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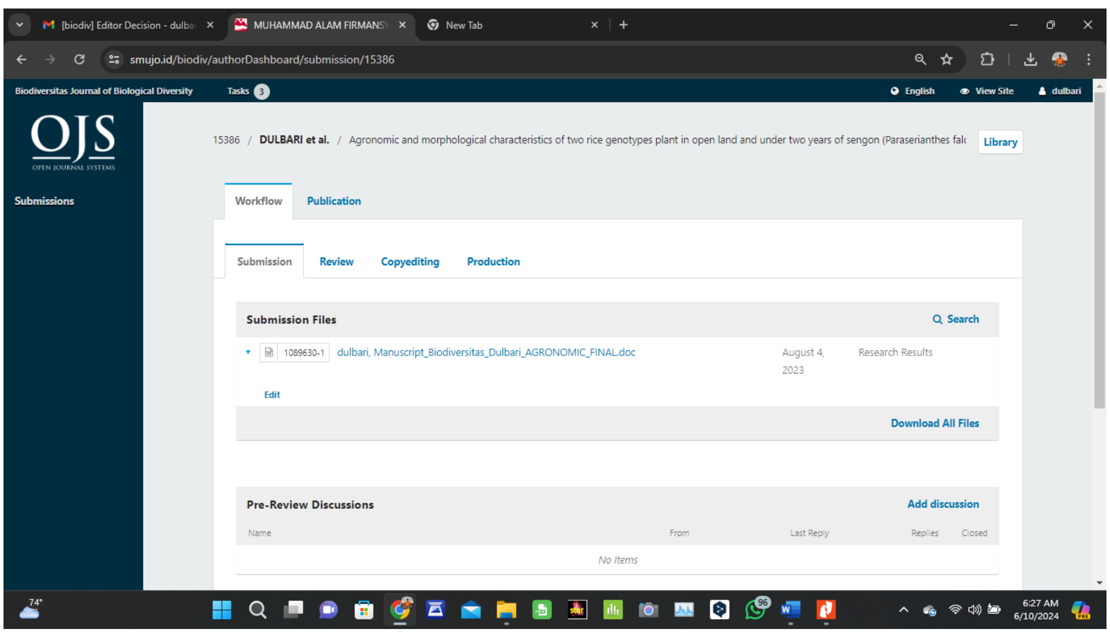

Agronomic and Morphological Characteristics of Two Rice Genotypes Plant in Open Land and Under Two Years of Sengon (*Paraserianthes falcataria* (L))

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Abstract. The increase in population is the biggest challenge for the agricultural sector in providing food needs. In Indonesia, the main problem in increasing food production is the limited agricultural land. To address this issue and enhance production capacity, specifically for rice at the national level, there is a need to explore alternative land options. One of the potential solutions is to use land currently occupied by plantation crops and forests that can be managed through agroforestry. Sengon is a forestry plant that offers a comparative advantage for investigation when combined in agroforestry systems due to its relatively open canopy cover and classification as a legume. Therefore, this research aimed to determine the response of the morphological and agronomic characters of two genotypes of rice planted in open land conditions and under 2-year-old sengon stands. The experiment was conducted from October 2017 to March 2018 in the Sengon community forest of Cikarawang, Bogor, with coordinates 06° 33.061' S and 106° 43.987' E. The results showed that two rice genotypes grown under one-year-old sengon stands experienced a decrease in the number of productive tillers, plant height, stem strength, and the number as well as the weight of grains per panicle. The IR 64 genotype decreased by 40.65% in grain weight per panicle, while the Situ Patenggang genotype experienced a 56.21% decrease

Key words: Adaptation, agroforestry, constraint, sengon, shade

Abbreviations: RBD- randomized block design; G1-Genotype 1= IR46; G2-Genotype 2=Situ Patenggang; MST-weeks after planting; O-open land cultivation; A-Agroforestry system cultivation under 2-year-old sengon plants with a spacing of 2.5 m x 2.5 m.

Running title: Agronomic and Morphological Characteristics of Two Rice Genotypes

INTRODUCTION

The population of Indonesia in 2021 is more than 270 million, with a growth rate of 1.22 per year (BPS, 2022). This growing population poses a challenge in ensuring adequate food sufficiency, which is a crucial factor in achieving the welfare of the people. The adequacy of food, specifically rice, is a significant indicator of economic and political stability. Despite this significance, efforts to maintain food availability and stability still face various obstacles, including reduced productive agricultural land due to conversion for non-agricultural purposes. The conversion of land for the construction of housing, factories, and industrial facilities has a significant impact on the availability of agricultural land. Therefore, to maintain production stability and food security, alternative solutions are needed to increase the area of agricultural land.

One of the solutions that can be implemented is planting food crops, specifically rice, using the plantation and forestry concept. This practice, also known as agroforestry, involves the use of forests for agricultural activities. According to Alrasjid (1980), agroforestry is a land-use system where forest stands and crops are planted on the same land. Weichang and Pikun (2000) stated that agroforestry is the main driving technique in the implementation of social forestry, with broad connotation. Furthermore, the objectives of agroforestry or intercropping in forest areas (Perum Perhutani, 1990 in Adiputranto, 1995), include (1) increasing food supply, (2) expanding employment opportunities, (3) increasing the income and welfare of the community around the forest, and (4) increasing the success of forest plantations.

Perhutani (2002) defines agroforestry as optimal and sustainable land use, by combining forestry and agricultural activities on the same land management unit, considering the physical, social, economic, and cultural conditions of the participating communities. The main purpose of agroforestry and the intercropping system is to improve the welfare of village communities around the forest. This is carried out to provide opportunities for communities or ‘pesanggem’ farmers to grow food crops and increase their income. Through this approach, villagers around the forest are expected to play an active role in efforts to conserve and protect the forest and land from damage.

There is a need to research the adaptation of rice plants to low light stress conditions under plant stands. One suitable forestry vegetation for agroforestry with a light canopy is Sengon (*Paraserianthes falcataria* (L).), which is a native to Indonesia and thrives on well-drained, non-flooded land (Santoso 1992). Sengon is frequently incorporated into agroforestry systems due to its moderately dense canopy cover and leguminous characteristics. The roots of the Sengon (*Leguminoceae*) can form symbiotic relationships with Rhizobium, resulting in root nodules that can bind free Nitrogen from the air. This phenomenon contributes to the significant role of the plant in maintaining the availability of nutrients, specifically N in the soil (Fisher and Binkley, 2000).

Increasing the area of intercropping crops (agroforestry) and providing forest areas for food development is continuously carried out as an effort in the forestry sector to support food security (Mayrowani and Ashari, 2011). Furthermore, Sengon trees can also be combined with rice (*Oryza sativa* L.) on the same land, providing an alternative solution to increase community food security. Rice is a type of agricultural crop that can be developed on dry land. High rice production will increase the supply of rice which incidentally is a basic need for the Indonesian people. However, there are several obstacles in the development of rice varieties under plant stands. This includes the determination of genotypes that can effectively adapt and the appropriate age of Sengon stands for intercropping with rice plants.

This research aimed to determine the response of the morphological and agronomic characters of two genotypes of rice planted in open land conditions and under 2-year-old sengon stands. The results are expected to be used as input for increasing rice production capacity under agroforestry plantations or forestry plantations.

METHODS

Treatment and Research Design

The research was conducted from October 2017 to March 2018, using community forest land in Cikarang Village, Bogor Regency, West Java at coordinates 06° 33.061' North Latitude and 106° 43.987' South Latitude. The land was planted with 2-year-old Sengon, spaced at 2.5 m x 2.5 cm, and an open land area. The analysis was arranged using a randomized block design (RBD) with a single-factor treatment of rice genotypes, consisting of IR64 (G1) and Situ Patenggang (G2). Each treatment was repeated 5 times in 2 cultivation systems, namely open land cultivation (O) and agroforestry system cultivation under 2-year-old sengon plants with a spacing of 2.5 m x 2.5 m (A). The linear model and analysis of variance followed the approach by Mattjik and Sumertajaya (2013):

$$Y_{ij} = \mu + \tau_i + \beta_j + \acute{\varepsilon}_{ij}.$$

Notes: Y_{ij} –Observational value in the Ist treatment and jth group, μ-average, τ_i-effect of the ith treatment, β_j-jth group effect, $\acute{\varepsilon}_{ij}$-random effect in the Ith treatment and jth group.

Indicators of environmental conditions for the two planting locations were shown in Table 1.

Table 1. Environmental indicators for planting locations

Indicator	Open	Agroforestry	Information
pH KCl	4.29	4.53	
H_2O	4.90	5.20	
N-Total	0.26	1.62	%
P-Total	131.90	105.34	mg P_2O_5 $100g^{-1}$
K-Total	96.25	112.42	mg K_2O $100g^{-1}$
P-Tersedia	11.28	14.32	P_2O_5 ppm
C-Organik	0.25	1.74	%
KTK	21.43	21.41	Cmol(+) kg^{-1}
Al-dd	0.26	0.78	Cmol(+) kg^{-1}
H-dd	0.33	0.40	Cmol(+) kg^{-1}
Ca-dd	3.04	3.36	Cmol(+) kg^{-1}
Mg-dd	2.82	3.30	Cmol(+) kg^{-1}
K-dd	0.77	1.20	Cmol(+) kg^{-1}
Na-dd	0.15	0.11	Cmol(+) kg^{-1}

Research Implementation

The soil was processed to a depth of 25-30 cm, followed by creating beds with a width of 100 cm and a length of 1000 cm. Seeds were sown directly at a spacing of 25 cm x 25 cm, with 2-3 seeds per planting hole. Basic fertilization was carried out at the time of planting Urea 100 kg ha^{-1}, TSP 200 kg ha^{-1}, and KCl 50 kg ha^{-1}. Subsequently, a follow-up fertilization was conducted 4 weeks after planting, using Urea 100 kg ha^{-1} and KCl 50 kg ha^{-1}. Pest and disease control was also carried out using pesticides according to plant conditions in the field with recommended doses. Weed control was carried out twice at the age of 3 and 6 weeks after planting (MST).

The observation of agronomic and morphological characters encompassed several aspects, namely the number of productive tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter, stem strength, number of grain per panicle, and grain weight per panicle. These observations were carried out in line with the Guidelines for Characterization and Evaluation of Rice Plants (2014).

Leaf color index observations were carried out using SPAD meters. Observation of chlorophyll content was calculated using the equation: y = 0.113x, where y is the total leaf chlorophyll content, 0.113 = constant, and x = level of the greenness of leaves (results of SPAD measurements) (Dulbari: unpublished data).

The observational data were analyzed for diversity using the Barlett test. When the data met the requirements, further analysis of variance was carried out. Subsequently, the differences between treatments were analyzed using the T-test with $\alpha = 0.05$.

RESULTS AND DISCUSSION

Character number of productive tillers and plant height

The results of observing the number of tillers and plant height characters were shown in Figure 1.

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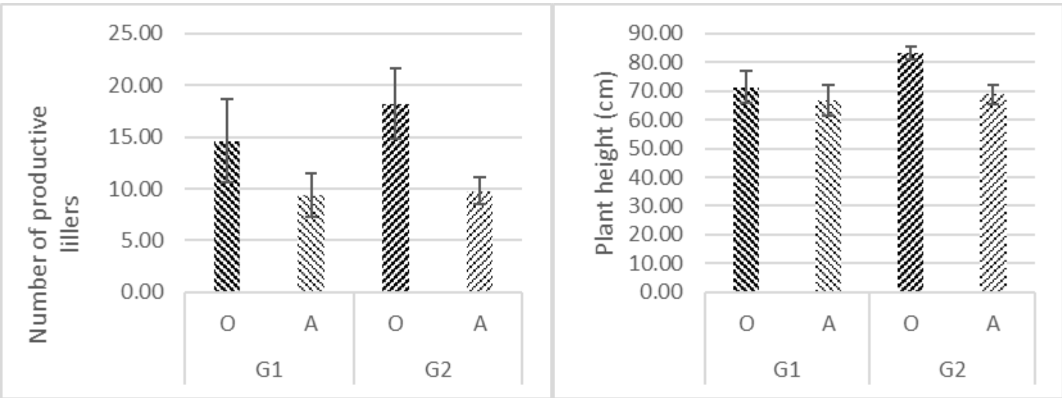

A B

Figure 1. A-number of productive tiller character, b-plant height character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The results also showed that plants no longer have the energy to distribute assimilates to the necessary parts. This distribution used tools such as proteins, and proton pumps driven by ATP (ATP-Ase), necessitating energy and enzymes for the process. Similarly, Pedersen et al. (2007) stated that plants maintained an electrochemical balance within the entire biomembrane to ensure survival.

The closing rate of 2-year-old Sengon stands with a spacing of 2.5 m x 2.5 m prevented light interception by approximately 80%. Therefore, the process of photosynthesis, which served as the main energy source for plants to carry out growth processes, was disrupted.

Leaf Color Index Character and Leaf Chlorophyll Content

The results of leaf color index character observations and leaf chlorophyll content are shown in Figure 2.

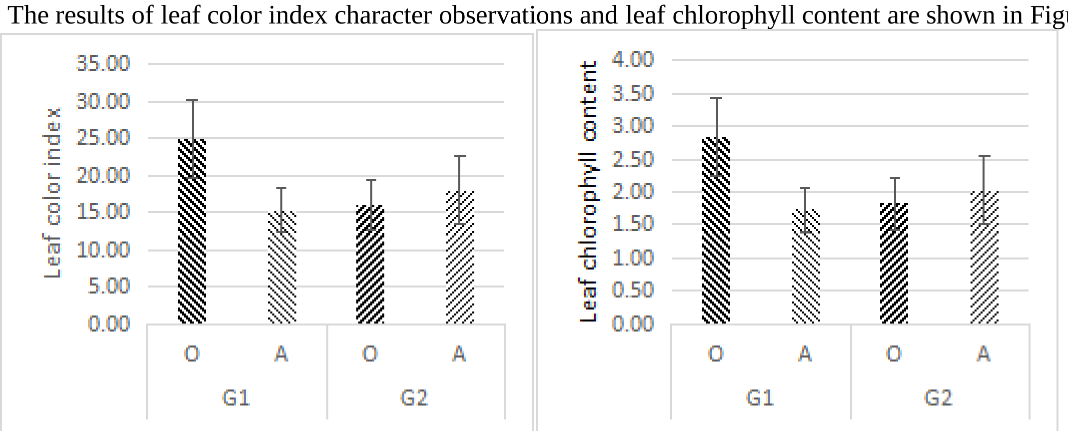

Figure 2. A-leaf color index (SPAD), b-leaf chlorophyll content (KLO), G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The leaf color index characters and leaf chlorophyll content of the two genotypes had different tendencies. For genotype 1 (IR 64), these variables showed a decrease in growing conditions under 2-year-old sengon stands (agroforestry). The leaf color index decreased from 25.02 to 15.34, while the chlorophyll content of the leaves reduced from 2.83 to 1.73. For genotype 2 (Situ Patenggang), the variables showed a tendency to increase in growing conditions under 2-year-old sengon stands (agroforestry), where leaf color index increased from 16.10 to 17.96, and chlorophyll content increased from 1.82 to 2.03. This showed that the genotypic response to leaf color index characters and chlorophyll content was different due to the variation in the adaptability of the IR64 and Situ Patenggang rice genotypes to shade stress.

Each genotype exhibited a different response and ability to adapt to the environment. In this research, the plant growth environment was different, specifically in terms of sunlight intensity. The differences in light intensity were responded to by plants according to their genetic capacity. Furthermore, plants developed acclimatization and plasticity methods to respond to environmental stress through morphological, anatomical, and physiological adjustments (Zhang et al., 2003)

Flag Leaf Size Character

The results of observations of flag leaf size characters were shown in Figure 3.

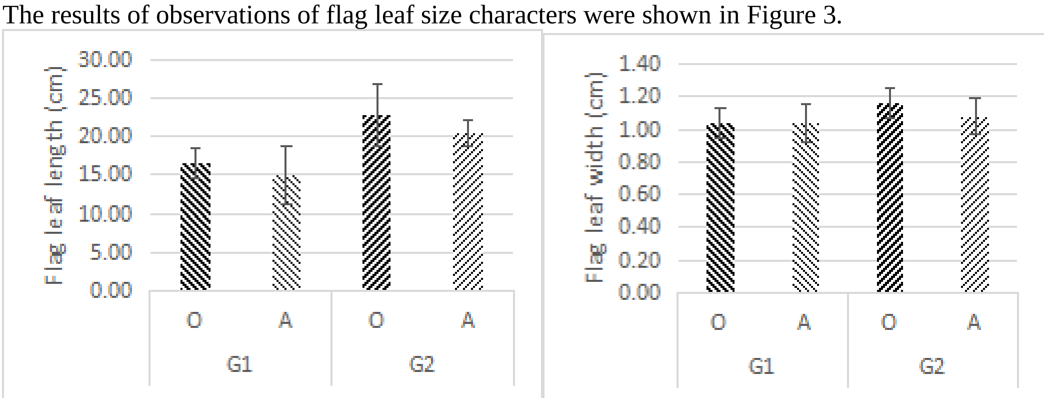

Figure 3. A-flag leaf length character, b-flag leaf width character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The responses to flag leaf size characters (length and width) of the two rice genotypes did not show any significant differences under open location and 2-year-old sengon (agroforestry) planting conditions. However, significant variations were observed between the genotypes, indicating that the genotypes had different adaptation abilities to the stresses. The IR64 genotype showed a relatively stable response to flag leaf length and width, namely 16.58 and 15.04 as well as 1.04 and 1.04. Meanwhile, the Situ Patenggang genotype showed an insignificant decreasing trend for length measurements from 22.76 to 20.54 and width sizes from 1.16 to 1.08.

The morphology of the flag leaf (Sink) of rice plants played an important role in the process of filling the grains of the plant. The large sink character in superior varieties of rice had a higher photosynthetic rate. Furthermore, the upright morphology of the leaves allowed greater penetration and distribution of light to the bottom, causing an increase in plant photosynthesis. According to a previous research, the photosynthesis of plants in upright leaf canopies is about 20% higher than in drooping leaf canopies under high leaf area index conditions (Murchie et al., 2002). The flag leaf as a light-harvesting organ can allocate its assimilate results for panicle formation, thereby influencing the length of the panicle and the number of seeds per panicle. The less ideal flag leaf morphology also affected tiller growth and grain growth (Liu et al., 2014). Furthermore, the size of the flag leaf affected the number of stomata pores, which influenced the ability to exchange H_2O and CO_2 (Kinoshita, 2001)

Diameter and Stem Strength Character

The results of observations of stem diameter and strength characters were shown in Figure 4

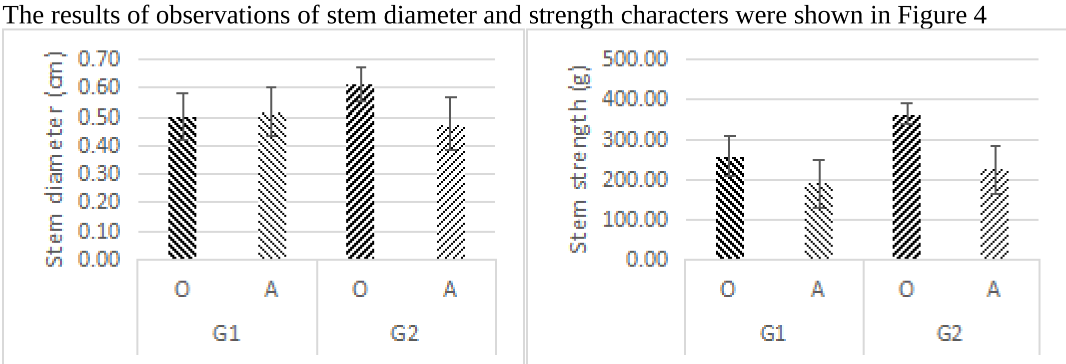

Figure 4. A-stem diameter character, b-stem strength character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The responses of the two rice genotypes, cultivated under open conditions and 1-year-old sengon trees did not show significant differences in the stem diameter character. However, there was a significant variation in the stem strength character. The responses of the stem diameter characters of the two genotypes were different, as IR64 showed a tendency not to experience a change in stem diameter, compared to Situ Patenggang which exhibited a decrease in stem diameter from 0.61 cm to 0.47 cm. Under underexposed conditions and a 2-year-old Sengon tree to stem strength characters, both genotypes experienced a significant decrease. The IR 64 genotype decreased from 260.00 g to 191.00 g, and Situ Patenggang reduced from 364.00 g to 226.00 g.

The character of stem strength was needed for plants to withstand lodging, which can significantly affect crop production due to potential yield losses (Dulbari, 2018). Larger stem diameter plants also exhibit better strength and the character of KBTB is significantly correlated with DBTG, at a correlation coefficient value (0.77) (Dulbari; data has not been published). This indicated that genotypes of rice plants with a larger lower stem diameter (± 10 cm above the soil surface) had a better stem strength, thereby strengthening the research of Zhang et al. (2014) and Li et al. (2011)

Character Number of Grain and Grain Weight Per Panicle

The results of observing the character of the number of grains and the weight of grain per panicle were shown in Figure 5.

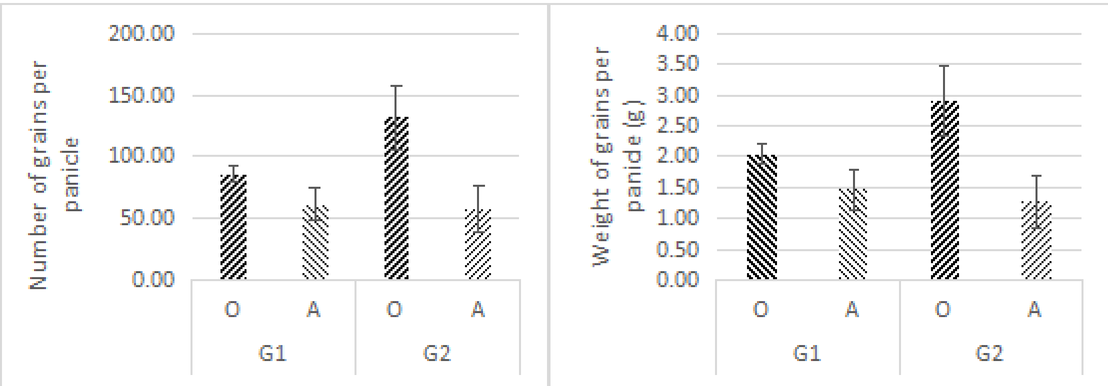

Figure 5. A-the number of grains per panicle character, b-the weight of grains per panicle, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The response of the two rice genotypes cultivated in open land conditions and under 2-year-old Sengon trees experienced a significant decrease in the number of grains per panicle and grain weight per panicle, which were the yield component characteristics. The IR 64 genotype exhibited a smaller reduction in the number of grains per panicle (85.00 to 61.40), compared to the Situ Patenggang (132.00 to 57.60). Similarly, the grain weight per panicle also had the same tendency, with IR 64 genotype ranging from 2.40 to 1.46 (40.65%) and Situ Patenggang from 2.90 g to 1.27 g (56.21%). This showed that genotype had a significant influence on planting plans under agroforestry crop stands..

The characters of grain number and weight were the results of plant metabolism processes, which were closely related to the process of photosynthetic ability (source) and the distribution of the assimilates to the sink. The ability of plants to produce the amount of grain and the weight of grain per panicle was significantly influenced by environmental conditions, such as light, temperature, and humidity. Furthermore, light intensity was closely related to temperature, with lower values resulting in reduced rice products and quality (Dutta et al., 2017).

Light played a significant role in regulating the opening and closing of stomata. Lower light intensity will make stomata tend to close, thereby hindering the entry of CO_2. Limited CO_2 and sunlight also caused a decrease in the rate of photosynthesis, impacting the assimilation of carbohydrates and biomass formation (Liu et al. 2014). Moreover, regulation of stomatal opening is a dynamic and reversible process, where water loss and CO_2 inflow can be rapidly adjusted in response to several environmental and intrinsic signals, such as light, CO_2, and the plant stress hormone abscisic acid (Nilson et al., 2007). The ability of plants to produce and distribute photosynthate to storage organs is an important part of increasing crop production (Fisher et al., 2012).

Agronomic and Morphological Characteristics of Two Rice Genotypes Under Open Conditions and Agroforestry

The results of the observations of the agronomic and morphological characters of the two rice genotypes planted in open land conditions and under 2-year-old sengon stands were shown in Table 2.

The agronomic and morphological characters of the two rice genotypes grown in different environmental conditions (open and under a 2-year-old Sengon stand) showed different responses. These included the number of tillers, plant height, stem strength, number of grains per panicle, and grain weight per panicle. The response of the agronomic and morphological characteristics of cultivated plants under 2-year-old Sengon trees significantly decreased. There was no significant difference in the leaf color index characters, leaf chlorophyll content, stem diameter, as well as the length and width of the flag leaf. This showed that the character was more determined by genetic factors. However, the overall character was still influenced by pressure due to environmental factors, with light being the dominant. Measurements showed that the intensity of sunlight on open land was 52800 lux, which decreased to 10468 lux on agroforestry land (shade 80%). The limitation of the light availability was the main factor contributing to the genotypic response experiencing a decrease in the ability to optimally express morphological and agronomic characters.

