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Research Article

Land use efficiency of sweet corn intercropping with different cowpea planting dates

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ABSTRACT

Cultivation of cowpea and sweet corn can optimize land use through an intercropping system, however, the planting date on intercropping is rarely evaluated. The research aimed to evaluate land use efficiency in sweet corn intercropping of different planting dates of cowpea. This research was conducted from January to May 2024 in Bocek Village, Malang, East Java. The study used a randomized complete block design with a single factor consisting of 7 levels, i.e., monoculture sweet corn, and sweet corn intercropping with different cowpea planting dates (0, 7, 14, 21, 28, and 35 days after sweet corn planting (DAP). Plant growth, yield, land equivalent ratio (LER), and area time equivalent ratio (ATER) were evaluated. The results showed that the intercropping sweet corn and cowpea planted at 21 DAP produced a higher yield than other planting dates. The highest LER of 1.96 and ATER of 1.93 was achieved in the sweet corn with cowpea planted at 21 DAP, indicating the highest land use efficiency occurred at the planting date of cowpea 21 days after planting sweet corn.

Keywords: ATER; cropping system; LER; planting time; *Vigna unguiculata*; *Zea mays*

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INTRODUCTION

Demand for national consumption of sweet corn has increased, which is directly proportional to the population growth in Indonesia. Sweet corn (*Zea mays* L. var. *saccarata*) has sugar contents of 5-6%, which is 2 times higher than regular corn (Silalahi et al., 2018). The high sugar content attracts people to consume sweet corn. Cowpea (*Vigna unguiculata* L.) is a legume, the seeds are a source of protein (Tukidi & Erwandri, 2023). Cowpea cultivation has lower production costs compared to other beans. However, the production is still limited due to land availability.

An effort to overcome land limitations is by optimizing land use through intercropping systems. Based on data from BPS (2022), monoculture patterns are still widely applied by corn and bean farmers in Indonesia. Meanwhile, the application of intercropping patterns is still low around 16.90% of the total land used area. Intercropping is a form of crop diversification pattern with two or more types of plants cultivated on the same planting area at the same or different times which aims to increase yield per unit area of land and reduce the risk of crop failure (Lestari et al., 2020).

Cowpea is widely cultivated in intercropping systems (Mentari et al., 2023). The system increases soil fertility and crop yield diversification (Kholid et al., 2023). Intercropping with legumes also minimizes competition for the main crop. The competition among species in intercropping for nutrients, water, and sunlight, is still an issue in the study of intercropping. The planting date is important to minimize crop competition. However, evaluation of planting dates on cowpea intercropping is still scarce.

Planting time can reduce competition from the utilization of resources and growing space (Warman & Kristiana, 2018). Planting time is related to the vegetative growth phase of plants, so it affects the occurrence of minimal competition in maintaining production yields per unit area of land. Adjusting planting time and growing space is necessary to optimize crop growth (Sari et al., 2022). Structured planting of sweet corn and cowpea at the appropriate planting time is one of the efforts of crop production management technology that needs to be developed by examining the optimal timing in intercropping, therefore why this research was conducted. The research aimed to evaluate land use efficiency in sweet corn intercropping of different planting dates of cowpea.

MATERIALS AND METHODS

Research site

This research was conducted from January to May 2024 at Bocek Village (715 m above sea level), Karangploso District, Malang Regency, East Java. Bocek village is located at 7°21′-7°31′ S and 110°10′-111°40′ E. Average rainfall was 2,400 mm year^{-1} with a daily temperature of 23 to 31 °C and relative humidity 70 to 85%.

Experimental design

This research was conducted using a randomized complete block design (RCBD) with a single factor consisting of 7 levels, namely monoculture sweet corn (P0), sweet corn + cowpea planted at same date (P1), sweet corn + cowpea planted 7 days after planting (DAP) (P2), sweet corn + cowpea planted 14 DAP (P3), sweet corn + cowpea planted 21 DAP (P4), sweet corn + cowpea planted 28 DAP (P5), and sweet corn + cowpea planted 35 DAP (P6). Cowpea monoculture was planted as control. Sweet corn was planted on January 23 for both monoculture and intercropping, while cowpea was planted at different times depending on the treatment, i.e., P1 (January 23), P2 (January 30), P3 (February 06), P4 (February 13), P5 (February 20) and P6 (February 27). For example, 'same date' planting means cowpea was planted at the same time as sweet corn, and 7 DAP meant planted 7 days after planting of sweet corn. Each treatment was repeated 4 times, resulting in 28 treatment plot units.

