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Optimization of Intercropping Corn in Immature Oil Palm Plantations (Non Yielding Stage)

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ABSTRACT

The optimization of land use in immature oil palm plantations (non-yielding stage) is crucial to enhancing productivity and supporting sustainable agriculture. This study aimed to evaluate the effect of corn intercropping systems on vegetative growth, yield, and land-use efficiency in immature oil palm plantations. An experimental method with a Randomized Block Design was employed, consisting of two treatments: corn monoculture (control) and corn intercropped in the inter-row spaces of immature oil palms, each replicated three times. Observed parameters included plant height, number of leaves, cob weight, grain yield, and Land Equivalent Ratio (LER). The results demonstrated that intercropped corn exhibited higher vegetative growth, including increased plant height and leaf number, due to optimal utilization of growing space and improved microclimatic conditions, such as stable soil moisture and light shading. Generative growth also improved, as evidenced by higher cob weight and grain yield, which reached 7.6 t/ha compared to 6.9 t/ha in monoculture. The LER value of 1.10 indicated a 10% higher land-use efficiency in intercropping systems. Positive interactions among crops minimized competition for nutrients and water, enhanced weed control, and maintained stable microclimatic conditions, contributing to sustainable plantation management. Economically, intercropping provided additional income for farmers during the immature phase of oil palms without compromising the main crop. In conclusion, corn intercropping in immature oil palm plantations optimizes space, improves both vegetative and generative growth, enhances yield per unit area, increases LER, and offers ecological and economic benefits, making it a viable and sustainable strategy for maximizing productivity and supporting diversified agricultural systems.

Keywords:, ***Intercropping, Corn, TBM Oil Palm, Land Productivity, Land Use Efficiency***

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INTRODUCTION

Optimal utilization of agricultural land is one of the main challenges in improving productivity in Indonesia's plantation sector, particularly for oil palm commodities. According to Pahan (2019), the management of oil palm plantations must be conducted efficiently to enhance productivity and ensure the sustainability of farming operations. In immature oil palm plantations (non-yielding stage), there are considerable empty spaces between palms that are not yet fully utilized, which can potentially lead to resource wastage. This situation provides an opportunity to implement intercropping systems as a strategy to increase land-use efficiency. Furthermore, Siregar and Harahap (2020) explain that optimizing non-yielding oil palm areas can increase farmers' income while improving agroecosystem conditions. Therefore, utilizing the inter-row spaces in immature oil palm plantations through intercropping becomes a strategic solution to sustainably enhance land productivity.

Intercropping is a cultivation technique involving the simultaneous planting of two or more crop species on the same land within a specific period. Beets (2018) states that intercropping can increase the efficiency of resource use such as light, water, and nutrients through complementary interactions between crops. Additionally, research by Rauf and Ritonga (2021) demonstrates that intercropping can improve land productivity and soil structure by increasing organic matter content. This system also helps reduce the risk of crop failure due to environmental fluctuations and pest attacks. With proper management, intercropping can enhance agricultural production stability while supporting sustainable farming practices. Therefore, the application of intercropping systems is a relevant alternative in the development of modern, efficient, and environmentally friendly agriculture.

Corn is a strategic food commodity that plays a vital role in national food security. Subandi (2017) explains that corn has high adaptability to various environmental conditions and a relatively short harvest period, making it suitable for intercropping systems. Moreover, research by Syafruddin et al. (2018) shows that corn can adapt well to lightly shaded conditions, such as those in immature oil palm plantations. Corn also has high economic value and stable market demand, providing additional income for farmers. Due to these characteristics, corn is a promising crop to cultivate in non-yielding oil palm plantations. Therefore, integrating corn into intercropping systems can enhance land productivity while supporting agricultural diversification.

The utilization of immature oil palm plantation land through intercropping also offers ecological and economic benefits. Ginting and Tarigan (2020) note that intercropping can increase biodiversity and improve soil ecosystem balance. Additionally, the enhancement of soil microbial activity in intercropping systems can improve soil fertility and nutrient uptake efficiency. From an economic perspective, Lubis (2019) shows that utilizing the inter-row spaces in immature oil palm plantations can increase farmers' income before the oil palms start producing. This is significant because the non-yielding stage is relatively long and does not yet provide primary production. Therefore, applying intercropping systems in immature oil palm plantations provides dual benefits both ecological and economic.

