Improved the growth and yield of rubber at mature period throught "iles-iles" (*Amorphophallus muelleri* Blume) intercropping

Sahuri[1*]

[1]Indonesian Rubber Research Institute
Jalan Raya Palembang – P. Balai KM. 29, PO BOX 1127 Palembang, Indonesia
*Corresponding author. Email: sahuri_agr@ymail.com

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ABSTRACT

Rubber plants that have produced can be improved through iles-iles farming. This study aims to determine the effect of the iles-iles rubber intercropping system on soil fertility, rubber growth, and latex yield. The study used a completely randomized block design (CRBD) with three replications. The treatment compared the rubber monoculture system with iles-iles rubber intercropping. The results showed that the cultivation of iles-iles as a rubber intercropping during the mature period of two years of observation did not inhibit the growth of rubber because it was not significantly different (P = 0.255) compared to the monoculture system but had a significant (P = 0.0013) effect on the latex yield. The BEP (Break Event Point) value of this farming system was achieved at the price of wet tubers of IDR 7.139 kg^{-1} with a production of 2.368 kg ha^{-1}, while the value of the LER (Land Equivalent Ratio) in this farming system was 1.84.

Keywords: *iles-iles, rubber growth; latex yield; rubber intercrops.*

INTRODUCTION

The system of intercropping rubber with other economic crops can increase land productivity, increase rubber growth and production, increase the intensity of farmer control over their rubber plantations, increase rubber farmer income, and reduce the risk of loss of income if one of the commodities experiences a decrease in selling price (Mousavi & Eskandari, 2011; Ferry et al., 2013; Esekhade et al., 2014; Pansak, 2015; Sahuri & Rosyid, 2015; Sahuri, 2017; Sahuri, 2019a). Intercropping systems can also increase soil organic matter (Rodrigo et al., 2004; Raintree, 2005; Pathiratna and Perera, 2006; Snoeck et al., 2013; Sahuri and Rosyid, 2015) and increase land use efficiency (Ogwuche et al., 2012; Pansak, 2015; Hondrade et al., 2017; Romyen et al., 2018; Mousavi & Eskandari, 2011; Sahuri, 2019b; Sahuri, 2020).

Some of the results of research on rubber intercropping systems with food crops (for example, upland rice, corn, soybeans, sorghum, etc.), horticulture (for example, pineapple, banana, chili, etc.), medicinal plants (for example, turmeric, ginger, etc.), and other plantation crops (e.g., cocoa, coffee, oil palm, sugarcane, etc.) have been documented since the 1980s in the Indonesian Rubber Research Institute annual research reports. The results showed that there was no negative effect of the intercropping system on rubber growth and production (Rosyid et al., 2007; Sahuri & Rosyid, 2015; Sahuri, 2017; Sahuri, 2019a; Sahuri, 2019b; Sahuri, 2020). Research in other places also shows the same results as the rubber intercropping system with medicinal plants (Pathiratna & Perera, 2006); rubber plantations with upland rice and green beans (Hondrade et al., 2017); rubber plants with sorghum and soybeans (Tistama et al., 2016); rubber plants with bananas (Rodrigo et al., 2005; Snoeck et al., 2013; Rinojati et al., 2016); and rubber plants with cocoa (Zakariyyya et al., 2016).

The main obstacle to the rubber intercropping system is the low light intensity due to the shade factor of the rubber plant canopy. In rubber plants with a single planting distance of 6 m x 3 m, when they are more than two years old, the light reduction reaches 50–60%. Intercrops planted under less than 50% shade have decreased yields by up to 60% compared to conditions without shade (Wirnas, 2007; Fikriati, 2010; Tistama et al., 2016). Therefore, shade-tolerant intercrops are needed, namely iles-iles or porang. Iles-iles is suitable as an intercrop in rubber plantation areas with closed crowns because it can grow under 40–50% shade (Sumarwoto, 2005; Santosa et al., 2006; Harijati and Mastuti, 2014; Santosa, 2014). This character corresponds to the condition of the rubber plantation area where the canopy has begun to close with a maximum sunlight intensity of only 30–40% at the age of the rubber plant of more than 2 years (Rodrigo et al., 2004; Xianhai et al., 2012; Sahuri, 2019a). In addition, iles-iles also has the ability to be an anti-fungal (Khan et al., 2007; Ansil et al., 2014), so it can indirectly function as a control of white root fungus in rubber plantation areas.

