The effects of intercropping of sweet corn and groundnut in immature durian orchard on the biological and economic yield indices

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ABSTRACT Sweet corn (*Zea mays convar. saccharata var. rugosa*) and groundnut (*Arachis hypogaea L.*) are important crops with significant nutritional and economic value. However, monoculture practices and land underutilization in immature durian (*Durio zibethinus Murr.*) orchards present challenges such as soil degradation and reduced productivity. This study evaluated the biological and economic yield indices of intercropping sweet corn and groundnut in immature durian orchards as a sustainable alternative. The research was conducted at the Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah, Sandakan campus, over five months, the experiment employed a randomized complete block design (RCBD) with four treatments: monoculture of sweet corn (T1), monoculture of groundnut (T2), and two intercropping systems with staggered planting times (T3 and T4). Parameters measured included Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER), Aggressivity (A), Competitive Ratio (CR), Relative Crowding Coefficient (RCC), Actual Yield Loss (AYL), Monetary Advantage Index (MAI), and Gross Profits (GP). However, results showed that T3 and T4 intercropping systems outperformed monocultures, with T4 yielding the highest fresh weight, MAI, and GP. LER and ATER exceeded 1 in T3 and T4, demonstrating greater land-use efficiency. Sweet corn exhibited higher competitiveness (A and CR) in intercropping systems, while groundnut showed reduced yields under shading. The study concludes that intercropping sweet corn and groundnut in immature durian orchards optimizes land productivity, improves economic returns, and offers a sustainable solution for enhancing orchard management.

KEYWORDS: Intercropping; Sweet corn; Groundnut; Biological indices; Economic yield indices
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INTRODUCTION

Sweet corn (*Zea mays convar. saccharata var. rugosa*) is a cereal crop from the Poaceae family, recognized as one of the world's most important crops alongside rice and wheat (Ranum *et al.*, 2014). Originating as a domesticated plant in the Americas, sweet corn plays a vital role in both fresh consumption and processing markets globally, serving as a significant source of carbohydrates for human and animal consumption due to its high nutritional value (Undie *et al.*, 2012). Beyond its role as a staple food, sweet corn contributes to biofuel production, and its demand has risen sharply in recent decades. Farmers are increasingly adopting specialized sweet corn cultivation for its higher returns and employment opportunities, particularly in urban settings. Nutritionally, sweet corn is rich in carbohydrates, sugars, vitamins A, B3, and C, as well as proteins, fiber, minerals, and folic acid, making it beneficial for human health (Baveja *et al.*, 2021). Groundnut (*Arachis hypogaea* L.), a legume from the Fabaceae family, is a key food and oilseed crop in tropical and subtropical regions. It is rich in protein, healthy fats, and essential vitamins such as thiamine and niacin (Baraker *et al.*, 2017), making it both nutritionally and economically significant. However, groundnut yields are sensitive to soil moisture stress during critical growth stages, affecting productivity (Shiyam, 2010).

Intercropping, the simultaneous cultivation of multiple crops, is a sustainable farming practice that enhances land productivity and resource use efficiency. Common cereal-legume systems, such as corn–groundnut, improve protein yields and diversify production while maintaining environmental sustainability (Li *et al.*, 2023). This is particularly relevant in durian (*Durio zibethinus* Murr.) orchards, where land between immature trees is usually left fallow, allowing weeds to grow and causing soil degradation. Intercropping sweet corn and groundnuts in immature durian orchards could maximize land use, improve soil health, and provide supplemental income during the unproductive period of durian trees. However, there is a dearth of research on the biological and economic benefits of intercropping in such systems. The study is an attempt to explore the possibility of intercropping sweet corn and groundnut under immature durian trees using evidence from other intercropping systems on its effects on productivity and diversification of incomes.

