Performance evaluation for yield of four cultivars of cassava intercropped with three varieties of maize in Anyigba, Kogi State

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ABSTRACT

Background and Objectives: A field experiment was conducted during the 2021/2022 rainy season at Prince Abubakar Audu University Teaching and Research Farm to investigate the yield and yield performance of four cultivars of cassava intercropped with three varieties of maize in Anyigba, Kogi State, Nigeria.

Methodology: Treatment consisted of four cultivars of cassava – TMS0581, TME419, LOCAL, and TMS30572 and three maize varieties – SAMAZ52, OBASUPER6, and LOCAL, which were factorially combined to give a total of twelve treatment combinations plus a plot each of three varieties of maize and four cultivars of cassava. A total of 19 treatments were laid in a randomized complete block design replicated three times, giving 57 plots.

Main Results: Results revealed a significant ($P < 0.05$) difference between cassava and/or maize yield parameters in sole and/or intercrops. Intercropping maize and cassava cultivars (TMS0581/SAMAZ52) produced significantly ($P < 0.05$) the highest number of ears/plant (1.43) for maize. In contrast, the sole planting of TMS0581 produced higher yields for cassava crops than in its corresponding intercrop. Cassava (TMS0581) yielded 17.33 t ha^{-1} when planted as the sole crop, and the yield dropped to 5.42 t ha^{-1} when intercropped with maize (LOCAL variety), thus indicating a 68.8% yield loss to intercropping. All cassava cultivars planted sole had the highest number of stands at harvest and were at par with TMS30572/OBASUPER6 and TMS30572/LOCAL. Similarly, cassava varieties exhibited an advantage in intercropping (SAMAZ52/TME419 and OBASUPER6/TMS30572 cultivars being the highest). However, TME419 and LOCAL cassava cultivars had the tallest height when planted sole. Maize varieties grew taller in intercrops than when planted sole. Other maize and cassava yield characters were significantly not influenced ($P > 0.05$) by sole and intercropping systems throughout the trial. SAMAZ52 had the highest yield (3,533.35 kg ha^{-1}) when intercropped with TME419 but was not significantly different from other intercropping and sole cropping systems. Very high aggressivity coefficient (0.72) of cassava over maize and preponderances of high value (15.17) of relative crowding coefficient and competitive ratio (17.06) of cassava over maize may be an indication that some cassava cultivars (especially TMS30572 and LOCAL) have high smothering capacity over maize.

Conclusions: From the previous result, sole cropping of TMS0581 was outstanding for tuber yield in Anyigba. Interaction of cassava and maize showed that OBASUPER6 intercropped with TMS30572 and TME419 intercropped SAMAZ52 provided significantly the highest yield for both mixtures and thus recommended. Given the rate at which the population is growing and its attendant urbanization threats, the need to conserve land through intercropping cannot come at a better time than now. For intercropping to be effective, adequate research on compatible crop mixtures has to be adequately and effectively worked upon in other locations. This implies screening all possible crop variety combinations. In situations where more than two crop varieties are involved, the situation can only be better imagined.

Keywords: Aggressivity, intercropping, competitive indices, competitive ratio, relative crowding coefficient

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz), as a significant staple starch in most parts of the tropics, plays a vital role in food security, employment creation, and income generation for farm families in parts of the humid tropics where hunger and starvation prevail. Farmers generally realize a higher income from cassava production than most other staples. Cassava is, however, not usually planted solely under the traditional cropping system to maximize the farmer's income generation and also to produce diverse crops on the limited available land area. Substantially, maize is a staple food for an estimated 50% of the population and provides 50% of the essential calories. It is an important source of carbohydrates, protein, iron, vitamin B, and minerals. Maize is commonly grown in mixed cropping situations. Okigbo and Greenland (1976) report that about 76% of the maize area in Nigeria and 84% in Uganda is in mixtures with other crops. Due to the limitation of land, most subsistence farmers practice intercropping for several years without fallow, with no definite planting pattern, and little or no fertilizers are applied. Both soil fertility and crop yields decline over time (Ayoola and Makinde, 2009). Intercropping systems use the land more efficiently than growing crops separately. Cassava is suited to intercropping because of its initial slow growth rate with its field maturity period of 12 to 18 months and the establishment at a spacing of one meter. It is usually intercropped with short-duration crops like maize. In Mali, cassava production is concentrated around the Central Delta of Niger in the lake plains and rivers side, in the Moptie zone. In all these cassava growing areas, intercropping with sorghum, groundnut, maize, and vegetables is common (Dembelé *et al*., 2013). Cassava/maize intercrop is popular in many areas of southern Nigeria. Various intercropping systems involving cassava that are practiced in Africa and Asia have been reported (Ofori and Stern, 1987; Amanullah *et al*., 2006).

In the Nigerian intercropping system, cassava is planted alongside crops such as yam, maize, and vegetables. Yam is generally planted at the top of the mound, while cassava is planted on the side of the slope of the mound or ridges (Stefan *et al*., 2015). However, in the north-central part of Nigeria, Benue State, and Kogi State, cassava is intercropped with crops such as yam, maize, guinea corn, okra, and beans. Competition, however, exists for available resources among crops planted in mixtures, which could lead to yield depression (Ikeorgu, 1984; Ambe *et al*., 1988). There is, therefore, a need for adequate replenishment of soil nutrients when crops are planted in mixtures. A study in six states (Benue, Cross Rivers, Enugu, Kogi, Ondo, and Oyo) in Nigeria showed that the mixed cassava cropping system is more male-dominated than the sole cropping system. The study also revealed that the cassava mono-cropping system is more economically profitable than the mixed one. At the same time, the latter provides opportunities for all-year-round farm incomes to serve as a better poverty-alleviating mechanism (Ajayi, 2014). Assessing the comparative advantages in crop mixtures, Musa and Yusuf (2021) reported that intercropping maize with either cowpea, peanut, or soybean in a 2:1 ratio is most productive in terms of maize equivalent yield and thus maintained superiority over sole planting of maize in Anyigba environment. They further maintained that maize + peanut intercrop in a 2:1 ratio recorded the highest mean Monetary Advantage Index.

In contrast, the highest cost-benefit ratio was obtained with maize + soybean (4:1) during the years 2017 and 2018 of the experiment. Cassava can produce a maximum yield in low fertile soil, which makes it valuable in regions where rainfall is low or its seasonal distributions are irregular (Yahaya *et al.,* 2016). However, the production of roots and tuber plants in Nigeria has not been considered adequately by agricultural political planners regarding research and subsector organizations. On the international scale, the crop benefited from common support as it had been chosen by donors to be the crop that could ensure food security in Africa because of its multiple uses (Anthony *et al.,* 2003). In the Anyigba environment, cultivating local cassava cultivars with local/improved maize varieties is widespread. Yield emanating from such intercrops is often low due to inherent competition among crops involved in the mixture (Willey and Osiru, 1972). Literature on relevant cassava cultivars and maize varieties used in intercrops is either minor or near nil, especially in the Anyigba environment. The relevant research institutes have released improved cultivars of cassava and maize. However, packages on intercropping of various cassava cultivars and maize varieties are almost not available, at least for the Anyigba environment.

