlorophyll content and overall plant health, varied among treatments. Interestingly, IR 64 under agroforestry exhibited the highest greenish leaf index (29.06±4.1), suggesting possible shade adaptation, whereas Situpatenggang under monoculture had lower greenness (19.53±6.29). Wet and dry plant weight was generally higher under monoculture conditions for Situpatenggang (158.94 g and 65.23 g, respectively) and IR 64 (151.90 g and 73.16 g), though IR 64 under agroforestry recorded the highest wet biomass (180.84 g), indicating potential biomass plasticity under shaded environments.

Plant tissue and grain moisture content was substantially lower in agroforestry systems. Plant moisture content in agroforestry Situpatenggang and IR 64 dropped to 20.54% and 20.24%, respectively, compared to higher levels in monoculture (46.02% for Situpatenggang and 42.94% for IR 64). Similarly, grain moisture content was reduced under agroforestry (27% in Situpatenggang and 21% in IR 64) compared to monoculture conditions (25% and 20%, respectively). This may reflect microclimatic differences influenced by canopy coverage. Grain yield indicators, including the weight of 100 wet and dry grains, were higher in agroforestry systems for both varieties. Situpatenggang recorded the highest 100 wet grain weight (0.71 g) and dry grain weight (0.52 g) under agroforestry, while IR 64 performed similarly (0.67 g wet and 0.53 g dry). These findings imply a potential compensatory mechanism in grain filling despite reduced vegetative growth. Light intensity differed markedly between systems, with monoculture plots receiving significantly higher irradiance (32,632 lux) than agroforestry (13,748.75 lux), confirming the expected reduction in light availability due to tree canopy presence. This reduction likely influenced several morphological and physiological traits observed in agroforestry-grown upland paddy.

Duncan's multiple tests showed no significant differences between the weight parameters of paddy grains, leaf greenness, disease attack intensity, panicle length, plant height for IR 64, and Situpatenggang varieties planted under sengon stands with agroforestry pattern and planted monoculturally (Table 2). The significantly different parameter was the number of leaves where it was higher in the open area (planted monoculturally) than in the second shaded (Figure 2). Only this parameter is covered by the intensity of attacks that attack paddy leaves (Figure 2 and Table 2).

Table 2. Growth and yield parameters of paddy under monoculture and sengon agroforestry systems

Parameters	Monoculture		Agroforestry	
	Situpatenggang	IR 64	Situpatenggang	IR 64
Percent of growing seeds (%)	100a	100a	100a	100a
Percent life (%)	61.20a	83.40a	83.40a	83.40a
Disease incidence (%)	100a	100a	100a	100a
Plant height (cm)	80.16 + 2.92a	78 + 2.78a	63.16 + 3.81a	62.83 + 1.04a
Panicle length (cm)	15.28 + 0.65a	14.67 + 0.70a	11.74 + 1.14a	12.15 + 1.23a
Greenish leaves	19.53 + 6.29a	19.60 + 6.00a	16.63 + 2.63a	29.06 + 4.1a
Wet plant weight (g)	158.94a	151.90a	120.58a	180.84a
Plant dry weight (g)	65.23a	73.16a	24.77a	36.62a
Plant moisture content (%)	46.02a	42.94a	20.54a	20.24a
The weight of 100 wet grains (g)	0.61b	0.50a	0.71b	0.67b
100 dry grain weights (g)	0.46a	0.40a	0.52b	0.53b
Grain moisture content (%)	25a	20a	27a	21a
Light intensity (lux)	32632.00a		13748.75a	

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

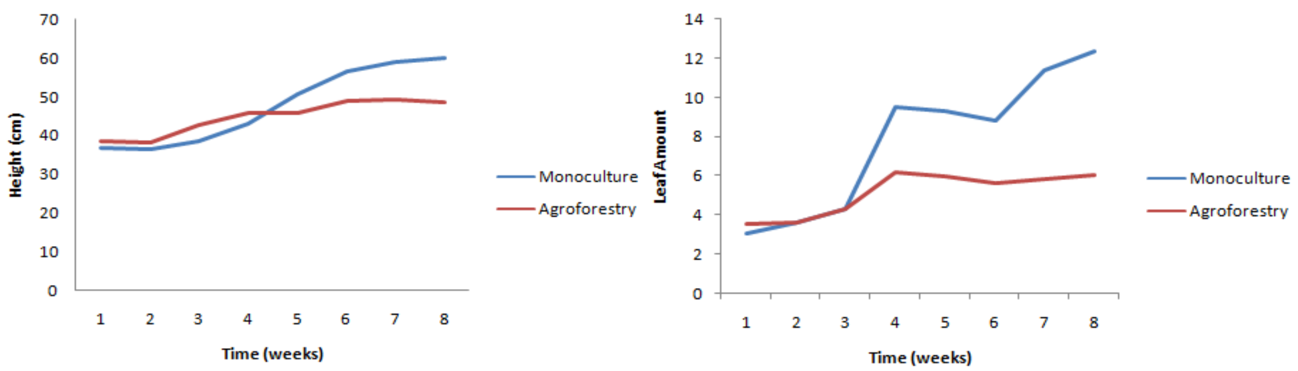

Figure 2. Paddy plant growth curve under sengon agroforestry and monoculture systems

