Effects of cassava density on productivity of plantain and cassava intercropping system

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Abstract — Introduction. An experiment was conducted at Ayepe, Osun State, Nigeria, to determine the appropriate cassava density in association with plantain in order to achieve maximum yield. **Materials and method**. Plantain at a density of 1 666 plants·ha^{-1} was intercropped with cassava at three densities (5 000; 7 000 and 10 000 plants·ha^{-1}). Both crops were also planted in monoculture at the highest densities in the intercrop. The experiment was arranged in a randomized complete block design with four replications. **Results**. For the highest cassava densities, plantain shooting time was delayed by 89 d, while the number of fingers per bunch and number of hands per bunch were significantly reduced in the intercropping system. Plantain bunch weight also decreased significantly as cassava density increased in the intercropping system. Bunch yield was reduced by 44 and 56 % at 7 000 and 10 000 plants·ha^{-1} of cassava, respectively. On the other hand, cassava tuber yield increased with increase in density. The total relative yield of the two crops was greater than 1.0 in all the intercrops. At present price level (10 naira per kg for plantain and 0.90 nairas per kg for cassava), plantain in intercrop with 5 000 plants·ha^{-1} gave a higher return than plantain intercropped with other population densities of cassava or a monoculture of the two crops. **Discussion**. If plantain is the main crop and must be intercropped with cassava, farmers should not intercrop plantain with cassava at a population greater than 5 000 plants·ha^{-1}. © Éditions scientifiques et médicales Elsevier SAS

***Musa* (plantains) / *Manihot esculenta* / cropping systems / companion crops / spacing / yields / Nigeria**

Effets de la densité de plantation du manioc sur la productivité du plantain et du manioc dans un système d'association plantain / manioc.

Résumé — Introduction. Une expérimentation a été conduite à Ayepe, dans l'état de Osun au Nigéria, pour déterminer la densité de plantation du manioc donnant le meilleur rendement dans une culture associée plantain / manioc. **Matériel et méthodes**. Du plantain cultivé à 1 666 plants·ha^{-1} a été associé à une culture de manioc testée à trois densités de plantation (5 000, 7 000 et 10 000 plants·ha^{-1}). Parallèlement, les deux productions ont été plantées en monoculture (1 666 plants·ha^{-1} pour le plantain, 10 000 plants·ha^{-1} pour le manioc). L'essai a été conduit en blocs en randomisation totale avec quatre répétitions. **Résultats**. Avec les densités de manioc les plus élevées, le temps de sortie des rejets du plantain a été augmenté de 89 d, tandis que les nombres de doigts et de mains par régime étaient significativement réduits dans les cultures associées. Le poids du régime a également diminué de façon significative en même temps qu'augmentait la densité des plants de manioc entrant dans l'association. Le rendement en régimes a été réduit de 44 % pour le plantain associé à du manioc à 7 000 plants·ha^{-1}, et de 56 % avec du manioc à 10 000 plants·ha^{-1}. Par ailleurs, le rendement en tubercules du manioc a augmenté avec la densité des plants. Le rendement relatif global pour les deux cultures a été supérieur à 1 dans tous les cas d'association. Avec le prix actuel de 10 nairas·kg^{-1} de plantain et de 0,90 nairas·kg^{-1} de manioc, c'est l'association plantain / manioc à 5 000 plants·ha^{-1} qui donne le meilleur profit par rapport aux autres densités testées dans l'association ou aux deux monocultures. **Discussion**. Si du plantain exploité en culture principale doit être associé avec du manioc, il est recommandé de ne pas planter le manioc à une densité supérieure à 5 000 plants·ha^{-1}. © Éditions scientifiques et médicales Elsevier SAS

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1. introduction

The wide interrow space of plantain coupled with the greater length of time it takes to completely shade the interrow make plantain lend itself very well to at-planting intercropping systems with short and medium cycle crops. Farmers with small land holdings have few choices to cope with food problem. They depend almost entirely on intercropping in order to produce enough food to satisfy their dietary and cash requirements. Plantain is usually grown in intercrop with food crops such as melon, soybean, maize and sweetpotato [1–3]. Under such conditions, efficient use of growth resources may be achieved and increase in land productivity may be expected through this crop combinations.

Cultivation of cassava in the country by farmers has recently increased tremendously. The rapid expansion of cassava production is due to its adaptation to shorter periods of fallow, its ability to thrive without irrigation in the areas where the dry season ranges from 1 to 5 months as well as an increase in demand for cheaper staple foods in urban centres [4].

