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OPTIMIZING INTERCROPPING OF SWEET CORN AND GROUNDNUT YIELD AND ECONOMIC ASSESSMENT

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Abstract

Intercropping is a cost-effective strategy for enhancing agricultural productivity under conditions of limited land availability and increasing food demand. This study evaluated the biological, competitive, and economic performance of a sweet corn–groundnut intercropping system using the Land Equivalent Ratio (LER), Aggressivity Index (AI), and Monetary Advantage Index (MAI). Field experiments were conducted under three cropping regimes: sweet corn monoculture (T1), groundnut monoculture (T2), and intercropping treatments (T3, T4, T5). The intercropping involved strip planting with different sowing times: simultaneous planting (T3), groundnut sown two weeks before sweet corn (T4), and sweet corn sown two weeks before groundnut (T5). Findings revealed that sweet corn monoculture (T1) consistently outperformed intercropping in terms of profitability, largely due to market pricing based on ears rather than weight, which favored corn sales. The T4 system achieved the highest LER, reflecting better land-use efficiency, while the Aggressivity Index (AI), Competitive Ratio (CR), Relative Crowding Coefficient (RCC), and Actual Yield Loss (AYL) confirmed the dominance of corn in intercropping arrangements. However, the Area Time Equivalent Ratio (ATER) remained below 1, suggesting no temporal advantage over monocropping systems. Positive values of CR, RCC, and AYL further confirmed corn dominance in intercropping. The highest MAI was observed in T4, indicating potential economic benefits, but sweet corn monoculture (T1) remained more profitable. Additionally, plant density was higher in monoculture than in intercropped plots. Overall, while intercropping improved land-use efficiency, sweet corn monoculture provided greater profitability for smallholder farmers under the tested conditions.

Keywords: Intercropping sweet corn and groundnut, durian orchard, land equivalent ratio (LER), area time equivalent ratio (ATER), aggressivity index (AI)

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Introduction

Durian (*Durio zibethinus* Murr.), known as the "King of Fruits," is a tropical fruit notable for its unique volatile sulfur compounds (Husin et al., 2018). In Malaysia, it is extensively cultivated and harvested (A Aziz & Mhd Jalil, 2019), ranking first in fruit production at 49.20%, followed by pineapple, banana, watermelon, papaya, rambutan, nangka, jambu batu, manggis, and belimbing. In 2023, durian covered 89,547.40 ha with 58,819.09 ha harvested, producing 592,052.57 tonnes valued at approximately USD 2.5 billion in 2021 [DoA (Department of Agriculture of Malaysia), 2023]. Of this, 27,480 tonnes were exported, generating USD 444.95 thousand (Trade Map, 2024). Durian trees begin producing economically in five to six years (Rushidah et al., 2006), requiring smallholders to seek interim income. Intercropping with other crops is a viable option due to the wide 10–12 m spacing between trees.

Corn (*Zea mays* L.) of the Gramineae family is a monoecious, cross-pollinated cereal similar to wheat, rice, and millet (DoA, 2008). Known as “corn” in North America and “maíz” in Spanish, its Latin name was derived by Linnaeus (Brewbaker, 2003). Based on kernel traits, there are seven types: Flint, Dent, Sweet, Popcorn, Waxy, Floury, and Pod Corn (DoA, 2008). However, there are two varieties of corn popularly cultivated in Malaysia namely grain or field corn (Flint and Dent Corn) and Sweet Corn (Mohammad Nor *et al.*, 2020; Mohd Syauqi *et al.*, 2021; Nik Syafiah, 2023). Sweet corn, with a shorter maturity period of 70 days, is a more lucrative and sustainable option for farmers. It boasts a more favorable B/C ratio, has more planting seasons per year, and requires no drying process compared to grain corn (Nik Syafiah, 2023).