Before, crop breeders concentrated most of their efforts on identifying varieties with the potential for high sole crop yields. This has not gone down well with our local farmers, as most do not practice sole cropping. Identifying compatible genotypes in mix-cropping systems for maximum yields could be one significant means of coming to terms with small-scale farming practices. There is a need to adapt the cultivation of improved varieties of cassava in the intercropping system with improved maize cultivars through this study to maximize the production of duo in the country and boost the efforts for food security, using four competition indices such as aggressivity (A), relative crowding coefficient (RCC), and competitive ratio (CR), as outlined by Willey (1979) to assess yield advantage of the two crops in the intercropping system in Anyigba, Kogi State.

MATERIALS AND METHODS

Study Area

This trial was carried out during the rainy season of 2021 at Kogi State University Student Research Farm, Anyigba, Kogi State, Nigeria, located on latitude 7°28’51.39” N and longitude 7°11’14.86” E on an elevation of 420 m above sea level. Anyigba, located within the Southern Guinea Savannah Ecological zone of Nigeria, is characterized by an average rainfall of about 180 mm, mostly distributed between April and October. The mean monthly minimum and maximum temperatures are about 17°C and 36.2°C, respectively. The soils generally are sandy to sandy-loam. The mean monthly temperature varies between 15.1°C and 31.3°C (Amhakhian *et al*., 2012).

Treatments and Experimental Design

Treatments consist of four cassava cultivars, TMS0581, TME419, LOCAL cassava, and TMS30572, respectively, and three maize varieties: SAMAZ52, OBASUPER6, and LOCAL maize. Combined in every possible way to give 19 treatments and cassava and maize sole crops. These treatments were laid in a randomized complete block design with three replications. Each replicate consisted of 19 plots. Each plot measures 15 m^2 and contains four ridges. Plots are separated 1 m apart, as ridges were separated by 0.5 m. Each replicate was separated by 1.5 m spacing. A total of 57 plots were used in the experiment.

Planting and Planting Material

Planting was done on the 30th day of April 2021 when soil moisture was sufficient at the time of planting. Maize seeds were planted one week before the cassava stems at a spacing of 0.5 m intra-row and 0.5 m inter-row spacing at a depth of maize 5 cm. Cassava cutting 20 cm long was planted horizontally on ridges by placement of 2/3 of its length underground at 1 m within a row and 0.75 m between rows (Bationo and Buerkert, 2001). Three improved cassava cultivars were obtained from the National Root Crops Research Institute (NRCRI), Umudike, Abia State, while two maize hybrids were obtained from the Institute of Agricultural Research, Zaria. Local cultivars of both cassava and maize were obtained from the Anyigba market. NPK 20-10-10 was applied to maize at 120 kg ha^{-1} in two split-dose in ring form. The first application was made 3 weeks after planting, while the second application was 6 weeks after planting. The same brand of fertilizer was applied to cassava at 250 kg ha^{-1} in a single dose. Plots were weeded when due manually throughout the experiment. Neem oil extract + Thiopsin 70% ppm was applied at 30 mL/16 L every 3 weeks to control the disease. A 0.25% solution of Gammalin 20 was also sprayed to control grasshoppers (*Zonocerus variegatus*). Maize harvesting was done in August 2021, while cassava was harvested in December 2021.

Observations and Data Collection

All observations on yield parameters and yield of cassava, such as the number of stands cassava at harvest, total number of tubers plant^{-1}, average tuber length plant^{-1}, biological yield (total biomass plant^{-1}), and economic yield (tuber weight ha^{-1}) were made at harvest. Observations on maize yield and yield characters such as days to ear emergence, days to tasseling, numbers of ears plant^{-1}, ear length, biomass weight, spindle weight, and grain weight plot^{-1} were recorded at harvest.

Analysis of Data

All data were subjected to analysis of variance using the MSTAT statistical package described by Snedecor and Cochran (1967). Significant treatment means for each crop were separated using Duncan's new multiple range test at a 5% probability level. Competitive indices are used in evaluating the extent of competition between different intercropped species, and different indices were suggested (Connolly *et al.*, 2001). In this present study, some competitive behaviors of component crops in different maize/cassava planting patterns were determined in terms of aggressivity, relative crowding coefficient, and competitive ratio.

Aggressivity

Aggressivity (A) is a competitive index that measures how much the relative yield of one crop component is greater than that of another (McGilchrist, 1965). Aggressivity is expressed as;

$$A_{cassava} = \frac{Y_{ci}}{Y_c \times P_{ci}} = \frac{Y_{mi}}{Y_m \times P_{mi}} \quad \text{------- (1)}$$

$$A_{maize} = \frac{Y_{mi}}{Y_m \times P_{mi}} = \frac{Y_{ci}}{Y_c \times P_{ci}} \quad \text{------- (2)}$$

where P_{ci} is the sown proportion of cassava in mixture with maize, P_{mi} is the sown proportion of maize in mixture with cassava, Y_c is the yield of cassava as sole crops, Y_m is the yield of maize as sole crops, Y_{ci} is the yield of cassava as intercrops, and Y_{mi} is the yield of maize as intercrops. If $A_{cassava}$ or A_{maize} = 0, both crops are equally competitive. When $A_{cassava}$ is positive, the cassava species is dominant, and when it is negative, maize is the dominating species.

Relative Crowding Coefficient

De Wit (1960) introduced the relative crowding coefficient (RCC or K) in plant competition study. The K allowed evaluating and comparing the competitive ability of one species to the other in a mixture (Zhang *et al.*, 2011). The K was calculated as:

$$K = K_{cassava} \times K_{maize} \quad \text{------- (3)}$$

$$K_{cassava} = \frac{Y_{ci} \times P_{mi}}{(Y_c \times P_{ci}) \times P_{ci}} \quad \text{------- (4)}$$

$$K_{maize} = \frac{Y_{mi} \times P_{ci}}{(Y_m \times P_{mi}) \times P_{ci}} \quad \text{------- (5)}$$

If $K_{cassava}$ is greater than K_{maize}, cassava is more competitive than maize. Also, there is a yield advantage when the product of the two coefficients ($K_{cassava}$ and K_{maize}) is greater than 1. When K is equal to 1, there is no yield advantage, and when it is less than 1, there is a disadvantage.

Competitive Ratio

The competitive ratio (CR), introduced by Willey and Rao (1980), was used as an indicator to evaluate the competitive ability of different species in intercropping (Uddin *et al*., 2014). It was calculated by the following formula (Willey and Rao, 1980; Uddin *et al*., 2014):

$$\text{CR cassava} = \frac{LER_c}{LCR_m} \times \frac{P_{mi}}{P_{ci}} \quad \text{------- (6)}$$

$$\text{CR maize} = \frac{LER_m}{LCR_c} \times \frac{P_{ci}}{P_{mi}} \quad \text{------- (7)}$$

where LER_c is the land-equivalent ratio of cassava, and LER_m is the land-equivalent ratio of maize. If CR cassava is greater than 1, cassava is more competitive than maize, and if CR cassava is less than 1, then cassava is less competitive than maize (Zhang *et al*., 2011).

