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Research Article

Effect of row orientation and cowpea row numbers on sweet corn-cowpea intercropping

Atikah Fajri [1], Heni Purnamawati [2,*], and Maya Melati [2]

[1] Agronomy and Horticulture Study Program, Graduate School, IPB University (Bogor Agricultural University), Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, INDONESIA
[2] Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, INDONESIA
* Corresponding author (✉ h_purnama@apps.ipb.ac.id)

ABSTRACT

Intercropping between sweet corn (Zea mays L. var. saccharata Sturt) and cowpea (Vigna unguiculata L. Walp) can improve land productivity, but requires optimization of row orientation and cowpea row number. This study evaluated the effects of row orientation and cowpea row number on the growth, yield, and economic performance of sweet corn–cowpea intercropping. The experiment was conducted from June to September 2024 at the IPB experimental field in Sawah Baru, Bogor, Indonesia. A split-plot design with four replications was employed. The main plots consisted of two row orientations (North–South and East–West), while the sub-plots included maize monoculture, intercropping with one row, and two rows of cowpea. A significant interaction between row orientation and cowpea row number was observed on maize height, leaf number, and stem diameter at two weeks after planting. Although row orientation did not significantly affect maize and cowpea performance, the East–West orientation increased cowpea yield by 14.6% and reduced maize yield by 5.3% compared to the North–South orientation. The East–West orientation combined with one cowpea row produced the highest land equivalent ratio (LER = 1.93) and benefit–cost ratio (R/C = 1.45).

Keywords: LER, R/C ratio, aggressivity, competitive ratio

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INTRODUCTION

Sweet corn is a high-value horticultural crop with increasing demand in Indonesia due to population growth. Unlike field corn, it has a sweeter taste preferred by consumers and is widely processed into various food products. Sweet corn contains 13% water, 11.2% protein, 4.6% fat, 72.3% starch, 2.3% sugar, and 8.2% fiber, while 100 g kernels provide 5.6 mg vitamin A, 1.5 mg vitamin B, 6.8 mg vitamin C, 0.46 mg Zn, 0.52 mg Fe, and 37 mg Mg (Budak & Aydemir, 2018). Increasing domestic productivity is essential to meet consumption needs and improve farmers' income. In contrast, soybean demand in Indonesia is largely import-dependent, with an import dependency ratio of 94.64–97.66% during 2019–2023, indicating that local production contributes less than 4–6% to national demand (Wahyuningsih, 2024). Cowpea can be an alternative in fulfilling the need for soybeans as industrial raw materials. Cowpea contains 21.02-26.90% protein, 2.96-3.25% fat, and 45.68-55.74% carbohydrate. Cowpea can be a good source of nutrition for the body, especially in diversifying dietary foods with low fat content (Otitoju et al., 2015). In addition, cowpea leaves can be utilized as vegetables that contain protein, carbohydrates, fat, iron, prebiotics, as well as calcium, phosphorus, magnesium, potassium, and sodium that can meet the daily nutritional intake of humans (Enyiukwu et al., 2018).

Maize is a C4 crop that has good adaptability to various limiting factors. Compared to C3 plants, maize plants exhibit a higher photosynthetic rate, accompanied by lower photorespiration and transpiration rates, as well as greater efficiency in water use (Goldsworthy & Fisher, 1984). In contrast, cowpea plants are C3 plants. Cowpea has a lower crown than corn, and the photosynthetic rate of cowpea is optimum at relatively low intensity and temperature. Thus, cowpea can adapt to shaded conditions. Overall, cowpea is more tolerant of shade, making it suitable for intercropping with sorghum or maize, two tall crops that can provide greater shade (Angadi et al., 2022).

Row orientation and the number of intercrop rows are crucial for optimizing spatial arrangement and solar radiation use in intercropping systems. The east–west row orientation creates a corridor effect that allows greater light penetration into the canopy (El-Maksoud, 2008). However, this orientation is not always feasible, particularly on sloping land facing east or west, where a north–south orientation is required to reduce erosion and surface runoff. A conservation approach through contour planting combined with bench terrace construction recorded the highest rainfall (29.21 mm) but the lowest erosion (0.56 tons ha^{-1}) and surface runoff (5.45 L m^{-2}) (Fajeriana et al., 2024). Contour-based soil cultivation in combination with contour planting has proven effective in reducing soil erosion and surface runoff (Wijayanto et al., 2021). Additionally, regulating the number of cowpea rows is essential for improving the yield of both maize and cowpea by optimizing plant spacing in the intercropping system.

