Effect of variety, planting density, and fertilizer on the yield and the relative competitive ability of intercropped maize and cassava

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SUMMARY

Different stands of two each of contrasting maize (*Zea mays* L.) and cassava (*Manihot esculenta* Cranz) varieties were established as intercrops in experiments at Fumesua and Kwadaso near Kumasi (6⁰ 43' N, 1⁰ 36' W), from 1986 to 1989. The objective was to identify the factors that play crucial role as determinants of yield of maize and cassava grown as intercrops. Genotype, planting density, and fertilizer application proved important in the performance of both intercrops. Each intercrop had a depressive effect on the other, maize being about two and half times more competitive than cassava. Interspecific superiority was, however, not constant for variety, planting density, and fertilizer application. Suitable combinations of genotypes of maize and cassava are suggested based on land equivalent ratio (LER) and competitive ratio (CR) values and suitable planting densities of the intercrops recommended.

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RÉSUMÉ

ASAFU-AGYEI, J. N. & OSAFO, D. M.: *Effet de la variété, la densité de plantation et l'engrais sur le rendement et la capacité concurrentielle relative de maïs et de manioc semés en lignes alternantes.* Des différentes récoltes sur pied, deux pour chacune des variétés contrastées de maïs (*Zea mays* L.) et de manioc (*Manihot esculenta* Cranz) étaient cultivées comme deux cultures en lignes alternantes dans les expériences à Fumesua et à Kwadaso auprés de Kumasi (6° 43¹, N, 1° 36¹, W) de 1986 à 1989. Le but était d'identifier les facteurs qui jouent des rôles décisifs comme les déterminants du rendement de maïs et de manioc cultivés comme deux cultures en lignes alternantes. Le génotype, la densité de plantation et l'application d'engrais se montraient importants dans le rendement des deux cultures semées en lignes alternantes. Chaque culture semée entre les lignes d'une autre culture avait un effet depressiff sur l'autre, le maïs étant environ deux et demie fois plus concurrentiel que le manioc. La supériorité interspécifique, cependant, n'était pas continuelle pour la variété, la densité de plantation et l'application d'engrais. Les combinaisons appropriées des génotypes de maïs et de manioc sont proposées basées sur la Proportion d'Equivalent de Terre (PET) et les valeurs de la Proportion Concurrentielle (PC), et les densités de plantation appropriées des deux cultures recommandées d'être semées en lignes alternantes.

Introduction

When maize and cassava are intercropped, the resulting competition tends to be severe during the first 4 months, which is a relatively early period for cassava. The fast-growing maize exploits the environment early, and the slow-growing cassava exploits it later after the maize harvest (Wilson & Lawson, 1980). Wilson & Lawson (1980) have also found that maize and cassava competed mainly during the first 4 months that maize makes its peak demand on resources. Although maize suppresses cassava during their early growth, it recovers rapidly after the maize has been harvested. Yield of cassava could, therefore, be reasonably high, since root bulking occurs during the long post-competition period. Temporal compatibility would be expected in a crop combination such as intercropped maize and cassava, because maize is usually harvested at 120 days or less, while the duration for cassava can extend from 180 days in very early varieties to 360 days. Cassava varieties that grow even up to 550 days are available (Ezumah *et al.,* 1990). Yet, cassava yield is often reduced by the short duration during which maize interferes. Research in Ghana (GGDP, 1986, 1987) has shown that full-season maize should be interplanted with long-season cassava, while early-maize varieties are more compatible with early cassava varieties.

Apart from greater yield stability and better insurance against total crop failure, other obvious advantages of intercropping include efficient use of growth resources by plants of different canopy structure, different rooting systems which allow exploitation of different depths, varying nutrient requirements at different periods, and different maturity periods. Growth and yield of maize and cassava seem diverse and, therefore, the plants probably differ in their use of growth resources. When these two crops are intercropped, cassava is either planted simultaneously with maize, or 1 to 4 weeks later. Maize always establishes faster and develops a full canopy long before leaf area development is accelerated in cassava. Maize is then harvested within 4 months of growth, while cassava may need an extra 5 months or more to be ready for harvesting. Wilson & Agboola (1979) therefore attributed the popularity of maize and cassava intercrops to the high compatibility and complementation between the two crops.

