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Optimizing Cassava and Bottle Gourd Intercrop Yields through Varying Plant Densities under the North Delta Conditions

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A study was conducted to assess competitive guide in intercropping cassava (*Manihot esculenta* Crantz) and bottle gourd (*Lagenaria siceraria*) to enhance both crops' productivity. Field experiments were performed at Sakha Horticultural Research Station in North Delta during the 2022 and 2023 growing seasons. The research examined the impact of intercropping cassava with bottle gourd at varying cassava plant densities (2.0 x0.5 m, 2.0 x1.0 m, and 2.0 x 1.5 m) while maintaining a constant 2 x 1 spacing for bottle gourd on the growth, yield, and yield elements from both crops. A randomized complete block design with three repetitions was utilized for the study. The findings make known that the highest cassava root yield was achieved with the closest cassava wideness (2.0 x 0.5 m). Conversely, the greatest bottle gourd yield was observed when intercropped with cassava at the widest cassava plant spacing (2.0 x1.5 m) through both seasons. The maximum total land equivalent ratio (LER) was achieved whenever cassava was planted at 2.0 x 1.0 m spacing and intercropped with bottle gourd in the two seasons. For the maximum total area time equivalent ratio (ATER), 2.0 x 0.5 and 2.0 x 1.0 gave the highest values without significant differences.

Keywords: *Manihot esculenta Crantz, Lagenaria siceraria*, Intercropping, Plant spacing, LER, ARTM, CR.

1. Introduction

By 2050, the world's population is expected to surpass 10 billion people, necessitating a 70% increase in agricultural output and 100 trillion hectares of arable land (Van Dijk et al., 2021; Pastor et al., 2019). One of the most significant agro-global concerns is crop production, specifically the challenge of output in the face of shifting environmental conditions. This production must be boosted to meet the world's needs for fuel, fiber, feed, and food (El-Ramady *et al.*, 2020). Plant production systems around the world, such as horticulture, forestry, and agriculture, are struggling to meet these diverse needs, which are essential for accomplishing many of the Sustainable Development Goals set forth by the UN. Introducing a new and advantageous crop to a nation's culture is a significant contribution that may be offered to any nation. Oil-producing plants, traditional food crops, and high-fiber pulp crops are examples of emerging, promising crops (Jolliff and Snapp, 1988).

Cassava (Manihot esculenta Crantz), a woody shrub that grows perennially and originates from the Amazon basin, is known for its edible roots that store starch, is now widely grown throughout the tropics and subtropics and

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is regarded as a "climate-smart" crop capable of thrive in harsh conditions (El-Sharkawy 2006). Cassava, which ranks third among crops after rice and maize, is essential to many people's lives and global food security (Hyman *et al*., 2012 and Howeler *et al*., 2013). According to FAO statistics, the area dedicated to cassava cultivation expanded from 16.8 million ha in 1994 to 28.2 million ha in 2020 (FAO, 2022). In 2022, more than 330 million tons (32.04 million hectares) cultivated cassava was produced in the African continent, Asia, and South and Central American nations (FAO, 2024). Cassava flour can be used to replace up to 30% of the wheat in bread production. Moreover, dried cassava chips can substitute 20–25% of maize in animal feed. The crop is versatile, serving as both human food (its roots) and fodder for sheep, camels, and other livestock**.** Cassava can be cultivated profitably in Egypt on low-fertility soils. It is an inexpensive crop to produce and ranks among the most affordable food sources. Cassava is a long-duration crop, so growing it as a single crop is not cost-effective. It also underutilizes soil and has no market in Egypt at the moment. In addition, the large spacing between rows and the way the plants grow allows for the growth of vegetables between cassava rows, which diversify production. Due to cassava has a slow initial growth, intercropping with cowpea, maize, watermelon, and groundnut is widely applied (Jala *et al*., 2019; Ravi *et al*., 2021). Because bottle gourd is a productive crop and shares about half of the season with cassava, intercropping with it is beneficial.

