An Assessment of some Fertilizer Recommendations under Different Cropping Systems in a Humid Tropical Environment

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Summary

Studies were carried out to determine the effects of four fertilizer recommendation systems (blanket recommendation, soil test recommendation, recommendation based on nutrient supplementation index and unfertilized control) on five cropping systems (sole cassava, maize, melon, cassava + maize and cassava + maize + melon). The experiment was a split-plot in randomised complete block design, with fertilizer recommendation systems in main plots and cropping systems in subplots. Observations were made on plant growth and yield. Plant samples were also analyzed for N, P and K uptake. Cassava and melon gave higher yields in sole cropping than intercropping while maize yield under intercropping exceeded that under sole cropping by 17%. Cassava root yield was significantly reduced by 24 and 35% in cassava + maize and cassava + maize + melon plots. Fertilizer recommendation based on nutrient supplementation index (NSI) gave the highest crop yield 41, 31, and 27 t/ha of maize in sole maize, maize + cassava and maize + cassava + melon and 0.6 and 0.2 t/ha of sole melon and intercropped melon respectively. Nitrogen uptake by cassava and maize was highest under NSI, but fertilizer recommendation based on soil test gave the highest crop yield and monetary returns per unit of fertilizer used.

Resumé

Evaluation de quelques recommandations d'engrais sous divers systèmes de cultures dans un milieu tropical humide

Des études ont été réalisées pour déterminer les effets de quatre recommandations de fertilisation (application en couverture des exportations, sur base d'analyse du sol, en utilisant l'indice de supplémentation nutritif et un témoin non fertilisé), sur cinq systèmes de cultures (manioc, maïs, melon, cultivés seuls, associations manioc- maïs et manioc- maïs- melon) selon un dispositif expérimental en parcelles divisées réparties aléatoirement dans des blocs (le mode de fertilisation différenciant les parcelles principales et le type de système de culture différenciant les sous-parcelles). Les observations ont concerné la croissance et le rendement des plantes. Des échantillons de plantes ont été analysés pour évaluer les prélèvements en N, P et K. Le manioc et le melon ont donné un meilleur rendement en culture pure qu'en culture associée tandis que la production de maïs en culture associée dépassait de 17% celle obtenue en culture pure. Le rendement en racine du manioc était réduit significativement dans les associations manioc- maïs (- 24%) et manioc- maïs- melon (- 35%). La recommandation de fertilisation basée sur l'indice de supplémentation nutritive (ISN) a donné le plus haut rendement pour le manioc (respectivement 41; 31 et 27 tonnes par ha en culture pure et dans les associations manioc- maïs et manioc- maïs- melon) ; pour le maïs (respectivement 3,9 ; 4,6 et 4,6 tonnes par ha pour les trois systèmes de culture comparés) et pour le melon (0,6 et 0,2 tonnes par ha en culture pure et en culture associée). Le prélèvement d'azote par manioc était le plus élevé pour la recommandation basée sur l'ISN mais le plus haut rendement cultural par unité de fertilisant appliqué a été obtenu pour la recommandation basée sur l'analyse du sol.

Introduction

The aim of all cropping systems should be maximum profit from the farming operation (16). In evaluating a crop and soil management system for its effects on sustained high production, one of the major factors that must be considered is plant nutrient supply. There is little information on fertilizer management practices in sub-saharan Africa. One of the greatest needs in this regard is how fertilizer recommendations for multiple cropping can be based on soil testing, which is the most important aspect of soil fertility evaluation embracing physical and chemical measurement on the soil. Over the years blanket fertilizer recommendations have been applied to crop mixtures. For example, in a cassava + maize intercrop, some researchers are of the opinion that fertilizer recommendation be based either on the sole cassava or maize requirement. This opinion is however, not supported by any research data.

