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Research Article

Growth and yield of sweet corn intercropping with caisim of different plant densities and planting times

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ABSTRACT

Intercropping of sweet corn and caisim is an effort to improve land efficiency. The study aimed to determine the land use optimization of intercropping between sweet corn and caisim from different plant densities and planting times. Research was carried out from May to July 2024, in Bocek Village, Malang, East Java. The study used a randomized complete block design with a single factor consisting of 7 treatments, i.e., monoculture sweet corn, and sweet corn + caisim (1 and 2 rows) planted 7 days before, at the same time, and 7 days after planting corn. Results showed that all intercropping treatments resulted in R/C ratio and LER values > 1, with the highest values observed of sweet corn + caisim of 1 row planting at the same time. The R/C ratio was 1.22 and the LER was 1.35, indicating that land use was optimized without causing a decline in growth or production for either crop.

Keywords: cropping system, LER, number of rows, R/C ratio, *Zea mays* saccharata

INTRODUCTION

Sweet corn (*Zea mays saccharata* Sturt L.) is one of the horticultural commodities with vast potential for utilization for daily consumption and food industries. The demand for corn in Indonesia is predicted to keep increasing due to several factors, such as population growth and the rapid development of the food and animal feed industries. The corn consumption tends to increase with an annual growth rate of 17.23% or approximately 900,000 tons per year (Saputra et al., 2022). On the other side, demand for various vegetable commodities also tends to increase, particularly for caisim (*Brassica chinensis* var. *parachinensis*). Caisim production in Indonesia in 2021 increased by 8.99% compared to the previous year, reaching a total of 727,467 tons (BPS, 2022).

In spite of increasing demand for sweet corn and caisim, however, the decreasing agricultural land area due to conversion potentially limits its production levels. The issue of limited land requires efforts to optimize agricultural land use (Warman & Kristiana, 2018). One way to increase land productivity is through the intercropping system of sweet corn and caisim. The intercropping system of sweet corn and caisim can optimize land use by incorporating caisim as an intercrop plant, thereby maximizing land productivity (Makoi & Ndakidemi, 2020). Intercropping aims to intensify crop yields by increasing production per unit area of limited land, thereby improving profitability (Kebebew et al., 2014). However, intercropping systems also come with certain risks that may potentially reduce crop yields due to inter-specific competition. This competition between the two crops could reduce yields, so efforts are needed to optimize the growing space for the plants in the intercropping system (Warman & Kristiana, 2018).

An effort to minimize the competition in intercropping is through planting time management (Suseno et al., 2014; Khan et al., 2017). Specifically, in an intercropping system, the plant species that is planted first has a competitive advantage, while the species planted later has lower competitive ability. Planting time management is intended

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to allow plants to utilize resources efficiently and to minimize competition between plants during their rapid growth phase (Yu et al., 2015).

Another effort to minimize competition is determining the intercrop plant density. Adjusting the number of rows for the companion crop aims to optimize land use efficiently and reduce the risk of yield loss between the two crops (Lihiang et al., 2023). Low plant density might reduce land productivity, while dense plants might reduce yields. Therefore, the population density of the companion crop must be optimized (Isaac et al., 2020). Thus, regulating the intercrop plant density is crucial. Reducing the population density of the companion crop can increase the growing space, allowing for more efficient light interception, which can optimize plant growth (Alemayehu et al., 2017). The study aimed to determine the land use optimization of intercropping between sweet corn and caisim from different plant densities and planting times.

MATERIALS AND METHODS

Research site

This research was conducted from May to July 2024 in Bocek Village (715 m asl; 7°21′-7°31′ S and 110°10′-111°40′ E), Karangploso District, Malang Regency, East Java. Karangploso District is located at an elevation of 525 to 715 meters above sea level, with an average annual temperature ranging from 23.3 to 24.7 °C, average humidity between 61% and 78%, and average annual rainfall of 1,250 mm.