The land was prepared by weed cleaning, adding manure, making beds, and ditching flow. Sweet corn used Prima variety; the seed was planted at a spacing of 70 cm × 20 cm in intercropping and monoculture. Cowpea used five seeds in a planting hole with a single row between sweet corn. The planting distance of cowpea was 35 cm x 15 cm for intercropping and monoculture.

Fertilizer used manure 10 tons ha^{-1}, SP-36 (100 kg ha^{-1}), urea (350 kg ha^{-1}), and KCl (100 kg ha^{-1}) following the local recommended doses for sweet corn. Manure was applied at the time of land preparation, while NPK fertilizers were applied at planting time (50%), 14 (25%), and 28 DAP (25%).

Plant maintenance included irrigation, thinning, weeding, and pest and disease controls. Harvesting of sweet corn was done at 80 DAP, while harvesting of cowpea plants was done at 65-70 DAP.

Data collection

Sweet corn growth was observed at 14, 28, 42, and 56 DAP on plant height (cm), leaf number, leaf area (cm^2), and stem diameter (mm). At harvest, the measurement included the length and diameter of the ear without husk (cm), ear weight with and without husk per plant (g), ear weight per hectare (tons), and sugar content of seed (°Brixx). In cowpea plants, observation included the number and weight of pods per plant (g), seed dry weight per plant (g), and yield per hectare (tons).

Land equivalent ratio (LER) and area time equivalent ratio (ATER) were calculated based on Ceunfin et al. (2017). LER indicates the level of profit on land from intercropping relative to monoculture. ATER is an extension of LER but considers the duration of intercropping time. ATER measures how efficiently land and time are utilized in intercropping systems compared to monocropping. A higher ATER (>1) indicates that the intercropping system is more efficient in using both land and time than growing crops separately.

Data analysis

Data were analyzed using analysis of variance (ANOVA) at the 5% level. If the results showed any significant difference for some treatments, then it was continued with the honestly significant difference (HSD) test at the 5% level. In addition, some parameters were also analyzed for correlation levels using simple regression. Data was analyzed using SPSS and Microsoft Excel software for Windows 10.

RESULTS AND DISCUSSION

Sweet corn growth

Plant height and stem diameter showed that the intercropping treatment with different times of 35 DAP gave higher results and was almost equivalent to the monoculture treatment at the age of 56 DAP (Figure 1). The growth pattern in plant height and stem diameter in the monoculture sweet corn treatment had greater results compared to the intercropping treatment of sweet corn + cowpea planted at differences in planting date. Meanwhile, the effect of all treatments on monoculture and intercropping at different planting times did not give different results (Figure 1).