Sunlight is a source of energy for the process of photosynthesis. The absorption of sunlight by the plant canopy is an important factor that determines photosynthesis and plant yield. A previous research reported that plants use the light spectrum in the wavelength range of 400-700 nm, commonly called Photosynthetically Active Radiation (PAR) (Sopandie, 2014). Generally, the presence of shade affects the intensity of sunlight received by plants, which influences the availability of energy to be used for growth and yield processes (Pantilu et al., 2012). To avoid the harmful effects of low light, tolerant varieties can be used to maintain the ability to produce carbohydrates, improve photosynthetic efficiency, and enhance the ability to produce antioxidants as a form of plant adaptation to stress in low light conditions (Liu et al., 2012).

Table 2. Character number of tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter of 2 rice genotypes in open environment, and agroforestry

Replication	Number of tillers				Plant height				Leaf color index				Leaf chlorophyll content				Stem diameter			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	10.00	23.00	11.00	9.00	70.00	84.00	60.00	66.00	26.10	20.90	13.30	18.30	2.95	2.36	1.50	2.07	0.56	0.69	0.43	0.41
2	14.00	18.00	8.00	10.00	72.00	80.00	70.00	74.00	32.90	18.40	13.10	24.20	3.72	2.08	1.48	2.73	0.51	0.65	0.61	0.36
3	21.00	20.00	9.00	8.00	80.00	86.00	72.00	68.00	24.90	14.20	15.20	19.50	2.81	1.60	1.72	2.20	0.41	0.58	0.60	0.49
4	15.00	15.00	12.00	11.00	65.00	84.00	62.00	70.00	18.50	14.10	14.70	15.90	2.09	1.59	1.66	1.80	0.43	0.62	0.47	0.59
5	13.00	15.00	7.00	11.00	70.00	82.00	70.00	66.00	22.70	12.90	20.40	11.90	2.57	1.46	2.31	1.34	0.59	0.53	0.48	0.52
Mean	14.60	18.20	9.40	9.80	71.40	83.20	66.80	68.80	25.02	16.10	15.34	17.96	2.83	1.82	1.73	2.03	0.50	0.61	0.52	0.47
Combine	16.40		9.60		312.00		208.50		20.56		16.65		2.32		1.88		0.56		0.50	
Stdev	4.01		1.65		66.63		60.28		6.29		3.87		0.71		0.44		0.09		0.08	
Notation	**				**				ns				ns				ns			
P-Value	0.001				0.002				0.161				0.161				0.240			

Note : O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% level t test

Table 3. Characteristics of stem strength, length of flag leaf, the width of flag leaf, number of grains per panicle, and grain weight per panicle of 2 rice genotypes in an open environment and agroforestry

Replication	Stem strength				Flag leaf length				Flag leaf width				Number of grains per panicle				Grains weight per panicle			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	310.00	360.00	180.00	190.00	14.30	27.00	11.00	20.00	1.00	1.20	1.00	1.00	86.00	165.00	66.00	50.00	2.05	3.64	1.57	1.10
2	220.00	380.00	150.00	240.00	16.20	16.00	20.00	23.20	1.00	1.10	1.20	1.00	75.00	98.00	48.00	52.00	1.79	2.16	1.14	1.15
3	220.00	340.00	130.00	140.00	16.60	23.50	12.30	20.00	1.00	1.30	1.10	1.20	86.00	130.00	61.00	87.00	2.05	2.87	1.45	1.92
4	230.00	340.00	285.00	290.00	16.30	22.80	17.50	21.00	1.00	1.10	0.90	1.20	88.00	147.00	81.00	63.00	2.10	3.24	1.93	1.39
5	320.00	400.00	210.00	270.00	19.50	24.50	14.40	18.50	1.20	1.10	1.00	1.00	93.00	120.00	51.00	36.00	2.22	2.65	1.22	0.79
Mean	260.00	364.00	191.00	226.00	16.58	22.76	15.04	20.54	1.04	1.16	1.04	1.08	85.60	132.00	61.40	57.60	2.04	2.91	1.46	1.27
Gabungan	312.00		208.50		19.67		17.79		1.10		1.06		108.80		59.50		2.48		1.37	
Stdev	66.63		60.28		4.43		3.98		0.11		0.11		30.14		15.56		0.60		0.36	
Notation	**				ns				ns				**				**			
P-Value	0.001				0.226				0.373				0.001				0.001			

Note : O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% level t test

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In conclusion, the two genotypes of rice planted under 2-year-old Sengon stands experienced a decrease in the characters of the number of productive tillers, plant height, stem strength, number of grains, and grain weight per panicle. The IR 64 genotype decreased grain weight per panicle by 40.65% and the Situ Patenggang genotype by 56.21%.

The growth limitations imposed by the 2-year-old Sengon trees suppressed the expression of character indices of leaf color, leaf chlorophyll content, stem diameter, length, and width of flag leaves of two genotypes of rice plants. However, these results showed no statistically significant.

Recommendations

There is a need to evaluate the use of rice agroforestry systems under 2-year-old Sengon stands with a spacing of 2.5m x 2.5m. Moreover, when the conditions require further planting, thinning should be carried out beforehand to provide sufficient space for the intensity of sunlight to support the process of plant growth and production.

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[biodiv] Submission Acknowledgement

1 pesan

Ahmad Dwi Setyawan via SMUJO <support@smujo.com> 4 Agustus 2023 pukul 11.12
Balas Ke: Ahmad Dwi Setyawan <editors@smujo.id>
Kepada: Dulbari Dulbari <dulbari@polinela.ac.id>

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Thank you for submitting the manuscript, "Agronomic And Morphological Characteristics Of Two Rice Genotypes Plant In Open Land And Under Two Years Of Sengon (Paraserianthes falcataria (L))" to Biodiversitas Journal of Biological Diversity. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

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Agronomic and Morphological Characteristics of Two Rice Genotypes Plant in Open Land and Under Two Years of Sengon (*Paraserianthes falcataria* (L))

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Manuscript received: DD MM 2016 (Date of abstract/manuscript submission). Revision accepted: .... 2016.

Abstract. The increase in population is the biggest challenge for the agricultural sector in providing food needs. In Indonesia, the main problem in increasing food production is the limited agricultural land. To address this issue and enhance production capacity, specifically for rice at the national level, there is a need to explore alternative land options. One of the potential solutions is to use land currently occupied by plantation crops and forests that can be managed through agroforestry. Sengon is a forestry plant that offers a comparative advantage for investigation when combined in agroforestry systems due to its relatively open canopy cover and classification as a legume. Therefore, this research aimed to determine the response of the morphological and agronomic characters of two genotypes of rice planted in open land conditions and under 2-year-old sengon stands. The experiment was conducted from October 2017 to March 2018 in the Sengon community forest of Cikarawang, Bogor, with coordinates 06° 33.061' S and 106° 43.987' E. The results showed that two rice genotypes grown under one-year-old sengon stands experienced a decrease in the number of productive tillers, plant height, stem strength, and the number as well as the weight of grains per panicle. The IR 64 genotype decreased by 40.65% in grain weight per panicle, while the Situ Patenggang genotype experienced a 56.21% decrease.

Key words: Adaptation, agroforestry, constraint, sengon, shade

Abbreviations: RBD- randomized block design; G1-Genotype 1= IR46; G2-Genotype 2=Situ Patenggang; MST-weeks after planting; O-open land cultivation; A-Agroforestry system cultivation under 2-year-old sengon plants with a spacing of 2.5 m x 2.5 m.

Running title: Characteristics of rice plant genotypes under shade conditions.

INTRODUCTION

The population of Indonesia in 2021 is more than 270 million, with a growth rate of 1.22 per year (BPS, 2022). This growing population poses a challenge in ensuring adequate food sufficiency, which is a crucial factor in achieving the welfare of the people. The adequacy of food, specifically rice, is a significant indicator of economic and political stability. Despite this significance, efforts to maintain food availability and stability still face various obstacles, including reduced productive agricultural land due to conversion for non-agricultural purposes. The conversion of land for the construction of housing, factories, and industrial facilities has a significant impact on the availability of agricultural land. Therefore, to maintain production stability and food security, alternative solutions are needed to increase the area of agricultural land.

One of the solutions that can be implemented is planting food crops, specifically rice, using the plantation and forestry concept. This practice, also known as agroforestry, involves the use of forests for agricultural activities. According to Korneeva (2022), agroforestry is a land-use system where forest stands and crops are planted on the same land. Octavia et al., (2022) stated that agroforestry is the main driving technique in the implementation of social forestry, with broad connotation. Furthermore, the objectives of agroforestry or intercropping in forest areas (Nair et al., 2021), include (1) increasing food supply, (2) expanding employment opportunities, (3) increasing the income and welfare of the community around the forest, and (4) increasing the success of forest plantations.

Defines agroforestry as optimal and sustainable land use, by combining forestry and agricultural activities on the same land management unit, considering the physical, social, economic, and cultural conditions of the participating communities (de Mendonça et al., 2022). The main purpose of agroforestry and the intercropping system is to improve the welfare of village communities around the forest. This is carried out to provide opportunities for communities or ‘pesanggem’ farmers to grow food crops and increase their income. Through this approach, villagers around the forest are expected to play an active role in efforts to conserve and protect the forest and land from damage.

There is a need to research the adaptation of rice plants to low light stress conditions under plant stands. One suitable forestry vegetation for agroforestry with a light canopy is Sengon (*Paraserianthes falcataria* (L).), which is a native to Indonesia and thrives on well-drained, non-flooded land (Danarto et al., 2019). Sengon is frequently incorporated into agroforestry systems due to its moderately dense canopy cover and leguminous characteristics. The roots of the Sengon (*Leguminoceae*) can form symbiotic relationships with Rhizobium, resulting in root nodules that can bind free Nitrogen from the air. This phenomenon contributes to the significant role of the plant in maintaining the availability of nutrients, specifically N in the soil (Binkley & Fisher, 2019).

Increasing the area of intercropping crops (agroforestry) and providing forest areas for food development is continuously carried out as an effort in the forestry sector to support food security (Duffy et al., 2021). Furthermore, Sengon trees can also be combined with rice (*Oryza sativa* L.) on the same land, providing an alternative solution to increase community food security. Rice is a type of agricultural crop that can be developed on dry land. High rice production will increase the supply of rice which incidentally is a basic need for the Indonesian people. However, there are several obstacles in the development of rice varieties under plant stands. This includes the determination of genotypes that can effectively adapt and the appropriate age of Sengon stands for intercropping with rice plants.

This research aimed to determine the response of the morphological and agronomic characters of two genotypes of rice planted in open land conditions and under 2-year-old sengon stands. The results are expected to be used as input for increasing rice production capacity under agroforestry plantations or forestry plantations.

METHODS

Treatment and Research Design

The research was conducted from October 2017 to March 2018, using community forest land in Cikarang Village, Bogor Regency, West Java at coordinates 06° 33.061' North Latitude and 106° 43.987' South Latitude. The land was planted with 2-year-old Sengon, spaced at 2.5 m x 2.5 cm, and an open land area. The analysis was arranged using a randomized block design (RBD) with a single-factor treatment of rice genotypes, consisting of IR64 (G1) and Situ Patenggang (G2). Each treatment was repeated 5 times in 2 cultivation systems, namely open land cultivation (O) and agroforestry system cultivation under 2-year-old sengon plants with a spacing of 2.5 m x 2.5 m (A). The linear model and analysis of variance followed the approach by Mattjik & Sumertajaya (2013):

$$Y_{ij} = \mu + \tau_i + \beta_j + \acute{\varepsilon}_{ij}.$$

Notes: Y_{ij} –Observational value in the I^{st} treatment and j^{th} group, μ-average, τ_i-effect of the i^{th} treatment, β_j-j^{th} group effect, $\acute{\varepsilon}_{ij}$-random effect in the I^{th} treatment and j^{th} group.

Indicators of environmental conditions for the two planting locations were shown in Table 1.

Table 1. Environmental indicators for planting locations

Indicator	Open	Agroforestry	Information
pH KCl	4.29	4.53	
H_2O	4.90	5.20	
N-Total	0.26	1.62	%
P-Total	131.90	105.34	mg P_2O_5 $100g^{-1}$
K-Total	96.25	112.42	mg K_2O $100g^{-1}$
P-Tersedia	11.28	14.32	P_2O_5 ppm
C-Organik	0.25	1.74	%
KTK	21.43	21.41	Cmol(+) kg^{-1}
Al-dd	0.26	0.78	Cmol(+) kg^{-1}
H-dd	0.33	0.40	Cmol(+) kg^{-1}
Ca-dd	3.04	3.36	Cmol(+) kg^{-1}
Mg-dd	2.82	3.30	Cmol(+) kg^{-1}
K-dd	0.77	1.20	Cmol(+) kg^{-1}
Na-dd	0.15	0.11	Cmol(+) kg^{-1}

Research Implementation

The soil was processed to a depth of 25-30 cm, followed by creating beds with a width of 100 cm and a length of 1000 cm. Seeds were sown directly at a spacing of 25 cm x 25 cm, with 2-3 seeds per planting hole. Basic fertilization was carried out at the time of planting Urea 100 kg ha^{-1}, TSP 200 kg ha^{-1}, and KCl 50 kg ha^{-1}. Subsequently, a follow-up fertilization was conducted 4 weeks after planting, using Urea 100 kg ha^{-1} and KCl 50 kg ha^{-1}. Pest and disease control was also carried out using pesticides according to plant conditions in the field with recommended doses. Weed control was carried out twice at the age of 3 and 6 weeks after planting (WAT).

The observation of agronomic and morphological characters encompassed several aspects, namely the number of productive tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter, stem strength, number of grain per panicle, and grain weight per panicle. These observations were carried out in line with the Guidelines for Characterization and Evaluation of Rice Plants (Silitonga et al., 2014).

Leaf color index observations were carried out using SPAD meters. Observation of chlorophyll content was calculated using the equation: $y = 0.113x$, where y is the total leaf chlorophyll content, 0.113 = constant, and x = level of the greenness of leaves (results of SPAD measurements) (Dulbari: unpublished data).

The observational data were analyzed for diversity using the Barlett test. When the data met the requirements, further analysis of variance was carried out. Subsequently, the differences between treatments were analyzed using the T-test with $\alpha = 0.05$.

RESULTS AND DISCUSSION

Character number of productive tillers and plant height

The results of observing the number of tillers and plant height characters were shown in Figure 1.

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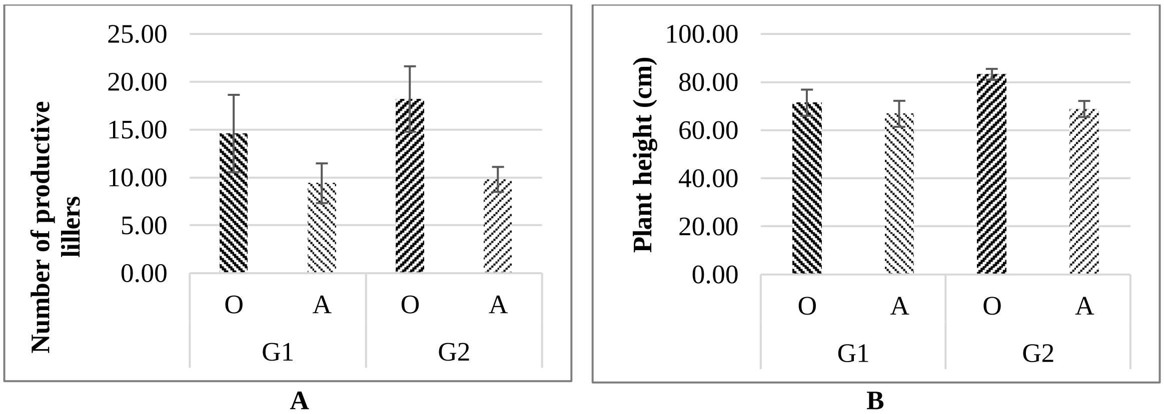

Figure 1. A-number of productive tiller character, b-plant height character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The results also showed that plants no longer have the energy to distribute assimilates to the necessary parts. This distribution used tools such as proteins, and proton pumps driven by ATP (ATP-Ase), necessitating energy and enzymes for the process. Similarly, (Amin et al., 2021) stated that plants maintained an electrochemical balance within the entire biomembrane to ensure survival.

The closing rate of 2-year-old Sengon stands with a spacing of 2.5 m x 2.5 m prevented light interception by approximately 80%. Therefore, the process of photosynthesis, which served as the main energy source for plants to carry out growth processes, was disrupted.

Leaf Color Index Character and Leaf Chlorophyll Content

The results of leaf color index character observations and leaf chlorophyll content are shown in Figure 2.

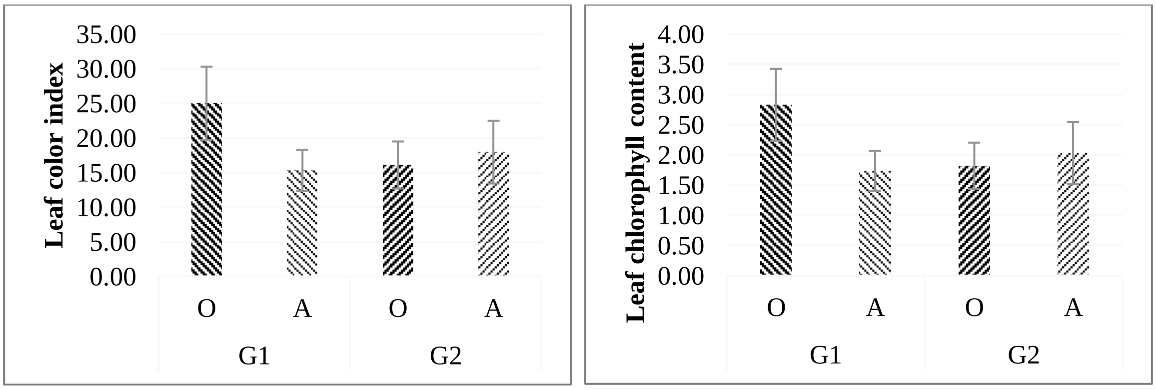

Figure 2. A-leaf color index (SPAD), b-leaf chlorophyll content (Chl Leaf), G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The leaf color index characters and leaf chlorophyll content of the two genotypes had different tendencies. For genotype 1 (IR 64), these variables showed a decrease in growing conditions under 2-year-old sengon stands (agroforestry). The leaf color index decreased from 25.02 to 15.34, while the chlorophyll content of the leaves reduced from 2.83 to 1.73. For genotype 2 (Situ Patenggang), the variables showed a tendency to increase in growing conditions under 2-year-old sengon stands (agroforestry), where leaf color index increased from 16.10 to 17.96, and chlorophyll content increased from 1.82 to 2.03. This showed that the genotypic response to leaf color index characters and chlorophyll content was different due to the variation in the adaptability of the IR64 and Situ Patenggang rice genotypes to shade stress.

Each genotype exhibited a different response and ability to adapt to the environment. In this research, the plant growth environment was different, specifically in terms of sunlight intensity. The differences in light intensity were responded to by plants according to their genetic capacity. Furthermore, plants developed acclimatization and plasticity methods to respond to environmental stress through morphological, anatomical, and physiological adjustments (Yetgin, 2023).

Flag Leaf Size Character

The results of observations of flag leaf size characters were shown in Figure 3.

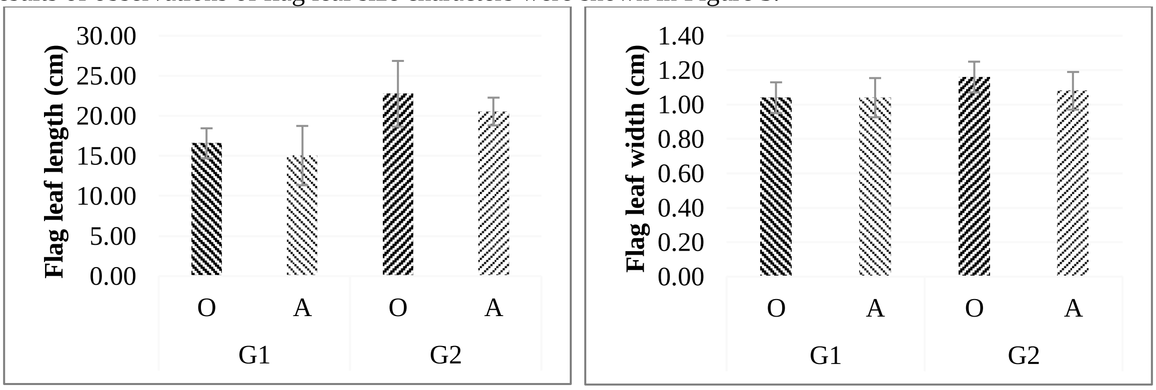

Figure 3. A-flag leaf length character, b-flag leaf width character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The responses to flag leaf size characters (length and width) of the two rice genotypes did not show any significant differences under open location and 2-year-old sengon (agroforestry) planting conditions. However, significant variations were observed between the genotypes, indicating that the genotypes had different adaptation abilities to the stresses. The IR64 genotype showed a relatively stable response to flag leaf length and width, namely 16.58 and 15.04 as well as 1.04 and 1.04. Meanwhile, the Situ Patenggang genotype showed an insignificant decreasing trend for length measurements from 22.76 to 20.54 and width sizes from 1.16 to 1.08.

The morphology of the flag leaf (Sink) of rice plants played an important role in the process of filling the grains of the plant. The large sink character in superior varieties of rice had a higher photosynthetic rate. Furthermore, the upright morphology of the leaves allowed greater penetration and distribution of light to the bottom, causing an increase in plant photosynthesis. According to a previous research, the photosynthesis of plants in upright leaf canopies is about 20% higher than in drooping leaf canopies under high leaf area index conditions (Pan et al., 2023). The flag leaf as a light-harvesting organ can allocate its assimilate results for panicle formation, thereby influencing the length of the panicle and the number of seeds per panicle. The less ideal flag leaf morphology also affected tiller growth and grain growth (Liu et al., 2014). Furthermore, the size of the flag leaf affected the number of stomata pores, which influenced the ability to exchange H_2O and CO_2 (Franks & Beerling, 2009).

Diameter and Stem Strength Character

The results of observations of stem diameter and strength characters were shown in Figure 4

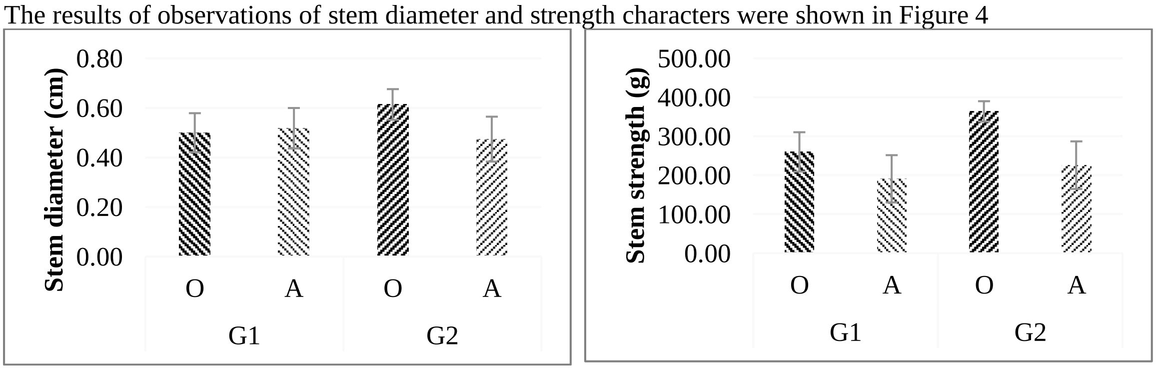

Figure 4. A-stem diameter character, b-stem strength character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The responses of the two rice genotypes, cultivated under open conditions and 1-year-old sengon trees did not show significant differences in the stem diameter character. However, there was a significant variation in the stem strength character. The responses of the stem diameter characters of the two genotypes were different, as IR64 showed a tendency not to experience a change in stem diameter, compared to Situ Patenggang which exhibited a decrease in stem diameter from 0.61 cm to 0.47 cm. Under underexposed conditions and a 2-year-old Sengon tree to stem strength characters, both genotypes experienced a significant decrease. The IR 64 genotype decreased from 260.00 g to 191.00 g, and Situ Patenggang reduced from 364.00 g to 226.00 g.

The character of stem strength was needed for plants to withstand lodging, which can significantly affect crop production due to potential yield losses (Dulbari et al., 2018). Larger stem diameter plants also exhibit better strength and the character of stem strength is significantly correlated with stem diameter, at a correlation coefficient value (0.77) (Dulbari; data has not been published). This indicated that genotypes of rice plants with a larger lower stem diameter (± 10 cm above the soil surface) had a better stem strength, thereby strengthening the research of (Zhang et al., 2014) and (Dreccer et al., 2020)

Character Number of Grain and Grain Weight Per Panicle

The results of observing the character of the number of grains and the weight of grain per panicle were shown in Figure 5.