Research procedure

This research used single factor experiment designed based on a randomized complete block design consisting of 7 treatments, namely; sweet corn monoculture (P0); intercropping of sweet corn + caisim (1 row), planted 7 days before corn planting (P1); intercropping of sweet corn + caisim (2 rows), planted 7 days before corn planting (P2); intercropping of sweet corn + caisim (1 row), planted at the same time (P3); intercropping of sweet corn + caisim (2 rows), planted at the same time (P4); intercropping of sweet corn + caisim (1 row), planted 7 days after corn planting (P5); intercropping of sweet corn + caisim (2 rows), planted 7 days after corn planting (P6). Caisim monoculture was set as control. Each treatment was repeated 4 times, resulting in 28 experimental units.

Caisim seed of the Tosakan variety was sown in seedling beds according to the planting time. Consequently, the sowing time was done at three different times corresponding to the treatment schedules. The caisim seedlings were transplanted at 14 days after sowing (DAS). Soil preparation involved raising beds for each treatment. The experimental plots were sized 2 m x 3.5 m, providing a total area of 7 m^2 per plot. The corn seed was planted at a spacing of 70 cm × 20 cm in both intercropping and monoculture. Caisim was planted with a single row (10 plants per row) and a double row (20 populations of caisim per row). The planting distance of caisim in a row was 20 cm, while the double row used 20 cm x 20 cm.

Fertilizer doses were calculated based on the recommendation for maize (main crop) and applied side dressing. Organic manure was applied one week before planting maize at a rate of 50 tons per hectare. Urea and KCl at rates of 250 kg ha^{-1} and 200 kg ha^{-1}, respectively, were applied at two different times, i.e., 14 days after planting (DAP) (2/3 dose) and 28 DAP (1/3 dose). SP-36 was applied at the time of planting at a rate of 100 kg ha^{-1}.

At 7 DAP, non germinated seed was replanted. Hilling soil along maize row was performed at 14 and 28 DAP, at the same time with the application of fertilizer and weed control. Pests and diseases were managed using insecticides with active ingredients carbosulfan 25%, carbofuran 5%, profenofos 500 g L^{-1}, and fungicides with active ingredient dematomorph 50%.

Sweet corn was harvested at 80 DAP (corn husks became dry, cobs fully filled, and hard kernels). Caisim was harvested at 35 DAP.

Observation variables

Sweet corn was observed for plant height, leaf area, cob size (length and diameter), sugar content, cob weight without husk, and cob per hectare. Observation of caisim included fresh plant weight and yield per hectare. Farm management analysis was performed including revenue:cost ratio (R/C ratio) and land equivalent ratio (LER). LER was calculated based on Ramadhani et al. (2024) and Sumarni and Anggoro (2024).

Data analysis

Observation data were analyzed using analysis of variance (ANOVA) at the 5% level. For any significant differences caused by treatments, a further test was performed using the Honestly Significant Difference (HSD) test at the 5% level.

RESULTS AND DISCUSSION

Sweet corn growth and yield

Treatments had a significant effect on plant height and leaf area of sweet corn at 14 and 28 days after planting (DAP) (Tables 1 and 2). For the plant height variable at 14 and 28 DAP, intercropping with 1 row of caisim + planting 7 days before sweet corn (P1) and intercropping with 2 rows of caisim + planting 7 days before sweet corn (P2) showed a significant reduction in plant height compared to the monoculture treatment. Similarly, for the leaf area at 14 and 28 DAP, intercropping with 1 row of caisim + planting 7 days before corn (P1) and intercropping with 2 rows of caisim + planting 7 days before corn (P2) also resulted in a significant reduction in leaf area compared to the monoculture. Figure 1 shows the performance of corn at 28 DAP and 56 DAP.