Soil parameters

Table 3 shows the impacts of land management and interaction between sengon and paddy under the agroforestry system on soil properties. Paddy planting positively impacted sengon stands due to the maintenance activities, one of which was fertilization. The results indicated that soil chemical properties exhibited noticeable variation between monoculture and agroforestry systems, reflecting the influence of land-use management on soil fertility and nutrient dynamics. The soil pH values measured in both distilled water (H_2O) and potassium chloride (KCl) were slightly higher under agroforestry (5.20 and 4.53) compared to monoculture (4.90 and 4.29), indicating a modest reduction in soil acidity under the tree-based system. Soil organic carbon content, measured using the Walkley and Black method, was also higher in agroforestry soils (1.74%) than in monoculture (1.62%). The increased C-organic content in agroforestry systems likely results from continuous litter input from trees and improved organic matter decomposition, which enhances soil structure and nutrient-holding capacity (Purnama et al. 2022). Aluminum saturation (Al-dd), a critical factor influencing soil toxicity in acidic soils, was significantly lower in agroforestry (0.26 cmol(+)/kg) compared to monoculture (0.78 cmol(+)/kg). Correspondingly, H-dd (hydrogen exchangeable acidity) also decreased under agroforestry (0.33 cmol(+)/kg) versus monoculture (0.40 cmol(+)/kg), further supporting the ameliorative effect of agroforestry systems on soil acidity parameters. Available phosphorus (P_2O_5), assessed using the Bray 2 extraction method and UV-VIS Spectrophotometry, was higher in agroforestry soils (14.32 ppm) relative to monoculture (11.28 ppm). Total potassium (K_2O), extracted using 25% HCl, also elevated in agroforestry (112.42 mg/100g) compared to monoculture (96.25 mg/100g), indicating improved nutrient retention and cation exchange capacity in soils under tree-crop integration (Table 3).

Sengon growth parameters

Figure 3 shows the average projection of the length and width of the sengon canopy for 2 years of age in the field. The canopy of the sengon tree overlapped due to the planting distance among the sengon trees being only 2 × 2 m. Carbon stock measurement was observed in sengon trees (2 years old). The number of these trees was 1774,89 trees/ha. Figure 4 resulted in total biomass was 16.96 Mg/ha, while the total carbon stock was 7.80 Mg/ha.

Discussion

This research resulted in the paddy growth being almost similar for all treatments. The paddy growth in the shaded area under sengon agroforestry was slightly more depressed than in the open area under monoculture planting as indicated with the number of leaves, which was higher when planted monoculturally (Figure 2). According to Tsaniya et al. (2022), the intensity of the light at the ground surface will decrease with the upland paddy canopy growth. Upland paddy varieties influenced the changes in the percentage of canopy cover, light intensity, and growing space between rows (Rianto et al. 2019; Ermanto et al. 2021; Wijayanto and Briliawan 2022). The ability of plants to receive radiation depends on the shape of the canopy, the leaf, and its chlorophyll content (Ermanto et al. 2021).

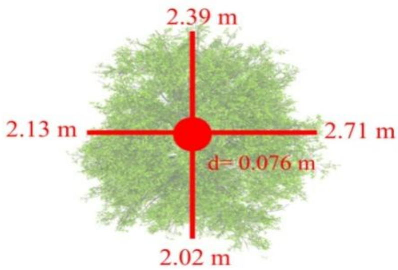

Figure 3. Average projection of canopy and stem diameter of sengon trees aged 2 years