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The need for a sound fertilizer recommendation based on soil and plant tissue analyses cannot be overemphasized. This would entail a knowledge of the various relationships between applied and absorbed quantity of a plant nutrient or its uptake as well as between the applied quantity of nutrients and yield of deserved products. The measurement of growth and yield and analysis of plant tissue are useful indicators of these relationships. Some advances in fertilizer recommendations have involved the use of fertilizer factor, (Ff) (9), nutrient supplementation index (NSI) (18) and fractional recovery (FR) (1). While the concept of NSI is the amount of soil nutrients taken up by the crop, that of Ff is the amount actually available to the crop under a given condition of soil physical and chemical properties. The NSI has not been supported by actual and practical evidence regarding the application of fertilizer rates to crops.

The objective of this study was therefore to determine the effect of different fertilizer recommendation systems on crop yield and nutrient uptake under sole and mixed cropping systems.

Material and methods

Site description, cropping history and experimental layout

The experiment was carried out in the Faculty of Agriculture Experimental Farm, University of Ibadan (7° 30'N; 3°54'E), Nigeria between 1988 and 1991. Ibadan is characterized by an average rainfall of 1 229 mm *per annum*, with a bimodal distribution. Annual temperatures range between 21 and 31°C. The soil is Oxic Tropudalf (17), locally classified as Egbeda soil series and is loamy sand at the top 0-10 cm to sandy clay at the sub-soil. Pre-cropping soil chemical properties were: pH = 6.4; total N = 0.1 g/100 g; K = 0.42 cmol/kg; Ca = 1.74 cmol/kg and Mg = 3.72 cmol/kg. The plot was cleared from a secondary bush in 1950 and used as paddock by the department of Animal Science of the University. It was first planted to elephant grass and grazed for 2-3 years, fallowed for about 2 years before planting to *Stylosanthes* as permanent pasture. Prior to the commencement of this study, the plot was planted to maize + cassava for two years without fertilizer, after which it was fallowed for two years.

The land was manually cleared in each year of the experiment; weed and crop residues were burnt *in-situ*, and the ashes distributed onto the plots. This was followed by conventional tillage before the experiment was laid into a split-plot in randomised complete blocks. The main plots received fertilizer according to the following recommendation systems. (1) no fertilizer (A1), (2) Blanket recommendation (A2), (3) recommendation based on soil test (A3) and (4) recommendation based on nutrient supplementation index (A4). The sub-plot treatments were five cropping systems, namely (a) sole cassava (B1), (b) sole maize (B2), (c) sole melon (B3), (d) cassava + maize (B4) and (e) cassava + maize + melon (B5). Thus there were 20 treatment combinations and these were replicated three times.

Estimation of N, P and K rates applied for each fertilizer recommendation system

Blanket fertilizer rate was applied as NPK (15:15:15) at 400 kg/ha (12). For the soil test recommendation which considered the N availability index of soils of south-western Nigeria (3), 150 kg N/ha was applied to the soil in each of the three seasons. Using the critical value for available P for these soils, the procedure of Agboola (6) was used to calculate the elemental P required to amend the soil P level. Sixteen and 11 kg/ha of P were applied in 1988 and 1989 while no application was made in 1990. Potassium was not applied because the soil test value was higher than the critical level of 0.2-0.25 cmol/kg (2).

Fertilizer recommendation based on NSI was used only during the third cropping season 1990. The uptake of N, P and K from the 1989 cropping was used to compute NSI values as the percentage of the amount of nutrient applied in a sole crop of each of cassava, maize and melon that has to be added when these crops are grown in mixtures. The formula used for calculating the NSI was: $NSI_A = 100\ (Na + Nb/NA - 1)\%$ where NSI_A = nutrient supplementation index for species A for a given element defined as the percentage of the usual uptake for that element by a sole crop of A that should be added to the mixture to meet the combined needs of intercropped A and B; NA = nutrient uptake by sole crop of A per specified unit area of land; Na = nutrient uptake of A in the mixture for the same land area as sole cropped A and Nb = nutrient uptake of B in the mixture for the same land area as the sole crop. Table 1 presents the fertilizer amounts used for the study.

