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Research Article
Enhanced Intercropping Productivity of Sweet Corn and Okra in Young Rubber Plantation

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Abstract

Background and Objective: Intercropping remains a common practice in many developing nations due to the increasing focus on sustainability and food security. A field study was conducted to evaluate the productivity of sweet corn and okra planted in intercropping as affected by crop ratios. **Materials and Methods:** The study was conducted in a Randomized Complete Block Design with three replications. The crop ratio treatments of intercropping pattern were T_1 (20% okra+80% sweet corn+rubber), T_2 (50% okra+50% sweet corn+rubber), T_3 (80% okra+20% sweet corn+rubber), T_4 (100% okra+rubber) and T_5 (100% sweet corn+rubber). **Results:** The sweet corn results revealed that the number of marketable cobs, cob yield and biomass yield was significantly influenced by the cropping pattern where the highest values were obtained in sole sweet corn. The number of okra fresh pods per plant, length and diameter of the fresh pod, weight per pod as well as fresh pod yield per hectare was significantly reduced when okra was intercropped with sweet corn. With regard to intercropping efficiency, the highest Land Equivalent Ratio (LER) and Monetary Advantage Index (MAI) were from the intercropping pattern of T_1 (20% okra+80% sweet corn+rubber) with 1.14 and RM 3388 ha^{-1}, respectively. **Conclusion:** Thus, sweet corn-okra intercropping pattern of 20% okra+80% sweet corn+rubber is the most preferred practice in young rubber plantation than sole cropping of sweet corn or okra.

Key words: Intercropping, sweet corn, okra, yield, rubber plantation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rubber (*Hevea brasiliensis*) belongs to the family Euphorbiaceae is among the major plantation crops in Malaysia. However, the Malaysian rubber industry requires urgent innovations for increased efficiency and productivity. Increasing farm income during the early period of the immaturity of the rubber trees such as intercropping with short-term cash crops is an approach that has been promoted to improve land productivity. Besides the problem of later harvest of the main crop of rubber during the early and replanting phases can also be partially solved through intercropping.

Intercropping is the cultivation of two or more crops together in the same field for some time; the crops may differ by species or cultivars. Intercropping has existed early in the evolution of agriculture and remains a common practice in many developing nations[1]. In recent years, developed agricultural regions have demonstrated a resurgence of interest and implementation of intercropping due to the increasing focus on sustainability and food security. Several reports were available on cereal-based intercropping, such as maize-bean, maize-potato, maize-cassava, maize-yam, maize-soybean and maize-groundnut, amongst many others[2]. Studies on intercropping have recently focused on the cereal-vegetable mixture[3-5].

Well-designed intercropping operations efficiently use natural resources, increase biodiversity, manage pest and disease problem and in many instances, enhance crop productivity and quality and natural soil fertility by reducing consumption of off-farm inputs. Intercropping is a labour-intensive practice largely adopted by smallholder farmers to increase yield productivity per unit area, cope with crop failure and market fluctuations, meet food preference and cultural demands and increase income[6,7].

Rubber intercropping has emerged as a resilient farming system in the traditional rubber growing countries of Southeast Asia such as Indonesia, Malaysia and Thailand[8]. Intercropping that depends on altitude and crop choice had positive economic and ecological effects, for example, rubber intercropped with tea reduced economic uncertainty and improved economic conditions of farmers in high altitude[9]. Studies by Déo-Gratias *et al.*[10] concluded that the most important advantage related to rubber-cassava intercropping was a 50–59% reduction in operating costs during the immature period of the rubber trees. Overall, rubber intercropping was shown to account for approximately 10% of the net annual income of the household, regardless of the level of their income.

Many benefits can be obtained by the implementation of intercropping practices at rubber plantation areas. Even though how significant the impact is, increasing plantation area obviously will reduce the land for local food production and because of the long immature period of between 1-5 years, planting rubber represents a loss of income to the farmers. Thus, this study examined the intercropping efficiency and potential of sweet corn-okra intercropping grown in the immature rubber plantation. This study was therefore carried out to determine the growth, physiological attributes and yield performances of sweet corn-okra intercropping planted in different corporations in the immature 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 and 31°C, respectively. The soil series is Batang Merbau with soil texture (sandy clay loam) consisting of an average of 75.92% sand, 4.50% silt and 20.36% clay. The RRIM 3001 rubber clone was planted in this area on 23rd March, 2018. The planting distance between the rubber trees was 3×6 m.