Few studies have assessed the effect of the iles-iles intercropping system on rubber growth and yield. On the other hand, when recommending this intercropping system, it is very important to see how it influences rubber growth and production. Therefore, this study aims to determine the effect of the iles-iles intercropping pattern of rubber on soil fertility, growth of rubber girths, and latex yields.

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MATERIALS AND METHODS

The research was conducted at the production and experimental garden of the Sembawa Rubber Research Institute, South Sumatra, which is located at 03°55.684' South Latitude and 104°32.382' East Longitude with an altitude of 10 m above sea level. The type of soil in the research location is red-yellow podzolic with a sandy loam texture. The research location was chosen in a rubber plantation area that produced a fairly uniform type of rubber clone, PB 260, planted in 2010. The research time was approximately two years, from December 2016 to December 2018.

The study used a completely randomized block design (CRBD) with three replications to compare the treatment of monoculture system rubber plants and iles-iles intercropping system rubber plants. The area of each treatment plot was 500 m^2 (a population of 50 rubber plants per plot). In each experimental unit, 20 rubber plants and iles-iles were taken as sample plants. Tillage is carried out on each plot at a minimum, as is the cleaning of weeds. The spacing for rubber is 6 m x 3 m (550 trees ha^{-1}), and the spacing for iles-iles is 100 cm x 50 cm (18,000 plants ha^{-1}), with a distance of 1.5 m from the rubber plantations. Manure of 7.5 tons ha^{-1} and dolomite of 4 tons ha^{-1} were applied one week before planting iles-iles (Sumarwoto, 2005), and chemical fertilizers using 45 kg of ammonium sulfate ha^{-1}, 110 kg of super phosphate ha^{-1}, and 130 kg of potassium chloride ha^{-1} were given at the time of planting, and another 45 kg of ammonium sulfate ha^{-1} was added (Kasno, 2008). The fertilizer applied to rubber trees is presented in Table 1, and the rubber intercropping system with iles-iles can be seen in Figure 1.

Observations consisted of chemical analysis of the soil carried out at a depth of 20 cm, including pH, C-organic, N, P_2O5, K_2O, cation exchange rates of Ca and Mg, and cation exchange capacity (CEC). Climate data collection with AWS (Automatic Weather Stations) The rubber plant parameters observed included measuring the stem girth at a height of 100 cm from the ground surface of 20 sample trees in each treatment plot and measuring the yield of latex per tree per tapping (g t^{-1} t^{-1}) using a half-spiral tapping system that was tapped every 3 days. For one year of tapping (1/2S D/3) as many as 20 sample trees in each treatment plot and measuring the light intensity every 6 months using the LI-COR Line Quantum Sensor. The parameters of the intercrops observed were the yield of wet iles-iles tubers in each treatment plot, which was then calculated by converting the average tuber weight to the number of iles-iles plants in one hectare, assuming a population per hectare of 16,000 plants. Data analysis used the ANOVA table F test; if there was a significant difference, it was continued with Duncan's Multiple Range Test (DMRT) at the 5% level (Gomez and Gomez, 1995).

Table 1. The fertilizer applied to rubber trees

Type of fertilizer	Amount of fertilizer applied to rubber plants (kg $tree^{-1}$ $year^{-1}$)		
	Ten years after planting	Eleventh year after planting	Twelfth year after planting
Ammonium sulphate	0.35	0.35	0.35
Super phosphate	0.26	0.26	0.26
Potassium chloride	0.30	0.30	0.30
Kieserit	0.08	0.08	0.08

Note: The dosage of fertilizer used is based on the results of soil and leaf nutrient analyses at the study site.