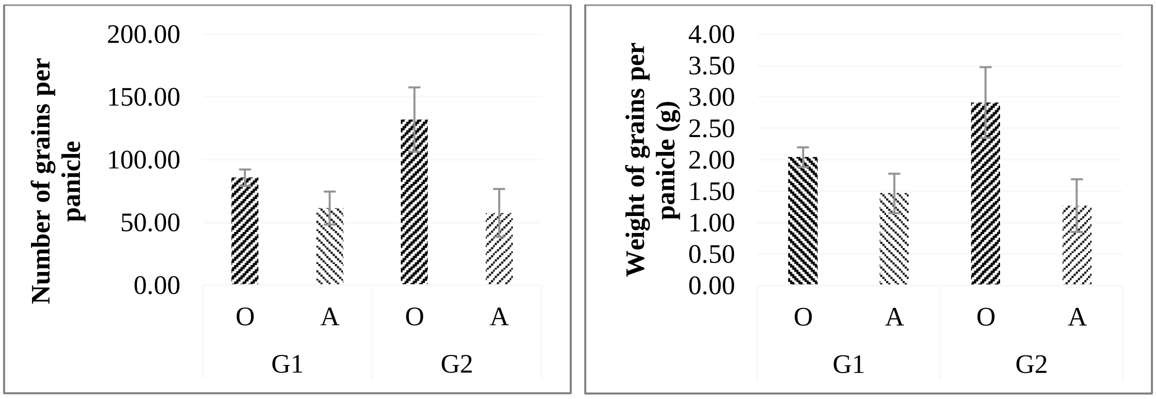

Figure 5. A-the number of grains per panicle character, b-the weight of grains per panicle, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The response of the two rice genotypes cultivated in open land conditions and under 2-year-old Sengon trees experienced a significant decrease in the number of grains per panicle and grain weight per panicle, which were the yield component characteristics. The IR 64 genotype exhibited a smaller reduction in the number of grains per panicle (85.00 to 61.40), compared to the Situ Patenggang (132.00 to 57.60). Similarly, the grain weight per panicle also had the same tendency, with IR 64 genotype ranging from 2.40 to 1.46 (40.65%) and Situ Patenggang from 2.90 g to 1.27 g (56.21%). This showed that genotype had a significant influence on planting plans under agroforestry crop stands..

The characters of grain number and weight were the results of plant metabolism processes, which were closely related to the process of photosynthetic ability (source) and the distribution of the assimilates to the sink. The ability of plants to produce the amount of grain and the weight of grain per panicle was significantly influenced by environmental conditions, such as light, temperature, and humidity. Furthermore, light intensity was closely related to temperature, with lower values resulting in reduced rice products and quality (Dutta et al., 2017).

Light played a significant role in regulating the opening and closing of stomata. Lower light intensity will make stomata tend to close, thereby hindering the entry of CO_2. Limited CO_2 and sunlight also caused a decrease in the rate of photosynthesis, impacting the assimilation of carbohydrates and biomass formation (Liu et al., 2014). Moreover, regulation of stomatal opening is a dynamic and reversible process, where water loss and CO_2 inflow can be rapidly adjusted in response to several environmental and intrinsic signals, such as light, CO_2, and the plant stress hormone abscisic acid (Bhattacharya, 2021). The ability of plants to produce and distribute photosynthate to storage organs is an important part of increasing crop production (Fischer et al., 2012).

Agronomic and Morphological Characteristics of Two Rice Genotypes Under Open Conditions and Agroforestry

The results of the observations of the agronomic and morphological characters of the two rice genotypes planted in open land conditions and under 2-year-old sengon stands were shown in Table 2.

The agronomic and morphological characters of the two rice genotypes grown in different environmental conditions (open and under a 2-year-old Sengon stand) showed different responses. These included the number of tillers, plant height, stem strength, number of grains per panicle, and grain weight per panicle. The response of the agronomic and morphological characteristics of cultivated plants under 2-year-old Sengon trees significantly decreased. There was no significant difference in the leaf color index characters, leaf chlorophyll content, stem diameter, as well as the length and width of the flag leaf. This showed that the character was more determined by genetic factors. However, the overall character was still influenced by pressure due to environmental factors, with light being the dominant. Measurements showed that the intensity of sunlight on open land was 52800 lux, which decreased to 10468 lux on agroforestry land (shade 80%). The limitation of the light availability was the main factor contributing to the genotypic response experiencing a decrease in the ability to optimally express morphological and agronomic characters.

Sunlight is a source of energy for the process of photosynthesis. The absorption of sunlight by the plant canopy is an important factor that determines photosynthesis and plant yield. A previous research reported that plants use the light spectrum in the wavelength range of 400-700 nm, commonly called Photosynthetically Active Radiation (PAR) (Prakash et al., 2023). Generally, the presence of shade affects the intensity of sunlight received by plants, which influences the availability of energy to be used for growth and yield processes (Raffo et al., 2020). To avoid the harmful effects of low light, tolerant varieties can be used to maintain the ability to produce carbohydrates, improve photosynthetic efficiency, and enhance the ability to produce antioxidants as a form of plant adaptation to stress in low light conditions (Kowalczewski et al., 2020).

Table 2. Character number of tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter of 2 rice genotypes in open environment, and agroforestry

Replication	Number of tillers				Plant height				Leaf color index				Leaf chlorophyll content				Stem diameter			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	10.00	23.00	11.00	9.00	70.00	84.00	60.00	66.00	26.10	20.90	13.30	18.30	2.95	2.36	1.50	2.07	0.56	0.69	0.43	0.41
2	14.00	18.00	8.00	10.00	72.00	80.00	70.00	74.00	32.90	18.40	13.10	24.20	3.72	2.08	1.48	2.73	0.51	0.65	0.61	0.36
3	21.00	20.00	9.00	8.00	80.00	86.00	72.00	68.00	24.90	14.20	15.20	19.50	2.81	1.60	1.72	2.20	0.41	0.58	0.60	0.49
4	15.00	15.00	12.00	11.00	65.00	84.00	62.00	70.00	18.50	14.10	14.70	15.90	2.09	1.59	1.66	1.80	0.43	0.62	0.47	0.59
5	13.00	15.00	7.00	11.00	70.00	82.00	70.00	66.00	22.70	12.90	20.40	11.90	2.57	1.46	2.31	1.34	0.59	0.53	0.48	0.52
Mean	14.60	18.20	9.40	9.80	71.40	83.20	66.80	68.80	25.02	16.10	15.34	17.96	2.83	1.82	1.73	2.03	0.50	0.61	0.52	0.47
Combine	16.40		9.60		312.00		208.50		20.56		16.65		2.32		1.88		0.56		0.50	
Stdev	4.01		1.65		66.63		60.28		6.29		3.87		0.71		0.44		0.09		0.08	
Notation	**				**				ns				ns				ns			
P-Value	0.001				0.002				0.161				0.161				0.240			

Note : O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% level t test.

Table 3. Characteristics of stem strength, length of flag leaf, the width of flag leaf, number of grains per panicle, and grain weight per panicle of 2 rice genotypes in an open environment and agroforestry

Replication	Stem strength				Flag leaf length				Flag leaf width				Number of grains per panicle				Grains weight per panicle			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	310.00	360.00	180.00	190.00	14.30	27.00	11.00	20.00	1.00	1.20	1.00	1.00	86.00	165.00	66.00	50.00	2.05	3.64	1.57	1.10
2	220.00	380.00	150.00	240.00	16.20	16.00	20.00	23.20	1.00	1.10	1.20	1.00	75.00	98.00	48.00	52.00	1.79	2.16	1.14	1.15
3	220.00	340.00	130.00	140.00	16.60	23.50	12.30	20.00	1.00	1.30	1.10	1.20	86.00	130.00	61.00	87.00	2.05	2.87	1.45	1.92
4	230.00	340.00	285.00	290.00	16.30	22.80	17.50	21.00	1.00	1.10	0.90	1.20	88.00	147.00	81.00	63.00	2.10	3.24	1.93	1.39
5	320.00	400.00	210.00	270.00	19.50	24.50	14.40	18.50	1.20	1.10	1.00	1.00	93.00	120.00	51.00	36.00	2.22	2.65	1.22	0.79
Mean	260.00	364.00	191.00	226.00	16.58	22.76	15.04	20.54	1.04	1.16	1.04	1.08	85.60	132.00	61.40	57.60	2.04	2.91	1.46	1.27
Gabungan	312.00		208.50		19.67		17.79		1.10		1.06		108.80		59.50		2.48		1.37	
Stdev	66.63		60.28		4.43		3.98		0.11		0.11		30.14		15.56		0.60		0.36	
Notation	**				ns				ns				**				**			
P-Value	0.001				0.226				0.373				0.001				0.001			

Note : O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% level t test.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In conclusion, the two genotypes of rice planted under 2-year-old Sengon stands experienced a decrease in the characters of the number of productive tillers, plant height, stem strength, number of grains, and grain weight per panicle. The IR 64 genotype decreased grain weight per panicle by 40.65% and the Situ Patenggang genotype by 56.21%.

The growth limitations imposed by the 2-year-old Sengon trees suppressed the expression of character indices of leaf color, leaf chlorophyll content, stem diameter, length, and width of flag leaves of two genotypes of rice plants. However, these results showed no statistically significant.

Recommendations

There is a need to evaluate the use of rice agroforestry systems under 2-year-old Sengon stands with a spacing of 2.5m x 2.5m. Moreover, when the conditions require further planting, thinning should be carried out beforehand to provide sufficient space for the intensity of sunlight to support the process of plant growth and production.

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[biodiv] Editor Decision

1 pesan

Smujo Editors via SMUJO <support@smujo.com> 4 September 2023 pukul 19.44
Balas Ke: Smujo Editors <editors@smujo.id>
Kepada: Dulbari Dulbari <dulbari@polinela.ac.id>

Dulbari Dulbari:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (Paraserianthes falcataria (L))". Complete your revision with a Table of Responses containing your answers to reviewer comments (for multiple comments) or enable Track Changes.

Our decision is: Revisions Required

Reviewer D:

REVIEWER COMMENTS: ==================

Suggestions which would improve the quality of the paper but are not essential for publication:

1. Headings of the "Result and Discussion" section should be homogenous.
2. In all figures denotation are somewhere in uppercase and in some lowercase (i.e. A and b). It should be homogenous.
3. In "Introduction" section authors should point out the goals of research much more according to some of their own previous findings.

Changes which must be made before publication:

1. In 'Abstract' section the plant '*Sengon*' used in the agro forestry experiments of the current study has been described as plant with relatively open canopy cover (line 16) but in 'Introduction' section it is described as plant with moderately dense canopy cover(line 52). Both should be homogenous.
2. Barlett test should be Bartlett test (line 97).
3. In line no 168, it was showed that the cultivation of rice was under 1 year old *Sengon* tree, but in abstract and remaining part of the text it was described as 2 year old *Sengon*
4. In all figures indentation of the second character should be homogenous with the first character (b should be B).
5. Line number 101 is misleading.
6. The characters, number of productive tillers and plant height has not been well analyzed and discussed.
7. In line 110, it is not clear that how author predict that the studied plant no longer have the energy to distribute assimilates to the necessary parts.
8. In line number 117, proper tabulation for the data showing correlation coefficient (0.77) has been depicted.

Recommendation: Revisions Required

Reviewer T:
Recommendation: Accept Submission

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REVIEWER COMMENTS: =================

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8. In line number 117, proper tabulation for the data showing correlation coefficient (0.77) has been depicted.

Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (*Paraserianthes falcataria* (L))

Abstract. The increase in population is the biggest challenge for the agricultural sector in providing food needs. In Indonesia, the main problem in increasing food production is the limited agricultural land. To address this issue and enhance production capacity, specifically for rice at the national level, there is a need to explore alternative land options. One of the potential solutions is to use land currently occupied by plantation crops and forests that can be managed through agroforestry. Sengon is a forestry plant that offers a comparative advantage for investigation when combined in agroforestry systems due to its relatively open canopy cover and classification as a legume. Therefore, this research aimed to determine the response of the morphological and agronomic characters of two genotypes of rice planted in open land conditions and under 2-year-old sengon stands. The experiment was conducted from October 2017 to March 2018 in the Sengon community forest of Cikarawang, Bogor, with coordinates 06° 33.061' S and 106° 43.987' E. The results showed that two rice genotypes grown under one-year-old sengon stands experienced a decrease in the number of productive tillers, plant height, stem strength, and the number as well as the weight of grains per panicle. The IR 64 genotype decreased by 40.65% in grain weight per panicle, while the Situ Patenggang genotype experienced a 56.21% decrease.

Keywords: Adaptation, agroforestry, constraint, sengon, shade

Abbreviations: RBD- randomized block design; G1-Genotype 1= IR46; G2-Genotype 2=Situ Patenggang; MST-weeks after planting; O-open land cultivation; A-Agroforestry system cultivation under 2-year-old sengon plants with a spacing of 2.5 m x 2.5 m.

Running title: Characteristics of rice plant genotypes under shade conditions.

INTRODUCTION

The population of Indonesia in 2021 is more than 270 million, with a growth rate of 1.22 per year (BPS, 2022). This growing population poses a challenge in ensuring adequate food sufficiency, which is a crucial factor in achieving the welfare of the people. The adequacy of food, specifically rice, is a significant indicator of economic and political stability. Despite this significance, efforts to maintain food availability and stability still face various obstacles, including reduced productive agricultural land due to conversion for non-agricultural purposes. The conversion of land for the construction of housing, factories, and industrial facilities has a significant impact on the availability of agricultural land. Therefore, to maintain production stability and food security, alternative solutions are needed to increase the area of agricultural land.

One of the solutions that can be implemented is planting food crops, specifically rice, using the plantation and forestry concept. This practice, also known as agroforestry, involves the use of forests for agricultural activities. According to Korneeva (2022), agroforestry is a land-use system where forest stands and crops are planted on the same land. Octavia et al., (2022) stated that agroforestry is the main driving technique in the implementation of social forestry, with broad connotation. Furthermore, the objectives of agroforestry or intercropping in forest areas (Nair et al., 2021), include (1) increasing food supply, (2) expanding employment opportunities, (3) increasing the income and welfare of the community around the forest, and (4) increasing the success of forest plantations.

Defines agroforestry as optimal and sustainable land use, by combining forestry and agricultural activities on the same land management unit, considering the physical, social, economic, and cultural conditions of the participating communities (de Mendonça et al., 2022). The main purpose of agroforestry and the intercropping system is to improve the welfare of village communities around the forest. This is carried out to provide opportunities for communities or 'pesanggem' farmers to grow food crops and increase their income. Through this approach, villagers around the forest are expected to play an active role in efforts to conserve and protect the forest and land from damage.

There is a need to research the adaptation of rice plants to low light stress conditions under plant stands. One suitable forestry vegetation for agroforestry with a light canopy is Sengon (*Paraserianthes falcataria* (L).), which is a native to Indonesia and thrives on well-drained, non-flooded land (Danarto et al., 2019). Sengon is frequently incorporated into agroforestry systems due to its relatively open canopy cover and leguminous characteristics. The roots of the Sengon (*Leguminoceae*) can form symbiotic relationships with Rhizobium, resulting in root nodules that can bind free Nitrogen from the air. This phenomenon contributes to the significant role of the plant in maintaining the availability of nutrients, specifically N in the soil (Binkley & Fisher, 2019).

Increasing the area of intercropping crops (agroforestry) and providing forest areas for food development is continuously carried out as an effort in the forestry sector to support food security (Duffy et al., 2021). Furthermore, Sengon trees can also be combined with rice (*Oryza sativa* L.) on the same land, providing an alternative solution to increase community food security. Rice is a type of agricultural crop that can be developed on dry land. High rice production will increase the supply of rice which incidentally is a basic need for the Indonesian people. However, there are several obstacles in the development of rice varieties under plant stands. This includes the determination of genotypes that can effectively adapt and the appropriate age of Sengon stands for intercropping with rice plants.

This research aimed to determine the response of the morphological and agronomic characters of two genotypes of rice planted in open land conditions and under 2-year-old sengon stands. The results are expected to be used as input for increasing rice production capacity under agroforestry plantations or forestry plantations.

MATERIALS AND METHODS

Treatment and research design

The research was conducted from October 2017 to March 2018, using community forest land in Cikarang Village, Bogor Regency, West Java at coordinates 06° 33.061' North Latitude and 106° 43.987' South Latitude. The land was planted with 2-year-old Sengon, spaced at 2.5 m x 2.5 cm, and an open land area. The analysis was arranged using a randomized block design (RBD) with a single-factor treatment of rice genotypes, consisting of IR64 (G1) and Situ Patenggang (G2). Each treatment was repeated 5 times in 2 cultivation systems, namely open land cultivation (O) and agroforestry system cultivation under 2-year-old sengon plants with a spacing of 2.5 m x 2.5 m (A). The linear model and analysis of variance followed the approach by Mattjik & Sumertajaya (2013):

$$Y_{ij} = \mu + \tau_i + \beta_j + \acute{\varepsilon}_{ij}.$$

Notes: Y_{ij} –Observational value in the Ist treatment and jth group, μ-average, τ_i-effect of the ith treatment, β_j-jth group effect, $\acute{\varepsilon}_{ij}$-random effect in the Ith treatment and jth group.

Indicators of environmental conditions for the two planting locations were shown in Table 1.

Table 1. Environmental indicators for planting locations

Indicator	Open	Agroforestry	Information
pH KCl	4.29	4.53	
H_2O	4.90	5.20	
N-Total	0.26	1.62	%
P-Total	131.90	105.34	mg P_2O_5 $100g^{-1}$
K-Total	96.25	112.42	mg K_2O $100g^{-1}$
P-Tersedia	11.28	14.32	P_2O_5 ppm
C-Organik	0.25	1.74	%
KTK	21.43	21.41	Cmol(+) kg^{-1}
Al-dd	0.26	0.78	Cmol(+) kg^{-1}
H-dd	0.33	0.40	Cmol(+) kg^{-1}
Ca-dd	3.04	3.36	Cmol(+) kg^{-1}
Mg-dd	2.82	3.30	Cmol(+) kg^{-1}
K-dd	0.77	1.20	Cmol(+) kg^{-1}
Na-dd	0.15	0.11	Cmol(+) kg^{-1}

Research implementation

The soil was processed to a depth of 25-30 cm, followed by creating beds with a width of 100 cm and a length of 1000 cm. Seeds were sown directly at a spacing of 25 cm x 25 cm, with 2-3 seeds per planting hole. Basic fertilization was carried out at the time of planting Urea 100 kg ha^{-1}, TSP 200 kg ha^{-1}, and KCl 50 kg ha^{-1}. Subsequently, a follow-up fertilization was conducted 4 weeks after planting, using Urea 100 kg ha^{-1} and KCl 50 kg ha^{-1}. Pest and disease control was also carried out using pesticides according to plant conditions in the field with recommended doses. Weed control was carried out twice at the age of 3 and 6 weeks after planting (WAT).

The observation of agronomic and morphological characters encompassed several aspects, namely the number of productive tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter, stem strength, number of grain per panicle, and grain weight per panicle. These observations were carried out in line with the Guidelines for Characterization and Evaluation of Rice Plants (Silitonga et al., 2014).

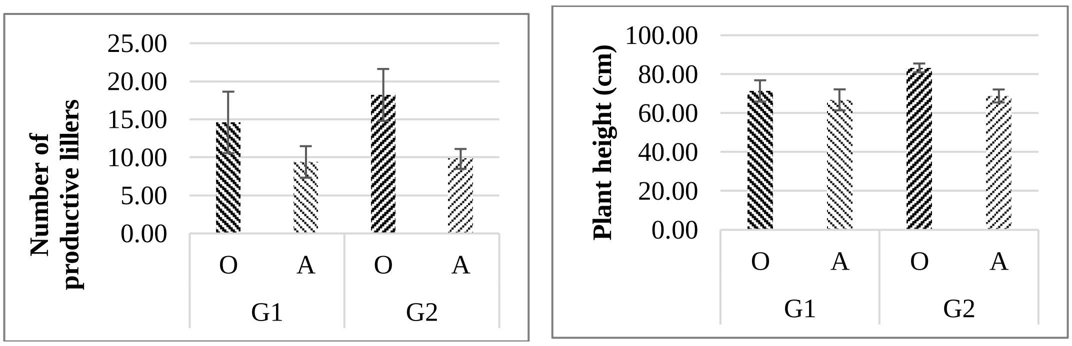
Leaf color index observations were carried out using SPAD meters. Observation of chlorophyll content was calculated using the equation: $y = 0.113x$, where y is the total leaf chlorophyll content, 0.113 = constant, and x = level of the greenness of leaves (results of SPAD measurements) (Dulbari: unpublished data).

The observational data were analyzed for diversity using the Bartlett test. When the data met the requirements, further analysis of variance was carried out. Subsequently, the differences between treatments were analyzed using the T-test with $\alpha = 0.05$.

RESULTS AND DISCUSSION

Character number of productive tillers and plant height

The results of observing the number of tillers and plant height characters were shown in Figure 1.



a **b**

Figure 1. a-number of productive tiller character, b-plant height character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

This showed that the two rice genotypes experienced decreased growth and yield responses due to the dominant environmental influences of sunlight. The reduction in response to plant height and the number of productive tillers in the two rice genotypes was due to the low intensity of sunlight, leading to a hindered rate of photosynthesis, tt's supposed to be a genetic factor. That plants no longer have the energy to distribute assimilates to the necessary parts. This distribution used tools such as proteins, and proton pumps driven by ATP (ATP-Ase), necessitating energy and enzymes for the process. Similarly, (Amin et al., 2021) stated that plants maintained an electrochemical balance within the entire biomembrane to ensure survival.

The closing rate of 2-year-old Sengon stands with a spacing of 2.5 m x 2.5 m prevented light interception by approximately 80%. Therefore, the process of photosynthesis, which served as the main energy source for plants to carry out growth processes, was disrupted.

Leaf color index character and leaf chlorophyll content

The results of leaf color index character observations and leaf chlorophyll content are shown in Figure 2.

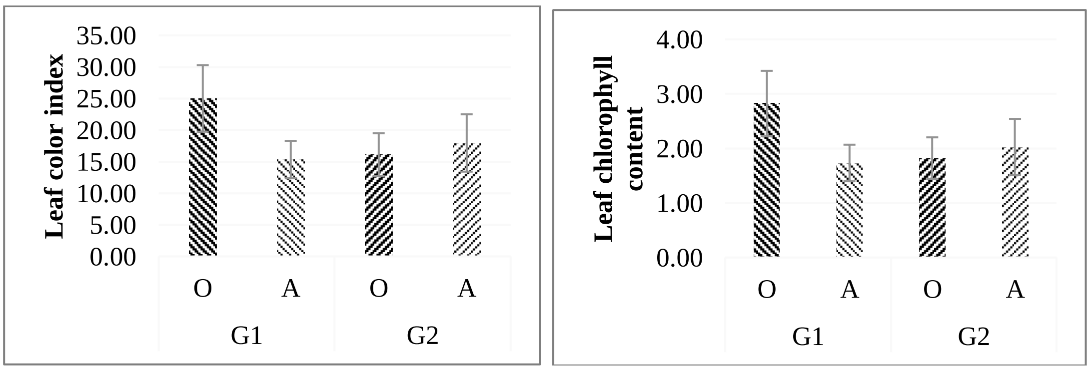


Figure 2. a-leaf color index (SPAD), b-leaf chlorophyll content (Chl Leaf), G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The leaf color index characters and leaf chlorophyll content of the two genotypes had different tendencies. For genotype 1 (IR 64), these variables showed a decrease in growing conditions under 2-year-old sengon stands (agroforestry). The leaf color index decreased from 25.02 to 15.34, while the chlorophyll content of the leaves reduced from 2.83 to 1.73. For genotype 2 (Situ Patenggang), the variables showed a tendency to increase in growing conditions under 2-year-old sengon stands (agroforestry), where leaf color index increased from 16.10 to 17.96, and chlorophyll content increased from 1.82 to 2.03. This showed that the genotypic response to leaf color index characters and chlorophyll content was different due to the variation in the adaptability of the IR64 and Situ Patenggang rice genotypes to shade stress.

Each genotype exhibited a different response and ability to adapt to the environment. In this research, the plant growth environment was different, specifically in terms of sunlight intensity. The differences in light intensity were responded to by plants according to their genetic capacity. Furthermore, plants developed acclimatization and plasticity methods to respond to environmental stress through morphological, anatomical, and physiological adjustments (Yetgin, 2023).

Flag leaf size character

The results of observations of flag leaf size characters were shown in Figure 3.

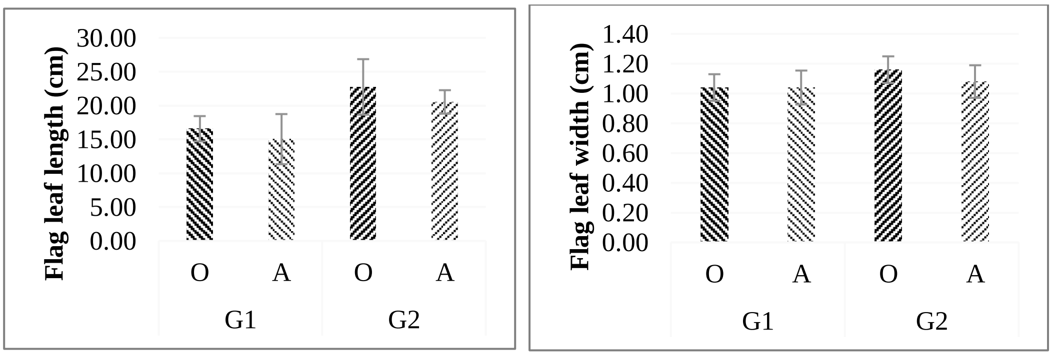


Figure 3. a-flag leaf length character, b-flag leaf width character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The responses to flag leaf size characters (length and width) of the two rice genotypes did not show any significant differences under open location and 2-year-old sengon (agroforestry) planting conditions. However, significant variations were observed between the genotypes, indicating that the genotypes had different adaptation abilities to the stresses. The IR64 genotype showed a relatively stable response to flag leaf length and width, namely 16.58 and 15.04 as well as 1.04 and 1.04. Meanwhile, the Situ Patenggang genotype showed an insignificant decreasing trend for length measurements from 22.76 to 20.54 and width sizes from 1.16 to 1.08.