Experimental design, treatments and field management: The study was conducted in Randomized Complete Block Design (RCBD) with three replications. Intercropping patterns having five crop ratios and each was planted in five rows per plot as follows; T_1 (20% okra+80% sweet corn+rubber), T_2 (50% okra+50% sweet corn+rubber), T_3 (80% okra+20% sweet corn+rubber), T_4 (100% okra+rubber) and T_5 (100% sweet corn+rubber). The details of the intercropping patterns in five rows each are presented in Table 1.

The experimental site was ploughed and harrowed and the seeds of sweet corn and okra were sown on the planting beds, in the distance of 30×100 cm for both sole crops and mixed stands in 15×18 m plots of 750 plants. 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 OP 1 Okra Amazon King was used.

Both sweet corn and okra were planted at the same time on 15th November, 2019 as sole crops and in the intercropping pattern. The NPK Green (15:15:15) was applied to all plants two weeks after sowing at the rate of 40 g per plant. The second application used NPK Blue (12:12:17:2) with

Table 1: Details of five different sweet corn-okra intercropping patterns

Treatment	Treatment arrangement	Patterns
T_1	20% okra+80% sweet corn+rubber	SSSSSSSSSSSS
		SSSSSSSSSSSS
		OOOOOOOOO
		SSSSSSSSSSSS
		SSSSSSSSSSSS
T_2	50% okra+50% sweet corn+rubber	OOOOOOOOO
		SSSSSSSSSSSS
		SSSSSSOOOOO
		OOOOOOOOO
		SSSSSSSSSSSS
T_3	80% okra+20% sweet corn+rubber	OOOOOOOOO
		OOOOOOOOO
		SSSSSSSSSSSS
		OOOOOOOOO
		OOOOOOOOO
T_4	100% okra+rubber	OOOOOOOOO
		OOOOOOOOO
T_5	100% sweet corn+rubber	SSSSSSSSSSSS
		SSSSSSSSSSSS

O: Okra, S: Sweet corn

50 g per plant at four weeks after sowing. On day 45, NPK Blue (50 g per plant) was applied using the ring method of fertilizer application. Plots were manually weeded regularly and pest and disease control activities were applied depending on infestation.

Data collection and analysis: Data taken for sweet corn included plant height (cm) which was recorded using a measuring tape and the number of leaves was counted manually. The other measurements taken for sweet corn were cob length and girth (cm) using a measuring tape. The cobs were weighed using an electronic weighing digital balance to obtain cob weight (g). The cobs were later shelled manually, thereafter, 1000 grains were taken and weighed using an electronic weighing digital balance. On top of that, the measurements taken for okra were plant height (cm), pod length and diameter (cm), number of fruits per plant and average pod weight (g). The fresh pods of okra (kg ha^{-1}) and sweet corn cob yield (kg ha^{-1}), as well as biomass yield (kg ha^{-1}), were weighed using an electronic digital balance.

Land Equivalent Ratio (LER) from the yields of sweet corn and okra was used to evaluate the productivity of intercropping versus sole cropping. The LER was determined with the following Eq. as described by Willey[11]:

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

Monetary Advantage Index (MAI) was developed to describe the competition and economic advantage of intercropping compared to sole cropping[12]. The MAI was calculated as described by Lithourgidis *et al.*[13] using the Eq:

$$\text{MAI} = \frac{\text{Value of combined intercrops}}{\text{LER}} \times \text{LER-1}$$

Statistical analysis: Data were analyzed using ANOVA of SAS package and the mean of the treatments found to be statistically significant were compared using the Least Significant Difference Test (LSD) ($p \leq 0.05$).