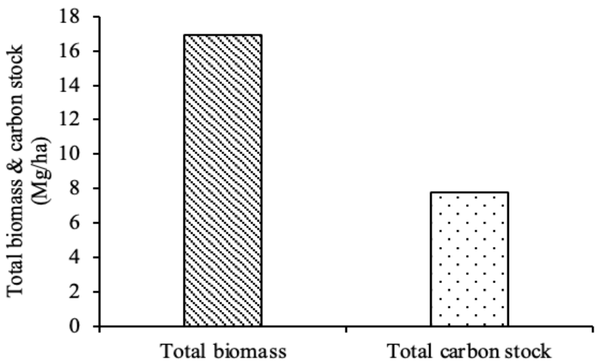

Figure 4. Total biomass and carbon stock of sengon in agroforestry system

Table 3. Soil analysis on monoculture and sengon agroforestry systems

Land type	pH		C-Organic (%)	Al-dd (cmol(+)/kg)	H-dd (cmol(+)/kg)	P available (P_2O_5 ppm)	K total (mg K_2O/100g)
	H_2O	KCl	Walkley and Black	Extract: KCl 1M		Extract: Bray 2	Extract: HCl 25%
				Measurement: titrimetric		Measurement: spectrophotometer UV-VIS	
Monoculture	4.90a	4.29a	1.62a	0.26a	0.33a	11.28a	96.25a
Agroforestry	5.20a	4.53a	1.74a	0.78a	0.40a	14.32a	112.42a

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

The reduced plant moisture content observed in agroforestry systems was primarily due to the altered microclimatic conditions created by tree canopy cover. Light intensity was significantly lower in such systems than in open monoculture fields (Table 2). However, the parameters of the harvested paddy (rice grain yields) in agroforestry were not significantly different from those in monoculture. This condition indicates that the paddy will still grow well even cultivated under agroforestry. Photosynthesis is essential for maintaining the growth and development of plants. Water is one of the factors in the process of photosynthesis. Photosynthesis is the fundamental process in plant chloroplasts, allowing plants to convert solar energy into chemical energy, which fuels their growth and development (Sela et al. 2020). The lack of water availability causes the photosynthetic rate to decrease, resulting in reduced chlorophyll synthesis. Lack of water also causes an increase in temperature and transpiration, causing the disintegration of chlorophyll (Purbajanti et al. 2017; Rahmawati et al. 2021). Chlorophyll content can be a reliable indicator for evaluating the metabolic imbalance between photosynthesis and yields in water shortage (Purbajanti et al. 2017). In addition to water availability, nutrients in the soil support paddy growth. Nitrogen, phosphorus, and potassium fertilizers have responded to some upland paddy (Kaizzi et al. 2018). Phosphorus is an essential element in grain formation, an element that is needed in large quantities in filling grain so that the grain becomes pithy. The availability of sufficient nutrients can affect the weight gain process and improve the quality of the result (Tsaniya et al. 2022).

The 100% disease incidence in all treatments, including non-inoculated controls, showed a massive and rapid transmission rate. The level of disease intensity that occurred in the field was also almost similar for all treatments. It affected the increase in the amount of empty grain produced. Most paddy grains were empty and only had the grain skin (Table 2). The environment profoundly influences plant diseases; a virulent pathogen will not infect a susceptible host if the environmental conditions are not conducive to disease (Velásquez et al. 2018). In addition, environmental conditions in the field support the development of *Rhizoctonia* sp. Temperature, humidity, and light intensity are some environmental parameters affecting fungus attacks. The average temperature on this site is 28-29°C with a relative humidity >80%. This temperature and relative humidity belonged to the optimum temperature and relative humidity for the life cycle of *Rhizoctonia* sp. The optimum temperature for the life cycle of *Rhizoctonia* sp. is 27-30°C with a relative humidity >80%. In suitable environmental conditions, *Rhizoctonia* sp. can attack within 3-7 days (Singh et al. 2020b). Biotic stresses due to *Rhizoctonia* sp. affected the empty paddy grains. The disease may appear at any stage of the growth and development of the plant, attacking the seed sown, root system, foliage, stalk, leaf sheath, inflorescence, and even the developing grain (Singh et al. 2020a).

The findings from this research indicated that *Rhizoctonia* sp. fungal attacks affected both Situpatenggang and IR64 paddy varieties with similar intensity, demonstrating that varietal differences did not significantly impact the severity of the fungal infections. This suggests that both varieties are highly susceptible to *Rhizoctonia* sp., making them prone to recurrent infections. Weekly observations revealed a continuous threat from the fungus, emphasizing the necessity of monitoring and implementing effective disease management practices throughout the growing season. Interestingly, despite the similar levels of fungal attack, Situpatenggang displayed higher resistance to *Rhizoctonia* sp. compared to IR64, confirming earlier observations made by Suprihatno et al. (2011). Situpatenggang's increased resistance could be attributed to inherent genetic traits that enable better defense mechanisms against fungal infections. This makes Situpatenggang a more viable choice for regions where fungal diseases are prevalent, particularly in dryland areas where it has proven to thrive.