However, implementing intercropping systems requires careful management to avoid competition among crops for nutrients, water, and light. Hidayat (2021) explains that crop competition in intercropping can affect growth and yield if not properly managed. Plant spacing, fertilization, and water management are crucial factors in the success of intercropping systems. Moreover, research by Susanto and Nugroho (2022) indicates that managing light intensity and selecting appropriate crop varieties can minimize competition among crops. Therefore, intercropping systems must be based on sound agronomic principles to ensure mutually beneficial crop interactions and optimal land productivity.

Optimizing intercropping systems in immature oil palm plantations also plays a role in improving land-use efficiency through the Land Equivalent Ratio (LER). Sitompul and Guritno (2016) state that an LER value greater than one indicates that intercropping systems are more efficient than monoculture systems. Research by Prasetyo et al. (2021) shows that corn intercropping in plantation areas can increase land-use efficiency and total crop productivity. This efficiency occurs because crops utilize growing space optimally both above and below the soil surface. Thus, optimizing intercropping systems in immature oil palm plantations not only increases production but also improves the overall efficiency of agricultural resource use.

Based on the discussion above, research on optimizing corn intercropping systems in immature oil palm plantations is essential to evaluate the effectiveness of this system in enhancing land productivity and crop growth. Sugiyono (2020) emphasizes that systematic research is needed to obtain empirical data that can serve as a basis for decision-making in agricultural management. In addition, Wibowo and Setiawan (2022) highlight that innovations in cultivation technology are key to improving efficiency and sustainability in the plantation sector. Therefore, this study is expected to provide scientific contributions to the development of sustainable agricultural systems and serve as a reference for farmers and policymakers in optimizing the use of non-yielding oil palm plantation land.

METHODS

This study employed an experimental method with a quantitative approach aimed at examining the effect of corn intercropping systems on plant growth and productivity in immature oil palm plantations (non-yielding stage). The experimental method was selected because the study involved specific treatments to determine the cause-and-effect relationship between treatment variables and crop response variables, allowing analysis of the influence of corn intercropping on vegetative growth, yield, and land-use efficiency.

The research was conducted in immature oil palm plantations aged 1–3 years. The study spanned one corn growing season, starting from land preparation, planting, maintenance, to harvest. The research site featured soil characteristics suitable for corn cultivation and adequate light availability in the inter-row spaces of oil palms. These conditions enabled corn plants to access light, water, and nutrients optimally, allowing accurate analysis of interspecific interactions within the intercropping system.

The experimental design used a Randomized Block Design (RBD) with two treatments: P1 as the control with corn monoculture, and P2 with corn intercropped in immature oil palm plantations. Each treatment was replicated three times, resulting in six experimental units. Blocking was based on relatively homogeneous land conditions to minimize environmental factors, such as soil fertility and light availability, thus enhancing the validity of the results.

The research procedure began with land preparation, including weed and residue removal, followed by soil tillage through hoeing or plowing to improve soil structure and aeration. In the intercropping treatment, corn was planted in the spaces between rows of immature oil palms. The corn seeds used were superior varieties with high germination rates. Planting was carried out at a spacing of 75 cm × 25 cm or adjusted according to the available inter-row space of the oil palms, with two seeds sown per planting hole. Fertilization followed recommended corn nutrient requirements using both basal and top-dressing fertilizers, including nitrogen (N), phosphorus (P), and potassium (K), applied equally to all treatments. Crop maintenance involved irrigation, weeding, pest and disease control, and top-dressing fertilization, conducted intensively to ensure optimal growth. Harvesting occurred when corn reached physiological maturity, indicated by dry husks and hard kernels.