RESULTS AND DISCUSSION

Evaluation of sweet corn-okra intercropping pattern on the growth and yield performances of sweet corn: For the plant height of sweet corn, there was no significant difference between the intercropping pattern of T_5 and T_1 with 193.46 and 185.87 cm, respectively in Table 2. There was also no significant difference between pattern T_2 (166.35 cm) with patterns T_1 and T_3 (146.67 cm). However, the planting ratio of 80% okra+20% sweet corn+rubber significantly produced a lower plant height of sweet corn than the other intercropping patterns except for T_2. The impact of competition was expected since crops are not generally grown in isolation but closely spaced population, it is expected that at some point as the seedlings grow, they will begin to interfere and compete with each other for growth factors[14].

Table 2 showed T_5 and T_1 produced a significantly higher number of leaves per plant, with 15.67 and 14.33, respectively, compared with T_3 (10.00). However, T_2 (12.33) pattern was not significantly different from other cropping patterns (T_5, T_1 and T_3) in the number of leaves per plant as affected by sweet corn-okra intercropping patterns. This result is in agreement with Ijoyah and Jimba[4] and Oyewole[14] who stated that the intercropping pattern did not significantly ($p \leq 0.05$) impact the leaf number of maize. In contrast, Hamma *et al.*[15] showed a significant difference ($p \leq 0.05$) in the number of leaves per plant of maize affected by the maize-okra intercropping system.

The highest cob length of sweet corn was obtained from T_5 with 27.52 cm followed by T_1 with 26.27 cm (Table 2). T_3 and T_2 produced the lowest cob length with only 23.33 and 23.00 cm, respectively. Overall, there was no significant difference betweenT_1 with intercropping patterns T_5, T_3 and T_2 on cob length of sweet corn as affected by sweet corn-okra intercropping pattern. Besides, cob girth also showed a similar trend as cob length (Table 2). The highest cob girth was from T_5 (17.85 cm) followed by T_1 (15.60 cm) and the lowest was from T_2 (14.44 cm) and T_3 (13.33 cm). Ijoyah and Jimba[4] also reported cob length and girth of maize were not significantly affected by intercropping with okra.

Planting sole sweet corn (T_5) did not significantly differ with the pattern of 20% okra+80% sweet corn+rubber (T_1) for the number of grains cob^{-1}. However, both patterns were significantly different with an intercropping pattern of T_2 and T_3. The highest number of grains cob^{-1} was 466.33 (T_5) while the lowest was from T_3 with only 408.33 as shown in Table 2. Higher yields obtained in sole crops compared to intercrop was suggested to be due to the lesser interspecific competition pressure than the intraspecific competition[1,16,17].

Similarly, the weight of the cob showed no significant difference between sole sweet corn (T_5) and the intercropping pattern of 20% okra+80% sweet corn+rubber (T_1). Apart from this, both patterns indicated a significant difference between T_2 and T_3. From the result presented in Table 2, the highest weight of cobs was observed at T_5 with 295.35 g, followed by T_1 (295.28 g) while the lowest was T_2 and T_3 with 289.00 and 287.33 g, respectively. The effects of the sweet corn-okra intercropping pattern on the weight of 1000 grains varied significantly between T_5 and T_3 (Table 2). The highest weight of 1000 grains was recorded at T_5 with 269.83 g while the lowest was from T_3 with only 232.56 g. Besides, T_1 was not significantly different in weight of 1000 grains compared with other patterns (T_5 and T_2) due to different crop ratios. In general, this result is in contrast with Ijoyah and Jimba[4] who mentioned that all yield components of maize were not significantly affected by intercropping. The sole sweet corn recorded the highest yield component which might be due to population advantage in the pattern and less intraspecific competition among each other[18].