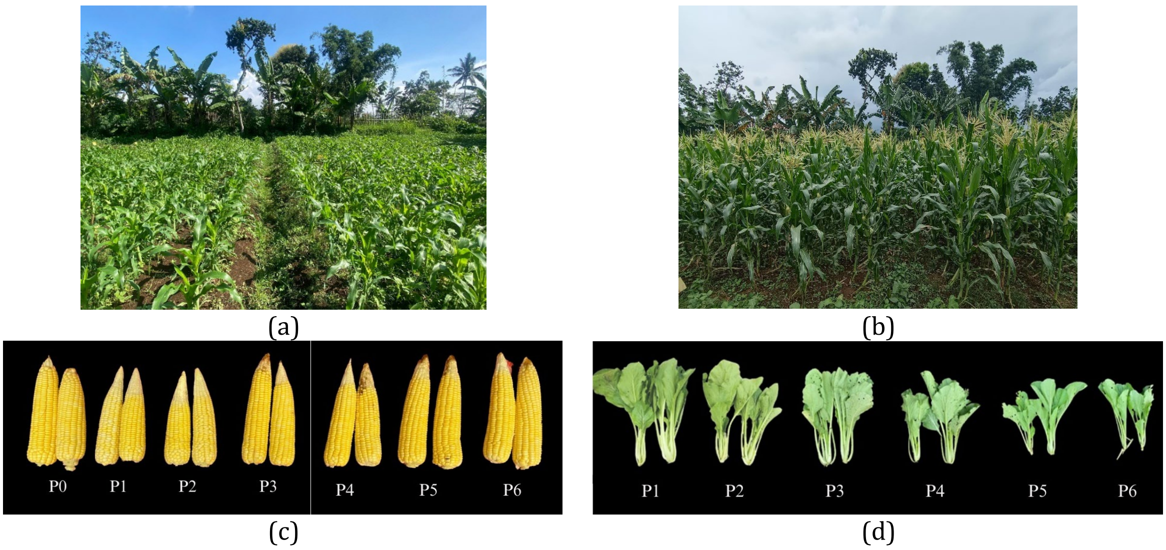

Figure 1. Sweet corn and caisim performances in intercropping. (a) Sweet corn at 28 DAP; (b) Sweet corn at 56 DAP; (c) Sweet corn without husk; (d) Caisim yield. P0: Sweet corn monoculture, P1: Sweet corn + caisim (1 row) planted 7 DBP, P2: Sweet corn + caisim (2 rows) planted 7 DBP, P3: Sweet corn + caisim (1 row) planted at the same time, P4: Sweet corn + caisim (2 rows) planted at the same time, P5: Sweet corn + caisim (1 row) planted 7 DAP, P6: Sweet corn + caisim (2 rows) planted 7 DAP; DBP: days before planting; DAP: days after planting.

At 14 and 28 DAP, the intercropping treatments with caisim planted before planting corn resulted in a significant reduction in both plant height and leaf area of corn compared to the monoculture treatment, whether with 1 row or 2 rows of caisim (Table 1 and Table 2). This could be due to the presence of competition among crops, but caisim as the companion crop had a better competitive advantage. According to Yu et al. (2015), plants in an intercropping system that were planted earlier have higher competition than the second one. The higher competitive ability of caisim allowed it to utilize abiotic factors, such as light, more effectively than corn (Alemayehu et al., 2018). Planting caisim 7 days before corn reduced the competitive ability of corn, leading to lower plant height and leaf area. This finding is in line with the study of Chapagain et al. (2018), which noted that corn planted simultaneously or before the companion crop showed a higher growth rate as compared to corn planted after the companion crop.

Table 1. Plant height of sweet corn from different planting times and population of caisim in intercropping system.