RESULTS AND DISCUSSION

Effect of Cassava-Maize Intercrop on Yield and Yield Characters of Maize in Anyigba

Results on yield parameters of maize, as influenced by cassava-maize intercrop, are presented in Table 1. Intercropping significantly influenced the number of ears plant^{-1} of maize varieties. TMS0581/SAMAZ52 intercrop had the highest mean number of ears plant^{-1} of 1.43, followed by SAMAZ52, OBASUPER6, LOCAL/OBASUPER6, TMS30572/SAMAZ52, LOCAL/SAMAZ52, TMS30572/OBASUPER6 and TMS30572/LOCAL. However, TMS0581/LOCAL, TME419/LOCAL, LOCAL/LOCAL MAIZE, and LOCAL maize cultivars had the lowest mean number of ears plant^{-1} (1.00).

Table 1 Yield parameters of maize as influenced by sole maize and cassava-maize intercropping system in Anyigba during the 2021/2022 rainy seasons

Treatments	Days to tasseling	Days to ear emergence	Number of ears plant^{-1}	Ear length (cm)
Sole maize				
SAMAZ52	56.60 ± 0.03	63.83 ± 0.12	1.37 ± 0.04^{ab}	14.01 ± 0.28
OBASUPER6	57.60 ± 0.22	64.02 ± 0.17	1.37 ± 0.04^{ab}	14.61 ± 0.12
LOCAL	56.52 ± 0.05	63.67 ± 0.08	1.00 ± 0.05^{d}	14.82 ± 0.07
Standard error (±)	3.46	2.95	0.08	2.30
Intercrops				
TMS0581/SAMAZ52	54.68 ± 0.52	61.10 ± 0.57	1.43 ± 0.05^{a}	15.45 ± 0.09
TMS0581/OBASUPER6	56.43 ± 0.07	63.27 ± 0.02	1.10 ± 0.03^{cd}	15.53 ± 0.11
TMS0581/LOCAL	58.42 ± 0.44	64.60 ± 0.32	1.00 ± 0.05^{d}	14.10 ± 0.25
TME419/SAMAZ52	53.43 ± 0.84	60.97 ± 0.61	1.20 ± 0.00^{bcd}	16.87 ± 0.45
TME419/OBASUPER6	59.02 ± 0.59	65.10 ± 0.45	1.10 ± 0.03^{cd}	13.93 ± 0.30
TME419/LOCAL	58.83 ± 0.54	65.83 ± 0.64	1.00 ± 0.05^{d}	13.11 ± 0.51
LOCAL/SAMAZ52	55.60 ± 0.29	62.17 ± 0.30	1.33 ± 0.03^{ab}	16.45 ± 0.35
LOCAL/OBASUPER6	57.37 ± 0.16	64.37 ± 0.26	1.37 ± 0.04^{ab}	13.83 ± 0.32
LOCAL/LOCAL MAIZE	57.10 ± 0.09	63.50 ± 0.04	1.00 ± 0.05^{d}	18.41 ± 0.85
TMS30572/SAMAZ52	56.03 ± 0.17	62.43 ± 0.23	1.37 ± 0.04^{ab}	15.41 ± 0.08
TMS30572/OBASUPER6	57.67 ± 0.24	63.50 ± 0.04	1.30 ± 0.02^{abc}	15.45 ± 0.09
TMS30572/LOCAL	55.53 ± 0.31	61.77 ± 0.40	1.30 ± 0.02^{abc}	14.41 ± 0.17
Standard error (±)	3.46	2.95	0.08	2.30
CV (%)	4.32	4.24	9.81	13.08

Note: CV = coefficient of variation. Means followed by the same letters within a sampling period are not statistically different at a 5% probability level using Duncan's new multiple range test.

Sole cropping of maize and its intercrop with cassava had no significant influence (P > 0.05) on the days to tasseling, days to ear emergence, and ear length. The greater soil moisture conservation under intercropping could have promoted a greater absorption of soil nutrients. Ogindo and Walker (2005) reported that intercrops have been identified to conserve water. Our results also corroborate the findings of Filho (2000) on maize-cowpea intercrop, where he concluded that growth resources such as water and solar radiation are better utilized in intercrop than sole cropping. Stressing the significance of number of ears plant^{-1} (Table 1), intercropping TMS0581 cassava and SAMAZ52 maize shows a strong competitive advantage of maize over cassava. This advantage resulted from maize's ability to utilize and maximize available resources for optimum photosynthate accumulation, which yields an increased number of ears.

Our results are also similar to those of Moges (2015). Higher ear length at intercrop has been attributed to varietal compatibility and competition for growth resources, particularly nutrients, water, and light. As reported by Al-Naggar *et al*. (2015), the competitive advantage of maize plants in intercrop allows for the accumulation of biomass with a higher capacity to make assimilates for depositing into the sinks, resulting in more and longer ears.

Intercropping maize with cassava was not significant (P > 0.05) for maize grain weight, biomass weight, and spindle weight (Table 2). Both sole cropping and intercrops of maize performed equally. Maize requires high light intensity for optimal grain production. Hence, shading severely affects grain yield. Our results negate that of Zamir *et al.* (2011), who reported that the number of ears plant^{-1} increased with decreased plant population density. Maize spindle weight was higher in cassava and maize intercropping systems (LOCAL/OBASUPER6 and LOCAL/LOCAL MAIZE) compared to sole cropping. A similar result was also obtained for the grain weight of TME419 and SAMAZ52. This is because high plant population establishment creates competition for light, aeration, and nutrients and consequently compels the plants to undergo less reproductive growth. Grain weight, biomass weight, and spindle weight were not significantly influenced by cassava-maize intercropping. This result does not connect with Ijoyah *et al*. (2012), who reported that maize yield in a yam mini-set and maize intercrop was greater by 11.7% and 10.0%, respectively, compared to the yield obtained from sole maize at equivalent population density probably because of varietal compatibility, competition for growth resources among maize and cassava in the intercrop.

Effect of Cassava-Maize Intercropping on Number of Stands at Harvest, Number of Tubers Plot^{-1}, Average Tuber Length, Biomass Weight and Tuber Weight of Cassava Plant

Table 3 showed that sole cassava cropping and cassava-maize intercropping significantly influenced (P < 0.05) the number of cassava stands and tuber weight of cassava at harvest. All cassava varieties planted in sole cropping and intercrop of TMS30572/OBASUPER6 and TMS30572/LOCAL had the best performance and were statistically indifferent in terms of the number of cassava stands at harvest relative to TME419 which produced the highest number of cassava stands (20.00), this might be attributed to interspecific competition between the intercrop components for growth resources (light, water, nutrients, and air) and the depressive effects of shading by maize (Joseph *et al.*, 2018). Other intercropping systems followed with non-statistically different results. However, the number of cassava stands obtained with LOCAL/SAMAZ52 (11.33) and LOCAL/LOCAL MAIZE (11.00) was the lowest.