The number of marketable cobs (yield ha^{-1}) was significantly influenced ($p \leq 0.05$) by the intercropping pattern (Table 2). The highest number of marketable cobs was observed in the ratio of 100% sweet corn+rubber (T_5) with 31999 followed by intercropping pattern 20% okra+80% sweet corn+rubber (T_1) with 25600 and T_2 (16333) with the pattern of 50% okra+50% sweet corn+rubber. Meanwhile, the lowest number of marketable cobs was observed in an intercropping pattern of 80%+20% sweet corn+rubber (T_3) with only 6460. A similar trend was also found in cob yield (kg ha^{-1}) that was significantly affected by the sweet corn-okra intercropping pattern. Sole sweet corn (T_5) produced the highest cob yield with 9845 kg ha^{-1} and followed by T_1 with 7874 kg ha^{-1}. The third highest result was found at T_2 with 4817 kg ha^{-1} while the lowest cob yield was observed in an intercropping pattern of 80% okra+20% sweet corn+rubber (T_3) with only 1916 kg ha^{-1}.

The effects of the intercropping pattern on biomass yield (kg ha^{-1}) of sweet corn- okra varied significantly as shown in Table 2. The highest value was recorded in sole sweet corn (T_5) with 32816 kg ha^{-1} followed by T_1 (27121 kg ha^{-1}) and T_2 (17651 kg ha^{-1}). T_3 showed the lowest biomass yield among the other patterns with only 7608 kg ha^{-1}. As reported above, the yield of sweet corn in all intercropping patterns was significantly reduced when it was intercropped with okra. The highest number of marketable cobs, cob yield and biomass yield were observed in sole sweet corn (T_5) due to population advantage and less intraspecific competition among them. This result agrees with Habtam and Tesfaye[18] and Oyewole[14] who stated that sole maize gave the highest yield than intercropped okra. Similar results have been reported by Morgado and Willey[19], who stated the yield of intercropped maize tended to increase with an increasing maize population. Conversely, maize yield was greater in intercropped okra and maize compared to the yield obtained from sole maize at equivalent population density[4] and planting sole maize did not significantly differ with intercropped maize-okra in cob yield (kg ha^{-1}) in both 2013 and 2014 cropping seasons[15]. On the other hand, a reduction in the number of marketable cobs, cob yield and biomass yield as a result of intercropping was basically due to a reduction in sweet corn population ratio in the intercrop pattern rather than any other factors[14].

Evaluation of sweet corn-okra intercropping pattern on the growth and yield performances of okra: From the results presented in Table 3, it appears that okra plant height varied significantly due to different intercropping patterns. The highest plant height of okra was obtained from sole okra (T_4) with 116.13 cm and significantly reduced when it was intercropped with sweet corn. There was no significant difference in plant height between T_3 and T_2 with 102.28 and 101.33 cm, respectively. The lowest plant height was recorded in the intercropping pattern of 20% okra+80% sweet corn+rubber (T_1) with only 93.20 cm. The greater population ratio of okra plants under sole cropping and the greater efficiency of sole okra in utilizing growth environment and less intraspecific competition might have induced higher okra plant height. These results are in agreement with Muoneke and Ndukwe[20] who stated that okra plant height was reduced by intercropping with *Amaranthus*. Odedina *et al.*[21] revealed that the plant height of sole cropping of okra was higher than intercropping with cowpea.

Table 3 showed pod length was not significantly affected by the intercropping patterns. There was no significant difference between T_4 and T_3 for pod length of okra (Table 3). The highest pod diameter (1.84 cm) was observed in sole okra (T_4), which was significantly reduced when okra was intercropped with sweet corn (Table 3). There was no significant difference in pod diameter between T_3 (1.50 cm) and T_2 (1.33 cm). However, T_1 recorded the lowest pod diameter with only 1.04 cm among the intercropping patterns. This might be due to the competitive effect when both crops are in the mixture[4].

The number of pods per plant was significantly greater for sole okra than for intercropped okra. T_4 produced the highest number of pods per plant with 34.00, followed by intercropping pattern T_3 and T_2 with 29.33 and 28.33, respectively. However, there was no significant difference between intercropping patterns T_3 and T_2. Table 3 also revealed that intercropping pattern T_1 obtained the lowest number of pods per plant with only 23.00. Besides, the highest average pod weight (13.67 g) was observed in sole okra (T_4), which significantly reduced when intercropped with sweet corn. There was no significant difference between T_2 and T_1 for the lowest average pod weight as shown in Table 3. Similarly, intercropping patterns T_3 and T_2 did not significantly influence the average pod weight. This finding is supported by Ijoyah and Jimba[4] and Oyewale[14] who reported that sole okra produced a greater number of pods compared with intercropped okra. Besides population ratios, greater competition for available nutrients and light could be responsible for the decrease in the production of pods and pod weight obtained from the intercropping pattern.