Figure 1. Rubber intercropping system with iles-iles

RESULTS AND DISCUSSION

Climatic conditions, planting schedule, and harvest of Iles-iles

The average rainfall in 2016–2018 at the study site was 2,107 mm/year, with the highest rainfall in November–April (> 200 mm) and dry months May–October (< 100 mm). The average humidity throughout the year is >80%, with an average air temperature of 23–32 ^{o}C. The first plants were harvested at the age of 2 years in September and October of 2018, and the next one was not replanted because new plants were grown from seeds and bulbils at the study site (Figure 2). Based on the climatic criteria for iles-iles (Kasno, 2008), it shows that the research area is suitable for planting iles-iles with temperature conditions of 25–35 °C.

Based on the average monthly rainfall from 2016 to 2018, it shows that the research location is included in the C3 Climate Type, which is a rather humid climate type with the number of wet months (rainfall > 200 mm) between 5 and 6 months and the number of dry months (rainfall 100 mm) between 4 and 6 months (As-Syakur, 2009). This condition indicates that optimal planting of iles-iles in this location can only be done once a year. Based on the climate suitability class for rubber trees (Wijaya, 2015), the research location is in the S2 class (somewhat suitable).

Soil Analysis

The type of soil in the research location is ultisol. The results of soil analysis at the study site indicated that the presence of intercrops among rubber trees had a positive effect on increasing the fertility of rubber land. Based on the criteria for soil fertility for rubber plants (Wijaya, 2018), it states that soil pH conditions increased from very acidic to acidic, C-organic increased from low to high, and P increased from low to medium, while N, K, and CEC were still low (Table 2). Soil fertility due to intercropping increased by an average of 31% compared to monoculture rubber. This is due to the presence of nutrient inputs such as dolomite, inorganic and organic fertilizers, and the maintenance of iles-iles plants, which cause better soil structure and soil conditions rich in nutrients that are needed by rubber plants.

The rubber intercropping system with iles-iles has a positive effect on the soil because it does not cause competition for nutrients in the soil. As reported by Esekhade et al. (2014), the rubber intercropping system can significantly increase organic carbon, nitrogen, and phosphorus in the soil. However, if the land continues to be cultivated in the long term, there will be nutrient depletion as a result of the intercropping treatment. Therefore, the addition of fertilizers, especially organic fertilizers, nitrogen, and phosphorus, is still being done to increase the growth of rubber trees and intercrops. Khongdee & Pansak (2015) also reported that the rubber intercropping treatment did not negatively affect nutrient content or soil moisture, so it did not cause competition for nutrients in the soil. Furthermore, Tetteh et al. (2019) also reported that the rubber intercropping system can increase organic carbon and nitrogen-fixing microbes in the soil.

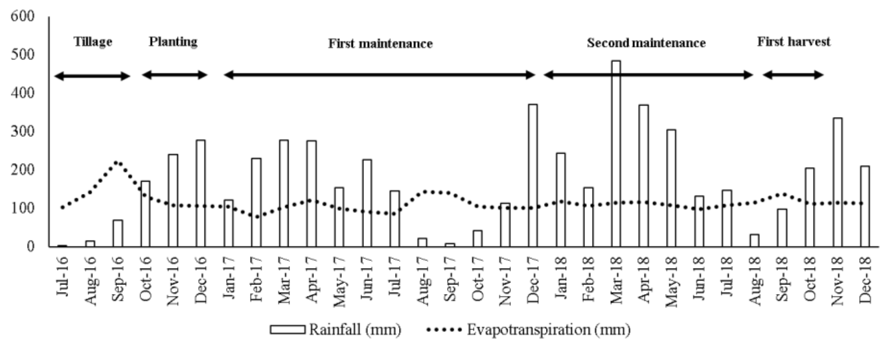

Figure 2. Average monthly rainfall, evapotranspiration rate, and schedule from planting to iles-iles harvest in the 2016–2018 planting season at the Sembawa Rubber Research Center Station

Table 2. The chemical and physical properties of the soil in the monoculture system and the iles-iles intercropping system

Analysis Variable	Treatment		Enhancement
	Monoculture	Iles-iles	
pH	4.21va	5.24a	20%
C - Organic (%)	1.34l	3.47h	61%
N-total (%)	0.23l	0.31l	26%
C/N ratio	5.82l	11.21m	48%
P_2O_5 (Bray II) (ppm)	4.25vl	5.36l	21%
K_2O (Morgan) (me/100 gr)	0.14l	0.16l	13%
CEC (me/100 gr)	8.58vl	11.86l	28%