Bottle gourd is one of the most important cucurbit vegetables thrive in tropical and subtropical regions (Achigan *et al*., 2006). It can adapt to challenging soil conditions, including water scarcity, high salinity, and soil-borne diseases, as the Delta region conditions (Abd Alla *et al*., 2013; Ibrahim and Elkader, 2015). It is a creep plant known by various names across various countries, including, white-flowered gourd, and long melon, is cultivated for its fruit. The bottle gourd can be harvested young for vegetable consumption or allowed to mature (Decker-Walters *et al*., 2001). It is a highly nutritious crop with great importance as a health staple, The fruit of bottle gourd can grow to a length of 1 meter, featuring a smooth, light green exterior and white interior (Shefali *et al*., 2024). The bottle gourd seeds are rich in phytochemicals, vitamins, minerals, amino acids, and fatty acids. The seed kernels contain 45% oil and approximately 35% protein (Lokesh *et al*., 2024). These seeds serve as superior source of essential fatty acids, including omega-3 and omega-6, also antioxidants. They have potential as a protein supplement in cereal-based complementary diets or as a substitute for animal proteins in conventional foods (Ogunbusola *et al*., 2010). The addition of bottle gourd seed corn flour to bread can enhance both quality and nutritional value. In Egypt, the bottle gourd is cultivated primarily for its seeds, which are extracted to produce oil used in salads (Hegazy and El Kinawy 2011) and consumed as a snack.

In tropical regions, the practice of intercropping cassava with legumes has gained popularity. When compared to monocultures, competition emerged as the primary factor significantly affecting the growth rate and yield of intercropped plant species. Higher yields were observed in intercropping systems when interspecific competition was less severe than intraspecific competition (Caballero *et al*., 1995; Mbah *et al*., 2008; Zhang *et al*., 2011 and Hidoto and Loha, 2013). Metrics such as land equivalent ratio (LER), area time equivalent ratio (ATER), and competitive ratio (CR) can be utilized to assess the competitive and agronomic advantages of intercropping (Willey and Rao, 1980; Weigelt and Jolliffe, 2003). Intercropping, a method commonly employed on the scale of small farmers in developing nations, involves planting two or more crops at the same time or non- at the same time in the same field to optimize resource utilization (Rodrigues and Mederiros 2018). This approach has been widely renowned for its significant advantages in enhancing yield, managing pests and diseases, and conserving land, particularly in developing countries. Crop yield in both monocultures and intercropping systems can be influenced by the locative arrangement of plants, which can be adjusted by modifying the distance between planting rows or plants within the oneself row (Doubi *et al*., 2016; Ribeiro *et al*., 2018; Amoako *et al*., 2022; El-Habbakb and El-Mehy, 2023 and Wang *et al*., 2024). Incorporating cassava and bottle gourd as novel crops in the Egyptian cropping structure is crucial for providing alternative means to boost farm income through product diversification, market expansion, and increased exports. This integration can contribute to economic growth in rural areas. Furthermore, both crops serve as potential sources of new human foods and animal feeds, and they exemplify excellent plant models for intercropping in tropical and subtropical regions (Jolliff, 2004; Enete, 2009).

So, the goal of this research is to analyze the vegetative development and yield of cassava and bottle gourd in diverse populations. Additionally, using competition indices identify the most hopeful cropping systems that incorporate cassava and bottle gourd, focusing on their agronomic benefits for root production (cassava) and seed yield (bottle gourd).

2. Materials and Methods

2.1. Study area

The study was conducted at the experimental farm of the Sakha Horticultural Research Station in Kafr El-Shaikh Governorate, Egypt, during the summer seasons of 2022 and 2023. The investigation focused on evaluating the impact of various plant spacings in cassava-bottle gourd intercropping on the growth, yield, and yield components of both crops. Located approximately 6 meters above sea level, the research site's coordinates are 31.094059◦ N, 30.933899◦ E. To analyze physical and chemical properties, soil samples were collected from the experimental farm at a depth of 0-30 cm. These analyses followed the methodologies described by Page (1982) and Klute (1986). Table 1 presents a selection of the soil characteristics examined, and Table 2 presents the location's average temperature and relative humidity.

TABLE 1. Some Chemical and physical properties of the soil of experimental location (average of two years)

EC, dS m^{-1}	pH	OM (%)	Soluble cations (meq/L)				Soluble anions (meq/L)			Particle size distribution			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	So_4^{--}	Clay %	Silt %	Sand %	Texture
8.28	7.42	1.23	1.8	2.3	5.4	0.14	3.2	3.5	3.2	49.5	26.3	24.2	Clay