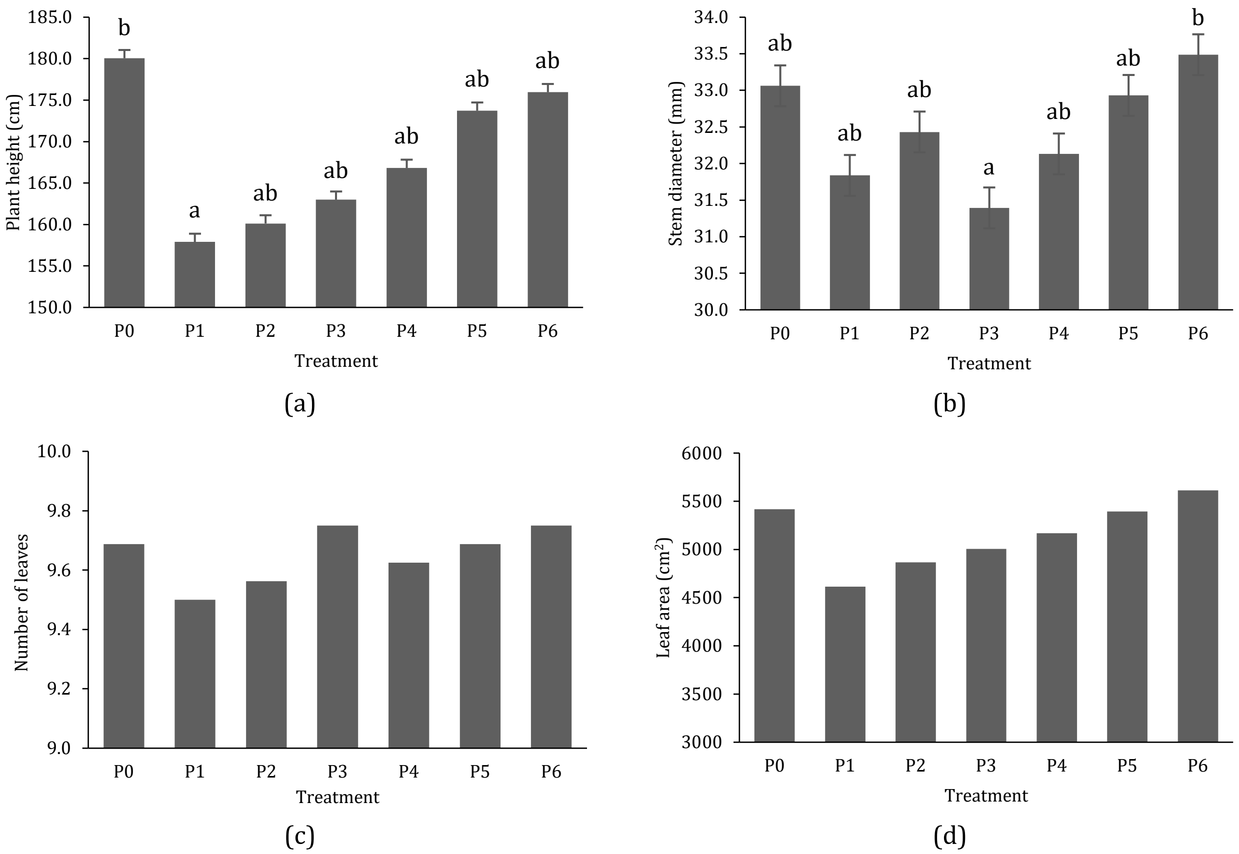

Figure 1. Growth variables of sweet corn at the age of 56 DAP (a) plant height; (b) diameter of the stem; (c) number of leaves; (d) leaf area on several treatments. P0= monoculture sweet corn, P1= sweet corn + cowpea planted on the same date, P2= sweet corn + cowpea planted 7 DAP, P3= sweet corn + cowpea planted 14 DAP, P4= sweet corn + cowpea planted 21 DAP, P5= sweet corn + cowpea planted 28 DAP, P6= sweet corn + cowpea planted 35 DAP.

The number of leaves and leaf area were not different in all treatments (monoculture and intercropping) (Figure 1C). At the age of 56 DAP, the leaf number of sweet corn was 9-10 leaves when plants reached the maximum vegetative phase. Leaves of sweet corn growing with cowpea planted at 35 DAP were larger than that in cowpea planted at 0 DAP (planted at the same time). Such a situation was probably due to the utilization of different resources between main crops and intercrops that triggered competition in the critical period phase of the plant. In the early growth stage, sweet corn seems more sensitive to stress due to the limitation of sunlight, water, and nutrients. In general, at the early vegetative phase or during the rapid growth phase a lot of assimilates is required. According to Elonard & Lusianingsih (2018), monoculture produces higher yields due to better utilization of growing space, sunlight, water, and nutrients. The right use of planting time is an effort to optimize nutrient utilization in the intercropping system (Aksarah et al., 2022).

The planting time of cowpea at 35 DAP produced a larger sweet corn stem diameter (Figure 1B). This is due to the photosynthate obtained from the photosynthesis process and influenced by the level of nutrient absorption in the roots of sweet corn plants which is a factor in the development of plant organs. Based on Neo & Ceunfin (2018), the results of the photosynthesis process are translocated to plant organs such as stems, leaves, and reproductive organs. The larger stem diameter of the plant indicates high transporting photosynthate to all other plant organs (Metboki, 2019).

