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Cassava/Maize Intercrop Yield Response to Different Plant Population Densities in Makurdi and Lafia

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Abstract— **Twofield experiments were conducted from 2015 to 2016 in Teaching and Research Farm of the Federal University of Agriculture, Makurdi, Benue State and Research and Teaching Farm of the College of Agriculture, Lafia, Nasarawa State all in Nigeria. The objective of the experiment was to evaluate the effect of planting density on the yield of intercropped maize with cassava.The result obtained from the experiment showed that intercropping depressed both the growth and yield of both maize and cassava. Sole cropping gave higher grain yield of maize than intercropping in Lafia (2.41t/ha and 1.59t/ha repectively) and Makurdi (2.51t/ha amd 1.66t/ha respectively). Intercropping also decreased the plant height of maize at harvest, leaf area index at harvest, cob circumference, cob length, number of rows per cob, number of seeds per cob, cob weightand 100-seed weightof maize. Maize sown at a population density of 40,000 plants per hectare produced the highest cob weight of maize in Lafia (4.32t/ha) and Makurdi (4.43t/ha). A similar trend was observed in grain yield where maize sown at 40,000 plants/ha gave the highest grain yield in Lafia (2.52t/ha) and Makurdi (2.56t/ha). The plant population density of 20,000 plants/ha gave higher values for all other parameters evaluated. Cassava intercropped wit maize at a population density of 20,000 plants per hectare produced higher yield and yield parameters of cassava than any other density.Although the yields of sole crops were higher than their intercrop counterparts, intercropping was more productive than sole crop components as evidenced by Land Equivalent Ratio and Land Equivalent coefficient values, which were above unity and 0.25, respectively. Maize was the more competitive component of the maize/cassava intercropping in both Lafia and Makurdi locations.**

Index Terms— **cassava, density, intercropping, Maize, sole cropping.**

I. INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop grows in different parts of the world including in Africa serving as source of food and industrial raw materials [1]. It is a key source of food and livelihood for millions of people in many countries of the world. It is produced extensively in Nigeria, where it is consumed roasted, baked, fried, pounded or fermented [2]. Maize grains have great nutritional value as they contain 72 % starch, 10 % protein, 4.8 % oil, 8.5 % fibre, 3.0 % sugar and 1.7 % ash [3]. The stalk, leaves, grain and immature ears are cherished by different species of livestock [4].

Cassava (*Manihot esculenta* Crantz) has served as a major source of energy for more than 500 million people in tropical countries of Africa, Asia and Latin America[5]. All parts of the plants are important. The leaves which are rich in protein, minerals and vitamins are important vegetables [6] while the stem cuttings are commercially used as planting material [7].

Cassava and maize are prominent crops under intercropping and have been extensively studied in Nigeria [8] [9] [10]. They (cassava/maize intercrop) have been indicated to be productive and compatible mainly because maize is a short season crop while cassava is a long duration crop [11] .

Studies on the effect of planting density on the yield and yield components of maize abound [12] [13], however, documented scientific information on the influence of planting density of maize on the performance of intercropped maize with cassava in Southern Guinea Savanna of Nigeria is scarce.

The study reported here was therefore undertaken to fill this gap and the main objective was to evaluate the influence of planting density of maize on the productivity of maize/cassava intercropping systems in Makurdi and Lafia with a view to enhance food security in the Southern Guinea Savanna region of Nigeria.

II. MATERIAL AND METHODS

A. Experimental Locations

Two experiments were conducted from 2015 to 2016 in two locations viz:-

i. Teaching and Research Farm of the Federal University of Agriculture, Makurdi [Latitude 07º 45′ - 07º 50′ N, Longtitude 08º 45′- 08º 50′ E, elevation 98 m] in Benue State, located in Southern Guinea Savannah of Nigeria.

ii. Research and Teaching Farm of the College of Agriculture, Lafia (Latitude 08.33N and Longitude 08.32E) in Nasarawa State, located in Southern Guinea Savannah of Nigeria.

The objective of the experiment was to evaluate the effect of planting density on the yield of intercropped maize with cassava.