Groundnut (*Arachis hypogaea* Linn.) derives its name from the Greek words *Arachis* (legume) and *hypogaea* (below ground), referring to pod formation in the soil (Nautiyal, 2002). It is an annual herbaceous legume widely grown in tropical and temperate regions as an important oilseed and food crop (Nautiyal, 2002; Syed et al., 2021). The species comprises two subspecies: *hypogaea* (Virginia) and *fastigiate* (Valencia) (Singh & Oswalt, 1995). In Malaysia, groundnuts are consumed boiled, steamed, fried, or roasted, while in other countries they serve as a source of cooking oil, with the oilcake used as high-protein animal feed. Groundnuts were once a key legume crop in Malaysia, with Kelantan, Kedah, Perak, and Terengganu as the main producers in 1990, planting 514, 305, 240, and 192 ha, respectively (Zaharah, 2007). By 2022, cultivation had declined to 71.84 ha, with 63.24 ha productive, yielding 200.91 t (DoA, 2022). In the same year, Malaysia imported 64,832 t of groundnuts worth 91,284 thousand USD, a 39.02% increase from 2019, highlighting a growing reliance on imports (Trade Map, 2024).

Intercropping is a viable strategy for diversifying cropping systems to alleviate food insecurity, especially as agricultural land decreases and food crop demand rises due to rapid population growth (Gitari et al., 2020). Intercropping offers multiple benefits, such as enhanced yield, environmental security, production sustainability, and greater ecosystem services (Maitra et al., 2021). Various intercropping systems have been introduced to increase crop yields, including strip, relay, mixed, strip relay, and mixed relay intercropping systems (Lithourgidis et al., 2011; Bybee-Finley & Ryan, 2018; Raza et al., 2022). Researchers are exploring different aspects of intercropping, such as planting density (Sandhu et al., 2021), planting distance (Bolly, 2021), planting patterns (Te et al., 2022) and suitability of associated crops (Li et al., 2022).

The effectiveness of intercropping systems for enhancing crop yield can be assessed using various biological, competition, and economic indices (Gitari et al., 2020). Biological indices include the land equivalent ratio (LER) (Willey & Osiru, 1972) and area time equivalent ratio (ATER) (Hiebsch & Macollam, 1987). Competition indices encompass the aggressivity index (AI) (McGilchrist, 1965), competition ratio (CR) (Willey & Rao, 1980), relative crowding coefficient (RCC or K) (De Wit, 1960), and actual yield loss (AYL) (Banik, 1996). Economic indices include the monetary advantage index (MAI), gross profit (GP), net income (NI), rate of return (RR), and profit margin (PM). These indices have been calculated based on the work of several researchers (Willey, 1979; Khairol, 1991; Norman et al., 1995; Neto et al., 2010). However, the combined effects of these indices, particularly in sweet corn and groundnut intercropping systems, have not been thoroughly studied. This study aims to assess the impact of sweet corn and groundnut association in selected strip and strip relay intercropping systems using various indices. The novelty of this study lies in its comprehensive approach, applying biological, competition, and economic indices specifically for sweet corn and groundnut intercropping systems.

Methods

Experimental Site and Study Period Description

The experiments were conducted in a durian orchard, where the trees were approximately 40–60 cm in height, at Pusat Pertanian Putra (PPP), Universiti Putra Malaysia (UPM), Puchong, Selangor (N 2° 98′ 61.9″, E 101° 64′ 65.6″). The study evaluated various designated cropping systems using sweet corn and groundnut as the main treatments. The experiments were carried out over two growing seasons: the first from January to April 2020, and the second from January to April 2021. The experimental plots were established among 30 durian trees. Routine activities and general field maintenance for the durian trees, including weeding, manuring, and liming, were performed by PPP, UPM Puchong on a scheduled basis. All recommended cultural practices for sweet corn and groundnut, including crop protection and general field management, were implemented according to the production manuals for sweet corn (DoA, 2008) and groundnut (Kementerian Pertanian Indonesia, 2016). During the study, the mean monthly temperature fluctuated between 24.40 and 34.70 °C, monthly rainfall ranged from 3.70 to 17.40 mm, and mean relative humidity varied from 49.20% to 74.60% (Malaysian Meteorological Department, 2022).

Treatments
The study consists of five different cropping systems namely:

T1	:	Monoculture of sweet corn
T2	:	Monoculture of groundnut
T3	:	Sweet corn and groundnut intercropping (both crops planted on the same days)
T4	:	Sweet corn and groundnut intercropping (groundnut were planted two weeks after sweet corn
T5	:	Sweet corn and groundnut intercropping (sweet corn were planted two weeks after groundnut