Optimizing light interception in crop mixtures may involve the choice of crops by morphology, relative growth duration, planting pattern or geometry, and planting density (Lawson, 1988). This is especially so, as Ezumah *et al.* (1990) reported that with increasing maize population, the top/root ratio for cassava yield increased, indicating a preferential accumulation of dry matter in shoot. The sink capacity of cassava was also reduced, because root number tended to increase while root size and total yield decreased. A tall C_4 crop and a short C_3 plant might, therefore, facilitate better spatial use of incident light in intercrops. (In grasses of tropical origin like maize, sorghum, millet and amaranthus, there is an assimilation of CO_2 involving an additional chemical pathway termed the C_4 dicarboxylic acid pathway, unlike the Calvin cycle or C_3 pathway common to most plant species like cassava, and in species of temperate origin like wheat, oats, and barley). Maize and cassava intercrop should fit neatly into such a productive arrangement. The component maize density is a main factor. With increasing maize population, the top/root ratio for cassava yield increased (Ezumah *et al.*, 1990), indicating a preferential accumulation of dry matter in shoot.

These trials, therefore, aimed at assessing the yield of maize and cassava as intercrops, and identifying the factors which play crucial role as determinants of yield when the two crops are grown as intercrops.

Materials and methods

The study comprised three trials involving interplanting maize and cassava as intercrops, to estimate growth and yield of the two components. The trials were conducted in a randomized complete block design with a 2^4 factorial arrangement. There were four blocks per trial. The four factors were each evaluated at two levels. In Trial 1(Fumesua, 1986 first rainy season), the four factors in the intercrop were maize variety ('Dorke' and 'Dobidi'), maize density (20,000 and 40,000 plants/ha), cassava variety ('Bosome Nsia' and 'Ankra'), and maize fertilization (45 and 180 kg/ha N). The cassava was planted at 10,000 plants/ha. In Trial 2 (Fumesua, 1987 first rainy season) and Trial 3 (Kwadaso, 1987 second rainy season), the factors used were the same as those for 1986 at Fumesua, except that maize fertilization was replaced by a cassava density treatment at 10,000 and 20,000 plants/ha. Monocropped plots of maize and cassava were attached to the various blocks for comparison purposes only, and did not form part of the treatments in the factorial arrangement described for the intercrops.

At all locations where the trials were conducted, the land was prepared by disc ploughing and harrowing for a smooth seed bed. Cassava planting materials were obtained from a uniform bulking plot planted one year earlier. The cassava stem cuttings were about 20 cm long, and were planted on the flat in rows spaced 1.0 m apart. Maize seed was protected from predators by treatment with Furadan 350 ST (carbofuran) at a rate of 30 ml commercial product in 15 ml water per kilogram of seed.

Row length was 8 m and plots measured 8 m × 8 m. In all the trials, cassava was planted at mid-rows between two adjacent maize rows. For the intercrops, interplanting of cassava into maize was at the same time as maize planting, except where time did not permit this. In such cases, cassava planting was completed within 8 days of planting of the maize. For the monocrops, maize or cassava was planted at the same time as the intercropped maize and cassava, respectively.

Two maize varieties were used in these trials:

(i) 'Dorke' (CRI), a 105-day open-pollinated early white dent maize variety released in 1984 by the Crops Research Institute, Kumasi, Ghana. It is about 165 cm high, flowers in 45 days, and matures in 105 days.

(ii) 'Dobidi' (CRI), a 120-day full-season open-pollinated white dent variety released at the Crops Research Institute, Kumasi, Ghana, in 1984. 'Dobidi' grows to a height of about 200 cm, flowers in 60 days, and can be harvested in 120 days. Since 'Dobidi' is a full-season variety, it is best suited for the long-growing seasons in the forest, forest-savanna transition, and the Guinea savanna zones.

Two cassava varieties were used:

(i) 'Bosome Nsia', is an early (9 months maturity) but late-branching local variety grown mainly in the coastal savanna areas of Ghana. It grows to a height of about 180 cm in 9 months.

(ii) 'Ankra', a long-season (12 months maturity), late-branching local variety, is widely grown in the forest and transitional areas of Ghana. It grows to a height of about 280 cm in 12 months, and it is very susceptible to the African cassava mosaic virus (ACMV).

All fertilizers were applied by banding in furrows, 5 cm from the maize plants. In all the trials, the within-row spacings for maize and cassava were adjusted for the desired plant population densities. Weeds were controlled in each trial by a pre-emergent application of Primagram 500, a herbicide comprising a combination of 250 g/l metolachlor (2-chloro-N-(2-ethyl-6-methyl-phynyl)-N-(2-methoxy-1-methylethyl) acetamide), 235g/l atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s- triazine) and 10 g/l atrazine related compounds, at a rate of 2.0 kg a.i./ha. Supplementary handweeding was done in all the trials where necessary to control weed regrowth after the herbicide was applied.