Table 1
Fertilizer application rates used for this study

	1988	1988	1989	1989	1990			
Nutrient required for soil amendment (kg/ha)	A2	A3	A2	A3	A2	A3	A4	
							B4	B5
N	60.0	150.0	60.0	150.0	60.0	150.0	220.5	214.5
P	26.0	15.7	26.0	10.7	26.0	0.0	65.5	62.0
K	50.0	0.0	50.0	0.0	50.0	0.0	68.5	66.0
Fertilizer material used (kg/ha)								
NPK (15:15:15)	400.0	0.0	400.0	0.0	400.0	0.0	0.0	0.0
Urea (45% N)	0.0	333.0	0.0	333.0	0.0	333.0	490.0	477.0
SSP* (18% P_2O_5)	0.0	211.0	0.0	135.0	0.0	0.0	828.0	783.0
MOP** (56% K_2O)	0.0	0.0	0.0	0.0	0.0	0.0	123.0	118.0

* Single superphosphate; ** Muriate of potash
A2 = blanket fertilizer model; A3 = soil test fertilizer model; A4 = nutrient suplementation index model
B4 = cassava + maize, B5 = cassava + maize +melon

The field was manually planted to cassava, maize and melon using populations of 10 000 plants per hectare for cassava and melon at a spacing of 1 m x 1 m. Maize was also spaced 1 m x 1 m but with 2 plants per hill to give a population of 20 000 plants per hectare. Plant populations were the same for both sole and intercropped plots. The crop varieties used were TMS30572, an improved cassava cultivar commonly used for intercropping in South-western Nigeria; TZSR-Y-1 which is also an improved maize variety that matures in 90 days and a local melon variety widely grown in Ibadan environs.

Phosphorus in form of single super phosphate and K as muriate of potash were ring- applied to each plant stand 2 weeks after planting (WAP) for A3 and A4 fertilizer recommendations while two-third of nitrogen as urea was applied at the same time. For the blanket application (A2), NPK (15:15:15) fertilizer was applied also by ring method at 2 WAP.

The plots were manually weeded three times in each cropping cycle to minimize competition from weeds. In the 1990/91 season, cassava and melon leaves were sampled at 12 and 6 WAP while maize grain and stover were sampled at harvest to determine nutrient uptake. The samples were oven-dried (60°C) for 48 hours and milled to pass a 2 mm sieve for analysis. Two grames of the milled samples were digested according the procedure of Blanchar (11). Phosphorus in the extract was read from Bauch and Lomb spectrophotometer, Ca and Mg from the atomic absorption spectrophotometer and K from the flame photometer. Total N was determined by the microkjeldahl method (13).

Fresh cassava tuberous root was harvested at 48 WAP, maize grain at 12 WAP and melon at 14 WAP. The yields of maize and melon were expressed at 14% moisture content. To evaluate the fertilizer recommendation systems, a partial budget analysis was carried out by comparing the cost of fertilizer recommendation system with the monetary value of the crop yield. The analysis was done after converting the intercrop yields to an equicassava yield using the model of Ssali (15). GENSTAT statistical package was used for data analysis.

Results

Crop yields

Cassava

Blanket fertilizer application gave the lowest cassava tuberous root yield (13 t/ha), which was 23% lower than the yield from fertilizer recommendation based on soil test (Table 2). During 1988/89 cropping, cassava yield from plots under soil test recommendation system was significantly higher than those under blanket and zero fertilization. In the 1990/91 cropping, the yield from plots based on NSI significantly exceeded those of the other recommendation systems by between 83 and 142%. The average root yield across fertilizer recommendations, except NSI for the three years was 19.4 t/ha in sole cassava. This was reduced by 23 and 31% in cassava + maize and cassava + maize + melon (Table 2). The reduction was 26 and 33% in 1988/89; 26 and 34% in 1989/90 and 25 and 33% in 1990/91 cropping cycles.