It is a common practice by the peasant farmers to intercrop without adequate knowledge of the optimum populations of the companion crops that are compatible with the main crop. Consequently, high densities of the companion crops may lead to competition between the crops and the expected yield advantage due to intercropping may be small. It is therefore necessary to evaluate the effect of different population of cassava on the growth and yield of plantain to ascertain the appropriate cassava density that will achieve optimum yield and income of the intercropping system.

Table I.
Physical and chemical properties of the soil at the experimental site where productivity of plantain intercropped with cassava was studied (Nigeria).

Soil parameter	Value
pH (H_2O)	6.80
Organic carbon ($g \cdot kg^{-1}$)	23.0
Total nitrogen ($g \cdot kg^{-1}$)	2.40
Available P ($mg \cdot kg^{-1}$)	4.50
Exchangeable Ca ($cmol \cdot kg^{-1}$)	7.32
Exchangeable Mg ($cmol \cdot kg^{-1}$)	1.30
Exchangeable Mn ($cmol \cdot kg^{-1}$)	0.13
Exchangeable K ($cmol \cdot kg^{-1}$)	0.33
Exchangeable Na ($cmol \cdot kg^{-1}$)	0.26
Total acidity	0.01
Effective CEC ($cmol \cdot kg^{-1}$)	9.35
% Sand	74
% Silt	13
% Clay	13

2. materials and methods

The experiment was carried out between 1991 and 1993 at University of Ibadan / IITA On-farm adaptive research (OFAR) Station, Ayepe, Osun state of South western Nigeria. Ayepe is situated in the forest zone, about 50 km south-east of Ibadan at 70°15' N latitude. The experimental site lies in a zone of Alfisolic soils with 'Egbeda' (Oxic paleustalf) as dominant soil series. The soil of the site was sandy loam (*table I*). Rainfall pattern in the area is bimodal with long and short rainy seasons separated by a short period of uncertain rainfall (*table II*).

Sword suckers of false horn plantain (*Musa paradisiaca* cv. Agbagba) were planted in 30 × 30 cm holes dug at a spacing of 3 × 2 m to give a population density of 1 666 plants·ha^{-1}. The suckers were treated with 3 G Furadan at 2 kg active ingredient per ha to control plantain weevils (*Cosmopolites sordidus*) and nematode. Cassava (*Manihot esculentus* cv. TMS 30 572) cuttings were planted within the interows of plantain suckers at 1 × 2 m (5 000 plants·ha^{-1}); 1 × 1.5 m (7 000 plants·ha^{-1}) and 1 × 1 m (10 000 plants·ha^{-1}) for the intercrop combinations. Plantain and cassava soles were planted at 3 × 2 m (1 666 plants·ha^{-1}) and 1 × 1 m (10 000 plants·ha^{-1}) respectively. Thus the treatment were: 1. Plantain sole; 2. Plantain + cassava (5 000 plants·ha^{-1}); 3. Plantain + cassava (7 000 plants·ha^{-1}); 4. Plaintain + cassava (10 000 plants·ha^{-1}); 5. Cassava sole.

Basal fertilizer application of NPK (15–15–15) was done at the rate of 300 kg·ha^{-1} in two equal parts. The first dose was applied

Table II.
Rainfall distribution (mm) in the Nigerian site where productivity of plantain intercropped with cassava was studied from 1991 to 1993.

Month	1991	1992
January	0.0	0.0
February	103.5	0.0
March	41.9	34.2
April	290.5	188.9
May	372.0	223.6
June	100.7	143.6
July	243.2	204.7
August	249.5	43.1
September	147.1	359.9
October	274.8	164.4
November	31.4	42.0
December	0.0	0.0
Total	1 854.6	1 404.4

at 2 months after planting and the second was applied at 4 months after planting.

The experimental design was a randomised complete block with four replications in each season. The plot size was 13 × 10 m.

Data collected on plantain include pseudostem height and girth, number of functional leaves, number of days to shooting, number of hands per bunch, number of fingers per bunch and bunch weight.

Data on growth and yield components of cassava collected include stem height, girth, number of branches per plants, tuber number per plant, tuber length and fresh tuber weight.

Plantain was harvested at 90 d after shooting while cassava was harvested at 18 months after planting.

The analysis of variance (Anova) procedure was used for statistical analysis of all data and mean comparison was done using Duncan's multiple range test. The efficiency of intercropping relative to sole cropping was determined using Land Equivalent Ratio (LER) as proposed by IRRI [5].