Note: l = low; vl = very low; m = medium; a = acid; va = very acid; h = height

Light Penetration

Overall, the average light penetration among rubber trees in the study area during the three years of observation was 22.35% and 15.6% in narrow rows. This means that the light penetration is not more than 30% at any point measured (Figure 3). Based on the criteria for light requirements for iles-iles (Kasno, 2008), it shows that the research area is suitable for planting iles-iles with a maximum light requirement of 40%. Wijayanto and Pratiwi (2011) also reported that the growth and production of iles-iles were significantly good at 30% light penetration.

Stem Girth

The rubber stem girth is measured at a height of 100 cm from the ground. The planting of iles-iles as an intercrop between rubber plants did not have a negative effect on the growth of rubber girths. The results of the study during the two years of observation showed that the growth of rubber stem girths in the iles-iles intercropping pattern and the rubber monoculture pattern were not significantly different (P = 0.255). This shows that the presence of iles-iles as an intercrop between rubber plants does not inhibit the growth of rubber plants (Figure 4). The rubber girth is measured at a height of 100 cm from the ground. Planting iles-iles as an intercrop between rubber plants does not have a negative effect on the growth of rubber girths. The results of the research during the two years of observation showed that the growth of rubber girth in the iles-iles intercropping pattern and the rubber monoculture pattern were not significantly different (P = 0.255). This shows that the presence of iles-iles as an intercrop among the rubber plants does not inhibit the growth of the rubber plants (Figure 4).

The growth of rubber stem girths due to planting between iles-iles plants was significantly less hampered compared to the monoculture rubber system. This is due to the fact that the rubber plantation system is well maintained through N, P, and K fertilization, composting of iles-iles crop residues, iles-iles plant maintenance, weeding, monitoring, and controlling pests and diseases. As reported by Tistama et al. (2016), a rubber intercropping system with sorghum and soybean crops does not inhibit the growth of rubber stem girths because, through the intercropping system, soil fertility increases. Esekhad et al. (2014) and Romyen et al. (2018) also reported that rubber trees planted by intercropping could reach tapping maturity earlier than those planted by monoculture so as to shorten tapping time, thereby accelerating investment returns.

Latex Yield

Latex yields are expressed in units of g t^{-1} t^{-1} (grams per tree per tapping), obtained by calculating the volume of latex and dry rubber content divided by the number of sample plants. The planting of iles-iles between rubber plants has a positive effect on increasing latex yields. Two years of observation showed that the latex yield of the iles-iles intercropping system was 19% higher than the latex yield of the monoculture rubber system.

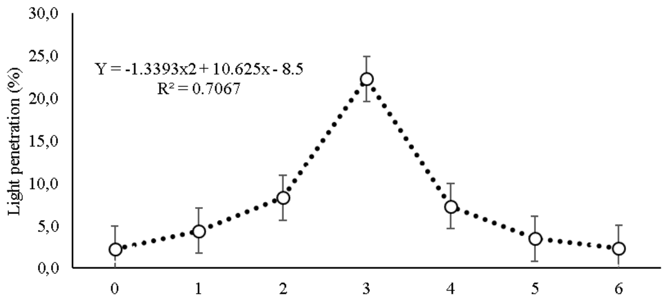

Figure 3. Light penetration between rubber trees over the two years of observation

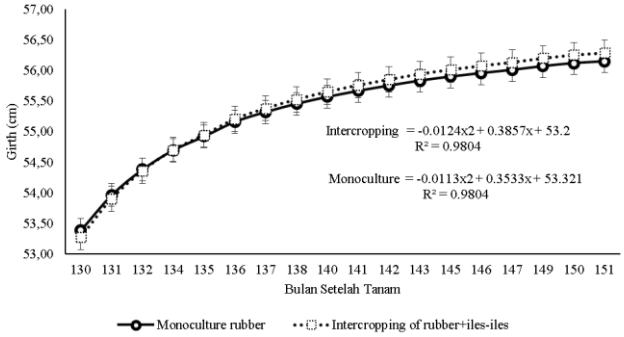

Figure 4. The growth of rubber stem girths with the iles-iles intercropping pattern and the monoculture rubber pattern during the two years of observation