Differences in the planting time of cowpea did not affect the leaf area in sweet corn (Figure 1D). According to Hasan et al. (2016), leaf number is influenced by genotypic and environmental factors. Here, no different genotypes were used, therefore any differences could be due to environmental conditions. Physiologically, the leaf number will reach its peak at a certain time and then remain constant (Ruswandi et al., 2022). According to Lestari et al. (2020), the number of leaves relates to photosynthesis where maize plants with more leaves receive light will have higher photosynthesis than those blocked ones. At the maximum vegetative stage, usually, some leaves are shaded by others resulting in a reduction in the net assimilation rate (Murdiono et al., 2016). Consequently, plants undergo a reduction in physiological processes including lower leaf formation (Ubaedillah et al., 2022).

Potential yield of sweet corn and cowpea

The ear length and diameter of the unhusked ear were not influenced by differences in planting time in intercropping or monoculture systems (Table 1). The results of different planting dates of cowpea plants did not give different responses. This is due to the difference in the use of resources between the main crop and intercrops, which triggers competition in the rapid growth phase of the plant and affects the yield of the main crop.

Table 1. Average length and diameter of ear without husk per plant due to different planting dates of cowpea in intercropping system.

Treatments	Ear length (cm)	Ear diameter (cm)
Sweet corn monoculture	23.02	5.41
Sweet corn + cowpea planted on the same date	18.18	4.94
Sweet corn + cowpea planted 7 DAP	19.38	5.07
Sweet corn + cowpea planted 14 DAP	20.27	5.11
Sweet corn + cowpea planted 21 DAP	22.55	5.25
Sweet corn + cowpea planted 28 DAP	21.98	5.05
Sweet corn + cowpea planted 35 DAP	22.66	5.12
HSD 5%	ns	ns
CV (%)	11.48	5.18

Note: ns: not significant; DAP: days after planting; HSD: honestly significant difference test; CV: coefficient of variation.

The use of the intercropping system with planting date arrangements can affect the nutrient availability to plants because it can minimize the competition of nutrient uptake between two plants on the same land. In addition, another influencing factor is the root system (Kholid et al., 2023). According to Supriatna et al. (2022), maize root systems have different types and depths. Corn root systems can grow deeper and have aerial roots, while cowpea has a taproot system and root branches that spread to the sides.

The results on the weight of the ear with the husk per plant showed that different planting times of cowpea in the intercropping system gave higher results, as well as the variable weight of the ear without the husk per plant (Figure 2A). Treatment of sweet corn monoculture and intercropping sweet corn + cowpea planted 21 DAP gave higher yields compared to sweet corn + cowpea planted at the same date, but did not give different results with the treatment of sweet corn + cowpea planted at 7, 14, 28, and 35 DAP.