The observed parameters included plant height (cm), number of leaves, cob weight (g), grain yield (ton/ha), and land-use efficiency (Land Equivalent Ratio/LER). Plant height was measured from the base to the highest growth point at specific ages, while the number of leaves was counted based on fully developed leaves. Cob weight was measured after harvest to determine production per plant, and grain yield was calculated per unit area. Land-use efficiency was calculated using the LER formula, where an LER value greater than 1 indicates that the intercropping system is more efficient than monoculture.

Data were collected through direct field measurements for each experimental unit. Observations were conducted periodically throughout the growth period until harvest, with all data recorded systematically to ensure accuracy. Data analysis involved descriptive statistics to describe crop growth and yield, as well as inferential statistics using ANOVA at a 5% significance level to determine differences in treatment effects on the observed parameters. If significant differences were detected, further tests were conducted to identify pairwise differences between treatments. This approach allowed the researchers to obtain accurate information on the effectiveness of corn intercropping systems in immature oil palm plantations.

RESULTS AND DISCUSSION

RESULTS

1. Corn Plant Growth

a. Plant Height

The presence of immature oil palm (non-yielding stage) significantly influenced the height of corn plants. On average, corn grown under intercropping systems tended to be taller compared to corn grown in monoculture. This increase in plant height is attributed to the more optimal utilization of growing space, allowing corn to access sufficient light, air, and nutrients to support vegetative growth. Additionally, the microclimatic conditions created in the inter-row spaces of immature oil palms provided more stable temperature and humidity, promoting the growth of stems and leaves. These conditions also reduce interspecific competition, allowing corn to develop more fully.

These findings are consistent with previous research by Rauf and Ritonga (2021), which showed that intercropping systems can enhance plant growth by using space and resources more efficiently while supporting plantation sustainability.

Table 1. Average Corn Plant Height (cm)

Treatment	Replication 1	Replication 2	Replication 3	Mean
P1 (Monoculture)	178	182	180	180.0
P2 (Intercropping)	185	188	186	186.3

As shown in Table 1, the average height of corn in the intercropping system (P2) was 186.3 cm, higher than that in the monoculture system (P1), which reached only 180.0 cm. This difference indicates that planting corn in the inter-row spaces of immature oil palms creates more optimal growth conditions, particularly regarding light and space utilization. The light shading from oil palm trees does not inhibit photosynthesis; rather, it helps maintain soil moisture and environmental temperature stability, allowing corn stems to grow taller. These results also suggest that positive interactions between crops in the intercropping system can reduce competition for nutrients and water. This finding aligns with the study by Syafruddin et al. (2018), which stated that intercropping systems increase land-use efficiency while significantly supporting vegetative growth of corn.

b. Number of Leaves

The number of leaves is an important indicator of vegetative growth, as it is directly related to photosynthetic capacity and the plant’s ability to capture solar energy. The results showed that corn grown in an intercropping system within immature oil palm plantations tended to have more leaves compared to corn grown in monoculture. The increase in leaf number is attributed to a more stable microclimate, such as maintained soil moisture and sufficient light intensity, despite light shading from oil palms. These conditions allow corn to develop leaves optimally without stress from space or light competition. Furthermore, efficient utilization of inter-row space allows corn to access nutrients and water more evenly.

These findings are in agreement with Syafruddin et al. (2018) and Rauf & Ritonga (2021), who emphasized that intercropping systems can enhance vegetative growth through positive interactions among crops while supporting overall land productivity.

Table 2. Average Number of Corn Leaves (leaves)

Treatment	Replication 1	Replication 2	Replication 3	Mean

P1 (Monoculture)	11	12	11	11.3
P2 (Intercropping)	13	12	13	12.7

As shown in Table 2, the average number of corn leaves in the intercropping system (P2) was 12.7 leaves, higher than corn in monoculture (P1) at 11.3 leaves. The increased leaf number in the intercropping system indicates that corn can utilize the growing space between oil palms more efficiently. The microclimatic conditions created such as stable soil moisture and adequate light intensity despite light shading support maximum leaf development. A higher number of leaves increases photosynthetic capacity, providing the plant with more energy for vegetative and generative growth. These results are consistent with Syafruddin et al. (2018) and Rauf & Ritonga (2021), confirming that intercropping systems can improve vegetative growth through positive crop interactions and more efficient land resource utilization, while also enhancing overall corn productivity.