Grain yield of maize was corrected to 15 per cent moisture, while storage root yield of cassava was either by fresh or dry weight (air forced oven at 70 °C for 2-3 days).

In Trial 1 (Fumesua, 1989 first rainy season), the maize was planted at 100 cm × 50 cm spacing, one plant/hill for the lower density and two plants/hill for the higher density. The fertilizer was applied as 45:19:19 (comprising 19:19:19 kg/ha $N:P_2O_5:K_2O$ of compound fertilizer at planting, and 26 kg/ha N of sulphate of ammonia side-dressed at 5-6 WAP of the maize) at the lower fertilizer level. At the higher level, four times this rate of N was applied. Planting dates were as follows: intercropped maize, 26 Mar 86; and intercropped cassava, 3 Apr 86.

In Trial 2 (Fumesua, 1987 first rainy season) and Trial 3 (Kwadaso, 1987 second rainy season), the cassava was planted at 100 cm × 100 cm spacing for lower density, and 100 cm × 50 cm spacing for higher density. Planting dates for Trial 2 were 30 Mar 87 and 3 Apr 87 for intercropped maize and cassava, respectively. Planting dates for Trial 3 were 8 Jul 87 and 9 Jul 87 for maize and cassava, respectively.

The yield advantage index, land equivalent ratio (LER), was calculated to determine the land-use efficiency. Mead & Willey (1980) defined LER as follows:

$$LER = \sum_{i=1}^{n} (Y^{I}_{i} / Y^{m}_{i})$$

where n = total number of crops in the intercropping system;

Y^{m}_{i} = yield of crop i in sole cropping; and

Y^{I}_{i} = yield of crop i in intercropping.

LER is, therefore, the ratio of the area needed under sole cropping to that of intercropping at the same management level to give an equal amount of yield. If the level of management under intercropping is similar to that of monocropping, then LER is the sum of the fractions of the yields of the intercrops relative to their sole crop yields (Willey, 1979a). When LER > 1, a larger area of land is needed to produce the same yield of a single crop of each component than with an intercrop mixture. When LER=1, there is no advantage of intercropping relative to monocropping (Fageria, 1992).

The competitive index, competitive ratio (CR), was estimated in 1986 as an index to evaluate the degree of competition between and among intercrops. The basic process is the calculation of two equivalence factors, one for each component species. The competitive index is the product of the two equivalence factors (Fageria, 1992). It was estimated according to the following procedures suggested by Willey & Rao (1980):

$$CR = [(1_a/M_a)(1_b/M_b)^{-1}] (S_b/S_a)$$

where 1_a = yield of crop a in intercropping;

1_b = yield of crop b in intercropping;

M_a = yield of crop a in sole cropping;

M_b = yield of crop b in sole cropping;

S_a = relative space occupied by crop a; and

S_b = relative space occupied by crop b.

It follows that CR of crop a in a system with crop b can be defined as follows:

$$CR_a = (LER_a/LER_b) \times (Z_{ba}/Z_{ab}).$$

where LER_a = LER of crop a;

LER_b = LER of crop b;

Z_{ab} = proportion of intercropped area initially allocated to crop a; and

Z_{ba} = proportion of intercropped area initially allocated to crop b.

A higher value of CR of a crop in the system relative to another indicated its dominance in the association.

Results and discussion

Competitive ability of intercropped maize

Trial 1, Fumesua, 1986. At the final harvest, the mean plant height of 'Dorke' was 158.0 cm. The corresponding value for 'Dobidi' was 207.0 cm. Table 1 shows that ear weight per plant and grain yield were lower in 'Dorke' than in 'Dobidi'. It also shows that maize grain yield was unaffected by maize density and maize fertilization, but was significantly influenced by the cassava variety used as intercrop. When intercropped with 'Bosome Nsia', grain yield was 3.6 t ha^{-1}, but with 'Ankra' the yield amounted to 2.6 t ha^{-1}.

If the grain yield differences due to maize variety, ie. 0.7 t ha^{-1} (3.4 t ha^{-1}- 2.7 t ha^{-1}); maize density, ie. 0.3 t ha^{-1} (3.2 t ha^{-1}- 2.9 t ha^{-1}); cassava variety, ie. 1.0 t ha^{-1} (3.6 t ha^{-1} -2.6 t ha^{-1}); and maize fertilization, ie. 0.2 t ha^{-1} (3.2 t ha^{-1}-3.0 t ha^{-1}) are summed up and used as a base, then the average contribution to maize grain yield of maize variety is 31.8 per cent which is 0.7/2.2, that of maize density is 13.6 per cent which is 0.3/2.2, that of cassava variety is 45.5 per cent which is 1.0/2.2, and maize fertilization is 9.0 per cent which is 0.2/2.2. This seemingly shows the importance of cassava variety in the performance of maize in the intercrop.