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B. Soil Sampling and Analysis

Thirty core samples were collected from 0-30cm depth from each experimental site before land preparation using a tubular sampling auger and bulked into a composite sample, air-dried and ground. The samples were sieved through 2mm and 0.05mm screens for the determination of the physical and chemical properties of the soil (Table 1) before planting. Both the physical and chemical analyses were done in the Soil Science Laboratory of the University of Agriculture, Makurdi.

C. Treatment and Experimental Design

The experiment was a 2 x 3 split plot laid out in randomized complete block design with three replications. The main plot treatment was two cropping systems [sole cropping (maize, cassava), intercropping (maize + cassava)] while the sub plot treatment comprised of three plant population densities for maize (20,000 plants/ha (100cm x 25cm) 40,000 plants/ha (100cm x 50cm) and 80,000 plants/ha (100cm x 100cm)]. The improved maize variety (Suwan 1-1) used for this study was obtained from Teaching and Research Farm of the Federal University of Agriculture, Makurdi while the cassava variety (NR 8082) was gotten from National Root Crops Research Institute (NRCRI) Umudike.

D. Spacing and Plant Population

The intra-row spacing of maize and concomitant plant population was as indicated in the Table 2 below. In intercropping, cassava was planted at the top of the ridges while maize was sown at the side of the ridge. Each sub plot consisted of 5 ridges spaced 1m apart and 4m long and the net plot was the three middle ridges, 3m long.

E. Agronomic Practices

The experimental site was cleared and ridged using cutlasses and hoes. Maize and cassava were sown either as sole crop or intercrop on ridges on the same day in both experimental locations (18 April, 2016 and 18 June, 2016 in Lafia and MAkurdi respectively). Maize seeds were dressed with Apron Plus® 50DS (10% metalaxy, 1.34% furanthiocarb, 61% carboxin) at the rate of one sachet per three kilogrammes of seed. Three maize seeds were planted per hill by the side of the ridge. Cassava cuttings measuring 30cm were planted at an angle of 45° at the top of the ridge a spacing of 100cm within rows. Maize was thinned to 2 seedlings/stand at 10 days after planting (DAP) while supplying was done to cassava at 14 DAP. Intercropping had a 1:1 (maize:cassava) row proportion. Fertilizer was applied to maize at the rate of 30kg N, 30kg P2O5 and 30kg K2O per hectare [14] obtained from NPK 15:15:15 in split doses at 3 and 6 WAP by side placement. At 4 W.A.P, cassava plots in both sole and intercropped were top dressed with 200kg of NPK 15:15:15 by side placement [14]. Two manual weedings were done at 3 and 7 weeks after planting (WAP) respectively. This was followed by remoulding at 12 WAP. All these operations were carried out by hoe. Hand pulling of the weeds in the experimental plots was done when necessary. 'Best'® (Cypermithrin 10% EC) at a dose of 60 ml in 10 litres of water was used for the control of insect pest on maize and this was repeated at fortnightly interval.Harvesting was done as each component crop reached physical maturity. In all cases local implements (knives, cutlasses and hoes) were used for harvesting. Maize cobs were cut and sundried before threshing and winnowing.

F. Data Collection

All data at harvest were collected from the net plot. For the maize component, data was collected on plant height at harvest, cob length, number of rows per cob, number of seeds per row grain yield and hundred seed weight. Data on cassava component was collected on plant height at harvest, root circumference, root length, number of saleable roots per plant and weight of saleable roots per hectare. Saleable roots were fresh roots ≥ 150g.

G. Assessment of Measures of Intercrop Productivity

a. Land equivalent ratio (LER) as described by [15].
b. Land equivalent coefficient (LEC) [16] (Adetiloye *et al.,* 1983).
c. Competitive ratio (CR) indicates the degree with which one crop competes with the intercrop. This was calculated using the formula proposed by [17] Willey *et al.,* (1980).

H. Data Analysis

Standard procedures were followed in collecting all data and analysis was done using GENSTAT statistical software. Whenever differences between treatment means were significant, means were separated by Fishers Least Significant Difference at 5% level of probability.

