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Research Paper

Growth and Yield of Corn (*Zea mays* L.) and Sorghum (*Sorghum bicolor* L.) Cultivated at Different Spacing in-Row Intercropping System with Rubber Crops (*Hevea brasiliensis* Muell. Arg.)

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Abstract
The efforts to increase productivity of rubber plantations can be carried out through polyculture planting patterns rubber of corn and sorghum. The aim of this research is to determine the rubber response and the growth of corn and sorghum intercrops with modified planting spacing. The research was conducted at the Rubber Research Facility, Faculty of Agriculture ($3°14'2''$S $104°38'12''$E), Universitas Sriwijaya, Indralaya, Ogan Ilir, South Sumatera. The research was conducted in two experimental units using a randomized block design with four replications. Planting spacing was as treatment. There were three plant spacings for corn, the treatment spacing, which consists of three levels, namely 75 cm × 25 cm (JT-J1), 75 cm × 30 cm (JT-J2) and 75 cm × 35 cm (JT-J3). Meanwhile, the spacing for sorghum were as follows 75 cm × 25 cm (JT-S1), 75 cm × 50 cm (JT-S2), 75 cm × 75 cm (JT-S3). The results of research on polyculture of rubber plants with plant spacing treatment had a positive effect on corn and sorghum crops. The growth and production of corn crops is significantly increased with a planting spacing of 75 × 35 cm for corn and 75 × 75 cm for sorghum was the optimal planting distance, as reflected in the growth of stem circumference, leaf greenness, stalk weight, and weight of 100 grains.

Keywords
Intercrops; Light intensity; Shade

1. INTRODUCTION

Rubber was one of Indonesia's leading export commodities. Indonesia was the second largest exporter after Thailand and Malaysia (Zuhdi, 2021). Rubber cultivation is becoming increasingly popular among Indonesians due to its promising economic potential. In addition, there is sufficient land suitable for rubber cultivation. However, most smallholder rubber farms are still monocultural. A monoculture farming system is a farming system that only cultivates one type of crop (Huang et al., 2023). This has an impact on farmers' income because they only rely on rubber yields. Efforts to increase farmers' income can be made by modifying the cropping system. A planting pattern that can be developed on rubber land was a polyculture system. Optimal utilization of land under annual crops can be achieved through a polyculture system (Hidayat et al., 2020). Polyculture was a system of cultivating various types of crops in one field. The polyculture planting method was one of the efforts to increase agricultural productivity. Rubber crops can be polycultured with several seasonal crops such as corn and sorghum.

Corn and sorghum are food crops. Corn and sorghum are major food commodities and are leading commodities that play a very important role in Indonesia's economic development (Widodo et al., 2023). Corn and sorghum have high adaptability, especially in marginal areas, as they can grow in areas with low rainfall and poor soil. Corn and sorghum are similar in that they are sources of food and feed. However, corn and sorghum production was not yet optimal due to limited cultivation land. Efforts to increase corn and sorghum production can be made by expanding the planting area, but in fact, the available land area was very limited. The development of corn and sorghum crops in rubber plantations was very possible, namely as intercrops in rubber plantations (Min et al., 2020). Furthermore, according to Barus (2013), the results of corn polyculture on rubber crops have not been beneficial in the drylands of Central Kalimantan for increasing farm income from corn intercropping. According to Asroh et al. (2015), corn cultivation with a planting distance of 50 × 60 cm produces the best corn yield.

Fluctuations in rubber crop yields affect farmers incomes. This not only impacts farmers' welfare but also affects state revenues. The polyculture rubber cultivation system with corn and sorghum offers various economic and environmental benefits. More efficient land use can increase soil fertility and increase farmers' income. This system has the potential to increase productivity and sustainability in rubber plantation land management. Polyculture planting patterns can increase land productivity, thereby positively impacting farmers' welfare and state revenue. Several studies have shown that Intercropping in the rubber inter-rows (gawangan) has a positive effect on the growth of rubber trees, and intercrops can provide income for farmers.