The morphology of the flag leaf (Sink) of rice plants played an important role in the process of filling the grains of the plant. The large sink character in superior varieties of rice had a higher photosynthetic rate. Furthermore, the upright morphology of the leaves allowed greater penetration and distribution of light to the bottom, causing an increase in plant photosynthesis. According to a previous research, the photosynthesis of plants in upright leaf canopies is about 20% higher than in drooping leaf canopies under high leaf area index conditions (Pan et al., 2023). The flag leaf as a light-harvesting organ can allocate its assimilate results for panicle formation, thereby influencing the length of the panicle and the number of seeds per panicle. The less ideal flag leaf morphology also affected tiller growth and grain growth (Liu et al., 2014). Furthermore, the size of the flag leaf affected the number of stomata pores, which influenced the ability to exchange H_2O and CO_2 (Franks & Beerling, 2009).

Diameter and stem strength character

The results of observations of stem diameter and strength characters were shown in Figure 4

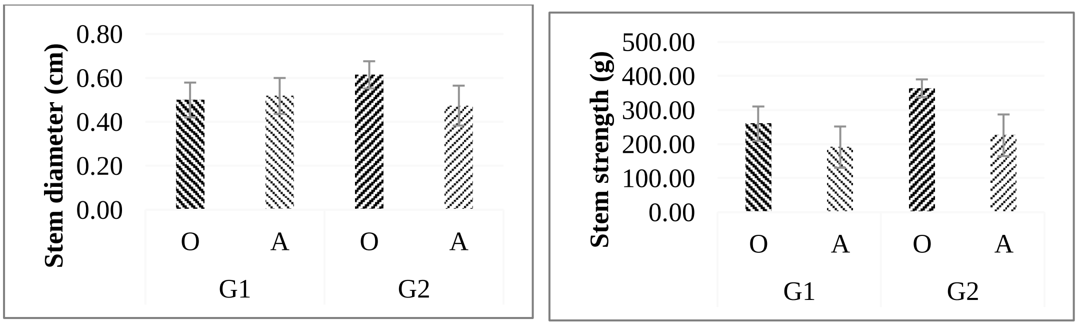


Figure 4. a-stem diameter character, b-stem strength character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The responses of the two rice genotypes, cultivated under open conditions and 2-year-old sengon trees did not show significant differences in the stem diameter character. However, there was a significant variation in the stem strength character. The responses of the stem diameter characters of the two genotypes were different, as IR64 showed a tendency not to experience a change in stem diameter, compared to Situ Patenggang which exhibited a decrease in stem diameter from 0.61 cm to 0.47 cm. Under underexposed conditions and a 2-year-old Sengon tree to stem strength characters, both genotypes experienced a significant decrease. The IR 64 genotype decreased from 260.00 g to 191.00 g, and Situ Patenggang reduced from 364.00 g to 226.00 g.

The character of stem strength was needed for plants to withstand lodging, which can significantly affect crop production due to potential yield losses (Dulbari et al., 2018). Larger stem diameter plants also exhibit better strength and the character of stem strength is significantly correlated with stem diameter, at a correlation coefficient value (0.77) (Dulbari; data has not been published). This indicated that genotypes of rice plants with a larger lower stem diameter (± 10 cm above the soil surface) had a better stem strength, thereby strengthening the research of (Zhang et al., 2014) and (Dreccer et al., 2020)

Character number of grain and grain weight per panicle

The results of observing the character of the number of grains and the weight of grain per panicle were shown in Figure 5.

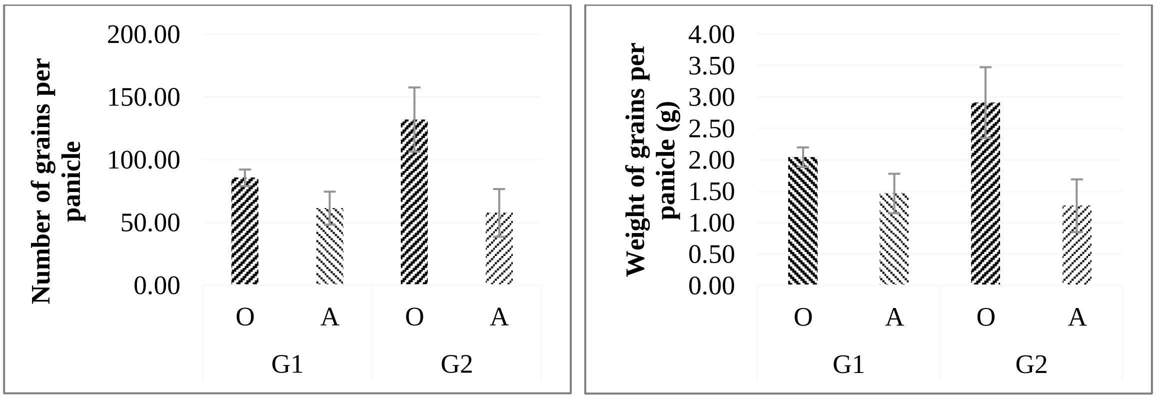


Figure 5. a-the number of grains per panicle character, b-the weight of grains per panicle, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The response of the two rice genotypes cultivated in open land conditions and under 2-year-old Sengon trees experienced a significant decrease in the number of grains per panicle and grain weight per panicle, which were the yield component characteristics. The IR 64 genotype exhibited a smaller reduction in the number of grains per panicle (85.00 to 61.40), compared to the Situ Patenggang (132.00 to 57.60). Similarly, the grain weight per panicle also had the same tendency, with IR 64 genotype ranging from 2.40 to 1.46 (40.65%) and Situ Patenggang from 2.90 g to 1.27 g (56.21%). This showed that genotype had a significant influence on planting plans under agroforestry crop stands..

The characters of grain number and weight were the results of plant metabolism processes, which were closely related to the process of photosynthetic ability (source) and the distribution of the assimilates to the sink. The ability of plants to produce the amount of grain and the weight of grain per panicle was significantly influenced by environmental conditions, such as light, temperature, and humidity. Furthermore, light intensity was closely related to temperature, with lower values resulting in reduced rice products and quality (Dutta et al., 2017).

Light played a significant role in regulating the opening and closing of stomata. Lower light intensity will make stomata tend to close, thereby hindering the entry of CO_2. Limited CO_2 and sunlight also caused a decrease in the rate of photosynthesis, impacting the assimilation of carbohydrates and biomass formation (Liu et al., 2014). Moreover, regulation of stomatal opening is a dynamic and reversible process, where water loss and CO_2 inflow can be rapidly adjusted in response to several environmental and intrinsic signals, such as light, CO_2, and the plant stress hormone abscisic acid (Bhattacharya, 2021). The ability of plants to produce and distribute photosynthate to storage organs is an important part of increasing crop production (Fischer et al., 2012).

Agronomic and morphological characteristics of two rice genotypes under open conditions and agroforestry

The results of the observations of the agronomic and morphological characters of the two rice genotypes planted in open land conditions and under 2-year-old sengon stands were shown in Table 2.

The agronomic and morphological characters of the two rice genotypes grown in different environmental conditions (open and under a 2-year-old Sengon stand) showed different responses. These included the number of tillers, plant height, stem strength, number of grains per panicle, and grain weight per panicle. The response of the agronomic and morphological characteristics of cultivated plants under 2-year-old Sengon trees significantly decreased. There was no significant difference in the leaf color index characters, leaf chlorophyll content, stem diameter, as well as the length and width of the flag leaf. This showed that the character was more determined by genetic factors. However, the overall character was still influenced by pressure due to environmental factors, with light being the dominant. Measurements showed that the intensity of sunlight on open land was 52800 lux, which decreased to 10468 lux on agroforestry land (shade 80%). The limitation of the light availability was the main factor contributing to the genotypic response experiencing a decrease in the ability to optimally express morphological and agronomic characters.

Sunlight is a source of energy for the process of photosynthesis. The absorption of sunlight by the plant canopy is an important factor that determines photosynthesis and plant yield. A previous research reported that plants use the light spectrum in the wavelength range of 400-700 nm, commonly called Photosynthetically Active Radiation (PAR) (Prakash et al., 2023). Generally, the presence of shade affects the intensity of sunlight received by plants, which influences the availability of energy to be used for growth and yield processes (Raffo et al., 2020). To avoid the harmful effects of low light, tolerant varieties can be used to maintain the ability to produce carbohydrates, improve photosynthetic efficiency, and enhance the ability to produce antioxidants as a form of plant adaptation to stress in low light conditions (Kowalczewski et al., 2020).

Table 2. Character number of tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter of 2 rice genotypes in open environment, and agroforestry

Replication	Number of tillers				Plant height				Leaf color index				Leaf chlorophyll content				Stem diameter			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	10.00	23.00	11.00	9.00	70.00	84.00	60.00	66.00	26.10	20.90	13.30	18.30	2.95	2.36	1.50	2.07	0.56	0.69	0.43	0.41
2	14.00	18.00	8.00	10.00	72.00	80.00	70.00	74.00	32.90	18.40	13.10	24.20	3.72	2.08	1.48	2.73	0.51	0.65	0.61	0.36
3	21.00	20.00	9.00	8.00	80.00	86.00	72.00	68.00	24.90	14.20	15.20	19.50	2.81	1.60	1.72	2.20	0.41	0.58	0.60	0.49
4	15.00	15.00	12.00	11.00	65.00	84.00	62.00	70.00	18.50	14.10	14.70	15.90	2.09	1.59	1.66	1.80	0.43	0.62	0.47	0.59
5	13.00	15.00	7.00	11.00	70.00	82.00	70.00	66.00	22.70	12.90	20.40	11.90	2.57	1.46	2.31	1.34	0.59	0.53	0.48	0.52
Mean	14.60	18.20	9.40	9.80	71.40	83.20	66.80	68.80	25.02	16.10	15.34	17.96	2.83	1.82	1.73	2.03	0.50	0.61	0.52	0.47
Combine	16.40		9.60		312.00		208.50		20.56		16.65		2.32		1.88		0.56		0.50	
Stdev	4.01		1.65		66.63		60.28		6.29		3.87		0.71		0.44		0.09		0.08	
Notation	**				**				ns				ns				ns			
P-Value	0.001				0.002				0.161				0.161				0.240			

Note : O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% level t test.

Table 3. Characteristics of stem strength, length of flag leaf, the width of flag leaf, number of grains per panicle, and grain weight per panicle of 2 rice genotypes in an open environment and agroforestry

Replication	Stem strength				Flag leaf length				Flag leaf width				Number of grains per panicle				Grains weight per panicle			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	310.00	360.00	180.00	190.00	14.30	27.00	11.00	20.00	1.00	1.20	1.00	1.00	86.00	165.00	66.00	50.00	2.05	3.64	1.57	1.10
2	220.00	380.00	150.00	240.00	16.20	16.00	20.00	23.20	1.00	1.10	1.20	1.00	75.00	98.00	48.00	52.00	1.79	2.16	1.14	1.15
3	220.00	340.00	130.00	140.00	16.60	23.50	12.30	20.00	1.00	1.30	1.10	1.20	86.00	130.00	61.00	87.00	2.05	2.87	1.45	1.92
4	230.00	340.00	285.00	290.00	16.30	22.80	17.50	21.00	1.00	1.10	0.90	1.20	88.00	147.00	81.00	63.00	2.10	3.24	1.93	1.39
5	320.00	400.00	210.00	270.00	19.50	24.50	14.40	18.50	1.20	1.10	1.00	1.00	93.00	120.00	51.00	36.00	2.22	2.65	1.22	0.79
Mean	260.00	364.00	191.00	226.00	16.58	22.76	15.04	20.54	1.04	1.16	1.04	1.08	85.60	132.00	61.40	57.60	2.04	2.91	1.46	1.27
Gabungan	312.00		208.50		19.67		17.79		1.10		1.06		108.80		59.50		2.48		1.37	
Stdev	66.63		60.28		4.43		3.98		0.11		0.11		30.14		15.56		0.60		0.36	
Notation	**				ns				ns				**				**			
P-Value	0.001				0.226				0.373				0.001				0.001			

Note : O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% level t test.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In conclusion, the two genotypes of rice planted under 2-year-old Sengon stands experienced a decrease in the characters of the number of productive tillers, plant height, stem strength, number of grains, and grain weight per panicle. The IR 64 genotype decreased grain weight per panicle by 40.65% and the Situ Patenggang genotype by 56.21%.

The growth limitations imposed by the 2-year-old Sengon trees suppressed the expression of character indices of leaf color, leaf chlorophyll content, stem diameter, length, and width of flag leaves of two genotypes of rice plants. However, these results showed no statistically significant.

Recommendations

There is a need to evaluate the use of rice agroforestry systems under 2-year-old Sengon stands with a spacing of 2.5m × 2.5m. Moreover, when the conditions require further planting, thinning should be carried out beforehand to provide sufficient space for the intensity of sunlight to support the process of plant growth and production.

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[biodiv] Editor Decision

1 pesan

Smujo Editors via SMUJO <support@smujo.com> 19 September 2023 pukul 16.12
Balas Ke: Smujo Editors <editors@smujo.id>
Kepada: Dulbari Dulbari <dulbari@polinela.ac.id>

Dulbari Dulbari:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (Paraserianthes falcataria (L))". Complete your revision with a Table of Responses containing your answers to reviewer comments (for multiple comments) or enable Track Changes.

Our decision is: Revisions Required

Reviewer A:

Plagiarism under 5% without references

The sentences in shading need more attention to accomplish.

Please check the combined data of 312.00 and 208.50; that number is too high. Interestingly, Figure 1.b shows the right number.

Moreover, when the conditions require more development, maybe this paragraph is better if you are pleased with this modification.

The wording character and characteristic is better to explore which word is used in each paragraph. In the Brittanica Encyclopedia, a character is defined (in some of its definitions) as a set of qualities that make a place or thing different from other places or things. At the same time, the characteristic is defined as (in some of its definitions) a special quality or trait that makes a person, thing, or group different from others. For example, physical/genetic characteristics; (often + of) what are some of the characteristics of this breed of dog?; The distinctive/unique characteristics of the population.

Many paragraphs follow the Indonesian English standard modified to the US English as the standard protocol.

Table 1 is not yet being explored in the Result and Discussion.

Recommendation: Revisions Required

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Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (*Paraserianthes falcataria*)

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Manuscript received: DD MM 2016 (Date of abstract/manuscript submission). Revision accepted: .... 2016.

Abstract. The increase in population is the biggest challenge for the agricultural sector in providing food needs. ~~In Indonesia, the main problem in increasing food production~~The main problem in increasing food production in Indonesia is the limited agricultural land. T~~o address this issue and enhance production capacity, specifically for rice at the national level, there is a need to explore alternative land options~~here is a need to explore alternative land options to address this issue and enhance production capacity, specifically for rice at the national level. One of the potential solutions is to use land currently occupied by plantation crops and forests that can be managed through agroforestry. Sengon is a forestry plant that offers a comparative advantage for investigation ~~when combined~~ in agroforestry systems due to its relatively open canopy cover and classification as a legume. Therefore, this research aimed to determine the response of the morphological and agronomic characters of two ~~genotypes of rice~~rice genotypes planted in open land ~~conditions and~~ under 2-year-old sengon stands. The experiment was conducted from October 2017 to March 2018 in the Sengon community forest of Cikarawang, Bogor, with coordinates 06° 33.061' S and 106° 43.987' E. The results showed that two rice genotypes grown under one-year-old sengon stands experienced ~~a decrease in the number of~~decreased productive tillers, plant height, stem strength, and the number and ~~as well as the~~ weight of grains per panicle. The IR 64 genotype decreased by 40.65% in grain weight per panicle, while the Situ Patenggang genotype experienced a 56.21% decrease.

Keywords: Adaptation, agroforestry, constraint, sengon, shade

Abbreviations: RBD- randomized block design; G1-Genotype 1= IR46; G2-Genotype 2=Situ Patenggang; MST-weeks after planting; O-open land cultivation; A-Agroforestry system cultivation under 2-year-old sengon plants with a spacing of 2.5 m x 2.5 m.

Running title: Characteristics of rice plant genotypes under shade conditions.

INTRODUCTION

The population of Indonesia in 2021 is more than 270 million, with a growth rate of 1.22 per year (BPS~~,~~ 2022). This growing population ~~poses a challenge~~ challenges~~in ensuring~~ adequate food sufficiency, ~~which is a crucial factor in achieving the~~ crucial to achieving people's welfare ~~of the people~~. The adequacy of food, specifically rice, is a significant indicator of economic and political stability. Despite this significance, many effort~~s~~s to maintain food availability and stability ~~still~~ face various obstacles, including reduced productive agricultural land due to conversion for non-agricultural purposes. The land conversion ~~of land~~ for ~~the construction of~~ housing, factories, and industrial facilities ~~has a significant impact on the availability of agricultural land~~significantly impacts agricultural land availability. Therefore, to maintain production stability and food security, alternative solutions are important~~needed~~ to increase the area of agricultural land.

Therefore, o~~O~~ne ~~of the solutions that can be implemented is~~solution is planting ~~plant~~ ~~ing~~ food crops, specifically rice, on~~using~~ the plantation and forestry; ~~concept. T~~ this ~~practice, also known as agroforestry,~~agroforestry practice involves ~~the use of~~using forests for agricultural activities. According to Korneeva (2022), agroforestry is a land-use system where forest stands and crops are planted on the same land. Octavia et al.~~,~~ (2022) stated that agroforestr~~y is the main driving technique in the implementation of social forestry, with broad connotation~~, with broad connotations, is the main driving technique in implementing social forestry. Furthermore, the objectives of agroforestry or intercropping in forest areas (Nair et al.~~,~~ 2021)~~,~~ include (1) increasing food supply, (2) expanding employment opportunities, (3) increasing the income and welfare of the community around the forest, and (4) increasing the success of forest plantations.

A~~Defines a~~groforestry is supposed as optimal and sustainable land use~~, by combining forestry and agricultural activities on the same land management unit, considering the physical, social, economic, and cultural conditions of the participating communities~~ by combining forestry and agricultural activities on the same land management, considering the participating communities' physical, social, economic, and cultural conditions (de Mendonça et al.~~,~~. 2022). The main purpose of agroforestry and the intercropping system is to improve the welfare of village communities around the forest. This ~~is carried out to provide~~provides ~~opportunities for communities or '*pesanggem*' farmer~~communities or 'pesanggem' farmers opportunities to grow food crops to~~and~~ increase their income. Through this approach, villagers around the forest are expected to play an ~~play an~~ active role in ~~efforts to conserve~~conserving and protecting the forest and land from damage.

Moreover, ~~There is a need to~~ research ~~on the adaptation of rice plants to low light stress conditions under plant stands~~adapting rice plants to low light stress conditions under plant stands is required. One suitable forestry vegetation for agroforestry with a light canopy is Sengon (*Paraserianthes falcataria* (L).), which is a native to Indonesia and thrives on well-drained, non-flooded land (Danarto et al~~.,~~. 2019). Sengon is frequently incorporated into agroforestry systems due to its relatively open canopy cover and leguminous characteristics. The ~~roots of the Sengon (*Leguminoceae*)~~Sengon (Leguminoceae) roots ~~can~~ form symbiotic relationships with Rhizobium, resulting in root nodules that ~~can~~ bind free Nitrogen from the air. This phenomenon contributes to the ~~significant role of the plant in maintaining the availability of nutrients,~~ plant's significant role in maintaining nutrient availability, specifically N, in the soil (Binkley and~~&~~ Fisher~~,~~ 2019).

Increasing the area of intercropping crops (agroforestry) and providing forest areas for food development is continuously carried out ~~as an effort~~ in the forestry sector to support food security (Duffy et al~~.,~~. 2021). Furthermore, Sengon trees can ~~also~~ be combined with rice (*Oryza sativa* L.) on the same land, providing an alternative solution to increase community food security. Rice is a~~ type of~~n agricultural crop that can be developed on dry land; h~~. H~~igh rice production will increase ~~the supply of rice which incidentally~~rice supply, ~~is~~ a basic need for the Indonesian people. However, there are several obstacles in ~~the development of~~developing rice varieties under plant stands, ~~. This~~ ~~includes~~ including ~~the determination of~~determining genotypes that ~~can~~ effectively adapt and the appropriate age of Sengon stands for intercropping~~ with rice plants~~.

This research aimed to determine the response of the morphological and agronomic characters of two ~~genotypes of rice~~rice genotypes planted in open land conditions and under 2-year-old sengon stands. The results ~~are expected to~~will be used as input for increasing rice production capacity under agroforestry plantations or forestry plantations.

MATERIALS AND METHODS

Treatment and research design

The research was conducted from October 2017 to March 2018, using community forest land in Cikarang Village, Bogor Regency, West Java, at coordinates 06° 33.061' North Latitude and 106° 43.987' South Latitude. The land was planted with 2-year-old Sengon, spaced at 2.5 m x 2.5 cm in~~, and~~ an open land area. The analysis was arranged using a randomized block design (RBD) with a single-factor treatment of rice genotypes~~,~~ consisting of IR64 (G1) and Situ Patenggang (G2). Each treatment was repeated 5 times in 2 cultivation systems, namely open land cultivation (O) and agroforestry system cultivation under 2-year-old sengon plants ~~with a spacing of 2.5 m x 2.5 m~~ (A). The linear model and analysis of variance followed the approach by Mattjik and~~&~~ Sumertajaya (2013):

$$Y_{ij} = \mu + \tau_i + \beta_j + \acute{\varepsilon}_{ij}.$$

Notes: Y_{ij} –Observational value in the Ist treatment and jth group, μ-average, τ_i-effect of the ith treatment, β_j-jth group effect, $\acute{\varepsilon}_{ij}$-random effect in the Ith treatment and jth group.

Indicators of environmental conditions for the two planting locations ~~were~~ are shown in Table 1.

Table 1. Environmental indicators for planting locations

Commented [A1]: Table 1 is not yet being explored in the Result and Discussion.

Indicator	Open	Agroforestry	Information
pH KCl	4.29	4.53	
H_2O	4.90	5.20	
N-Total	0.26	1.62	%
P-Total	131.90	105.34	mg P_2O_5 100g^{-1}
K-Total	96.25	112.42	mg K_2O 100g^{-1}
P-Tersedia	11.28	14.32	P_2O_5 ppm
C-Organik	0.25	1.74	%
KTK	21.43	21.41	Cmol(+) kg^{-1}
Al-dd	0.26	0.78	Cmol(+) kg^{-1}
H-dd	0.33	0.40	Cmol(+) kg^{-1}
Ca-dd	3.04	3.36	Cmol(+) kg^{-1}
Mg-dd	2.82	3.30	Cmol(+) kg^{-1}
K-dd	0.77	1.20	Cmol(+) kg^{-1}
Na-dd	0.15	0.11	Cmol(+) kg^{-1}

Research implementation

The soil was processed to a depth of 25-30 cm, followed by creating beds with a width of 100 cm and a length of 1,000 cm. Seeds were sown directly at ~~a spacing of 25 cm x 25 cm~~25 cm x 25 cm spacing, with 2-3 seeds per planting hole. Basic fertilization was carried out ~~at the time of~~when planting Urea 100 kg ha^{-1}, TSP 200 kg ha^{-1}, and KCl 50 kg ha^{-1}. Subsequently, a follow-up fertilization was conducted 4 weeks after planting, using Urea 100 kg ha^{-1} and KCl 50 kg ha^{-1}. Pest and disease control was ~~also~~ carried out using pesticides according to plant conditions in the field with recommended doses. Weed control was carried out twice at the age of 3 and 6 weeks after planting (WAT).

The ~~observation of~~ agronomic and morphological characteristics~~s~~ observation includes~~encompassed~~ several aspects~~,~~ ~~namely~~: the number of productive tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter, stem strength, ~~number of~~ grain per panicle, and grain weight per panicle. These observations were carried out ~~in line with~~per the Guidelines for Characterization and Evaluation of Rice Plants (Silitonga et al.~~,~~ 2014).

~~Leaf~~ The leaf color index was observed~~ations were~~ ~~carried out~~ using SPAD meters. Observation of chlorophyll content was calculated using the equation: y = 0.113x, where y is the total leaf chlorophyll content, 0.113 = constant, and x = level of the greenness of leaves (~~results~~ from~~of~~ SPAD measurements) (Dulbari: unpublished data).

The observational data were analyzed for diversity using the Bartlett test. When the data met the requirements, further analysis of variance was carried out. Subsequently, the differences between treatments were analyzed using the T-test with α = 0.05.

RESULTS AND DISCUSSION

Number of productive tillers and plant height

The results of observing the number of tillers and plant height characteristics ~~were~~ are shown in Figure 1.

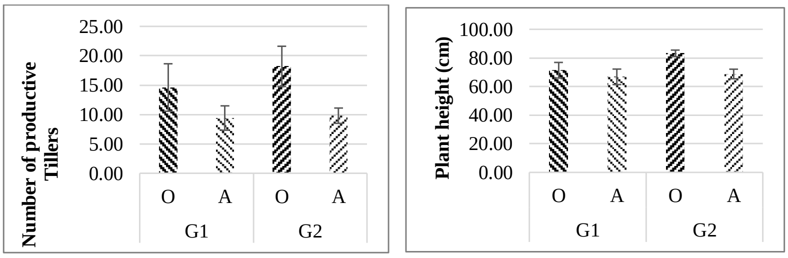

Figure 1. a-number of productive tiller character, b-plant height character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The two rice genotypes experienced decreased growth and yield responses due to the dominant environmental influences of reduced sunlight. The reduction in response to plant height and the number of productive tillers in the two rice genotypes was due to the low intensity of sunlight, leading to a hindered rate of photosynthesis~~,~~; ~~tt's~~ it's supposed to be a genetic factor. Th~~at~~is showed ~~that~~ plants no longer have the energy to distribute assimilate~~ss~~ production to the demanded~~necessary~~ plant parts. This distribution was done using tools such as proteins and proton pumps driven by ATP (ATP-Ase), which necessitated energy and enzyme~~used tools such as proteins, and proton pumps driven by ATP (ATP-Ase), necessitating energy and enzymes for the process~~s. Similarly, (Amin et al.~~,~~ 2021) stated that plants maintained an electrochemical balance within the entire biomembrane to ensure survival.