Land use efficiency can be seen from the competition and yield advantages of the land equivalent ratio (Ceunfin et al., 2017). The intercropping pattern of sweet corn with a planting distance of 80 cm x 20 cm and soybean variety Dena-2 has an LER value of 1.57 (Aisyah & Herlina, 2018). Intercropping corn and cowpea together resulted in a LER of 1.39 (Suhi et al., 2022).

This study aimed to analyze the growth and yield of sweet corn and cowpea under intercropping systems with different row orientations and varying numbers of cowpea rows. The research problem focused on identifying the optimal row orientation and number of cowpea rows to minimize interspecific competition and efficiently utilize resources such as light, water, and nutrients to enhance the growth and productivity of both crops. The study is expected to provide valuable insights into appropriate row orientation and cowpea row configurations to optimize sweet corn–cowpea intercropping outcomes, evaluated from morphological, yield, and economic perspectives, including land equivalent ratio (LER) and benefit–cost ratio (R/C ratio).

MATERIALS AND METHODS

Research design

The research was conducted from June 2024 to September 2024 at the IPB experimental field in Sawah Baru, Bogor, Indonesia (6°33'49“ S 106°44'07” E; 180 m above sea level). A split-plot design was employed for the experiment with two factors: row orientation (North–South and East–West) as the main plot, and number of cowpea rows (sweet corn monoculture, one row of cowpea, and two rows of cowpea) as the subplot, each replicated four times, resulting in 24 treatment plots. An additional three plots of cowpea monoculture were included: one row of cowpea with north–south orientation (spacing 80 cm × 20 cm), one row with east–west orientation (spacing 80 cm × 20 cm), and two rows of cowpea (spacing 40 cm × 40 cm), giving a total of 27 experimental plots. The monoculture sweet corn plot contained 40 plants. In the intercropping plots, both one-row and two-row treatments included 40 maize and 40 cowpea plants per plot, while cowpea monoculture plots also contained 40 plants per plot (Figure 1). The area of each experimental plot is 8 m^2.

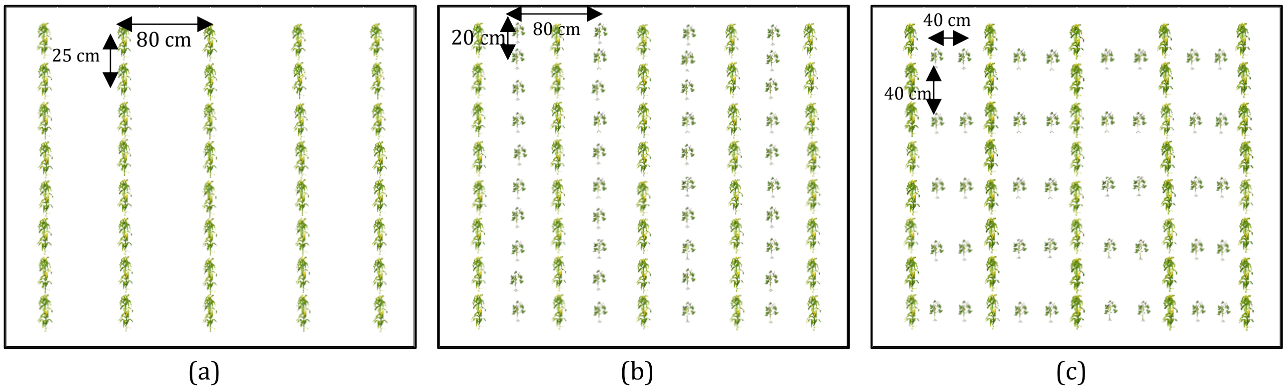

Figure 1. Planting arrangements with different numbers of cowpea plants: (a) sweet corn monoculture, (b) one row of cowpea, (c) two rows of cowpea.