Table 3 presents that fresh pod yield was significantly ($p \leq 0.05$) reduced by intercropping. The highest fresh pod yield (11333.00 kg ha^{-1}) was observed in sole okra (T_4), which significantly reduced when intercropped with sweet corn followed by T_3 with 9737.30 kg ha^{-1} and T_2 with 6916.20 kg ha^{-1}. The lowest fresh pod yield was T_1 with 3867.40 kg ha^{-1}. The biomass yields also indicated a similar trend as fresh pod yield while the ratios in all intercropping patterns varied significantly (Table 3). Sole okra produced the highest biomass yield with 22973.85 kg ha^{-1} followed by intercropping pattern T_3 with 20717.65 kg ha^{-1} and T_2 (15601.62 kg ha^{-1}). Meanwhile, the lowest biomass yield was indicated by intercropping pattern T_1 with only 8994.00 kg ha^{-1}. Similarly, sole okra gave the highest yield compared to intercropping with sweet corn because of population advantage and less intraspecific competition among each other[4,14,15,18].

Evaluation of sweet corn-okra intercropping efficiency: Land Equivalent Ratio (LER) is the most widely used indicator to examine the failure or success of intercropping systems in

Table 2: Evaluation of intercropping pattern on the growth and yield components of sweet corn

Intercropping pattern	Plant height (cm)	Number of leaves/ plant	Cob length (cm)	Cob girth (cm)	Number of grains cob^{-1}	Weight of cobs (g)	Weight of 1000 grains (g)	Number of marketable cobs (yield ha^{-1})	Cob yield (kg ha^{-1})	Biomass yield (kg ha^{-1})
T_1 = 20% okra+80% sweet corn+rubber	185.87^{ab}	14.33^{a}	26.27^{ab}	15.60^{ab}	455.67^{a}	295.28^{a}	262.78^{ab}	25600^{b}	7874^{b}	27121^{b}
T_2 = 50% okra+50% sweet corn+rubber	166.35^{bc}	12.33^{ab}	23.00^{b}	14.44^{b}	432.67^{b}	289.00^{b}	242.70^{bc}	16333^{c}	4817^{c}	17651^{c}
T_3 = 80% okra+20% sweet corn+rubber	146.67^{c}	10.00^{b}	23.33^{b}	13.33^{b}	408.33^{c}	287.33^{b}	232.56^{c}	6460^{d}	1916^{d}	7608^{d}
T_5 = 100% sweet corn+rubber	193.46^{a}	15.67^{a}	27.52^{a}	17.85^{a}	466.33^{a}	295.35^{a}	269.83^{a}	31999^{a}	9845^{a}	32816^{a}

abcdMeans within the same column with the common superscripts are not significantly different (p>0.05) using LSD

Table 3: Evaluation of intercropping pattern on the growth and yield components performances of okra

Intercropping pattern	Plant height (cm)	Pod length (cm)	Pod diameter (cm)	Number of pods/plant	Average pod weight (g)	Fresh pod yield (kg ha^{-1})	Biomass yield (kg ha^{-1})
T_1 = 20% okra+80% sweet corn+rubber	93.20^{c}	9.13^{b}	1.04^{c}	23.00^{c}	9.67^{c}	3867.40^{d}	8994.00^{d}
T_2 = 50% okra+50% sweet corn+rubber	101.33^{b}	9.73^{b}	1.33^{b}	28.33^{b}	10.20^{bc}	6916.20^{c}	15601.62^{c}
T_3 = 80% okra+20% sweet corn+rubber	102.28^{b}	11.23^{ab}	1.50^{b}	29.33^{b}	11.51^{b}	9737.30^{b}	20717.65^{b}
T_4 = 100% okra+rubber	116.13^{a}	13.08^{a}	1.84^{a}	34.00^{a}	13.67^{a}	11333.00^{a}	22973.85^{a}

abcdMeans within the same column with the common superscripts are not significantly different (p>0.05) using LSD