Sweet corn was grown using a strip double-row planting pattern and served as the control treatment. The planting distance was 0.3 m within rows, 0.3 m between rows, and 0.7 m between double rows, with a total of 192 plants. The experimental period lasted 70 days. The sweet corn cropping system (T1) was established following the methods of Sams (2015), Jaya et al. (2017), and Ihwan et al. (2019). Groundnut was also grown in a strip double-row pattern as a control treatment, with planting distances of 0.2 m within rows, 0.3 m between rows, and 0.7 m between double rows. A total of 288 plants were used, and the experiment lasted 90 days. The groundnut cropping system (T2) was based on the studies by Lanier et al. (2004) and Raja Zulkifli et al. (2006). In all mixed systems (T3, T4 and T5), two rows of sweet corn alternated with two rows of groundnut, following the planting distances used in T1 and T2. The total number of plants was 240 (96 sweet corn and 144 groundnut). The experimental durations were 90 days (T3), 96 days (T4), and 104 days (T5). The design of the strip and strip relay intercropping systems was adapted from Dahmardeh (2013), Mas-ud et al. (2016), and Wibisana et al. (2017).

Plot Layout and Experimental Design
This study was conducted using a randomized complete block design (RCBD) with four replications. The size of the experimental area for the second experiment was 2000.00 m^2 (50.00 m x 40.00 m). Within this experimental area, there were 20 experimental plots representing each cropping system and replication. Each of these plots measured 5.60 m x 5.10 m, with a total area of 28.56 m^2. These plots were constructed within durian cultivation rows, approximately 2.00 m away from the durian seedlings.

Biological and Competition Indices
The fresh yields of corn and groundnut from each cropping system were harvested and weighed to determine fresh weight per plot. These data were used to calculate biological indices like land equivalent ratio (LER) and area time equivalent ratio (ATER), along with competition indices such as aggressivity index (AI), competition ratio (CR), relative crowding coefficient (RCC or K), and actual yield loss (AYL).

Land Equivalent Ratio
The land equivalent ratio (LER) was calculated based on the formula described by Willey and Osiru (1972):

$$LER = LER_{xy} + LER_{yx}$$

$$LER_x = Y_{xy} / Y_x \; ; \; LER_y = Y_{yx} / Y_y$$

Where, LER_{xy} is partial land equivalent ratio of species ‘x’, LER_{yx} is partial land equivalent ratio of species ‘y’, Y_{xy} is yield of ‘x’ under intercropping system, Y_x is yield of ‘x’ under monoculture system, Y_{yx} is yield of ‘y’ under intercropping system and Y_y is yield of ‘y’ under monoculture system. The value of LER > 1 indicates the intercropping increases the yield of the crops grown in the mixture, LER = 1 indicates no intercropping advantages in a comparison to the collection of monocultures and LER < 1 indicates disadvantages or poor performance of the intercrops (Laster & Furr, 1972; Ofori & Stern, 1987; Caballero et al., 1995).

Area Time Equivalent Ratio

The area time equivalent ratio (ATER) was computed according to Hiebsch & Macollam (1987):

$$ATER = [(LER_{xy} \times t_{xy}) + (LER_{yx} \times t_{yx})] / T]$$

Where, t_{xy} is growth duration (in days) for species 'x', t_{yx} is growth duration (days) for species 'y' and T is growth duration (days) for the intercropping systems.

Aggressivity Index

The aggressivity index (AI) was determined based on the following formula described by McGilchrist (1965):

$$A_{xy} = [Y_{xy} / (Y_x \times Z_{xy})] – [Y_{yx} / (Y_y \times Z_{yx})]$$

$$A_{yx} = [Y_{yx} / (Y_y \times Z_{yx})] – [Y_{xy} / (Y_x \times Z_{xy})]$$

Where, Z_{xy} represents the sown proportion of species 'x' in a mixture with species 'y', and Z_{yx} represents the sown proportion of species 'y' in the mixture. If $A_{xy} = 0$, both species are equally competitive; if A_{xy} is positive, species 'x' is dominant; and if A_{xy} is negative, species 'x' is dominated. The same applies inversely to A_{yx} (Mahapatra, 2010).

Competition Ratio

The competition ratio (CR) was described by Willey and Rao (1980) and computed based on the equation below:

$$CR_{xy} = [(Y_{xy} / Y_x) / (Y_{yx} / Y_y)] / Z_{xy} / Z_{yx}$$

$$CR_{yx} = [(Y_{yx} / Y_y) / (Y_{xy} / Y_x)] / Z_{yx} / Z_{xy}$$

If $CR_{xy} = 0$, both species are equally competitive, If, $CR_{xy} > 1$, x' is more competitive than 'y' and if $CR_{xy} < 1$, x is less competitive than 'y'. This obligation is also applied to CR_{yx}.