The closing rate of 2-year-old Sengon stands with a spacing of 2.5 m x 2.5 m prevented light interception by approximately 80%. Therefore, ~~the process of~~ photosynthesis, which served as the main energy source for plants to carry out growth processes, was disrupted.

Leaf color index character and leaf chlorophyll content

The results of leaf color index characteristic observations and leaf chlorophyll content are shown in Figure 2.

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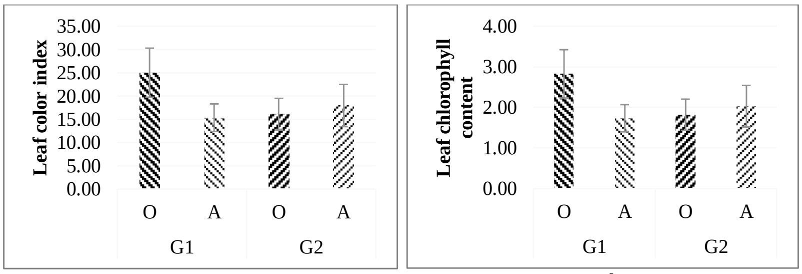

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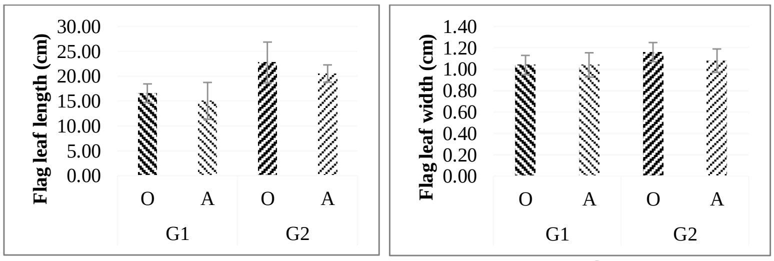
Figure 2. a-leaf color index (SPAD), b-leaf chlorophyll content (Chl Leaf), G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The ~~leaf color index characters and leaf chlorophyll content of the two genotypes~~two genotypes' leaf color index characters and leaf chlorophyll content had different tendencies. For genotype 1 (IR 64), these variables showed ~~a decrease in~~decreased growing conditions under 2-year-old sengon stands (agroforestry). The leaf color index decreased from 25.02 to 15.34, while the chlorophyll content of the leaves reduced from 2.83 to 1.73. For genotype 2 (Situ Patenggang), the variables showed a tendency to increase in growing conditions under 2-year-old sengon stands (agroforestry), where leaf color index increased from 16.10 to 17.96, and chlorophyll content increased from 1.82 to 2.03. Th~~at~~is showed ~~that~~ the genotypic response to leaf color index characters and chlorophyll content ~~was different due to the variation in~~differed due to the adaptability of the IR64 and Situ Patenggang rice genotypes to shade stress.

Each genotype exhibited a different response and ability to adapt to the environment. In this research, the plant growth environment was different, specifically ~~in terms of~~regarding sunlight intensity. ~~The differences in light intensity were responded to by plants~~Plants responded to the differences in light intensity according to their genetic capacity. Furthermore, plants developed acclimatization and plasticity methods to respond to environmental stress through morphological, anatomical, and physiological adjustments (Yetgin~~,~~ 2023).

Flag leaf size character

The results of observations of flag leaf size characters ~~were~~ are shown in Figure 3.



a b

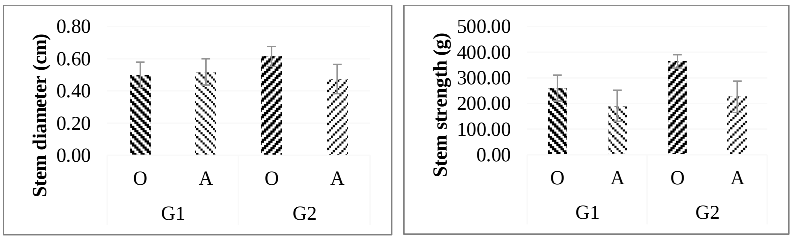
Figure 3. a-flag leaf length character, b-flag leaf width character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The ~~responses to flag leaf size characters (length and width) of the two rice genotypes~~two rice genotypes' responses to flag leaf size characters (length and width) ~~did not show any~~showed no significant differences under open location and 2-year-old sengon (agroforestry)~~ planting conditions~~ planting. However, significant variations were observed between the genotypes, indicating that the genotypes had different adaptation abilities to the stresses. The IR64 genotype showed a relatively stable response to flag leaf length and width, namely 16.58 and 15.04, as well as 1.04 and 1.04. Meanwhile, the Situ Patenggang genotype showed an insignificant decreasing trend for length measurements from 22.76 to 20.54 and width sizes from 1.16 to 1.08.

The morphology of ~~the flag leaf (Sink) of rice plants~~rice plants' flag leaf (Sink) ~~played an important role~~was important in ~~the process of filling the grains of the plant~~filling the plant's grains. The large sink characteristic in superior ~~varieties of rice~~rice varieties had a higher photosynthetic rate. Furthermore, the upright morphology of the leaves allowed greater penetration and distribution of light to the bottom, causing an increase in plant photosynthesis. According to ~~a~~ previous research, the photosynthesis of plants in upright leaf canopies is about 20% higher than in drooping leaf canopies under high leaf area index conditions (Pan et al.~~,~~ 2023). The flag leaf, as a light-harvesting organ, can allocate its assimilates ~~results for~~to panicle formation, thereby influencing the length of the panicle and the number of seeds per panicle. The less ideal flag leaf morphology also affected tiller ~~growth~~ and grain growth (Liu et al.~~,~~ 2014). Furthermore, ~~the size of~~ the flag leaf size affected the number of stomata pores, ~~which influenced~~influencing the ability to exchange H_2O and CO_2 (Franks and~~&~~ Beerling~~,~~ 2009).

Diameter and stem strength character

The results of observations of stem diameter and strength characters ~~were~~ are shown in Figure 4



a b

Figure 4. a-stem diameter character, b-stem strength character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The responses of the two rice genotypes, cultivated under open conditions and 2-year-old sengon trees, did not show significant differences in the stem diameter character. However, there was a significant variation in the stem strength characteristics. The ~~responses of the stem diameter characters of the two genotypes were different, as~~ IR64 ~~showed a tendency~~tended not to experience a change in stem diameter, compared to Situ Patenggang~~ which exhibited a decrease in~~, which decreased stem diameter from 0.61 cm to 0.47 cm. On~~Under~~ underexposed conditions and a 2-year-old Sengon tree to stem strength characters, both genotypes experienced a significant decrease. The IR 64 genotype decreased from 260.00 g to 191.00 g, and Situ Patenggang reduced from 364.00 g to 226.00 g.

The characteristic of stem strength ~~was~~ is crucial~~needed~~ for plants to withstand lodging, which can significantly affect crop production due to potential yield losses (Dulbari et al.~~,~~ 2018). Larger stem diameter plants also exhibit better strength and the characteristic of stem strength is significantly correlated with stem diameter, at a correlation coefficient value (0.77) (Dulbari; data has not been published). Th~~i~~ats~~ ~~ indicated ~~that genotypes of~~ rice plant~~s~~ genotypes with a larger lower stem diameter (± 10 cm above the soil surface) had a better stem strength, thereby followi~~strengtheni~~ng the research of (Zhang et al.~~,~~ 2014) and (Dreccer et al.~~,~~ 2020)

~~Character~~ The number of grain and grain weight characteristics per panicle

The results of observing the character of the number of grains and the weight of grain per panicle ~~were~~ are shown in Figure 5.

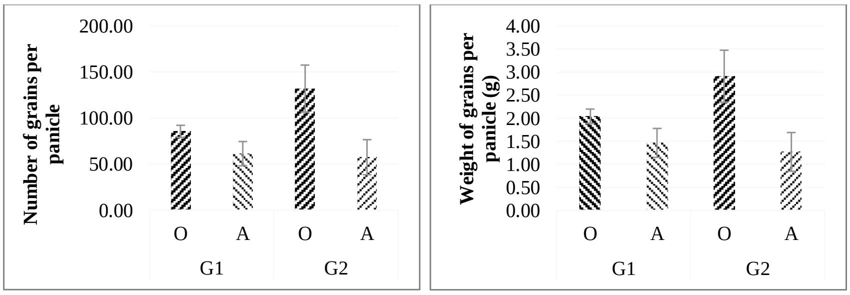


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Figure 5. a-the number of grains per panicle character, b-the weight of grains per panicle, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The response of the ~~two~~ rice genotypes cultivated in open land conditions and under 2-year-old Sengon trees experienced a significant decrease in the number of grains per panicle and grain weight per panicle, which were the yield component characteristics. The IR 64 genotype exhibited a smaller reduction in the number of grains per panicle (85.00 to 61.40)~~,~~ compared to the Situ Patenggang (132.00 to 57.60). Similarly, the grain weight per panicle also had the same tendency, with IR 64 genotypes ranging from 2.40 to 1.46 (40.65%) and Situ Patenggang from 2.90 g to 1.27 g (56.21%). This showed that genotype ~~had a significant influence on~~significantly influenced planting plans under agroforestry crop stands~~.~~.

The characteristics of grain number and weight were the results of plant metabolism processes, which were closely related to the process of photosynthetic ability (source) and the distribution of the assimilates to the sink. ~~The ability of plants to produce the amount of grain and the weight of grain~~Environmental conditions, such as light, temperature, and humidity, significantly influenced plants' ability to produce the grain amount and weight per panicle~~ per panicle was significantly influenced by environmental conditions, such as light, temperature, and humidity~~. Furthermore, light intensity was closely related to temperature, with lower values resulting in reduced rice products and quality (Dutta et al.~~,~~ 2017).

Light is~~played a~~ crucial~~significant role~~ in regulating the opening and closing of stomata. Lower light intensity will make stomata tend to close, thereby hindering ~~the entry of~~ CO_2 entry. Limited CO_2 and sunlight also caused a decrease in the rate of photosynthesis, impacting the assimilation of carbohydrates and biomass formation (Liu et al.~~,~~ 2014). Moreover, the regulation of stomatal opening is a dynamic and reversible process;~~, where~~ water loss and CO_2 inflow ~~can be~~ rapidly adjust~~ed~~ in response to several environmental and intrinsic signals, such as light, CO_2, and the plant stress hormone abscisic acid (Bhattacharya~~,~~ 2021). The ability of plants to produce and distribute photosynthate to their storage organs is an important part of increasing crop production (Fischer et al., 2012).

Agronomic and morphological characteristics of two rice genotypes under open conditions and agroforestry

The results of the observations of the agronomic and morphological characters of the two rice genotypes planted in open land conditions and under 2-year-old sengon stands ~~were~~ are shown in Table 2.

The agronomic and morphological characters of the two rice genotypes grown in different environmental conditions (open and under a 2-year-old Sengon stand) showed different responses. These included the number of tillers, plant height, stem strength, number of grains per panicle, and grain weight per panicle. The response of the agronomic and morphological characteristics of cultivated plants under 2-year-old Sengon trees significantly decreased. There was no significant difference in the leaf color index characters, leaf chlorophyll content, stem diameter, as well as the length and width of the flag leaf. This showed that the character was more determined by genetic factors. However, the overall character was still influenced by pressure due to environmental factors, with light being the dominant. Measurements showed that the intensity of sunlight on open land was 52,800 lux, which decreased to 10,468 lux on agroforestry land (shade 80%). The limitation of ~~the~~ light availability was the main ~~factor~~ contributing factor to the genotypic response experiencing a decrease~~ in the~~d ability to ~~optimally express morphological and agronomic characters~~express morphological and agronomic characters optimally.

Sunlight is a source of energy for ~~the process of~~ photosynthesis. The absorption of sunlight by the plant canopy is an important factor that determines photosynthesis and plant yield. ~~A p~~Previous research reported that plants use the light spectrum in the ~~wavelength range of 400-700 nm,~~ 400-700 nm wavelength range, commonly called Photosynthetically Active Radiation (PAR) (Prakash et al.~~,~~ 2023). Generally, ~~the presence of shade affects the intensity of sunlight received by plants, which influences the availability of energy to be used f~~shade affects the intensity of sunlight plants receive, influencing energy availability or growth and yield processed~~s~~ (Raffo et al., 2020). Therefore, to avoid the harmful effects of low light, tolerant varieties can be used to maintain the ability to produce carbohydrates, improve photosynthetic efficiency, and enhance the ability to produce antioxidants as a form of plant adaptation to stress in ~~low~~ low-light conditions (Kowalczewski et al.~~,~~ 2020).

Table 2. Character number of tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter of 2 rice genotypes in an open environment, and agroforestry

Replication	Number of tillers				Plant height				Leaf color index				Leaf chlorophyll content				Stem diameter			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	10.00	23.00	11.00	9.00	70.00	84.00	60.00	66.00	26.10	20.90	13.30	18.30	2.95	2.36	1.50	2.07	0.56	0.69	0.43	0.41
2	14.00	18.00	8.00	10.00	72.00	80.00	70.00	74.00	32.90	18.40	13.10	24.20	3.72	2.08	1.48	2.73	0.51	0.65	0.61	0.36
3	21.00	20.00	9.00	8.00	80.00	86.00	72.00	68.00	24.90	14.20	15.20	19.50	2.81	1.60	1.72	2.20	0.41	0.58	0.60	0.49
4	15.00	15.00	12.00	11.00	65.00	84.00	62.00	70.00	18.50	14.10	14.70	15.90	2.09	1.59	1.66	1.80	0.43	0.62	0.47	0.59
5	13.00	15.00	7.00	11.00	70.00	82.00	70.00	66.00	22.70	12.90	20.40	11.90	2.57	1.46	2.31	1.34	0.59	0.53	0.48	0.52
Mean	14.60	18.20	9.40	9.80	71.40	83.20	66.80	68.80	25.02	16.10	15.34	17.96	2.83	1.82	1.73	2.03	0.50	0.61	0.52	0.47
Combine	16.40		9.60		312.00		208.50		20.56		16.65		2.32		1.88		0.56		0.50	
Stdev	4.01		1.65		66.63		60.28		6.29		3.87		0.71		0.44		0.09		0.08	
Notation	**				**				ns				ns				ns			
P-Value	0.001				0.002				0.161				0.161				0.240			

Note~~-~~: O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% t-test level ~~t-test~~.

Table 3. Characteristics of stem strength, length of flag leaf, the width of flag leaf, number of grains per panicle, and grain weight per panicle of 2 rice genotypes in an open environment and agroforestry

Replication	Stem strength				Flag leaf length				Flag leaf width				Number of grains per panicle				Grain~~s~~ weight per panicle			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	310.00	360.00	180.00	190.00	14.30	27.00	11.00	20.00	1.00	1.20	1.00	1.00	86.00	165.00	66.00	50.00	2.05	3.64	1.57	1.10
2	220.00	380.00	150.00	240.00	16.20	16.00	20.00	23.20	1.00	1.10	1.20	1.00	75.00	98.00	48.00	52.00	1.79	2.16	1.14	1.15
3	220.00	340.00	130.00	140.00	16.60	23.50	12.30	20.00	1.00	1.30	1.10	1.20	86.00	130.00	61.00	87.00	2.05	2.87	1.45	1.92
4	230.00	340.00	285.00	290.00	16.30	22.80	17.50	21.00	1.00	1.10	0.90	1.20	88.00	147.00	81.00	63.00	2.10	3.24	1.93	1.39
5	320.00	400.00	210.00	270.00	19.50	24.50	14.40	18.50	1.20	1.10	1.00	1.00	93.00	120.00	51.00	36.00	2.22	2.65	1.22	0.79
Mean	260.00	364.00	191.00	226.00	16.58	22.76	15.04	20.54	1.04	1.16	1.04	1.08	85.60	132.00	61.40	57.60	2.04	2.91	1.46	1.27
Gabungan	312.00		208.50		19.67		17.79		1.10		1.06		108.80		59.50		2.48		1.37	
Stdev	66.63		60.28		4.43		3.98		0.11		0.11		30.14		15.56		0.60		0.36	
Notation	**				ns				ns				**				**			
P-Value	0.001				0.226				0.373				0.001				0.001			

Note~~-~~: O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% t-test level ~~t-test~~.

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CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In conclusion, the ~~two genotypes of rice~~rice genotypes planted under 2-year-old Sengon stands experienced ~~a decrease in the characters of the number of~~decreased productive tillers, plant height, stem strength, number of grains, and grain weight per panicle characteristics. The IR 64 genotype decreased grain weight per panicle by 40.65%, and the Situ Patenggang genotype by 56.21%.

The growth limitations imposed by the 2-year-old Sengon trees suppressed the expression of character indices of leaf color, leaf chlorophyll content, stem diameter, length, and width of flag leaves of two genotypes of rice plants. However, these results showed no statistically significant.

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Recommendations

There is a need to evaluate the use of rice agroforestry systems under 2-year-old Sengon stands with a spacing of 2.5m × 2.5m. Moreover, when the conditions require more development~~further planting~~, thinning should be carried out beforehand to provide sufficient space for the intensity of sunlight to support ~~the process of~~ plant growth and production.

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Table 3. Characteristics of stem strength, length of flag leaf, the width of flag leaf, number of grains per panicle, and grain weight per panicle of 2 rice genotypes in an open environment and agroforestry

Replication	Stem strength				Flag leaf length				Flag leaf width				Number of grains per panicle				Grain weight per panicle			
	O		**A**		**O**		**A**		**O**		**A**		**O**		**A**		**O**		**A**	
	G1	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**
1	310	360	180	190	14.3	27	11	20	1	1.2	1	1	86	165	66	50	2.05	3.64	1.57	1.1
2	220	380	150	240	16.2	16	20	23.2	1	1.1	1.2	1	75	98	48	52	1.79	2.16	1.14	1.15
3	220	340	130	140	16.6	23.5	12.3	20	1	1.3	1.1	1.2	86	130	61	87	2.05	2.87	1.45	1.92
4	230	340	285	290	16.3	22.8	17.5	21	1	1.1	0.9	1.2	88	147	81	63	2.1	3.24	1.93	1.39
5	320	400	210	270	19.5	24.5	14.4	18.5	1.2	1.1	1	1	93	120	51	36	2.22	2.65	1.22	0.79
Mean	260	364	191	226	16.58	22.76	15.04	20.54	1.04	1.16	1.04	1.08	85.6	132	61.4	57.6	2.04	2.91	1.46	1.27
Gabungan	312		208.5		19.67		17.79		1.1		1.06		108.8		59.5		2.48		1.37	
Stdev	66.63		60.28		4.43		3.98		0.11		0.11		30.14		15.56		0.6		0.36	
Notation	**				ns				ns				**				**			
P-Value	0.001				0.226				0.373				0.001				0.001			
	260.0	364.0	191.0	226.0	16.6	22.8	15.0	20.5	1.0	1.2	1.0	1.1	85.6	132.0	61.4	57.6	2.0	2.9	1.5	1.3
		312		208.5		19.67		17.79		1.1		1.06		108.8		59.5		2.48		1.366

Note : O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% t-test level.

Table 2. Character number of tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter of 2 rice genotypes in an open environment, and agroforestry

Replication	Number of tillers				Plant height				Leaf color index				Leaf chlorophyll content				Stem diameter			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	10	23	11	9	70	84	60	66	26.1	20.9	13.3	18.3	2.95	2.36	1.5	2.07	0.56	0.69	0.43	0.41
2	14	18	8	10	72	80	70	74	32.9	18.4	13.1	24.2	3.72	2.08	1.48	2.73	0.51	0.65	0.61	0.36
3	21	20	9	8	80	86	72	68	24.9	14.2	15.2	19.5	2.81	1.6	1.72	2.2	0.41	0.58	0.6	0.49
4	15	15	12	11	65	84	62	70	18.5	14.1	14.7	15.9	2.09	1.59	1.66	1.8	0.43	0.62	0.47	0.59
5	13	15	7	11	70	82	70	66	22.7	12.9	20.4	11.9	2.57	1.46	2.31	1.34	0.59	0.53	0.48	0.52
Mean	14.6	18.2	9.4	9.8	71.4	83.2	66.8	68.8	25.02	16.1	15.34	17.96	2.83	1.82	1.73	2.03	0.5	0.61	0.52	0.47
Combine	14.6		9.6		312		208.5		20.56		16.65		2.32		1.88		0.56		0.5	
Stdev	4.01		1.65		66.63		60.28		6.29		3.87		0.71		0.44		0.09		0.08	
Notation	**				**				ns				ns				ns			
P-Value	0.001				0.002				0.161				0.161				0.24			
	14.6	18.2	9.4	9.8	71.4	83.2	66.8	68.8	25.0	16.1	15.3	18.0	2.8	1.8	1.7	2.0	0.5	0.6	0.5	0.5
		16.4		9.6		77.3		67.8		20.56		16.65		2.32		1.88		0.56		0.5

Note : O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% level t test.

Table 1. Environmental indicators for planting locations

Indicator	Open	Agroforestry	Information
pH KCl	4.29	4.53	
H_2O	4.9	5.2	
N-Total	0.26	1.62	%
P-Total	131.9	105.34	mg P_2O_5 $100g^{-1}$
K-Total	96.25	112.42	mg K_2O $100g^{-1}$
P-Tersedia	11.28	14.32	P_2O_5 ppm
C-Organik	0.25	1.74	%
KTK	21.43	21.41	Cmol(+) kg^{-1}
Al-dd	0.26	0.78	Cmol(+) kg^{-1}
H-dd	0.33	0.4	Cmol(+) kg^{-1}
Ca-dd	3.04	3.36	Cmol(+) kg^{-1}
Mg-dd	2.82	3.3	Cmol(+) kg^{-1}
K-dd	0.77	1.2	Cmol(+) kg^{-1}
Na-dd	0.15	0.11	Cmol(+) kg^{-1}

Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (*Paraserianthes falcataria*)

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Abstract. The increase in population is the biggest challenge for the agricultural sector in providing food needs. The main problem in increasing food production in Indonesia is the limited agricultural land. There is a need to explore alternative land options to address this issue and enhance production capacity, specifically for rice at the national level. One of the potential solutions is to use land currently occupied by plantation crops and forests that can be managed through agroforestry. Sengon is a forestry plant that offers a comparative advantage for investigation in agroforestry systems due to its relatively open canopy cover and classification as a legume. Therefore, this research aimed to determine the response of the morphological and agronomic characters of two rice genotypes planted in open land under 2-year-old sengon stands. The experiment was conducted from October 2017 to March 2018 in the Sengon community forest of Cikarawang, Bogor, with coordinates 06° 33.061' S and 106° 43.987' E. The results showed that two rice genotypes grown under one-year-old sengon stands experienced decreased productive tillers, plant height, stem strength, and the number and weight of grains per panicle. The IR 64 genotype decreased by 40.65% in grain weight per panicle, while the Situ Patenggang genotype experienced a 56.21% decrease.

Keywords: Adaptation, agroforestry, constraint, sengon, shade

Abbreviations: RBD- randomized block design; G1-Genotype 1= IR46; G2-Genotype 2=Situ Patenggang; MST-weeks after planting; O-open land cultivation; A-Agroforestry system cultivation under 2-year-old sengon plants with a spacing of 2.5 m x 2.5 m.

Running title: Characteristics of rice plant genotypes under shade conditions.

INTRODUCTION

The population of Indonesia in 2021 is more than 270 million, with a growth rate of 1.22 per year (BPS 2022). This growing population challenges adequate food sufficiency, crucial to achieving people's welfare. The adequacy of food, specifically rice, is a significant indicator of economic and political stability. Despite this significance, many efforts to maintain food availability and stability face various obstacles, including reduced productive agricultural land due to conversion for non-agricultural purposes. The land conversion for housing, factories, and industrial facilities significantly impacts agricultural land availability. Therefore, to maintain production stability and food security, alternative solutions are important to increase the area of agricultural land.

Therefore, one solution is planting food crops, specifically rice, on the plantation and forestry; this agroforestry practice involves using forests for agricultural activities. According to Korneeva (2022), agroforestry is a land-use system where forest stands and crops are planted on the same land. Octavia et al. (2022) stated that agroforest, with broad connotations, is the main driving technique in implementing social forestry. Furthermore, the objectives of agroforestry or intercropping in forest areas (Nair et al. 2021) include (1) increasing food supply, (2) expanding employment opportunities, (3) increasing the income and welfare of the community around the forest, and (4) increasing the success of forest plantations.

Agroforestry is supposed as optimal and sustainable land use by combining forestry and agricultural activities on the same land management, considering the participating communities' physical, social, economic, and cultural conditions (de Mendonça et al. 2022). The main purpose of agroforestry and the intercropping system is to improve the welfare of village communities around the forest. This provides communities or 'pesanggem' farmers opportunities to grow food crops to increase their income. Through this approach, villagers around the forest are expected to play an active role in conserving and protecting the forest and land from damage.