METHODOLOGY

Experimental Site and Study Period Description

The field experiment was conducted at the immature durian orchard in Faculty of Sustainable Agriculture (FSA) Sandakan campus, University Malaysia Sabah. This study was taken for 4 to 5 months, starting from June 2024 to October 2024. The experiment laid out a randomized complete block design (RCBD) replicated 4 times for each treatment. Data from this study was collected at the end of the field experiment. In this study, each block consists of four plots, with a distance between plots of 1.3 meters and a distance between blocks of 5.3 meters. The size of each plot is 4.9 meters by 4 meters. Each plot contains three subplots, each with a width of 1.2 meters. Sweet corn was planted with a spacing of 30 cm by 30 cm, and groundnuts are planted with a spacing of 30 cm by 30 cm. The planting distance between sweet corn and groundnuts is 20 cm. All the seeds were directly planted in the field. The groundnut will be harvested 90 days after planting (DAP) meanwhile sweet corn was harvested 70 days after planting.

Planting Materials and Planting Procedure

Sweet corn and groundnut seeds were purchased from the nearby agricultural store in Sandakan. 2000 sweet corn seeds and 3900 groundnut seeds are required for this study. The study was conducted in a durian orchard covering an area of 0.075 hectares, which was considered an ideal site for intercropping due to its unique qualities. The plot's hilly terrain and hard soil necessitated careful land preparation. The land was tilled using a rotovator, and subsequently, it was measured to form several plots designated for treatments and replications. The soil was plowed to prepare it for planting and to facilitate future boundary preparation tasks, ensuring the plot was structured and suitable for the intercropping system of sweet corn and groundnut. The crop borders were manually established using hoes. In 2018, the Department of Agriculture recommended an application of a total of 130 kg of organic manure at the rate of 2.6 kg per seedbed, to be mixed with the soil before planting commences. This is to be done 30 days before planting. The liming process is conducted after laboratory tests of the soil show an acidic pH of 4.5. The Department of Agriculture (2020) advised that the liming process requires thorough mixing of lime in the soil up to a depth of 6 to 8 inches. The process must be done 30 days before the planting period.

Seeds are directly and manually planted into the seedbeds. In each planting hole on the seedbed, two seeds of sweet corn and three seeds of groundnut will be planted. In a study conducted by Pang et al. (2021), it was observed that the germination rate of sweet corn seeds significantly decreased with an increase in aging time. The germination percentage of normal seeds was reported to be about 80%, while that of aged seeds ranged between 0 and 18.47%. On the other hand, the germination rate for groundnuts was found to be between 70% and 100% (Ahmed *et al.*, 2017). Treatments 1 and 2 were set up as monoculture systems while in Treatment 3, groundnut was sown two weeks before the planting of sweet corn, and in Treatment 4, groundnut was planted three weeks in advance of sweet corn. According to the Department of Agriculture in 2008, 12.5 kg of Urea (46% N) was required for sweet corn. The application of urea was divided into two phases, carried out approximately 20 and 40 days after planting. Additionally, a complex fertilizer, blue NPK with a ratio of 12:12:17:2 kg/ha, was recommended for sweet corn and applied at a rate of 260 grams per seedbed.

Data Collection and Analysis

The fresh yield of sweet corn and groundnut in each designated cropping system was harvested and weighed to determine the fresh weight yield per plot. The data obtained were used to compute various intercropping indices in this study, such as the land equivalent ratio (LER), area time equivalent ratio (ATER), aggressivity index (AI), competition ratio (CR), relative crowding coefficient (RCC or K), actual yield loss (AYL), monetary advantage index (MAI) and gross profits (GP). The data were analyzed using descriptive statistics. Statistical analysis will be evaluated using Minitab Statistical Analysis Software application. The trial will be made as a randomized complete block design (RCBD). One-way ANOVA with randomized block was chosen to determine the effect of cropping pattern on yield components. Treatments were compared using the Tukey Pairwise Comparison test at $P \leq 0.05$.