Relative Crowding Coefficient

The relative crowding coefficient (RCC or K) was introduced in plant competition theory (De Wit, 1960). It was computed as:

$$K = K_{xy} \times K_{yx}$$

$$K_{xy} = (Y_{xy} \times Z_{yx}) / [(Y_x – Y_{xy}) \times Z_{xy}];\ K_{yx} = (Y_{yx} \times Z_{xy}) / [(Y_y – Y_{yx}) \times Z_{yx}]$$

If, $K_{xy} > K_{yx}$, species 'x' is more competitive than 'y' and vice versa. If $K = 1$, there is no yield advantage, if $K > 1$, there is yield advantage, and if $K < 1$, there is a yield disadvantage.

Actual Yield Loss

The actual yield loss (AYL) is the proportionate yield loss or gain of intercrops in comparison to the respective sole crop. It was calculated based on the following formula (Banik, 1996):

$$AYL = AYL_{xy} + AYL_{yx}$$

$$AYL_{xy} = [(Y_{xy} / Z_{xy}) / (Y_x / Z_x) – 1];\ AYL_{yx} = [(Y_{yx} / Z_{yx}) / (Y_y / Z_y) – 1]$$

Where, AYL is the actual yield losses in intercropping systems, AYL_{xy} and AYL_{yx} are the actual yield loss of species 'x' and 'y' in intercropping systems, respectively. The Z_x and Z_y are the proportion of 'x' and 'y' planting in monocropping systems, respectively. $AYL > 0$ indicate the intercropping system has the yield advantage while $AYL < 0$ indicate that the intercropping system has no yield advantage.

Economical Indices

All economic parameters, including the monetary advantage index (MAI), gross profit (GP), net income (NI), rate of return (RR), and profit margin (PM), were measured based on the yield per hectare. Sweet corn was marketed based on the number of marketable ears (RM10.00 per 14 ears), while groundnut was marketed based on weight per kilogram (RM6.00/kg). These values were calculated using the average market prices in Serdang, Malaysia, in October 2022. In a 1 ha durian orchard, only 8400 m^2 can be planted with other crops, considering the spacing requirements of the durian seedlings and the available area for intercropping.

Sweet Corn Marketable Ear Numbers Per Hectare

The number of ears of sweet corn depends on the number of individual plants, as on average, each plant produces one marketable ear. The calculation below is based on DoA (2008).

In monoculture system:

$Y_{sc.ha}$ = 56000 x 70%

In intercropping system:

$Y_{sc.ha}$ = 28000 x 70%

Where $Y_{sc.ha}$ is potential yield of sweet corn ha^{-1}, 56 000 and 28 000 are number of sweet corn plants in monoculture (occupies in 8400 m^2 areas) and intercropping systems (occupies in 4200 m^2) in durian orchard, respectively, planted as double rows system and 70% is percentage of estimated marketable ears that can produced ha^{-1}.

Groundnut Marketable Pods Fresh Weight Per Hectare

Total fresh weight of groundnut marketable pods ha^{-1} was calculated based on Norman et al. (1995) and Khairol (1991).

In monoculture system:

$Y_{g.ha}$ = (Y_p x 8400 m^2 / S_p) x 95%

In intercropping system:

$Y_{g.ha}$ = (Y_p x 4200 m^2 / S_p) x 95%

Where $Y_{g.ha}$ is potential marketable pod fresh weight of groundnut ha^{-1} (kg), Y_p is yield of groundnut $plot^{-1}$ (kg), 8400 m^2 and 4200 m^2 are available areas for groundnut cultivation in monoculture and intercropping systems in durian orchard, respectively, S_p is size of experimental plot (28.56 m^2) and 95% is estimated yield that can be produced ha^{-1} after 5% loss or damage of marketable pods during harvesting.

Monetary Advantage Index (MAI)

The MAI was used to calculate economic feasibility of intercropping over monocropping systems. It was computed according to the formula described by Willey (1979):

MAI = [(P_{xy} + P_{yx}) x (LER -1)] / LER

P_{xy} = P_x x Y_{xy}; P_{yx} = P_y x Y_{yx}

Where, P_x and P_y are the price of species 'x' and 'y', respectively, Y_{xy} and Y_{yx} is the yield of each species per hectare, respectively. The higher the value of MAI, the more profitable is the cropping system (Mahapatra, 2010). In this context, the prices of species 'x' and 'y' refer to the marketable ears of sweet corn and the marketable pods of groundnut, respectively.