Maize

During the 1988/98 cropping cycle, maize yield from the unfertilized plot was the lowest (1.4 t/ha), being 22 and 126% lower than the yields under blanket and soil test recommendation systems (Table 3).

Table 2
Cassava yield (t/ha) under the different fertilizer recommendation and cropping systems

Cropping systems (CS)	Fertilizer recommendations (FR)				
	Zero	Blanket	Soil test	NSI	Mean
	1st season (1988/89)				
Sole cassava	14.8	16.8	24.9		18.3
C + M	11.0	12.5	18.3		13.9
C + M + Me	9.9	11.4	16.7		12.7
Mean	12.0	13.6	20.0		-
LSD (5%) - FR	-	6.5			1.5
LSD (5%) - FR x CS	-	NS	-		-
	2nd season (1989/90)				
Sole cassava	20.8	17.3	24.4		20.8
C + M	15.5	13.0	17.6		15.4
C + M + Me	13.7	11.3	16.2		13.8
Mean	16.7	13.9	19.4		-
LSD (5%) - FR	-	NS	-		1.7
LSD (5%) - FR x CS	-	NS	-		-
	3rd season (1990/91)				
Sole cassava	21.8	16.9	22.7	41.2	25.7
C + M	16.6	12.6	16.4	31.2	19.2
C + M + Me	14.8	11.7	15.3	27.2	17.2
Mean	17.7	13.7	18.1	33.2	-
LSD (5%) - FR	-	-	8.6	-	1.2
LSD (5%) - FR x CS	-	-	2.4	-	-
	Average data (1988-91)				
Sole cassava	19.1	17.0	22	-	19.4
C + M	14.3	12.7	17.4	-	14.8
C + M + Me	12.8	11.5	16.1	-	13.4
Mean	15.4	13.0	19.2	-	-

NS = not significant

Table 3
Maize yield (t/ha) under the different fertilizer recommendation and cropping systems

Cropping systems (CS)	Fertilizer recommendations (FR)				
	Zero	Blanket	Soil test	NSI	Mean
	1st season (1988/89)				
Sole maize	1.4	1.6	2.9		2.0
C + M	1.6	1.8	3.5		2.3
C + M + Me	1.6	1.9	3.5		2.3
Mean	1.5	1.8	3.3		-
LSD (5%) - FR	-	0.1	-		0.03
LSD (5%) - FR x CS	-	0.04	-		-
	2nd season (1989/90)				
Sole maize	1.3	1.6	2.9		1.9
C + M	1.5	1.9	3.4		2.3
C + M + Me	1.5	1.9	3.4		2.3
Mean	1.4	1.8	3.2		-
LSD (5%) - FR	-	0.2	-		0.03
LSD (5%) - FR x CS	-	0.1	-	-	
	3rd season (1990/91)				
Sole maize	1.2	1.5	2.9	3.9	2.4
C + M	1.4	1.8	3.5	4.6	2.8
C + M + Me	1.4	1.8	3.5	4.6	2.8
Mean	1.4	1.7	3.3	4.4	-
LSD (5%) - FR	-	0.3	-	-	0.03
LSD (5%) - FR x CS	-	0.1	-	-	-
	Average data (1988-91)				
Sole maize	1.3	1.6	2.9	-	1.9
C + M	1.5	1.9	3.4	-	2.3
C + M + Me	1.5	1.9	3.5	-	2.3
Mean	1.4	1.8	3.3	-	-

In the 1989/90. Cropping cycles the yield from the soil test recommendation was highest whereas in 1990/91. Cropping cycle, grain yield under NSI exceeded those of soil test recommendation by 33%, blanket recommendation by 154% and the unfertilized control by 219%. Across the fertilizer recommendation systems except NSI, the mean yield of sole maize for the 3 years was 1.9 t/ha. This increased by 18% in the intercropped plots. The interaction between cropping system and fertilizer recommendation systems significantly affected maize grain yield in all seasons.

