Effects of Rotation and Nitrogen on Crop Yield: 1. Cassava

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ABSTRACT

Most low resource farmers in the humid tropical zone of West and Central Africa grow cassava in complex mixtures, often with cereals and vegetables, for a two year period after which the land's fertility is restored by fallowing for many years, sometimes up to ten. Improved cassava production systems without fallowing is needed since long fallowing are no longer possible because of population pressure on the land. The effects of cassava-based intercropping and rotation systems on cassava yields were studied in Southern Nigeria. The three intercrop and the two year rotation systems were (1) monocrop cassava-based (cassava followed by (fb) maize fb cowpea) (2) two crop mixture (cassava + maize fb yam + cowpea) and (3) three crop mixture control (cassava + grain maize + melon fb cassava + green maize + okra). Three nitrogen levels 0, 45 and 90 kg/ha were applied. The design was split-plot of intercrop combination (main) and nitrogen (split).

The mean two year cycle root yield of the three crop mixture combination (15.2 tons/ha) was exactly the same as sole crop yield per cycle. The three crop mixture yield was, however, obtained in two years while for the monocrop system, it was in only one year. The two crop combination gave 63%. N application averaged over rotation system gave only 15% and 8% higher root yield at 90 and 40 kg/ha compared with zero N. Thus irrespective of crop mixture and rotation system, only small, non-significant increases in cassava yield due to N were obtained. Yields decline during the two years following the first, then increased in the fourth year. The causes of these are being investigated but is suspected to relate to improved rainfall and soil environment as well as better weed control.

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Cassava is an important crop in tropical Africa where it is a major source of food energy for 160 million people. It is second to maize upon which 200 million Africans depend for much of their calorific needs (Nweke *et al.*, 1988). However, cassava takes long to develop enough leaf area to cover the soil, as monocrop it takes 63 days to cover 50% of the ground surface (Lal 1977). This contrasts with soybean (38 days), and pigeon pea (48 days). To check soil erosion and runoff losses in high rainfall regions one of the practices advocated is that the soil be protected by vegetation (Hulugalle and Ter Keile, 1984). Intercropping of cassava with fast growing annuals is one of the methods commonly applied to protect the soil during the first 6-8 weeks of cassava growth when its leaf development is slow (Ikeorgu et al., 1989, Lal, 1977). It has been shown that if fast growing annuals are not introduced at that phase, weeds take their place and compete vigorously with cassava (Akobundu, 1987, Leihner, 1983). Short term two year studies to determine the advantages of intercropping some annuals, commonly grown by farmers in humid West Africa, such as maize, cowpeas, yams, okra and egusi melon with cassava have shown high level of complementarity (Unamma et al., 1987, Ezumah and Lawson, 1990, Ikeorgu et al., 1989, Juo and Ezumah, 1990, Adetiloye 1986). The intercrop yield advantages ranging from 20% to 100% have been reported.

Among the factors leading to the advantages of intercropping are reduced soil erosion and run off loses (Aina et al., 1977, Lal 1977). These should result in better nutrient conservation under intercropping systems. Improved soil physical and chemical properties and soil microbial activities, have been reported (Lal, 1977, Ezumah and Hulugalle, 1989, Hulugalle and Ezumah, 1990, Kang, 1989.). Reduced nutrient losses of intercropping may be better expressed in the performance of proceeding crop as determined in economic yield and biomass production. But such long term rotation studies with cassava have not been done in West Africa. This reasoning led to a study of effects of three cropping systems which included cassava in four two year rotation cycles. This report of cassava root yield is part of the rotation experiment conducted to:

1. determine the yield of cassava grown in sole crop rotations, in two and three crop mixture combinations and rotations and
2. evaluate the interactions of rate of nitrogen applications and cassava-based rotation.

The overall aim is to develop a recommendation package to be tested for use in cassava-based intercropping and rotation system for some humid areas of the tropics.

MATERIALS AND METHODS

The field study was conducted from 1985-1989 at the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. Ibadan is 7°30′N, 3°54′E in transitional zone between forest - savannah of South-western Nigeria. The rainfall is bimodal with mean annual of 1250 mm and ranging between 1000 mm and 1500 mm (Figure 1). Usually rains start in late March/early April and continues to July. A short break of 2-3 weeks occurs in August. Rain starts again in early September and ceases in early November. Minimum temperatures (usually $< 20^{\circ}C$) are usually observed in December/January during the windy harmattan period. Maximum temperatures ($> 32^{\circ}C$) usually occurs February/March. The soil, within the Ibadan series is Oxic Paleastalf with sandy loam top soil and sandy clay subsoil.

