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Study on the Growth of *Falcataria moluccana* at 14-Month-Old and the Productivity Rice Plant (*Oryza sativa*) IPB 3S in Agroforestry System

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ABSTRACT

Agroforestry is a forestry and agriculture plant utilization system using sustainable land management to gain more products. *Falcataria moluccana* is a forestry plant that has been cultivated mostly in an agroforestry system by the Indonesian people, particularly on Java Island. Appropriate *F. moluccana* species selection and planting space in an agroforestry system are expected to improve plant growth and suppress the damage level that occurred in *F. moluccana*. The agroforestry system with *F. moluccana* and rice plant (*Oryza sativa*) is one of the alternative ways to support the national food needs. This study aimed to analyze the growth of various provenances of *F. moluccana* at the age of 14 months and analyze the productivity of IPB 3S rice in two planting spaces of *F. moluccana*. This study used a completely randomized two-factorial design, with the first factor being the provenance of *F. moluccana*, i.e., Solomon F1, Solomon F2, and local Kendal, and the *F. moluccana* spacing of 1.5 m × 3.0 m and 1.5 m × 1.5 m was the second factor. The *F. moluccana* growth parameters, rice plant growth parameters, and rice plant productivity in agroforestry systems were analyzed using an analysis of variance (ANOVA). If a significant effect on each parameter at a 5% confidence level occurred, the parameters were further analyzed with Duncan's Multiple Range Test (DMRT). The study found that provenance had no significant effect on the growth of 14-month-old *F. moluccana*. The results also showed that the growth of 14-month-old Solomon F2 had a relatively higher value on the parameters of height and diameter. The highest productivity of IPB 3S rice was found in the local *F. moluccana* shade at a spacing of 1.5 m × 1.5 m, reaching 0.201 tons/ha. The highest rice productivity was due to the magnitude of the light intensity received by rice of 5414.30 lux.

1. Introduction

Rice (*Oryza sativa*) is an essential food source for the world's population. In Asian populations, rice is one of the majoring needed, especially in Indonesia. However, national development activities in Indonesia often eliminate paddy-field. As a result, farmers have begun to seek solutions to keep their cultivation activities. Farmers seek the new paddy fields to meet consumption and achieve sustainable rice production. One of the lands that could be managed is the dry land. Eventually, the farmer selects the agroforestry system. Agroforestry has been determined as a sustainable land management solution that increases the yield of the land productivity, integration of forestry, agriculture, and livestock in turns or simultaneously in one unit of land. Agroforestry systems allow the development of a wide variety of products. Agroforestry obtains economic (Maqsood et al. 2013), ecological (Budiman and Arisoesilaningsih 2015), and cultural (Muhidin et al. 2013) benefits.

The combination between paddies and forest plants is already being done in various parts of the world. For example, Tomar et al. (2013) reported the response of paddy under the stands of *Erythrina indica, Alnus nepalensis, Parkia roxburghii, Acacia auriculiformis,* and *Cassia siamena.* However, the study on upland paddy cultivation under some *F. moluccana (F. moluccana*) stands has never been conducted. The selection of *F. moluccana* stands is based on its relatively fast-growth characteristics and economically valuable wood (Hughes et al. 2011). *F. moluccana* leaves are also used for animal feed, and in Sukabumi, West Java, Indonesia, are usually grown on agro-ecosystem land (Iskandar et al. 2017). In addition, its canopy is light, so it can be optimized for planting crops under the stands.

However, this has not been able to fully meet the community's needs in the future. This indicates that staple food production must continue to be increased, despite the decrease in agricultural land availability. Agroforestry is a land-use system that combines annual crops with seasonal crops or livestock on the same unit of land and can be used to meet food needs in Indonesia (Ningrum et al. 2019; Wijayanto and Nurunnajah 2012).

F. moluccana is a tree species widely cultivated in almost all parts of Indonesia. This species is widely developed because it has a fast growth rate, can adapt to various site conditions, and can be cultivated using a simple silvicultural technique (Wasis and Saidah 2019). In addition, *F. moluccana* has a light canopy so that the land underneath is relatively open and suitable for developing agricultural crops.

Rice is one of the plants that can be developed in agroforestry with *F. moluccana* plants (Ningrum et al. 2019). Rice is one of the most widely developed crops in Indonesia (Senjaya et al. 2018). Rice has many varieties, including IPB 3S rice. According to Wati et al. (2019), the IPB 3S rice variety has good adaptability to irrigate and rainfed rice fields, so the potential to be developed in agroforestry land is large. Based on this information, it is very important to conduct research on the growth of *F. moluccana* and rice productivity of IPB 3S in the agroforestry system as a consideration for meeting rice needs in Indonesia. Therefore, this study aimed to analyze the growth of various provenances of *F. moluccana* (Solomon F1, Solomon F2, and local Kendal) at the age of 14 months and analyze the productivity of IPB 3S rice in two spacing patterns of *F. moluccana* (1.5 m × 1.5 m and 3.0 m × 1.5 m).

2. Materials and Methods

2.1. Study Area

This research began in October 2019 and ended in February 2020. The research site was on a 14-month-old Sengon stand. The research location is in the Cikabayan Forest, Darmaga campus, IPB University, Bogor, Indonesia. Rainfall during the 4 months of the study was 381.9, 330.1, 552.8, and 383.5 mm/month (BMKG 2020). The humidity and temperature at the study location were 70-73% and 29.8-30.73°C. The research location is located at 06º 32' 48.8" latitude and 106º 43' 02.4" east longitude with an altitude of 162 m.a.s.l. and a slope of 0% (**Fig. 1**). Meanwhile, data were analyzed at the Silviculture Laboratory, Department of Silviculture, Faculty of Forestry and Environment, IPB University.