Melon

Melon seed yield as affected by fertilizer recommendation and cropping systems is presented in Table 4. During 1989/90 cropping cycle melon seed yield under the blanket and soil test recommendations exceeded that of the unfertilized plots by 5 and 33% respectively. In 1988/89 season melon had no yield because of the excessive rainfall, but in 1990/91 the yield under NSI significantly exceeded that of soil test by 32%, blanket recommendation by 105% and unfertilized control by 85% respectively. The yield from plots fertilized based on soil test recommendation significantly exceeded those of the blanket recommendation and unfertilized control by 8 and 30%.

With the exception of NSI the average melon seed yield across fertilizer recommendation systems was reduced by 70% in melon + cassava + maize. The yield reduction of intercropped melon by cropping cycle was 55% in 1988/89 and 70% in 1990/91.

Table 4
Melon yield (t/ha) as affected by fertilizer recommendation and cropping systems
Fertilizer recommendations (FR)

Cropping systems (CS)	Fertilizer recommendations (FR)				
	Zero	Blanket	Soil test	NSI	Mean
	2nd season (1989/90)				
Sole melon	0.32	0.4	0.43		0.38
C+M+Me	0.09	0.12	0.14		0.17
Mean	0.21	0.26	0.28		-
LSD (5%) - FR	-	0.06	-		0.05
LSD (5%) – FR X CS	-	NS	-		-
	3rd season (1989/90)				
Sole melon	0.32	0.29	0.43	0.57	0.40
C+M+Me	0.09	0.07	0.14	0.16	0.12
Mean	0.20	0.18	0.28	0.37	-
LSD (5%) - FR	-	0.04	-	-	0.03
LSD (5%) – FR X CS	-	0.06	-	-	-
	Average data (1989/91)				
Sole melon	0.32	0.35	0.43		0.37
C+M+Me	0.09	0.10	0.14		0.11
Mean	0.21	0.22	0.28		-

NS = not significant

Nutrient uptake

Data on nutrient uptake as reflected by the content in the tissues of the crops are presented in Table 5.

Cassava

Nitrogen content of cassava that received no fertilizer was similar in sole cassava and cassava + maize, but doubled that of cassava + maize + melon (Table 5). Under the blanket fertilizer recommendation, the N content of sole and intercropped cassava was not different, whereas the content under soil test recommendation was similar in sole cassava and cassava + maize + melon but was double that of cassava + maize. In the NSI, the N content of sole cassava was about half that of intercropped cassava. Across the fertilizer recommendation systems, the N content of sole cassava was significantly highest in the unfertilized control and blanket recommendation, while the content in cassava + maize + melon under NSI significantly exceeded other recommendation systems.

Table 5
Effect of fertilizer recommendation and cropping systems on crop nutrient uptake (kg/ha) in 1990