Table 2 Biomass weight, spindle weight, and grain weight of maize intercropped with cassava cultivars in Anyigba during the 2021/2022 rainy season

Treatments	Biomass weight (kg plant^{-1})	Spindle weight (kg plant^{-1})	Grain weight (kg ha^{-1})
Sole maize			
SAMAZ52	7.37 ± 0.52	1.47 ± 0.07	2,446.68 ± 68.96
OBASUPER6	8.50 ± 0.23	1.63 ± 0.03	2,513.35 ± 51.75
LOCAL	9.33 ± 0.02	1.67 ± 0.02	2,580.01 ± 34.54
Standard error (±)	2.96	0.40	1,066.67
Intercrops			
TMS0581/SAMAZ52	10.67 ± 0.32	1.87 ± 0.03	3,200.01 ± 125.53
TMS0581/OBASUPER6	9.30 ± 0.02	1.80 ± 0.01	2,420.01 ± 75.85
TMS0581/LOCAL	7.93 ± 0.37	1.73 ± 0.00	2,086.68 ± 161.92
TME419/SAMAZ52	12.00 ± 0.67	2.01 ± 0.06	3,533.35 ± 211.60
TME419/OBASUPER6	9.63 ± 0.06	1.53 ± 0.05	1,866.68 ± 218.72
TME419/LOCAL	6.60 ± 0.72	1.27 ± 0.12	2,333.35 ± 98.23
LOCAL/SAMAZ52	8.83 ± 0.14	1.50 ± 0.06	3,000.01 ± 73.89
LOCAL/OBASUPER6	9.07 ± 0.08	2.17 ± 0.11	3,020.06 ± 79.07
LOCAL/LOCAL MAIZE	10.80 ± 0.36	2.17 ± 0.11	2,420.01 ± 75.85
TMS30572/SAMAZ52	10.67 ± 0.32	1.67 ± 0.02	3,020.06 ± 79.07
TMS30572/OBASUPER6	10.70 ± 0.33	1.87 ± 0.03	3,133.35 ± 108.32
TMS30572/LOCAL	9.57 ± 0.04	1.87 ± 0.03	3,133.35 ± 108.32
Standard error (±)	2.96	0.40	1,066.67
CV (%)	13.93	31.86	42.20

Note: CV = coefficient of variation. Means followed by the same letters within a sampling period are not statically different at a 5% level of probability using Duncan's new multiple range test.

The number of tubers plot^{-1}, average tuber length, and total plant biomass plot^{-1} were not significantly influenced by sole cassava cropping and intercropping systems. This could be due to the efficiency in the utilization of available resources, which obviously kept duo performance at optimum. This result is also in line with Ijoya *et al*. (2012). For tuber weight, sole planting of TMS0581 produced the highest yield (17.33 t ha^{-1}). This was significantly different from other sole and intercropping systems of cassava crops. This response was followed by the sole planting of LOCAL (13.62 t ha^{-1}) and TME419 (13.09 t ha^{-1}), respectively. All cassava-maize combinations in the intercropping system showed significant differences in the tuber weight of cassava. However, the yield of cassava intercrops of TMS30572/OBASUPER6 tends to give the highest tuber weight at 8.69 t ha^{-1} followed by TME419/SAMAZ52 (8.47 t ha^{-1}) and TMS30572/SAMAZ52 (7.69 t ha^{-1}) and TMS0581/SAMAZ52 (6.69 t ha^{-1}). Sole planting of TMS30572 in cassava also gave the lowest tuber weight (2,337.07 kg ha^{-1}). Non-significant yield characteristics of cassava obtained with the cassava-maize intercropping system are similar to the results of Egbe *et al*. (2010), who in their assessment study of extra-early and early-maturing cowpea varieties intercropped with maize in the Southern Guinea Savanna of Nigeria reported that intercropping had no significant influence on yield and yield characters of crop species in the system relative to their sole crop, hence resultant yield advantage.

Table 3 Yield parameters of cassava cultivars intercropped with four varieties of maize in Anyigba during the 2021/2022 rainy seasons

Treatments	Number of stands at harvest	Number of tubers plant^{-1}	Average tuber length (cm)	Total biomass plant^{-1} (kg)	Tuber weight (kg ha^{-1})
Sole cassava					
TMS0581	17.33 ± 0.39^{a}	71.00 ± 5.77	37.51 ± 0.85	11.07 ± 1.10	17,331.60 ± 2536.9^{a}
TME419	20.00 ± 1.05^{a}	77.00 ± 7.27	45.26 ± 1.08	12.70 ± 1.51	13,086.73 ± 1475.7^{abc}
LOCAL	18.00 ± 0.55^{a}	63.00 ± 3.77	41.10 ± 0.04	11.67 ± 1.25	13,620.07 ± 1609.0^{abc}
TMS30572	19.00 ± 0.80^{a}	73.33 ± 6.35	42.69 ± 0.44	9.20 ± 0.63	2,337.07 ± 1790.1^{ab}
Standard error (±)	2.31	17.33	9.36	5.31	2,653.35
Intercrops					
TMS0581/SAMAZ52	16.00 ± 0.05^{ab}	51.67 ± 0.94	40.56 ± 0.09	5.40 ± 0.31	6,686.70 ± 124.3^{cd}
TMS0581/OBASUPER6	15.00 ± 0.19^{ab}	42.67 ± 1.30	35.78 ± 1.28	3.37 ± 0.82	5,420.03 ± 440.9^{d}
TMS0581/LOCAL	15.00 ± 0.19^{ab}	37.33 ± 2.64	49.17 ± 2.05	3.90 ± 0.69	5,420.03 ± 440.9^{d}
TME419/SAMAZ52	15.33 ± 0.11^{ab}	52.67 ± 1.19	50.00 ± 2.26	9.23 ± 0.64	8,466.71 ± 320.7^{bcd}
TME419/OBASUPER6	14.00 ± 0.44^{ab}	33.00 ± 3.72	37.49 ± 0.86	4.43 ± 0.56	4,133.35 ± 762.63^{d}
TME419/LOCAL	14.00 ± 0.44^{ab}	32.67 ± 3.80	38.18 ± 0.68	3.57 ± 0.77	4,620.02 ± 640.9^{d}
LOCAL/SAMAZ52	11.33 ± 1.11^{b}	28.33 ± 4.89	31.96 ± 2.24	3.17 ± 0.87	3,220.02 ± 990.9^{d}
LOCAL/OBASUPER6	15.00 ± 0.19^{ab}	31.33 ± 4.14	38.12 ± 0.70	4.20 ± 0.61	5,580.03 ± 400.9^{d}
LOCAL/LOCAL MAIZE	11.00 ± 1.19^{b}	31.33 ± 4.14	38.12 ± 0.70	5.10 ± 0.39	5,580.03 ± 400.9^{d}
TMS30572/SAMAZ52	15.00 ± 0.19^{ab}	46.00 ± 0.47	39.33 ± 0.40	7.37 ± 01.7	7,686.71 ± 125.70^{cd}
TMS30572/OBASUPER6	18.33 ± 0.64^{a}	39.33 ± 2.14	37.27 ± 0.92	7.27 ± 0.15	8,686.71 ± 375.7^{bcd}
TMS30572/LOCAL	18.00 ± 0.55^{a}	55.67 ± 1.94	52.38 ± 2.86	5.03 ± 0.41	5,380.02 ± 450.9^{d}
Standard error (±)	2.31	17.33	9.36	5.31	2,653.35
CV (%)	19.57	47.84	17.03	60.91	19.30

Note: CV = coefficient of variation. Means followed by the same letters within a sampling period are not statistically different at a 5% probability level using Duncan's new multiple range test.