On the other hand, IR64, while more vulnerable to *Rhizoctonia* sp., is more suited to wetland environments, suggesting that it may perform better under specific ecological conditions that favor water retention. The study also highlights that both varieties could grow and produce under a 2-year-old sengon stands in dryland conditions. Remarkably, the wet and dry weights of 100 seeds from both varieties grown under sengon were higher than those cultivated in open fields. The wet and dry weight of 100 seeds was higher than in the open area (Table 2).

The results of the soil properties analysis showed that the soil under the sengon stands had a higher pH, C-Organic, P available, and K Total than those in the open area (Table 3). According to Wijayanto and Tsaniya (2022), upland paddy cultivated under sengon could increase the soil's pH, C-organic, and N-total content. Agroforestry systems also produce more and different litter, resulting in more organic matter (Purnama et al. 2022; Wijayanto and Tsaniya 2022). Fertile soil increased the weight of paddy in the shaded area of agroforestry even though there were other abiotic stresses in the form of denser shading among the sengon trees (Figure 3). Paddy grown under sengon agroforestry 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).

The infection of *Rhizoctonia* sp. on paddy crops occurs when the fungus makes direct contact with the host plant. In this study, the statistical analysis indicated that both paddy varieties evaluated lacked resistance to *Rhizoctonia* sp., showing susceptibility to infection across all treatments. This aligns with previous findings where pathogen attacks on paddy plants outpaced the natural lignification process, which is crucial for enhancing plant resistance (Lee et al. 2019). Lignification is the process by which lignin is deposited in cell walls, strengthening them and making the host more resistant to pathogen invasion. However, in this case, the rate of *Rhizoctonia* sp. infection surpassed the plants' ability to form lignin, rendering them vulnerable to disease. Lignin is critical in disease resistance through structural and biochemical defense mechanisms. Its deposition in the cell walls acts as a physical barrier, limiting pathogen spread, while biochemically, lignin-associated compounds can have antimicrobial effects (Lee et al. 2019). The inability of the paddy varieties to lignify rapidly enough suggests that genetic factors may influence their susceptibility to *Rhizoctonia* sp. Future breeding programs might focus on enhancing the rate or effectiveness of lignification to improve disease resistance in paddy.

In addition to disease resistance, the agroforestry system's impact on sengon's growth was also assessed. Interestingly, adding fertilizer as a nutrient supply has contributed to the enhanced development of sengon, though this effect may have been indirect. It is hypothesized that the nutrients provided for the paddy also benefited the sengon, either through root interaction or other soil processes. Furthermore, regular weeding and other maintenance activities on the agroforestry land likely improved soil conditions, further promoting sengon growth.

This study observed that sengon diameter growth was approximately 1.8 cm over four months. This growth rate is notably higher than that reported by Sopacua et al. (2021), who recorded an average diameter growth of 1.54 cm over the same period for sengon aged 1.5 years. This difference in growth rates may be attributed to variations in environmental conditions, nutrient availability, or agroforestry management practices. This study's combination of nutrient supply and improved land management practices, such as weeding, likely contributed to the observed growth rates. These findings suggest that agroforestry systems, when adequately managed, can enhance the growth and productivity of tree species like sengon.

Agroforestry systems are essential for increasing carbon stock and carbon sequestration. This research resulted in the total biomass being 16.95 Mg/ha, while the total carbon stock was 7.80 MgC/ha (Figure 4). This value was lower than Prayogo and Arfarita (2022) reported, with a total carbon of 19.03 MgC/ha in agroforestry sengon aged three years. These results were lower than those of the other agroforestry systems due to the fact that the sengon was still two years old. C-organic soil in agroforestry was higher than in different types of agricultural cover; the litter from forest plants was added to the land and increased C-organic soil (Budiadi and Ishii 2010; Crespo et al. 2022; Purnama et al. 2022). The storage of carbon depends on the development of its root system since it is a system that is constantly renewed and provides large amounts of organic matter (Pessôa et al. 2022). However, it is possible to have high carbon stock when sengon grows up because this species is classified as fast-growing species

In conclusion, the results of this study indicated that the attack of *Rhizoctonia* sp. on paddy could not be avoided for both agroforestry and monoculture systems. Nonetheless, the dry weight and wet weight of paddy grains were higher in the sengon agroforestry system than in monoculture planting. The combination of upland paddy and sengon in the agroforestry system provides an additional benefit in P and K available, total biomass, and carbon stock. Future research should focus on optimizing the spatial arrangement and density of sengon trees to balance light availability and disease suppression while maintaining high crop yield. Additionally, long-term studies on soil microbial dynamics and carbon sequestration potential in agroforestry systems are recommended to validate their ecological and agronomic advantages further.

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