III. RESULTS

A. Maize Component

B. Plant Height at Harvest

The main effect of cropping system x plant population density as well as the interaction effects of cropping system x plant population density on the plant height of maize at harvest was significant c in Lafia and Makurdi.
Data presented in Table 4 showed that maize had higher plant height values in Makurdi than Lafia. Irrespective on the cropping system, maize planted at a population density of 20,000 plants/ha gave the highest plant height of maize at harvest in Lafia and Makurdi. In both locations, maize intercropped at a plant population density of 80,000 plants/ha produced the lowest plant height of maize at harvest (Table 4).
On a general note, sole cropping produced significantly higher plant height at harvest than intercropping. Maize sown at a plant population density of 20,000 plants/ha produced significantly higher plant height at harvest than that sown at 40,000 plants/ha which in turn gave significantly higher plant

Table 1: Physical and chemical properties of the surface soil (0-15 cm) at the experimental sites in Makurdi and Ibi in 2015

Parameters	**Makurdi**	**Lafia**
Sand (%)	72.20	73.10
Silt (%)	12.20	11.30
Clay (%)	14.40	13.50
Textural class	Sandy loam	Sandy loam
pH (H_2O)	5.93	6.30
Organic Carbon (%)	0.72	0.80
Organic Matter (%)	1.25	1.36
Total Nitrogen (%)	0.70	0.78
Available Phosphorus (ppm)	3.60	2.90
Cal^{2+} Cmol kg^{-1} soil)	3.41	3.57
Mg^{2+} (Cmol kg^{-1} soil)	1.62	1.70
K^{+}Cmol kg^{-1} soil)	0.29	0.30
Na^{+}Cmol kg^{-1} soil)	0.60	0.52
CEC Cmol kg^{-1} soil)	6.25	6.40
Base Saturation (%)	94.40	95.00

Table 2: Treatment, Spacing and Plant Population of Maize and Cassava as Undertaken in the Experiment Layout.

S/No	Treatment	Spacing
1.	Sole maize	100cm x 100cm x 2 plants/hill
2.	Sole maize	100cm x 50cm x 2 plants/hill
3.	Sole maize	100cm x 25cm x 2 plants/hill
5.	Sole cassava	100cm x 100 x 1 plant/hill
6.	Intercropped maize + cassava	100cm x 100cm x 2 plants/hill 100cm x 100cm x 1 plant/hill
7.	Intercropped maize + cassava	100cm x 50cm x 2 plants/hill 100cm x 100cm x 1 plant/hill
8.	Intercropped maize + cassava	100cm x 25cm x 2 plants/hill 100cm x 100cm x 1 plant/hill

population density that that sown at 80,000 plants/ha in both locations (Table 3).

C. Leaf Area Index at Harvest

The leaf area index of maize at harvest as influenced by the main effect of cropping system x plant population density as well as the interaction effects of cropping system x plant population density was significant (P≤ 0.05) in Lafia and Makurdi.

In both locations, the highest leaf area index of maize at harvest was produced when maize was sown as sole at a density of 20,000 plants/ha and this was significantly higher than that produced by any other treatment. Maize intercropped at a population density of 80,000 plants/ha produced the lowest leaf area index value at harvest and Lafia and Makurdi (Table 4).

Sole cropping produced significantly higher leaf area index values than intercropping in Lafia and Makurdi. Among the plant population densities evaluated, 20,000 plants/ha and 80,000 plants/ha gave the highest and lowest leaf area index at harvest respectively in both locations (Table 3).

D. Cob Circumference

The cob circumference of maize as influenced by the main effect of cropping system x plant population density as well as the interaction effects of cropping system x plant population density was significant (P≤ 0.05) in Lafia and Makurdi.

Higher cob circumference values were produced in Lafia than Makurdi (Table 3 and 4). In both locations, sole maize produced the highest cob circumference when it was sown at a population density of 20,000 plants/ha and this was only significantly higher than that produced when intercropped maize was sown at a population density 40,000 and 80,000 plants/ha (Table 4).