Table 4 explains the interaction of cassava cultivars and maize varieties on the tuber yield of cassava plants. TMS30572 had the optimum response (13.03 t ha^{-1}) to yield when combined with OBASUPER6. This was statistically indifferent from the yield obtained (12.70 t ha^{-1}) when TME419 and SAMAZ52 were combined. Other cassava-maize varietal combinations showed non-significant differences in yield. However, the combination of the LOCAL cassava variety with SAMAZ52 and TMS30572 with SAMAZ52 had the lowest response to yield.

Table 4 The interaction of cassava cultivars and maize varieties on total tuber yield (t ha^{-1}) in Anyigba during the 2021/2022 rainy season

Cassava cultivars	Maize varieties		
	SAMAZ52	OBASUPER6	LOCAL
TMS0581	10.03 ± 0.53^{ab}	8.13 ± 0.01^{ab}	8.13 ± 0.01^{ab}
TME419	12.70 ± 1.30^{a}	6.20 ± 0.57^{ab}	6.93 ± 0.36^{ab}
LOCAL	4.83 ± 0.96^{b}	6.93 ± 0.36^{ab}	8.37 ± 0.05^{ab}
TMS30572	4.83 ± 0.96^{b}	13.03 ± 1.39^{a}	8.07 ± 0.03^{ab}
Standard error (±)		2.52	

Note: Means followed by the same letter within a sampling period are not statistically different at a 5% probability level using Duncan's new multiple range test.

Heights of Cassava and Maize as Affected by Sole and Intercropping of Cassava and Maize in the Anyigba Environment

Table 5 presents the heights of maize and cassava as affected by sole and intercropping systems. At 24 WAP, TME419 was the tallest amongst other cultivars grown as sole crops though was statistically indifferent from yield obtained with LOCAL cassava cultivar. Cassava varieties planted in the intercropping system with maize had a height advantage in TME419/SAMAZ52 and TMS30572/OBASUPER6 intercrop over maize, producing the tallest cassava crops (76.83 and 76.00 cm, respectively). Thus, TME419 and TMS30572 outgrew their respective component crops, SAMAZ52 and OBASUPER6, in their maize varieties. This may have resulted from their ability to smooth maize components due to tough competition for growth resources, e.g., nutrients, water, and light (Joseph *et al.,* 2018). Other cassava cultivars in intercrops behaved alike, with heights that were significantly indifferent from one another. LOCAL cassava cultivar was the shortest when intercropped with SAMAZ52.

Similarly, at 32 WAP, TME419/OBASUPER6 and TME419/SAMAZ52 produced the tallest cassava plants (108.33 and 106.67 cm, respectively). Other cassava cultivars intercropped had heights that were significantly different from one another. LOCAL cassava cultivar also had the shortest crops when combined with SAMAZ52. This may have resulted in the influence of the component crops on the population of cassava crops. Hay (1989) had earlier reported that a significant effect of increasing plant population density is to increase rivalry between adjacent plants. This may reduce growth and yield characteristics with increases in plant density above a critical limit depending on plant species/genotype. This assertion was also supported by Egbe and Bar-Anyam (2011).

Table 5 Heights of maize and cassava as affected by the sole and intercropping system in Anyigba during the 2021/2022 raining season

Treatments	Height of cassava (cm)		Treatments	Height of maize (cm)	
	24 WAP	32 WAP		6 WAS	8 WAS
Sole cassava			Sole maize		
TMS0581	62.43 ± 0.18^{bcd}	$89.67 \pm 0.33^{a-d}$	SAMAZ52	12.29 ± 0.73^{e}	56.30 ± 1.25^{bcd}
TME419	98.50 ± 8.83^{a}	123.00 ± 8.66^{a}	OBASUPER6	$14.97 \pm 0.04^{b-e}$	55.00 ± 1.58^{cd}
LOCAL	70.00 ± 1.71^{a}	88.00 ± 0.08^{bcd}	LOCAL	16.96 ± 0.46^{abc}	57.11 ± 1.04^{bcd}
TMS30572	48.00 ± 3.78^{bcd}	76.17 ± 3.03^{bcd}	Standard error (±)	2.98	12.59
Standard error (±)	9.93	10.91			
Intercrops			Intercrops		
TMS0581/SAMAZ52	59.17 ± 0.99^{bcd}	85.00 ± 0.83^{bcd}	SAMAZ52/TMS0581	$15.09 \pm 0.01^{b-e}$	$63.74 \pm 0.67^{a-d}$
TMS0581/OBASUPER6	58.00 ± 1.28^{bcd}	85.83 ± 0.62^{bcd}	OBASUPER6/TMS0581	18.32 ± 0.82^{a}	65.64 ± 1.16^{abc}
TMS0581/LOCAL	60.33 ± 0.70^{bcd}	73.33 ± 3.74^{bcd}	LOCAL/TMS0581	13.02 ± 0.54^{de}	$61.46 \pm 0.08^{a-d}$
TME419/SAMAZ52	76.83 ± 3.41^{ab}	106.67 ± 4.58^{ab}	SAMAZ52/TME419	17.70 ± 0.66^{ab}	73.23 ± 3.12^{a}
TME419/OBASUPER6	70.00 ± 1.71^{bc}	108.33 ± 5.00^{ab}	OBASUPER6/TME419	12.29 ± 0.73^{e}	52.73 ± 2.17^{d}
TME419/LOCAL	66.17 ± 0.75^{bcd}	$95.83 \pm 1.87^{a-d}$	LOCAL/TME419	14.33 ± 0.20^{cde}	55.33 ± 1.50^{cd}
LOCAL/SAMAZ52	39.33 ± 5.95^{d}	64.17 ± 6.03^{d}	SAMAZ52/LOCAL	18.61 ± 0.89^{a}	68.55 ± 1.91^{ab}
LOCAL/OBASUPER6	63.17 ± 0.01^{bcd}	88.33 ± 0.00^{bcd}	OBASUPER6/LOCAL	13.48 ± 0.43^{de}	53.65 ± 1.93^{cd}
LOCAL/LOCAL MAIZE	67.17 ± 1.00^{bcd}	77.50 ± 2.70^{bcd}	LOCAL MAIZE/LOCAL	16.79 ± 0.42^{abc}	66.07 ± 1.27^{abc}
TMS30572/SAMAZ52	50.83 ± 3.08^{bcd}	80.33 ± 1.99^{bcd}	SAMAZ52/TMS30572	$15.08 \pm 0.01^{b-e}$	$61.13 \pm 0.00^{a-d}$
TMS30572/OBASUPER6	76.00 ± 3.21^{ab}	101.67 ± 3.33^{abc}	OBASUPER6/TMS30572	12.75 ± 0.61^{de}	$64.16 \pm 0.77^{a-d}$
TMS30572/LOCAL	44.50 ± 4.66^{cd}	69.33 ± 4.74^{cd}	LOCAL/TMS30572	15.46 ± 0.08^{bcd}	$63.03 \pm 0.48^{a-d}$
Standard error (±)	9.93	10.91	Standard error (±)	2.98	2.98
CV (%)	29.17	20.40		2.98	12.59

Note: WAP = weeks after planting, WAS = weeks after sowing. CV = coefficient of variation. Means followed by the same letters within a sampling period are not statically different at a 5% level of probability using Duncan's new multiple range test.