Table 4: Evaluation of sweet corn-okra intercropping efficiency

Intercropping pattern	Partial Okra	Partial Sweet corn	Total LER	Value (RM ha^{-1}) Okra	Value (RM ha^{-1}) Sweet corn	MAI (RM)
T_1 = 20% okra+80% sweet corn+rubber*	0.34	0.80	1.14^a	9669	17920	3388^a
T_2 = 50% okra+50% sweet corn+rubber*	0.61	0.49	1.10^b	17291	11433	2611^b
T_3 = 80% okra+20% sweet corn+rubber*	0.86	0.20	1.06^c	24343	4522	1634^c
T_4 = 100% okra+rubber*	1	-	1.00^d	28333	-	-
T_5 = 100% sweet corn+rubber*	-	1	1.00^d	-	22399	-

Means within the same column followed by unlike letters are statistically significant ($p \leq 0.05$) using LSD. MAI*: Excluding rubber, field price 1 kg okra: RM 2.50, field price 1 sweet corn cob: RM 0.70, LER: Land Equivalent Ratio, RM: Ringgit Malaysia, ha: Hectares, MAI: Monetary advantage index

increasing total yield[1]. LER values of the sweet corn-okra intercrops were all above 1.00 with the highest LER of 1.14 from the intercropping pattern of 20% okra+80% sweet corn+rubber (T_1) in Table 4, following that were intercropping patterns T_2 and T_1 with 1.10 and 1.06, respectively. The productivity of sweet corn-okra intercropping as determined by total LER, in all combinations, was superior in resource use efficiency compared with growing the two crops separately. The present results are in agreement with Oyewole[14], Ijoyah and Jimba[4], Ijoyah *et al.*[22] and Habtam and Tesfaye[18] who reported that LER greater than 1.00, could be due to greater efficiency of resource utilization in intercropping.

Another measurement of efficiency of the intercropping system is the Monetary Advantage Index (MAI), the most commonly used conventional method for intercrop against sole crop comparisons in terms of economic assessment[17]. It was developed to describe the competition and economic advantage of intercropping compared to sole cropping[12]. T_1 showed the highest MAI of RM 3388 ha^{-1} followed by T_2 (RM 2611 ha^{-1}) and the lowest was from T_3 with RM 1634 ha^{-1} (Table 4). All MAI values were positive, indicating the economic advantages of sweet corn-okra intercropping. The LER and MAI values from this study showed that the intercropping system could obtain greater productivity per unit of land than a monoculture of either crop. This could give an advantage for farmers to generate extra income during the immature period of the rubber trees. The highest LER and MAI obtained from T_1 (20% okra+80% sweet corn+rubber) indicated that sweet corn from this combination ratio was the main component influencing the efficiency and productivity of the intercropping system studied and this finding is supported by Lima Filho[23] who studied on the intercropping population of maize cowpea.

CONCLUSION

Results revealed that intercropping of sweet corn-okra in different patterns could influence the growth and yield performances of the planted crops. The sole sweet corn and okra plantings gave the highest yield and the yield of results revealed that sweet corn and okra growth and yield performance were reduced by intercropping because of the population ratio and competition of the two crops in the mixture for growth resources. The productivity of sweet corn-okra intercropping as determined by total LER, in all combinations was superior in resource use efficiency compared to the sole planting of the two crops. Intercropping pattern with a ratio of 20% okra+80% sweet corn+rubber gave the highest LER and MAI values, thus showing that the sweet corn-okra intercropping system could obtain greater productivity per unit of land area than the monoculture of either crop.

SIGNIFICANCE STATEMENT

This study discovered that the intercropping efficiency and potential of sweet corn-okra grown in immature rubber plantation can be beneficial to rubber small holders in generating early income by the cultivation of food crops during the immature period of the rubber trees. This study will assist researchers in uncovering the critical areas of intercropping in young rubber plantations that many researchers were not able to explore before. Thus, a new approach to the sweet corn-okra intercropping pattern in young rubber plantations may be proposed in commercial crop production.

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