One of the obstacles faced in polyculture cropping systems is competition between crops for light and nutrients. Therefore, it is necessary to regulate population or planting distance. However, planting distances that are too far apart can also reduce land use efficiency, because intercrops cannot make good use of the open space between the main crops. Therefore, planting distance must be adjusted to the needs of each plant and the available land conditions. Through proper planting distance adjustment, it is hoped that competition between crops can be reduced. There has been little research on the planting distance of corn and sorghum polyculture with rubber. This study aims to evaluate the response of polyculture planting patterns with planting distance treatments on the growth and production of rubber crops with corn and sorghum.

2. EXPERIMENTAL SECTION

2.1 Research Location and Time

This research was conducted at the Rubber Research Plantation of the Faculty of Agriculture (3°14′2″S 104°38′12″E), Sriwijaya University, North Indralaya District, Ogan Ilir, South Sumatra from December 2022 to March 2023. Sorghum research location and corn research location are presented in Figure 1.

2.2 Research Procedure

The research location was a rubber plantation with trees aged 17 years. The rubber variety used was PB 260, aged 15 years. The rubber planting distance was 5 m × 3 m. Tapping was carried out every two days and latex collection was carried out once a week. The land was tilled with an 80 HP tractor before being planted with corn and sorghum. Land tillage began with plowing the soil using a tractor to a depth of 30-40 cm. After that, dolomite lime was applied at the recommended dose of 4 tons/ha or 0.4 kg/m^2. Then, research plots measuring 3.5 m × 2 m were made in the rubber plantation area. The corn variety used was Hibrida Betras 9, while the sorghum variety used was Bioguma 1.

2.3 Experimental Design

The study was conducted on two experimental units. Corn and shorgum was plant in inter row of rubber tree plantation. Planting began 100 cm from the rubber tree trunks. The planting sites were located in adjacent blocks within the plantation (Figure 1). The land was tilled with tractor to facilitate seedling planting. The corn study used a Randomized Block Design (RBD). Planting distance was used as the treatment, consisting of three levels: 75 cm × 25 cm (JT-J1), 75 cm × 30 cm (JT-J2) and 75 cm × 35 (JT-J3). Furthermore, the sorghum study used a Randomized Block Design (RBD). Planting distance was used as the treatment, consisting of three levels: 75 cm × 25 cm (JT-S1), 75 cm × 50 cm (JT-S2), and 75 cm × 75 cm (JT-S3). Each treatment was repeated four times. All collected data were analyzed using analysis of variance (ANOVA). Furthermore, significant differences between treatments were tested using the Least Significant Difference (LSD) at $\alpha \leq 5\%$.

2.4 Data Collection

The data collected consisted of rubber tree parameters, including total rubber tree latex production and stem circumference growth. Furthermore, data related to the morphology and yield of corn and sorghum crops was collected. The morphological and yield data for corn and sorghum crops consisted of plant height, stem diameter, leaf greenness, wet and dry stalk weight, and 100-seed weight. Leaf greenness was measured using a Konica Minolta SPAD-502 Plus device. Meanwhile, data related to microclimate data consisted of light intensity. As supporting data, soil pH measurements were taken at the research site. Light intensity measurements were taken using a lux light meter. Measurements were taken at noon (12:00-13:00 WIB) every month. Measurements were taken at two locations: on unshaded land (open land) with rubber trees and under the shade of rubber trees (inter-rows). Meanwhile, soil pH measurements were taken in the laboratory by taking soil samples from the inter-rows. Samples were taken at four locations. Soil pH measurements were only taken at the beginning of the study.

3. RESULTS AND DISCUSSION

Table 1. Light intensity (lx) in rubber plantations (A) and in open fields (B).