TABLE 2. Location weather data for monthly average in Kafr El-Sheikh Governorate

Seasons	2022				2023			
Month	Air temperature(°C)		Relative humidity (%)		Air temperature (°C)		Relative humidity (%)	
	Min.	Max.	7:30	13:30	Min.	Max.	7:30	13:30
April	19.6	27.6	76.5	45.5	16.7	26.8	81.8	53.6
May	21.7	29.0	79.6	44.4	19.2	29.3	87.8	51.5
June	25.5	31.3	81.6	50.4	23.8	31.8	86.4	53.1
July	25.5	33.3	64.9	77.7	24.8	34.7	93.0	55.5
August	25.9	34.3	77.1	68.5	25.5	33.5	91.3	59.9
September	23.9	30.9	83.6	55.2	24..5	34.1	91.8	57.5
October	20.8	28.8	90.9	60.6	22.5	30.2	91.5	60.3
November	16.6	25.5	92.1	61.9	17.9	25.8	92.5	65.1
Mean	22.4	30.1	77.1	60.5	21.9	30.8	89.5	57.1

Source: Sakha Agriculture Research Center Meteorological Station

2.2. Treatments, experimental design, and planting materials

The study employed a randomized complete block design (RCBD) with three replications over two years. Treatments were randomly allocated to plots measuring 7.0 x 4.0 m (28 m^2). Bottle gourd plants were maintained at a density of 1900 plants/fed (2.0 × 1.0 m), while cassava plant density varied in intercropping treatments. The cassava plant spacing in intercropping treatments were as follows:

- T1= 2.0 x 0.5 m (3800 plant/fed.)
- T2= 2.0 x1.0 m (1900 plant/fed.)
- T3= 2.0 x 1.5 m (1266 plant/fed.)
- Sole cassava = 1.0 x 0.5 m (7600 plant/fed.).

Indonesia cultivar cassava cuttings were planted on April 1st and 5th in 2022 and 2023, respectively. The cuttings, 25-30 cm in length, were manually inserted vertically at a depth of approximately 10-12 cm. A local bottle gourd variety, sourced from the Cross Pollinated Vegetables Crops Department of the Horticulture Research Institute, was sown manually with two or three seeds per hill, later thinned to the required densities. The cassava stayed with the bottle gourd for about six months. Agricultural practices adhered to the guidelines set forth by the Agriculture Ministry. Also, common cultural practices were followed for diseases, insects and weeds control.

2.3 Studied parameters

Three cassava plants per each replicate were randomly taken, 180 days after the planting date to determine highest point of plant (cm), number of stems/plant, stem diameter (cm), and total chlorophyll. Additionally, at harvest time three plants per replicate were randomly harvested, 270 days after the planting date to determine the no of roots / plant, length, and diameter (cm) of root, root weight (kg/plant), and total yield per feddan, each plot was harvested and root yield was determined in kg/plot, then it was converted to estimate yield per feddan in ton fed^{-1}. Samples of cassava roots were dried in a forced air oven at 70 ^{0}C until constant weight, and ground to determine starch content according to **Subroto *et al.*, (2020).**

To measure leaf area (cm^2) and total chlorophyll, three bottle gourd plants were randomly selected from each experimental unit 45 days after the sowing date. At harvest, a random sample of five plants was selected from each plot to measure fruit length and diameter (cm), fruit weight (g), fruit weight (100 seeds), and total yield (kg/fed). A portable leaf area meter (LI-3100-LI-COR, Lincoln, Nebraska, USA) was used to measure the area of the plant leaves. Using a SPAD-502 meter (Minolta Inc., Osaka, Japan), the amount of chlorophyll in the leaves was calculated. employing portable chlorophyll absorbance meters, which use absorbance at 650 and 940 nm to generate an index **(Mielke et al. 2012).** Following the harvest of each plot, the seed yield was calculated in kilograms per plot and converted to an estimated yield per feddan in kilograms fed^{-1}.

2.4. Competitive relationships

I. Land Equivalent Ratio (LER)

As described by **Mead and Willey (1980),** it was as follows.