Experimental procedure

The materials used included sweet corn seeds of the Exotic variety, cowpea seeds of the Albina IPB variety, urea fertilizer at 350 kg ha^{-1}, SP-36 at 100 kg ha^{-1}, KCl at 75 kg ha^{-1}, carbofuran 3% at 10 kg ha^{-1}, and chicken manure at 5 tons ha^{-1}. Soil analysis was conducted before planting at the Testing Laboratory of the Department of Agronomy and Horticulture, IPB University. The soil samples used were composite soil taken from five points, taken diagonally with 20 cm in depth. After the land preparation, chicken manure was applied to the maize planting rows and cowpea planting rows and left for 3 weeks.

Sweet corn and cowpea were planted at the same time. Sweet corn was spaced at 80 cm × 25 cm, cowpea at 80 cm × 20 cm (one row) and 40 cm × 40 cm (two rows) (Figure 1). Two seeds of sweet corn and cowpea were sown per planting hole, and 3% carbofuran was applied at planting. Inorganic fertilizer was applied only to sweet corn at a distance of 10 cm from the planting row following the recommended dosage. Urea was applied in two splits: 1/3 at planting (93.3 g per plot) and 2/3 at 4 weeks after planting (186.7 g per plot), while SP-36 (80 g per plot) and KCl (60 g per plot) were applied entirely at planting. Cowpeas did not receive inorganic fertilizer, as previous studies indicated their low responsiveness to N, P, and K fertilization (Gustiningsih et al., 2023). Moreover, reducing inorganic fertilizer input can lower production costs and improve the R/C ratio. Nevertheless, cowpea received chicken manure as basal fertilization.

Crop maintenance included replanting at 7-10 days after planting (DAP), thinning to a single plant per hill at 2 WAP, hilling-up at 4 WAP to cover maize roots around the stem base, irrigation, pest and disease control, and ear thinning at 8 WAP to maintain a single ear per maize plant. Sweet corn was harvested at 11 WAP, while cowpea was harvested four times between 10 and 13 WAP.

Observation

Observations on sweet corn included plant height (cm), leaf number, stem diameter (mm), leaf area (m^2), and leaf dry weight at 8 WAP (g), ear weight with and without husks (g), total and seeded ear length (cm), ear diameter (mm), and yield (tons ha^{-1}). Cowpea observations included shoot and root dry weight at 54 DAP (g), 50% flowering time (DAP), number of pods per plant, pod weight per plant (g), number of seeds per pod, seed weight per pod (g), weight of 100 grains (g), and productivity (tons ha^{-1}).

The assessment of intercropping competition includes land equivalence ratio (LER), aggressivity (A), Competitive ratio (CR), and actual yield loss (AYL) calculated using the following formula (Ceunfin et al., 2017):

- $\text{LER} = \frac{\text{IMY}}{\text{MMY}} + \frac{\text{ICY}}{\text{MCY}}$
- $\text{CR} = \frac{\text{Maize LER}}{\text{Cowpea LER}} \times \frac{\text{PCI}}{\text{PMI}}$
- $\text{A} = \frac{\text{IMY}}{\text{MMY x PMI}} - \frac{\text{ICY}}{\text{MCY x PCI}}$
- $\text{AYL} = \frac{\frac{\text{IMY}}{\text{PMI}}}{\frac{\text{MMY}}{\text{PMM}}} - 1$

The description of the equations is as follows: IMY = intercropped maize yield, MMY = monoculture maize yield, ICY = intercropped cowpea yield, MCY = monoculture cowpea yield, PMI = proportion of maize in intercropping, PCI = proportion of cowpea in intercropping, PMM = proportion of maize in monoculture.

The calculation of farming efficiency can use the Return Cost Ratio (R/C ratio), which is the ratio between revenue and costs incurred, formulated as follows (Elisabeth and Harsono 2020).

$$R/C = \frac{\text{total income}}{\text{total costs}} = \frac{\text{(price x quantity)}}{\text{(fixed costs + variable costs)}}$$

Data analysis

Data were analyzed using analysis of variance (ANOVA) at a 5% level, followed by Duncan's multiple range test (DMRT) at 5%. Data processing was performed using RStudio software and Microsoft Excel 2021.

RESULTS AND DISCUSSION

The experimental site had favorable conditions for sweet corn and cowpea, with average temperatures of 26-27 °C, humidity of 77-82%, and 6.5-7 hours of sunlight per day. Rainfall was moderate from June to August and high in September. The soil was slightly acidic, with low organic carbon and nitrogen, very high phosphorus, low potential potassium, very high available potassium, and moderate cation exchange capacity. Overall plant growth was good, though cowpea tendrils began twining around maize stems at 39 DAP, requiring maintenance to prevent lodging.