Treatment	December	January	February	March
Inter-rows	276.0	381.0	412.0	391.0
Open land	13817.4	33642.4	45751.9	19692.8

Sunlight exposure that significantly affects light intensity was influenced by the shade of rubber trees in rubber plantations. There was a significant difference between light intensity under the shade of rubber trees and under direct sunlight (Table 1). Light intensity under rubber trees was influenced by several factors such as rubber planting distance and tree age. Planting rubber trees close together and the age of the crops will reduce the intensity of light entering. In addition, weather factors also affect light intensity, where during the dry season rubber trees usually lose many leaves, resulting in more intense light entering between the trellises. The low light intensity received by corn

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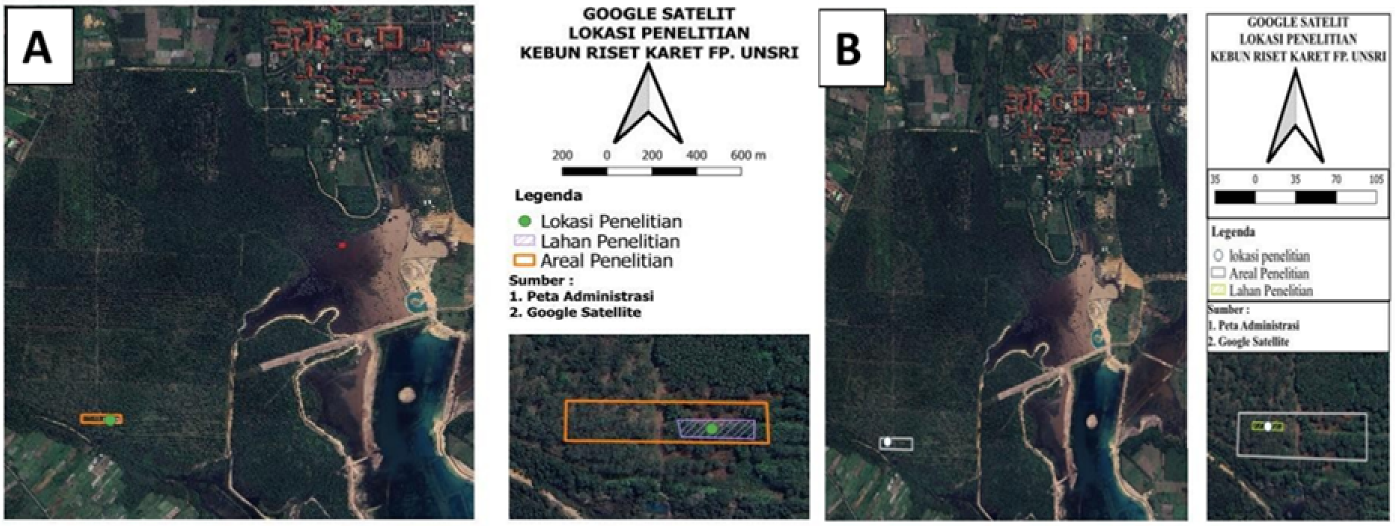

Figure 1. Sorghum research location (A) and corn research location (B).

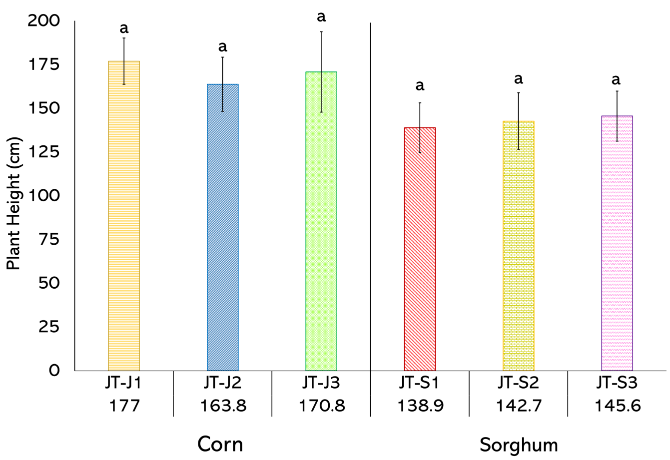

Figure 2. Plant height of corn and sorghum. Corn planting distances consist of: 75 cm × 25 cm (JT-J1); 75 cm × 30 cm (JT-J2); 75 cm × 35 cm (JT-J3). Meanwhile, the sorghum planting distances consist of: 75 cm × 25 cm (JT-S1); 75 cm × 50 cm (JT-S2); 75 cm × 75 cm (JT-S3).