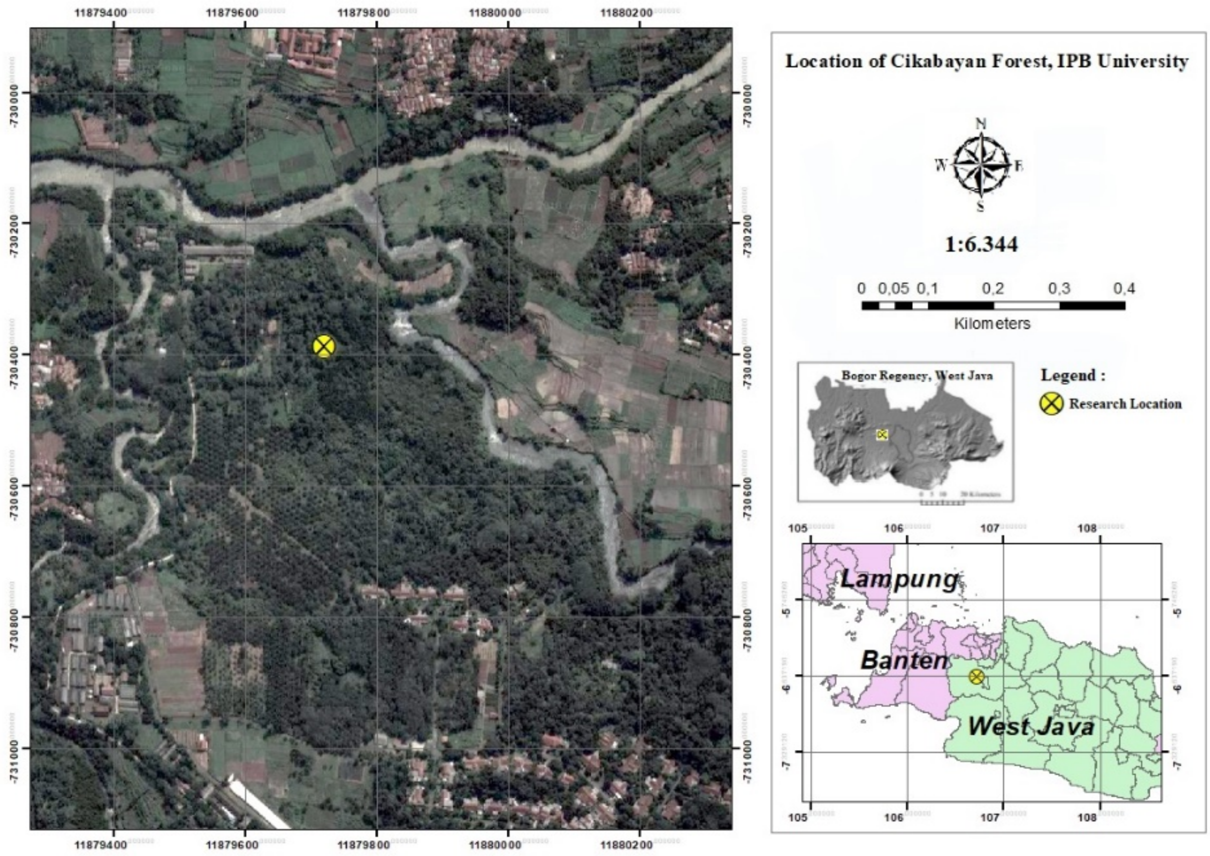

Fig. 1. Research location of Cikabayan Forest, Bogor, Indonesia.

2.2. Materials

The *F. moluccana* used in this study was 14 months old and consisted of Solomon F1, Solomon F2, and local Kendal. *F. moluccana* seeds were purchased from community forest farmers in Kendal Regency, Central Java. The tools used in this study consisted of a tally sheet, laptop, hoe, sewing meter, ruler, raffia rope, tape meter, trashbag, stationery, camera, paper envelope, oven, balance, Microsoft Word software, Microsoft Excel software, SPSS software, lux meter, thermohygrometer and ground drill. The materials used included compost, *F. moluccana* stands of three provenances, rice seeds (*O. sativa*) of IPB 3S variety, several types of fertilizers (biological organic, urea, SP36, KCl), and pesticides containing the active ingredients fipronil and furadan.

2.3. Research Procedure

2.3.1. Research design

The *F. moluccana* stands of three provenances were obtained from community forest farmers in Kendal, Central Java. The spacing of *F moluccana* used was 1.5 m × 1.5 m and 3.0 m × 1.5 m. IPB 3S rice was planted with a spacing of 25 cm × 25 cm, with each hole filled with 5 rice seeds (Christanto and Agung 2014; Fitria and Ali 2014). The layout of *F. moluccana* and rice planting can be seen in **Fig 2.**