The heights of maize crops were also affected by sole and intercropping systems. Maize varieties grew taller in intercrops than when planted sole. At 6 WAS, the SAMAZ52 maize variety produced the tallest crops (18.61 cm) when intercropped with the LOCAL cassava cultivar. This was, however, significantly not different from heights obtained with OBASUPER6/TMS0581. This was followed by SAMAZ52/TME419 (17.70 cm) and LOCAL MAIZE/LOCAL (16.79 cm). Other maize varieties were significantly not different in sole and intercropping systems OBASUPER6/TME419, and sole cropping of SAMAZ52 maize variety produced the shortest plants (12.29 cm) consistently. At 8 WAS, SAMAZ52/TME419 produced significantly taller crops (73.23 cm) which were not significantly different from heights obtained with SAMAZ52/LOCAL (68.55 cm). Other maize varieties in both sole and intercrops had closely related heights. However, OBASUPER6 produced the shortest crops when intercropped with the TME419 cassava cultivar. Our result corroborates with Mohammed and Hamad (2015), who reported increased plant height and number of branches plant^{-1} in intercropping patterns compared to the sole cropping of either safflower or fenugreek crops, respectively. A similar report has been published by Sarkar and Raghav (2010) on capsicum when intercropped with maize, and Bitew *et al.* (2014) on lupine intercropped with wheat, barley, and finger millet.

Table 6 Value of competition indices of yield in cassava and maize mixed cropping in Anyigba during the 2021/2022 rainy season

Cropping mixture	Aggressivity of cassava over maize (A)	Relative crowding coefficient (RCC or K)		Competitive ratio of cassava over maize (CR)
		Cassava	Maize	
TMS0581/SAMAZ52	0.21 ± 0.01	-4.28 ± 1.22	-1.58 ± 0.62	10.22 ± 0.46
TMS0581/OBASUPER6	0.11 ± 0.04	5.77 ± 1.67	0.45 ± 0.04	8.10 ± 0.14
TMS0581/LOCAL	0.77 ± 0.14	5.57 ± 1.61	0.46 ± 0.04	8.10 ± 0.14
TME419/SAMAZ52	0.73 ± 0.13	-3.50 ± 1.00	1.83 ± 0.35	6.57 ± 0.58
TME419/OBASUPER6	0.00 ± 0.07	5.93 ± 1.72	0.46 ± 0.04	9.05 ± 0.13
TME419/LOCAL	0.42 ± 0.04	2.92 ± 0.85	0.55 ± 0.01	6.34 ± 0.65
LOCAL/SAMAZ52	-0.88 ± 0.32	-3.69 ± 1.05	0.31 ± 0.08	17.06 ± 2.44
LOCAL/OBASUPER6	-0.20 ± 0.13	-6.65 ± 1.91	0.51 ± 0.02	10.38 ± 0.51
LOCAL/LOCAL MAIZE	0.05 ± 0.06	-6.39 ± 1.83	0.69 ± 0.02	8.62 ± 0.00
TMS30572/SAMAZ52	0.72 ± 0.13	15.17 ± 4.38	0.97 ± 0.11	5.67 ± 0.84
TMS30572/OBASUPER6	0.61 ± 0.10	-5.62 ± 1.61	1.26 ± 0.19	6.55 ± 0.59
TMS30572/LOCAL	0.61 ± 0.10	-5.62 ± 1.61	1.26 ± 0.19	6.55 ± 0.59

LOCAL/LOCAL MAIZE gave low aggressivity (0.05) in maize and cassava, LOCAL/SAMAZ52 (-0.88) and LOCAL/OBASUPER6 (-0.20) gave negative aggressivity. Positive aggressivity values obtained with cassava-maize intercrop indicated that cassava is dominant, while negative aggressivity indicates that maize is more dominant. Cassava growth became more aggressive after maize was removed at harvest. Olorunmaiye (2010) reported that cassava and maize are prominent crops under intercropping and have been extensively studied in Nigeria (Adeniyan *et al.*, 2014). They have been reported to be productive and compatible mainly because maize is seasoned while cassava is a long-duration crop (Ikeorgu, 2002). The aggressivity of cassava over maize

(Table 6) showed that TMS0581, when intercropped with LOCAL maize, was more aggressive. This was due to the genetic makeup of the improved cassava, while LOCAL/SAMAZ52 and LOCAL/OBASUPER6 showed negative aggression with values of -0.88 and -0.20 respectively. Our result also corroborates with Mohammed and Hamad (2015), who reported positive aggressivity values for safflower against fenugreek, attributing this behavior to dominance.

Effect of Cassava-Maize Intercropping on Aggressivity, Relative Crowding Coefficient and Competitive Ratio of Cassava Plant

Table 6 presents positive aggressivity of cassava over maize, given TMS0581/LOCAL had the highest aggressivity of (0.77) followed by TME419/SAMAZ52 (0.73), TMS30572/SAMAZ52 (0.72), TMS30572/OBASUPER6 (0.61), TMS30572/LOCAL (0.61), TME419/LOCAL (0.42), TMS0581/SAMAZ52 (0.21), and TMS0581/OBASUPER6 (0.11), respectively.

The result from RCC shows a positive and negative interaction between some of the combinations in the intercropping system. TMS30572/SAMAZ52 had the highest value (15.17 and 0.97), and LOCAL/SAMAZ52 had the lowest negative value (-3.69 and 0.31) for cassava and maize, respectively (Table 6). TMS30572, when intercropped with SAMAZ52, has the highest RCC with a value of 15.17 for cassava and 0.97 for maize. Most cassava varieties showed a negative RCC, such as TMS0581/SAMAZ52, TME419/SAMAZ52, and all combinations of LOCAL maize varieties. Meanwhile, LOCAL cassava, when intercropped with OBASUPER6, had the lowest RCC value of -6.65 for cassava against 0.51 for maize. It is also observed that in all combinations of cassava and maize in the intercropping system, cassava had a higher value of RCC than maize. This means that cassava is more competitive than maize. For the product of the RCC of maize and cassava, yield advantage was found for TMS30572/SAMAZ52, TME419/OBASUPER6, and TMS0581/LOCAL. The crop with a higher RCC or K value in the intercrop was more competitive than the other. Our results negate the result of Khonde *et al.* (2018), who reported higher partial RCC value for maize against cowpea and soybean in maize-cowpea mixtures and maize-soybean mixture, indicating that maize is more competitive than its associated crop. In our result, crop mixtures where cassava has RCC values greater than 1 indicated yield advantage over maize. Similar results were reported by Banik *et al*. (2000) in chickpea-wheat intercropping and Dhima *et al*. (2007) in cereal-vetch intercropping.

