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RESEARCH ARTICLE

# Yield and intercropping indices of sweet corn and okra grown in young rubber plantation

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## ABSTRACT

Intercropping is a labor-intensive practice largely adopted by smallholder farmers to increase yield per unit area, cope with crop failures and market fluctuations, meet food preferences and increase farm income. A field experiment was conducted to examine the yield performances and intercropping efficiencies of sweet corn and okra planted in a young rubber plantation. The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications. The treatments ratios were 20% okra + 80% sweet corn (strip and strip relay intercropping) with sole okra and sweet corn as the control. This consisted of strips intercropping (okra and sweet corn planted on the same date), strip relay intercropping (sweet corn planted 4 weeks after okra planting), sole okra and sole sweet corn. The highest yield of okra was obtained from strip relay intercropping while the highest yield of sweet corn was produced from the pattern of strip intercropping. However, the economic analysis showed that the strip intercropping recorded the maximum gross margin and cost-benefit ratio of RM 17,733.20 $ha^{-1}$ and 2.09, respectively. Immature rubber growth was unaffected by intercropping with sweet corn and okra crops. Strip intercropping not only resulted in the higher land equivalent ratio (1.29), but also area time equivalent ratio, % land saved and monetary advantage index of 1.14, 22.28% and RM 7,583.50 $ha^{-1}$, respectively compared with strip relay intercropping. The highest assessment of intercropping based on relative crowding coefficient was recorded by strip intercropping with 4.56. With regard to competition between the intercrops, okra was a more dominant species as measured by the positive value of aggressivity. However, strip intercropping was indicated the lowest competitive ratio than the strip relay intercropping. Thus, this intercropping pattern can be recommended to the farmers for adoption.

**Keywords:** Intercropping efficiency; Okra; Rubber plantation; Sweet corn; Yield

## INTRODUCTION

Rubber (*Hevea brasiliensis*) belongs to the family Euphorbiaceae and is expected to become the number one commodity in the Malaysian economy. Malaysia is the world's leading producer and exporter of rubber gloves, as well as a major exporter of condoms and catheters (Teresa, 2018).

The long gestation period is the major challenge in the production of rubber worldwide, necessitating farmers to earn extra money during the immature phase. Therefore, the intercropping system of perennial crops has been promoted and expanded with annual crops. The problem such as low income in the main crop and no source of income during the replanting season can be solved by intercropping (Tetteh et al., 2019).

Intercropping is a type of mixed cropping practice of two or more crops in the same planting area (Hugar and Palled, 2008). Intercropping has existed in the evolution of agriculture and remains a widespread practice in many developing countries due to its emphasis on sustainability and food security (Glaze-Corcoran et al., 2020). Traditionally, it has been practiced to enhance crop production, increase land-use efficiency, as well a strategy against crop failure (Bybee-Finley and Ryan, 2018). As intercropping can improve yield and the overall sustainability of cropping systems, it is a priority to facilitate sustainable intensification with the aim of smallholders could exploit crop diversification and fully utilize the potential benefits from intercropping.

In an experiment to examine the yield of corn in a corn-okra mixture as a function of time, Ijoyah and Dzer (2012)

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found that planting corn at the same time as okra resulted in the highest intercropped corn yield. This result is in line with a study by Muoneke et al. (1997) who found that planting corn at the same time as okra in a corn-okra intercropping yielded the best results. In a study by Oyewole (2010), corn intercropped with okra revealed a significant difference of cropping system on final heights of corn and okra, the total number of okra pods harvested $ha^{-1}$, total pod weight $ha^{-1}$ and corn yield. In addition, intercropping corn with okra significantly gave a higher yield than sole corn or okra (Hamma et al., 2015).

A study has been conducted on okra intercropping with other crops indicating several benefits such as yield increases of 25-30% and that there were higher economic returns in the okra-cassava intercropping (Muoneke and Mbah, 2007). One economic implication showed that the profit from maize-okra intercropping was 10% higher than monocropping (Alabi and Esobhawan, 2006).

Agriculturists most commonly utilize the land equivalent ratio (LER) to determine whether intercropping systems are successful or not in boosting total output (Maitra et al., 2021; Glaze-Corcoran et al., 2020; Bybee-Finley and Ryan, 2018; Lithourgidis et al., 2011). In terms of LER and EV (energy value) of maize-bean, intercropping showed higher profitability and productivity compared to sole cropping (Tsubo et al., 2004). Moreover, cereal-legume intercropping systems produced greater income due to a higher LER and other intercropping indices (Hussain et al., 2002). In 2009 and 2010, studies on maize-okra intercropping reported LER values of 1.84 and 1.80, respectively and 45.70% (2009) and 44.40% (2010) of the land saved showing that cultivating the two crops together yielded higher productivity per unit area than growing them individually (Ijoyah and Jimba, 2012).

The competitive ratio (CR) is a useful indicator for evaluating the competition between intercropped species. The competitive ratios of potatoes and legumes were all positive, indicating that the potato was the dominating crop within the combination with lower CR (Gitari et al., 2020). The previous research by Lithourgidis et al. (2011), reported that cereal competitive values were higher than pea, implying that cereal was more dominant than pea. In the okra-maize intercropping, the lowest competitive ratio was recorded when they were planted simultaneously in mid-June in 2010 and 2011 (Ijoyah and Dzer, 2012).