2. Corn Production

a. Cob Weight

Cob weight is a primary indicator for assessing crop yield because it reflects the plant's ability to produce high-quality and economically valuable grains. The results of this study showed that cob weight in the intercropping system (P2) tended to be higher than in corn monoculture (P1). This increase in cob weight is attributed to optimal land utilization and the more uniform availability of nutrients, water, and light in the inter-row spaces of immature oil palms, minimizing competition among plants. Furthermore, the more stable microclimatic conditions in the non-yielding oil palm areas supported generative growth, including grain filling in the cobs.

These findings are consistent with the research by Rauf & Ritonga (2021), which reported that intercropping systems can increase cob weight and crop productivity through efficient land resource use and positive interspecific interactions, thus providing more optimal and sustainable harvests for farmers.

Table 3. Average Cob Weight of Corn (g/plant)

Treatment	Replication 1	Replication 2	Replication 3	Mean
P1 (Monoculture)	215	220	218	217.7
P2 (Intercropping)	225	228	230	227.7

As shown in Table 3, the average cob weight in the intercropping system (P2) reached 227.7 g per plant, higher than corn in monoculture (P1) at 217.7 g per plant. This indicates that implementing intercropping in immature oil palm plantations significantly enhances grain filling and cob weight. Optimal utilization of inter-row spaces, combined with stable microclimatic conditions, allows the plants to access water, light, and nutrients evenly, maximizing generative growth. These conditions also reduce competition among corn plants, resulting in higher cob weight. These findings are in line with Syafruddin et al. (2018) and Rauf & Ritonga (2021), who emphasized that intercropping systems increase crop productivity through efficient land use and positive plant interactions, thus providing higher and sustainable harvests.

b. Grain Yield

Grain yield is a critical parameter for evaluating the success of intercropping systems because it is calculated per unit area and reflects overall land-use efficiency. The results showed that corn grown in the intercropping system (P2) had higher yield compared to corn monoculture (P1). This increase is attributed to optimal utilization of the growing space in the inter-row areas of immature oil palms, allowing corn to access light, water, and nutrients more evenly without excessive competition. Stable microclimatic conditions, including maintained soil moisture and light shading from oil palms, also supported generative growth.

These findings are consistent with Rauf & Ritonga (2021) and Syafruddin et al. (2018), who reported that intercropping systems can increase yield per unit area while providing additional economic benefits to farmers during the non-yielding stage of oil palm.

Table 4. Corn Yield (ton/ha)

Treatment	Replication 1	Replication 2	Replication 3	Mean
P1 (Monoculture)	6.8	7.0	6.9	6.9
P2 (Intercropping)	7.5	7.7	7.6	7.6

As shown in Table 4, the average grain yield in the intercropping system (P2) was 7.6 tons per hectare, higher than in the monoculture system (P1) at 6.9 tons per hectare. This increase demonstrates that intercropping in immature oil palm plantations can utilize growing space more effectively, allowing corn to access light, nutrients, and water evenly without excessive competition. The more stable microclimate, resulting from light shading by oil palms, helps maintain soil moisture and environmental temperature, optimizing generative growth and grain filling. These results align with Syafruddin et al. (2018) and Rauf & Ritonga (2021), confirming that intercropping systems enhance land-use efficiency and crop yield per unit area, providing additional economic benefits to farmers and supporting sustainable plantation management.

3. Land Use Efficiency (Land Equivalent Ratio/LER)

Land use efficiency in this study was evaluated using the Land Equivalent Ratio (LER), which indicates the advantage of intercropping systems over monoculture. An LER value greater than one signifies that the intercropping system utilizes land resources more efficiently. The results showed that the corn intercropping system in immature oil palm plantations (P2) had an LER value of 1.10, meaning that land use was 10% more efficient compared to monoculture.