The results showed that plant height, leaf number, and stem diameter of maize at two WAP were influenced by the interaction between row orientation and the number of cowpea rows. The treatment with one row of cowpea in a north-south orientation produced greater plant height (Table 1), leaf number (Table 2), and stem diameter (Table 3) compared to maize monoculture and the two-row cowpea treatment under the same row orientation. This may be attributed to the cowpea's ability to fix atmospheric nitrogen and make it available to neighboring plants. In soybeans, effective nodulation for nitrogen fixation typically begins around 10-12 days after planting (Liem et al., 2019). Therefore, by two weeks after planting, cowpea is presumed to have formed root nodules capable of fixing nitrogen, which the adjacent maize plants could utilize.

Table 1. The effect of row orientation and number of cowpea rows on the height of maize at 2 WAP.

Row orientations	Number of cowpea rows		
	0	1	2
North-South	16.68±1.77b	19.91±2.23a	16.59±2.72b
East-West	18.30±3.89ab	17.20±2.80ab	18.55±2.39ab

Note: Numbers followed by different letters were significantly different based on the DMRT test at α = 5% level.

Table 2. The effect of row orientation and number of cowpea rows on the leaf number of maize at 2 WAP.

Row orientations	Number of cowpea rows		
	0	1	2
North-South	2.8±0.2b	3.3±0.3a	2.9±0.2b
East-West	3.0±0.4ab	2.8±0.4b	3.0±0.2ab

Note: Numbers followed by different letters were significantly different based on the DMRT test at α = 5% level.

Table 3. The effect of row orientation and number of cowpea rows on the stem diameter of maize at 2 WAP.

Row orientations	Number of cowpea rows		
	0	1	2
North-South	3.26±0.43b	3.94±0.58a	3.24±0.62b
East-West	3.37±0.86b	3.42±0.60b	3.68±0.77ab

Note: Numbers followed by different letters were significantly different based on the DMRT test at α = 5% level.

Row orientation had no significant effect on maize plant height, leaf number, and stem diameter. In contrast, the two-row cowpea treatment reduced maize plant height at 8 WAP, leaf number at 6 WAP, and stem diameter at 6 and 8 WAP, compared to the maize monoculture treatment (Table 4). Row orientation (North–South, East–West, and Northeast–Southwest) did not significantly affect maize growth or yield, as solar radiation was optimal at the experimental site, and maize, as a C4 crop, has a high capacity for utilizing light energy (Corrêa et al., 2019; Wirawan et al., 2023).

Row orientation had no significant effect on leaf area and leaf dry weight at 8 WAP, but the number of cowpea rows significantly affected both variables (Table 5). Although maize may benefit from nitrogen fixed by cowpea, interspecific competition in the intercropping system reduced plant height, leaf number, stem diameter, leaf area, and leaf dry weight. This was likely due to cowpea tendrils twining around maize stems, restricting maize growth.

Table 4. Plant height, leaf number, and stem diameter of maize at 6 WAP and 8 WAP.

Treatment	Plant height (cm)		Leaf number		Stem diameter (mm)	
	Plant age (weeks after planting)					
	6	8	6	8	6	8
Row orientations						
North-South	106.00	168.08	7.9	10.9	17.18	23.62
East-West	109.00	164.32	8.0	10.8	16.95	22.07
CVa (%)	11.20	12.90	12.7	6.4	12.70	10.70
Number of cowpea rows						
0	110.33	174.10a	8.3a	11.2	18.77a	26.06a
1	110.05	165.55ab	8.2a	10.8	17.49ab	21.77b
2	102.33	158.95b	7.3b	10.6	14.93b	20.70b
CVb (%)	12.6	6.4	9.3	4.5	14.30	10.10
Interaction	ns	ns	ns	ns	ns	ns

Note: Numbers followed by different letters in the same column were significantly different based on the DMRT test at α = 5% level. CVa = coefficient of variation of row directions, CVb = coefficient of variation of number of bean rows. ns = not significant.

Table 5. Leaf area and leaf dry weight of maize at 8 WAP.