Competitive ratio of cassava over maize shows that LOCAL/SAMAZ52 was highly competitive with a mean value of 17.06 followed by LOCAL/OBASUPER6 (10.38), TMS0581/SAMAZ52 (10.22), TME419/OBASUPER6 (9.05), LOCAL/LOCAL MAIZE (8.62), TMS0581/OBASUPER6 (8.10), TMS0581/LOCAL (8.10), TME419/SAMAZ52 (6.57), TMS30572/OBASUPER6 (6.55), TMS30572/LOCAL (6.55), TME419/LOCAL (6.34), and TMS30572/SAMAZ52 (5.67), respectively. Similar to RCC value, CR values indicated that cassava was more competitive than maize given that CR cassava over maize was greater than 1 (Zhang *et al*., 2011). This may probably be due to the height advantage of cassava over the maize component. The cassava component grows faster and taller to intercept more solar radiation and shade the slower-growing maize component. Crawley (1997) stated that such competition usually decreased the survival, growth, or reproduction of at least one species, the shaded species. He further reported that the interactions frequently occurred at the interface between two crop species where they were nearest in distance, resulting in an increase or decrease in growth, development, and even yields. As illustrated in Table 6, LOCAL cassava was more competitive than the maize variety in LOCAL/SAMAZ52, this might be because of the adaptation to the soil type and environmental condition. A similar result has been reported in cereal-legume intercrop. According to Yilmaz *et al.* (2008), in their cowpea, soybean, and maize intercropping experiment, increasing the cereal rate in mixtures usually elevates the crowding efficiency over legumes, doubling the rate per se may commence competition among maize plants, which had probably resulted in weaker growth, thereby, lower CR and aggressivity in the cereal component. Similarly, Mbah and Ogbodo (2013) reported that vegetable cowpeas were more competitive than sweet corn. In their experiment, they attributed this to higher population advantage and its ability to fix atmospheric nitrogen. They added that at the lowest vegetable cowpea mixture population, sweet corn was aggressively more competitive. Similar results have been reported by Mahapatra (2011) in Sebai grass and black gram intercrop grown in the warm, humid monsoon climate of India, Egbe and Idoko (2009) in sweet potato and pigeon pea varieties intercrop in the Southern Guinea Savanna of Nigeria.

CONCLUSIONS

Based on the results obtained above, we have come to the conclusion that sole cropping of either crop maize or cassava was higher than their corresponding components in intercropping system, yield characters differ significantly ($P < 0.05$) with respect to varieties of cassava and maize examined in their intercropping mixtures while the significant cassava cultivar and maize variety interactions observed during the period of the experiment is an indication that variety and cultivar/clone behaved differently when intercropped under the same system and environment. Significant yield was obtained by intercropping TMS30572 with OBASUPER6, and TME419 with SAMAZ52, and sole cropping of TMS0581 was outstanding for tuber yield in Anyigba. This is thus recommended for the Anyigba environment. Biologically, the yield obtained from either of the two intercrops was significantly different. The preponderance of relatively low coefficient of variability obtained for most of the parameters studied could be an indication of precision and, by extension reliability of the study. The highest aggressivity index of 0.77 obtained with the TMS0581/LOCAL maize variety indicates that this combination is the best compatible as the TMS0581 had the greatest ability to smooth the LOCAL variety most. TMS30572/SAMAZ52 had the highest RCC while LOCAL/SAMAZ52 had the highest CR, which is an indication of the smothering ability of the maize in the mixture. This character (smothering) should be exploited by weed scientists and farmers alike in weed control.

REFERENCES

Adeniyan, O.N., O.A. Aluko, S.O. Olanipekun, J.O. Olasoji and V.O. Aduramigba-Modupe. 2014. Growth and yield performance of cassava/maize intercrop under different plant population density of maize. J. Agric. Sci. 6(8): 35–40. https://doi.org/10.5539/jas.v6n8p35.

Ajayi, J.O. 2014. Comparative economic study of mixed and sole cassava cropping systems in Nigeria. Agris On-line Pap. Econ. Inform. 6(4): 15–23. https://doi.org/10.22004/ag.econ.196522.

Al-Naggar, A.M.M., R. Shabana, M.M.M. Atta and T.H. Al-Khalil. 2015. Regression of grain yield of maize inbred lines and their diallel crosses on elevated levels of soil-nitrogen. Int. J. Plant Soil Sci. 4(6): 499–512. https://doi.org/10.9734/IJPSS/2015/14228.

Amanullah, M.M., K. Vaiyapuri, A. Alagesan, E. Samasundaram, K. Sathyamoorth and S. Pazhanivelan. 2006. Effect of intercropping and organic manures on the yield and biological efficiency of cassava intercropping system (*Manihot esculenta* Crantz.). Res. J. Agric. Biol. Sci. 2(5): 201–208.

Ambe, T.J., S.N. Lyonga, A.A. Agboola and S.K. Hahn. 1988. The performance of cassava with other staples in intercrops in Cameroon, pp. 91–97. *In:* Proceedings of the 1st Annual Meeting of Cassava-based Cropping System Research Group. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Amhakhian, S.O., H.H. Isitekha and P.I. Ezeaku. 2012. Influence of land uses on structural stability of some guinea savanna soils in Anyigba, Kogi State. Proceedings of Soil Science Society of Nigeria. 30: 308–314.

Anthony, E.K., L.P. Natali and D. Haln. 2003. Cassava Lifeline for the Rural Household. UNICEF, New York, USA.

Ayoola, O.T. and E.A. Makinde. 2009. Maize growth, yield and soil nutrient changes with N-enriched organic fertilizers. Afr. J. Food Agric. Nutr. Dev. 9(1): 580–592. https://doi.org/10.4314/ajfand.v9i1.19214.

Banik, P., T. Sasmal, P.K. Ghosal and D.K. Bagchi. 2000. Evaluation of mustard (*Brassica campestris* var. Toria) and legume intercropping under 1:1 and 2:1 row-replacement series systems. J. Agron. Crop Sci. 185(1): 9–14. https://doi.org/10.1046/j.1439-037X.2000.00388.x.

Bationo, A. and A. Buerkert. 2001. Soil organic carbon management for sustainable land use in the Sudano-Sahelian West Africa. Nutr. Cycl. Agroecosyst. 61: 131–142. https://doi.org/10.1023/A:1013355822946.

Bitew, Y., F. Abay and T. Dessalegn. 2014. Effect of lupine (*Lupinns* spp.) intercropping and seed proportion on the yield and yield component of small cereals in North Western Ethiopia. Afr. J. Agric. Res. 9(30): 2287–2297. https://doi.org/10.5897/AJAR2014.8729.

Connolly, J., H.C. Goma and K. Rahim. 2001. The information content of indicators in intercropping research. Agric. Ecosyst. Environ. 87(2): 191–207. https://doi.org/10.1016/S0167-8809(01)00278-X.

Crawley, M.J. 1997. Plant Ecology. Blackwell Scientific Publications, Cambridge, UK.

De Wit, C.T. 1960. On Competition. Verslagen Landbouwkundige Onderzoekingen No. 66.8. Wageningen, The Netherlands.

Dembelé, D., B. Diarra, F. Sanogo, M. Bengali, A. Ballo, O. Samake and M. Sissoko. 2013. Evaluation De Variétés Locales De Manioc Et Patate Douce Au Mali. Rapport Final Enquête Diagnostic. Institut d'Economie Rurale, Bamako, Mali.

Dhima, K.V., A.S. Lithourgidis, I.B. Vasilakoglou and C.A. Dordas. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Res. 100(2–3): 249–256. https://doi.org/10.1016/j.fcr.2006.07.008.

Egbe, O.M. and J.A. Idoko. 2009. Agronomic assessment of some sweet potato varieties for intercropping with pigeonpea in the Southern Guinea Savanna of Nigeria. Agro-Science: Journal of Tropical Agriculture, Food, Environment and Extension. 8(2): 74–83. https://doi.org/10.4314/as.v8i2.51100.