Fertilizer recommendation	Sole crop			Cassava+maize			Cassava+maize+melon		
	N	P	K	N	P	K	N	P	K
					Cassava				
Zero	18.8a	1.2b	5.9b	19.4b	1.3b	7.7b	11.3c	0.8c	4.4c
Blanket	19.6a	4.2a	8.8a	20.5b	1.8ab	11.1a	22.3b	1.9b	15.2a
Soil test	17.3ab	1.2b	7.0ab	9.7c	0.8c	4.1c	16.1c	1.2bc	5.9c
NSI	15.3b	1.5b	8.5a	32.3a	2.4a	11.1a	31.0a	2.7a	13.4a
					Maize				
					Grain				
Zero	30.4b	4.1b	8.7c	30.2c	3.2b	8.5b	21.7c	2.6c	8.1b
Blanket	33.2b	4.5b	10.4bc	25.4c	3.8b	9.1b	35.0b	5.7b	10.6b
Soil test	29.7b	5.3ab	12.9b	40.3b	6.0a	12.9a	36.3b	4.5b	11.4b
NSI	74.1a	7.9a	19.5a	51.8a	7.0a	14.7a	63.8a	7.5a	20.2a
					Stover				
Zero	17.0c	4.5a	29.2c	27.0b	3.9a	24.8c	19.8b	3.7b	23.8b
Blanket	49.8a	5.3a	55.0a	38.9a	3.3a	43.3b	34.1a	3.7b	36.6b
Soil test	57.8a	4.6a	40.7ab	39.9a	3.9a	36.4b	33.0a	4.1b	30.1b
NSI	30.8b	4.6a	35.9b	37.6a	4.9a	64.6a	38.6a	5.9a	68.7a
					Melon				
Zero	11.0b	0.9a	7.8a				11.7b	1.0b	6.5b
Blanket	16.6a	1.3a	11.2b				15.4a	1.3a	10.9a
Soil test	14.7ab	1.1a	10.4b				13.2a	1.3a	8.9a
NSI	12.7b	0.7a	16.6a				16.0a	1.2a	9.4a

Means followed by the same letters are not significantly different.

Phosphorus content in non fertilized plots was similar in sole cassava and cassava + maize, but significantly exceeded that of cassava + maize + melon by 56%. Plants under blanket recommendation system had similar P content in the intercropped plots whereas the content in sole cassava was higher by 127%. Phosphorus content of cassava under the soil test recommendation was not different among the cropping systems. However, under NSI, the content was lowest in sole cassava (1.5 kg/ha) and highest in cassava + maize + melon (2.7 kg/ha). Irrespective of the fertilizer recommendation system, the P content was higher in sole cropping than intercropping.

The potassium content of cassava under the non fertilized plots was highest in cassava + maize, and lowest in cassava + maize + melon. Under the soil test recommendation, the uptake was highest (7.0 kg/ha) in sole cassava but under the blanket recommendation it was highest in cassava + maize + melon. However, the K content of sole cassava and cassava + maize + melon was similar. Under NSI cassava plants had similar K content with those under the blanket recommendation. The highest content under NSI (13.4 kg/ha) was in cassava + maize + melon. In all cases, the K content was significantly lowest in the non fertilized control.

Maize

In the non fertilized plots, the N content of sole maize grain and maize + cassava was similar, but much higher (40%) than the content in maize + cassava + melon (Table 5). The N content of maize grain under blanket fertilizer recommendation was higher in maize + cassava + melon than in sole maize and maize + cassava by 31 and 38% respectively. Under soil test recommendation, the N content in maize + cassava was higher than those of sole maize and maize + cassava + melon by 36 and 112%, while under the NSI, the content in sole maize grain was higher than those in maize + cassava and maize + cassava + melon by 43 and 16% respectively.

Nitrogen content in the maize stover from the non fertilized plot of maize + cassava was higher than those of sole maize and maize + cassava + melon by 59 and 36%. Under blanket recommendation the N content in the stover of sole maize was higher than those of maize + cassava and maize + cassava + melon by 28 and 46% whereas under the soil test recommendation it was higher by 45 and 75% respectively. The N content of sole maize stover under NSI was 24% higher than in the intercropped plots.

In the non fertilized plots, the P content of maize grain was higher in sole maize than in maize + cassava and maize + cassava + melon by 28 and 58%, but under blanket recommendation, the P content in maize + cassava + melon was 27 and 50% higher than those of sole maize and maize + cassava. Phosphorus content under soil test recommendation was higher in maize + cassava than sole maize and maize + cassava + melon by 13 an 33%. Under NSI, the P content in sole maize and maize + cassava + melon was similar, both being higher than the content in maize + cassava by about 10%.