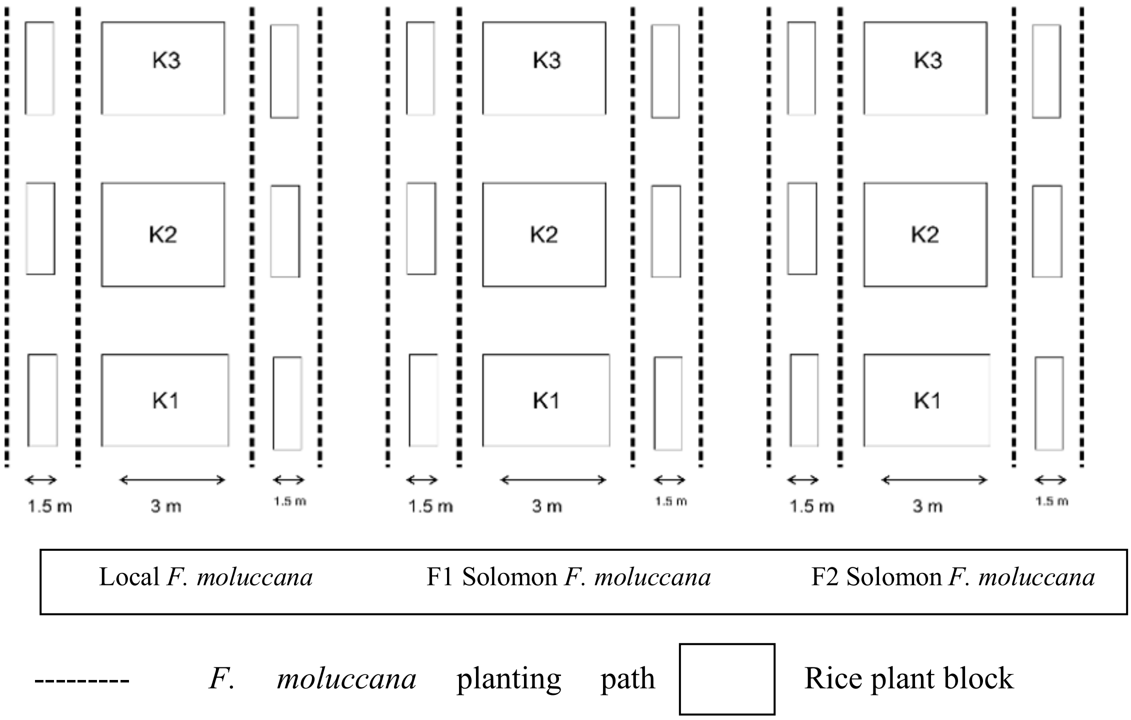

Fig. 2. Overall *F. moluccana* layout in the research area.

The research design used was a Factorial Completely Randomized Design (2 Factors) on *F. moluccana* and rice IPB 3S. Completely Randomized Design in Paddy IPB 3S, the first factor was the spacing, and the second factor was the provenance of the tree/shade. The first factor was the planting space of *F. moluccana* of 1.5 m × 1.5 m and 3.0 m × 1.5 m. The second factor was the *F. moluccana* provenances, namely Solomon F1, Solomon F2, and local Kendal. The experimental design model is as follows (Mattjik and Sumertajaya 2002):

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

where Y_{ijk} is observations for differences in i level path size, tree species shader level j, on the k test, μ is average, α_i is the effect planting space at i level, β_j is the effect of shade tree provenance at j level, ε_{ijk} is the test error for i level, j is the level path size difference for differences in tree origin/shade as well as in repetition.

2.3.2. Planting activities

The rice seeds that will be planted first are broken dormancy by soaking the rice seeds in a solution of water and POH with a concentration of 30%. Activities before planting include land preparation, basic fertilization, making planting holes, and cleaning weeds (Hartoyo et al. 2014).

The rice planting holes were made with a drilling system (*tugal*), and each hole has a depth of 2-3 cm with a rice planting distance of 25 cm × 25 cm. The initial fertilization of the land is in the form of basic fertilization, with the type given in the form of compost and manure. Compost is used to improve soil structure and increase soil fertility.

IPB 3S rice seeds were inserted into the planting holes at a distance of 25.0 cm × 25.0 cm (Christanto and Agung 2014). Each planting hole is given five rice seeds which are then backfilled with soil (Fitria and Ali 2014). The fertilizers given to the research area consisted of organic and inorganic fertilizers. Organic fertilizer was given to rice in the form of biological organic fertilizer.

Meanwhile, the inorganic fertilizers provided were urea, SP36, and KCl. Urea, SP36, and KCl were applied at 10 DAP (days after planting) with each fertilizer dose of 15.0 kg/1500 m^2. The same fertilizer and dose were given again when the rice plants were 20 days old.

Embroidery is an activity to replace rice plants that die or do not grow on the planting path with new plants. Embroidery was conducted when the plant is 10 DAP. The maintenance carried out in agroforestry was weeding, watering, and pest control. Pest control techniques used were physical-mechanical and chemical control techniques. The active ingredient pesticide Fipronil 50 g/l was used to control pests such as *Leptocorisa oratorius* and insecticide carbofuran furadan for termites. In addition, physical-mechanical control was also carried out by using a sweep net to control the pest of stink bugs.