The experiment design was a split plot with three rotation systems with cassava as main plots and three Nitrogen levels as subplots. Details of the rotation treatments are given in Table 1. The N levels, supplied as urea are 0, 45 and 90 kg/ha. Each phase of every rotation treatment occurred in each year giving a total of six rotation treatments. Variations due to years are thus removed from the error variance. There were four replications. Crop combinations, sequences and populations are given in Table 1. Spatial arrangements are shown in Figure 2. Subplot size was 15 m long × 5.5 m wide.

The field had been cropped continuously for three years from 1982. The upper half of the field was used for a maize + cowpea intercropping experiment for two years (1983 and 1984) following a cassava varietal multiplication in 1982. The lower half was used for cassava multiplication from 1982 to 1983. In 1984, Mucuna utilis was established for soil fertility restoration. Because of this cropping history, 2 of the four replications were located in the upper half and the other two at the lower half.

The entire field was disc-harrowed to 20 cm depth at beginning of the experiment in 1985. For the remaining years, no-tillage (Lal, 1989) was used except during years of yam + cowpea planting when ridges, 75 cm apart and 30 cm high, were made. All the crops except the sole cowpea were established during the first season of each year, usually by the second week of May. Sole cowpea was planted in Mid-September. Crop varieties used are given in Table 1. Seed bed fertilizer was at 60 kg/ha P and 60 kg/ha K in all plots. Thereafter, subplots were randomly assigned the 0, 45 and 90 kg N/ha treatments. Fertilizer formulations were calcium ammonium nitrate, single superphosphate and muriate of potash. "Galex" (metabromourant metolachlor) at 3 kg ai/ha was used for preplanting weed control. Hand weeding was supplemented at rates of 3 weedings in the sole crop cassava and 2 weedings in sole crop maize and cowpea plots; two weedings each in the yam + cowpea and cassava + maize crop combinations and only one weeding in the three crop mixtures (Table 1). Cassava harvest was at $11\frac{1}{2}$-12 months depending upon earliness of rain to soften the soil and facilitate harvesting.

Cassava yield data were analyzed by year and combined across years using the GENSTAT (Lawes Agricultural Trust, 1980) package.

RESULTS AND DISCUSSION

Root yield of cassava can be expressed by root weight and root number. Biomass production is roughly shoot plus root weights. Total plant number at harvest is an indication of establishment and survival through the growth season.

Table 2 shows the significant F-values for each of the four years for number of cassava plants, root number, shoot and root weights/ha. Table 3 shows the same cassava variables across the two rotation cycles during the four year period, 1985-1989. Significant mean effects and interactions will be discussed in details. However, trends in mean effects of rotation and N rate on cassava population and root number at harvest (Table 4) and cassava root and shoot weights (Table 5) will help explain overall rotation and nitrogen effects on cassava.

Number of cassava plants and roots

Number of cassava plants/ha at harvest averaged 6,500 or only about 65% of the 10,000 stakes planted. Generally fewer plants were harvested from the three crop mixture Table 4. Root number was fewer in the two crop and the three crop plots compared with sole cassava. Addition of N did not affect plants/ha averaged over the four years, nor root number/ha.

Year to year variations of plant and root number as affected by nitrogen and rotation shows that number of plants at harvest ranged from 5,200 in 1986-1987 season to 8,100 in 1988-1989. Trend in root number corresponded with number of plants, ranging from 27,000 in 1986-1987 to 69,500 in 1988-1989 (Table 4). The reduced plant and root number during 1986-1987 is attributable to low rainfall which was below the 16 year average at the IITA site (Figure 1). A more important factor may be an early cut off of rain, there being no rainfall in October. Though the 1988-1989 rainfall was also low, its distribution was good and the rainfall in November and December might have decreased cassava growth (Figure 1). Increasing complexity of crop mixture reduced root number more than number of plants, especially in the three crop mixture rotation (Table 4).