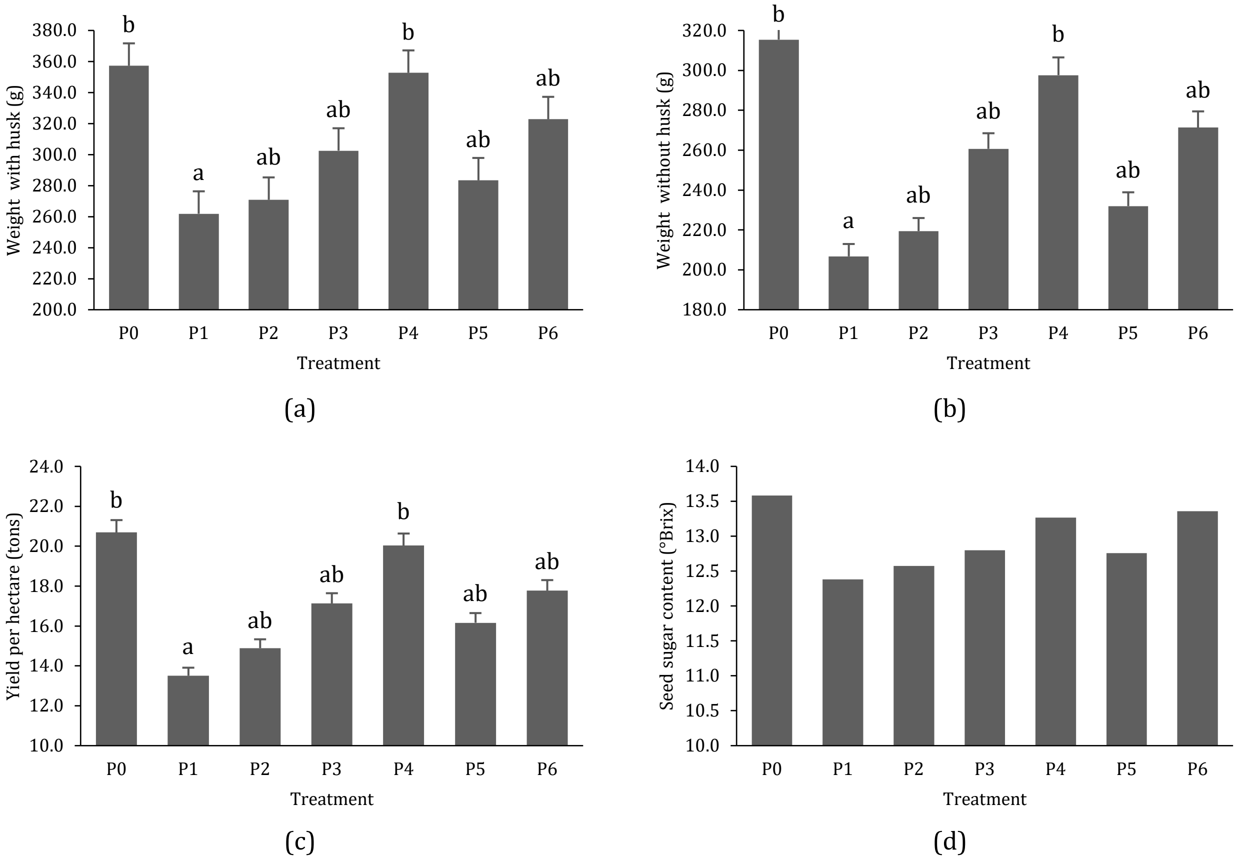

Figure 2. Yield variables of sweet corn (a) weight of ear with husk; (b) weight of ear without husk; (c) weight of ear per hectare; (d) seed sugar content. P0 = monoculture sweet corn, P1 = sweet corn + cowpea planted on the same date, P2 = sweet corn + cowpea planted 7 DAP, P3 = sweet corn + cowpea planted 14 DAP, P4 = sweet corn + cowpea planted 21 DAP, P5 = sweet corn + cowpea planted 28 DAP, P6 = sweet corn + cowpea planted 35 DAP.

Delaying the planting time of cowpea at the age of 21 DAP affected the yield of ear weight in sweet corn plants (Figure 1C). Based on the research of Zamzami et al. (2023), the monoculture system produces higher crop quality, this is because there is no competition with interspecies plants in the same plot. In the present experiment, the management intercropping was more complex than monoculture because maintenance should consider two species with different characteristics. However, different planting date regulates the level of plant sensitivity based on the phase of the critical period of plant growth to reduce the competition between crops (Yang et al., 2022). Light competition could be minimized by different planting dates. Total ear weight could be an indicator of plant efficiency in photosynthate allocation in sweet corn (Ratri et al., 2015; Warman & Kristiana, 2018). According to Suseno et al. (2014), in the intercropping system, the width of the canopy between intercropped plants will affect the receipt of sunlight which affects the photosynthate to the overall yield. Competition for interception of solar radiation can reduce photosynthesis, which will lead to a decrease in plant yield (Subagiono, 2017).

Table 2 shows that the yield of cowpea fluctuated, however, it was not significantly different among planting dates. It was evident that the late planting of cowpea benefited sweet corn growth (Figure 1). Conversely, the sweet corn yield component was reduced by cowpea planting as intercrop, except when cowpea was planted at P4 (21 days after planting sweet corn). The critical time of the sweet corn yield component is probably disrupted by the presence of cowpea. In intercropping, Panda et al. (2021) noted that there is interspecies competition between sweet corn and cowpea. Moreover, Pirman et al. (2022) pointed out that competition in intercropping reduces sweet corn yield if not combined with the proper planting date of intercrop plants. In the present experiment, the situation could be in line with from hypothesis of Panda et al. (2021) and Pirman et al. (2022). According to Kefi et al. (2022), a critical time for sweet corn yield competition is 6-8 weeks. In the present research, all cowpea planting dates interfered with the critical time of sweet corn, implying that competition could exist during corn grain filling.

Table 2. Average yield component of cowpea crops due to different planting times of intercrops in intercropping system.