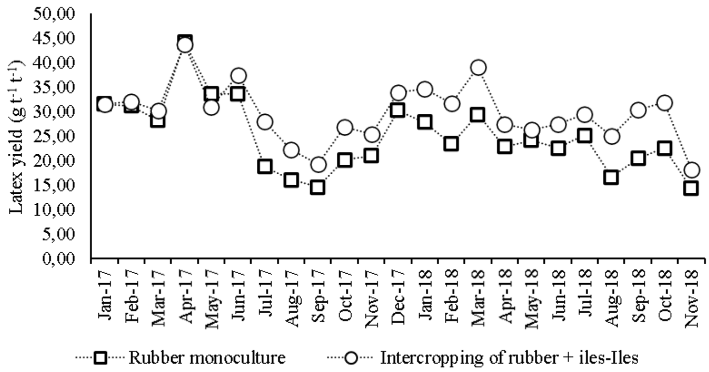

Figure 5. Latex yield gram per tree per tapping monoculture system and iles-iles intercropping system for two years of observation

Table 3. Production costs of iles-iles farming between rubber plantations that are already producing

Description	1st year		2nd year	
	Physical	Value (Rp ha^{-1})	Physical	Value (Rp ha^{-1})
Land clearing (tractor)	0.50	250,000		
Labor ha^{-1}	44	2,442,132	36	1,998,108
Transports			1	200,000
Iles-iles seed ha^{-1}	9,600	28,800,000		
Dolomite (kg ha^{-1})	2,400	2,808,000		
Manure (kg ha $^{-1}$)	4,200	1,344,000		
Urea (kg/ha karet)	27	75,600		
SP-36 (kg/ha karet)	66	237,600		
KCl (kg/ha karet)	78	526,500		
Insecticide (l ha^{-1})	3	180,000		
Carbofuran (kg/ha karet)	3	22,500		
Roundup herbicide (l ha^{-1})	3	195,000		
Production cost (Rp ha^{-1})		36,881,332		2,198,108
Total Production Cost (Rp ha^{-1})		39,079,440		
Yield (kg ha^{-1})				
Wet tubers (kg ha^{-1})			5,474	
The average price of wet tubers/kg			16,500	
Revenue (Rp ha^{-1})				90,327,270
Benefit (Rp ha^{-1})				51,247,830
B/C Ratio				1.31
BEP Harga (Rp)				7,139
Production BEP (kg ha^{-1})				2,368

Note: Processed from primary data (2018); Population and area of iles-iles as intercropping of rubber are 60% from monoculture, with a distance from row of rubber trees of 1.0–1.5 m.

Table 4. Yield potential of iles-iles between productive rubber plantations

Treatment	Population (ha^{-1})	Yield (kg.ha^{-1})
Monoculture System		
Rubber	500	1.014
Iles-iles	16.000	9.124
Intercropping System		
Rubber	500	1.260
Iles-iles	9.600	5.474

Note: Processed from primary data (2018); The population and area of iles-iles as rubber intercropping are 60% from monoculture with a distance of 1.0–1.5 m from the row of rubber trees; iles-iles products are wet tubers, and rubber products are latex.

Based on the results of statistical analysis, the results of the latex iles-iles intercropping system and the monoculture rubber pattern were significantly different (P = 0.0013). This shows that the presence of iles-iles planted between rubber plants did not reduce latex yields and even significantly increased latex yields (Figure 5). The rubber intercropping system can increase the productivity of rubber plantations so that rubber production increases and farmer household income also increases. Mousavi and Eskandari (2011) reported that latex yields increased with intercropping due to an increase in soil fertility. Snoeck et al. (2013) also reported that the rubber intercropping system can increase the productivity of rubber plantations and farmer household income. Furthermore, Romyen et al. (2018) added that the rubber intercropping system is more economically profitable than monoculture.