Gross Profit, Net Income, Return Rate and Profit Margin

Gross profit (GP), net income (NI), return rate (RR) and profit margin (PM) were calculated based in Neto et al. (2010). These data were computed based on the following formula:

GP_{sc} = Y_{sc} x P_{sc}

GP_g = Y_g x P_g

GP_{scg} = (Y_{isc} x P_{sc}) + (Y_{ig} x P_g)

NI = GP – PC

RR = GP / PC

PM = NI / GP x 100%

Where, GP_{sc} and GP_g are gross profit of sweet corn and groundnut in monoculture systems, respectively, GP_{scg} is gross profit of sweet corn and groundnut in intercropping systems. Y_{sc} and Y_g are the yields of sweet corn and groundnut in monoculture systems, respectively. Y_{isc} and Y_{ig} are the yields of sweet corn and groundnut in intercropping systems, respectively. P_{sc} and P_g are price of sweet corn ears and groundnut pods fresh weight, respectively. GP and NI are expressed in RM ha^{-1} while PR is expressed in percent (%). GP is the value of produce in each cropping systems, regardless of PC (all cost of production including input and labors in each intercropping system).

Statistical Analysis

The biological indices, including LER, ATER, AI, CR, RCC (K), AYL, and MAI, were calculated to evaluate the performance of the intercropping system. However, these indices were not subjected to statistical analysis, as they are derived parameters rather than directly measured experimental variables. Statistical analysis was performed using one-way analysis of variance (ANOVA), followed by Tukey's pairwise comparisons to evaluate the statistical significance of multiple economic indices such as MAI, GP, NI, RR, and PM. A p-value ≤ 0.05 was used to determine the level of significance.

Results and Discussion

Sweet Corn and Groundnut Fresh Weight Yield Per Plot

The T1 cropping system had a significantly higher fresh weight of marketable corn ears compared to other intercropping systems in both seasons (both has $p = 0.00$) (Table 1). In season 1, T2 had a significantly higher fresh weight of marketable groundnut pods ($p = 0.01$), but no significant difference was observed in season 2 ($p = 0.06$). The total fresh yield weight of T2 was significantly lower than that of the other intercropping systems in both seasons (both has $p = 0.00$). In season 1, there was no significant difference in the total fresh yield weight between T1 and T3, T4, and T5. However, in season 2, T1 had a significantly higher total fresh yield weight than these cropping systems.

Table 1. Fresh weight yield of sweet corn and groundnut per plot (28.56 m²) as affected by various intercropping systems.

Intercropping systems	Season 1			Season 2		
	Corn mar. ears FW (A)	Groundnut mar. pods FW (B)	Tot. FW (A+B)	Corn mar. ears FW (A)	Groundnut mar. pods FW (B)	Tot. FW (A+B)
	kg plot^{-1}					
T1	48.53a± 5.87	-	48.53a±5.87	66.83a±2.69	-	66.83a±2.69
T2	-	12.81a±1.41	12.81b±1.41	-	9.37a±2.17	9.37c±2.17
T3	29.78b± 0.66	5.59b±1.03	35.37a±1.49	32.19b±2.75	4.45a±0.79	36.64b±2.00
T4	27.36b± 2.18	5.73b±1.01	33.09a±3.07	34.53b±0.57	5.41a±0.62	39.94b±1.17
T5	31.04b± 1.44	4.07b±2.23	35.11a±2.90	31.76±b1.1	4.89a±0.69	36.65b±1.13
p-value	0.00	0.01	0.00	0.00	0.06	0.00

Note: T1 = Monoculture of sweet corn, T2 = Monoculture of groundnut, T3 = Strip intercropping of corn and groundnut (corn and groundnut planted at the same day), T4 = Strip relay intercropping of corn and groundnut (corn planted two weeks after groundnut), T5 = Strip relay intercropping of corn and groundnut (groundnut planted two weeks after corn). Mar. = marketable, Tot. = total and FW = fresh weight. Different letters follow different treatments within columns indicate a significant difference at $p \leq 0.05$. The values are the means of four replicates.