In Lafia and Makurdi, sole cropping generally produced significantly higher cob circumference of maize than intercropping. The population density of 20,000 plants/ha gave the highest cob circumference of maize but this was only significantly higher than that produced by 80,000 plants/ha (Table 3).

E. Cob Length

The main effect of cropping system x plant population density as well as the interaction effects of cropping system x plant population density on the cob length of maize was significant (P≤ 0.05) in Lafia but in Makurdi, only the main effect of plant population density and the interaction effects of cropping system x plant population density was significant (P≤ 0.05).

Regardless of the cropping system used, the plant population density of 20,000 plants/ha gave the highest cob length of maize in Lafia and Makurdi. Maize intercropped at a population density of 80,000 plants/ha gave the lowest cob length values in both locations (Table 4).

Sole cropping gave higher cob length of maize in Lafia and Makurdi than intercropping but only that of Lafia was significantly higher. The plant population density of 20,000 plants/ha gave higher cob length than 40,000 and 80,000 plants per hectare respectively in both locations (Table 3).

A. Number of Rows per Cob

The main effect of cropping system x plant population density as well as the interaction effects of cropping system x plant population density was significant (P≤ 0.05) on the number of rows per cob of maize in Makurdi but in Lafia, only the main effect of plant population density and the interaction effects of cropping system x plant population density was significant (P≤ 0.05).

In Lafia, the population density of 20,000plants/ha gave the same number of rows per cob of maize and this represented the highest number of rows per cob in Makurdi. A dissimilar trend was observed in Makurdi where a population density of 40,000 plants/ha gave the highest number of rows per cob. In both locations, intercropped maize sown at a plant population density of 80,000 plants/ha produced the lowest number of rows per cob (Table 6).

In Makurdi, intercropping gave significantly higher number of rows per cob than sole cropping. Maize sown at a plant population density of 20,000 plants/ha generally gave higher number of rows per cob than that sown at 40,000 and 80,000 plants/ha respectively (Table 5).

F. Number of Seeds per Row

The main effect of cropping system x plant population density as well as the interaction effects of cropping system x plant population density on the number of seeds per row of maize at harvest was significant (P≤ 0.05) in Lafia and Makurdi.

In both locations, sole maize produced the highest number of seeds per row when it was sown at a population density of 20,000 plants/ha in both locations but the difference was not significantly higher than that produced when sole maize was planted at a population density of 40,000 plants/ha. Maize intercropped at a population density of 80,000 plants/ha gave the lowest number of seeds per row in both locations (Table 6).

Sole cropping produced significantly higher number of seeds per row than intercropping in Lafia and Makurdi. Regardless of the location, maize sown at a population density of 20,000 plants/ha gave the highest number of seeds per row (Table 5).

G. Cob Weight

The cob weight of maize as influenced by the main effect of cropping system and plant population density as well as the interaction effects of cropping system x plant population density was significant (P≤ 0.05).

Data presented in Table 6 revealed that maize sown at a population density of 40,000 plants/ha gave the highest cob weight in both locations regardless of the cropping system used. Intercropped maize sown at a plant population density of 20,000 plants/ha gave the lowest cob weight of maize while that sown at a population density of 80,000 plants/ha gave the lowest cob weight in Makurdi (Table 6).

In all locations, sole cropping gave higher cob weight than intercropping and the difference was significant. Maize sown at a plant population density of 40,000 plants/ha produced significantly higher cob weight of maize than that sown at

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20,000 and 80,000 plants/ha respectively in Lafia and Makurdi (Table 5).

Table 3: Effect of Cropping System and Plant Population Density of the Pant Height, Leaf Area Index, Cob Circumference and Cob Length of Maize in Lafia and Makurdi.