$LER = LER_c + LER_b$

$LER_c = Y_{cc}/Y_{ci}$ $\qquad$ $LER_b = Y_{bb}/Y_{bi}$

Where, Y_{cc} and Y_{bb} are the yields per feddan of cassava and bottle gourd, respectively, as sole crops and Yci and Ybi are intercrop yield of cassava and bottle gourd, respectively**.**

II. Area Time Equivalent Ratio (ATER)

It was calculated according to the following equation:

$ATER = (ATER_{cassava} + ATER_{bottle\ gourd})$;

$ATER_{cassava} = (Y_{ci}/Y_{cc}) * (T_c/T)$ $\qquad$ $ATER_{bottle\ gourd} = (Y_{bi}/Y_{bb}) * (T_b/T)$

Y_{ci} and Y_{bi} intercrop yield of cassava and bottle gourd, Y_{cc} and Y_{bb} Sole yield of cassava and bottle gourd, respectively. T_c, T_b, and T the duration of cassava in days (270 days), bottle gourd in days (180 days), and the total duration of the intercropping system in days, respectively **(Hiebesch and McCollum, 1987).**

III. Competitive Ratio (CR)

The competitive ratio was calculated by the formula proposed by **Willey and Rao (1980**):

$CR_{cassava} = (LER_{cc}/LER_{bb}) * (P_{bi}/P_{ci})$

$CR_{bottle\ gourd} = (LER_{bb}/LER_{cc}) * (P_{ci}/P_{bi})$.

Where P_{ci} is the sown proportion of cassava in the mixture with bottle gourd and P_{bi} is the sown proportion of bottle gourd in the mixture.

If CR cassava > 1, cassava is more competitive than bottle gourd, and if CR cassava < 1, then cassava is less competitive than bottle gourd (**Zhang *et al*., 2011**)

2.5 Statistical Analyses

With the use of the COSTAT software, the data from this study were statistically examined, and differences between treatment means were deemed significant when they exceeded the L.S.D. at 5%.

3. Results

3.1. Effect of plant density on cassava growth, yield, and its components

Table 3 displays the mean performance of cassava intercropped with bottle gourd regarding growth, yield, and associated components (including plant height, number of stems per plant, stem diameter, number of roots, root length, and diameter, and yield per plant) for the 2022 and 2023 seasons. The findings indicate that plant density significantly influenced all traits. As the distance between plants increased, plant height decreased. Sole cassava notably affected plant height in both seasons. Additionally, the cropping system and cassava density significantly influenced root diameter and root length in both 2022 and 2023 (Table 3).

TABLE 3. Effect of plant density on cassava growth, yield, and its components during 2022 and 2023

Treatment	Plant height (cm)	Stems number plant^{-1}	Stem diameter (cm)	Root number plant^{-1}	Root length (cm)	Root diameter (cm)	Yield plant^{-1} (kg)
				1st Season			
Sole	240.00a	1.87 c	1.84 c	3.99 b	30.43 c	8.04 c	1.75 d
T1	210.17 b	2.13 b	2.68 bc	3.54 c	26.67 d	7.50 d	2.09 bc
T2	186.98 c	2.80 b	3.47ab	5.06 a	34.27 b	8.59 b	2.45 ab
T3	161.25 d	3.77 a	4.16 a	5.33 a	36.87 a	9.75 a	2.95 a
LSD $_{0.05}$	22.574	0.460	0.908	0.371	1.456	0.317	0.395
				2nd Season			
Sole	258.33 a	1.93 d	1.97 c	4.32 b	32.27 c	8.37 c	1.91 d
T1	231.83 b	2.53 c	2.74 bc	3.96 b	28.63 d	7.79 d	2.31 c
T2	206.83 c	3.08 b	3.75 ab	5.27 a	36.61 b	8.86 b	2.79 b
T3	180.00 d	3.93 a	4.29 a	5.44 a	40.03 a	9.88 a	3.22 a
LSD $_{0.05}$	17.983	0.52	1.154	0.421	1.322	0.350	0.268

Sole cassava 1* 0.5m T1= cassava 2*0.5 m T2= cassava 2*1 m T3= cassava 2* 1.5 m

When compared to the other treatments in both seasons, the T3 treatment (2 x 1.5 m) produced the greatest values for the number of stems per plant, stem diameter, number of roots per plant, length, root diameter, and root yield per plant. The maximum cassava spacing (T3=2.0 x 1.5 m) produced the highest yield per plant. On the other hand, in the two seasons, the lowest value was linked to the lowest cassava spacing (T1= 2.0 x 0.5 m). However, in terms of stem diameter and the number of roots per plant in both seasons, there is no discernible difference between the T2 and T3 treatments. As plant density grew, cassava root yield per feddan increased as well (Figure, 1). The highest yield per feddan (10.11 and 10.5 tons) was obtained from the sole cassava (1 x 0.5 m), in contrast, the lowest yield per feddan (3.77 and 4.33 tons) was from treatment T3 in both seasons, respectively.