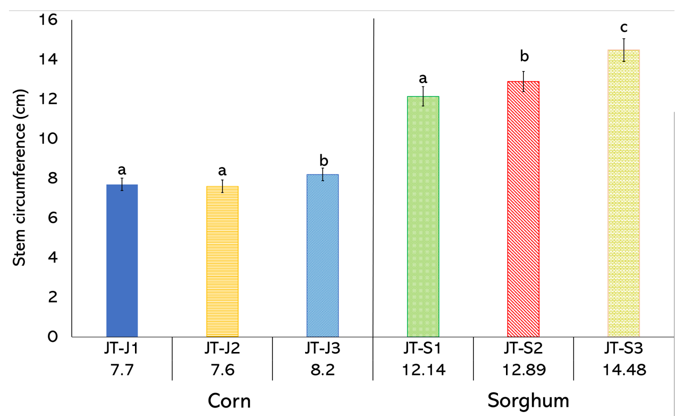

Figure 3. Stem circumference of corn and sorghum. Corn planting distances consist of: 75 cm × 25 cm (JT-J1); 75 cm × 30 cm (JT-J2); 75 cm × 35 cm (JT-J3). Meanwhile, the sorghum planting distances consist of: 75 cm × 25 cm (JT-S1); 75 cm × 50 cm (JT-S2); 75 cm × 75 cm (JT-S3).

and sorghum crops under the shade of rubber trees in polyculture systems can inhibit the productivity of intercropped crops. Corn polyculture with soybeans reduces soybean production due to the lack of light intensity received by soybean crops as a result of shade (Liu et al., 2017).

There was no significant difference in pH values at the research site for either corn or sorghum (Table 2). The pH conditions at the corn and sorghum polyculture rubber plantation site were classified as acidic. Such soil conditions are classified as problematic land with low fertility levels. Therefore, the soil requires the addition of lime and organic matter to increase land productivity, growth, and production of rubber, corn, and sorghum crops. According to Hartemink and Barrow (2023), the availability of N, P, K, Ca, and Mg nutrients was influenced by soil pH. According to Sarto et al. (2021), in acidic soils, corn and sorghum crops are sensitive to P nutrient deficiency and Al stress.

Corn crops intercropped with rubber crops initiate better stem height growth compared to sorghum crops. A planting distance of 75 cm × 25 cm has a positive effect on corn plant height. However, unlike sorghum crops, a planting distance of 75 cm × 25 cm does not have a positive effect on sorghum plant height (Figure 2). Corn plant growth tends to be inhibited by too wide a distance. This was in contrast to sorghum crops, which actually require a wider planting distance. Planting distances that are too

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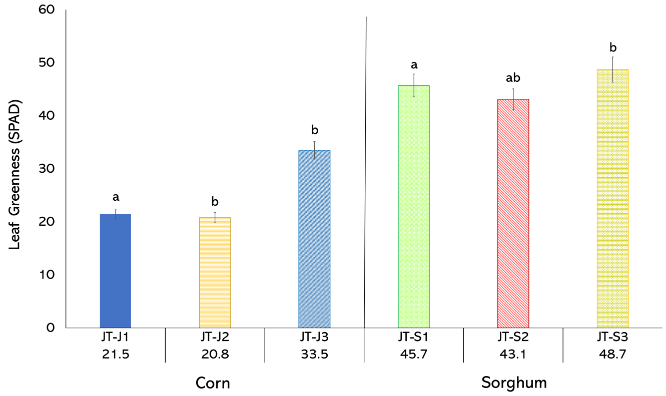

Figure 4. Leaf greenness levels of corn and sorghum. Corn planting distances consist of: 75 cm × 25 cm (JT-J1); 75 cm × 30 cm (JT-J2); 75 cm × 35 cm (JT-J3). Meanwhile, the sorghum planting distances consist of: 75 cm × 25 cm (JT-S1); 75 cm × 50 cm (JT-S2); 75 cm × 75 cm (JT-S3).