Costs and Profits of Iles-Iles Farming Between Producing Rubber Plants

The iles-iles population planted between rubber trees with a spacing of 6 m x 3 m is 60% of the monoculture population with a distance of 1.0–1.5 m from the rows of rubber trees. The yield potential of iles-iles between mature rubber plantations is presented in Table 3. The revenue obtained in the second year came from the sale of wet tubers, namely IDR. 90,327,270. The total profit of iles-iles farming for two years planted between rubber plantations is IDR 90,327,270. The value of the B/C ratio of 1.31 > 0 indicates that the iles-iles farming planted between rubber plantations is feasible for development. The BEP (Break Event Point) value is a condition indicating that the farm has neither a profit nor a loss (break even), that is, the income equals the total cost. In iles-iles farming planted between productive rubber plantations, the BEP was reached at a tuber price of IDR 7,139 kg^{-1} with a production of 2,368 kg ha^{-1}.

The profit of the intercropping system is determined using the Land Equivalent Ratio (LER) analysis, which is the ratio between the area required in a monoculture system and the unit area of the intercropping system at the same management level to provide the same amount of yield in monoculture (Jalloh et al., 2003). The scenario results between monoculture and intercropping systems are presented in Table 4.

$$\text{LER} = \left(\frac{1.260}{1.014} + \frac{5.474}{9.124}\right)$$

$$= 1.24 + 0.60$$

$$= 1.84 \text{ ha}$$

The total area required for rubber and iles-iles planted in a monoculture system to produce the equivalent of one hectare in an intercropping system is 1.84. This means that the intercropping pattern has advantages compared to monoculture.

CONCLUSION

Farming of iles-iles as an intercrop between rubber plants during two years of observation did not inhibit the growth of rubber plants because it was not significantly different (P = 0.255) compared to the monoculture system but had a significant effect (P = 0.0013) on the yield of rubber latex. The BEP value of this farming system was achieved at a wet tuber price of IDR 7,139/kg with a production of 2,368 kg/ha, while the LER value in this farming system was 1.84.

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REFERENCES

Ansil, P. N., Wills, P. J., Varun, R., & Latha, M. S. (2014). Cytotoxic and apoptotic activities of *Amorphophallus campanulatus* (Roxb.) Bl. tuber extracts against human colon carcinoma cell line HCT-15. *Saudi Journal of Biological Sciences*, 21(6), 524-531.

As-syakur, A.R. (2009). Evaluasi zona agroklimat dari klasifikasi Schimidt-Ferguson menggunakan aplikasi Sistem Informasi Geografi (SIG). *Jurnal Pijar MIPA*, 3(1), 17-22.

Esekhade, T.U., Idoko, S.O., Osazuwa, Kore, I.K., & Mesike, C.S. (2014). Effect of intercropping on the gestation period of rubber. *Journal of Agricultural Research*, 3(8), 150-153.

Ferry, Y., Pranowo, D., & Rusli. (2013). The effect of intercropping on the growth of immature rubber in a gradual felling system. *Buletin Riset Tanaman Industri*, 4(3), 225-230.

Fikriati, M. (2010). Adaptation test of soybean *(Glycine max (L.) Merr.)* shade tolerance under rubber in rubber smallholder in Sarolangun District, Jambi. Skripsi Institut Pertanian Bogor, Indonesia . http://repository.ipb.ac.id/jspui/bitstream/123456789/27130/6/Bab%20I%20Pendahulua n%20A10dpr-3.pdf.

Harijati, N., & Mastuti, R. (2014). Estimation of diverse porang (*Amorphophallus muelleri* Blume) age in forest area based on brancing pattern of leaf petiolule. *Research Journal of Life Science*, 1(1), 20-25.

Hondrade, R.F., Edwin, H., Zheng, L., Elazegui, F., Lynne, J.A., Duque, E., Christopher, C.M., Casiana M.VC., & Garrett, K.A. (2017). Cropping system diversification for food production in Mindanao rubber plantations: a rice cultivar mixture and rice intercropped with mungbean. *Peer Journal*, 5, 1-20. DOI 10.7717/peerj.2975.