LER and ATER

The LER and ATER were presented in Table 2. The LER responded positively to the T4 cropping system. The highest LER values were 1.01 and 1.09 for T4, while the lowest were 0.96 and 0.70 for the T5 cropping system in season 1 and season 2, respectively. The LER increased with the increment of marketable ear and marketable pod fresh weight per plot of corn and groundnut in T4. This indicates that to achieve an LER greater than 1, groundnuts need to be planted two weeks earlier than corn. Groundnut, being a crop with a shorter canopy structure, generally requires adequate sunlight and is affected by shade when intercropped with taller crops (Maitra et al., 2021). Therefore, groundnuts should be planted first to ensure they receive sufficient sunlight for photosynthesis. Sowing one species earlier increases its competitiveness and decreases the competitiveness of the later-sown species (Yu et al., 2016). If corn is planted first, it will grow rapidly and provide shade to the groundnut at a time when groundnuts need a lot of sunlight during their early growth stages. Corn was the superior competitor when intercropped with groundnut, and its productivity dominated the yield of the intercropping system (Li et al., 2019). This relationship is called asymmetric competition, where one species performs better in an intercrop by suppressing the growth of other species (Bybee-Finley & Ryan, 2018).

The ATER for corn and groundnut in all intercropping systems was less than 1.00 in both seasons. This indicates that most of the intercropping systems used in the study did not offer an advantage over monocropping systems of corn or groundnut in terms of the time taken to complete one production cycle. ATER was introduced to address the conceptual inadequacy in LER, where time is not considered. The duration of land occupancy by an intercrop is often longer than the production-cycle duration for one or more of the interplanted species (Hiebsch & McCollum, 1987). The ATER for T3 decreased by 8% and 15%, for T4 by 12% and 2%, and for T5 by 30% and 23% in season 1 and season 2, respectively. The reduction in ATER for these cropping systems was likely due to the reduced yield of groundnut, which was heavily shaded by corn, especially in T5. Groundnut experienced significant shading from the corn during critical stages such as flowering, pegging, and pod development (Rao & Mittra, 2008; Vara Prasad et al., 2010; Quamruzzaman et al., 2018). This shading reduced the weight and size of the marketable pods and seeds of groundnut. In T4, groundnut produced a better pod yield than in T3 and T5, but it was still not enough to compete with groundnut grown under a monoculture system. This was due to shading stress still experienced by groundnut during the R6 stage (full seed stage). The best condition for growing groundnut is under natural light, not shade, as shading stress reduces groundnut yield, as shown by several researchers (Chen et al., 2020; Noertjahyani et al., 2020; Hemon & Hanafi, 2021).

Table 2. LER and ATER of sweet corn and groundnut as affected by various intercropping systems.

Intercropping systems	LER		ATER	
	Season 1	Season 2	Season 1	Season 2
T3	1.05	0.96	0.92	0.85
T4	1.01	1.09	0.88	0.98
T5	0.96	1.00	0.70	0.77

Note: T3 = Strip intercropping of corn and groundnut (corn and groundnut planted at the same day), T4 = Strip relay intercropping of corn and groundnut (corn planted two weeks after groundnut), T5 = Strip relay intercropping of corn and groundnut (groundnut planted two weeks after corn). LER = land equivalent ratio and ATER = area time equivalent ratio.

AI, CR, RCC (K) and AYL

The AI and CR were presented in Table 3 while RCC and AYL were presented in Table 4. These parameters responded positively to corn in both seasons, indicating that corn is more dominant and competitive than groundnut in intercropping systems. Similar results were observed when corn was planted with groundnut or other legumes, as noted in several studies (Yang et al., 2017; Feng et al., 2022; Gidey et al., 2024). These studies show that cereals are more aggressive, often suppressing the growth of legumes (Maitra et al., 2021). Corn, being a gramineous crop, has a greater nutrient uptake capacity and higher biomass yield. Additionally, as a C4 plant, corn is the competitively dominant species in terms of resource utilization when intercropped (Kheroar & Patra, 2014; Feng et al., 2022). Overall, cereals tend to be more dominant than legumes (Choudhary, 2014).