3. results

3.1. vegetative growth of plantain and cassava

Intercropping plantain with different population of cassava significantly increased plantain pseudostem height. The height increased with increase population density. Plantain in mixture with 10 000 plants·ha^{-1} of cassava gave the highest height. Contrarily, plantain pseudostem girth significantly decreased with increase in cassava population while plantain number of functional leaves was not significantly influenced by intercropping in the two seasons (*table III*). Generally, the significant differences were more obvious in 1991 than in 1992, where no significant difference was observed at 9 months after planting.

When compared to sole plantain, increasing cassava population density to 10 000 plants·ha^{-1} significantly delayed plantain days to shooting by 85 and 92 d in 1991 and 1992, respectively. The pseudostem height increased by 22 % while the girth decreased by 20 % at shooting in both years (*table IV*).

Increasing cassava population to 10 000 plants·ha^{-1} significantly decreased number of suckers/stool in both years. Cassava stem height increased with increase in population. The stem height at 10 000 plants·ha^{-1} in both sole and intercrop gave the heighest stem height, these were significantly higher than 5 000 plants·ha^{-1} in 1991 and than 5 000 and 7 000 plants·ha^{-1} in 1992 (*table V*). The least height was obtained at 5 000 plants·ha^{-1} in both years. The stem girth and number of stem branches per plant decreased with increase in cassava population density, while shoot weight per plant at 5 000 plants·ha^{-1} was the highest in intercropping system with plantain. However, there was no significant difference in plant height and girth between sole and intercropped cassava at 10 000 plants·ha^{-1}.

3.2. yield and yield components of plantain and cassava

Increasing population density of cassava significantly reduced plantain yield and

yield components. Plantain number of hands and fingers per bunch decreased as cassava population density increased above 5 000 plants·ha^{-1} in the intercropping system (*table VI*). The highest bunch weight of 11.9 and 11.2 t·ha^{-1} obtained in plantain sole plots in 1991 and 1992, respectively, gave better yield advantages of 56, 43 and 30 % over 10 000, 7 000 and 5 000 plants·ha^{-1} treatment in 1991 and 55, 45 and 37 %, respectively, for the same treatments in 1992. The result revealed that intercropping plantain with cassava up to 10 000 plants·ha^{-1} reduced the bunch yield by an average of 55 %. Apart from cassava tuber number per plant which produced highest tuber at 7 000 plants·ha^{-1}, other cassava yield components (tuber length and tuber weight per

Table III.
Effects of three densities of cassava on the pseudostem height, girth and functional leaves of plantain (1 666 plants·ha^{-1}) in a plantain / cassava intercropping system (Nigeria).

Intercropping system	Cassava density (plants·ha^{-1})	Pseudostem height (cm)		Pseudostem girth (cm)		Number of functional leaves	
		9 map[1]	12 map[1]	9 map[1]	12 map[1]	9 map[1]	12 map[1]
1991							
Plantain sole		125.58	161.67 b	25.04	43.78 a	8.75	9.75
Plantain + cassava	5 000	146.17	187.08 ab	25.28	41.58 a	8.00	8.50
	7 000	134.50	187.54 ab	21.84	37.23 ab	8.25	8.75
	10 000	165.75	227.67 a	22.87	33.17 b	7.75	8.25
Significance	–	ns	**	ns	**	ns	ns
1992							
Plantain sole		119.25 c	156.50 c	28.84 a	45.60 a	8.00	9.25 a
Plantain + cassava	5 000	123.50 c	171.15 bc	25.58 b	31.04 b	8.25	9.00 a
	7 000	142.15 b	189.50 b	25.72 b	28.51 bc	7.50	8.75 a
	10 000	171.52 a	222.50 a	20.50 c	27.08 c	7.75	8.00 a
Significance	–	**	**	**	**	ns	ns

[1] map: months after planting.
a, b, c: means followed by a different letter in a column within a year are significantly different by the Duncan's multiple range test at 5 % level.
ns: column means not significantly different.

Table IV.
Growth response of plantain (1 666 plants·ha^{-1}) at shooting to intercropping with three cassava densities (Nigeria).

Cassava density (plants·ha^{-1})	Pseudostem height (cm)		Pseudostem girth (cm)		Time to shooting (d)		Number of suckers / stool	
	1991	1992	1991	1992	1991	1992	1991	1992
0	208.83 b	212.50 b	63.06 a	64.75 a	337 c	344 c	8.50 a	8.25 a
5 000	220.50 ab	230.00 b	58.52 ab	59.30 ab	343 c	351 c	7.50 a	8.00 a
7 000	225.50 ab	233.80 b	55.24 ab	56.50 ab	390 b	401 b	5.50 b	5.25 b
10 000	259.75 a	281.50 a	50.94 b	51.25 b	422 a	436 a	4.15 c	5.10 b

a, b, c: means followed by a different letter in a column are significantly different by the Duncan's multiple range test at 5 % level.

plant) gave highest value at 5 000 plants·ha^{-1} (*table VI*). Cassava total tuber yield per hectare increased with increase in population density. Yields of 22.76 and 21.54 t·ha^{-1} were obtained in 1991 and 1992, respectively.