Treatment	Plant Height at Harvest		Leaf Area Index at Harvest (cm^2)		Cob Circumference (cm)		Cob Length (cm)	
	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi
Cropping System								
Intercropping	172.89	192.47	185.00	199.03	12.98	13.84	25.65	29.90
Sole Cropping	180.86	203.82	196.97	220.97	15.40	15.86	29.98	29.80
F-LSD (0.05)	3.54	4.32	4.65	4.93	2.03	1.54	2.54	NS
Density								
20,000 plants/hectare	192.75	204.48	219.15	249.93	15.04	15.59	29.21	30.94
40,000 plants/hectare	174.97	198.99	184.20	204.49	14.30	14.97	27.50	29.70
80,000 plants/hectare	162.91	190.97	169.60	175.59	13.24	14.01	26.73	28.92
F-LSD (0.05)	2.34	3.54	5.43	6.43	1.52	1.21	1.14	1.32

Table 4: Interaction Effects of Cropping System x Plant Population Density of the Pant Height, Leaf Area Index, Cob Circumference and Cob Length of Maize in Lafia and Makurdi.

Cropping System	Density	Plant Height at Harvest (cm)		Leaf Area Index at Harvest (cm^2)		Cob Circumference (cm)		Cob Length (cm)	
		Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi
Intercropping	**20,000 plants/hectare**	192.87	195.54	211.60	229.50	14.30	14.70	26.78	30.20
	40,000 plants/hectare	164.67	193.43	179.90	195.37	12.73	13.93	25.43	30.17
	80,000 plants/hectare	161.13	188.43	163.50	172.23	11.90	12.90	24.73	29.33
Sole Cropping	**20,000 plants/hectare**	192.63	213.42	226.70	270.35	15.77	16.47	31.63	31.67
	40,000 plants/hectare	185.27	204.54	188.50	213.60	15.87	16.00	29.57	29.23
	80,000 plants/hectare	164.68	193.51	175.70	178.95	14.57	15.11	28.73	28.50
F-LSD (0.05)		3.71	4.16	6.43	6.95	1.86	2.53	3.76	1.54

Table 5: Interaction Effects of Cropping System and Plant Population Density on some Yield and Yield Parameters of Maize in Lafia and Makurdi

Treatment	Number of Rows per Cob		Number of Seeds per Row		Cob Weight (t/ha)		Grain Yield (t/ha)		100-Seed Weight (g)	
	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi
Cropping System										
Intercropping	17.33	14.82	23.82	27.99	3.47	3.63	1.59	1.66	30.60	27.73
Sole Cropping	17.32	18.81	27.56	28.54	4.22	4.39	2.41	2.51	35.33	34.41
F-LSD (0.05)	NS	2.21	0.43	0.21	0.22	0.41	0.41	0.50	2.54	2.65
Density										
20,000 plants/hectare	18.33	18.17	27.50	29.55	3.70	3.88	1.91	1.87	37.43	35.66
40,000 plants/hectare	17.30	17.50	26.00	28.54	4.32	4.43	2.52	2.56	32.42	34.00
80,000 plants/hectare	16.35	14.78	23.56	26.70	3.52	3.73	1.59	1.83	29.05	23.55
F-LSD (0.05)	1.34	1.41	1.33	0.32	0.34	0.32	0.52	0.58	2.56	3.64

Table 6: Interaction Effects of Cropping System x Plant Population Density on some Yield and Yield Parameters of Maize in Lafia and Makurdi

Cropping System	Density	Number of Rows per Cob		Number of Seeds per Row		Cob Weight (t/ha)		Grain Yield (t/ha)		100-Seed Weight (g)	
		Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi
Intercropping	**20,000 plants/hectare**	18.33	17.33	26.00	28.67	3.11	3.36	1.27	1.32	35.30	32.65
	40,000 plants/hectare	17.36	15.00	23.33	28.31	4.11	4.21	2.28	2.35	29.32	29.57
	80,000 plants/hectare	16.31	12.13	22.12	26.98	3.18	3.33	1.23	1.30	27.17	20.98
Sole Cropping	**20,000 plants/hectare**	18.33	19.00	29.00	30.43	4.29	4.39	2.54	2.42	39.55	38.67
	40,000 plants/hectare	17.24	20.00	28.67	28.77	4.52	4.64	2.75	2.76	35.52	38.43
	80,000 plants/hectare	16.39	17.42	25.00	26.42	3.86	4.13	1.95	2.35	30.93	26.13
F-LSD (0.05)		1.12	1.62	2.31	2.54	0.21	0.23	0.14	0.34	3.21	3.42

H. Grain Yield

The grain yield of maize as influenced by the main effect of cropping system and plant population density as well as the interaction effects of cropping system x plant population density was significant (P≤ 0.05).