Treatments	Plant height of sweet corn (cm)			
	14 DAP	28 DAP	42 DAP	56 DAP
Sweet corn monoculture	10.10c	34.25b	111.60	192.70
Sweet corn + caisim (1 row) planted 7 DBP	8.13ab	26.50a	102.30	186.50
Sweet corn + caisim (2 rows) planted 7 DBP	7.96a	26.83a	94.58	176.30
Sweet corn + caisim (1 row) planted at the same time	10.00c	30.58ab	106.50	188.40
Sweet corn + caisim (2 rows) planted at the same time	8.25ab	27.83ab	97.17	184.70
Sweet corn + caisim (1 row) planted 7 DAP	10.10c	33.67ab	108.80	190.30
Sweet corn + caisim (2 rows) planted 7 DAP	9.75bc	32.17ab	107.50	187.50
HSD 5%	1.71	7.33	ns	ns
CV (%)	8.09	10.39	10.41	5.01

Note: Values in a column followed by the same letter indicate no significant difference at the HSD test of 5%; ns: not significant; DBP: days before planting; DAP: days after planting; CV: coefficient of variation.

Caisim was harvested earlier than sweet corn in all treatments. In terms of recovery after harvesting caisim, sweet corn exhibited varying growth responses at 42 and 56 DAP. At 42 DAP, corn that had been intercropped with caisim resumed growth as shown in higher plant height and leaf area, indicating the presence of competition before harvesting caisim. By 56 DAP, the recovery was more pronounced, with corn plants showing near-normal growth rates. This finding aligns with previous studies by Zhao et al. (2019) and Ali et al. (2015), who observed that corn could recover its growth when the companion crop was removed after an initial competition phase. The ability of sweet corn to recover after the harvest of caisim supports the notion that intercropping systems, while initially competitive, can provide benefits if managed carefully, allowing both crops to utilize available resources at different stages for their growth cycles (Wimalasekera, 2019).

The number of rows of caisim affected the plant height (Table 1) and leaf area of sweet corn (Table 2). It was found that planting caisim before or simultaneously with sweet corn decreased plant height and leaf area. According to Villabos et al. (2016), in a given area, competition for nutrients, light, and water is positively correlated with the plant population density. Consequently, when the population density of companion plants is high, the level of competition between the main crop and the companion plants also increases leading to growth reduction in maize during the vegetative phase (Ali et al., 2015).

Table 2. Leaf area of sweet corn from different planting times and population of caisim in intercropping system.

Treatments	Leaf area of sweet corn (cm^2)			
	14 DAP	28 DAP	42 DAP	56 DAP
Sweet corn monoculture	139.5b	1,332c	4,129	5,633
Sweet corn + caisim (1 row) planted 7 DBP	115.6ab	961ab	3,928	5,381
Sweet corn + caisim (2 rows) planted 7 DBP	100.8a	859a	3,672	5,425
Sweet corn + caisim (1 row) planted at the same time	125.8ab	1,085abc	4,006	5,855
Sweet corn + caisim (2 rows) planted at the same time	116.3ab	916ab	3,834	5,902
Sweet corn + caisim (1 row) planted 7 DAP	133.8ab	1,165bc	4,099	6,242
Sweet corn + caisim (2 rows) planted 7 DAP	129.4ab	1,175bc	4,144	5,907
HSD 5%	36.7	288.4	ns	ns
CV (%)	12.78	12.22	10.61	8.14

Note: Values in a column followed by the same letter indicate no significant difference at the HSD test of 5%; ns: not significant; DBP: days before planting; DAP: days after planting; CV: coefficient of variation.

The competition for light, resulting from planting caisim 7 days prior to corn and using two rows of caisim, may significantly reduce the height and leaf area of corn. This competition limits the availability of light, which is essential for proper plant growth (Matusso et al., 2014). Wimalasekera (2019) pointed out that light is essential for photosynthesis, and when plants compete for light, it can impair photosynthetic efficiency, leading to growth reduction.

Sweet corn yield was not significantly affected by treatments on the cob diameter and sweetness content, but there was a significant effect on cob length, cob weight per plant, and its weight per hectare (Table 3). For the cob length and cob weight per plant, it was found that the treatment of 2 rows of caisim planted 7 days before corn (P2) caused a significant reduction than those of monoculture. Regarding the yield per hectare, the treatments with 1 and 2 rows of caisim planted 7 days before corn (P1 and P2) also showed a significant reduction in yield compared to the monoculture treatment.