2.3.3. Measurement of environmental data

In this study, supporting data is needed to be able to complete the existing data. The supporting data were soil analysis and climatic data, including light intensity, temperature, and relative humidity. Climatic data were measured when the rice was 2 weeks after planting (WAP), 7 WAP, and 12 WAP. Soil sampling was collected by purposive sampling. Soil samples were taken according to particular purpose boundaries representing the land **(Fig. 3).**

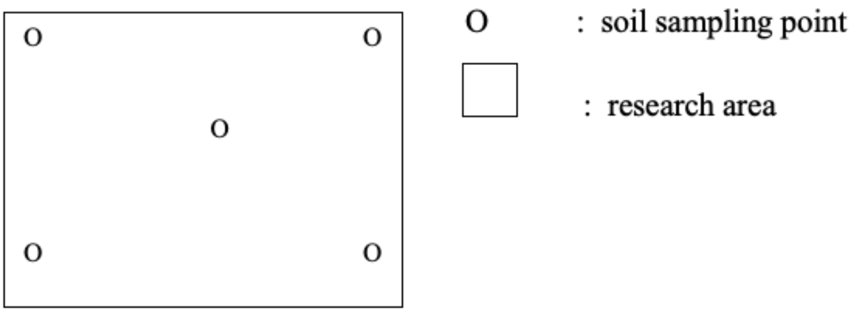

Fig. 3. Soil sampling method

Soil sampling was carried out at five points and taken compositely to represent soil conditions at the site research (Wicaksono et al. 2015). Soil samples were collected and tested in the laboratory to determine their physical and chemical properties. Sampling was carried out at the beginning of land preparation or after land preparation, after giving dolomite and planting *F. moluccana* and upland rice, and after the upland rice harvest or observation was completed.

2.3.4. F. moluccana growth parameters observed

The measurement of *F. moluccana* height used a pole or a hypsometer. This measurement was carried out once a month until the rice harvest. The plant height growth rate was calculated based on the difference between the beginning and the end of the observation. The stem diameter of *F. moluccana* was measured at breast height (dbh). The measurement used a tape measure and was carried out monthly until the rice was harvested. The stem diameter increment was calculated based on the difference in diameter between the beginning and the end of the observation. The canopy/crown area was conducted monthly until the rice was harvested by measuring the length and width of the canopy.

2.3.5. Rice plant parameters measurement

The rice growth parameters include plant height and the number of tillers were observed in plant samples every two weeks starting at 45 DAP (Fitria and Ali 2017). In addition, panicle length and the number of productive tillers were measured at harvest with plant samples. The weight of filled grain, empty grain weight, and rice productivity were measured after rice was harvested. The *F. moluccana* data collected consisted of total height, tree diameter, and canopy area at the beginning, middle, and end of the observation.

2.4. Data Analysis

Data analysis used variance (ANOVA) with a level of 5 % to see differences between treatments. Duncan's Multiple Range Test (DMRT) was carried out if the treatment gave significantly different results (Mattjik and Sumertajaya 2002).

3. Results and Discussion

3.1. F. moluccana Tree Growth

Trees with fast growth rates will yield high productivity, yet they require the most suitable plant type and spacing management. Accordingly, the selection of *F. moluccana* to be cultivated in an agroforestry system intercropped with rice requires the correct choice of *F. moluccana* species and planting space, which might differ in every *F. moluccana* species (Widiyanto et al. 2013). Trees planting generally require several treatments, such as selecting the appropriate species or provenance and setting the spacing. This is intended to prevent competition for nutrients and light to optimize plant growth (Widiyanto et al. 2013).

The *F. moluccana* of Solomon provenance has a genetic condition that is highly adaptive to various environmental conditions (Ikhfan and Wijayanto 2019; Susanto and Baskorowati 2018). The environmental conditions of the growing habitat and the proper spacing cause *F. moluccana* of Solomon provenance to grow better than the *F. moluccana* of local provenance (Azizah et al. 2019; Hayati et al. 2012; Ikhfan and Wijayanto 2019; Schwerz et al. 2020; Wahyudi et al. 2014). The growth of tree dimensions is strongly influenced by the diversity of the environment in which it grows, including temperature, humidity, rainfall, and light intensity (Messaoud and Chen 2011; Susanto and Baskorowati 2018). The ANOVA results of the effect of provenance and plant spacing on the growth of *F. moluccana* are presented in **Table 1**.

Table 1. The ANOVA results of the effect of provenance and plant spacing on the growth of *F. moluccana*

Parameter	Treatment		
	Provenance	**Spacing**	**Provenance × spacing**
Height (m)	0.16ns	0.16ns	0.36ns
Diameter (cm)	0.60ns	0.29ns	0.83ns
Canopy area (m^2)	0.96ns	0.82ns	0.86ns

Notes: ns = treatment has no significant effect on the 95% confidence interval with a significant value (P-value) > 0.05 (α).

The prevalence of *F. moluccana* and plant spacing did not significantly affect all parameters (**Fig. 4**). Tree height is one of the most widely used parameters in measuring plant growth. The height of a plant is influenced by environmental factors, one of which is light intensity (Dewi et al. 2018). The *F. moluccana* of Solomon F1, Solomon F2, and local Kendal provenances at 14 months had no significant difference in height and diameter growth. However, Solomon F2 provenance had a relatively higher increase in total plant height and stem diameter than the other provenances (**Fig. 4**). Solomon F2 provenance has a relatively wider canopy area than Solomon F1 and local Kendal provenances. Azizah et al. (2019) reported that *F. moluccana* of Solomon F1 provenance aged 6 months had relatively better growth than Solomon F2 and local provenances. The results were in line with the previous studies (Azizah et al. 2019; Hardiyanto 2010; Ikhfan and Wijayanto 2019; Setiadi et al. 2014; Sopacua et al. 2021; Susanto and Baskorowati 2018), reporting that *F. moluccana* of Solomon provenance has advantages over local provenance, particularly in growth and adaptation rate, which can be related to genetic factors (Ikhfan and Wijayanto 2019; Susanto and Baskorowati 2018).