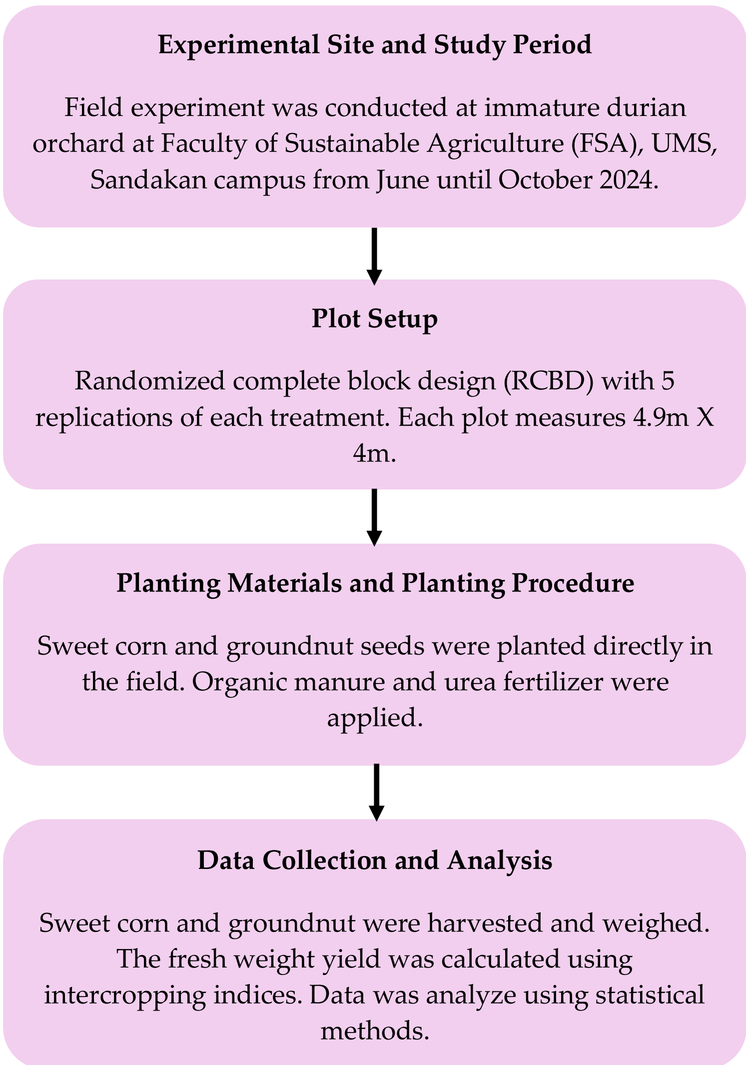

Figure 1. Methodological flowchart of the intercropping of sweet corn and groundnut in immature durian orchard.

Figure 2. Lining activity: Measuring and marking the planting plots between durian seedlings prior to conducting the intercropping experiment.

Figure 3. The plot site after 60 days of planting.

RESULT AND DISCUSSION

Biological Indices

Fresh weight yield per plot

In this result, Table 1 shows fresh weight of sweet corn and groundnut per plot in all cropping systems. There are no significant differences in marketable ear fresh weight of sweet corn as affected by the various cropping systems. Marketable pod fresh weight was significantly high for T2 if compared to both T3 and T4. The total fresh weight of both crops was significantly increased by T3 and T4 if compared to T2.

Table 1. Fresh weight yield of sweet corn and groundnut plot-1 (19.6m^2) as affected by various cropping systems.

Cropping Systems	Marketable Ears Fresh	Marketable Pods Fresh	Total Fresh Weight
	kg plot^{-1}		
T1	20.19a	-	20.19ab
T2	-	12.98a	12.98b
T3	24.00a	2.48b	26.48a
T4	22.86a	4.06b	26.92a

Note: T1 = Monoculture of sweet corn, T2 = Monoculture of groundnut, T3 = Mixed relay intercropping of sweet corn and groundnut (sweet corn planted two weeks after groundnut), T4 = Mixed relay intercropping of sweet corn and groundnut (sweet corn planted three weeks after groundnut).