It is evident that planting caisim 7 days before corn reduced corn yield, unlike planting simultaneously or after planting corn (Table 3). Figure 1c shows that the tip of the cob indicated an empty seed, especially P1 and P2. It seemed that growth recovery after harvesting caisim is unable to maintain a high sweet corn yield. This is obvious that the timing of planting in an intercropping system affects the level of competition. Plants that are planted earlier tend to have a higher competitive ability as they have more opportunities to utilize abiotic factors, such as light, nutrients, and water (Choudhary et al., 2014). On the other hand, plants planted later have lower competitive ability compared to those planted earlier, thus increasing the potential for a reduction in growth and yield (Kimou et al., 2017). In the present case, caisim planted 7 days before corn resulted in a decrease in corn cob weight and yield per hectare. This finding is in line with research by Wang et al. (2021), which showed that the dry kernel weight of corn decreased when corn was planted 14 and 28 days after the companion crops were planted, due to competition for abiotic factors.

Table 3. Sweet corn yield components from different planting times and populations of caisim in intercropping system.

Treatments	Cob size		Cob weight/ plant (g)	Yield (tons ha^{-1})	Sugar content (°brix)
	Length (cm)	Diameter (mm)			
Sweet corn monoculture	21.54b	48.04	256.5b	22.19b	13.30
Sweet corn + caisim (1 row) planted 7 DBP	18.83ab	45.84	229.6ab	18.15a	12.88
Sweet corn + caisim (2 rows) planted 7 DBP	18.17a	44.29	194.7a	17.16a	12.55
Sweet corn + caisim (1 row) planted at the same time	21.25ab	47.63	267.0b	21.53b	13.13
Sweet corn + caisim (2 rows) planted at the same time	20.66ab	45.38	237.4ab	19.67ab	13.13
Sweet corn + caisim (1 row) planted 7 DAP	20.92ab	47.78	264.9b	21.71b	13.00
Sweet corn + caisim (2 rows) planted 7 DAP	21.13ab	46.63	259.7b	21.95b	12.88
HSD 5%	3.35	ns	59.57	2.57	ns
CV (%)	7.05	7.54	10.44	5.47	8.93

Note: Values in a column followed by the same letter indicate no significant difference at the HSD test of 5%; ns: not significant; DBP: days before planting; DAP: days after planting; CV: coefficient of variation.

Caisim growth and yield

Table 3 shows that the caisim planted in 1 and 2 rows with a planting time of 7 days before and simultaneously with corn has the potential to cause a significant decrease compared to the monoculture treatment. This is because a high population density leads to a narrowing of the planting spacing, causing the canopies of the plants to overlap at 14-28 DAP. Increasing the population of intercropped plants reduces the growing space between the companion and main crops, which can lead to canopy overlap and increased competition for light between the plant components (Alemayehu et al., 2017).

Planting two rows of caisim reduced corn yields (Table 3). However, its reduction could be compensated by increased caisim yields per hectare due to higher caisim populations. This finding is in line with Zhang et al. (2020), where doubling the population of intercrop plants increases the yield of the intercrop plant although it creates intense competition with the main crop. Population arrangement is important for planting before or after planting the main crop.

The results showed a significant effect of the treatments on the caisim yield components (Table 4). For the fresh plant weight, it was found that the treatment of 1 row of caisim + planting time simultaneously with corn (P3) did not result in a significant difference in caisim yield that was planted at 7 days before corn in either 1 row or 2 rows (P1 and P2).

Moreover, caisim planted 7 days before corn in 2 rows produced the highest weight per hectare as compared to other treatments (Table 4). On the other hand, the treatment where caisim was planted 7 days after corn in 1 row resulted in the lowest weight per hectare compared to all treatments.

Table 4. Caisim yield from different planting times and population densities in an intercropping system with sweet corn.