The positive monetary advantage index (MAI) values, clearly indicate the profitability of intercropping over monocropping systems. Thus, a study of sorghum-soybean intercropping systems produced 46% higher income returns per unit area than sole cropping (Iqbal et al., 2017). Meanwhile, intercropping systems always recorded higher MAI over monoculture was a clear indication of gain from intercropping (Gitari et al., 2020; Kheroar and Patra, 2013).

The last few decades have brought remarkable development of rubber plantations as well as socio-economic transformation in Malaysia. Even though how significant the impact is, rubber smallholders face a loss of income at the early stage of rubber trees due to the rubber long gestation period and plantation expansion will inevitably diminish the amount of land available for agricultural activities in producing the local food production. Intercropping practices might offer promising options in which crops for intercropping are properly selected and could be considered as sustainable crop production. As a result, this study investigated the intercropping efficiency and potential of sweet corn-okra intercropping patterns developed in a young rubber plantation. The objectives of the study were to determine the yield performances and to measure the components of intercropping efficiency (biological efficiency, ecological efficiency and economic efficiency) of sweet corn-okra intercropping in the young rubber plantation.

## MATERIALS AND METHODS

### Site description

The study was conducted at Malaysia Rubber Board sub to MINI Station of Rubber Research at Jasin, Mukim Ayer Barok, Melaka, with Latitude 2° 18' 60.00" N and Longitude 102° 25' 59.99" E. Jasin receives a minimum of 2800 mm of rain annually and the average annual minimum and maximum air temperatures are 25 $^0$C and 31 $^0$C, respectively. The soil texture is sandy clay loam consisting of an average of 75.92% sand, 4.50% silt and 20.36% clay.

### Experimental design, treatments and field management

The study was conducted in Randomized Complete Block Design (RCBD) with three replications. Intercropping ratios of 20% okra + 80% sweet corn were used for T1 and T2, whereas sole okra (100%) and sweet corn (100%) were used as controls. The study consisted of T1= strips [okra and sweet corn were planted on the same date (21$^{st}$ September 2020)], T2= strips relay intercropping [sweet corn was planted 4 weeks after okra planting date (okra:21$^{st}$ September 2020 and sweet corn: 21$^{st}$ October 2020)], T3= sole okra and T4= sole sweet corn. The detailed sweet corn-okra intercropping patterns are presented in Table 1.

The study site (216 $m^2$) was ploughed and harrowed, and the seeds of sweet corn and okra were sown manually on the planting beds, in the distance of 30 cm x 100 cm for

**Table 1: Four different sweet corn-okra intercropping patterns**

| Treatment | Intercropping patterns | Planting time | Ratios |
|---|---|---|---|
| T1 | Strip intercropping | Sweet corn and okra were planted on the same date | 20% Okra 80% Sweet Corn (20:80) |
| T2 | Strip relay intercropping | Sweet corn was planted four weeks after okra | |
| T3 | Sole okra | Planted at the same date with strip intercropping | 100% Okra |
| T4 | Sole sweet corn | Planted at the same date with strip intercropping | 100% Sweet Corn |

both sole crops and mixed stands in 12 m x 18 m plots of 600 plants per plot. Sweet corn and okra were planted manually by placing one seed per hole. The variety of sweet corn used was F1 Hybrid Asia Best Super Sweet Corn, while for okra was OP 1 Okra Amazon King. In addition, the rubber tree clone of RRIM 3001 was planted in this area in March 2018. The planting distance between the rubber trees was 3 m x 6 m.

A fertilizer with the ratio of 15:15:15 was applied to all plants two weeks after sowing at the dosage of 40 g plant$^{-1}$. The second application used 12:12:17:2 fertilizer with 50 g plant$^{-1}$ at four weeks after sowing and on days 45 and 60 using the ring method of fertilizer application. Watering was done twice a day in the morning and evening throughout the growing season, except for the rainy days. The study plot was sprayed with pre-emergent herbicide, Lasso® (a.i: 45.1% alachlor) 7 days before planting to suppress the initial growth of weeds. A broad-spectrum systemic herbicide, Ecomax® (a.i: 41.0% glyphosate-isopropylamine) was used for effective control on annual grasses and certain broadleaf weeds in the field that competed with crops in between the planting beds by adding 20 liters of water in 150 ml Ecomax®. Furthermore, weeds were also removed manually throughout the growing season. Pesticide and fungicide were sprayed depending on the infestation load. The pesticide, CH Carbaryl 85 (a.i: 85.0% carbaryl) was applied once an infestation occurred in order to control pest infestation on the stems, leaves, pods of okra and cobs of sweet corn.