The phosphorus content of sole maize stover was higher than those of maize + cassava and maize + cassava + melon by 15 and 22% in the non fertilized plots, 61 and 43% under blanket recommendation and 18 and 12% under the soil test recommendation. Phosphorus content in maize + cassava + melon was higher than sole maize and maize + cassava by 28 and 20% under NSI. Among the fertilizer recommendations, the P content of maize grain and stover was highest under the NSI.

The content of potassium in maize grain and stover from the non fertilized plots was similar in all cropping systems. Under blanket and NSI recommendations, the K content in sole maize and maize + cassava + melon was higher than maize + cassava by 15 and 35%. Potassium content in the grain of sole maize and maize + cassava was similar but much higher than in maize + cassava + melon by 14% under the soil test recommendation. Under NSI, the K content in sole maize and maize + cassava + melon exceeded that of maize + cassava by 35%.

In the non fertilized plots, the K content in the stover of sole maize was higher than those of intercropped maize by 20% whereas it was higher than maize + cassava and maize + cassava + melon by 27 and 50% under blanket recommendation and 12 and 35% under the soil test recommendation. Under NSI, the K content in the intercropped maize stover was double the content in sole maize.

Melon

The average N, P and K content of melon leaves is also presented in Table 5. Nitrogen content in melon leaves from the control plots was about the same in sole and intercropped melon whereas under the blanket and soil test recommendation, N content of sole melon was higher than that of intercropped melon by 8 and 12%. Under the recommendation based on NSI, the N content of intercropped melon was 29.7% higher than in sole melon. Generally, the N content of sole melon was significantly highest under NSI and lowest in the non fertilized plots.

Phosphorus uptake of intercropped melon under zero, soil test and NSI recommendations were 11, 18 and 71% higher than the content in sole melon but under blanket recommendation, the content was similar in sole and intercropped systems. Potassium content of sole melon was 20, 16 and 76% higher than intercropped melon in zero, soil test and NSI recommendations, but under blanket recommendation, the K content was similar in both cropping systems. Among the fertilizer recommendations, the content of K in sole melon was highest under NSI. Intercropped melon with no fertilizer application had the lowest K content.

Dry matter Yield

The dry matter yield of the edible portion of cassava tuberous roots, maize grain and melon seeds from the different cropping and fertilizer recommendation systems are presented in Table 6. The lowest yield across the fertilizer recommendations except NSI for the two years was obtained from sole melon (0.22 t/ha). Yields

from sole maize and cassava were 8 and 20 times higher than sole melon. Dry matter yield from cassava + maize + melon was also 34 and 28 times higher than sole melon. Under the NSI recommendation, the mean dry matter yield was much higher than in other recommendations, but the trend across the cropping systems was similar to those observed in other recommendations.

Table 6
Mean dry matter yield* (t/ha) of edible components of cassava, maize and melon under the fertilizer recommendation and cropping systems

Fertilizer recommendation	Sole cassava (C)	Sole maize (M)	Sole melon (Me)	C+M	C+M+Me	Mean
Zero	2.6	1.0	0.2	5.0	4.2	2.6
Blanket	6.4	1.4	0.2	10.2	6.3	4.9
Soil test	4.0	2.5	0.3	7.4	7.8	4.4
Mean	4.3	1.7	0.2	7.5	6.1	-
NSI**	5.5	3.4	0.3	8.7	11.6	5.9

*= Average data for two seasons; ** = only for the 3rd season

Partial Budget analysis

An economic analysis of the fertilizer recommendations is presented in Table 7. The highest gross monetary yield was obtained from recommendation based on NSI. However, when the monetary yield was expressed per unit cost of fertilizer applied, the soil test recommendation (which gave between N17 and N27 per kg of fertilizer applied) was most profitable.