Moreover, research on adapting rice plants to low light stress conditions under plant stands is required. One suitable forestry vegetation for agroforestry with a light canopy is Sengon (*Paraserianthes falcataria* (L).), which is a native to Indonesia and thrives on well-drained, non-flooded land (Danarto et al. 2019). Sengon is frequently incorporated into agroforestry systems due to its relatively open canopy cover and leguminous characteristics. The Sengon (Leguminoceae) roots form symbiotic relationships with Rhizobium, resulting in root nodules that bind free Nitrogen from the air. This phenomenon contributes to the plant's significant role in maintaining nutrient availability, specifically N, in the soil (Binkley and Fisher 2019).

Increasing the area of intercropping crops (agroforestry) and providing forest areas for food development is continuously carried out in the forestry sector to support food security (Duffy et al. 2021). Furthermore, Sengon trees can be combined with rice (*Oryza sativa* L.) on the same land, providing an alternative solution to increase community food security. Rice is an agricultural crop that can be developed on dry land; high rice production will increase rice supply, a basic need for the Indonesian people. However, there are several obstacles in developing rice varieties under plant stands, including determining genotypes that effectively adapt and the appropriate age of Sengon stands for intercropping.

This research aimed to determine the response of the morphological and agronomic characters of two rice genotypes planted in open land conditions and under 2-year-old sengon stands. The results will be used as input for increasing rice production capacity under agroforestry plantations or forestry plantations.

MATERIALS AND METHODS

Treatment and research design

The research was conducted from October 2017 to March 2018, using community forest land in Cikarang Village, Bogor Regency, West Java, at coordinates 06° 33.061' North Latitude and 106° 43.987' South Latitude. The land was planted with 2-year-old Sengon, spaced at 2.5 m x 2.5 cm in an open land area. The analysis was arranged using a randomized block design (RBD) with a single-factor treatment of rice genotypes consisting of IR64 (G1) and Situ Patenggang (G2). Each treatment was repeated 5 times in 2 cultivation systems, namely open land cultivation (O) and agroforestry system cultivation under 2-year-old sengon plants (A). The linear model and analysis of variance followed the approach by Mattjik and Sumertajaya (2013):

$$Y_{ij} = \mu + \tau_i + \beta_j + \acute{\varepsilon}_{ij}.$$

Notes: Y_{ij} –Observational value in the I^{st} treatment and j^{th} group, μ-average, τ_i-effect of the i^{th} treatment, β_j-j^{th} group effect, $\acute{\varepsilon}_{ij}$-random effect in the I^{th} treatment and j^{th} group.

Indicators of environmental conditions for the two planting locations are shown in Table 1.

Table 1. Environmental indicators for planting locations

Indicator	Open	Agroforestry	Information
pH KCl	4.29	4.53	
H_2O	4.90	5.20	
N-Total	0.26	1.62	%
P-Total	131.90	105.34	mg P_2O_5 $100g^{-1}$
K-Total	96.25	112.42	mg K_2O $100g^{-1}$
P-Tersedia	11.28	14.32	P_2O_5 ppm
C-Organik	0.25	1.74	%
KTK	21.43	21.41	Cmol(+) kg^{-1}
Al-dd	0.26	0.78	Cmol(+) kg^{-1}
H-dd	0.33	0.40	Cmol(+) kg^{-1}
Ca-dd	3.04	3.36	Cmol(+) kg^{-1}
Mg-dd	2.82	3.30	Cmol(+) kg^{-1}
K-dd	0.77	1.20	Cmol(+) kg^{-1}
Na-dd	0.15	0.11	Cmol(+) kg^{-1}

Research implementation

The soil was processed to a depth of 25-30 cm, followed by creating beds with a width of 100 cm and a length of 1,000 cm. Seeds were sown directly at 25 cm x 25 cm spacing, with 2-3 seeds per planting hole. Basic fertilization was carried out when planting Urea 100 kg ha^{-1}, TSP 200 kg ha^{-1}, and KCl 50 kg ha^{-1}. Subsequently, a follow-up fertilization was conducted 4 weeks after planting, using Urea 100 kg ha^{-1} and KCl 50 kg ha^{-1}. Pest and disease control was carried out using pesticides according to plant conditions in the field with recommended doses. Weed control was carried out twice at the age of 3 and 6 weeks after planting (WAT).

The agronomic and morphological characteristics observation includes several aspects: the number of productive tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter, stem strength, grain per panicle, and grain weight per panicle. These observations were carried out per the Guidelines for Characterization and Evaluation of Rice Plants (Silitonga et al. 2014).

The leaf color index was observed using SPAD meters. Observation of chlorophyll content was calculated using the equation: $y = 0.113x$, where y is the total leaf chlorophyll content, 0.113 = constant, and x = level of the greenness of leaves (from SPAD measurements) (Dulbari: unpublished data).

The observational data were analyzed for diversity using the Bartlett test. When the data met the requirements, further analysis of variance was carried out. Subsequently, the differences between treatments were analyzed using the T-test with $\alpha = 0.05$.

RESULTS AND DISCUSSION

Number of productive tillers and plant height

The results of observing the number of tillers and plant height characteristics are shown in Figure 1.

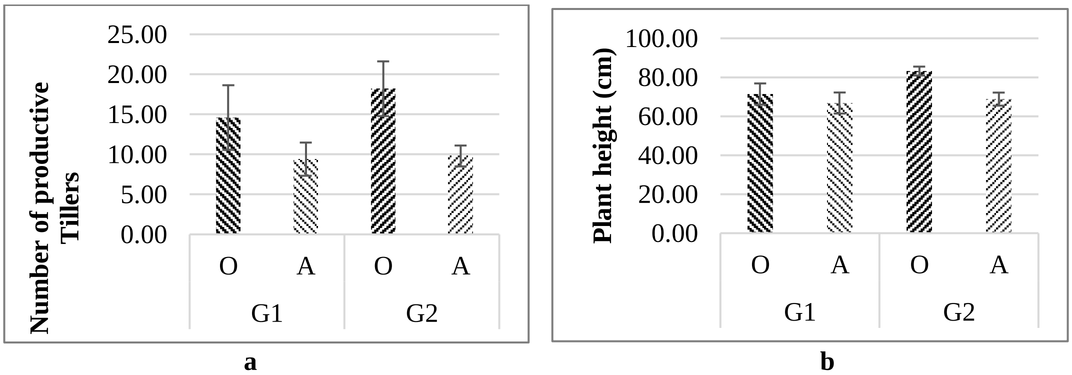


Figure 1. a-number of productive tiller character, b-plant height character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The two rice genotypes experienced decreased growth and yield responses due to the dominant environmental influences of reduced sunlight. The reduction in response to plant height and the number of productive tillers in the two rice genotypes was due to the low intensity of sunlight, leading to a hindered rate of photosynthesis; it's supposed to be a genetic factor. That showed plants no longer have the energy to distribute assimilates-production to the demanded plant parts. This distribution was done using tools such as proteins and proton pumps driven by ATP (ATP-Ase), which necessitated energy and enzymes. Similarly, (Amin et al. 2021) stated that plants maintained an electrochemical balance within the entire biomembrane to ensure survival.

The closing rate of 2-year-old Sengon stands with a spacing of 2.5 m x 2.5 m prevented light interception by approximately 80%. Therefore, photosynthesis, which served as the main energy source for plants to carry out growth processes, was disrupted.

Leaf color index character and leaf chlorophyll content

The results of leaf color index characteristic observations and leaf chlorophyll content are shown in Figure 2.

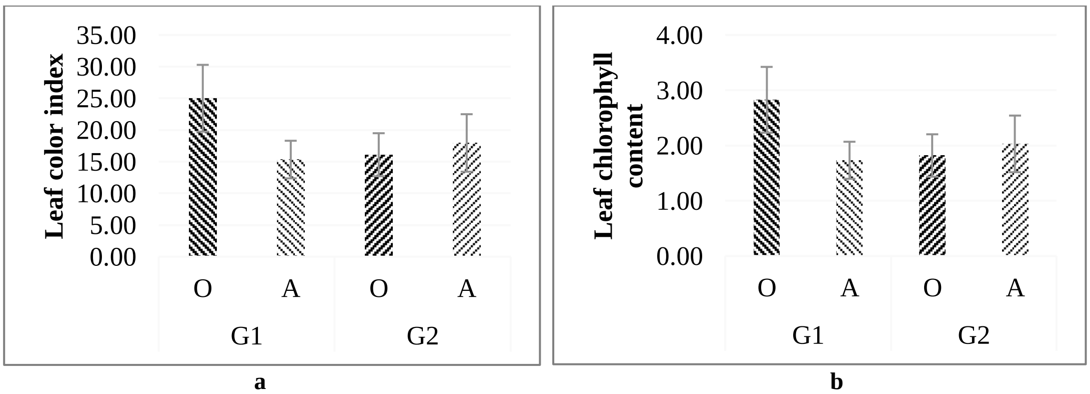


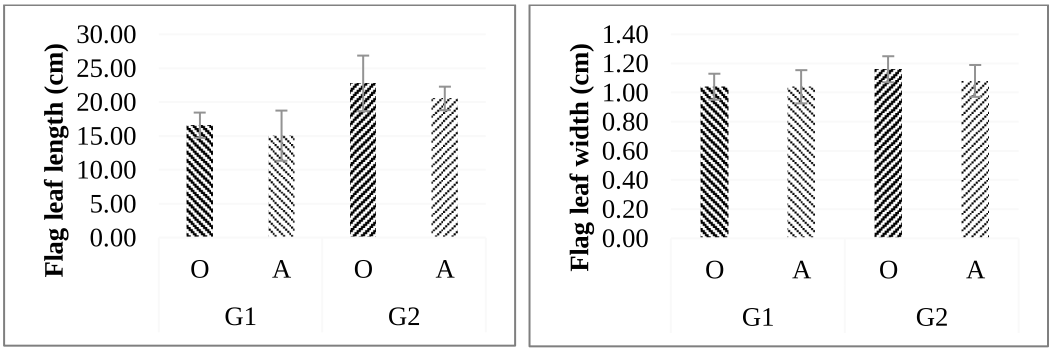
Figure 2. a-leaf color index (SPAD), b-leaf chlorophyll content (Chl Leaf), G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The two genotypes' leaf color index characters and leaf chlorophyll content had different tendencies. For genotype 1 (IR 64), these variables showed decreased growing conditions under 2-year-old sengon stands (agroforestry). The leaf color index decreased from 25.02 to 15.34, while the chlorophyll content of the leaves reduced from 2.83 to 1.73. For genotype 2 (Situ Patenggang), the variables showed a tendency to increase in growing conditions under 2-year-old sengon stands (agroforestry), where leaf color index increased from 16.10 to 17.96, and chlorophyll content increased from 1.82 to 2.03. That showed the genotypic response to leaf color index characters and chlorophyll content differed due to the adaptability of the IR64 and Situ Patenggang rice genotypes to shade stress.

Each genotype exhibited a different response and ability to adapt to the environment. In this research, the plant growth environment was different, specifically regarding sunlight intensity. Plants responded to the differences in light intensity according to their genetic capacity. Furthermore, plants developed acclimatization and plasticity methods to respond to environmental stress through morphological, anatomical, and physiological adjustments (Yetgin 2023).

Flag leaf size character

The results of observations of flag leaf size characters are shown in Figure 3.



a **b**

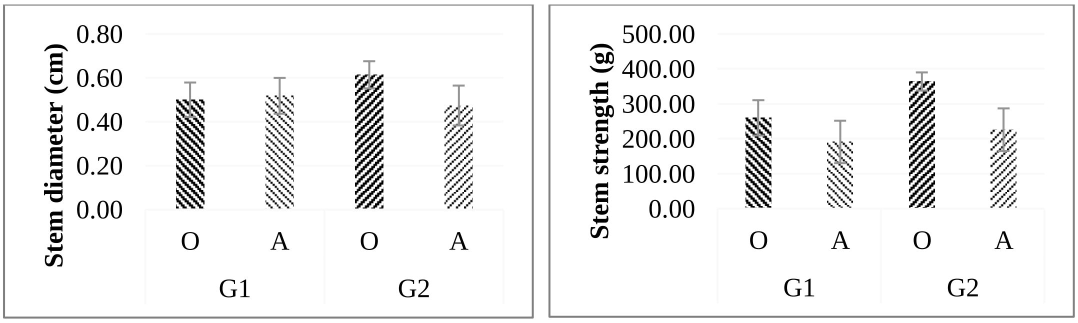
Figure 3. a-flag leaf length character, b-flag leaf width character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The two rice genotypes' responses to flag leaf size characters (length and width) showed no significant differences under open location and 2-year-old sengon (agroforestry) planting. However, significant variations were observed between the genotypes, indicating that the genotypes had different adaptation abilities to the stresses. The IR64 genotype showed a relatively stable response to flag leaf length and width, namely 16.58 and 15.04, as well as 1.04 and 1.04. Meanwhile, the Situ Patenggang genotype showed an insignificant decreasing trend for length measurements from 22.76 to 20.54 and width sizes from 1.16 to 1.08.

The morphology of rice plants' flag leaf (Sink) was important in filling the plant's grains. The large sink characteristic in superior rice varieties had a higher photosynthetic rate. Furthermore, the upright morphology of the leaves allowed greater penetration and distribution of light to the bottom, causing an increase in plant photosynthesis. According to previous research, the photosynthesis of plants in upright leaf canopies is about 20% higher than in drooping leaf canopies under high leaf area index conditions (Pan et al. 2023). The flag leaf, as a light-harvesting organ, can allocate its assimilates to panicle formation, thereby influencing the length of the panicle and the number of seeds per panicle. The less ideal flag leaf morphology also affected tiller and grain growth (Liu et al. 2014). Furthermore, the flag leaf size affected the number of stomata pores, influencing the ability to exchange H_2O and CO_2 (Franks and Beerling 2009).

Diameter and stem strength character

The results of observations of stem diameter and strength characters are shown in Figure 4



a **b**

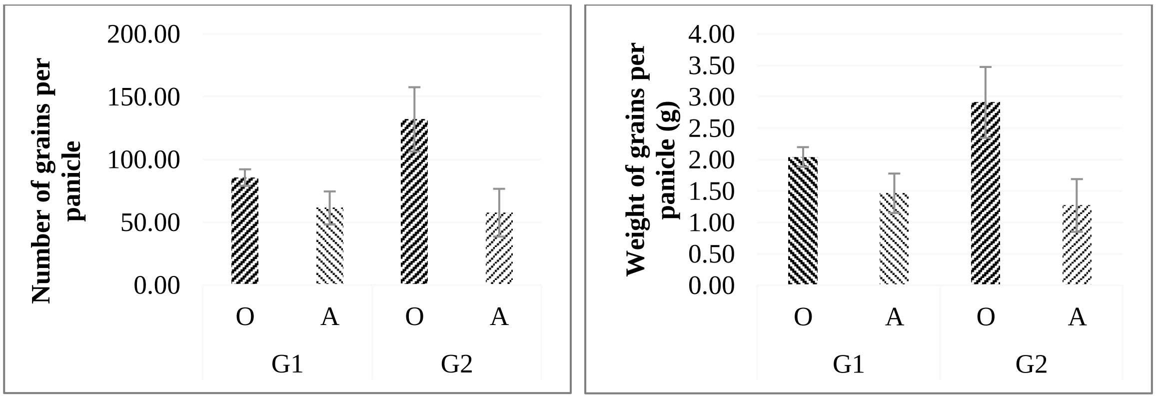
Figure 4. a-stem diameter character, b-stem strength character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The responses of the two rice genotypes, cultivated under open conditions and 2-year-old sengon trees, did not show significant differences in the stem diameter character. However, there was a significant variation in the stem strength characteristics. The IR64 tended not to experience a change in stem diameter, compared to Situ Patenggang, which decreased stem diameter from 0.61 cm to 0.47 cm. On underexposed conditions and a 2-year-old Sengon tree to stem strength characters, both genotypes experienced a significant decrease. The IR 64 genotype decreased from 260.00 g to 191.00 g, and Situ Patenggang reduced from 364.00 g to 226.00 g.

The characteristic of stem strength is crucial for plants to withstand lodging, which can significantly affect crop production due to potential yield losses (Dulbari et al. 2018). Larger stem diameter plants also exhibit better strength and the characteristic of stem strength is significantly correlated with stem diameter, at a correlation coefficient value (0.77) (Dulbari; data has not been published). That indicated rice plant genotypes with a larger lower stem diameter (± 10 cm above the soil surface) had a better stem strength, thereby following the research of (Zhang et al. 2014) and (Dreccer et al. 2020)

The number of grain and grain weight characteristics per panicle

The results of observing the character of the number of grains and the weight of grain per panicle are shown in Figure 5.



a **b**

Figure 5. a-the number of grains per panicle character, b-the weight of grains per panicle, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The response of the rice genotypes cultivated in open land conditions and under 2-year-old Sengon trees experienced a significant decrease in the number of grains per panicle and grain weight per panicle, which were the yield component characteristics. The IR 64 genotype exhibited a smaller reduction in the number of grains per panicle (85.00 to 61.40) compared to the Situ Patenggang (132.00 to 57.60). Similarly, the grain weight per panicle also had the same tendency, with IR 64 genotypes ranging from 2.40 to 1.46 (40.65%) and Situ Patenggang from 2.90 g to 1.27 g (56.21%). This showed that genotype significantly influenced planting plans under agroforestry crop stands.

The characteristics of grain number and weight were the results of plant metabolism processes, which were closely related to the process of photosynthetic ability (source) and the distribution of the assimilates to the sink. Environmental conditions, such as light, temperature, and humidity, significantly influenced plants' ability to produce the grain amount and weight per panicle. Furthermore, light intensity was closely related to temperature, with lower values resulting in reduced rice products and quality (Dutta et al. 2017).

Light is crucial in regulating the opening and closing of stomata. Lower light intensity will make stomata tend to close, thereby hindering CO_2 entry. Limited CO_2 and sunlight also caused a decrease in the rate of photosynthesis, impacting the assimilation of carbohydrates and biomass formation (Liu et al. 2014). Moreover, the regulation of stomatal opening is a dynamic and reversible process; water loss and CO_2 inflow rapidly adjust in response to several environmental and intrinsic signals, such as light, CO_2, and the plant stress hormone abscisic acid (Bhattacharya 2021). The ability of plants to produce and distribute photosynthate to their storage organs is an important part of increasing crop production (Fischer et al., 2012).

Agronomic and morphological characteristics of two rice genotypes under open conditions and agroforestry

The results of the observations of the agronomic and morphological characters of the two rice genotypes planted in open land conditions and under 2-year-old sengon stands are shown in Table 2.

The agronomic and morphological characters of the two rice genotypes grown in different environmental conditions (open and under a 2-year-old Sengon stand) showed different responses. These included the number of tillers, plant height, stem strength, number of grains per panicle, and grain weight per panicle. The response of the agronomic and morphological characteristics of cultivated plants under 2-year-old Sengon trees significantly decreased. There was no significant difference in the leaf color index characters, leaf chlorophyll content, stem diameter, as well as the length and width of the flag leaf. This showed that the character was more determined by genetic factors. However, the overall character was still influenced by pressure due to environmental factors, with light being the dominant. Measurements showed that the intensity of sunlight on open land was 52,800 lux, which decreased to 10,468 lux on agroforestry land (shade 80%). The limitation of light availability was the main contributing factor to the genotypic response experiencing a decreased ability to express morphological and agronomic characters optimally.

Sunlight is a source of energy for photosynthesis. The absorption of sunlight by the plant canopy is an important factor that determines photosynthesis and plant yield. Previous research reported that plants use the light spectrum in the 400-700 nm wavelength range, commonly called Photosynthetically Active Radiation (PAR) (Prakash et al. 2023). Generally, shade affects the intensity of sunlight plants receive, influencing energy availability or growth and yield processed (Raffo et al., 2020). Therefore, to avoid the harmful effects of low light, tolerant varieties can be used to maintain the ability to produce carbohydrates, improve photosynthetic efficiency, and enhance the ability to produce antioxidants as a form of plant adaptation to stress in low-light conditions (Kowalczewski et al. 2020).

Table 2. Character number of tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter of 2 rice genotypes in an open environment, and agroforestry

Replication	Number of tillers				Plant height				Leaf color index				Leaf chlorophyll content				Stem diameter			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	10.00	23.00	11.00	9.00	70.00	84.00	60.00	66.00	26.10	20.90	13.30	18.30	2.95	2.36	1.50	2.07	0.56	0.69	0.43	0.41
2	14.00	18.00	8.00	10.00	72.00	80.00	70.00	74.00	32.90	18.40	13.10	24.20	3.72	2.08	1.48	2.73	0.51	0.65	0.61	0.36
3	21.00	20.00	9.00	8.00	80.00	86.00	72.00	68.00	24.90	14.20	15.20	19.50	2.81	1.60	1.72	2.20	0.41	0.58	0.60	0.49
4	15.00	15.00	12.00	11.00	65.00	84.00	62.00	70.00	18.50	14.10	14.70	15.90	2.09	1.59	1.66	1.80	0.43	0.62	0.47	0.59
5	13.00	15.00	7.00	11.00	70.00	82.00	70.00	66.00	22.70	12.90	20.40	11.90	2.57	1.46	2.31	1.34	0.59	0.53	0.48	0.52
Mean	14.60	18.20	9.40	9.80	71.40	83.20	66.80	68.80	25.02	16.10	15.34	17.96	2.83	1.82	1.73	2.03	0.50	0.61	0.52	0.47
Combine	16.40		9.60		77.30		67.80		20.56		16.65		2.32		1.88		0.56		0.50	
Stdev	3.73		1.65		3.87		4.38		4.33		3.75		0.49		0.43		0.07		0.09	
Notation	**				**				ns				ns				ns			
P-Value	0.001				0.002				0.161				0.161				0.240			

Note: O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% t-test level.

Table 3. Characteristics of stem strength, length of flag leaf, the width of flag leaf, number of grains per panicle, and grain weight per panicle of 2 rice genotypes in an open environment and agroforestry

Replication	Stem strength				Flag leaf length				Flag leaf width				Number of grains per panicle				Grain weight per panicle			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	310.00	360.00	180.00	190.00	14.30	27.00	11.00	20.00	1.00	1.20	1.00	1.00	86.00	165.00	66.00	50.00	2.05	3.64	1.57	1.10
2	220.00	380.00	150.00	240.00	16.20	16.00	20.00	23.20	1.00	1.10	1.20	1.00	75.00	98.00	48.00	52.00	1.79	2.16	1.14	1.15
3	220.00	340.00	130.00	140.00	16.60	23.50	12.30	20.00	1.00	1.30	1.10	1.20	86.00	130.00	61.00	87.00	2.05	2.87	1.45	1.92
4	230.00	340.00	285.00	290.00	16.30	22.80	17.50	21.00	1.00	1.10	0.90	1.20	88.00	147.00	81.00	63.00	2.10	3.24	1.93	1.39
5	320.00	400.00	210.00	270.00	19.50	24.50	14.40	18.50	1.20	1.10	1.00	1.00	93.00	120.00	51.00	36.00	2.22	2.65	1.22	0.79
Mean	260.00	364.00	191.00	226.00	16.58	22.76	15.04	20.54	1.04	1.16	1.04	1.08	85.60	132.00	61.40	57.60	2.04	2.91	1.46	1.27
Combine	312.00		208.50		19.67		17.79		1.10		1.06		108.80		59.50		2.48		1.37	
Stdev	66.63		60.28		4.43		3.98		0.11		0.11		30.14		15.56		0.60		0.36	
Notation	**				ns				ns				**				**			
P-Value	0.001				0.226				0.373				0.001				0.001			

Note: O-open, A-agroforstry, G1-rice genotype (IR64), G2-rice genotype (Situ Patenggang), ns-not significant; **-significantly different in the α 1% t-test level.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In conclusion, the rice genotypes planted under 2-year-old Sengon stands experienced decreased productive tillers, plant height, stem strength, number of grains, and grain weight per panicle characteristics. The IR 64 genotype decreased grain weight per panicle by 40.65%, and the Situ Patenggang genotype by 56.21%.

The growth limitations imposed by the 2-year-old Sengon trees suppressed the expression of character indices of leaf color, leaf chlorophyll content, stem diameter, length, and width of flag leaves of two genotypes of rice plants. However, these results showed no statistically significant.

Recommendations

There is a need to evaluate the use of rice agroforestry systems under 2-year-old Sengon stands with a spacing of 2.5m × 2.5m. Moreover, when the conditions require more development, thinning should be carried out beforehand to provide sufficient space for the intensity of sunlight to support plant growth and production.

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Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (*Paraserianthes falcataria*)

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Abstract. *Dulbari, Mutaqin Z, Sutrisno H, Nuryanti NSP, Yuriansyah, Sudrajat D, Ahyuni D, Saputra H, Budiarti L, Priyadi, Rochman F, Rahmadi R, Firmansyah MA, Saijo. 2023. Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (*Paraserianthes falcataria*). Biodiversitas 24: xxxx-xxxx.* The increase in population is the biggest challenge for the agricultural sector in providing food needs. The main problem in increasing food production in Indonesia is the limited agricultural land. There is a need to explore alternative land options to address this issue and enhance production capacity, specifically for rice at the national level. One of the potential solutions is to use land currently occupied by plantation crops and forests that can be managed through agroforestry. Sengon is a forestry plant that offers a comparative advantage for investigation in agroforestry systems due to its relatively open canopy cover and classification as a legume. Therefore, this research aimed to determine the response of the morphological and agronomic characters of two rice genotypes planted in open land under 2-year-old sengon stands. The experiment was conducted from October 2017 to March 2018 in the Sengon community forest of Cikarawang, Bogor, with coordinates 06° 33.061' S and 106° 43.987' E. The results showed that two rice genotypes grown under one-year-old sengon stands experienced decreased productive tillers, plant height, stem strength, and the number and weight of grains per panicle. The IR 64 genotype decreased by 40.65% in grain weight per panicle, while the Situ Patenggang genotype experienced a 56.21% decrease.