For best maize performance,'Dorke' should be intercropped perferably with 'Bosome Nsia' at 40,000 plants ha^{-1} maize density (Table 2). Similarly, for good yield, 'Dobidi' could be intercropped with

TABLE 1

Intercropped Maize Yield and Ear Weight per Plant as Influenced by Maize Variety, Maize Density, Cassava Variety, Maize Fertilization, and Cassava Density

Factor	Fumesua 1986		Fumesua 1987		Kwadaso 1987	
	Grain yield (t ha^{-1})	Ear wt plant^{-1} (g)	Grain yield (t ha^{-1})	Ear wt plant^{-1} (g)	Grain yield (t ha^{-1})	Ear wt plant^{-1} (g)
Maize variety						
'Dorke'	2.7	125.3	1.2	61.0	2.1	115.0
'Dobidi'	3.4*	169.3*	2.7**	131.0**	3.5**	186.0**
Maize density (plants ha^{-1})						
20,000	3.2NS	202.0*	1.7	118.0**	2.4	181.0
40,000	2.9	92.6	2.2**	74.0	3.2**	120.0**
Cassava variety						
'Bosome Nsia'	3.6*	169.4**	2.1**	105.0**	2.8NS	151.0NS
Ankra'	2.6	125.2	1.8	87.0	2.8	150.0
Maize fertilization (kg ha^{-1} N)						
45	3.2NS	152.5NS				
180	3.0	142.1				
Cassava density (plants ha^{-1})						
10,000			1.9NS	95.0NS	2.8NS	149.0
20,000			1.9	95.0	2.8	153.0NS
CV (%)	16.1	21.8	10.1	11.4	15.6	17.8
SED	0.3	11.3	0.1	3.9	0.2	10.0
Mean	3.1	147.3	1.9	96.2	2.8	151.0

*Significant at $P = 0.05$ **Significant at $P = 0.01$ NS = Not significant

TABLE 2

Effect of Maize Variety, Maize Density, and Cassava Variety on Grain Yield of Intercropped Maize at Fumesua in 1986

Cassava variety	Maize density (plants ha^{-1})	Grain yield (t ha^{-1}) 'Dorke'	'Dobidi'
'Bosome Nsia'	20,000	3.0	4.3
'Ankra'	20,000	2.1	3.3
'Bosome Nsia'	40,000	3.6	3.3
'Ankra'	40,000	2.1	2.7
CV (%) 16.1			
SED 0.35			

Interaction significant at $P = 0.05$

'Bosome Nsia' at 20,000 plants ha^{-1}. Based on LER values, studies in Nigeria showed that late-maturing, taller maize types performed best at 40,000 plants ha^{-1} while an early-maturing, short maize type produced the best overall yield at 80,000 plants/ha (Ezumah *et al.*, 1990).

The monocrop yields were 'Dorke' = 3.1 (t ha^{-1}), 'Dobidi' = 3.9 (t ha^{-1}) at Fumesua in 1986; 'Dorke' = 1.4 (t ha^{-1}), 'Dobidi' = 3.1 (t ha^{-1}) at Fumesua in 1987; and 'Dorke' = 3.5 (t ha^{-1}), 'Dobidi' = 3.5 (t ha^{-1}) at Kwadaso in 1987. Thus, the monocrops yielded higher than the intercrops.

Although fertilizer application did not influence maize yield, in combination with cassava variety it was important in determining yield (Table 3) because this interaction was significant (P>0.05). The reduction in grain yield of maize intercropped with 'Ankra' was 67 per cent greater at 180 kg ha^{-1}N than at 45 kg ha^{-1}N. The stature of the cassava stands and, therefore, their ability to compete for light was probably enchanced by the higher level of N applied (Trenbath, 1976). Although maize density did not influence

TABLE 3

Effect of Cassava Variety and Maize Fertilization on Grain Yield of Intercropped Maize at Fumesua in 1986

Cassava variety	*Maize yield (t ha^{-1})* 45 kg N ha^{-1}	180 kg N ha^{-1}
Bosome Nsia'	3.4	3.7
"Ankra'	2.9	2.2
CV (%) 16.1		
SED 0.25		

Interaction significant at P = 0.05

intercropped maize grain yield, it had such a significant impact on ear weight per plant that the higher levels of N fertilization could not change this trend (Table 4).