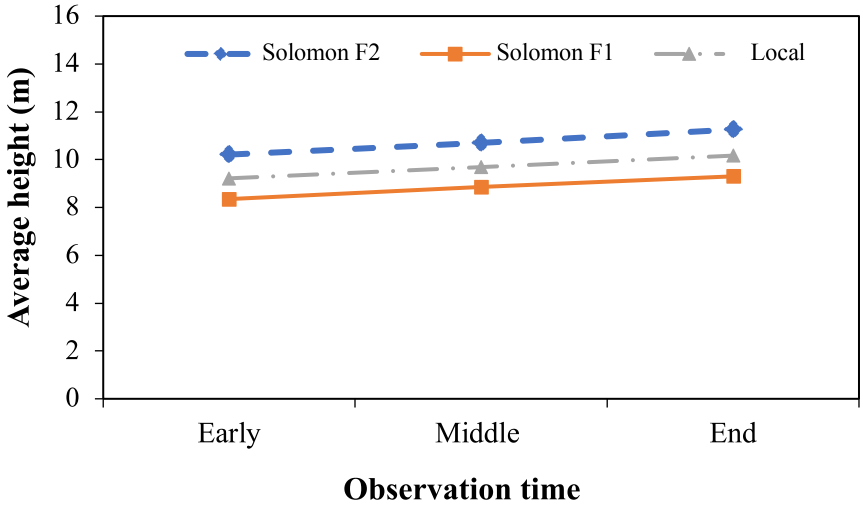

Fig. 4. Average height of *F. moluccana* at a spacing of 3.0 m × 1.5 m.

Planting distance of 1.5 m × 1.5 m planted with *F. moluccana* of Solomon F2 provenance had a relatively higher increase in plant height of 11.26 m (**Fig. 5**). Meanwhile, Solomon F1 and local Kendal provenances have a height of 8.81 m and 10.11 m. Solomon F2 provenance has the largest height increase of 0.45 m/month compared to Solomon F1 and Solomon F2 provenances of 0.43 m/month and 0.42 m/month, respectively. Overall, a relatively higher increase in total plant height was found in the Solomon F2 provenance with the spacing of 3 m × 1.5 m. The high growth at wider spacing is caused by little nutrient competition so that growth is optimal (Widiyanto et al. 2013).

Tree diameter is one of the growth parameters that is heavily influenced by environmental factors such as light intensity and nutrients (Hoffman and Tomescu 2013). *F. moluccana* of Solomon F2 provenance had a relatively higher diameter increment than the other provenances, showing an average diameter of 7.9 cm at a spacing of 3 m × 1.5 m (**Fig. 6**). This has a relatively higher value than the Solomon F1 and local Kendal provenances of 6.8 cm and 6.3 cm, respectively. The average diameter increments of Solomon F2 provenance reached 0.3 cm/month. These values are higher than the diameter increment in the Solomon F1 and local Kendal provenances of 0.25 cm/month and 0.15 cm/month, respectively.

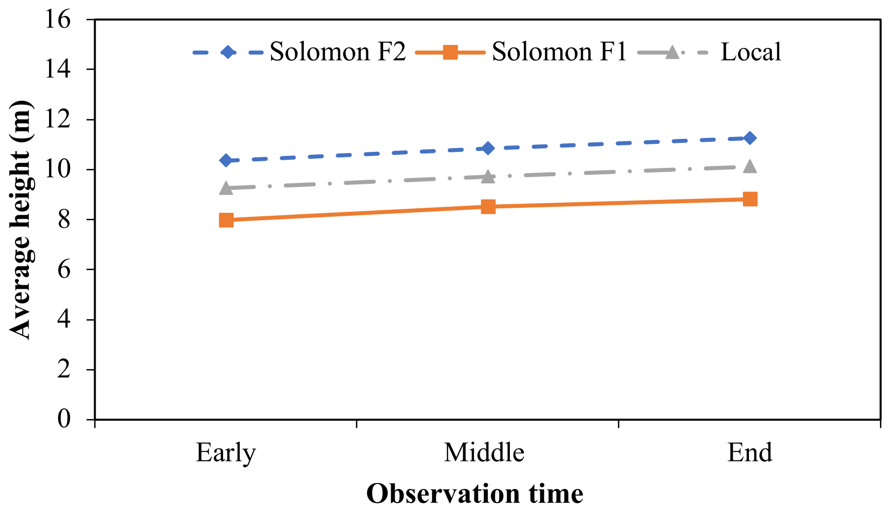

Fig. 5. Average height of *F. moluccana* at a spacing of 1.5 m × 1.5 m.

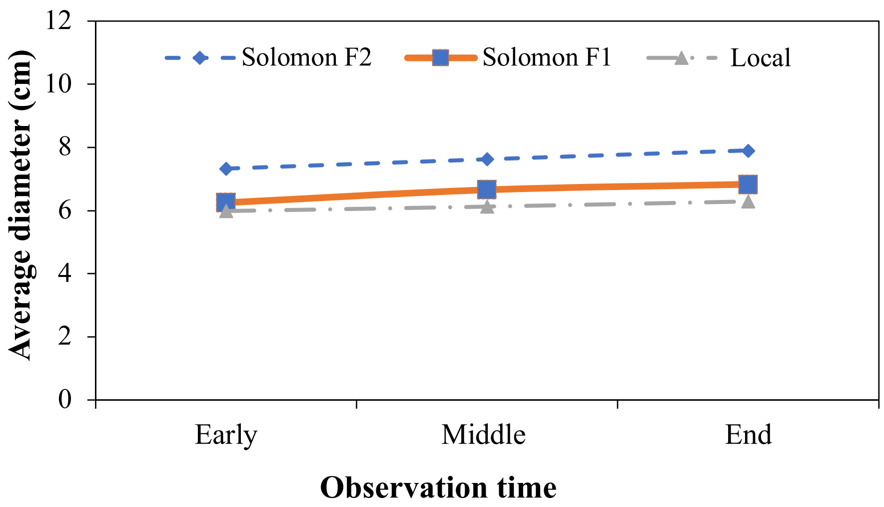

Fig. 6. The average diameter of *F. moluccana* at a spacing of 3 m × 1.5 m.