Keywords: Adaptation, agroforestry, constraint, *sengon*, shade

Abbreviations: RBD: Randomized Block Design; G1: Genotype 1 IR46; G2: Genotype 2 Situ Patenggang; WAP: Weeks After Planting; O: Open land cultivation; A: Agroforestry system cultivation under 2-year-old *sengon* plants with a spacing of 2.5 m × 2.5 m

INTRODUCTION

The population of Indonesia in 2021 is more than 270 million, with a growth rate of 1.22 per year (BPS 2022). This growing population challenges adequate food sufficiency, crucial to achieving people's welfare. The adequacy of food, specifically rice, is a significant indicator of economic and political stability. Despite this significance, many efforts to maintain food availability and stability face various obstacles, including reduced productive agricultural land due to conversion for non-agricultural purposes. The land conversion for housing, factories, and industrial facilities significantly impacts agricultural land availability. Therefore, to maintain production stability and food security, alternative solutions are important to increase the area of agricultural land.

Therefore, one solution is planting food crops, specifically rice, on the plantation and forestry; this agroforestry practice involves using forests for agricultural activities. According to Korneeva (2022), agroforestry is a land-use system where forest stands and crops are planted on the same land. Octavia et al. (2022) stated that agroforest, with broad connotations, is the main driving technique in implementing social forestry. Furthermore, the objectives of agroforestry or intercropping in forest areas (Nair et al. 2021) include (i) increasing food supply, (ii) expanding employment opportunities, (iii) increasing the income and welfare of the community around the forest, and (iv) increasing the success of forest plantations.

Agroforestry is supposed as optimal and sustainable land use by combining forestry and agricultural activities on the same land management, considering the participating communities' physical, social, economic, and cultural conditions (de Mendonça et al. 2022). The main purpose of agroforestry and the intercropping system is to improve the welfare of village communities around the forest. This provides communities or *pesanggem f*armers opportunities to grow food crops to increase their income. Through this approach, villagers around the forest are expected to play an active role in conserving and protecting the forest and land from damage.

Moreover, research on adapting rice plants to low light stress conditions under plant stands is required. One suitable forestry vegetation for agroforestry with a light canopy is *sengon* (*Paraserianthes falcataria* (L.).), which is a native to Indonesia and thrives on well-drained, non-flooded land (Danarto et al. 2019). *Sengon* is frequently incorporated into agroforestry systems due to its relatively open canopy cover and leguminous characteristics. The *sengon* (Leguminoceae) roots form symbiotic relationships with Rhizobium, resulting in root nodules that bind free Nitrogen from the air. This phenomenon contributes to the plant's significant role in maintaining nutrient availability, specifically N, in the soil (Binkley and Fisher 2019).

Increasing the area of intercropping crops (agroforestry) and providing forest areas for food development is continuously carried out in the forestry sector to support food security (Duffy et al. 2021). Furthermore, Sengon trees can be combined with rice (*Oryza sativa* L.) on the same land, providing an alternative solution to increase community food security. Rice is an agricultural crop that can be developed on dry land; high rice production will increase rice supply, a basic need for the Indonesian people. However, there are several obstacles in developing rice varieties under plant stands, including determining genotypes that effectively adapt and the appropriate age of Sengon stands for intercropping.

This research aimed to determine the response of the morphological and agronomic characters of two rice genotypes planted in open land conditions and under 2-year-old *sengon* stands. The results will be used as input for increasing rice production capacity under agroforestry plantations or forestry plantations.

MATERIALS AND METHODS

Treatment and research design

The research was conducted from October 2017 to March 2018, using community forest land in Cikarang Village, Bogor Regency, West Java, at coordinates 06° 33.061' North Latitude and 106° 43.987' South Latitude. The land was planted with 2-year-old *sengon*, spaced at 2.5 m x 2.5 cm in an open land area. The analysis was arranged using a randomized block design (RBD) with a single-factor treatment of rice genotypes consisting of IR64 (G1) and Situ Patenggang (G2). Each treatment was repeated 5 times in 2 cultivation systems, namely open land cultivation (O) and agroforestry system cultivation under 2-year-old *sengon* plants (A). The linear model and analysis of variance followed the approach by Mattjik and Sumertajaya (2013):

$$Y_{ij} = \mu + \tau_i + \beta_j + \acute{\varepsilon}_{ij}.$$

Notes: Y_{ij} -Observational value in the Ist treatment and jth group, μ-average, τ_i-effect of the ith treatment, β_j-jth group effect, $\acute{\varepsilon}_{ij}$-random effect in the Ith treatment and jth group.

Indicators of environmental conditions for the two planting locations are shown in Table 1.

Table 1. Environmental indicators for planting locations

Indicator	Open	Agroforestry	Information
pH KCl	4.29	4.53	
H_2O	4.90	5.20	
N-Total	0.26	1.62	%
P-Total	131.90	105.34	mg P_2O_5 100g^{-1}
K-Total	96.25	112.42	mg K_2O 100g^{-1}
P-Tersedia	11.28	14.32	P_2O_5 ppm
C-Organik	0.25	1.74	%
KTK	21.43	21.41	Cmol(+) kg^{-1}
Al-dd	0.26	0.78	Cmol(+) kg^{-1}
H-dd	0.33	0.40	Cmol(+) kg^{-1}
Ca-dd	3.04	3.36	Cmol(+) kg^{-1}
Mg-dd	2.82	3.30	Cmol(+) kg^{-1}
K-dd	0.77	1.20	Cmol(+) kg^{-1}
Na-dd	0.15	0.11	Cmol(+) kg^{-1}

Research implementation

The soil was processed to a depth of 25-30 cm, followed by creating beds with a width of 100 cm and a length of 1,000 cm. Seeds were sown directly at 25 cm x 25 cm spacing, with 2-3 seeds per planting hole. Basic fertilization was carried out when planting Urea 100 kg ha^{-1}, TSP 200 kg ha^{-1}, and KCl 50 kg ha^{-1}. Subsequently, a follow-up fertilization was conducted 4 weeks after planting, using Urea 100 kg ha^{-1} and KCl 50 kg ha^{-1}. Pest and disease control was carried out using pesticides according to plant conditions in the field with recommended doses. Weed control was carried out twice at the age of 3 and 6 weeks after planting (WAT).

The agronomic and morphological characteristics observation includes several aspects: the number of productive tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter, stem strength, grain per panicle, and grain weight per panicle. These observations were carried out per the Guidelines for Characterization and Evaluation of Rice Plants (Silitonga et al. 2014).

The leaf color index was observed using SPAD meters. Observation of chlorophyll content was calculated using the equation: y = 0.113x, where y is the total leaf chlorophyll content, 0.113 = constant, and x = level of the greenness of leaves (from SPAD measurements) (Dulbari: unpublished data).

The observational data were analyzed for diversity using the Bartlett test. When the data met the requirements, further analysis of variance was carried out. Subsequently, the differences between treatments were analyzed using the T-test with α = 0.05.

RESULTS AND DISCUSSION

Number of productive tillers and plant height

The results of observing the number of tillers and plant height characteristics are shown in Figure 1.

The two rice genotypes experienced decreased growth and yield responses due to the dominant environmental influences of reduced sunlight. The reduction in response to plant height and the number of productive tillers in the two rice genotypes was due to the low intensity of sunlight, leading to a hindered rate of photosynthesis; it's supposed to be a genetic factor. That showed plants no longer have the energy to distribute assimilates-production to the demanded plant parts. This distribution was done using tools such as proteins and proton pumps driven by ATP (ATP-Ase), which necessitated energy and enzymes. Similarly, (Amin et al. 2021) stated that plants maintained an electrochemical balance within the entire biomembrane to ensure survival.

The closing rate of 2-year-old *sengon* stands with a spacing of 2.5 m x 2.5 m prevented light interception by approximately 80%. Therefore, photosynthesis, which served as the main energy source for plants to carry out growth processes, was disrupted.

Leaf color index character and leaf chlorophyll content

The results of leaf color index characteristic observations and leaf chlorophyll content are shown in Figure 2.

The two genotypes' leaf color index characters and leaf chlorophyll content had different tendencies. For genotype 1 (IR 64), these variables showed decreased growing conditions under 2-year-old sengon stands (agroforestry). The leaf color index decreased from 25.02 to 15.34, while the chlorophyll content of the leaves reduced from 2.83 to 1.73. For genotype 2 (Situ Patenggang), the variables showed a tendency to increase in growing conditions under 2-year-old *sengon* stands (agroforestry), where leaf color index increased from 16.10 to 17.96, and chlorophyll content increased from 1.82 to 2.03. That showed the genotypic response to leaf color index characters and chlorophyll content differed due to the adaptability of the IR64 and Situ Patenggang rice genotypes to shade stress.

Each genotype exhibited a different response and ability to adapt to the environment. In this research, the plant growth environment was different, specifically regarding sunlight intensity. Plants responded to the differences in light intensity according to their genetic capacity. Furthermore, plants developed acclimatization and plasticity methods to respond to environmental stress through morphological, anatomical, and physiological adjustments (Yetgin 2023).

Flag leaf size character

The results of observations of flag leaf size characters are shown in Figure 3.

The two rice genotypes' responses to flag leaf size characters (length and width) showed no significant differences under open location and 2-year-old *sengon* (agroforestry) planting. However, significant variations were observed between the genotypes, indicating that the genotypes had different adaptation abilities to the stresses. The IR64 genotype showed a relatively stable response to flag leaf length and width, namely 16.58 and 15.04, as well as 1.04 and 1.04. Meanwhile, the Situ Patenggang genotype showed an insignificant decreasing trend for length measurements from 22.76 to 20.54 and width sizes from 1.16 to 1.08.

The morphology of rice plants' flag leaf (Sink) was important in filling the plant's grains. The large sink characteristic in superior rice varieties had a higher photosynthetic rate. Furthermore, the upright morphology of the leaves allowed greater penetration and distribution of light to the bottom, causing an increase in plant photosynthesis. According to previous research, the photosynthesis of plants in upright leaf canopies is about 20% higher than in drooping leaf canopies under high leaf area index conditions (Pan et al. 2023). The flag leaf, as a light-harvesting organ, can allocate its assimilates to panicle formation, thereby influencing the length of the panicle and the number of seeds per panicle. The less ideal flag leaf morphology also affected tiller and grain growth (Liu et al. 2014). Furthermore, the flag leaf size affected the number of stomata pores, influencing the ability to exchange H_2O and CO_2 (Franks and Beerling 2009).

Diameter and stem strength character

The results of observations of stem diameter and strength characters are shown in Figure 4.

The responses of the two rice genotypes, cultivated under open conditions and 2-year-old *sengon* trees, did not show significant differences in the stem diameter character. However, there was a significant variation in the stem strength characteristics. The IR64 tended not to experience a change in stem diameter, compared to Situ Patenggang, which decreased stem diameter from 0.61 cm to 0.47 cm. On underexposed conditions and a 2-year-old *sengon* tree to stem strength characters, both genotypes experienced a significant decrease. The IR 64 genotype decreased from 260.00 g to 191.00 g, and Situ Patenggang reduced from 364.00 g to 226.00 g.

The characteristic of stem strength is crucial for plants to withstand lodging, which can significantly affect crop production due to potential yield losses (Dulbari et al. 2018). Larger stem diameter plants also exhibit better strength and the characteristic of stem strength is significantly correlated with stem diameter, at a correlation coefficient value (0.77) (Dulbari; data has not been published). That indicated rice plant genotypes with a larger lower stem diameter (± 10 cm above the soil surface) had a better stem strength, thereby following the research of (Zhang et al. 2014) and (Dreccer et al. 2020).

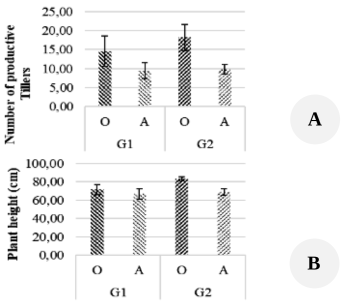

Figure 1. A. Number of productive tiller character, B. Plant height character. G1: Rice genotype 1 (IR64); G2: Rice genotype 2 (Situ Patenggang); O: Open, A: Agroforestry

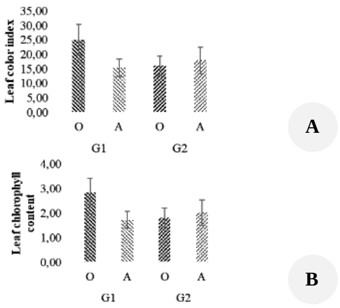

Figure 2. A. Leaf color index (SPAD), B. Leaf chlorophyll content (Chl Leaf), G1: Rice genotype 1 (IR64); G2: Rice genotype 2 (Situ Patenggang), O: Open; A: Agroforestry

The number of grain and grain weight characteristics per panicle

The results of observing the character of the number of grains and the weight of grain per panicle are shown in Figure 5.

The response of the rice genotypes cultivated in open land conditions and under 2-year-old *sengon* trees experienced a significant decrease in the number of grains per panicle and grain weight per panicle, which were the yield component characteristics. The IR 64 genotype exhibited a smaller reduction in the number of grains per panicle (85.00 to 61.40) compared to the Situ Patenggang (132.00 to 57.60). Similarly, the grain weight per panicle also had the same tendency, with IR 64 genotypes ranging from 2.40 to 1.46 (40.65%) and Situ Patenggang from 2.90 g to 1.27 g (56.21%). This showed that genotype significantly influenced planting plans under agroforestry crop stands.

The characteristics of grain number and weight were the results of plant metabolism processes, which were closely related to the process of photosynthetic ability (source) and the distribution of the assimilates to the sink. Environmental conditions, such as light, temperature, and humidity, significantly influenced plants' ability to produce the grain amount and weight per panicle. Furthermore, light intensity was closely related to temperature, with lower values resulting in reduced rice products and quality (Dutta et al. 2017).

Light is crucial in regulating the opening and closing of stomata. Lower light intensity will make stomata tend to close, thereby hindering CO_2 entry. Limited CO_2 and sunlight also caused a decrease in the rate of photosynthesis, impacting the assimilation of carbohydrates and biomass formation (Liu et al. 2014). Moreover, the regulation of stomatal opening is a dynamic and reversible process; water loss and CO_2 inflow rapidly adjust in response to several environmental and intrinsic signals, such as light, CO_2, and the plant stress hormone abscisic acid (Bhattacharya 2021). The ability of plants to produce and distribute photosynthate to their storage organs is an important part of increasing crop production (Fischer et al. 2012).

Agronomic and morphological characteristics of two rice genotypes under open conditions and agroforestry

The results of the observations of the agronomic and morphological characters of the two rice genotypes planted in open land conditions and under 2-year-old *sengon* stands are shown in Table 2.

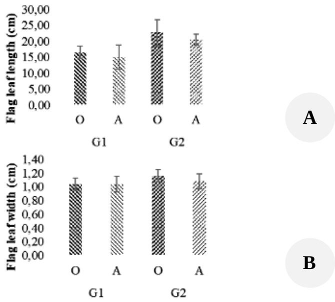

Figure 3. A. Flag leaf length character, B. Flag leaf width character. G1: Rice genotype 1 (IR64); G2: Rice genotype 2 (Situ Patenggang); O: Open; A: Agroforestry

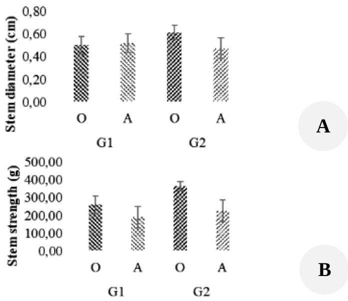

Figure 4. A. Stem diameter character, B. Stem strength character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

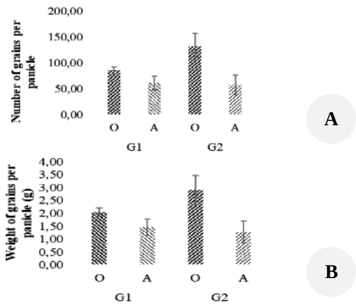

Figure 5. A. The number of grains per panicle character; B. The weight of grains per panicle; G1: Rice genotype 1 (IR64); G2: Rice genotype 2 (Situ Patenggang); O: Open; A: Agroforestry

Table 2. Character number of tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter of 2 rice genotypes in an open environment, and agroforestry

Replication	Number of tillers				Plant height				Leaf color index				Leaf chlorophyll content				Stem diameter			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	10.00	23.00	11.00	9.00	70.00	84.00	60.00	66.00	26.10	20.90	13.30	18.30	2.95	2.36	1.50	2.07	0.56	0.69	0.43	0.41
2	14.00	18.00	8.00	10.00	72.00	80.00	70.00	74.00	32.90	18.40	13.10	24.20	3.72	2.08	1.48	2.73	0.51	0.65	0.61	0.36
3	21.00	20.00	9.00	8.00	80.00	86.00	72.00	68.00	24.90	14.20	15.20	19.50	2.81	1.60	1.72	2.20	0.41	0.58	0.60	0.49
4	15.00	15.00	12.00	11.00	65.00	84.00	62.00	70.00	18.50	14.10	14.70	15.90	2.09	1.59	1.66	1.80	0.43	0.62	0.47	0.59
5	13.00	15.00	7.00	11.00	70.00	82.00	70.00	66.00	22.70	12.90	20.40	11.90	2.57	1.46	2.31	1.34	0.59	0.53	0.48	0.52
Mean	14.60	18.20	9.40	9.80	71.40	83.20	66.80	68.80	25.02	16.10	15.34	17.96	2.83	1.82	1.73	2.03	0.50	0.61	0.52	0.47
Combine	16.40		9.60		77.30		67.80		20.56		16.65		2.32		1.88		0.56		0.50	
Stdev	3.73		1.65		3.87		4.38		4.33		3.75		0.49		0.43		0.07		0.09	
Notation	**				**				ns				ns				ns			
P-Value	0.001				0.002				0.161				0.161				0.240			

Note: O: Open; A: Agroforestry; G1: Rice genotype (IR64); G2: Rice genotype (Situ Patenggang); ns: not significant; **: significantly different in the α 1% t-test level

Table 3. Characteristics of stem strength, length of flag leaf, the width of flag leaf, number of grains per panicle, and grain weight per panicle of 2 rice genotypes in an open environment and agroforestry

Replication	Stem strength				Flag leaf length				Flag leaf width				Number of grains per panicle				Grain weight per panicle			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	310.00	360.00	180.00	190.00	14.30	27.00	11.00	20.00	1.00	1.20	1.00	1.00	86.00	165.00	66.00	50.00	2.05	3.64	1.57	1.10
2	220.00	380.00	150.00	240.00	16.20	16.00	20.00	23.20	1.00	1.10	1.20	1.00	75.00	98.00	48.00	52.00	1.79	2.16	1.14	1.15
3	220.00	340.00	130.00	140.00	16.60	23.50	12.30	20.00	1.00	1.30	1.10	1.20	86.00	130.00	61.00	87.00	2.05	2.87	1.45	1.92
4	230.00	340.00	285.00	290.00	16.30	22.80	17.50	21.00	1.00	1.10	0.90	1.20	88.00	147.00	81.00	63.00	2.10	3.24	1.93	1.39
5	320.00	400.00	210.00	270.00	19.50	24.50	14.40	18.50	1.20	1.10	1.00	1.00	93.00	120.00	51.00	36.00	2.22	2.65	1.22	0.79
Mean	260.00	364.00	191.00	226.00	16.58	22.76	15.04	20.54	1.04	1.16	1.04	1.08	85.60	132.00	61.40	57.60	2.04	2.91	1.46	1.27
Combine	312.00		208.50		19.67		17.79		1.10		1.06		108.80		59.50		2.48		1.37	
Stdev	66.63		60.28		4.43		3.98		0.11		0.11		30.14		15.56		0.60		0.36	
Notation	**				ns				ns				**				**			
P-Value	0.001				0.226				0.373				0.001				0.001			

Note: O: Open; A: Agroforestry; G1: Rice genotype (IR64): G2: Rice genotype (Situ Patenggang); ns: not significant; **: significantly different in the α 1% t-test level

Commented [A1]: Table 3 is need to be mentioned in body text

The agronomic and morphological characters of the two rice genotypes grown in different environmental conditions (open and under a 2-year-old *sengon* stand) showed different responses. These included the number of tillers, plant height, stem strength, number of grains per panicle, and grain weight per panicle. The response of the agronomic and morphological characteristics of cultivated plants under 2-year-old *sengon* trees significantly decreased. There was no significant difference in the leaf color index characters, leaf chlorophyll content, stem diameter, as well as the length and width of the flag leaf. This showed that the character was more determined by genetic factors. However, the overall character was still influenced by pressure due to environmental factors, with light being the dominant. Measurements showed that the intensity of sunlight on open land was 52,800 lux, which decreased to 10,468 lux on agroforestry land (shade 80%). The limitation of light availability was the main contributing factor to the genotypic response experiencing a decreased ability to express morphological and agronomic characters optimally.

Sunlight is a source of energy for photosynthesis. The absorption of sunlight by the plant canopy is an important factor that determines photosynthesis and plant yield. Previous research reported that plants use the light spectrum in the 400-700 nm wavelength range, commonly called Photosynthetically Active Radiation (PAR) (Prakash et al. 2023). Generally, shade affects the intensity of sunlight plants receive, influencing energy availability or growth and yield processed (Raffo et al. 2020). Therefore, to avoid the harmful effects of low light, tolerant varieties can be used to maintain the ability to produce carbohydrates, improve photosynthetic efficiency, and enhance the ability to produce antioxidants as a form of plant adaptation to stress in low-light conditions (Kowalczewski et al. 2020).

In conclusion, the rice genotypes planted under 2-year-old *sengon* stands experienced decreased productive tillers, plant height, stem strength, number of grains, and grain weight per panicle characteristics. The IR 64 genotype decreased grain weight per panicle by 40.65%, and the Situ Patenggang genotype by 56.21%.

The growth limitations imposed by the 2-year-old *sengon* trees suppressed the expression of character indices of leaf color, leaf chlorophyll content, stem diameter, length, and width of flag leaves of two genotypes of rice plants. However, these results showed no statistically significant.

There is a need to evaluate the use of rice agroforestry systems under 2-year-old Sengon stands with a spacing of 2.5 m × 2.5 m. Moreover, when the conditions require more development, thinning should be carried out beforehand to provide sufficient space for the intensity of sunlight to support plant growth and production.

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Politeknik Negeri Lampung and Institut Pertanian Bogor have supported this research and publication, and all who have assisted in this research.

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[biodiv] Editor Decision

1 pesan

Team Support Smujo via SMUJO <support@smujo.com> 2 Oktober 2023 pukul 15.20
Balas Ke: Team Support Smujo <support@smujo.id>
Kepada: DULBARI <dulbari@polinela.ac.id>, ZAINAL MUTAQIN <author@smujo.id>, "M. ALAM FIRMANSYAH" <alam@apps.ac.id>

DULBARI, ZAINAL MUTAQIN, HERY SUTRISNO, NI SILUH PUTU NURYANTI, YURIANSYAH, DENNY SUDRAJAT, DESTIEKA AHYUNI, HIDAYAT SAPUTRA, LINA BUDIARTI, PRIYADI, FAJAR ROCHMAN, RIZKY RAHMADI, M. ALAM FIRMANSYAH, SAIJO:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (Paraserianthes falcataria)".

Our decision is to: Accept Submission

Best Regards,
Team Support Smujo.id

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Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th annual symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

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Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.). Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

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Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (*Paraserianthes falcataria*)

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[2]Department of Silviculture, Faculty of Forestry, Institut Pertanian Bogor. Jl. Ulin, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia. Tel.: +62-251-8626806, ♥email: alam@apps.ipb.ac.id, dulbari@polinela.ac.id
[3]Faculty of Agriculture and Forestry, Universitas Muhammadiyah Palangkaraya. Jl. RTA. Milono KM 1.5, Pahandut, Palangka Raya 73111, Central Kalimantan, Indonesia

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Abstract. *Dulbari, Mutaqin Z, Sutrisno H, Nuryanti NSP, Yuriansyah, Sudrajat D, Ahyuni D, Saputra H, Budiarti L, Priyadi, Rochman F, Rahmadi R, Firmansyah MA, Saijo. 2023. Agronomic and morphological characteristics of two rice genotypes plant in open land and under two years of sengon (*Paraserianthes falcataria*). Biodiversitas 24: 4927-4933.* The increase in population is the biggest challenge for the agricultural sector in providing food needs. The main problem in increasing food production in Indonesia is the limited agricultural land. There is a need to explore alternative land options to address this issue and enhance production capacity, specifically for rice at the national level. One of the potential solutions is to use land currently occupied by plantation crops and forests that can be managed through agroforestry. Sengon (*Paraserianthes falcataria* (L) I.C.Nielsen) is a forestry plant that offers a comparative advantage for investigation in agroforestry systems due to its relatively open canopy cover and classification as a legume. Therefore, this research aimed to determine the response of the morphological and agronomic characters of two rice genotypes planted in open land under 2-year-old sengon stands. The experiment was conducted from October 2017 to March 2018 in the Sengon community forest of Cikarawang, Bogor, with coordinates 06° 33.061' S and 106° 43.987' E. The results showed that two rice genotypes grown under one-year-old sengon stands experienced decreased productive tillers, plant height, stem strength, and the number and weight of grains per panicle. The IR 64 genotype decreased by 40.65% in grain weight per panicle, while the Situ Patenggang genotype experienced a 56.21% decrease.