Treatments	Fresh caisim yield	
	Per plant (g)	Per hectare (tons)
Sweet corn + caisim (1 row) planted 7 DBP	234.2c	22.76d
Sweet corn + caisim (2 rows) planted 7 DBP	195.4bc	28.91e
Sweet corn + caisim (1 row) planted at the same time	213.8bc	19.26c
Sweet corn + caisim (2 rows) planted at the same time	166.9b	24.61d
Sweet corn + caisim (1 row) planted 7 DAP	104.2b	9.57a
Sweet corn + caisim (2 rows) planted 7 DAP	95.1a	14.24b
HSD 5%	61.53	2.14
CV (%)	15.92	4.70

Note: Values in a column followed by the same letter indicate no significant difference at the HSD test of 5%; DBP: days before planting; DAP: days after planting; CV: coefficient of variation.

The decrease in caisim weight when planted after corn was presumably due to insufficient light intensity received by caisim during its rapid growth phase. Shading of the main crop (corn) reduces the light intensity received by intercrop plants (Kumar et al., 2024). Intercropped plants like caisim, when planted earlier or simultaneously with the main crop will receive adequate light intensity allowing optimum photosynthetic activity (Raza et al., 2019). Isaac et al. (2020) stated that planting intercropped plants simultaneously or before corn tends to have a higher crop growth rate (CGR) compared to those planted after corn. Moreover, Bugilla et al. (2023) noted that intercropped plants planted after corn experience reduced light interception due to shading from corn resulting in a lower leaf area index (LAI) and reduced photosynthesis leads to lower yields. Thus, shading of corn canopy reduced the amount of light received by caisim during its rapid growth phase, leading to a decrease in caisim yield.

Here, caisim planted in two rows produced lower fresh weight per plant compared to those planted in a single row (Table 4). However, caisim in two rows yielded higher weight per hectare as compared to planting in a single row due to the higher plant population in the two-row treatment. This finding is in line with Isaac et al. (2020), where increasing in plant density of intercropped species resulted in higher yields per unit area. However, Kebebew et al. (2014) noted that too high densities of intercrop plants might reduce the growth and yield of the main crop, and the level of reduction is influenced by planting time, row arrangement pattern, and spacing.

R/C ratio and land equivalent ratio (LER)

The highest R/C ratio was found in the treatment of intercropping caisim 1 row + planting time simultaneous with corn (P3) with a value of 1.22 (Table 5) or about 4.09% higher than the value in monoculture. On the other hand, the lowest R/C ratio value was found in the treatment of intercropping caisim in 2 rows + planting caisim 7 days before corn (P2), with a value of 1.08 or about 14% lower than the monoculture treatment. The cause of P3 treatment produced the highest R/C ratio was proper planting time. Proper planting time is important in intercropping to support high yields of both main and intercrop plants (Saputra et al., 2022). According to Bugilla et al. (2023), planting time in an intercropping system has a significant impact on the yield of both crops, therefore, optimizing planting time is a crucial step for achieving high yields in an intercropping system. In the present experiment, planting caisim before corn reduced corn yield while planting caisim after corn reduced caisim yield.

Table 5. Total cost, revenue, profit, and revenue:cost ratio (R/C ratio) intercropping sweet corn and caisim of different planting times and population densities.

Treatments	Total costs (Rp)	Revenue (Rp)	Profit (Rp)	R/C ratio
Sweet corn monoculture	47,550,000	55,468,750	7,918,750	1.17
Sweet corn + caisim (1 row) planted 7 DBP	50,238,000	54,489,285	4,251,285	1.08
Sweet corn + caisim (2 rows) planted 7 DBP	53,436,000	54,460,218	1,024,218	1.02
Sweet corn + caisim (1 row) planted at the same time	50,238,000	61,535,019	11,297,019	1.22
Sweet corn + caisim (2 rows) planted at the same time	53,436,000	59,025,198	5,589,198	1.10
Sweet corn + caisim (1 row) planted 7 DAP	50,238,000	58,107,638	7,869,638	1.16
Sweet corn + caisim (2 rows) planted 7 DAP	53,436,000	60,569,543	7,133,543	1.13

Note: DBP: days before planting; DAP: days after planting.