The average diameter of Solomon F2 provenance at a spacing of 1.5 m × 1.5 m was 7.7 cm, showing a higher value than Solomon F1 and local Kendal provenances of 6.7 cm and 6.9 cm, respectively (**Fig. 7**). The diameter increment of Solomon F2 provenance was 0.45 cm/month. The value was relatively greater than that in the Solomon F1 and local Kendal provenances of 0.44 cm/month and 0.19 cm/month, respectively.

Setiadi et al. (2014) reported that the diameter of Solomon provenance is three times larger than the local Kendal provenance. This is thought to be due to genetic factors and the ability to adapt to different environments (Azizah et al. 2019; Ozcelik et al. 2014; Rahman et al. 2018; Tun et al. 2018). In addition, the average diameter at wider spacing is greater than at narrow spacing due to a small space competition, so the absorption of light and nutrients will be more optimal (Azizah 2019). Other studies also reported that wider tree spacing in agroforestry systems results in higher tree diameters (Wahyudi et al. 2014; Widiyanto et al. 2013).

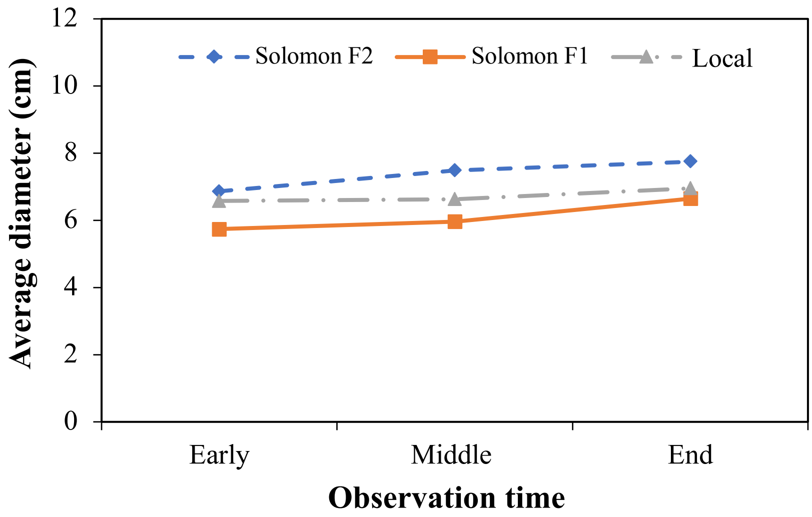

Fig. 7. The average diameter of *F. moluccana* at a spacing of 1.5 m × 1.5 m.

The crown size of a plant shows space competition for light (Raharjo and Sadono 2008). The *F. moluccana* of Solomon F1 provenance has a relatively higher canopy area than Solomon F2 and local Kendal provenances (**Fig. 8**). The higher canopy area of Solomon F1 provenance indicates competition for greater light than other provenances. This is because the location of the Solomon F1 planting is in the middle of the land, so little light is received.

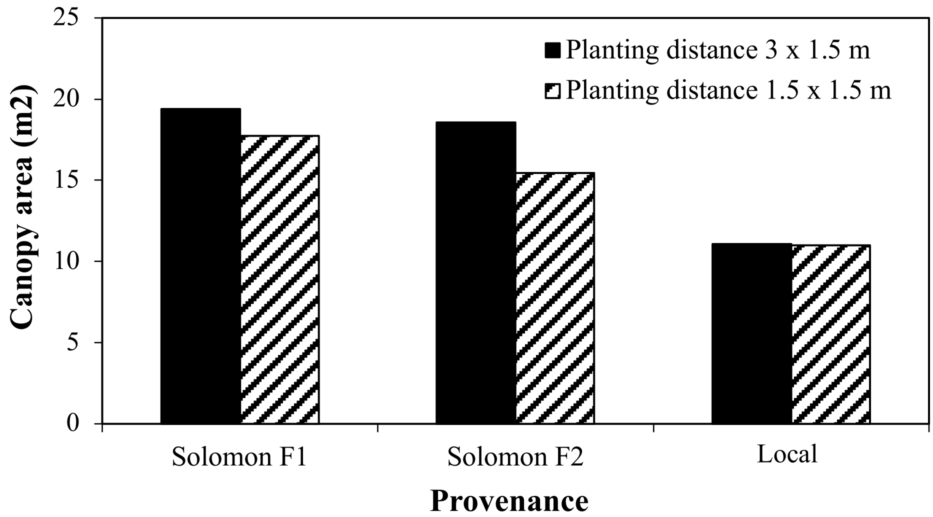

Fig. 8. The area of the *F. moluccana* canopy in the research area at the end of the observation.