Sweet corn and okra were harvested manually from a random sample (2 plants per plot) of both sole and mixed crops. The entire plants were harvested by cutting the stems at the ground level and total fresh weight was determined. The cobs were separated manually from the stover. Okra pods were harvested five times within 90 days after sowing. Okra was harvested when the tip of the pod was observed to break easily when pressed with the fingertip (Usman, 2001). The first harvest was done at 50 days after sowing and then followed by every 10 days until 90 days after sowing.

### Yield and economic analysis

The fresh pods of okra (kg ha$^{-1}$) and sweet corn cob yield (kg ha$^{-1}$) were weighed using a digital balance. Economic analysis was done to evaluate the economic feasibility of intercropped sweet corn-okra in the immature rubber plantation. The cost of production, including the cost of seeds, fertilizers, pesticides, herbicides, labor and transport, were calculated based on the local rates. Gross income was calculated by considering the economic yield based on the current field prices (field price 1 kg okra= RM 3.50; Field price 1 sweet corn cob = RM 0.70. Gross margin was taken as the difference between gross income and the cost of production. In contrast, the benefit-cost ratio was calculated by dividing gross income with the cost of production (Gitari et al., 2020).

### Immature rubber growth performance

Data were generated on the stem girth and average canopy diameter of immature rubber trees at the end of the study by using a vernier caliper and measuring tape. Average canopy diameter was calculated using the formula of Angombe et al. (2020) by taking two diameter measurements at the widest sections of the canopy and the two measurements were then averaged to give the average canopy diameter.

### Assessment of the biological efficiency of sweet corn-okra intercropping pattern

The biological efficiency of the sweet corn-okra intercropping system was assessed using the land equivalent ratio (LER), system productivity index (SPI), area time equivalent ratio (ATER) and percentage of land saved. LER is the most widely used method that is currently applied to examine the failure or success of intercropping systems to increase yield and is a measurement of yield obtained from the growing of two or more crops compared to their yield obtained in a monoculture on one unit of land (Mead and Willey, 1980). LER from the yields of sweet corn and okra was used to evaluate the productivity of intercropping versus sole cropping. The LER (Eqs. 1) was determined with the following formula:

$$\text{LER} = \frac{\text{Pod yield of okra intercropped}}{\text{Pod yield of sole okra}} + \frac{\text{Cob yield of sweet corn intercropped}}{\text{Cob yield of sole sweet corn}} \quad (1)$$

The system productivity index was used to assess productivity and stability of the intercropping pattern by standardizing the yield of okra (as a secondary crop) in term of the sweet corn (primary crop) (Agegnehu et al., 2006; Lithourgidis et al., 2011; Gitari et al., 2020) and was calculated using Eqs.(2).

$$SPI = \left(\frac{Ys}{Yo}\right) Yos + Yso \tag{2}$$

where Ys and Yo are average yields of sweet corn and okra in monocrops, respectively and Yos and Yso are the average yields of sweet corn and okra in intercropping.

The area time equivalent ratio (ATER) was proposed by Mead and Willey (1980) as a modification for LER. It is used to compare the yield advantage of intercropping to the monocropping by taking into consideration the time taken by the component crops under intercropping in the field from planting to harvesting (Hiebsch and McCollum, 1987; Doubi et al., 2016; Gitari et al., 2020). ATER was computed following the formula by Hiebsch and McCollum (1987) in Eqs. (3).

$$ATER = \frac{Lsts + Loto}{T} \tag{3}$$

where Ls and Lo are yields of the LER's for sweet corn and okra, respectively and ts and to are the growth period in days for sweet corn and okra, respectively. T is the duration of the component crop with the longest growing period.

The percentage (%) land saved (Eqs. 4) as described by Willey (1985) was derived using the formula:

$$\%Land\ Save = 100 - \frac{1}{LER} x\ 100 \tag{4}$$

**Assessment of the ecological efficiency of sweet corn-okra intercropping pattern**

Aggressivity is often used to indicate how much the relative yield increase in 'a' crop is greater than that of 'b' crop in intercropping (Agegnehu et al., 2006; Lithourgidis et al., 2011). The aggressivity index (AI) was developed by McGilchrist and Trenbath (1971) as expressed in Eqs. (5-6).

$$AIo = \frac{Yos}{Yo\ x\ \ Zos} - \frac{Yso}{Ys\ x\ Zso} \tag{5}$$

$$AIs = \frac{Yso}{Ys\ x\ Zso} - \frac{Yos}{Yo\ x\ \ Zos} \tag{6}$$

where AIo and AIs are the aggressivity indices of okra and sweet corn, respectively. Zos and Zso represent the sowing proportion of okra and sweet corn, respectively. An aggressivity value of zero indicates that intercropped species have equal competitiveness. The greater the numerical value, the bigger the difference in competitive abilities of the intercrop components (Glaze-Corcoran et al., 2020).

Competitive ratio (CR) is an important index to assess competition between species grown in intercropping. CR differs from aggressivity because it considers individual LERs and the proportion of the mix in the intercropping (Willey and Rao, 1980). The CR (Eqs. 7-8) was calculated as follows:

$$CRo = \left(\frac{LER\ o}{LER\ s}\right) x \left(\frac{Zso}{Zos}\right) \tag{7}$$

$$CRs = \left(\frac{LER\ s}{LER\ o}\right) x \left(\frac{Zos}{Zso}\right) \tag{8}$$

where CRo and CRs represent the competitive ratio of okra and sweet corn, respectively. LERo is LER for okra whereas LERs is for sweet corn.