As shown in Fig. 2, total chlorophyll and starch percentage were significantly increased with decreasing plant density in both seasons. In both seasons, treatment T3 produced the highest levels of total chlorophyll (18.11 and 19.03, respectively). Other than that, solo cassava produced the lowest readings in both seasons (13.54 and 13.92, respectively). Likewise, the highest values of starch % (28.17%, 30.63%) were recorded by T3 treatment in both seasons, respectively.

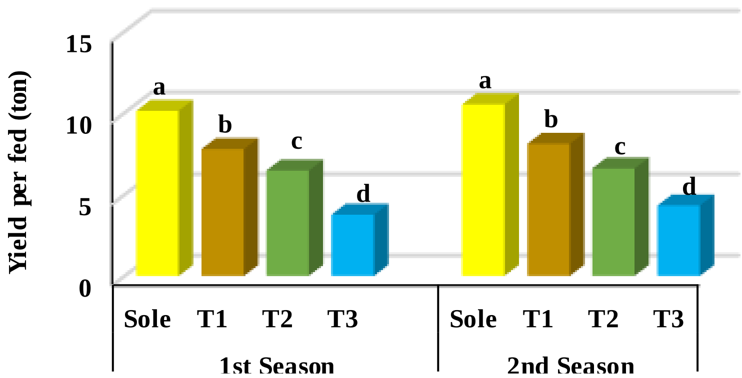

Fig. 1. Effect of plant density cassava on cassava total yield per feddan during 2022 and 2023
Sole cassava=1*0.5 m T2= cassava 2*0.5 m T2= cassava 2*1 m T3= cassava 2* 1.5 m

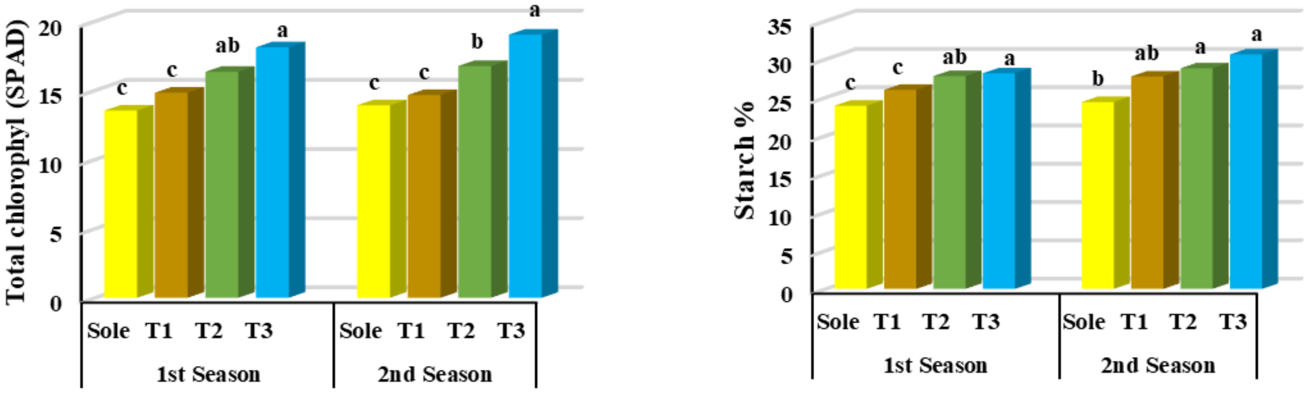

Fig. 2. Effect of plant density cassava on total chlorophyll and starch % during 2022 and 2023
Sole cassava=1*0.5m T2= cassava 2*0.5 m T2= cassava 2*1 m T3= cassava 2* 1.5 m

3.2. Effect of plant density on bottle gourd yield and its components

The effect of cassava plant density on bottle gourd yield and its components during 2022 and 2023 is shown in Table 4. The highest fruit length (72.3 and 75.0cm), fruit diameter (38.5 and 40.83 cm), weight of seeds per fruit (116.4 and 120.8 g), weight of 100 seed (23.94 and 27.32 g), yield per feddan (821.3 and 830.2 kg) were obtained from sole bottle gourd during the two seasons respectively, while T1 treatment gave the lowest values for all traits in both seasons. Data in Fig. 3, show the effect of treatments on total chlorophyll and leaf area. The results demonstrated that total chlorophyll and the leaf area were increased under the sole bottle gourd in both seasons. Therefore, sole bottle gourd gave the highest values of total chlorophyll (14.1 and 14.3) while T1 treatment gave the lowest ones (13.63 and 13.80) in both seasons, respectively. Likewise, the sole bottle gourd gave the highest values of leaf area (414.33 and 425 cm^2). In contrast, T1 treatment recorded the lowest values (379.33 and 387.33 cm^2) compared to other treatments in both seasons, respectively.