In all locations, sole maize gave the highest grain yield of maize when it was sown at a population density of 40,000 plants/ha irrespective of the cropping system used. The grain yield of maize was produced when maize was intercropped at a population density of 80,000 plants/ha (Table 6).

On a general note, sole cropping gave significantly higher grain yield than intercropping in Makurdi and Lafia. In both locations, plant population density of 40,000 plants/ha gave significantly higher grain yield than 20,000 and 80,000 plants/ha respectively (Table 5).

I. 100-Seed Weight

The main effect of cropping system x plant population density as well as the interaction effects of cropping system x plant population density on the 100-seed weight of maize was significant (P≤ 0.05) in Lafia and Makurdi.

Maize sown at a population density of 20,000 plants/ha gave higher 100-seed weight of maize in Lafia and Makurdi irrespective of the cropping system. In both locations, maize intercropped at a population density 80,000 plants/ha consistently gave the lowest 100-seed weight of maize (Table 6).

Data contained in Table 5 showed that in both locations, sole cropping produced significantly higher 100-seed weight of maize than intercropping. Among the population densities examined, maize sown at a population density of 20,000 plants/ha generally gave higher 100-seed weight of maize than the other densities in Lafia and Makurdi (Table 5).

Cassava Component

A. Plant Height at Harvest

The effect of cropping system and plant population density was significant (P≤ 0.05) on the plant height of cassava at harvest in Lafia and Makurdi. Data shown in Table 7 revealed that in Lafia and Makurdi, sole cassava produced the highest plant height at harvest and the difference was significant. Among the treatments intercropped, cassava intercropped at a population of 20,000 plants/ha gave the highest plant height at harvest (Table 7).

B. Root Circumference

The root circumference of cassava as influenced by cropping system and plant population density was significant (P≤ 0.05) in Lafia and Makurdi. Sole cropping gave significantly higher root circumference than intercropping in Lafia and Makurdi. Cassava intercropped at a population density of 20,000 plants/ha gave the highest root circumference among the treatments intercropped irrespective of the location (Table 7).

C. Root Length

The root length of cassava was significantly (P≤ 0.05) affected by cropping system and plant population density in Lafia and Makurdi. In both locations, sole cropping gave significantly higher root length than all the other treatments. The root length of cassava shortened as the population density of maize increased. Sole cropping generally gave higher root length than intercropping in Lafia and Makurdi (Table 7).

D.Number of Marketable Roots per Plant

The number of marketable roots per plant was significantly (P≤ 0.05) influenced by cropping system and plant population density in Lafia and Makurdi. Sole cropping gave significantly higher number of marketable roots per plant than intercropping in both locations. In both locations, cassava intercropped at a population density of 20,000 plants/ha gave the highest number of marketable roots per plant among treatments intercropped. Cassava intercropped with maize at a population density of 80,000 plants/ha gave the lowest number of marketable roots per plant (Table 8).

E.Number of Unmarketable Roots per Plant

The number of unmarketable roots per plant was significantly (P≤ 0.05) influenced by cropping system and plant population density in Lafia and Makurdi. Sole cassava produced significantly higher number of unmarketable roots per plant than any other treatment irrespective of the location. Maize intercropped at a population density of 80,000 plants/ha gave the lowest number of unmarketable roots per plant in Lafia and Makurdi (Table 8).

F.Root Weight

Cropping system and plant population density had significant (P≤ 0.05) effect on the root weight of cassava in Lafia and Makurdi. Sole cassava gave higher root weight of cassava than any other treatment and the difference was significant. Cassava intercropped at a population density of 20,000 plants/ha gave the highest root weight among the treatments intercropped. Cassava intercropped at a density of 80,000 plants/ha produced the lowest root weight (Table 8).