Treatments	Pod weight per plant (g)	Pods number per plant (g)	Seed dry weight per plant (g)	Seed yield (tons ha^{-1})
Cowpea monoculture	36.78	14.75	29.77	2.55
Sweet corn + cowpea planted on the same date	33.62	13.88	26.63	2.28
Sweet corn + cowpea planted 7 DAP	34.70	14.13	27.71	2.38
Sweet corn + cowpea planted 14 DAP	37.00	14.31	28.92	2.48
Sweet corn + cowpea planted 21 DAP	36.41	14.63	29.38	2.52
Sweet corn + cowpea planted 28 DAP	35.93	14.50	28.94	2.48
Sweet corn + cowpea planted 35 DAP	35.98	14.56	28.98	2.48
HSD 5%	ns	ns	ns	ns
CV (%)	10.31	9.12	13.15	13.29

Note: ns: not significant; DAP: days after planting; HSD: honestly significant difference test; CV: coefficient of variation.

The critical period phase is also one of the factors that determine the success of intercropping because it affects the ability of plants to compete (Pertiwi & Ervina, 2019). Therefore, the intercropping system needs to set the right pattern and model to maintain the high productivity of each crop (Lestari et al., 2020). Although the critical periods of sweet corn could vary depending on the variety, Pertiwi & Ervina (2019) and Murdiono et al. (2016) stated that the initial critical period of sweet corn occurs at the first 25-33% of the plant age. Probably, the critical period of competition for sweet corn yield is not a single period.

Land and area time equivalent ratio

The results of the calculation of LER and ATER values showed that the intercropping treatment of sweet corn + cowpea at different planting times showed more profitable and feasible results compared to the monoculture sweet corn system with LER and ATER value > 1 (Table 3). Sweet corn + cowpea intercropping planted at 21 DAP had a higher LER value compared to sweet corn monoculture and other treatments with an LER value of 1.96 (Table 3). The LER value of all treatments was 1.55-1.96. This proves that the land use efficiency is among the highest and can be profitable reaching a value of 96% and the LER and ATER value > 1 means the high land use efficiency (Ceunfin et al., 2017). ATER value was 1.93. This proves that in calculating the profit of yield per unit of land, it is influenced by planting time, and it means that the longer the type of crop planted on the land, the profit based on time will also be so that these results are profitable. The finding is in line with Sari et al. (2022) where intercropping systems with LER > 1 are considered more profitable than monoculture. In the present study, the LER of intercropping sweet corn + cowpea planted 21 DAP was 1.96, indicating 96% land efficiency in intercropping. According to Suntari et al. (2023), the selection of the right combination of plants and cropping systems can form a symbiotic mutualism between plants. Cowpea can fix nitrogen from the air, leading to a good crop for intercropping from the perspective of ecology and agronomy (Lestari et al., 2020). However, LER and ATER values are sensitive to crop yields, thus factors affecting crop yields such as shading or other competition determine the LER and ATER values (Ceunfin et al., 2017; Neo & Ceunfin, 2018). Moreover, Wei et al. (2022) demonstrated that high LER values are influenced by radiation use efficiency and high PAR values of plants.

Table 3. LER and ATER calculation value of sweet corn and cowpea intercropping due to different planting times of cowpea.

Treatments	Yield (tons ha^{-1})		Duration land occupied (days)	Duration plants co-exist (days)	LER	ATER
	Sweet corn	Cowpea				
Cowpea monoculture	-	2.55	68	0	-	-
Sweet corn monoculture	20.69	-	80	0	-	-
Sweet corn + cowpea planted on the same date	13.50	2.28	80	70	1.55	1.52
Sweet corn + cowpea planted 7 DAP	14.89	2.38	80	71	1.65	1.61
Sweet corn + cowpea planted 14 DAP	17.13	2.48	80	69	1.80	1.79
Sweet corn + cowpea planted 21 DAP	20.03	2.52	80	70	1.96	1.93
Sweet corn + cowpea planted 28 DAP	16.16	2.48	80	72	1.75	1.70
Sweet corn + cowpea planted 35 DAP	17.77	2.48	80	71	1.83	1.79

Note: DAP: days after planting; LER: land equivalent ratio; ATER: area time equivalent ratio.