In intercropping, legumes are often the dominant species, as demonstrated by several studies, such as those involving mungbean with sunflower (Imran et al., 2011), dolichos or bean with potato (Gitari et al., 2020) and mungbean or soybean with sesame (Baraki et al., 2023). Therefore, legumes should be planted first to increase their competitiveness, as shown in the T4 cropping system. Sweet corn in T4 is less competitive than in T3 and T5 due to the increased competitiveness of groundnut in the T4 cropping system, which is reflected by most intercropping indices. Consequently, the total RCC and AYL for T4 were always positive, indicating a cropping advantage. Additionally, both parameters increased from season 1 to season 2. Thus, it is preferable to sow a weaker competitor in a mixture earlier relative to the aggressor to improve its performance (Santo et al., 2023).

Table 3. AI and CR of sweet corn and groundnut as affected by various intercropping systems.

Intercropping systems	AI				CR			
	Season 1		Season 2		Season 1		Season 2	
	AI_{sc}	AI_g	AI_{sc}	AI_g	CR_{sc}	CR_g	CR_{sc}	CR_g
T3	0.20	- 0.20	0.19	- 0.19	2.11	0.47	1.52	0.66
T4	0.19	- 0.19	0.21	- 0.21	1.89	0.53	1.34	0.75
T5	0.21	- 0.21	0.19	- 0.19	3.02	0.33	1.37	0.73

Note: T3 = Strip intercropping of corn and groundnut (corn and groundnut planted at the same day), T4 = Strip relay intercropping of corn and groundnut (corn planted two weeks after groundnut), T5 = Strip relay intercropping of corn and groundnut (groundnut planted two weeks after corn). AI_{sc}, = aggressivity of corn, AI_g = aggressivity of groundnut, CR_{sc}, = competition ratio of corn and CR_g = competition ratio of groundnut.

Table 4. RCC (K) and AYL of sweet corn and groundnut as affected by various intercropping systems.

IS	RCC (K)						AYL					
	Season 1			Season 2			Season 1			Season 2		
	K_c	K_g	K_T	K_c	K_g	K_T	AYL_c	AYL_g	AYL_T	AYL_c	AYL_g	AYL_T
T3	2.38	0.52	1.24	1.39	0.60	0.83	0.23	-0.13	0.10	-0.04	-0.05	-0.09
T4	1.94	0.54	1.05	1.60	1.14	1.82	0.13	-0.11	0.02	0.03	0.15	0.18
T5	2.66	0.31	0.82	1.36	0.73	0.99	0.28	-0.36	-0.08	-0.05	0.04	-0.01

Note: T3 = Strip intercropping of corn and groundnut (corn and groundnut planted at the same day), T4 = Strip relay intercropping of corn and groundnut (corn planted two weeks after groundnut), T5 = Strip relay intercropping of corn and groundnut (groundnut planted two weeks after corn). IS = Intercropping systems, K_{sc} = RCC of corn K_g = RCC of groundnut, K_T = product of the coefficient, AYL_{sc} = yield loss or gain of 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.

MAI

The MAI responded positively to T4 in both seasons (Table 5). T5 had negative MAI values (-776.17 and -52.38 in season 1 and season 2, respectively), indicating no yield advantage. T3 only showed an intercropping advantage in season 1 (MAI value = 890.12), but not in season 2 (MAI value = -804.60). In season 1, the MAI value for T4 was 206.09, while in season 2, it increased to 1593.48. This scenario indicates that the T4 system has a definite yield advantage and is more profitable compared to sole cropping. The positive MAI values in both seasons were due to LER values greater than one, demonstrating a clear yield advantage for the sweet corn and groundnut intercropping system (Nurgi et al., 2023). Additionally, the MAI values increased from season 1 to season 2. The higher the MAI value, the more profitable the intercropping system (Ghosh, 2004).

Table 5. MAI of sweet corn and groundnut as affected by various intercropping systems.

Intercropping systems	Season 1	Season 2
T3	890.12	-804.60
T4	206.09	1593.48
T5	-776.17	-52.38

Note: T3 = Strip intercropping of corn and groundnut (corn and groundnut planted at the same day), T4 = Strip relay intercropping of corn and groundnut (corn planted two weeks after groundnut), T5 = Strip relay intercropping of corn and groundnut (groundnut planted two weeks after corn). MAI = monetary advantage index. The higher the MAI values, the more profitable is the cropping system.