Fresh weight yield per plot in T1 and T2 was not significantly influenced by the cropping system, suggesting that monoculture systems for these treatments maintained consistent productivity levels. However, the marketable pod fresh weight was highest in T2 at 12.98 kg/plot, highlighting the potential of monoculture groundnut to produce competitive pod yields under favorable conditions. On the other hand, intercropping systems in T3 and T4 showed a significant advantage in yield, with marketable fresh weights of 26.48 kg per plot and 26.92 kg per plot, respectively. This shows that the productivity of intercropping has been increased due to, likely, better use of resources and synergistic interactions among the crops. The high yields in T3 and T4 validate the assumption that intercropping systems can increase agricultural efficiency and profitability, which agrees with the earlier studies showing the benefits of crop diversification over monoculture practices (Kamanga *et al.*, 2010; Rasool *et al.*, 2021). In addition, the corn-legume intercropping practice increased corn yield due to increased nitrogen availability and facilitated light and space resource use efficiency (Yu *et al.*, 2015).

LER and ATER

Table 2 shows that T3 and T4 have LER values higher than 1, with 1.55 and 1.47 respectively. Moreover, the ATER for T3 and T4 also surpasses 1, with 1.26 and 1.21 respectively.

Table 2. Land equivalent ratio and area time equivalent ratio of sweet corn and groundnut as affected by the various cropping systems.

Cropping Systems	LER	ATER
T3	1.55	1.26
T4	1.47	1.21

Note: T3 = Mixed relay intercropping of sweet corn and groundnut (sweet corn planted two weeks after groundnut), T4 = Mixed relay intercropping of corn and groundnut (sweet corn planted three weeks after groundnut). LER = land equivalent ratio, ATER = area time equivalent ratio.

The T3 cropping system had the highest LER with a value of 1.55, while the lowest LER of 1.47 was obtained under the T4 cropping system. The higher LER under T3 was due to higher fresh weights of marketable ears and pods per plot for sweet corn and groundnut, respectively. This stresses the importance of planting groundnuts two weeks before sweet corn to achieve an LER above 1. Rezapour (2023) calculated that LER greater than 1.00 under the intercropping system of groundnuts and sweet corn is an indication of advantage in yield over monoculture practice. Shading, by growing groundnuts with taller crops like sweet corn, decreases growth, yield, and quality of groundnuts. This effect is more severe in shade-sensitive cultivars than in shade-tolerant ones, especially at the critical flowering stage (Wang *et al.*, 2024). The sowing time of groundnut is an important determinant of its competitiveness and overall yield. Earlier sown groundnuts exhibit better growth parameters in terms of plant height and biomass compared to later sown ones (Stirling *et al.*, 1990). When sweet corn is first planted in an intercropping system, it very fasts reach to a dominating position by developing a dense canopy, which shades groundnut during its early and most critical growth stages. Consequently, this shading reduces the sunlight that can reach groundnut, thus inhibiting its photosynthetic activities and growth.

The ATER for sweet corn and groundnut in all the intercropping systems surpassed 1.00, indicating that most of the intercropping systems studied here had a time-related advantage over monocropping systems of either crop in completing a production cycle. Research shows that ATER is a better indicator of land use efficiency in intercropping systems, especially where there are large disparities in growth duration between the component crops. Consequently, ATER emerges as a crucial instrument for fully leveraging the benefits of intercropping, delivering insights that extend beyond those offered by LER (Yahuza, 2011). The ATER values for T3 and T4 are recorded as exceeding 1, specifically at 1.26 and 1.21, respectively. The decline in ATER for these cropping systems is likely attributable to the diminished yield of groundnut, which was significantly overshadowed by sweet corn, particularly in T4. Pan *et al.* (2016) reported that low light conditions led to yield loss per plant by reducing the number of pods produced per plant, the number of kernels produced per plant as well as weight of 100 kernels. In intercropping systems, the yield loss in groundnuts may reach 35 to 55%, depending on the intensity of the shading by the taller crop like sweet corn (Adjahossou *et al.,* 2008). The study by Hemon and Hanafi (2021) demonstrates that continuous shade from planting to harvest significantly reduces groundnut yield, highlighting the importance of natural light for optimal groundnut growth.