Competition for light is closely related to the wide canopy area of a plant. The lower the light intensity level, the wider the canopy will be. This is because, at a low light intensity, a plant will spur the widening of its canopy to get light (Raharjo and Sadono 2008). In general, the diameter and height of the Solomon F2 *F. moluccana* have a greater value than the Solomon F1 *F. moluccana* and local *F. moluccana*. Meanwhile, according to Azizah (2019), the height and diameter of Solomon F1 have a greater value than Solomon F2 and local. The small growth of Solomon F1 provenance in the study was due to a large number of stressed trees due to the shaded trees and the attack of the pest *Eurema* sp. and termites. Therefore, the spacing of trees in the agroforestry system must be appropriate to control competition for light and nutrients (Wahyudi et al. 2014; Widiyanto et al. 2013).

Eurema sp. is a pest that, in the larval phase, attacks *F. moluccana* a lot, causing the tree leaves to yellow. This results in stunted tree growth due to less effective photosynthesis. In addition, termites eat the xylem and phloem, so the process of spreading photosynthesis and absorption of nutrients is disrupted. This also causes plant growth to be stunted (Azizah 2019). The Solomon F1 is an *F. moluccana* provenance with the highest potential to be attacked by pests and diseases compared to other *F. moluccana* provenances. This is because *F. moluccana* Solomon F1 has uniform nature, making it susceptible to major pests (Setiadi et al. 2014).

3.2. Rice Growth

The tree spacing and shade in the agroforestry system are closely related to the success of planting in agroforestry. Therefore, the analysis of variance (ANOVA) was intended to determine the effect of spacing and provenance of *F. moluccana* on the growth of IPB 3S rice. The treatment of shade tree provenance significantly affected rice height, panicle length, rice productivity, and productive tillers (**Table 2**). Meanwhile, the spacing treatment significantly affected the weight parameters of filled grain and productive tillers. Finally, the interaction between planting distance and the provenance of *F. moluccana* trees significantly affected the weight of empty grain and rice productivity.

Table 2. The ANOVA results of the effect of shade provenance and spacing in agroforestry systems

Parameter	**Treatment**		
	***F. moluccana* provenance**	**Planting distance**	**Planting distance × provenance *F. moluccana***
Rice height (cm)	0.02*	0.62ns	0.01*
Total tillers	0.23ns	0.40ns	0.67ns
Panicle length (cm)	0.02*	0.72ns	0.68ns
Weight of grain content (g)	0.10ns	0.04*	0.59ns
Weight of empty grain (g)	0.11ns	0.85ns	0.03*
Productivity (ton/ha)	0.01*	0.24ns	0.04*
Productive tillers	0.02*	0.02*	0.52ns

Notes: *= the treatment had a significant effect at 5% significance level, ns = the treatment had no significant effect at 5% significance level.

The rice grain weight is one of the major components determining the yields (Xing and Zhang 2010) that could provide information on density and grain size (Nurhasanah et al. 2017). However, the interaction between upland paddy variety and *F. moluccana* stand was not significantly different. Furthermore, the rice grain weight in this study showed no significant difference from the previous study's results in monoculture conditions (Azizah 2019).

Rice grain weight is one of the traits that is influenced by shade during the reproductive process (Wang et al. 2015). This study found that the interaction between variety and *F. moluccana* stand did not significantly affect the filled grain weight traits (**Table 3**). Most varieties tended to produce the highest filled grain weight planted under the local *F. moluccana* provenance. The grain filling process is affected by light radiation and environment temperature (Guo et al. 2015).

The weight of filled grain and productive tillers at a spacing of 3.0 m × 1.5 m had a higher value (**Table 3**). This is because the wider shaded tree spacing caused the grain content weight to increase in the agroforestry pattern (Christanto and Agung 2014). This might be due to the optimal photosynthesis process, so there is a lot of grain content. Meanwhile, the high number of productive tillers at a shaded tree spacing of 3.0 m × 1.5 m was caused by sunlight entering the forest floor. Thus, the productive tillers formed will be even greater (Arinta and Lubis 2018).

Table 3. Duncan's Multiple Range Test (DMRT) results from the effect of spacing on rice growth

Parameter	Planting Distance	
	3.0 m × 1.5 m	**1.5 m × 1.5 m**
Weight of grain content (g)	2.43a	1.23b
Productive tillers	3.16a	2.28b

Notes: different letters in the same row explain that the treatment is significantly different.

Based on DMRT, rice height, panicle length, productive tillers, and rice productivity showed greater values in the shade of local *F. moluccana* than other provenances (**Table 4**). This is because the canopy area of local Kendal has a smaller value than Solomon F1 and F2 provenances. A large canopy in agroforestry can reduce the level of production of crops. Panicle length is closely related to the amount of grain produced by rice. The number of productive tillers showed a positive relationship to rice productivity. However, this is not always the case if the production of empty grain shows a large value (Arinta and Lubis 2018).

Table 4. Duncan's Multiple Range Test (DMRT) results in the effect of provenance on rice growth.

Parameter	Provenance *F. moluccana* shade		
	Solomon F1	**Solomon F2**	**Local**
Height (cm)	40.94b	51.50a	53.32a
Panicle length (cm)	6.60b	7.64b	11.76a
Productivity (ton/ha)	0.02b	0.02b	0.14a
Productive tillers	1.96b	2.97ab	3.22a

Notes: numbers followed by different letters in the same row indicate significantly different treatments at a 95% confidence interval.

3.3. Rice Productivity

Calculation of productivity is closely related to the amount of rice production that a rice planting area can produce. Based on **Table 5**, the highest productivity of IPB 3S rice is in the shade of local *F. moluccana* provenance, which is 0.144 ton/ha. This is because the local *F. moluccana* provenance has a small canopy area, so the incoming light will be even greater. According to Dewi et al. (2018), a dense tree canopy will reduce the light that reaches the ground. In agroforestry conditions, the paddy productivity was lower than in monoculture conditions. The decrease was caused by the decreasing light intensity received by the paddy. A similar observation was reported by previous studies (Hairmansis et al. 2017; Liu et al. 2014; Sanou et al. 2012), showing the lower light intensity caused by shading during the reproductive stage would decrease the bigger yields than during the vegetative stage.