It is evident that intercropping sweet corn with cowpea, irrespective of the planting date of cowpea, increases land efficiency as shown by LER and ATER value > 1 (Table 3). Sweet corn and cowpea also grew normally, without any abnormality (Figure 3). ATER >1 illustrates that growing in intercropping requires less land than monoculture (Ceunfin, 2018). Moreover, Sari et al. (2022) noted that intercropping systems can increase the efficiency of plants in utilizing available resources. The availability of nitrogen from legumes in the intercropping system might encourage the rooting system of sweet corn resulting in better stem diameter (Figure 1B). The finding is unlikely to support the finding of Panda et al. (2021) where intercrop legume stimulates corn yields.

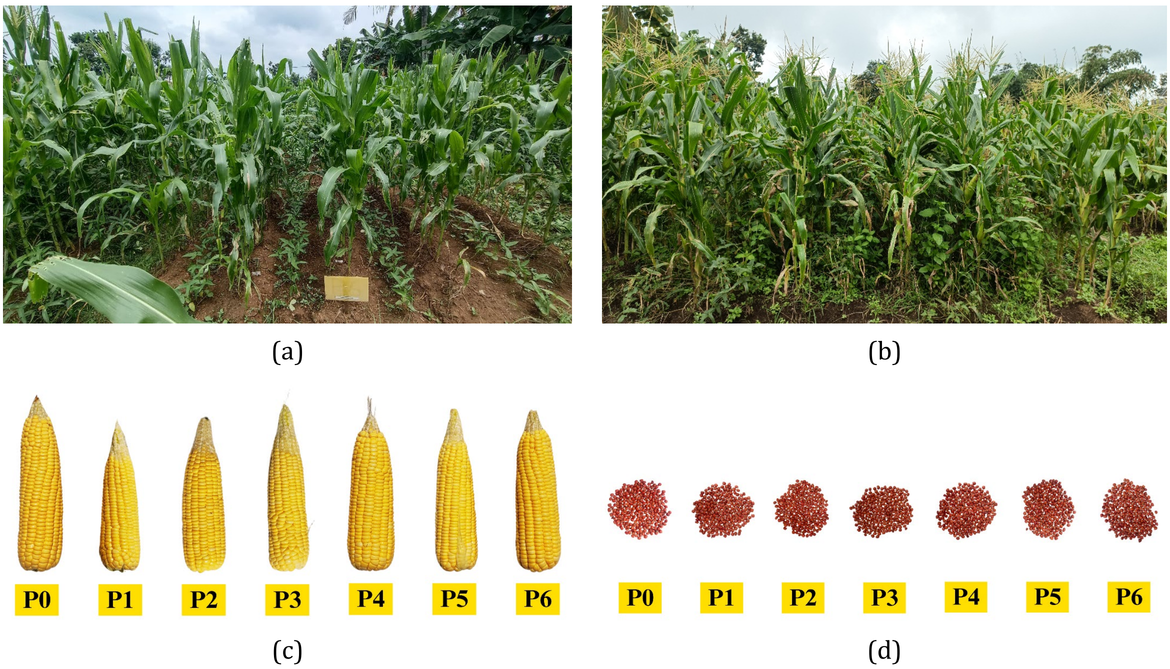

Figure 3. The figure of plants and yield of intercropping. (a) growth phase at 28 DAP; (b) growth phase at 56 DAP; (c) yield of sweet corn without husk; (d) dry yield of cowpea seeds. P0 = monoculture sweet corn, P1 = sweet corn + cowpea planted on the same date, P2 = sweet corn + cowpea planted 7 DAP, P3 = sweet corn + cowpea planted 14 DAP, P4 = sweet corn + cowpea planted 21 DAP, P5 = sweet corn + cowpea planted 28 DAP, P6 = sweet corn + cowpea planted 35 DAP.

Different planting date facilitates sweet corn and cowpea to pass critical growing periods at different times. However, in the present study, the late planting of cowpea had no significant effect on cowpea yield (Table 3) but affected sweet corn yield (Figure 2C). It means that sweet corn competition is sensitive according to the growing stage, especially in the 7 days after planting. To minimize the effect on the yield of sweet corn, planting delays for cowpea of at least 7 is recommended. Raza et al. (2019) recommended to defoliate maize in intercropping to favor the growth of intercrop plants. However, such practice is not necessary for the present result due to no negative effect of sweet corn leaves on cowpea yield as an intercrop plant.