GP, NI, RR and PM

The GP, NI, RR, and PM showed positive responses under the T1 cropping system (Table 6). Corn was more profitable than groundnut due to its higher market price. Corn is sold per ear at approximately RM10.00 per 14 ears, whereas groundnut is sold per kilogram at RM6.00/kg, based on average market prices in Serdang, Malaysia (October 2022). Profitability was calculated using 2022 market prices for data collected in 2020–2021, which may not fully reflect the actual returns during the experimental years and should be considered a limitation of this study. Farmers can earn around RM0.70 per ear of corn, while groundnut yields about 22.70 g of marketable pods per plant, providing approximately RM0.13 per plant. This demonstrates that groundnut alone generates relatively low profit, and therefore, T2 is not recommended.

Cropping systems T3, T4, and T5 were less profitable than T1 because they contained fewer corn plants, resulting in lower yields of marketable ears. Therefore, studies on corn planting density are often conducted to determine the optimal number of corn plants per area to maximize yield without compromising the quality of marketable ears, as demonstrated in studies by Shin et al. (2014), Dhaliwal and Williams (2019) and Ye et al. (2023).

Table 6. GP, NI, RR and PM of sweet corn and groundnut per hectares as affected by various intercropping systems.

Parameters	Season	T1	T2	T3	T4	T5	p-value
GP (RM)	1	28000±950a	21480.54±720ab	18773.27±650b	18758.63±640b	18568.99±630b	0.003
	2	28000±940a	15702.02±710b	17719.89±640b	18538.05±630b	18097.75±620b	0.007
NI (RM)	1	18617±620a	7428.11±410b	6743.22±380b	6728.13±380b	6538.22±370b	0.004
	2	18617±600a	1649.45±350b	5689.64±340b	6508.53±340b	6067.39±330b	0.009
RR	1	2.98±0.12a	1.53 ± 0.08b	1.56 ± 0.08b	1.56 ± 0.08b	1.54 ± 0.08b	0.005
	2	2.98±0.11a	1.12 ± 0.07b	1.47 ± 0.07b	1.54 ± 0.07b	1.50 ± 0.07b	0.006
PM (%)	1	198.42±5.2a	52.86 ± 2.1b	56.05 ± 2.1b	55.93 ± 2.1b	54.35 ± 2.0b	0.002
	2	198.42±5.1a	11.74 ± 1.9b	47.29 ± 2.0b	54.10 ± 2.0b	50.43 ± 2.0b	0.004

Note: T1 = Monoculture system of corn, T2 = Monoculture system of groundnut, T3 = Strip intercropping of corn and groundnut (corn and groundnut planted at the same day), T4 = Strip relay intercropping of corn and groundnut (corn planted two weeks after groundnut), T5 = Strip relay intercropping of corn and groundnut (groundnut planted two weeks after corn. GP = gross profit, NI = net income, RR = return rate, PM = Profit margin and RM = Malaysian ringgit. Different letters follow different treatments within rows indicate a significant difference at $p \leq 0.05$. The values are the means of four replicates.

Conclusion

In conclusion, cultivating sweet corn as a monoculture (T1) in durian orchards is more profitable than growing groundnut alone or intercropping. It was due to sweet corn being marketed based on the number of ears, which commands a higher market price compared to groundnut, typically sold by pod weight. Among intercropping systems, T4 is the most effective for increasing yield and quality, as planting groundnut two weeks earlier allows it to grow vigorously and compete with corn. This helps control sweet corn's excessive vegetative growth, leading to optimal sweet corn yields and improved groundnut yields. However, despite its agronomic benefits, the T4 intercropping system still falls short of T1 in terms of profitability. It was due to higher plant population of sweet corn in the T1 system, which directly contributes to a greater number of marketable ears. Therefore, the monoculture system of sweet corn (T1) is recommended for smallholders with durian orchards to generate income before the durian trees begin to bear fruit and provide returns.

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Author Contribution

Borhan Abdul Haya – conducting experiment, collecting data, analysis and writing; Zulkefly Sulaiman, Mohd Fauzi Ramlan, Mohd Rizal Ariffin, Martini Mohammad Yusoff and Tsan Fui Ying – Supervision, review and editing. All authors reviewed the results and approved the final version of the manuscript

Conflict of Interest

The author(s) declared no conflict of interest for this research.

Declaration on the Use of Generative AI

The entire content of this article is the original idea of the author, and ChatGPT was only used for language enhancement. I also confirm that its use does not compromise the originality, intellectual contribution, or scientific integrity of the work.

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