A, CR, RCC or K and AYL

Table 3 shows that the A_{sc} and A_g of both T3 and T4 have positive and negative values, respectively. The CR_{sc} is generally hinger than CR_g in both cropping systems. Meanwhile the results in Table 4 indicate that K_{sc} in T4 is higher than K_{sc} in T3. Also, the K_g in T4 is higher than K_g in T3. The K of T3 shows a negative value for sweet corn but a lower positive value for groundnut. The K_T of T4 is higher than the T3. The AYL_{sc} has positive values in both cropping systems. However, the AYL_g has negative values for both intercropping systems. The AYL_T of T3 and T4 are positive, respectively.

Table 3. Aggressivity and competitive ratio of sweet corn and groundnut as affected by various cropping systems.

Cropping Systems	A		CR	
	A_{sc}	A_g	CR_{sc}	CR_g
T3	0.015	-0.015	3.91	0.15
T4	0.013	-0.013	3.89	0.46

Table 4. Relative crowding coefficient and actual yield loss of sweet corn and groundnut as affected by various cropping systems.

Cropping Systems	RCC or K			AYL		
	K_{sc}	K_g	K_T	AYL_{sc}	AYL_g	AYL_T
T3	-1.43	0.20	-0.71	2.04	-0.64	1.40
T4	9.97	0.41	15.25	1.85	-0.45	1.39

Note: T3 = Mixed relay intercropping of corn and groundnut (sweet corn planted two weeks after groundnut), T4 = Mixed relay intercropping of sweet corn and groundnut (sweet corn planted three weeks after groundnut). AIsc, = aggressivity of sweet corn, AIg = aggressivity of groundnut, CRsc, = competition ratio of sweet corn and CRg = competitive ratio of groundnut. K_{sc} = RCC of sweet corn K_g = RCC of groundnut, K_T = product of the coefficient, AYL_{sc} = yield loss or gain of sweet corn and AYL_g refers to yield loss or gain of groundnut. AYL_T = yield loss or gain of intercrops compared to their respective sole crops.

The A, CR, and AYL exhibited affirmative reactions to sweet corn during T3 and T4, suggesting that sweet corn possesses greater dominance and competitiveness compared to groundnut within intercropping systems. Similar results were noted when sweet corn was intercropped with groundnut or other leguminous plants, as recorded in the research conducted by Manasa *et al.* (2020) and Nekpreet Singh (2023). Sweet corn consistently produces yields that exceed those of intercropped legumes, with research demonstrating that its yields either remain constant or enhance within intercropping systems (Mugi-Ngenga *et al.,* 2022). Cereal crops frequently surpass legumes in competitive advantage owing to their superior nutrient absorption capabilities. However, in intercropping systems, sweet corn, being a C4 crop, demonstrates competitive advantage by taking advantage of temporal niche differentiation, resulting in increases in yield that are credited to reduced competition and not total suppression (Li *et al.*, 2020). All these studies' results show that cereals are generally more aggressive and often do so by suppressing legumes' growth (Maitra *et al.*, 2021).

Meanwhile, T4 had higher RCC for both crops compared with T3; though sweet corn showed negative RCC in T3, which indicates stress or inefficiency in resource use. The competitive interactions between legumes and cereals significantly affect nitrogen fixation and overall productivity in intercropping systems. Therefore, legumes should be sown first, as demonstrated in the T4 cropping system. In T4, sweet corn was less competitive than in T3 due to the improved competitiveness of groundnut, as reflected in most intercropping indices. Consequently, the total RCC and AYL values in T4 were consistently positive, signifying a cropping advantage. This highlights the importance of planting weaker crops, like legumes, earlier in mixed cropping systems. Doing so reduces the competitive pressure from dominant crops, such as cereals, allowing the legumes to thrive and ensuring a better balance between the two crops in the intercrop (Yu, 2016).

Economic Yield Indices

MAI

Table 5 shows that T4 has a higher MAI value than T3. The higher the MAI values, the more profitable the cropping system is.

Table 5. Monetary advantage index (MAI) of sweet corn and groundnut as affected by various cropping systems.