3.3. productivity of the mixture

Land Equivalent Ratio (LER) of all plantain / cassava intercrop was greater than 1, and decreased with increase in cassava population density (*table VII*). The Relative

Table V.
Effect of three cassava densities on the growth parameters of cassava in plantain / cassava intercropping system (Nigeria).

Intercropping system	Cassava density (plants·ha^{-1})	Stem height (cm)	Stem girth (cm)	Number of branches per plant	Number of shoots per plant
1991					
Plantain + cassava	5 000	266.13 b	3.38 a	3.10 a	3.70 a
	7 000	353.25 ab	3.13 a	2.40 b	2.48 b
	10 000	437.00 a	2.50 b	1.98 c	2.65 b
Cassava sole	10 000	482.88 a	2.43 b	2.03 c	3.85 a
1992					
Plantain + cassava	5 000	219.09 c	3.10 a	3.07 a	3.67 a
	7 000	316.50 b	2.47 b	2.17 b	2.57 b
	10 000	396.91 a	2.57 b	2.03 b	2.67 b
Cassava sole	10 000	380.47 a	2.41 b	2.10 b	2.97 ab

a, b, c: means followed by a different letter in a column within a year are significantly different by the Duncan's multiple range test at 5 % level.

Table VI.
Yield parameters of plantain and cassava as affected by three densities of cassava in a plantain / cassava intercropping system (Nigeria).

Intercropping system	Plant density (plants·ha^{-1})	Plantain			Cassava		
		No hands / bunch	No fingers / bunch	Bunch weight / plant	No tubers / plant	Tuber length (cm)	Tuber weight / plant (kg)
1991							
Plantain sole	1 666	6.00 a	21.25 a	7.06 a	–	–	–
Cassava sole	10 000	–	–	–	6.50 ab	25.88 c	2.30 b
Plantain + cassava	5 000	5.00 b	19.25 a	4.98 b	6.25 b	48.00 a	4.18 a
	7 000	4.25 b	14.75 b	4.03 c	8.50 a	42.75 ab	3.41 a
	10 000	4.25 b	13.50 b	3.85 c	7.00 ab	34.25 bc	2.18 b
1992							
Plantain sole	1 666	5.67 a	21.33 a	6.63 a			
Cassava sole	10 000				6.60 b	29.40 b	2.14 b
Plantain + cassava	5 000	5.00 ab	19.67 a	4.30 b	5.40 c	45.29 a	4.28 a
	7 000	4.67 bc	16.33 ab	4.03 b	7.47 a	35.80 b	3.45 ab
	10 000	4.00 c	13.67 b	3.70 b	5.13 c	32.60 b	2.15 b

a, b, c: means followed by a different letter in a column within a year are significantly different by the Duncan's multiple range test at 5 % level.

Table VII.
Yield, relative yield and gross return of plantain and cassava as affected by three densities of cassava in a plantain / cassava intercropping system (Nigeria).

Intercropping system	Plant density (plants·ha^{-1})	Yield (t·ha^{-1})		Relative yield		LER[1]	Gross return (N'000)	
		Plantain	Cassava	Plantain	Cassava		Plantain	Cassava
1991								
Plantain sole	1 666	11.85 a	–	1.00	–	1.00	11.85	–
Cassava sole	10 000	–	22.76 a	–	1.00	1.00	–	21.17
Plantain + cassava	5 000	8.32 b	15.80 c	0.70	0.69	1.40	8.32	14.69
	7 000	6.72 c	16.49 c	0.57	0.73	1.30	6.72	15.34
	10 000	5.23 d	18.87 b	0.44	0.83	1.27	5.23	17.55
1992								
Plantain sole	1 666	11.85 a	–	1.00	–	1.00	11.16	–
Cassava sole	10 000	–	21.54 a	–	1.00	1.00	–	19.39
Plantain + cassava	5 000	7.95 b	15.34 a	0.71	0.71	1.42	7.95	14.27
	7 000	6.14 c	16.09 ab	0.55	0.75	1.30	6.41	14.94
	10 000	5.23 d	18.87 b	0.44	0.83	1.27	5.23	17.55

a, b, c: means followed by a different letter in a column within a year are significantly different by the Duncan's multiple range test at 5 % level.
[1] LER: Land Equivalent Ratio [5].