From the CR and LER values (Table 5), the combination with the highest interspecific competition that would probably produce the worst combined yield or output was 'Dobidi' + 'Bosome Nsia'. The best combination was 'Dobidi' + 'Ankra'. The others fell in between these two combinations (Table 5). For the 'Dorke' + 'Ankra' combination, cassava had superior competitive ability compared to maize. For the 'Dobidi' + 'Ankra' combination, the maize was superior competitively, though the two had similar LER values; thus, indicating that competitive ability is not constant for a variety, but varies with other production factors.

TABLE 4

Effect of Maize Variety, Maize Density, and Maize Fertilization on Ear Weight per Plant of Intercropped Maize at Fumesua in 1986

Maize density (plant ha^{-1})	*Maize fertilization (kg N ha^{-1})*	*Ear wt plant^{-1} (g)* 'Dorke'	'Dobidi'
20,000	45	184.4	236.3
20,000	180	136.9	250.4
40,000	45	89.4	99.8
40,000	180	90.6	90.6
CV (%) 16.1			
SED 0.35			

Interaction significant at P = 0.05

If a farmer prefers more maize in his total output, the best combination would be 'Dobidi' + 'Ankra'. If the farmer prefers more cassava, then the best combination would be 'Dorke' + 'Ankra" in a location with similar weather and soil characteristics. The LER values indicated that intercropping allowed better exploitation of available resources by the two component crops and, therefore, greater total yields could be expected. Similar LER values were reported (Ezumah *et al*., 1990) for intercropped maize and cassava in southern Nigeria. The conclusion suggested could not have been arrived at, however, except in combination with CR and not from the LER values alone.

Work by Willey & Osiru (1972)seemingly suggest that the only real control a farmer could have over the yield balance was by the initial proportions of the species established. This study has, however, indicated that yield balance could also be controlled by proper choice of component crop varieties which would allow a fuller exploitation of the environment.

Trial 2, Fumesua, 1987. Results obtained at Fumesua in 1987 (Table 1) for intercropped maize, were similar to the 1986 results. 'Dobidi' was again taller than 'Dorke', and it caused a greater increase in cassava plant height than 'Dorke', apart from

TABLE 5

Effect of Varietal Combination on CR and LER of Intercropped Maize and Cassava at Fumesua in 1986

Intercrop	*CR* Maize-cassava (wet)		*LER*	*CR* Maize-cassava (dry)		*LER*
"Dorke'+'Bos.Nsia'	1.5	0.7	1.8	1.7	0.6	1.7
(difference (%)	(53)			(65)		
'Dobidi'+'Ankra'	1.1	0.9	1.5	1.2	0.9	1.4
(difference (%)	(18)			(25)		
'Dorke'+'Ankra'	0.8	1.2	1.5	0.9	1.2	1.5
(difference (%)	(-33)			(-25)		
'Dobidi'+'Bos. Nsia'	2.0	0.5	1.4	2.2	0.5	1.4
(difference (%)	(75)			(77)		
Average LER			1.6			1.5

giving a greater mean ear weight and a higher grain yield.

'Ankra' depressed the number of ears per plant, mean ear weight, and grain yield of the maize varieties. The average contribu-tions to maize grain yield were maize variety 65 per cent, maize density 22 per cent, and cassava variety 13 per cent. The difference calculated between the monocropped and intercropped maize yield at Fumesua was 13.3 and 12.9 per cent in 1987 and 1986, respectively. An interaction of maize variety and maize density also influenced ear weight, ear weight per plant being lower for the early season maize variety at high and low densities of maize. However, within a variety, ear weight was significantly higher at the lower density in 1986 at this location. Ear weight reduction due to density was moderated by cassava variety, being reduced 25 per cent by 'Ankra' at the lower maize density.However, this decrease was eliminated at the higher maize density. Maize density thus served as a stronger competitive character than cassava genotype in this instance.

Although cassava density did not seemingly influence the yield of intercropped maize, Table 6 shows that in combination with maize density it affected yield. Doubling the maize plant population density increased maize yield by 0.7 t ha^{-1} at a cassava density of 10,000 plants ha^{-1}, and by only 0.3 t ha^{-1} at 20,000 plants ha^{-1} cassava density. Thus, cassava at a density of 20,000 plants ha^{-1} exerted about 2.3 times greater competitive stress on maize yield than cassava at a density of 10,000 plants ha^{-1}. This finding agrees with the results of Yunusa (1989) that increasing or decreasing proportions of mixtures change the relative competitive abilities and yields of components. The results also agree with the findings of Willey (1979b) who emphasized that competitive ability is not a constant and quantifiable function for a given crop. The results (Table 6) also show that relatively high maize yields could be obtained at 40,000 plants ha^{-1} with cassava at 10,000 plants ha^{-1}.