Treatment	Leaf area (m^2)	Leaf dry weight (g)
Row orientations		
North-South	1.94	25.27
East-West	1.91	25.53
CVa (%)	24.1	18.80
Number of cowpea rows		
0	2.21a	29.28a
1	1.82b	24.60b
2	1.73b	22.33b
CVb (%)	9.9	14.9
Interaction	ns	ns

Note: Numbers followed by different letters in the same column were significantly different based on the DMRT test at α = 5% level. CVa = coefficient of variation of row directions, CVb = coefficient of variation of number of bean rows. ns = not significant.

Leaf area in intercropped maize decreased by 17.7% and 21.7% with one and two cowpea rows, respectively, compared to monoculture, resulting in narrower leaves. Leaf area is a critical factor, as larger leaf area enables more efficient solar radiation interception (Corrêa et al., 2019). An increase in leaf area index can enhance plant biomass and significantly improve photosynthetically active radiation (PAR) interception and radiation use efficiency (RUE) (Duan et al., 2024).

The row orientation treatment did not significantly affect maize yield components. However, the number of cowpea rows had a significant effect on maize yield (Table 6). Row orientation had no significant effect on maize growth and yield, likely because the study site is located at 6°33'49" S and 106°44'07", which lies in the tropics near the equator. The experiment was conducted from late June to mid-September, when the apparent solar movement shifted from the northern hemisphere toward the equator. During this period, sunlight fell almost perpendicularly on the canopy, providing full illumination regardless of row orientation. Astronomically, the sun reached its northernmost declination (+23.5°) at the June solstice (21 June 2024) and returned to the equator at the September equinox (22 September 2024) due to the 23.5° tilt of the Earth's axis. However, intercropping reduced maize ear weight, ear length, ear diameter, and yield compared to monoculture, except that ear diameter under one cowpea row was not significantly different. In this study, the east-west row orientation tended to reduce maize yield by 5.3% compared to the north-south orientation. The north-south row orientation provides narrower row spacing, allowing more direct light interception by the maize canopy (Insani, 2013).

Intercropping with one and two cowpea rows reduced maize yield by 17.5% and 27.8%, respectively, compared to monoculture (Table 6), due to interspecific competition for light, nutrients, and water (Pierre et al., 2022). Despite the application of organic fertilizer, cowpea likely competed for inorganic nutrients, especially P and K, intended for maize. Sufficient phosphorus (P) availability during the V6 to R1 stages is crucial for enhancing kernel weight and grain filling in maize (Ampong et al., 2024). Potassium application has a significant effect on thousand-kernel weight and grain yield of maize (Ul-Allah et al., 2020). Effective nutrient management in intercropping systems is essential for optimizing yield through the reduction of competition between component crops (Mohanty, 2024). The broad canopy and wrapping habit of cowpea may also have suppressed maize growth (Ceunfin, 2018). Although not statistically significant, one cowpea row tended to increase maize yield by 14.27% over two rows, likely due to wider spacing. A similar trend was observed where the closer spacing between soybean and maize reduced the ear weight of maize (Kim et al., 2018).

Table 6. Ear weight, length, diameter, and yield of maize at harvest.

Treatment	Ear weight		Ear length		Ear diameter (cm)	Yield (tons ha^{-1})
	With husks (g)	Without husks (g)	Total (cm)	Seeded (cm)		
Row orientations						
North-South	343.55	256.81	21.33	18.04	44.25	17.18
East-West	325.41	247.13	21.44	17.90	43.58	16.27
CVa (%)	26.30	27.80	9.20	11.30	7.10	26.30
Number of cowpea rows						
0	394.10a	291.73a	22.08	19.62a	45.37a	19.70a
1	325.00b	249.12b	21.35	17.53b	44.20a	16.25b
2	284.34b	215.06b	20.73	16.75b	42.18b	14.22b
CVb (%)	13.50	14.00	6.70	8.90	3.60	13.50
Interaction	ns	ns	ns	ns	ns	ns

Note: Numbers followed by different letters in the same column were significantly different based on the DMRT test at α= 5% level. CVa = coefficient of variation of row directions, CVb = coefficient of variation of number of bean rows. ns = not significant.