The IPB 3S rice productivity could reach an average value of 7 tons/ha (Ministry of Agriculture 2018). Meanwhile, the highest average production in the research area was found in the shade of local *F. moluccana* provenance of 0.144 ton/ha. Apart from the presence of *F. moluccana* shade, this was also caused by the attack of the pest bug on the research area. The attack of the pest *Leptocorisa oratorius* causes a decrease in rice productivity (Sumini et al. 2018). This is because *Leptocorisa oratorius* absorbs the liquid flour on the rice grains. The final yield and the number of panicles are determined mainly by the number of productive tillers (Nurhasanah et al. 2017). The highest number of productive tillers significantly differs from the Inpago Lipi Go 1 rice variety. Azizah (2019) reported that Inpago Lipi Go 1 variety in monoculture conditions generated productive tillers of about 14 tillers. This study indicated the decreasing number of tillers due to the different planting conditions. Previous studies reported that shading affected the number of productive tillers (Hairmansis et al. 2017; Muhidin et al. 2013).

Table. 5. IPB 3S rice productivity in various shade provenances and spacing

***F. moluccana* provenance**	**Planting distance**	**Productivity (ton/ha)**
Solomon F1	3.0 m × 1.5 m	0.027
	1.5 m × 1.5 m	0.023
Average		0.025
Solomon F2	3.0 m × 1.5 m	0.038
	1.5 m × 1.5 m	0.002
Average		0.020
Local	3.0 m × 1.5 m	0.087
	1.5 m × 1.5 m	0.201
Average		0.144

The grain weight of the rice is also one of the traits affected by the shading during the reproductive stage (Wang et al. 2015). The result showed that the interaction between variety and *F. moluccana* stand did not affect the filled grain weight traits (**Table 2**). Most of the varieties tend to produce the highest filled grain weight that that planted under the local *F. moluccana* provenance. The grain filling process was affected by light radiation and environment temperature (Guo et al. 2015). The result showed that two varieties interaction did not affect the grains weight, filled grain weight, and filled grain weight per cluster. The decrease can be influenced by nutrient competition between *F. moluccana* stands. In addition, it can be influenced by plant morphological adaptation. The growth of height and widening of the leaf surface of plants is an effort to adapt plants to the influence of shade (Saptono and Ernawati 2011).

The paddy productivity in agroforestry conditions was lower than in monoculture conditions, caused by the decreasing light intensity received by paddy. A similar observation was reported by previous studies (Hairmansis et al. 2017; Liu et al. 2014; Sanou et al. 2012), stating that the lower light intensity caused by shading during the reproductive stage would decrease the bigger yields than during the vegetative stage.

3.4. Environmental Conditions

Table 6 showed that the highest light intensity was found in the shaded tree of local *F. moluccana* provenance of 5414.3 lux, causing high rice production in these plots. This is presumably because the *F. moluccana* local Kendal is located on the edge of the research site (**Fig. 1**), which is adjacent to open land. This condition caused the yield of rice production at the *F. moluccana* local Kendal location to be relatively high (**Table 6**). The *F. moluccana* of local Kendal provenance also has a relatively lower canopy area (**Fig. 8**). The process of photosynthesis that increases the productivity of a plant is determined mainly by the quality of the plant canopy (Cavalli and Finger 2016; Pretzsch et al. 2015; Sadono et al. 2015).

Table 6. Data on light intensity in the research area

***F. moluccana* provenance**	**Planting distance**	
	1.5 m × 3 m	**1.5 m × 1.5 m**
Solomon F1	1971.89	1180.56
Solomon F2	1306.48	1212.19
Local	3724.52	5414.30

The research area has a pH of 5.9, an average temperature of 28.63°C, and average relative humidity of 72.67%. The rainfall in October, November, December, January, and February 2020 were 381.9, 330.1, 552.8, 383.5, and 510 mm/month, respectively (BMKG 2020). Susanto and Baskorowati (2018) reported that *F. moluccana* requires a temperature of 26-30°C and minimum rainfall of 291 mm/month for its development. Meanwhile, rice requires a minimum temperature of 18.7°C for its growth. The optimal pH for the development of rice plants is 4-7, with a humidity of 70.5%. In contrast, the minimum rainfall in the development of rainfed rice fields is 200 mm/month. Sunlight is essential in plant growth and development because it is one of the main components in photosynthesis and energy formation (Salisbury and Ross 1985). Therefore, the intensity of sunlight is very important for the photosynthesis, growth, and productivity of rice plants (Liu et al. 2014; Ningrum et al. 2019; Wang et al. 2015).

4. Conclusions

The growth of *F. moluccana* at the age of 14 months was not affected by the type of provenances (Solomon F1, Solomon F2, and local Kendal). The growth of *F. moluccana* of Solomon F2 provenance had a relatively higher value than the Solomon F1 and local Kendal provenances. The effect of tree spacing had significant effects on the bulk weight and productive tillers. Meanwhile, the treatment of shaded tree provenance significantly affected height, panicle length, productivity, and productive tillers. The IPB 3S rice had the highest productivity in the shaded tree of local *F. moluccana* provenance at a spacing of 1.5 m × 1.5 m with a value of 0.201 ton/ha.

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