The relative crowding coefficient (K) reflects the relative dominance of one species over the other one in an intercropping (Glaze-Corcoran et al., 2020). The component crop with the greatest K value (Eqs. 9-11) is dominant and those with lower K values are dominated (Tahir et al., 2003). K was calculated as follows:

$$K = Kos\ x\ Kso \tag{9}$$

$$Kos = \frac{Yos\ *Zso}{(Yo - Yos)\ *Zos} \tag{10}$$

$$Kso = \frac{Yso\ *Zos}{(Ys - Yso)\ *Zso} \tag{11}$$

where Kos represents the relative crowding coefficient for okra when intercropped with sweet corn and Kso is the relative crowding coefficient for sweet corn when intercropped with okra.

Actual yield loss (AYL) is s used to provide detailed information about competition between intercrops as it indicates the equivalent yield gain or loss of component crops in comparison to the respective pure stands (Gitari et al., 2020). Moreover, Banik et al. (2000) reported that the actual yield loss index, based on yield per plant, gave more precise information than other indices about the competition between and within component crops and the behavior of each species in intercropping. The AYL was calculated according to the following formula (Banik et al., 2000) (Eqs. 12-14):

$$AYL = AYLo + AYLs \quad (12)$$

$$AYLo = LER * \left(\frac{100}{Zos}\right) - 1 \quad (13)$$

$$AYLs = LER * \left(\frac{100}{Zso}\right) - 1 \quad (14)$$

where AYLo and AYLs represent the proportionate actual yield loss or gain of each species when grown as intercrops compared to their yield in monocropping. The AYL can have positive or negative values indicating an advantage or disadvantage of intercropping (Lithourgidis et al., 2011).

### Assessment of the economic efficiency of sweet corn-okra intercropping pattern

The monetary advantage index (MAI) is the most-used conventional method for intercrop versus sole crop comparisons in terms of economic assessment (Sadeghpour et al., 2013). MAI was developed to describe the competition and economic advantage of intercropping compared to sole cropping. MAI was determined as indicated in Eqs. (15) (Lithourgidis et al., 2011).

$$MAI = \text{RM value of combined intercrops} * \left(\frac{LER - 1}{LER}\right) \quad (15)$$

where RM is representing the Ringgit Malaysia.

Intercropping advantage (IA) is used to assess economic value in more detail than MAI, accounting for the partial value of individual crops. The index was derived from Eqs. (16-18) (Banik, 1996).

$$IA = IAo + IAs \quad (16)$$

$$IAo = AYLo * Po \quad (17)$$

$$IAs = AYLs * Ps \quad (18)$$

where IAo and IAs are the intercropping advantages of okra and sweet corn, respectively. Po is the field price of okra (the current price is RM 3.50 $kg^{-1}$) whereas Ps is the field price of sweet corn cob (the current price is RM 0.70 $cob^{-1}$).

### Statistical analysis

Data were analyzed using ANOVA of SAS package (SAS Institute, 2004) and the means of the treatments found to be statistically significant were compared using the Least Significant Difference Test (LSD) ($P \leq 0.05$) following the procedure of Gomez and Gomez (1984). T-Test of Statistical Analysis System (SAS version 9.4; SAS Institute, Cary, NC) was used to detect the difference between two of the treatments effects at the significance level of 0.05.

## RESULTS AND DISCUSSION

### Yield and economic efficiency under sweet corn-okra intercropping pattern

Different sweet corn-okra intercropping patterns significantly influenced the yields of sweet corn and okra (Table 2). Cob yield (9342.10 kg $ha^{-1}$) was highest for sole sweet corn (T4), but it was severely lowered when sweet corn was intercropped with okra. Due to population advantage and decreased intraspecific rivalry among the plants, sole sweet corn produced the most cobs. This finding supports by the study of Setu and Mitiku (2018) and Oyewole (2010), who found that sole maize yielded more than when it intercropped. However, the greatest cob yield of sweet corn under intercropping was obtained from strip intercropping (T1) with 8001.40 kg $ha^{-1}$ and the lowest was under pattern strip relay intercropping (6989.50 kg $ha^{-1}$) when sweet corn was sown four weeks after okra. This result agrees with Ijoyah and Dzer (2012) and Muoneke et al. (1997), who found that maize provided the highest intercropped yield when planted simultaneously with okra. In addition, Ijoyah (2010) also found that planting maize concurrently with white guinea yam in a white guinea yam – maize combination crop resulted in the highest intercropped maize yield.