Table 9 presents the results of measures of intercrop productivity [Land Equivalent Ratio (LER), Land Equivalent Coefficient (LEC)] and measures of competitive interactions [Competitive Ratio (CR)] between the intercrop components of maize and sweet potato in Lafia and Makurdi in 2016.

All intercrop combinations had LER figures above 1.0 and LEC values above 0.25 in both locations. CR values of maize were consistently higher than those of cassava in all intercrop combinations (Table 9).

IV. DISCUSSION

A. Maize Component

The results of this study indicated that in both locations, plants sown at lower population densities grew taller than those grown at higher densities. This might have resulted from the decreased competition for growth resources (nutrients, water, light) in lower population densities. This result was in agreement with the findings of Nthabise. who also reported increased plant height with decreased population density. The decreases in leaf area index, cob circumference, cob length, number of rows per cob, number

Table 7: Plant Height, Root Circumference and Root Length of Cassava as Influenced by Cropping System and Plant Population Density in Lafia and Makurdi

Treatment	Plant Height at Harvest (cm)		Root Circumference (cm)		Root Length (cm)	
	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi
Cassava + Maize (10,000 + 20,000 plants/ha)	126.33	138.90	16.67	18.67	36.00	39.67
Cassava + Maize (10,000 + 40,000 plants/ha)	120.90	128.33	13.67	14.37	33.00	37.33
Cassava + Maize (10,000 + 80,000 plants/ha)	112.23	122.57	11.67	12.57	29.67	34.17
Intercrop Mean	119.82	129.93	14.00	15.20	32.89	37.06
Sole Cassava (10,000 plants/ha)	147.18	163.18	24.00	25.80	53.28	55.53
Grand Mean	126.66	138.25	16.50	17.85	37.99	41.68
F-LSD (0.05)	9.22	3.21	2.93	2.62	5.41	2.00

of seeds per cob and 100-seed weight in Lafia and Makurdi with increased plant population density might have resulted from intensification of competition for growth resources as the density increased. [18] had showed that the main effect of increasing plant population density is to increase rivalry between adjacent plants, resulting in reduced yields with increases in plant density above a critical limit dependent on plant species/genotype [19]. The cob weight and grain yield of maize per plant was higher at a population density of 20,000 plants/ha (data not shown) but the yield per hectare was higher at 40,000 plants/ha. [20] also reported that maize grain yield increased as maize plant density increased up to a point in maize/soybean intercropping.

The growth and yield reduction of intercropped maize might be due to interspecific competition between the intercrop components for growth resources (light, water, nutrients, air, etc.) and the depressive effects of cassava. [21] made similar observations in their study and attributed it to inter- specific competition for light, nutrients, water, air and other growth resources.

B. Cassava Component

Intercropping depressed all growth and yield parameters (plant height, root circumference, root length, number of unmarketable roots, number of marketable roots, and root weight per hectare) evaluated in this study in both locations. This result agrees with the findings of [22] who reported plant height, number of roots per plant and root weight/yield to be depressed by intercropping. The lowered growth and yield of intercropped cassava might be attributed to interspecific competition between the intercrop components for growth resources (light, water, nutrients, air) and the depressive effects of shading by maize.

In Lafia and Makurdi, cassava intercropped at a plant population density of 20,000 plants/ha gave higher growth and yield of cassava than those intercropped at 40,000 and 80,000 plants/ha. The better performance of cassava at 20,000 plants/ha than at 40,000 and 80,000 plants/ha might be ascribed to reduced competitiveness for growth resources at 40,000 and 80,000 plants/ha as compared to 20,000 plants/ha. [23] explained that at lower planting densities, there is a surplus of production factors (water, nutrients, and light), with a tendency for increased yields of roots, stems, and leaves. As planting densities increase, competition for those factors increases and, beyond a certain density, which varies with the trait being evaluated, yield values decrease.