TABLE 4. Effect of plant density on bottle gourd yield, and its component during 2022 and 2023

Treatment	Fruit length (cm)	Fruit diameter (cm)	Weight of seed/fruit (g)	Weight of 100 seed (g)	Yield (kg /fed.)
			1st Season		
Sole	72.30 a	38.50 a	116.40 a	23.94a	821.33a
T1	55.80 c	30.34 c	88.63d	15.17 c	501.67d
T2	60.70 bc	32.43 b	93.80 c	17.65 b	663.43c
T3	66.50 ab	34.05 b	105.b	21.64a	725.33b
LSD $_{0.05}$	10.00	2.07139	5.1557	2.30	18.72
		2nd Season			
solid	75.00 a	40.83 a	120.83 a	27.32a	830.17a
T1	59.00 b	31.83 c	96.60 d	17.00d	518.57d
T2	66.00 ab	34.47 b	100.57 c	19.53c	674.57c
T3	70.00 a	36.30 b	112.67b	22.50b	737.67b
LSD $_{0.05}$	9.10	2.056	3.11	1.79	16.66

Sole= Bottle gourd 2*1 m T1= cassava 2*0.5 m T2= cassava 2*1 m T3= cassava 2* 1.5 m

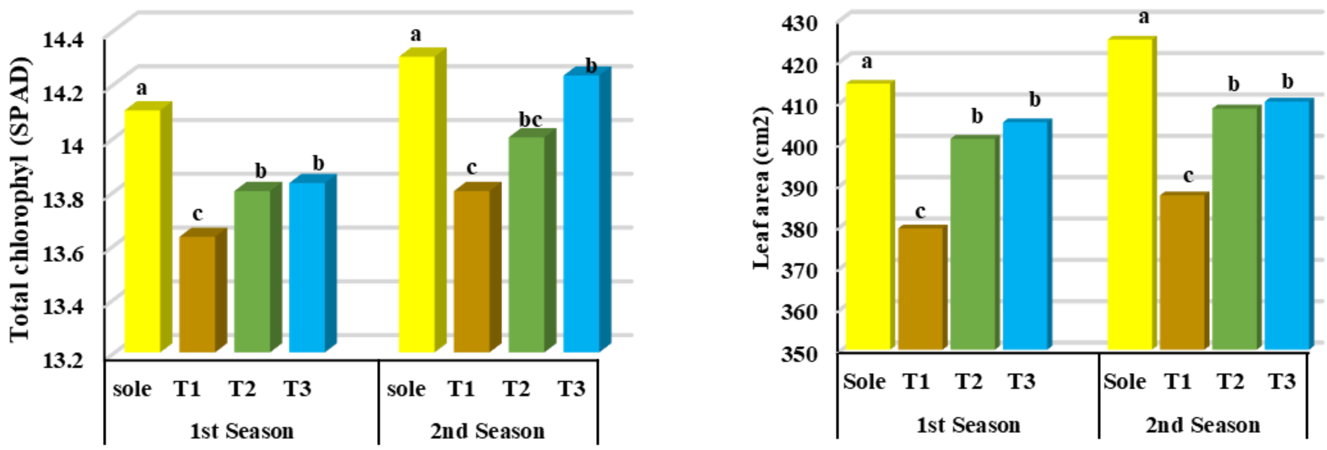

Fig. 3. Effect of plant density on bottle gourd total chlorophyll and leaf area during 2022 and 2023 seasons

Sole= Bottle gourd 2*1 m T1= cassava 2*0.5 m T2= cassava 2*1 m T3= cassava 2* 1.5 m

3.3. Competitive indices

The Land Equivalent Ratio (LER) and Area Time Equivalent Ratio (ATER) were significantly impacted by intercropping combinations during both growing seasons, according to the data analysis shown in Table 5. As a result, during both growth seasons, the T2 treatment had the greatest total LER values (1.447 and 1.441), whereas the T3 treatment had the lowest (1.256 and 1.301).