Okra pod yield was significantly ($P \leq 0.05$) reduced by intercropping (Table 2). Sole okra (T3) had the maximum pod production (10734.00 kg $ha^{-1}$), which was drastically reduced when intercropped with sweet corn. Under intercropping, the highest okra pod yield was recorded from strip relay intercropping (T2) with 5133.80 kg $ha^{-1}$ which could be due to the delayed introduction of sweet corn into the crop mixture. The lowest okra pod yield was obtained from strip intercropping with 4588.40 kg $ha^{-1}$. The result in the present study is consistent with the finding of Muoneke et al. (1997), who discovered that when a crop was added earlier in the crop combination, its production was higher than that of another component crop. When component crops in a combination were seeded at various times, the component crop that was sown first typically had an early competitive edge over the component crop that was sown later (Andersen et al., 2005).

**Table 2: Yield and economics of pure stands and sweet corn-okra intercropping pattern**

| Intercropping pattern | Yield (kg $ha^{-1}$) | | Cost and income (RM $ha^{-1}$) | | | Benefit-cost ratio |
|---|---|---|---|---|---|---|
| | Sweet corn | Okra | Gross income | Cost of production | Gross margin | |
| T1= Strip Intercropping | 8001.40$^{b}$ | 4588.40$^{c}$ | 34038.20 | 16305.00 | 17733.20 | 2.09 |
| T2= Strip Relay Intercropping | 6989.50$^{c}$ | 5133.80$^{b}$ | 34628.30 | 17255.00 | 17373.30 | 2.01 |
| T3= Sole Okra | - | 10734.00$^{a}$ | 37569.00 | 25545.00 | 12024.00 | 1.47 |
| T4= Sole Sweet Corn | 9342.10$^{a}$ | - | 22010.80 | 13620.00 | 8390.80 | 1.62 |

$^{abc}$Means within the same column followed by unlike letters are statistically significant ($P \leq 0.05$) using LSD.

Economic analysis is an important tool to evaluate the economic feasibility of the intercropping system. The gross income, cost of production, gross margin and benefit-cost ratio are shown in Table 2. All treatments were subjected to cost-benefit analysis and the maximum gross income (RM 37569.00 $ha^{-1}$) was recorded in sole okra followed by strip relay and strip intercropping with RM 34628.30 $ha^{-1}$ and RM 34038.20 $ha^{-1}$, respectively. Sole sweet corn gave the lowest gross income with RM 22010.80 $ha^{-1}$. Results revealed that strip intercropping was more profitable with a higher gross margin (RM 17733.20 $ha^{-1}$) compared with sole sweet corn and okra. A similar observation was made in strip relay intercropping which recorded 52% and 31% higher gross margin compared to sole sweet corn and okra, respectively.

The benefit-cost ratio differed substantially between intercropping patterns with the highest value noted in strip intercropping (2.09) followed by strip relay intercropping (2.01) and sole sweet corn (1.62) whereas sole okra had the lowest ratio with only 1.47. Therefore, if rubber smallholders choose to practice strip intercropping, they could expect as high as RM 2.09 in benefits for each RM 1.00 cost of production.

Intercropped sweet corn-okra yielded higher economic returns, demonstrating that intercropping systems provide a financial benefit. However, within the two systems, strip intercropping gave the highest gross margin and benefit-cost ratio compared with the strip relay intercropping while the lowest was from the sole crop. These results are confirmed by Gitari et al. (2020); Kumar et al. (2013); Mucheru-Muna et al. (2011) and Jat and Ahlawat (2010) who stated that a higher gross margin was from the intercropping system compared to sole crops.

In a previous study, Iqbal et al. (2017) revealed that when soybean sowing was delayed for 15 days in a sorghum-soybean relay intercropping system resulted in the highest benefit-cost ratio and monetary benefits. To maximize the benefits of intercropping, it was proposed that delayed sowing of one component crop be investigated. This viewpoint contradicts with the present study and the discrepancy in results could be attributed to different types of crop combinations and varying climatic circumstances at the study sites.

Conversely, according to Borghi et al. (2013), deferred sowing of guinea grass recorded a considerable drop in net profit however, sorghum-guinea grass intercrops under tropical circumstances resulted in 2.4 times better monetary returns compared to sole crops. This view agrees with the finding of the present study where strip relay intercropping produced a lower gross margin than strip intercropping.

Moreover, the cost of production in strip relay intercropping increased as the time of planting both crops was increased. In addition, the succeeding crop yields were less in relay intercropping compared to normal sowing in sequential cropping (Maitra et al., 2021). Thus, strip intercropping is a better option for rubber smallholders to increase their revenue and earn extra money during the early stage of rubber.

### Effect of the sweet corn-okra intercropping pattern on the growth of immature rubber

The rubber intercropped with sweet corn and okra was not significantly affected the stem girth and average canopy diameter of immature rubber trees (Figs. 1 and 2). The result of the effects of intercropping on the immature rubber stem girth showed no significant difference between planting rubber as sole crops or when rubber was planted with other crops which agree with Singh et al. (2019), Jalloh et al. (2009) and Esekhade et al. (2003). This may simply be due to greater availability of growing nutrients and absence of the intercropping competition towards rubber trees. This also implies that sweet corn-okra intercropping in between rubber had no negative impact on young rubber trees.