In this study, caisim planted in two rows produced higher yields per unit area, but caisim planted in two rows with a 7-day delay before corn planting reduced corn yields (Table 3 and Table 4). Consequently, the R/C ratio for caisim planted in two rows was lower as compared to the caisim planted in one row (Table 5). According to Khalid et al. (2023), increasing the population density of either the main crop or the intercrop increases the yield per unit area, but if the population density of the intercrop is too high, it may reduce the yield of the main crop. Therefore, with the decrease in the yield of the main crop (corn), the R/C ratio becomes lower because the profit from intercropping is mainly derived from the main crop rather than the intercrop as stated by Kefi et al. (2022).

The intercropping system can increase land use efficiency due to LER values > 1 (Table 5). The highest LER value was observed when caisim was planted in two rows at the same time as corn, with a value of 1.37. In this context, 1.37 times the area is needed for monoculture planting for the yields equivalent to the intercropping system, see Kebebew et al. (2014) for the explanation.

Table 6. Land equivalent ratio (LER) intercropping sweet corn and caisim of different planting times and population densities.

Treatments	LER
P1: Sweet corn + caisim (1 row) planted 7 DBP	1.26
P2: Sweet corn + caisim (2 rows) planted 7 DBP	1.34
P3: Sweet corn + caisim (1 row) planted at the same time	1.35
P4: Sweet corn + caisim (2 rows) planted at the same time	1.37
P5: Sweet corn + caisim (1 row) planted 7 DAP	1.16
P6: Sweet corn + caisim (2 rows) planted 7 DAP	1.27

Note: Caisim monoculture was 51.40 ton ha^{-1}, sweet corn monoculture with cob was 22.19 ton ha^{-1}; DBP: days before planting; DAP: days after planting.

On the other side, the lowest LER (1.16) was found for caisim planted in one row with planting 7 days after corn planting (Table 6). Additionally, planting caisim in two rows also resulted in higher yields per unit area. This is supported by Lestari et al. (2020), who found that intercropping with corn resulted in the highest LER when the intercrop was planted simultaneously with corn, compared to planting the intercrop after the corn. The study also showed that increasing the density of the intercrop, such as planting caisim in two rows, improved the LER compared to lower-density planting, such as planting caisim in one row.

Ali et al. (2015) optimized intercropping corn with various vegetables including leafy vegetables such as radish and spinach. However, little report is available on intercropping with *Brassica sp*, like in the present experiment. Corn is fast fast-growing species and the canopy is usually established at 6-8 weeks after sowing (Olasantan, 2011). In the present experiment, the corn canopy started to expand at 28 DAP (Figure 1a) and had already closed at 56 DAP (Figure 1b). It means that selecting of intercrop plant is very important. Yulianti et al. (2018) evaluated the suitability of *Solanum nigrum* for intercropping using an artificial shading net revealing its suitability for growing under 50% reduced light intensity. Moreover, Agusta et al. (2021) noted the potential of increasing nitrate concentration in Brassica rapa growing under 50% shading. Unfortunately, the level of nitrate and the level of shading was not evaluated in the present experiment. It is interesting in the future to evaluate the quality of caisim growing in an intercropping system to ensure its sustainability from a health perspective.

CONCLUSIONS

The intercropping of sweet corn and caisim in a single row with simultaneous planting did not result in significant reductions in the growth and yield of corn compared to monoculture. The monoculture treatment yielded corn of 22.19 tons per hectare, while the intercropping treatment with caisim planted in one row at the same time as corn resulted in corn of 21.53 tons per hectare and caisim of 19.26 tons per hectare. All intercropping treatments of sweet corn with caisim enhanced land productivity, as demonstrated by LER > 1 with the highest value reaching 1.37. The intercropping showed an R/C ratio > 1 with the highest ratio being 1.22, indicating a high prospective for farmers.

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