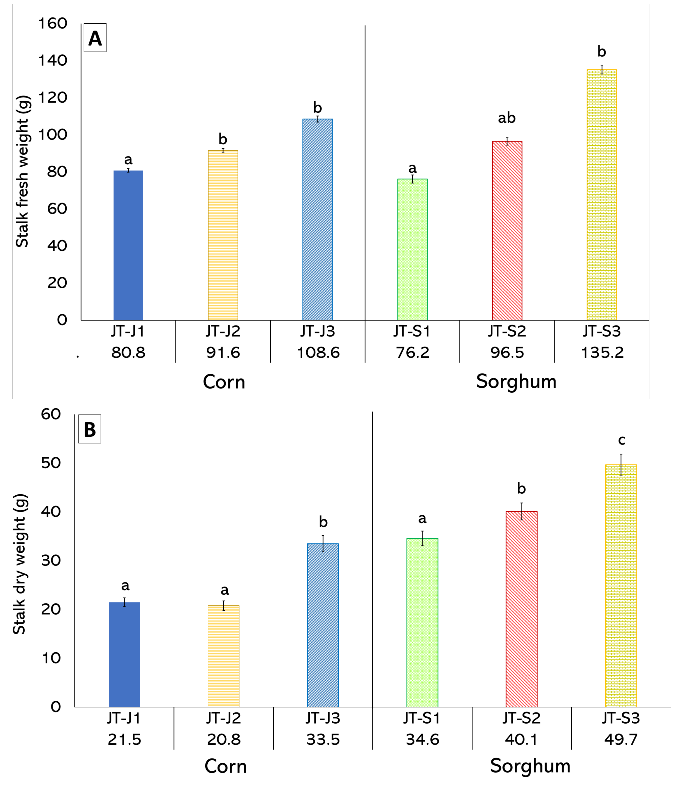

Figure 5. Corn and sorghum stalks weight. Fresh stalk weight (A) and dry stalk weight (B) of corn and sorghum crops.

close together have the potential to cause mutual shading of plant canopies. This will have an impact on competition for sunlight. Conversely, if the planting distance was too wide, the plant canopy cannot cover the area completely, resulting in a lot of empty space and inefficient land use. Generally, the lower the intensity of light received by crops, the taller the crops will grow because they experience etiolation. Shaded plant canopies can trigger the action of the hormone auxin in the apical buds, causing them to grow actively in search of light in order to perform photosynthesis more optimally (Handriawan et al., 2016). Furthermore, according to Gao et al. (2021), planting with the right spacing will help the roots to develop, which will have an impact on plant growth.

The stem circumference of corn and sorghum intercropped with rubber crops had little effect on stem diameter growth, whereas intercropping with corn initiated faster stem circumference growth. Furthermore, a planting distance of 75 cm × 35 cm was the best planting distance for corn in terms of stem diameter growth. A planting distance of 75 cm × 75 cm has a positive effect on the stem circumference growth of sorghum crops (Figure 3). A larger stem circumference will affect production yield. This was related to the physiological function of crops. The physiological process can run well in terms of the supply of assimilates from the source (leaves) to the sink (stems), thereby increasing stem biomass and seed formation (Kirkby et al., 2023). In addition, the circumference of sorghum stems increases with age and can be seen from the weight of fresh and dry stems. Fresh stem weight describes the level of water absorption by crops, while dry stem weight reflects the mechanism of photosynthesis (Rahayu et al., 2012).

Corn leaves were detected to be greener than sorghum leaves. Wide planting distances had a positive effect on leaf greenness, especially in sorghum crops. A planting distance of 75 cm × 75 cm for sorghum crops showed higher greenness compared to crops with other planting distances (Figure 4). This phenomenon was due to the fact that wider planting distances allow the entire canopy of the crops to be exposed to sunlight. Conversely, narrower planting distances cause sunlight to be blocked by the dense canopy, so that sunlight does not optimally reach the crops in between. According to Muda et al. (2024), a decrease in light intensity was followed by a decrease in leaf greenness, as a response to the nature of the leaves. Furthermore, plants exposed to direct sunlight had higher chlorophyll content than plants in low light conditions (Ramadhani et al., 2026).