Root and Shoot Yields

Rotation and N effects on root and shoot yields varied from year to year and the distribution of significant effects is presented in Table 2. Type of rotation system increased cassava root yield in all the years (Table 2). The best root yield averaged over the four years were obtained from the system in which sole cassava is rotated with maize in the preceding first season and cowpea in the second season. The increase was such that Cassava followed by (fb) maize-cowpea > casava + maize fb yam + cowpea > cassava + maize + melon fb cassava + green maize + okra in the following order 15.2 > 9.6 > 7.6 t/ha root yield.

Expressed as percentage the ratio was 100 > 63 > 50. Cassava root yields were generally lower in the years in which cut off of rain was early (October 1986-1987 and 1987-1988) compared with years in which rain continued till November (1985-1986), or later November/December (1988-1989), Table 5 and Figure 1. Root yields in 1986-1987 and 1987-1988 were 4.1 tons/ha and 5.5 t/ha lower than those for 1985-1986 and 1988-1989, respectively (Table 5).

Increasing N rate may increase cassava root yield by up to 3.8 t/ha only in the years in which rainfall was extended to November or December. The values were 10.8, 12.0 and 14.6 t/ha at 0, 45, and 90 kg N/ha in 1985-1986. These expressed in ratios are 74, 82 and 100%, respectively. Corresponding ratios for 1988-1989 with the yield differences at the same N levels of 13.1, 13.8 and 14.4 is 91, 96 and 100, Table 5. Within year root yield was not affected by rotation systems nor by N application.

The trend in cassava shoot yield as affected by rotation, N and year was similar to that of root yields which declined with increasing crop mixture complexity. Shoot yields are higher during cropping seasons in which rainfall extended beyond October to November/December. No consistent N effects on shoot yield within and between years were observed (Table 5).

N data on number of plants/ha, root number/ha, and root and shoot yields presented in Table 3 show significant cycle effects on cassava plants, and root number and on shoot yields but not for root yield. However, all these cassava agronomic characters varied significantly with rotation. Significant interactions will be discussed in detail later but some rotation × cycle and N × cycle effects are important to explain trends if any.

Cassava plant and root number at harvest were consistently higher ($P < 0.01$), during the second cycle (1987-1989) compared with the first (1985-1987), Figure 3. Similar cycle effects to those observed for root and plant number were also obtained for shoot weight (Table 3, Figure 4a).

Similar cycle effects to those observed for root and plant number were also obtained for shoot weight (Table 3, Figure 4a). The highest shoot weight was obtained from the sole crop rotation cycle i.e., cassava fb maize fb cowpea, the next was the three crop mixture and finally, the two crop mixture cycle (Figures 4a and 4b). Note that the three crop mixture cycle was based upon continuous crops of cassava while the others were alternate year cassava yields (Figures 4a and rb; Tables 4 and 5). Application of N at 45 kg/ha increased shoot yield over non-application. Root yield increased only slightly (non-significant) with increasing N from 45 kg to 90 kg/ha (Figure 5 and Figure 6a). Both cycles behaved similarly to N fertilization (Figure 6a). Interation of cycle and N rate for short yield was due to non-response to N in cycle 2, particularly beyond 45 kg N/ha; a trend not observed in cycle 1 when response to N was highly positive from 0 to 45 kg/ha N from which it declined rapidly at 90 kg N/ha (Figure 6).

GENERAL DISCUSSION:

Cassava root and shoot yields per year were lower in rotations in which cassava is mixed with maize and melon or with maize and okra. i.e., in rotations of three crop mixtures which include cassava than in two crop rotation mixture in which cassava and maize mixtures are alternated by yam and cowpea mixtures. Both three and two crop mixtures yielded lower than those in which sole cassava is alternated by sole maize in the first season and is followed by sole cowpea in the second season.

Addition of N at rates up to 90kg/ha had no effect on cassava root and shoot yield. However, root and shoot yields as well as other agronomic characters (plant number and root number/ha) increased significantly during years in which rainfall was extended into normally dry periods in a growing season. Therefore cultural practices which conferred and retained moisture during dry season or supplementary irrigation may increase cassava yield in the bimodal rainfall areas of Southern Nigeria. Moisture distribution during the cassava growing season appears to affect root and shoot yields more than total amount. Thus the early cut off of rain in October 1986 appears to be compensated for by early rains in January and February of 1987. The 1986-1987 root and shoot yields were thus, the same as that observed in 1987-1988 with higher total rainfall (Figure 1). The two crop mixture cassava root yield per rotation cycle declined to 63% of the monocrop yield per cycle. The three crop mixture gave cassava yield per cycle similar to the monocrop rotation yield. These ratios were not changed significantly by addition of Nitrogen.