TABLE 6

Effect of Maize Density and Cassava Density on Grain Yield of Intercropped Maize at Fumesua in 1987

Maize density (plants ha^{-1})	Cassava density (plants ha^{-1}) 10,000	20,000
	Maize yield (t ha^{-1})	
20,000	1.6	1.8
40,000	2.3	2.1
CV (%) 10.1		
SED 0.1		

Interaction significant at P = 0.05

Table 7 clearly shows the ability of plant density to moderate the competitive effect of cassava on maize. 'Ankra' reduced grain yield of maize, but this reduction was only important when the maize was planted at the lower density, as reflected by ear weight. This confirms the findings of Willey & Osiru (1972) that density affects competitive ability. However, this is relative and other equally important characters can suppress this ability.

TABLE 7

Effect of Maize Density and Cassava Variety on Grain Yield of Intercropped Maize at Fumesua in 1987

Maize density (plants ha^{-1})	Maize yield (t ha^{-1})	
	Cassava variety	
	'Bosome Nsia'	'Ankra'
20,000	2.0	1.5
40,000	2.2	2.1
CV (%) 10.1		
SED 0.1		

Interaction significant at P = 0.05

Trial 3, Kwadaso, 1987. The effects of all the production factors, except cassava variety, at Kwadaso in 1987 were similar to those in 1986 and 1987 at Fumesua (Table 1). Cassava genotype was unimportant in maize grain yield at Kwadaso, unlike at Fumesua in 1986 and 1987 (Table 1). Cassava density was also unimportant in the response variables estimated. Conditions in the second rainy season were particularly harsher, owing to the abrupt cessation of rains; and this being more detrimental to long-duration crops like cassava, was presumed to have depressed its performance.

40,000 plants ha^{-1} than at 20,000 plants ha^{-1} (Table 8). Therefore, maize variety apparently affected yield more than maize density.

Calculations similar to those for maize showed that cassava variety contributed 44 per cent of the effect on dry cassava root yield, maize density 27 per cent, while maize variety contributed 24 per

TABLE 8

Intercropped Cassava Yield and Root No. Plant^{-1} as Influenced by Maize Variety, Maize Density, Cassava Variety, Maize Fertilization, and Cassava Density

Factor	Fumesua 1986		Fumesua 1987		Kwadaso 1987	
	Dry root yield (t ha^{-1})	Root no. plant^{-1} (g)	Dry root yield (t ha^{-1})	Root no. plant^{-1} (g)	Dry root yield (t ha^{-1})	Root no. plant^{-1} (g)
Maize variety						
'Dorke'	4.3*	5.6**	3.0NS	4.6NS	3.8NS	4.7*
'Dobidi'	3.4	3.9	3.0	4.4	3.3	3.8
Maize density (plants ha^{-1})						
20,000	4.3*	5.2*	3.0NS	4.4	3.7NS	4.5NS
40,000	3.4	4.3	3.0	4.6NS	3.4	4.0
Cassava variety						
'Bosome Nsia'	2.3	3.4	0.7	3.5	2.5	4.0
'Ankra'	5.4**	6.1**	5.3**	5.5**	4.5**	4.4NS
Maize fertilization (kg ha^{-1} N)						
45	3.7	4.4				
180	4.0NS	5.2*				
Cassava density (plants ha^{-1})						
10,000			2.6	4.9*	3.2	4.8*
20,000			3.5*	4.1	3.9NS	3.7
CV (%)	24.7	23.3	18.7	27.0	39.4	26.3
SED	0.4	0.4	0.2	0.4	0.4	0.4
Mean	3.9	4.8	2.9	4.5	3.6	4.3

*Significant at P = 0.05 **Significant at P = 0.01 NS = Not significant

Competitive ability of intercropped cassava

Trial 1, Fumesua, 1986. Table 8 shows the effects of treatments on yield components and yield of intercropped cassava. Although competition from maize could not change the size of roots, root number was much affected by maize variety and maize density. There were 30 per cent less roots when cassava was interplanted with 'Dobidi' than with 'Dorke'. There were also 17 per cent less roots when the maize was planted at

TABLE 9

Effect of Maize Variety on Root Diameter of Intercropped Cassava at Fumesua in 1986

Maize variety	Root diameter (cm)	
	'Bosome Nsia'	'Ankra'
'Dorke'	4.03	4.24
'Dobidi'	3.61	4.53
CV (%)	8.3	
SED	0.17	

Interaction significant at P = 0.05

cent. Although maize genotype did not influence the size of cassava roots, it combined with cassava variety to influence root size (Table 9). Root size was reduced significantly when 'Bosome Nsia' was intercropped with 'Dobidi'. This effect was not observed in 'Ankra'. The bigger plant size of 'Ankra' might have increased its competitive ability to withstand such reduction. It would be reasonable to conclude that competition affects the size of roots in intercropped cassava.