This efficiency is attributed to optimal utilization of growing space, positive interspecific interactions, and more uniform distribution of light, water, and nutrients. The microclimatic conditions created between oil palm and corn plants support both vegetative and generative growth of corn without reducing the yield of the main crop. These findings are consistent with Rauf & Ritonga (2021) and Syafruddin et al. (2018), who reported that intercropping systems can improve land-use efficiency and crop productivity, provide additional economic benefits, and support sustainable agricultural practices.

Table 5. Land Equivalent Ratio (LER) Value

Parameter	Value
Corn yield in intercropping	7.6 ton/ha
Corn yield in monoculture	6.9 ton/ha
LER value	1.10

As shown in Table 5, the Land Equivalent Ratio (LER) for corn intercropping in immature oil palm plantations reached 1.10. This indicates that the intercropping system is 10% more efficient than monoculture corn planting. The efficiency results from optimal utilization of inter-row space, allowing corn to access light, nutrients, and water evenly without excessive competition. Additionally, stable microclimatic conditions such as balanced soil moisture and environmental temperature support vegetative and generative growth of corn, including cob weight and leaf number. These results align with Syafruddin et al. (2018) and Rauf & Ritonga (2021), confirming that intercropping systems can enhance land-use efficiency and crop productivity, provide additional economic benefits to farmers, and support long-term sustainability of plantation land.

DISCUSSION

1. Effect of Intercropping System on Corn Plant Growth

The results of this study indicate that implementing an intercropping system in immature oil palm plantations (TBM) can enhance the vegetative growth of corn, particularly plant height. Corn grown in the intercropping system exhibited greater height compared to monoculture due to more optimal utilization of inter-row space, allowing the stems to receive adequate light and evenly distributed nutrients. The more stable growing environment, particularly in maintaining soil moisture and surrounding temperature, supports efficient cell division and stem elongation. This finding aligns with Putra & Wulandari (2020), who reported that intercropping corn with other main crops can improve plant growth through efficient use of light and space. Maintaining a favorable microclimate also minimizes environmental stress, enabling more optimal growth of corn.

In addition to plant height, the number of corn leaves also increased significantly under the intercropping system. Leaf number is an important indicator of photosynthetic capacity, and higher leaf production reflects efficient utilization of solar energy for biomass formation. Light shading from immature oil palm trees does not impede photosynthesis; rather, it helps maintain soil moisture and reduce evaporation, providing a more stable growth environment. These findings are consistent with Hidayat & Santoso (2021), who demonstrated that intercropping systems increase leaf number through positive plant interactions and more even distribution of resources. With an optimal number of leaves, corn plants have higher capacity for both vegetative and generative growth.

Positive interactions among plants in the intercropping system also reduce competition for nutrients and water, supporting overall corn growth. Planting corn in the inter-row spaces of oil palms allows corn roots to exploit soil layers differently from oil palm roots, resulting in more even nutrient availability and balanced plant growth. Kurniawan et al. (2022) confirmed that intercropping systems enhance vegetative growth and land-use efficiency by maximizing the distribution of light, water, and nutrients among crops. Therefore, intercropping not only increases plant height and leaf number but also promotes more uniform growth, potentially improving overall corn productivity.

2. Effect of Intercropping System on Corn Production

The results of this study indicate that corn production in the intercropping system was higher compared to monoculture, both in terms of cob weight and yield per hectare. This increase in yield is attributed to optimal utilization of the growing space in the inter-row areas of immature oil palms (TBM), allowing corn to access light, water, and nutrients more evenly. Good land management practices, including fertilization and weeding, also supported generative growth, enabling cobs to develop with greater size and weight. These findings are consistent with Susanto & Prasetya (2020), who reported that intercropping systems enhance crop yield through efficient use of land resources, resulting in higher productivity per unit area compared to monoculture.

In addition to spatial utilization, intercropping systems also reduce weed growth, thereby lowering competition for nutrients and improving nutrient availability for the main crop. Light shading from immature oil palms helps maintain soil moisture and reduce evaporation, enabling corn plants to maximize photosynthesis and grain filling in the cobs. This supports the development of heavier cobs and higher overall productivity. Rahman & Wibowo (2021) demonstrated that natural weed suppression in intercropping systems positively affects generative growth and corn yield per hectare, especially in plantations that are not yet fully productive.