TABLE 5. Effect of plant density on LER and ATER during 2022 and 2023

Treatments	LER			ATER		
	Cassava	Bottle gourd	Total	Cassava	Bottle gourd	Total
			1st Season			
T1	0.769a	0.611c	1.38b	0.769a	0.409c	1.18a
T2	0.639b	0.808b	1.447a	0.637b	0.541b	1.17a
T3	0.373c	0.883a	1.256c	0.373c	0.592a	0.97b
LSD 0.5	0.058	0.028	0.065	0.0578	0.019	0.061
			2nd Season			
T1	0.772a	0.625c	1.397b	0.772a	0.419c	1.19a
T2	0.628b	0.813b	1.441a	0.628b	0.545b	1.17a
T3	0.412c	0.889a	1.301c	0.412c	0.595a	1.01b
LSD 0.5	0.049	0.017	0.039	0.048	0.012	0.0412

T1= cassava 2*0.5 m T2= cassava 2*1 m T3= cassava 2* 1.5 m

Similarly, the T1 and T2 treatments resulted in the highest total ATER values (1.18 and 1.17), (1.19 and 1.17) for both seasons, respectively. In contrast, the T3 treatment yielded the lowest ATER values (0.97 and 1.01) in both seasons. Regarding the Competitive Ratio (CR), the T1 treatment showed a value greater than one (1.26) for cassava, indicating its superior competitive ability compared to bottle gourd. Conversely, when intercropped with bottle gourd at low density (T3) cassava's CR value fell below one in both seasons, as shown in Table 6.

TABLE 6. Effect of plant density on the competitive ratio (CR) during 2022 and 2023

Treatments	Competitive ratio (CR)	
	Cassava	Bottle gourd
	1st Season	
T1	1.26a	0.794b
T2	0.395b	0.632b
T3	0.211c	1.192a
LSD $_{0.5}$	0.036	0.1774
	2nd Season	
T1	1.24a	0.811b
T2	0.386b	0.647c
T3	0.232c	1.081a
LSD $_{0.5}$	0.095	0.086

T1= cassava 2*0.5 m T2= cassava 2*1 m T3= cassava 2* 1.5 m

4. Discussion

The study evaluated the growth and yield of cassava (*Manihot esculenta*) and bottle gourd (*Lagenaria siceraria*) under different plant densities, focusing on the effects of different planting spacings on their vegetative development and production capacity. By analyzing multiple plant population configurations, the researchers sought to identify the ideal density for maximizing harvest while sustaining plant health. The findings from this investigation could offer valuable guidance to farmers and agricultural experts looking to enhance their cultivation techniques for cassava and bottle gourd. An additional objective was to assess various cropping systems using competition indices to determine those with the greatest agronomic benefits. These systems were examined for their ability to optimize both root yield (cassava) and seed yield (bottle gourd). Among the tested treatments, intercropping notably affected the vegetative characteristics and yield components of cassava. However, cassava exhibited different growth patterns in intercropping versus sole cropping scenarios. Sole cassava demonstrated highly significant effects on plant height during both growing seasons. This could be attributed to the quicker seedling establishment and enhanced vegetative growth and ground coverage of bottle gourd, which hindered cassava's development, potentially impacting its height and other parameters. Salau *et al*. (2011) noted faster seedling growth of pumpkin during the early stages of cassava growth. Conversely, improvements in other factors such as the number of stems per plant, stem diameter, number of roots, root length and diameter, yield per plant, total chlorophyll, and starch percentage were observed in the T3 treatment (cassava 2 x 1.5 m). This suggests that when plant density was decreased, cassava had a better opportunity to thrive alongside bottle gourd.