Maize density was also important in determining cassava root number and yield (Table 8). Since a study in Colombia has shown that cassava does not appear to form new roots with the capacity to thicken after the first 3 months of growth (CIAT, 1973), the effect of the maize in reducing root number indicated that competition was probably early, and the maize suppressed the cassava in early growth. The reduction in yield was presumed to be due to shading. Evidence by Cock (1984) and Fukai *et al.* (1984) would seem to suggest that reduced solar radiation resulting from the shading would limit assimilates available for root growth. Surprisingly, Ezumah (1990) suggested that a maize population of 40,000 to 80,000 plants ha^{-1} did not significantly reduce yield of intercropped cassava. This could be due to higher than average rainfall in that year.

Although the cassava root yield did not seemingly benefit from fertilizer application to maize (Table 8), an interaction with maize variety produced the following effect (Table 11): At 45 kg ha^{-1} N, wet root yield was reduced by 36 per cent when the intercrop was 'Dobidi', while wet root yield did not change at 180 kg ha^{-1} N. This interaction could not be observed for the dry root measurements.

Kasele *et al.* (1983) reported that cassava plants given K alone or in combination with N had significantly more storage cells than unfertilized plants, and the root number was also increased. Plants given 480 ppm K in unshaded conditions had the biggest roots. Potassium applied alone or with N also encouraged dry matter diversion to roots. However, N increased root number and shoot growth at the expense of root bulking (Kasole *et al.*, 1988).

In cereals, there is also a phasic development in which the leaf area is first of all developed before the grains are filled. Therefore, little competition is expected for the substrates used for the growth of the photosynthetic and the storage organs. This mode of nutrient use is different from that of cassava which, as observed by Cock (1984), has a simultaneous development of the leaf area and economic yield organs (the roots).

The root yield of monocropped cassava (Table 10) was higher than the root yield of intercropped cassava (Table 8). However, when the two crops grow together, they would make better use of the environment because of differences in quantity and composition of nutrient uptake. Nutrient uptake from the soil would, however, be greater than if each crop was growing alone. The other advantage of growing these two crops together is

TABLE 10

Root Yield of Monocropped Cassava (t ha^{-1}) at Fumesua and Kwadaso

Cassava variety	*Fumesua 1986*	*Fumesua 1987*	*Kwadaso 1987*
"Bosome Nsia' (wet)	10.9	9.5	16.9
'Bosome Nsia' (dry)	3.8	3.3	5.9
'Ankra' (wet)	19.7	16.8	30.0
'Ankra' (dry)	6.9	5.9	10.5

TABLE 11

Effect of Maize Variety and Fertilizer Application on Wet Root Yield of Intercropped Cassava at Fumesua in 1986

	Wet root yield (t ha^{-1})	
Maize variety	*45 kg N ha^{-1}*	*180 kg N ha^{-1}*
'Dorke'	12.9	11.5
'Dobidi'	8.3	11.0
CV (%) 27.5		
SED 1.5		

Interaction significant at $P = 0.05$

that their peak demands for nutrients are unlikely to coincide.

Root diameter and individual fresh root weight are important in the fresh root market in West Africa. The results (Table 12) show that while 'Dorke' had similar effect on 'Bosome Nsia' and "Ankra', 'Dobidi' caused a 40 per cent reduction in the weight of 'Bosome Nsia' as compared with 'Ankra'. The results for the dry root weight at Fumesua in 1986 were similar.

Trial 2, Fumesua, 1987. At Fumesua in 1987, 81 per cent variation in yield between the two varieties of intercropped cassava was observed (Table 8). Cassava density accounted for 16 per cent of the difference. Maize variety and density did not seem to have influenced the yield and yield components of intercropped cassava. Reduction in root yield by intercropping was higher in 1987 than in 1986 at Fumesua.