Cropping Systems	MAI
T3	20732
T4	25174

Note: T3 = Mixed relay intercropping of sweet corn and groundnut (sweet corn planted two weeks after groundnut), T4 = Mixed relay intercropping of sweet corn and groundnut (sweet corn planted three weeks after groundnut). MAI = monetary advantage index.

The MAI values presented positive results for the intercropping systems, where T3 had a value of 20,732 and T4 was valued at 25,174. It means that T4 system offers a clear benefit in yield as well as a financial advantage over sole cropping. Higher monetary advantage index (MAI) under the intercropping systems also implies that the total yield as well as the profitability of intercropped species are much more than that associated with monoculture. The index functions as an essential instrument for evaluating the economic feasibility of various crop combinations, assisting farmers in identifying intercropping approaches that enhance profitability (Karunarathna & Maduwanthi, 2022). This benefit results in favorable MAI values, highlighting the productivity advantages associated with intercropping. An elevated MAI value signifies increased profitability within an intercropping framework (Ghosh, 2004).

GP

Table 6 indicates that the GP of T4 is significantly higher than T1, T2, and T3. Meanwhile, GP for T2 is significantly lower compared with other treatments.

Table 6. Gross profit of sweet corn and groundnut per hectare is affected by various cropping systems.

Cropping Systems	T1	T2	T3	T4
Gross Profits (RM)	67,200a	30,172b	73,742a	76,571a

Note: T1 = Monoculture of sweet corn, T2 = Monoculture of groundnut, T3 = Mixed relay intercropping of sweet corn and groundnut (sweet corn planted two weeks after groundnut), T4 = Mixed relay intercropping of sweet corn and groundnut (sweet corn planted three weeks after groundnut).

The GP value indicated a positive response to the T4 cropping system, with corn proving to be more profitable than groundnut due to its higher market price. Sweet corn is sold by the ear at RM2.00 per ear, while groundnut is sold by weight at RM6.00 per kilogram, based on average prices at Pasar Batu 8, Sandakan, Malaysia, in October 2024. On average, farmers can earn around RM0.70 per ear of sweet corn, compared to RM0.13 per groundnut plant, as each plant produces approximately 22.70 g of marketable pods. This suggests that cultivating groundnut alone yields limited profits for farmers. As a result, the monoculture system for groundnut (T2) is not recommended. However, the yield of marketable ears increases proportionally with the number of individual sweet corn plants cultivated. As reviewed from previous study by Ye et al. (2023), increasing plant density generally increases fresh ear yields without negatively affecting grain quality. For instance, compact-type sweet corn varieties have demonstrated higher yields under increased planting densities, while maintaining stable grain carbohydrate concentrations. To sustain the benefits of the T4 intercropping system, the number of sweet corn plants should be maintained as in T1. Research shows that intercropping corn with legumes increases productivity as well as profitability compared to monocropping systems (Kamanga et al., 2010; Rasool et al., 2021; Sahoo et al., 2023), which agrees with the findings of this study. Groundnuts should be planted two to three weeks before sweet corn and strategically planted between the rows of corn for maximum utilization of resources and productivity.

CONCLUSION

This study highlights the high benefits of intercropping sweet corn and groundnut in young durian orchards, which can translate to increased biological productivity and financial viability. Based on the results obtained, intercropping treatments, particularly T3 and T4 with sweet corn and groundnut, showed marked advantages over the monoculture practices in terms of both biological productivity and economic profitability. These farming systems enhance the land productivity, as indicated by higher fresh weight yields and positive values for the Land Equivalent Ratio (LER) and Actual Time Equivalent Ratio (ATER). Planting groundnut earlier gives it a head start to grow and establish before the sweet corn gets too tall. This helps the groundnut receive more sunlight and minimizes the shading effect from the corn (P. Nambiar et al., 1983). On economic aspect intercropping is more profitable, with T4 showing high Monetary Advantage Index (MAI) and Gross Profit (GP) due to the higher market price and yield of sweet corn. Groundnut complement this profitability by adding more income when planted early. Intercropping, therefore, enhances the overall productivity as well as the farm's profitability.

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