Positive interactions among crops in the intercropping system also contribute to higher land-use efficiency, as measured by the Land Equivalent Ratio (LER). An LER value greater than one indicates that the intercropping system produces higher output than monoculture on the same land area. Planting corn in the inter-row spaces of immature oil palms allows for more uniform utilization of light, water, and nutrients, optimizing generative growth and increasing cob weight. These findings align with Kurnia & Anggraini (2022), who emphasized that intercropping not only increases corn production but also provides additional economic benefits for farmers while supporting the sustainability of plantation land.

3. Land Use Efficiency

Land use efficiency is an important indicator for evaluating the advantage of intercropping systems over monoculture. A Land Equivalent Ratio (LER) value greater than one indicates that intercropping can produce higher output on the same land area. This is attributed to the optimal utilization of growing space both above and below ground, allowing corn and immature oil palm (TBM) to synergistically utilize light, water, and nutrients. With more uniform resource distribution, both vegetative and generative growth of crops can increase without excessive competition. Nugroho & Setiawan (2022) reported that intercropping systems improve land-use efficiency by 10–15% compared to monoculture, resulting in higher total productivity per hectare and more sustainable outcomes.

In addition to improving production efficiency, intercropping systems provide additional economic benefits for farmers, especially during the immature phase of oil palm. By planting corn in the inter-row spaces of TBM oil palms, farmers can gain supplementary harvests without compromising the growth of the main crop. The microclimatic conditions created, such as maintained soil moisture and light shading from oil palm trees, further support corn growth and reduce environmental stress. This allows more optimal grain filling in the cobs and increases cob weight, thereby significantly enhancing farmers' income. These findings are consistent with Putri & Ramadhan (2021), who demonstrated that intercropping systems can provide short-term economic benefits while improving the sustainability of plantation land.

Positive interactions among crops in the intercropping system also contribute to weed control and efficient resource utilization. With light shading from oil palms and optimal use of subsurface soil space, corn can absorb nutrients and water more evenly, increasing productivity without affecting the main crop. This system also minimizes the risk of crop failure under extreme environmental conditions due to the more stable microclimate. Nugraha & Prasetyo (2020) emphasized that intercropping not only enhances land-use efficiency through LER > 1 but also supports sustainable farming practices and provides additional ecological and economic benefits for farmers, making it an effective strategy to increase plantation productivity during the immature phase.

CONCLUSION AND IMPLICATIONS

The implementation of corn intercropping in immature oil palm plantations significantly enhances both vegetative and generative growth, as demonstrated by increased plant height, leaf number, cob weight, and grain yield compared to monoculture. Optimal utilization of inter-row spaces allows for more uniform access to light, water, and nutrients, while microclimatic improvements, such as light shading and stable soil moisture, reduce environmental stress and support balanced plant growth. The intercropping system achieved a Land Equivalent Ratio

(LER) of 1.10, indicating 10% greater land-use efficiency. Additionally, intercropping offers economic advantages by providing supplementary harvests without affecting the main crop, improves weed management, and contributes to sustainable farming practices. Overall, corn intercropping represents an effective strategy for increasing productivity, efficiency, and ecological sustainability in immature oil palm plantations.

The application of corn intercropping in immature oil palm plantations (TBM) has several practical implications for improving productivity and land sustainability. By planting corn in the inter-row spaces of oil palms, growing space is utilized more efficiently, enabling crops to access light, water, and nutrients evenly. This positively affects plant height, leaf number, cob weight, and yield per hectare. Intercropping also reduces weed growth and competition among crops, thereby increasing resource-use efficiency. In addition, crop diversification provides additional income for farmers during the TBM phase. This practice supports sustainable agriculture by improving soil fertility, maintaining field microclimates, and reducing the risk of crop failure, making it an effective strategy to enhance plantation productivity while preserving the ecosystem.

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