Table 8: Effect of Cropping System and Plant Population Density on the Number of Marketable and Unmarketable roots per Plant and Root Weight of Cassava in Lafia and Makurdi

Treatment	Number of Marketable Roots per Plant		Number of Unmarketable Roots per Plant		Root Weight (t/ha)	
	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi
Cassava + Maize (10,000 + 20,000 plants/ha)	11.83	13.31	2.00	2.00	7.56	8.22
Cassava + Maize (10,000 + 40,000 plants/ha)	9.50	9.67	1.67	1.67	6.73	7.60
Cassava + Maize (10,000 + 80,000 plants/ha)	8.34	9.21	1.00	1.33	6.20	7.43
Intercrop Mean	9.89	10.73	1.56	1.67	6.83	7.75
Sole Cassava (10,000 plants/ha)	15.43	16.00	3.83	3.50	12.35	12.88
Grand Mean	11.28	12.05	2.13	2.13	8.21	9.03
F-LSD (0.05)	1.57	2.30	0.22	0.31	1.91	2.38

C. Productivity Assessment of Maize/Cassava Intercropping Systems

Land equivalent ratio (LER) values were above 1.0 in all intercrop combinations and in both locations (Table 19), signifying intercropping advantages for all treatments. Similarly, LEC figures were above 0.25, further indicating the yield advantage of intercropping maize with cassava at the various intra-row spacings in both locations. This indicates that all intercropping combinations were better in resource use efficiency compared to growing the two crops separately [24]. [22] and [24] also confirmed intercrop advantage in maize/cassava intercropping systems. The differences in the rooting system of cassava and maize might have been responsible for the complementarity in the maize/cassava intercropping. These differences may have resulted in a fuller exploration of the whole soil profile by component crops than can be achieved by separate sole crops. [20] reported that LER values above unity indicated complementarity in resource utilization by the component crops.

Competitive ratio values indicated that maize was more competitive than cassava in all densities of maize tested. This might probably be due to the height advantage of maize over the cassava component. The taller and faster-growing maize component intercepted more solar radiation and shaded the slower-growing cassava component. [25] had stated that such competition usually decreased survival, growth or reproduction of at least one species, usually the shaded species. He further reported that the interactions frequently occurred at the interface between two crop species where they were nearest in distance, and resulting in an increase or decrease of growth, development and even yields.

Table 9: Land Equivalent Ratio (LER), Land Equivalent Coefficient (LEC) and Competitive Ratio (CR) of Intercropped Maize with Cassava at Different Densities in Lafia and Makurdi

Treatment	LER		LEC		CR Maize		CR Cassava	
	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi	Lafia	Makurdi
Cassava + Suwan 1-1 (10,000 + 20,000 plants/ha)	1.04	1.14	0.27	0.32	1.92	1.08	1.09	0.92
Cassava + Suwan 1-1 (10,000 + 40,000 plants/ha)	1.44	1.49	0.51	0.54	1.35	1.33	0.74	0.75
Cassava + Suwan 1-1 (10,000 + 80,000 plants/ha)	1.13	1.13	0.32	0.32	1.26	0.96	0.80	1.04
Grand Mean	1.20	1.25	0.37	0.39	1.51	1.12	0.88	0.90
F-LSD (0.05)	0.16	0.21	0.12	0.14	1.03	1.22	0.32	0.21

V. CONCLUSION

In this study, the plant height at harvest, leaf area index at harvest, cob circumference, cob length, number of rows per cob, number of seeds per cob and 100-seed weight of maize component of maize/cassava intercropping systems increased with decreased plant population density, irrespective of the cropping system adopted in both Lafia and Makurdi locations. The highest cob weight and grain yield of maize was produced at a plant population density of 40,000 plants/ha. Intercropping depressed both the growth and yield of both maize and cassava. However, both maize and cassava produced higher grain yield and root weight under intercropping at lower plant population densities of maize. Although the yields of sole crops were higher than their intercrop counterparts, intercropping was more productive than sole crop components as evidenced by Land Equivalent Ratio and Land Equivalent coefficient values, which were above unity and 0.25, respectively. Maize was the more competitive component of the maize/cassava intercropping in both Lafia and Makurdi locations.

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