Jalloh, M. B. (2003). Modeling of solar radiation interception and biomass production in an intercropping system of rubber with banana and pineapple. PhD Thesis, University Putra Malaysia. http://webopac.upm.edu.my.

Kasno, A. (2008). Iles-iles umbi-umbian potensial sebagai tabungan tahunan. *Buletin Palawija*, 15, 15-20.

Khan. A., Rahman, M., & Islam, S. (2008). Antibacterial, antifungal, and cytotoxic activities of tuberous roots of *Amorphophallus camphanulatus. Indian Journal of Pharmacology. Biology*, 40(1), 41-44.

Khongdee, N., & Pansak, W. (2015). Effect of rubber intercropping on plant nutrients and soil moisture on slop land of Northern Thailand. *Research & Innovation*, 475-482. https://www.researchgate.net/publication/283623721.

Mousavi, S. R., & Eskandari, H. (2011). A general overview on intercropping and its advantages in sustainable agriculture. *J. Appl. Environ. Biol. Sci.*, 1(11), 482-486.

Ogwuche, P., Umar, H. Y., Esekhade, T. U., & Francis, S. Y. (2012). Economies of intercropping natural rubber with arable crops: a panacea for poverty alleviation of rubber farmers. *Journal of Agriculture Social Science*, 8(3), 100–102.

Pansak, W. (2015). Assessing rubber intercropping strategies in Northern Thailand using the water, nutrient, light capture in agroforestry systems model. *Kasetsart Journal*, 49, 785−794.

Pathiratna, L. S. S., & Perera, M. K. P. (2006). Effect of competition from rubber *(Hevea)* on the yield of intercropped medicinal plants, *Solatium virginianum* Schrad., *Aerva lanata* (L.) Juss. Ex. Schult and *Indigofera tinctoria* L. *Journal of the Rubber Research Institute of Sri Lanka*, 87, 36-45.

Raintree, J. (2005). Intercropping with rubber for risk management, improving livelihoods in the Lao PDR. *Agriculture and Forestry Research*, (2): 41-46.

Rinojati, N. D., Putra, R. C., Afifah, E., & Muliawansyah, I. (2016). Analisis efisiensi usahatani pisang diantara tanaman karet: studi kasus di kebun Cibungur PTPN VIII Jawa Barat. Warta Perkaretan, 35(1), 37-48. https:??doi.org/10.22302/ppk.wp.v35i1.79.

Rodrigo, V. H. L., Silva, T. U. K., & Munasinghe, E.S. (2004). Improving the spatial arrangement of planting rubber (*Hevea brasiliensis* Muell. Arg.) for long-term intercropping. *Field Crops Research*, 89(2), 327-335.

Rodrigo, V.H.L., Stirling, C.M., Silvaa, T.U.K., & Pathiranaa, P.D. (2005). The growth and yield of rubber at maturity is improved by intercropping with banana during the early stage of rubber cultivation. *Field Crops Research*, 91 (2005) 23–33. doi:10.1016/j.fcr.2004.05.005.

Romyen, A. Sausue, P., & Charenjiratragul, S. (2018). Investigation of rubber-based intercropping system in Southern Thailand. *Kasetsart Journal of Social Sciences*, 39, 135-142.https://doi.org/10.1016/j.kjss.2017.12.002 2452-3151.

Rosyid, M. J. (2007). Pengaruh tanaman sela terhadap pertumbuhan karet pada areal peremajaan partisipatif di kabupaten sarolangun, Jambi. *Jurnal Penelitian Karet*, 25(2), 25-36.

Sahuri & Rosyid, M. J. (2015). Optimization of land between rubber rows using cayenne pepper (*Capsicumfrutescens* Linn.) as intercrops. *Warta Perkaretan*, 34(2), 77-88. ISSN : 0216 – 6062.

Sahuri. (2017). Development of corn (Zea mays L.) in immature rubber period. *Jurnal Analisis Kebijakan Pertanian*, 15(2), 113-126. DOI: http://dx.doi.org/10.21082/akp.v15n2.2017.113-126 1.

Sahuri. (2019a). Technology of rubber-crop intercropping: constraints and opportunities of sustainable development. Jurnal Penelitian dan Pengembangan Pertanian, 38(1), 23-34. DOI: 10.21082/jp3.v38n1.2019.p23-34.