The finding of the present study is similar to those of Singh et al. (2019) and Mohamadu et al. (2009), who stated that intercropping did not give negative effects on young rubber growth and development. However, Esekhade et al. (2014) observed that faster growth rates of rubber when planted as intercropped with plantain, cassava, cherry and Avinger as compared with those planted as a sole crop due to microenvironment created by other crops (intercropping) that may have emerged in the effective use of crop resources, thus affected the physiological characteristic of rubber.

In line with the previous report, the adoption of young rubber trees intercropping with different food crops has also been practiced. For example, Siju et al. (2012) found differences in stem girth during certain periods of rubber growth with pineapple and revealed that the practice gained popularity of contract farming in the immature phase of rubber trees. Banana and pineapple intercropped with young rubber trees had higher yields than sole crops (Mohamadu et al., 2009). Also, intercropping increased rubber stem girth to 56.91 cm at the 8th year in a rubber-tea intercropping (Das et al., 2008).

Similarly, Partelli et al. (2014) found that intercropping had no detrimental influence on rubber growth and yield as well as coffee itself in the rubber-coffee intercropping. Rubber growth and dry matter yield remained unaffected by practicing intercropping as reported by Pathiratna and Edirisinghe (2004) in rubber-cinnamon intercropping. Food crops like sweet corn and okra may clearly be cultivated as intercrops while rubber is still young. This kind of intercropping might have beneficial impacts on the rubber smallholders as well as improve crop productivity and sustainability. Intercropping of young rubber has obviously agronomic practices since the systems effectively utilize the resource base in the plantation and ensure early returns on investment. However, owing to competition for resources, the practice can only be sustained for a limited number of years.

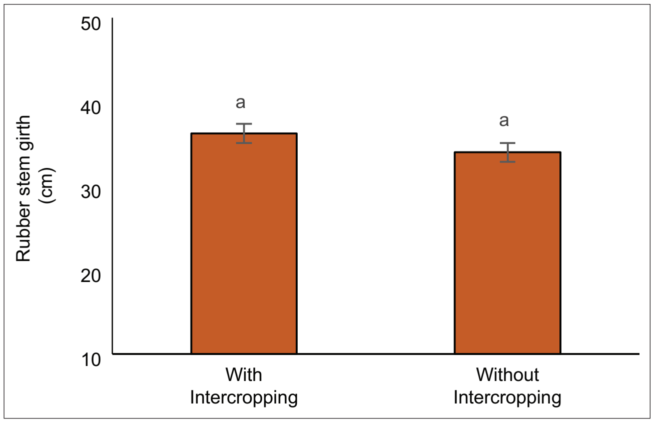


Fig 1. Rubber stem girth of rubber as affected by sweet corn-okra intercropping

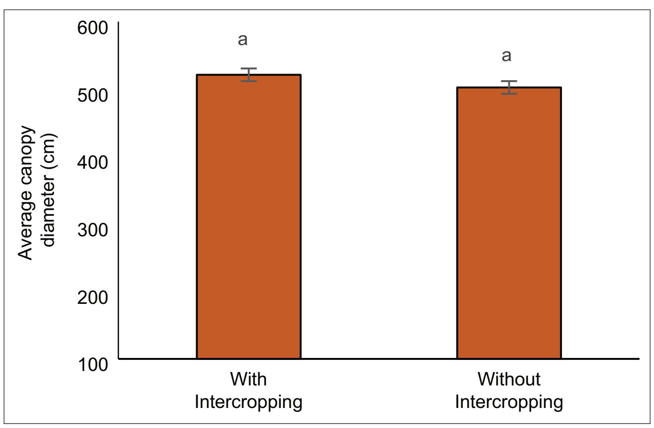


Fig 2. Average canopy diameter of rubber as affected by sweet corn-okra intercropping

## Biological efficiency of the sweet corn-okra intercropping

The LER values of the sweet corn-okra intercropping were all more than one, with the strip intercropping patterns yielding the highest ratio of 1.29. However, strip relay intercropping decreased significantly in LER value (1.23) when sowing of sweet corn was delayed four weeks after okra (Table 3).

The yield of sweet corn-okra intercropping, as evaluated by total LER, was greater in terms of effectiveness of the resource consumption when compared to cultivate the two crops individually in both patterns. The present results were supported by Glaze-Corcoran et al. (2020); Gitari et al. (2020); Situ and Mitiku (2018); Ijoyah and Dzer (2012); Ijoyah and Jimba (2012) and Lithourgidis et al. (2011), that the LER is more than 1.00 might be related to better resource consumption within the both crops in the mixture. Consequently, strip and strip relay intercropping systems were suggested to be more productive than sole cropping.