Egbe, O.M. and M.N. Bar-Anyam. 2011. Effects of sowing density of intercropped pigeonpea with sorghum on biomass yield and nitrogen fixation in Southern Guinea Savanna of Nigeria. PAT. 7(1): 1–14.

Egbe, O.M., S.E. Alibo and I. Nwueze. 2010. Evaluation of some extra-early- and early-maturing cowpea varieties for intercropping with maize in Southern Guinea Savanna of Nigeria. Agric. Biol. J. N. Am. 1(5): 845–858. https://doi.org/10.5251/abjna.2010.1.5.845.858.

Filho, J.M.P.N. 2000. Physiological response of maize and cowpea to intercropping. Pesq. Agropec. Bras. 35(5): 915–921. https://doi.org/10.1590/S0100-204X2000000500008.

Hay, R.K.M. 1989. Plant population density and yield, pp. 164–167. *In*: R.K.M. Hay and A.J. Walker, (Eds.), An Introduction to the Physiology of Crop Yield. Longman Scientific and Technical, John Wiley and Sons, Inc., New York, USA.

Ijoyah, M.O., R.I. Bwala and C.A. Iheadindueme. 2012. Response of cassava, maize and egusi melon in a three crop intercropping system at Makurdi, Nigeria. International Journal of Development and Sustainability. 1(2): 135–144.

Ikeorgu, J.E.C. 1984. Some Micro-environmental Changes under Cassava (*Manihot esculenta* Crantz) – Maize (*Zea mays* L.) Intercrops Grown with Okra (*Abelmoschus esculentus* L.) and 'Egusi' Melon (*Colocynthis vulgaris* L.). PhD Thesis, University of Ibadan, Nigeria.

Ikeorgu, J.E.C. 2002. Performance of yam minituber/maize intercrop in the humid tropics of Southeast Nigeria. Niger. Agric. J. 33: 83–87.

Joseph, I., A.G. Agnes and B.W. Akaazua. 2018. Cassava/maize intercrop yield response to different plant population densities in Makurdi and Lafia. World J. Res. Rev. 6(3): 98–108.

Khonde, P., K. Tshiabukole, M. Kankolongo, S. Hauser, M. Djamba, K. Vumilia and K. Nkongolo. 2018. Evaluation of yield and competition indices for intercropped eight maize varieties, soybean and cowpea in the Zone of Savanna of South-West RD Congo. OAlib. 5: e3746. https://doi.org/10.4236/oalib.1103746.

Mahapatra, S.C. 2011. Study of grass-legume intercropping system in terms of competitive indices and monetary advantage index under acid lateritic soil of India. Am. J. Exp. Agric. 1(1): 1–6. https://doi.org/10.9734/AJEA/2011/001.

Mbah, E.U. and E.N. Ogbodo. 2013. Assessment of intercropped sweetcorn (*Zea mays* var. Saccharata) and vegetable cowpea (*Vigna unguiculata* (L.) Walp) using competitive indices in the derived savanna of south-eastern Nigeria. J. Biol. Agric. Healthc. 3(3): 84–93.

McGilchrist, C.A. 1965. Analysis of competition experiments. Biometrics. 21(4): 975–985. https://doi.org/10.2307/2528258.

Moges, A. 2015. Effect of Nitrogen Fertilizer Rates and Plant Densities on Yield and Yield Related Traits of Maize under Irrigation in South Tigray, Ethiopia. MS Thesis, Haramaya University, Haramaya, Ethiopia.

Mohammed, A.I.A. and E.H.A. Hamad. 2015. Evaluation of productivity and competition indices of safflower and fenugreek as affected by intercropping pattern and foliar fertilization rate. Middle East J. Agric. Res. 4(4): 956–966.

Musa, U.T. and M. Yusuf. 2021. Yield potential and monetary advantage index of maize intercropped with grain legume in Anyigba, Kogi State, Nigeria. AJASET. 5(2): 262–270. https://doi.org/10.54536/ajaset.v5i2.104.

Ofori, F. and W.R. Stern. 1987. Cereal–legume intercropping systems. Adv. Agron. 41: 41–90. https://doi.org/10.1016/S0065-2113(08)60802-0.

Ogindo, H.O. and S. Walker. 2005. Comparison of measured changes in seasonal soil water content by rain fed maize-bean intercrop and component cropping systems in a semi-arid region of southern Africa. Phys. Chem. Earth. 30(11–16): 799–808. https://doi.org/10.1016/j.pce.2005.08.023.

Okigbo, B.N. and D.J. Greenland. 1976. Intercropping systems in tropical Africa, pp. 63–102. *In*: R.I. Papendick, P.A. Sanchez and G.B. Triplett, (Eds.), Multiple Cropping. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Inc., Wisconsin, USA.

Olorunmaiye, P.M. 2010. Growth and yield in maize/cassava intercrop as affected by interactions of weed control methods. Australian Journal of Agricultural Engineering. 1(3): 106–111.

Sarkar, M. and M. Raghav. 2010. Studies on growth and flowering characteristics of capsicum in maize based intercropping system. Res. J. Agric. Sci. 1(3): 271–272.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods. 6th Edition. Iowa State University Press, Ames, Iowa, USA.

Stefan, H., W. Lydia, L.A.A. Charles, O.A. Damian, J. Grace and U. Utiany. 2015. Cassava Cropping Guide. Africa Soil Health Consortium, Nairobi, Kenya.

Uddin, M.K.B., S. Naznin, M.A. Kawochar, R.U. Choudhury and M.A. Awal. 2014. Productivity of wheat and peanut in intercropping system. J. Expt. Biosci. 5(2): 19–26.

Willey, R.W. 1979. Intercropping- its importance and research needs. Part 1. Competition and yield advantages. Field Crops Abstracts. 32(1): 1–10.

Willey, R.W. and D.S.O. Osiru. 1972. Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference to plant population. J. Agric. Sci. 79(3): 517–529. https://doi.org/10.1017/S0021859600025909.

Willey, R.W. and M.R. Rao. 1980. A competitive ratio for quantifying competition between intercrops. Exp. Agric. 16(2): 117–125. https://doi.org/10.1017/S0014479700010802.

Yahaya, T.I., S. Ojoye and E.K. Tsado. 2016. Assessment of the relationship between increase in height of cassava growth rate and agro-climatic parameters in Ilorin area of Kwara State, Nigeria. Adv. Nat. Sci. 9(2): 16–22. https://doi.org/10.3968/8486.

Yilmaz, S., M. Atak and M. Erayman. 2008. Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean region. Turk. J. Agric. For. 32(2): 111–119.

Zamir, M.S.I., A.H. Ahmad, H.M.R. Javeed and T. Latif. 2011. Growth and yield behavior of two maize hybrids (*Zea mays* L.) towards different plant spacing. Cercetari Argonomice in Moldova. 44(2): 33–40.

Zhang, G., Z. Yang and S. Dong. 2011. Interspecific competitiveness affects the total biomass yield in an alfalfa and corn intercropping system. Field Crops Res. 124(1): 66–73. https://doi.org/10.1016/j.fcr.2011.06.006.