Figure 3 shows that sweet corn produced normal cobs (Figure 3C) and cowpea seeds (Figure 3D). Figure 3C shows that cobs of P1, P2, P3, and P5 lack adequate grain filling as indicated by many empty seeds at the tops. It is still unclear, why seeds on top cobs from those treatments unlike in P4 and P6 that relatively fully charged. Buriro et al. (2015) noted that the cob length of maize is affected by environmental conditions, especially air humidity, sunshine, and air temperature.

Correlation between growth and yield

Growth variables that are correlated to the yield and growth variables are plant height and leaf area, with both correlated to ear length and seed sugar content (Table 4). Plant height and leaf area had a relationship with the yield variables, namely ear length and seed sugar content. In the yield variable, all components affect and have indications of interconnection with other yield variables, namely between ear length, ear diameter, ear weight with husk, ear weight without husk, ear weight per hectare, and seed sugar content.

Table 4. Correlation analysis between growth and yield variables of sweet corn.

Variables	PH	NL	LA	SD	EL	ED	EWH	EWwH	EWHa
NL	0.664								
LA	0.938*	0.805*							
SD	0.808*	0.335	0.765*						
EL	0.900*	0.685	0.915*	0.654					
ED	0.666	0.398	0.517	0.328	0.753*				
EWH	0.670	0.503	0.596	0.320	0.845*	0.917*			
EWwH	0.685	0.560	0.604	0.296	0.832*	0.938*	0.991*		
EWHa	0.704	0.561	0.645	0.322	0.874*	0.939*	0.986*	0.989*	
SCS	0.831*	0.603	0.758*	0.573	0.910*	0.881*	0.950*	0.948*	0.937*

Note: * Value with significant correlation. PH: plant height, NL: leaf number, LA: leaf area, SD: stem diameter, EL: ear length, ED: ear diameter, EWH: ear weight with husk, EWwH: ear weight without husk, EWHa: ear weight per ha, SCS: seed sugar content.

The present study exhibited the duration of sweet corn and cowpea co-existence varied from 72-69 days (Table 3). The cowpea planted at 0 and 21 days after planting of sweet corn had similar days of co-exist between sweet corn and cowpea in the field, i.e., 70 days. The long interaction of the plants might be the reason why the sweet corn of P1, P2, and P3 treatments tended to have lower yields per hectare than control monoculture, although Aksarah et al. (2022) stated that planting intercrop at different times will reduce plant competition for nutrients, space, and water. Interestingly, sweet corn of P5 and P6 also tended to have a lower yield than the control, although plant co-existence was minimized, i.e., 72 and 71 days respectively. According to Lestari et al. (2020) when the vegetative phase of corn and bean occurs at the same time, the bean growth will be suppressed by maize due to less competition to absorb nutrients and water.

The cause of lower yield in P5 and P6 treatment was still unknown (Figure 2C). Here, cowpea harvests of P5 and P6 were conducted after harvesting sweet corn for 12 and 11 days, respectively. Figure 3B shows that at the maximum vegetative phase, the cowpea canopy position was still below the sweet corn canopy. Nevertheless, some sweet corn leaves were likely shaded by some cowpea leaves. Low light intensity reduces photosynthate which affects ear and seeds production in maize (Wang et al., 2012;

Akmalia & Suharyanto, 2017; Wei et al., 2022). Salsabila et al. (2022) noted that sweet corn intercropping with soybean has marked production increment in the presence of adequate water. Water competition could likely be an important explanation for the reduced yield of sweet corn in the present study, especially for P5 and P6 treatments. According to Bagula et al. (2022), about 45% of total water consumption in maize is absorbed in stages just before tasseling to mid-milk as the most critical growth stage.

CONCLUSIONS

Intercropping sweet corn with cowpea, irrespective of cowpea planting date, had higher LER and ATER values than the monoculture system. The highest value of LER was 1.96 and ATER was 1.93, of the cowpea planted at 21 days after sweet corn planting (DAP). Therefore, it is recommended to plant cowpea at 21 DAP in intercropping with sweet corn. Further study is required to evaluate the critical growth stages of plants in the intercropping system for better physiological understanding to improve plants' productivity.

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