Strip intercropping resulted in not only higher LER, but also ATER and % of land saved with respective higher values of 1.14 and 22.28% compared with strip relay intercropping (0.95 and 18.67%, respectively) (Table 3). The highest ATER values in strip intercropping patterns noted that the intercrops were efficient in terms of crop area utilization during a particular growing season (Gitari et al., 2020; Maitra, 2019). Similarly, with a higher % of land

**Table 3: Land equivalent ratio (LER), area time equivalent ratio (ATER), system productivity index (SPI) and % land saved as influenced by the sweet corn-okra intercropping pattern**

| Intercropping pattern | LER | | | ATER* | SPI | % Land Saved |
|---|---|---|---|---|---|---|
| | Sweet corn | Okra | Total | | | |
| T1= Strip Intercropping | 0.86 | 0.43 | 1.29[a] | 1.14[a] | 502.12[a] | 22.28[a] |
| T2= Strip Relay Intercropping | 0.75 | 0.48 | 1.23[b] | 0.95[b] | 499.85[a] | 18.67[b] |
| T3= Sole Okra | - | 1.00 | 1.00[c] | - | - | - |
| T4= Sole Sweet Corn | 1.00 | - | 1.00[c] | - | - | - |

[abc]Means within the same column followed by unlike letters are statistically significant ($P \leq 0.05$). *The land occupancy period of strip intercropping was 90 days while strip relay intercropping was 105 days.

**Table 4: Aggressivity index (AI), competitive ratio (CR), relative crowding coefficient (K) and actual yield loss (AYL) as influenced by the sweet corn-okra intercropping pattern**

| Intercropping pattern | AI | | CR | | K | | | AYL | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sweet corn | Okra | Sweet corn | Okra | Sweet corn | Okra | Total | Sweet corn | Okra | Total |
| T1= Strip Intercropping | -0.011 | 0.011 | 0.500[a] | 2.000[b] | 1.490 | 3.058 | 4.557[a] | 0.080 | 1.150 | 1.230[a] |
| T2= Strip Relay Intercropping | -0.015 | 0.015 | 0.393[a] | 2.650[a] | 0.740 | 3.887 | 2.877[b] | -0.060 | 1.400 | 1.340[a] |
| T3= Sole Okra | - | - | - | - | - | 1.000 | 1.000[c] | - | - | - |
| T4= Sole Sweet Corn | - | - | - | - | 1.000 | - | 1.000[c] | - | - | - |

[abc]Means within the same column followed by unlike letters are statistically significant ($P \leq 0.05$).

saved, it shows both crops were found to be compatible and most appropriate in the combination when planting was done simultaneously. In addition, there were no statistically significant variations in SPI values between the two intercropping patterns.

### Ecological efficiency of the sweet corn-okra intercropping

The competitive functions of sweet corn-okra intercropping patterns were assessed using AI, CR, K and AYL. In all patterns, AI values for okra under intercropping pattern were positive (0.011-0.015), whereas those sweet corns had negative values ranging from -0.015 to -0.011 (Table 4). Both intercropping patterns showed okra was the dominant species (AI of okra was positive) whereas AI of sweet corn was negative; hence it is regarded as the pattern's less dominating crop (Lithourgidis et al., 2011).

The value of CR for okra was greater compared to sweet corn in both strip and strip relay intercropping patterns. Intercropped okra had higher CR in both intercropping patterns, noted that okra was more competitive than sweet corn. However, strip intercropping (2.000) was indicated the lowest competitive ratio of okra than the strip relay intercropping (2.650) (Table 4). The study showed okra was the superior crop as assessed by the positive figure of AI and its CR of more than 1 in all patterns over sweet corn that had negative AI and its CR of less than 1 (Gitari et al., 2020; Lithourgidis et al., 2011; Aynehband and Behrooz, 2011).

In all patterns, the CR for sweet corn was positive but less than unity, indicating the positive relationship between both crop; hence, sweet corn and okra can potentially be intercropped. Lithourgidis et al. (2011) disclosed that the benefits derived from intercrops, as noticeable from competitive effects, are due to better exploitation of crop resources under the cereal-legume combination.

The result in the present study is in accordance with Brooker et al. (2015) who reported that complementarity effects which could have occurred were most likely to have increased the crop productivity of intercropped plants with complementary traits interacting positively. Due to this fact, with the lowest AI and CR value of okra in strip intercropping, this system provides a positive effect in the mixture thus it is recommended to achieve maximum productivity.

In an intercropping, the K value was employed to assess the relative dominance or aggressiveness of sweet corn on okra or vice versa. According to Ghosh (2004) and Lithourgidis et al. (2011), each species in each combination has its own K values. The present study noticed that the partial K values of okra were higher than partial K of sweet corn in both intercropping patterns, are evidence that they were more dominant and superior species over sweet corn. The highest evaluation of intercropping based on total K was recorded at strip intercropping with 4.557 followed by strip relay intercropping with only 2.877 (Table 4).

The strip and strip relay intercropping resulted in a return benefit stated that the K figure for each of them was larger than 1. Otherwise, a K figure that equals to 1 represents no return benefit whereas when the value is less than 1, it suggests an unprofitable (Glaze-Corcoran et al., 2020; Gitari et al., 2020).

A same tendency to AI, CR and K was also observed for AYL. Partial AYL of okra was positive and also higher than sweet corn in both intercropping patterns. However, the total value of AYL showed there were no statistically significant variations between strip and strip relay intercropping (Table 4). On the other hand, the negative partial AYL values for sweet corn under strip relay intercropping indicated that the sweet corn yield loss in the combination with okra.