Sahuri, Cahyo, A. N., Ardika, R., Nugraha, I. S., Alamsyah, A., & Nurmansyah. (2019b). Modification of Rubber (Hevea brasiliensis Muell. Arg.) Spacing for Long-term Intercropping. *Journal of Tropical Crop Science*, 6(1), 50-59. DOI: https://doi.org/10.29244/jtcs.6.01.50-59.

Sahuri. (2020). Improvement the growth and yield of rubber through rubber based intercropping system. Jurnal Penelitian Hutan Tanaman (JPHT). Jurnal Penelitian Hutan Tanaman, 17(1), 27-40. DOI: https://doi.org/10.20886/jpht.2020.17.1.27-40.

Santosa, E., Sugiyama, N., Nakata, M., & Lee, O. N. (2006). Growth and corm production of *Amorphophallus* at different shading levels in Indonesia. *Japanese Journal of Tropical Agriculture*, 50 (2), 87-91.

Santosa, E. (2014). Development of intercropping iles-iles plants for the welfare of farmers and the independence of the national food industry. *Risalah Kebijakan Pertanian dan Lingkungan*, 1(2), 73-79.

Snoeck, D., Lacote R., Lacrotte, R., Keli, Z. J., Doumbia, A., Chapuset, T., Jagoret, P., & Gohet, E. (2013). Association of hevea with other tree crops can be more profitable than hevea monocrop during first 12 years. *Industrial Crops and Products*, 43 : p. 578-586. DOI: 10.1016/j.indcrop.2012.07.053.

Sugiyama, N., Hikosaka, S., & Kawabata, S. (2003). Cultivation of *Amorphophallus muelleri Blume* in timber forests of East Java, Indonesia. Jpn. *J. Trop. Agric*., 47(3), 190–197.

Sumarwoto. (2005). Iles-iles (*Amorphophallus muelleri Blume*); description and other characteristics. *Biodiversitas*, 6(3), 185–190.

Tetteh, E.N., Abunyewa, A.A., Tuffour, H.O., Berchie, J.N., Acheampong, P.P., Ampofo, K.T., Dawoe, E., Logah, V., Agbenyega, O., Ennin, S.A., Nunoo, I., Melenya. C., Danquah, E.O., Barnes, V.R., & Partey, S.T. (2019). Rubber and plantain intercropping: Effects of different planting densities on soil characteristics. *PLoSONE*, 14(1), e0209260. https://doi.org/10.1371/journal.pone.0209260.

Tistama, R., Dalimunthe, C.I., Sembiring, Y.R.V., Fauzi, I.R., Hastuti, R.D., & Suharsono. (2016). Intercropping of shorgum and soybean for increasing of land productivity in rubber immature (*Hevea brasiliensis* Muell Arg). *Indonesian Journal of Natural Rubber Research*, 34(1), 61-76.

Wijayanto, N., & Pratiwi, E. 2011. The effect of shading from sengon stands (Paraserianthes falcataria (L) Nielsen) on the growth of porang plants (*Amorphophallus onchophyllu*s). *Jurnal Silvikultur Tropika*, 2(1), 46-51.

Wijaya, T. (2018). Soil and climate suitability for rubber plantations. *Warta Perkaretan*, 27(2), 34-44.

Wirnas, D. (2007). Selection of Character Selection Based on Biometric and Molecular Analysis for Assembling Low Light Intensity Tolerant Soybeans. Disertation. Sekolah Pasca Sarjana. Insitut Pertanian Bogor. Bogor. http://iirc.ipb.ac.id/handle/123456789/40547.

Xianhai, Z., Mingdao, C., & Weifu, L. (2012). Improving planting pattern for intercropping in the whole production span of rubber tree. *African Journal of Biotechnology*, 11(34), 8484-8490.

Zakariyya, F., Puspitasari, N., & Prawoto, A. A. (2016). Various models of cocoa-rubber intercropping patterns. *Warta Pusat Penelitian Kopi dan Kakao Indonesia*, 28(1), 19-28.