Rubber crops intercropped with corn crops have a positive effect on corn plant growth compared to sorghum crops. This was reflected in the weight of corn and sorghum plant stalks. Furthermore, a planting distance of 75 cm × 35 cm was the best planting distance for corn crops in terms of stalk weight. A planting distance of 75 cm × 75 cm has a positive effect on the weight of sorghum crops (Figure 5). A wider planting distance increases the weight of the crops. This was because a planting distance that was too wide affects the intensity of sunlight received by the crops. The assumption was that the wider the planting distance, the more sunlight the crops will receive. Sunlight was one of the determining factors in the photosynthesis process. Ac-

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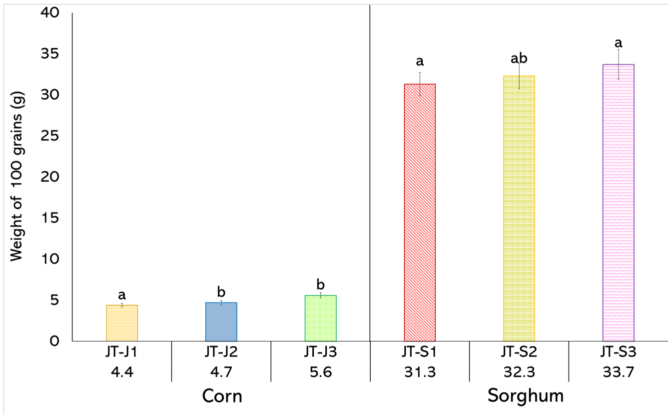

Figure 6. Fresh weight of 100 corn and sorghum grains. Corn planting distances consist of: 75 cm × 25 cm (JT-J1); 75 cm × 30 cm (JT-J2); 75 cm × 35 cm (JT-J3). Meanwhile, the sorghum planting distances consist of: 75 cm × 25 cm (JT-S1); 75 cm × 50 cm (JT-S2); 75 cm × 75 cm (JT-S3).

cording to Ratri et al. (2015), the dry weight of crops was highly dependent on the effectiveness of photosynthesis carried out by the leaves. This was because the photosynthesis process produces photosynthates which are then used for the growth and formation of plant vegetative organs. This process then determines the plant biomass produced.

Intercropping corn with rubber trees has a positive effect on production yields. Furthermore, a planting distance of 75 cm × 35 cm has a positive impact on the production of 100 corn grains. The production of 100 sorghum grains was influenced by the planting distance. A planting distance of 75 cm × 75 cm was the best distance for sorghum crops (Figure 6). A wide planting distance provides sufficient space for crops to receive sunlight. In addition, crops are more optimal in utilizing nutrients for corn and sorghum growth, thereby increasing crop production. Apart from water and nutrients, solar energy was one of the important factors that support plant growth and development. The right planting distance helps improve plant growth because it allows crops to fulfill their basic needs, such as sunlight, moisture, and other growth factors. Sunlight was needed by crops as a source of energy for photosynthesis. According to Zakaria et al. (2020), assimilates resulting from photosynthesis are mobilized and used to support plant growth and development in the vegetative and generative phases. This condition then causes the availability of sunlight energy to be the basis for determining the planting distance of intercrops. According to Silalahi and Widaryanto (2019), a lack of sunlight will affect the photosynthesis process, causing a decrease in photosynthetic products and thus slowing down plant development.

Table 2. Soil pH in polyculture fields of corn and sorghum with rubber trees at the start of the study.

Replication	H_2O	KCl
	Corn	
1	4.70	4.22
2	4.29	4.01
3	4.78	4.20
4	4.40	4.05
Average	4.54	4.12
	Sorghum	
1	4.63	4.23
2	4.62	4.46
3	4.45	4.43
4	4.54	4.48
Average	4.56	4.40

4. CONCLUSION AND SUGGESTION

Based on the results of the research and discussions that have been conducted, it can be concluded that intercropping rubber trees with corn and sorghum has a positive impact on corn and sorghum crops. The planting distance of 75 × 35 cm for corn and 75 × 75 cm for sorghum was the best planting distance, as reflected in the growth of stem circumference, leaf greenness, stalk weight, and weight of 100 grains. Corn was recommended to be planted not as an intercrop, while sorghum was recommended as an intercrop with a planting distance of more than 75 × 75 cm. Furthermore, it was necessary to review more specific measures that can increase the adaptability of sorghum as an intercrop.

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