The planting row orientation had no significant effect on shoot dry weight, root dry weight, or 50% flowering time of cowpea. However, the number of cowpea rows had a significant effect on root dry weight (Table 7). The two cowpea rows produced a higher root dry weight than the one cowpea row treatment because the distance between cowpea and sweet corn was 20 cm, compared with 40 cm in the one cowpea row treatment. This closer spacing likely enabled cowpea plants in the two-row treatment to utilize more fertilizer intended for sweet corn. The taproot system of cowpea can penetrate the soil up to 2.4 m deep (Jonah et al., 2024), in contrast to the fibrous roots of maize, which absorb nutrients mainly from the soil surface (Wang et al., 2024).

Cowpea grown in monoculture produced similar shoot and root dry weights to those grown in intercropping, except in the east–west monoculture with two rows, which showed a higher root dry weight of 3.15 g (Table 8). These results indicate that cowpea can adapt well when intercropped with corn.

Row orientation and number of cowpea rows had no significant effect on cowpea yield components and dry seed productivity (Table 9), likely due to shading from the maize canopy. However, the East-West orientation showed a potential yield increase of 14.6% compared to North-South, and a single cowpea row produced 8.5% higher yield than two rows, likely due to reduced inter-plant shading. Similarly, greater soybean yield was observed at wider spacing from maize, though not significantly different (Kim et al., 2018). The advantage of East-West orientation in maximizing intercropping yield was also reported in different ecological zones (Coulibaly et al., 2024).

Table 7. Shoot and root dry weight and flowering times of intercropped cowpea at 54 DAP.

Treatment	Shoot dry weight (g)	Root dry weight (g)^{tr}	50% flowering times (DAP)
Row orientations			
North-South	37.46	1.91	46.9
East-West	37.56	1.78	46.9
CVa (%)	18.50	24.70	1.5
Number of cowpea rows			
1	27.98	1.55b	47.8
2	47.04	2.14a	46.0
CVb (%)	15.50	10.30	4.2
Interaction	ns	ns	ns

Note: ^{tr} = data were transformed to $\sqrt{x}$ prior to ANOVA. Numbers followed by different letters in the same column were significantly different based on the DMRT test at α = 5% level. CVa = coefficient of variation of row directions, CVb = coefficient of variation of number of bean rows. ns = not significant.

Table 8. Shoot and root dry weight and flowering times of monoculture cowpea at 54 DAP.

Treatment	Shoot dry weight (g)	Root dry weight (g)	50% Flowering times (DAP)
Monoculture NS1	37.29	1.70	45
Monoculture NS2/EW2	33.83	3.15	46
Monoculture EW1	38.49	1.81	45

Note: NS1 = North-South row orientation and single row of cowpea, NS2 = North-South row orientation and two rows of cowpea, EW1 = East-West row orientation and single row of cowpea, EW2 = East-West row orientation and two rows of cowpea. Data were not tested using the F-test.

Table 9. Number of pods per plant, pod weight per plant, number of seeds per pod, seed weight per pod, weight of 100 grains, and productivity of intercropped cowpea at harvest.

Treatment	Number of pods per plant	Pod weight per plant (g)	Number of seeds per pod	Seed weight per pod	Weight of 100 grains (g)	Productivity (tons ha^{-1})
Row orientations						
North-South	17.1	31.14	9.8	1.29	14.10	1.37
East-West	18.4	34.88	9.9	1.38	14.86	1.57
CVa (%)	19.4	14.6	2.1	11.40	10.30	18.40
Number of cowpea rows						
1	18.1	34.30	9.9	1.37	14.57	1.53
2	17.4	31.72	9.7	1.30	14.39	1.41
CVb (%)	13.1	14.7	4.7	13.70	6.20	17.80
Interaction	ns	ns	ns	ns	ns	ns

Note: Numbers followed by different letters in the same column were significantly different based on the DMRT test at α= 5% level. CVa = coefficient of variation of row directions, CVb = coefficient of variation of number of bean rows. ns = not significant.

The cowpea yield observed in this study was below the potential yield of 3.88 tons ha^{-1} under both intercropping and monoculture systems (Table 10). This suboptimal performance is likely attributed to the shading effect of maize canopies in the intercropping system, which reduced the availability of solar radiation to the cowpea plants. The Albina IPB variety used in this study may be light-sensitive, and inadequate light interception could have limited photosynthetic efficiency, thereby restricting vegetative growth and reproductive development. This is consistent with previous findings, which reported that sole cowpea cropping allows greater light interception than intercropping. Although differences in light interception efficiency among cowpea varieties were observed, they were not statistically significant (Nuhu et al., 2017).