Keywords: Adaptation, agroforestry, constraint, *sengon,* shade

Abbreviations: RBD: Randomized Block Design; G1: Genotype 1 IR46; G2: Genotype 2 Situ Patenggang; WAP: Weeks After Planting; O: Open land cultivation; A: Agroforestry system cultivation under 2-year-old *sengon* plants with a spacing of 2.5 m × 2.5 m

INTRODUCTION

The population of Indonesia in 2021 is more than 270 million, with a growth rate of 1.22 per year (BPS 2022). This growing population challenges adequate food sufficiency, crucial to achieving people's welfare. The adequacy of food, specifically rice, is a significant indicator of economic and political stability. Despite this significance, many efforts to maintain food availability and stability face various obstacles, including reduced productive agricultural land due to conversion for non-agricultural purposes. The land conversion for housing, factories, and industrial facilities significantly impacts agricultural land availability. Therefore, to maintain production stability and food security, alternative solutions are important to increase the area of agricultural land.

Therefore, one solution is planting food crops, specifically rice, on the plantation and forestry; this agroforestry practice involves using forests for agricultural activities. According to Korneeva (2022), agroforestry is a land-use system where forest stands and crops are planted on the same land. Octavia et al. (2022) stated that agroforest, with broad connotations, is the main driving technique in implementing social forestry. Furthermore, the objectives of agroforestry or intercropping in forest areas (Nair et al. 2021) include (i) increasing food supply, (ii) expanding employment opportunities, (iii) increasing the income and welfare of the community around the forest, and (iv) increasing the success of forest plantations.

Agroforestry is supposed as optimal and sustainable land use by combining forestry and agricultural activities on the same land management, considering the participating communities' physical, social, economic, and cultural conditions (de Mendonça et al. 2022). The main purpose of agroforestry and the intercropping system is to improve the welfare of village communities around the forest. This provides communities or *pesanggem f*armers opportunities to grow food crops to increase their income. Through this approach, villagers around the forest are expected to play an active role in conserving and protecting the forest and land from damage.

Moreover, research on adapting rice plants to low light stress conditions under plant stands is required. One suitable forestry vegetation for agroforestry with a light canopy is *sengon* (*Paraserianthes falcataria* (L) I.C.Nielsen syn. *Falcataria falcata* (L.) Greuter & R.Rankin), which is a native to Indonesia and thrives on well-drained, non-flooded land (Danarto et al. 2019). *Sengon* is frequently incorporated into agroforestry systems due to its relatively open canopy cover and leguminous characteristics. The *sengon* (Leguminoceae) roots form symbiotic relationships with Rhizobium, resulting in root nodules that bind free Nitrogen from the air. This phenomenon contributes to the plant's significant role in maintaining nutrient availability, specifically N, in the soil (Binkley and Fisher 2019).

Increasing the area of intercropping crops (agroforestry) and providing forest areas for food development is continuously carried out in the forestry sector to support food security (Duffy et al. 2021). Furthermore, Sengon trees can be combined with rice (*Oryza sativa* L.) on the same land, providing an alternative solution to increase community food security. Rice is an agricultural crop that can be developed on dry land; high rice production will increase rice supply, a basic need for the Indonesian people. However, there are several obstacles in developing rice varieties under plant stands, including determining genotypes that effectively adapt and the appropriate age of Sengon stands for intercropping.

This research aimed to determine the response of the morphological and agronomic characters of two rice genotypes planted in open land conditions and under 2-year-old *sengon* stands. The results will be used as input for increasing rice production capacity under agroforestry plantations or forestry plantations.

MATERIALS AND METHODS

Treatment and research design

The research was conducted from October 2017 to March 2018, using community forest land in Cikarang Village, Bogor Regency, West Java, at coordinates 06° 33.061' North Latitude and 106° 43.987' South Latitude. The land was planted with 2-year-old *sengon,* spaced at 2.5 m x 2.5 cm in an open land area. The analysis was arranged using a randomized block design (RBD) with a single-factor treatment of rice genotypes consisting of IR64 (G1) and Situ Patenggang (G2). Each treatment was repeated 5 times in 2 cultivation systems, namely open land cultivation (O) and agroforestry system cultivation under 2-year-old *sengon* plants (A). The linear model and analysis of variance followed the approach by Mattjik and Sumertajaya (2013):

$$Y_{ij} = \mu + \tau_i + \beta_j + \acute{\varepsilon}_{ij}.$$

Where: Y_{ij} -Observational value in the Ist treatment and jth group, μ-average, τ_i-effect of the ith treatment, β_j-jth group effect, $\acute{\varepsilon}_{ij}$-random effect in the Ith treatment and jth group.

Indicators of environmental conditions for the two planting locations are shown in Table 1.

Research implementation

The soil was processed to a depth of 25-30 cm, followed by creating beds with a width of 100 cm and a length of 1,000 cm. Seeds were sown directly at 25 cm x 25 cm spacing, with 2-3 seeds per planting hole. Basic fertilization was carried out when planting Urea 100 kg ha^{-1}, TSP 200 kg ha^{-1}, and KCl 50 kg ha^{-1}. Subsequently, a follow-up fertilization was conducted 4 weeks after planting, using Urea 100 kg ha^{-1} and KCl 50 kg ha^{-1}. Pest and disease control was carried out using pesticides according to plant conditions in the field with recommended doses. Weed control was carried out twice at the age of 3 and 6 weeks after planting (WAT).

The agronomic and morphological characteristics observation includes several aspects: the number of productive tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter, stem strength, grain per panicle, and grain weight per panicle. These observations were carried out per the Guidelines for Characterization and Evaluation of Rice Plants (Silitonga et al. 2014).

The leaf color index was observed using SPAD meters. Observation of chlorophyll content was calculated using the equation: y = 0.113x, where y is the total leaf chlorophyll content, 0.113 = constant, and x = level of the greenness of leaves (from SPAD measurements) (Dulbari: unpublished data).

The observational data were analyzed for diversity using the Bartlett test. When the data met the requirements, further analysis of variance was carried out. Subsequently, the differences between treatments were analyzed using the T-test with α = 0.05.

Table 1. Environmental indicators for planting locations

Indicator	Open	Agroforestry	Information
pH KCl	4.29	4.53	
H_2O	4.90	5.20	
N-total	0.26	1.62	%
P-total	131.90	105.34	mg P_2O_5 100g^{-1}
K-total	96.25	112.42	mg K_2O 100g^{-1}
P-tersedia	11.28	14.32	P_2O_5 ppm
C-organik	0.25	1.74	%
KTK	21.43	21.41	Cmol(+) kg^{-1}
Al-dd	0.26	0.78	Cmol(+) kg^{-1}
H-dd	0.33	0.40	Cmol(+) kg^{-1}
Ca-dd	3.04	3.36	Cmol(+) kg^{-1}
Mg-dd	2.82	3.30	Cmol(+) kg^{-1}
K-dd	0.77	1.20	Cmol(+) kg^{-1}
Na-dd	0.15	0.11	Cmol(+) kg^{-1}

RESULTS AND DISCUSSION

Number of productive tillers and plant height

The results of observing the number of tillers and plant height characteristics are shown in Figure 1.

The two rice genotypes experienced decreased growth and yield responses due to the dominant environmental influences of reduced sunlight. The reduction in response to plant height and the number of productive tillers in the two rice genotypes was due to the low intensity of sunlight, leading to a hindered rate of photosynthesis; it's supposed to be a genetic factor. That showed plants no longer have the energy to distribute assimilates-production to the demanded plant parts. This distribution was done using tools such as proteins and proton pumps driven by ATP (ATP-Ase), which necessitated energy and enzymes. Similarly, Amin et al. (2021) stated that plants maintained an electrochemical balance within the entire biomembrane to ensure survival.

The closing rate of 2-year-old *sengon* stands with a spacing of 2.5 m x 2.5 m prevented light interception by approximately 80%. Therefore, photosynthesis, which served as the main energy source for plants to carry out growth processes, was disrupted.

Leaf color index character and leaf chlorophyll content

The results of leaf color index characteristic observations and leaf chlorophyll content are shown in Figure 2.

The two genotypes' leaf color index characters and leaf chlorophyll content had different tendencies. For genotype 1 (IR 64), these variables showed decreased growing conditions under 2-year-old sengon stands (agroforestry). The leaf color index decreased from 25.02 to 15.34, while the chlorophyll content of the leaves reduced from 2.83 to 1.73. For genotype 2 (Situ Patenggang), the variables showed a tendency to increase in growing conditions under 2-year-old *sengon* stands (agroforestry), where leaf color index increased from 16.10 to 17.96, and chlorophyll content increased from 1.82 to 2.03. That showed the genotypic response to leaf color index characters and chlorophyll content differed due to the adaptability of the IR64 and Situ Patenggang rice genotypes to shade stress.

Each genotype exhibited a different response and ability to adapt to the environment. In this research, the plant growth environment was different, specifically regarding sunlight intensity. Plants responded to the differences in light intensity according to their genetic capacity. Furthermore, plants developed acclimatization and plasticity methods to respond to environmental stress through morphological, anatomical, and physiological adjustments (Yetgin 2023).

Flag leaf size character

The results of observations of flag leaf size characters are shown in Figure 3.

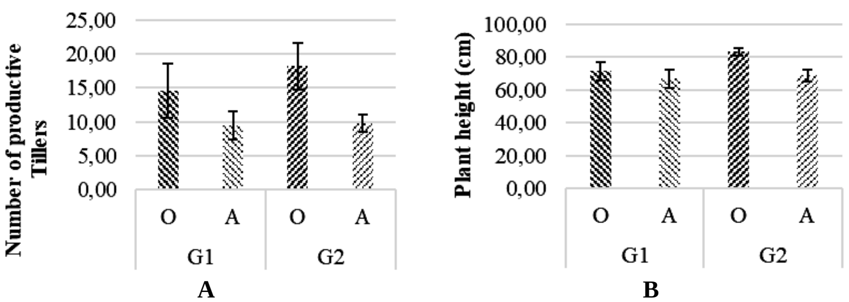

Figure 1. A. Number of productive tiller character, B. Plant height character. G1: Rice genotype 1 (IR64); G2: Rice genotype 2 (Situ Patenggang); O: Open, A: Agroforestry

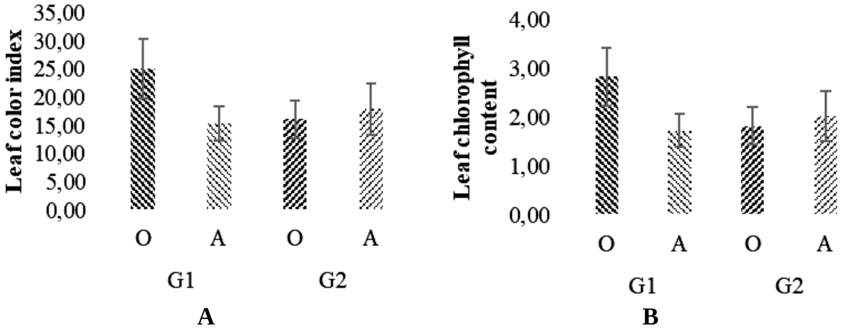

Figure 2. A. Leaf color index (SPAD), B. Leaf chlorophyll content (Chl Leaf), G1: Rice genotype 1 (IR64); G2: Rice genotype 2 (Situ Patenggang), O: Open; A: Agroforestry

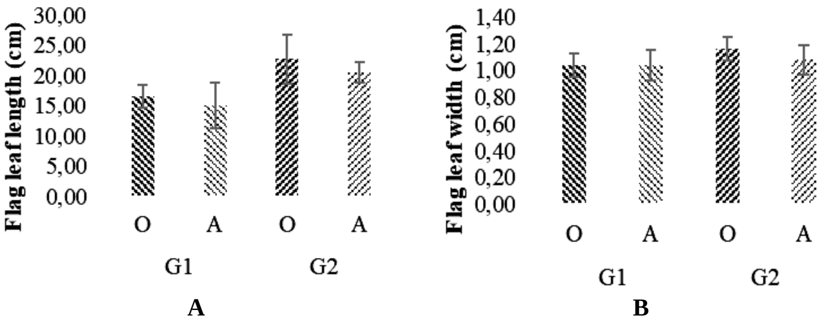

Figure 3. A. Flag leaf length character, B. Flag leaf width character. G1: Rice genotype 1 (IR64); G2: Rice genotype 2 (Situ Patenggang); O: Open; A: Agroforestry

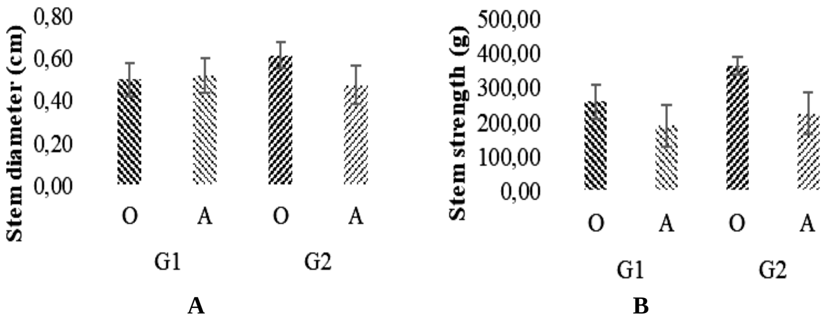

Figure 4. A. Stem diameter character, B. Stem strength character, G1-rice genotype 1 (IR64), G2-rice genotype 2 (Situ Patenggang), O-open, A-agroforestry

The two rice genotypes' responses to flag leaf size characters (length and width) showed no significant differences under open location and 2-year-old *sengon* (agroforestry) planting. However, significant variations were observed between the genotypes, indicating that the genotypes had different adaptation abilities to the stresses. The IR64 genotype showed a relatively stable response to flag leaf length and width, namely 16.58 and 15.04, as well as 1.04 and 1.04. Meanwhile, the Situ Patenggang genotype showed an insignificant decreasing trend for length measurements from 22.76 to 20.54 and width sizes from 1.16 to 1.08.

The morphology of rice plants' flag leaf (Sink) was important in filling the plant's grains. The large sink characteristic in superior rice varieties had a higher photosynthetic rate. Furthermore, the upright morphology of the leaves allowed greater penetration and distribution of light to the bottom, causing an increase in plant photosynthesis. According to previous research, the photosynthesis of plants in upright leaf canopies is about 20% higher than in drooping leaf canopies under high leaf area index conditions (Pan et al. 2023). The flag leaf, as a light-harvesting organ, can allocate its assimilates to panicle formation, thereby influencing the length of the panicle and the number of seeds per panicle. The less ideal flag leaf morphology also affected tiller and grain growth (Liu et al. 2014). Furthermore, the flag leaf size affected the number of stomata pores, influencing the ability to exchange H_2O and CO_2 (Franks and Beerling 2009).

Diameter and stem strength character

The results of observations of stem diameter and strength characters are shown in Figure 4.

The responses of the two rice genotypes, cultivated under open conditions and 2-year-old *sengon* trees, did not show significant differences in the stem diameter character. However, there was a significant variation in the stem strength characteristics. The IR64 tended not to experience a change in stem diameter, compared to Situ Patenggang, which decreased stem diameter from 0.61 cm to 0.47 cm. On underexposed conditions and a 2-year-old *sengon* tree to stem strength characters, both genotypes experienced a significant decrease. The IR 64 genotype decreased from 260.00 g to 191.00 g, and Situ Patenggang reduced from 364.00 g to 226.00 g.

The characteristic of stem strength is crucial for plants to withstand lodging, which can significantly affect crop production due to potential yield losses (Dulbari et al. 2018). Larger stem diameter plants also exhibit better strength and the characteristic of stem strength is significantly correlated with stem diameter, at a correlation coefficient value (0.77) (Dulbari; data has not been published). That indicated rice plant genotypes with a larger lower stem diameter (± 10 cm above the soil surface) had a better stem strength, thereby following the research of (Zhang et al. 2014) and (Dreccer et al. 2020).

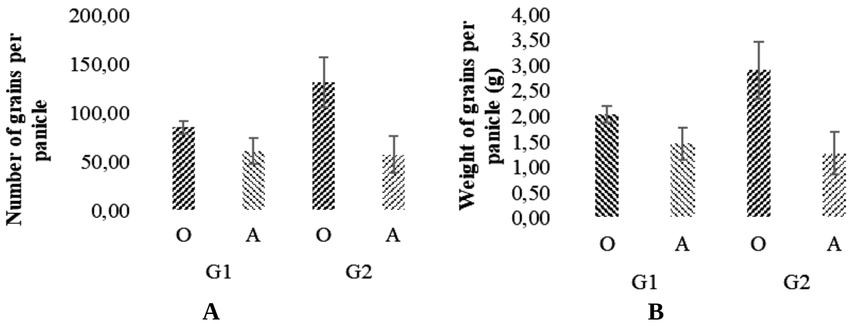

Figure 5. A. The number of grains per panicle character; B. The weight of grains per panicle; G1: Rice genotype 1 (IR64); G2: Rice genotype 2 (Situ Patenggang); O: Open; A: Agroforestry

The number of grain and grain weight characteristics per panicle

The results of observing the character of the number of grains and the weight of grain per panicle are shown in Figure 5.

The response of the rice genotypes cultivated in open land conditions and under 2-year-old *sengon* trees experienced a significant decrease in the number of grains per panicle and grain weight per panicle, which were the yield component characteristics. The IR 64 genotype exhibited a smaller reduction in the number of grains per panicle (85.00 to 61.40) compared to the Situ Patenggang (132.00 to 57.60). Similarly, the grain weight per panicle also had the same tendency, with IR 64 genotypes ranging from 2.40 to 1.46 (40.65%) and Situ Patenggang from 2.90 g to 1.27 g (56.21%). This showed that genotype significantly influenced planting plans under agroforestry crop stands.

The characteristics of grain number and weight were the results of plant metabolism processes, which were closely related to the process of photosynthetic ability (source) and the distribution of the assimilates to the sink. Environmental conditions, such as light, temperature, and humidity, significantly influenced plants' ability to produce the grain amount and weight per panicle. Furthermore, light intensity was closely related to temperature, with lower values resulting in reduced rice products and quality (Dutta et al. 2017).

Light is crucial in regulating the opening and closing of stomata. Lower light intensity will make stomata tend to close, thereby hindering CO_2 entry. Limited CO_2 and sunlight also caused a decrease in the rate of photosynthesis, impacting the assimilation of carbohydrates and biomass formation (Liu et al. 2014). Moreover, the regulation of stomatal opening is a dynamic and reversible process; water loss and CO_2 inflow rapidly adjust in response to several environmental and intrinsic signals, such as light, CO_2, and the plant stress hormone abscisic acid (Bhattacharya 2021). The ability of plants to produce and distribute photosynthate to their storage organs is an important part of increasing crop production (Fischer et al. 2012).

Agronomic and morphological characteristics of two rice genotypes under open conditions and agroforestry

The results of the observations of the agronomic and morphological characters of the two rice genotypes planted in open land conditions and under 2-year-old *sengon* stands are shown in Table 2.

The agronomic and morphological characters of the two rice genotypes grown in different environmental conditions (open and under a 2-year-old *sengon* stand) showed different responses. These included the number of tillers, plant height, stem strength, number of grains per panicle, and grain weight per panicle. The response of the agronomic and morphological characteristics of cultivated plants under 2-year-old *sengon* trees significantly decreased. There was no significant difference in the leaf color index characters, leaf chlorophyll content, stem diameter, as well as the length and width of the flag leaf. This showed that the character was more determined by genetic factors. However, the overall character was still influenced by pressure due to environmental factors, with light being the dominant. Measurements showed that the intensity of sunlight on open land was 52,800 lux, which decreased to 10,468 lux on agroforestry land (shade 80%). The limitation of light availability was the main contributing factor to the genotypic response experiencing a decreased ability to express morphological and agronomic characters optimally.

Sunlight is a source of energy for photosynthesis. The absorption of sunlight by the plant canopy is an important factor that determines photosynthesis and plant yield. Previous research reported that plants use the light spectrum in the 400-700 nm wavelength range, commonly called Photosynthetically Active Radiation (PAR) (Prakash et al. 2023). Generally, shade affects the intensity of sunlight plants receive, influencing energy availability or growth and yield processed (Raffo et al. 2020). Therefore, to avoid the harmful effects of low light, tolerant varieties can be used to maintain the ability to produce carbohydrates, improve photosynthetic efficiency, and enhance the ability to produce antioxidants as a form of plant adaptation to stress in low-light conditions (Kowalczewski et al. 2020).

Table 2. Character number of tillers, plant height, leaf color index, leaf chlorophyll content, stem diameter of 2 rice genotypes in an open environment, and agroforestry

Replication	Number of tillers				Plant height				Leaf color index				Leaf chlorophyll content				Stem diameter			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	10.00	23.00	11.00	9.00	70.00	84.00	60.00	66.00	26.10	20.90	13.30	18.30	2.95	2.36	1.50	2.07	0.56	0.69	0.43	0.41
2	14.00	18.00	8.00	10.00	72.00	80.00	70.00	74.00	32.90	18.40	13.10	24.20	3.72	2.08	1.48	2.73	0.51	0.65	0.61	0.36
3	21.00	20.00	9.00	8.00	80.00	86.00	72.00	68.00	24.90	14.20	15.20	19.50	2.81	1.60	1.72	2.20	0.41	0.58	0.60	0.49
4	15.00	15.00	12.00	11.00	65.00	84.00	62.00	70.00	18.50	14.10	14.70	15.90	2.09	1.59	1.66	1.80	0.43	0.62	0.47	0.59
5	13.00	15.00	7.00	11.00	70.00	82.00	70.00	66.00	22.70	12.90	20.40	11.90	2.57	1.46	2.31	1.34	0.59	0.53	0.48	0.52
Mean	14.60	18.20	9.40	9.80	71.40	83.20	66.80	68.80	25.02	16.10	15.34	17.96	2.83	1.82	1.73	2.03	0.50	0.61	0.52	0.47
Combine	16.40		9.60		77.30		67.80		20.56		16.65		2.32		1.88		0.56		0.50	
Stdev	3.73		1.65		3.87		4.38		4.33		3.75		0.49		0.43		0.07		0.09	
Notation	**				**				ns				ns				ns			
P-Value	0.001				0.002				0.161				0.161				0.240			

Note: O: Open; A: Agroforestry; G1: Rice genotype (IR64); G2: Rice genotype (Situ Patenggang); ns: not significant; **: significantly different in the α 1% t-test level

Table 3. Characteristics of stem strength, length of flag leaf, the width of flag leaf, number of grains per panicle, and grain weight per panicle of 2 rice genotypes in an open environment and agroforestry

Replication	Stem strength				Flag leaf length				Flag leaf width				Number of grains per panicle				Grain weight per panicle			
	O		A		O		A		O		A		O		A		O		A	
	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
1	310.00	360.00	180.00	190.00	14.30	27.00	11.00	20.00	1.00	1.20	1.00	1.00	86.00	165.00	66.00	50.00	2.05	3.64	1.57	1.10
2	220.00	380.00	150.00	240.00	16.20	16.00	20.00	23.20	1.00	1.10	1.20	1.00	75.00	98.00	48.00	52.00	1.79	2.16	1.14	1.15
3	220.00	340.00	130.00	140.00	16.60	23.50	12.30	20.00	1.00	1.30	1.10	1.20	86.00	130.00	61.00	87.00	2.05	2.87	1.45	1.92
4	230.00	340.00	285.00	290.00	16.30	22.80	17.50	21.00	1.00	1.10	0.90	1.20	88.00	147.00	81.00	63.00	2.10	3.24	1.93	1.39
5	320.00	400.00	210.00	270.00	19.50	24.50	14.40	18.50	1.20	1.10	1.00	1.00	93.00	120.00	51.00	36.00	2.22	2.65	1.22	0.79
Mean	260.00	364.00	191.00	226.00	16.58	22.76	15.04	20.54	1.04	1.16	1.04	1.08	85.60	132.00	61.40	57.60	2.04	2.91	1.46	1.27
Combine	312.00		208.50		19.67		17.79		1.10		1.06		108.80		59.50		2.48		1.37	
Stdev	66.63		60.28		4.43		3.98		0.11		0.11		30.14		15.56		0.60		0.36	
Notation	**				ns				ns				**				**			
P-Value	0.001				0.226				0.373				0.001				0.001			

Note: O: Open; A: Agroforestry; G1: Rice genotype (IR64): G2: Rice genotype (Situ Patenggang); ns: not significant; **: significantly different in the α 1% t-test level

In conclusion, the rice genotypes planted under 2-year-old *sengon* stands experienced decreased productive tillers, plant height, stem strength, number of grains, and grain weight per panicle characteristics. The IR 64 genotype decreased grain weight per panicle by 40.65%, and the Situ Patenggang genotype by 56.21%. The growth limitations imposed by the 2-year-old *sengon* trees suppressed the expression of character indices of leaf color, leaf chlorophyll content, stem diameter, length, and width of flag leaves of two genotypes of rice plants. However, these results showed no statistically significant. There is a need to evaluate the use of rice agroforestry systems under 2-year-old Sengon stands with a spacing of 2.5 m × 2.5 m. Moreover, when the conditions require more development, thinning should be carried out beforehand to provide sufficient space for the intensity of sunlight to support plant growth and production.

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