For instance, the AYL of sweet corn (-0.060) under strip relay intercropping indicated a 6% loss of sweet corn yield when grown in combination with okra as opposed to its sole crops. Nevertheless, the yield improvements of okra in this combination were substantial and adequate to compensate for the yield loss of sweet corn when both planted together. Overall, positive total AYL values in strip relay intercropping was also an indicator of the intercropping benefits.

### Economic efficiency of the sweet corn-okra intercropping

Monetary Advantage Index (MAI) is the most commonly used as a conventional approach for intercrop versus sole

**Table 5: Monetary advantage index (MAI) and intercropping advantage (IA) as influenced by the sweet corn-okra intercropping pattern**

| Intercropping pattern | MAI (RM ha$^{-1}$) | | | IA | | |
|---|---|---|---|---|---|---|
| | Sweet corn | Okra | Total | Sweet corn | Okra | Total |
| T1= Strip Intercropping | 17978.80 | 16059.40 | 7583.50$^{a}$ | 0.05 | 4.03 | 4.08$^{a}$ |
| T2= Strip Relay Intercropping | 16660.00 | 17968.30 | 6469.30$^{b}$ | 0.04 | 4.82 | 4.86$^{a}$ |
| T3= Sole Okra | - | 37569.00 | - | - | - | - |
| T4= Sole Sweet Corn | 22010.80 | - | - | - | - | - |

$^{ab}$Means within the same column followed by unlike letters are statistically significant (P≤0.05).

crop in terms of income returns (Sadeghpour et al., 2013; Ghosh, 2004). The sweet corn-okra intercropping pattern resulted in a significant effect on MAI (Table 5). Strip intercropping showed the highest MAI of RM 7583.50 ha$^{-1}$ and the lowest was from strip relay intercropping with RM 6469.30 ha$^{-1}$.

The intercropping pattern with the highest MAI is listed the most profitable (Gitari et al., 2020). All MAI values were positive, indicating the income return of sweet corn-okra intercropping over monocropping. The intercropping system could obtain greater yielding per unit area of land than a monoculture based on the MAI values in the present study. This could give a benefit for farmers to earn extra money during the immature period of the rubber trees. Obviously, strip intercropping creates a viable option to minimize income loss during the early unproductive period of rubber plantations.

From the results presented in Table 5, IA values showed that there were no significant differences between both intercropping patterns. The IA, which is an assessment of the profitability, affirmed that all sweet corn-okra intercropping patterns were superior combination due to the positive IA values. In fact, the ultimate considerations for the selection of the best intercropping pattern are based on yield benefits and their economics return (Banik et al., 2006).

Following the economic efficiencies in the present study, sweet corn-okra intercropping patterns is useful in raising the yield of the components crop resulting in larger economic gain compared to sole crops.

## CONCLUSIONS

The present study found that growing sweet corn and okra as a sole produced the maximum yield, and that intercropping reduced sweet corn and okra yields, most likely due to the population ratio and competition for crop resources between the two intercropping crops. However, the highest intercrop performances of okra were obtained from strip relay intercropping while the highest intercrop growth and yield of sweet corn were produced from the pattern of strip intercropping. Strip intercropping was also proven as a greater intercropping pattern due to the highest economic gain with maximum gross margin and benefit-cost ratio. Apart from that, it is concluded that the intercropping of rubber trees with sweet corn and okra is favorable in the early phases of rubber growth and has no negative impact on the performances of young rubber trees. Following the assessment of these intercropping efficiencies using the 10 indices, strip intercropping not only resulted in the higher LER, but also ATER, % land saved and MAI compared with strip relay intercropping. The highest evaluation of intercropping based on relative crowding coefficient was also recorded by strip intercropping. With respect to competition between the intercrops, okra was a more dominating species as judged by the positive value of aggressivity. However, strip intercropping resulted in the lowest competitive ratio than the strip relay intercropping. Thus, this intercropping pattern indicates a superior advantage and greater productivity per unit area that not only demonstrated the lowest competitive pressure but also grant the highest LER and MAI compared with strip relay intercropping. This pattern has the potential to be economically and ecologically beneficial in the creation of long-term agricultural sustainability and it should be advocated to the farmers for their adoption.

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### Authors' contributions

This project was conducted as a part of the Ph.D. project of Shampazuraini Samsuri and supervised by Dr. Martini Mohammad Yusoff. Shampazuraini Samsuri carried out the experiment and wrote the manuscript with support from all members of the Supervisory Committee.

Dr. Martini Mohammad Yusoff supervised the project and contributed to the final version of the manuscript. Prof. Dato' Dr. Mohd Fauzi Ramlan, Assoc. Prof. Dr. Zulkefly Sulaiman and Dr. Mark Buda were members of the Supervisory Committee of the Ph.D. project. Prof. Dato' Dr. Mohd Fauzi Ramlan provided the main conceptual ideas and helped shape the research, analysis and manuscript. Assoc. Prof. Dr. Zulkefly Sulaiman and Dr. Mark Buda provided critical feedback, performed the numerical calculations and contributed to the interpretation of the results. Isharudin Md Isa assisted with the design and statistical analysis. All authors discussed the results and commented on the manuscript.

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