The results of our study correspond with these ones reported by Mansaray *et al.* (2022), who notice increased root and grain production when intercropping grain legumes with cassava. This aligns with Kurtz (2006), who documented enhanced yields and yield-related factors for cassava in soybean intercropping systems compared to monocropped cassava. Nevertheless, sole cassava cultivation yielded a higher final output per faddan than other treatments, supporting the conclusions of Njoku and Muoneke (2008). They found that monocropped cassava systems produced higher yields due to reduced competition for growth resources. An additional explanation for this could be the lower plant density in sole cropping, which enables better utilization of sunlight and other growth factors. During the second season, particularly in September and October, we noted a rise in temperature and relative humidity. This change positively affected growth and biomass production, as increased heat leads to alterations in morphological composition, primarily through an increase in leaf count and stem diameter. Cassava plants exhibit high photosynthetic rates at temperatures ranging from 25–40°C, which contributes to their biomass production (El-Sharkawy, 2006; de Oliveira *et al*., 2022; Forbes *et al*., 2020). The research results indicated notable differences in how plant density affected the intercropping of cassava with bottle gourd, affecting the latter's vegetative growth, yield, and related components across two growing seasons. Sole bottle gourd cultivation produced the most impressive results in terms of fruit length, fruit diameter, seed weight / fruit, 100-seed weight, and yield / feddan. These observations align with the results of Mbah and Ogidi (2012) in their study of cassava-soybean intercropping. Furthermore, our outcomes corroborate those of Adeniyan *et al*. (2014), who observed that increasing plant density leads to increased grain yield. Our research indicated that the elevated yield across all bottle gourd treatments during the second season might be attributed to environmental factors. The high temperatures, extended daylight hours, and increased relative humidity prevalent in June and July likely contributed to a higher ratio of female to male flowers. This shift in flower distribution appears to be a key factor in boosting overall production and, consequently, enhancing crop yield.

The findings also demonstrated an increased land equivalent ratio (LER) for the cassava-bottle gourd intercropping system, suggesting that this combination yielded higher productivity per unit area compared to monocropping. This observation range with the work of Mbah *et al*. (2009), who noticed that yield advantages in cassava-soybean mixtures relative to other cropping methods. The diverse growth patterns and lifecycles of the combined crops resulted in differing resource requirements at various stages, enabling more efficient temporal use of growth resources. This phenomenon explains the frequent yield benefits associated with intercropping systems (Mbah and Muoneke, 2007). The area-time equivalent ratio (ATER), which evaluates both land and time efficiency, exhibited a comparable trend. T1 (1.18 and 1.19) and T2 (1.17 and 1.17) exhibited the highest overall ATER values across both seasons. These figures indicate superior productivity per unit of land and time, reflecting more effective utilization of both resources in comparison to other treatments. Conversely, T3 displayed the lowest ATER values, recording 0.97 and 1.01 in the respective seasons.

The data indicates that T3 was less productive in terms of land and time utilization, possibly due to increased competition or suboptimal crop combinations. Plant communities with low competition have been shown to achieve excellent Land Equivalent Ratio (LER) performance (Nassab *et al*., 2011 and Zhang *et al*., 2011). LER values exceeding 1.00 have been documented for various intercropping systems, including sorghum-bottle gourd and cassava-legumes (Chimonyo *et al*., 2016; Islami *et al*., 2011; Mbah and Ogidi, 2012 and Hidoto and Loha, 2013).

Comparable findings demonstrating enhanced environmental resources employment in intercropping have been reported by Aasim *et al*. (2008), Doubi *et al*. (2016), Hussien and Shamy (2017), and Amoako *et al.,* 2022 for different crop combinations such as cotton with cowpea, wheat with peanut, cassava with bottle gourd, garlic with sugar beet, and cassava with cowpea, respectively. Regarding competitive abilities in intercropping (CR), the CR value for cassava in T1 exceeded unity, indicating its superior competitive ability compared to bottle gourd. Conversely, the CR value for cassava in T3 was below unity when intercropped with low-density bottle gourd in the two trial seasons. The Competitive Ratio (CR) can be used to evaluate the competitive abilities of component crops in intercropping systems (Weigelt and Jolliffe, 2003; Wahla *et al*., 2009). In this context, Li *et al*. (2001) noted that the yield of an intercropping system is positively correlated with the interspecific competition of the component crops. These findings align with those of Ghosh (2004) and Mansaray *et al*. (2022).

4. Conclusions

Cassava and bottle gourd are two crops of considerable importance. While cassava can address food shortages, it requires a lengthy growing period and lacks an established market in Egypt. Bottle gourd, although profitable, is not extensively grown despite its many advantages. Consequently, it is crucial to promote awareness of both crops. Our study findings indicate that intercropping cassava with bottle gourd is beneficial. The study revealed the highest cassava root yield was achieved with the closest cassava spacing (2.0 x 0.5 m), in contrast, the greatest bottle gourd yield was obtained when intercropped with cassava at the widest cassava plant spacing (2.0 x1.5 m) in both seasons. The maximum Land Equivalent Ratio was attained when cassava was cultivated at 2.0 x 1.0 m spacing and intercropped with bottle gourd in both seasons.

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