Discussion

The combined crop yields across the fertilizer recommendations and cropping systems for the first two years showed that crop yields were in the order soil test > zero > blanket fertilizer recommendation. However, in the third year when fertilizer was applied based on NSI, crop yields were highest under NSI than in other recommendation systems. This reflects the higher abundance of major nutrients in soils where fertilizer was applied based on NSI. It is noteworthy that fertilizer application based on blanket recommendation gave the lowest yield and this could be ascribed to nutrient imbalance caused by disproportionate addition of N, P and K to the soil system. Since fertilization was not based on nutrients identified as limiting in the soil, whatever nutrient that was added may have improved the status of some elements while worsening those of others. The result of this phenomenon is reduced crop yield as was witnessed during this study. This contrasts with nutrient application based on the soil test recommendation. Here, fertilizer was applied at rates calculated to correct the observed deficiencies for optimal crop growth and yield.

It was observed in some cases that nutrient uptake by crops, especially the intercrops was higher than the quantities actually applied based on soil analysis data. This may be because some soil nutrients such as N and P often results from mineralisation of organic matter which could not be accounted for in the amount extracted by a soil test procedure (5). Since fertilizer use based on NSI was the highest, it was not surprising that crop uptake was also highest under this recommendation. Crops embark on luxury uptake of essential nutrients once availability exceeds the critical level in the soil.

Dry matter yield as represented by the weight of dry biomass of the edible portion of a crop is a measure of the ability of the crop under a given condition to convert the absorbed nutrients into biomass. In this study, dry matter was enhanced in the order: NSI > soil test > blanket > zero fertilizer recommendation. Intercropping increased total dry matter yields and the highest proportion of the dry matter was obtained from cassava. The position of cassava is enhanced by its high starch content as well as high root yields. As edible portion crop dry matter is directly related to calorie yields, farmers prefer mixed cropping since it gives higher dry mat-

Table 7.
Cost/benefit analysis of the fertilizer recommendations under the different cropping systems

Amount of fertilizer used (kg/ha)	1988 A2	1988 A3	1989 A2	1989 A3	1990 A2	1990 A3	1990 A4
NPK (15:15:15)	400	0	400	0	400	0	0
Urea (45% N)	0	333	0	333	0	333	484
SSP* (18% P_2O_5)	0	211	0	135	0	0	806
MOP** (56% K_2O)	0	0	0	0	0	0	121
Fertilizer cost (N/ha)*	1200	1632	1200	1404	1200	999	4229
Crop yield (Equicassava) (t/ha)							
Cassava	16.8	24.9	17.3	24.4	16.9	22.7	41.2
Cassava+maize	20.7	31.3	20.3	30.8	19.9	30.2	49.8
Cassava+maize+melon	21.9	33.4	21.3	33.0	20.7	32.6	49.7
Mean	19.8	29.9	19.6	29.4	19.2	28.5	46.9
Monetary yield (N/ha)**	19048	28732	18887	28283	18438	27417	46118
Return per Kg of fertilizer used (N)	16	17	16	20	15	27	11

*= Cost of a 50 kg bag of any of the fertilizers was N150 in 1991
** The price of fresh cassava tuberous roots was N 962/t in 1991
1 US$ = N9 (1991).

ter. Furthermore the monetary yield of intercrops has been reported to exceed those from pure stands for the same area of land (7, 8, 14). However, Adetiloye (4) observed that substantial agronomic advantages in intercropping may not always give corresponding economic advantages, thereby suggesting that crops with low financial returns should be de-emphasised in favour of economic crops either in the process of choosing crop proportions or allocating space in the formulation of intercropping systems.

The overall conclusion from this study is that the yields from crops fertilized based on blanket fertilizer recommendation was not significantly different from those of the non fertilized plots, probably due to nutrient imbalance. This explains why many farmers who apply fertilizer based on this recommendation as is often the case in sub-saharan Africa do not derive much benefit from fertilizer use. Fertilizer use based on soil test recommendation offers the best yield per unit of fertilizer applied.

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