The combined effect of cassava variety and density on root yield (Table 13) was as expected. The higher density increased root yield of 'Bosome

TABLE 12

Effect of Maize Variety on Wet Root Weight of Intercropped Cassava at Fumesua in 1986

Cassava variety	Wet root weight (g) 'Dorke'	'Dobidi'
'Bosome Nsia'	220.6	181.3
'Ankra'	235.8	300.6
CV (%) 21.7		
SED 25.5		

Interaction significant at $P = 0.05$

TABLE 13

Effect of Cassava Variety and Cassava Density on Dry Root Weight per Root of Intercropped Cassava at Fumesua in 1987

Cassava variety	Dry root weight (g) 10,000 plants ha^{-1}	20,000 plants ha^{-1}
'Bosome Nsia'	70.0	86.9
'Ankra'	96.0	76.0
CV (%) 23.2		
SED 9.5		

Interaction significant at $P = 0.05$

TABLE 14

Effect of Maize Density, Cassava Variety, and Cassava Density on Wet Root Yield per Plant of Intercropped Cassava at Fumesua in 1987

Maize density (plants ha^{-1})	Cassava variety	Wet root weight (g) 10,000 plants ha^{-1}	20,000 plants ha^{-1}
20,000	'Bosome Nsia'	403	508
20,000	'Ankra'	1535	935
40,000	'Bosome Nsia'	690	483
40,000	'Ankra'	1238	1045
CV (%)	26.5		
SED	160.0		

Interaction significant at $P = 0.05$

Nsia' by about 19 per cent, but depressed the root yield of 'Ankra' by about 21 per cent (Table 14).

Trial 3, Kwadaso, 1987. The results for intercropped cassava at Kwadaso in 1987 indicated the absence of competition due to maize genotype and maize density in the intercropped cassava, except for storage root number that was depressed (Table 8). This was similar to what was obtained at Fumesua in 1987. However, these results were dissimilar to those for 1986, as the monocropped yields were higher in 1987 at Kwadaso than those in 1986 and 1987 at Fumesua.

Cassava planted at Kwadaso in the 1987 second rainy season seemed to have benefited from more rainfall than cassava planted at Fumesua in 1986. Total rainfall at Fumesua for the period May 1986-April 1987 was 1005 mm, 26 per cent less than total rainfall at Kwadaso for the period August 1987-July 1988 which was 1350 mm (Table 15). The solar radiation income for the period May 1986-April 1987 was 2185.1 watt m^{-2}, 2 per cent more than the solar radiation income for the period August 1987-July 1988 which was 2139.6 watts m^{-2} (Table 16). Thus, the solar radiation income for the two locations was similar. The extra moisture probably explains why cassava withstood competition from the maize better in 1987.

The benefit accruing from the additional moisture (34 per cent more rainfall) did not appear

TABLE 15

Monthly Total Rainfall (mm) at Fumesua and Kwadaso

Month	*Fumesua 1986*	*Fumesua 1987*	*Kwadaso 1987*	*Kwadaso 1988*
Jan	22	2	12	0
Feb	42	40	74	0
Mar	94	126	114	32
Apr	112	119	230	119
May	156	46	66	128
Jun	214	156	238	357
Jul	139	136	178	98
Aug	14	156	144	13
Sep	62	210	352	145
Oct	133	88	120	162
Nov	0	8	0	8
Dec	0	4	0	0

TABLE 16

Mean Monthly Solar Radiation Income (watts m^{-2}) for Kumasi Area

Month	*1964-1988*	*1986*	*1987*	*1988*
Jan	172.1	184.8	156.2	158.9
Feb	195.1	208.9	186.7	187.6
Mar	207.4	195.0	195.5	196.8
Apr	211.8	211.6	204.3	202.4
May	206.6	208.9	199.6	207.9
Jun	181.8	190.4	179.3	177.5
Jul	154.0	135.9	155.3	162.7
Aug	140.4	135.9	147.0	125.7
Sep	159.0	155.3	171.0	150.6
Oct	186.1	171.9	188.6	189.5
Nov	194.8	183.9	187.6	183.0
Dec	162.1	160.8	151.6	160.8

to have been translated into yield. A comparison of the variety yields shows that at Kwadaso, the 1987 dry root yield was 19 per cent more for 'Ankra' than for 'Ankra' at Fumesua in 1986. The dry yield for 'Bosome Nsia' was, however, 44 per cent less at Kwadaso than at Fumesua (Table 8), presumably because of the drier weather at Fumesua.

It must be emphasized that this particular investigation hinged on the assumption that the season is more critical to maize growth and, therefore, maize should be the first crop planted after the onset of the rains. Maize is the crop given external inorganic fertilizer in such a system. This study confirms evidence produced by Russell & Caldwell (1989) in support of the fact that the competitive ability of maize could be enhanced by N fertilization. Cassava is the more suppressed species and, therefore, its performance would be determined by the availability of adequate amounts of soil moisture and sunlight. It would be of interest to determine the consequence of fertilizing the cassava component instead, if higher and more sustainable productivity was the goal of the farmer.

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