Insufficient inorganic fertilization may also contribute to suboptimal cowpea yield. Previous research indicates that NPK application can enhance cowpea grain yield by 22%–40% under various environmental conditions (Obour et al., 2024). Moreover, in this study, the cowpea plant population in the monoculture system was maintained equal to that in the intercropping system, which may have contributed to the relatively low monoculture yield. While lower plant densities provide more space for individual plant growth, they generally lead to reduced yield per unit area (Neonbeni et al., 2019).

Table 10. Number of pods per plant, pod weight per plant, number of seeds per pod, seed weight per pod, weight of 100 grains, and productivity of monoculture cowpea at harvest.

Treatment	Number of pods per plant	Pod weight per plant (g)	Number of seeds per pod	Seed weight per pod	Weight of 100 grains (g)	Productivity (tons ha^{-1})
Monoculture NS1	20.8	33.63	10.1	1.11	13.76	1.43
Monoculture NS2/EW2	23.9	41.50	9.6	1.19	12.57	1.77
Monoculture EW1	20.6	35.36	9.1	1.15	14.20	1.48

Note: NS1 = North-South row orientation and single row of cowpea, NS2 = North-South row orientation and two rows of cowpea, EW1 = East-West row orientation and single row of cowpea, EW2 = East-West row orientation and two rows of cowpea. Data were not tested using the F-test.

Intercropping treatments showed LER > 1, R/C ratio > 1, positive cowpea aggressivity, and a higher cowpea competitive ratio (Table 11). The highest LER (1.93) and R/C ratio (1.45) were observed in the East–West orientation with a single cowpea row. Total LER for maize and cowpea was significantly higher in the East–West orientation compared to North–South (Coulibaly et al., 2024). Similarly, other studies have indicated that an intercropping R/C ratio above 1 signifies a profitable and efficient farming system (Lubis et al., 2020).

Aggressivity values were positively correlated with the higher competition ratio of cowpea compared to maize, indicating that cowpea was more aggressive and competitive. This was likely due to cowpea vines wrapping around maize plants, restricting their growth and reducing maize yield. The competition ratio supports the aggressivity value, as more aggressive crops tend to compete more strongly (Ceunfin et al., 2017). Additionally, a positive AYL value indicated that the intercropping system produced 42–69% higher yields compared to monoculture, as maize occupied only 50% of the land area, resulting in greater land-use efficiency.

Table 11. Effect of row direction and number of cowpea rows on LER, R/C, aggressivity, competitive ratio, and actual yield loss.

Treatment	LER	R/C	Aggressivity		Competitive Ratio		Actual Yield Loss	
			Maize	Cowpea	Maize	Cowpea	Maize	Cowpea
Intercropping NS1	1.83	1.43	-0.43	0.43	0.79	1.27	0.61	0.02
Intercropping NS2	1.43	1.26	-0.03	0.03	0.98	1.02	0.42	-0.28
Intercropping EW1	1.93	1.45	-0.47	0.47	0.78	1.28	0.69	0.08
Intercropping EW2	1.60	1.30	-0.26	0.26	0.85	1.18	0.47	-0.13

Note: NS1 = North-South row orientation and single row of cowpea, NS2 = North-South row orientation and two rows of cowpea, EW1 = East-West row orientation and single row of cowpea, EW2 = East-West row orientation and two rows of cowpea.

CONCLUSIONS

A significant interaction between row orientation and the number of cowpea rows was observed on plant height, leaf number, and stem diameter of maize at two weeks after planting. Although row orientation did not significantly affect maize and cowpea performance, the East–West orientation increased cowpea yield by 14.6% and reduced maize yield by 5.3% compared to the North–South orientation. The number of cowpea rows had a significant effect on maize yield, with one and two rows of cowpea reducing maize yield by 17.5% and 27.8%, respectively, relative to monoculture. In contrast, the number of cowpea rows did not significantly affect cowpea yield; however, intercropping with one row of cowpea increased cowpea yield by 8.5% compared to two rows. The intercropping systems exhibited LER and R/C ratio > 1, indicating agronomic and economic advantages over monoculture. Competitive analysis showed that cowpea was more dominant than maize in utilizing growth resources within the intercropping system. Based on these findings, intercropping maize with one row of cowpea in an east–west row orientation is recommended as the most efficient configuration.

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