Yield (RY) of the two crops showed that plantain contribution to the LER decreased with increase in cassava population density. The monetary return of the intercrop decreased as cassava population density in the combination increased. Plantain intercropped with cassava at 5 000 plants·ha^{-1} gave the highest monetary returns.

4. discussion

The growth of plantain was severely affected by the associated cassava in the intercropping system. Pseudostem height of plantain increased as cassava population density increased in the system without a corresponding increase in girth of the pseudostem. This may be due to competition for available nutrient and moisture. This was similar to the findings of Joseph [6] and Ndubizu [7]. The delay to shooting of plantain with increase in cassava population density might have resulted from the effects of competition between cassava at high population on the phenological development of plantain.

According to Fukai and Trenbath [8], competition can greatly influence the phenological development of crops especially in additive intercropping to the extent of delaying flowering. This consequently resulted in a reduction in plantain number of hands, fingers and total bunch yield. Higher tuber length and tuber weight per plant of cassava in lower population density (5 000 plants·ha^{-1}) was not enough to increase the total tuber yield more than the 10 000 plants·ha^{-1} probably because more plants contributed to the total yield in the higher population density. The lower precipitation of 1992 and the resultant low soil moisture availability could have caused soil moisture stress with a probable higher adverse effect on plantain than on cassava. This may be the reason for the lower yield obtained in the second season (1992).

Though increasing cassava population increased the Land Equivalent Ratio (LER) and the total revenue in the intercropping system, plantain yield was significantly depressed. This resulted in cassava contributing more to the LER as its population density increased. This is similar to the observation of Ofori and Stern [9] who

reported high total LER when dominated crop species produced a high partial (Relative Yield) LER that is close to 1.0. In this study, plantain which is the dominant crop, increasingly gave a partial LER lower than 1.0 as cassava population increased in the intercropping system. The LER and the total revenue of this system were highest at plantain with cassava at 5 000 plants·ha^{-1}. This combination also gave highest Relative Yield compared to other treatments. It could be concluded from this study that intercropping plantain with cassava up to 10 000 plants·ha^{-1} may be detrimental to plantain. Therefore, if plantain is the main crop and must be intercropped with cassava, farmers should not intercrop plantain with cassava at a population greater than 5 000 plants·ha^{-1}.

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Efectos de la densidad de plantación de mandioca en la productividad de plátano y mandioca dentro de un sistema de asociación plátano/mandioca.

Resumen — Introducción. Se realizó un experimento en Ayepe, estado de Osun en Nigeria, para determinar la densidad de plantación de mandioca que proporcione el mejor rendimiento en un cultivo asociado plátano/mandioca. **Material y métodos**. El plátano con una densidad de 1 666 plantas·ha^{-1} se asoció a un cultivo de mandioca con tres densidades experimentales de plantación (5 000, 7 000 y 10 000 plantas·ha^{-1}). De forma paralela, se plantaron ambas producciones en monocultivos (1 666 plantas·ha^{-1} para el plátano, 10 000 plantas·ha^{-1} para la mandioca). Se realizó el ensayo mediante bloques de aleatoriación total con cuatro repeticiones. **Resultados**. Con las densidades de mandioca más altas, aumentó en 89 d el tiempo de brote de los hijos de plátanos, mientras que el número de dedos y manos por racimo disminuían significativamente en los cultivos asociados. También disminuyó significativamente el peso del racimo a medida que aumentaba la densidad de plantas de mandioca en la asociación. El rendimiento de los racimos se redujo un 44 % en el plátano asociado a la mandioca con 7 000 plantas·ha^{-1} y de un 56 % con mandioca a 10 000 plantas·ha^{-1}. Por otra parte, el rendimiento de la mandioca en tubérculos aumentó con la densidad de plantas. El rendimiento relativo global para los dos cultivos fue superior a 1 en todos los casos de asociación. Con el actual precio de 10 nairas·kg^{-1} de plátano y de 0,90 nairas·kg^{-1} de mandioca, es la asociación plátano / mandioca a 5 000 plantas·ha^{-1} la que proporciona el mejor beneficio con respecto a las otras densidades probadas en la asociación o a los dos monocultivos. **Discusión**. Si el plátano explotado como cultivo principal debe asociarse a la mandioca, se recomienda que no se plante la mandioca con una densidad superior a 5 000 plantas·ha^{-1}. © Éditions scientifiques et médicales Elsevier SAS

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