CONCLUSION

High cassava root yield is realized by rotating sole cassava in alternate years with maize and cowpea in bimodal rainfall zone of West Africa. About 40-50% of the cassava root yield may be met per year if mixed with maize alone or with maize and some subsidiary crop such as melon or okra. A cycle of two years gives as much cassava in continuous three crop system as in one year of sole crop based system. Rainfall appears to be important in overall performance. Year to year variations in yields were such that fourth year yield was not different from the first year's. Though soil moisture was not measured, it appears that rainfall distribution related closely to yield variations, with earliness of cut off being an important factor.

Evaluation of the yield data for cassava root yield per cycle of two years showed that the three crop mixture cycle yielded the same quantity of cassava as the sole crop rotation. Since a farmer will be interested in having some cassava every year, the significance of the lower yearly average yield of the three crop mixture should be viewed from the point of view of timely and sustained availability of the food needs of low resource farmers in the humid tropics of Africa.

Table 1: Crop combinations, and crop rotation treatments and populations 1985-1989.

Rotation Treatment	Phases	1985	1986	1987	1988	Plant population $/m^{-2}$
1	1	Ca	Ma–Cp	Ca	Ma–Cp	Ca=1,Ma=5.3;CP=6.2.
	2	Ma–Cp	Ca	Ma–Cp	Ca	
2	1	Ca+Ma	Y+Cp	Ca+Ma	Y+Cp	Ca=1;Ma=4;Y=1;CP=6.2.
	2	Y+Cp	Ca+Ma	Y+Cp	Ca+Ma	
3	1	Ca+Ma+Me	Ca+GMa+Ok	Ca+Ma+Me	Ca+GMa+Ok	Ca=1;Ma=4;Me=2;OK=3.
	2	Ca+Gma+Ok	Ca+Ma+Me	Ca+Gma+Ok	Ca+Ma+Me	GMa=4.

– = Followed by (fb)

\+ = intercropped with (iw)

fb = is followed by in next year

Y = Yam

Ca = Cassava

Ok = Okra

Ma = Maize

Cp = Cowpea

GMa = Green Maize

Me = Melon

Table 2: Significance of F-values from ANOVA for (a) cassava population and root number/ha and (b) cassava shoot and yield/ha, from, 1985-1989 rotation trial in Southern Nigeria.

Year of Rotation:

a) Cassava Population and Root Number/ha

Source	df	1985-86		1986-87		1987-88		1988-89	
		Plants	No. Roots	Plants	No. Roots	Plants	No. Roots	Plants	No. Roots
Rep.	3								
Rotation	2	NS	NS	*	**	NS	*	**	**
Error A	6								
N - Level	2	NS	NS	NS	NS	NS	NS	NS	NS
R x N	4	NS	NS	NS	NS	NS	*	NS	NS
Error B	18								
Total	36								
CV(%) Rotation		5.8	19.9	10.0	10.6	11.4	27.5	4.0	9.2

b) Cassava shoot and root weights/ha

Source	df	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Rep.	3								
Rotation	2	**	**	*	**	**	*	**	*
Error A	6								
N - Level	2	*	NS	NS	NS	**	NS	NS	NS
R x N	4	NS	NS	NS	*	NS	NS	NS	NS
Error B	18								
Total	36								
CV(%) Rotation		20.8	27.0	15.7	42.9	27.9	17.8	14.9	26.7

*, ** F test significant at 0.05 and 0.01 probability levels, respectively.

Table 3 Significance of the effects of rotation and N levels on cassava population, cassava root number, shoot and root yields across cycles during 1985-1989 in Southern Nigeria.

Source	df	Cassava Pop.	Root No.	Shoot Yld.	Root Yld.
Reps	3				
Cycle(C)	1	**	*	*	NS
Error A	3				
Rotation(R)	2	**	**	**	**
C×R	2	NS	*	NS	NS
Error B	12				
N-Level	2	NS	NS	**	*
C×N	2	NS	NS	*	NS
R×N	4	NS	NS	NS	NS
C×R×N	4	NS	NS	NS	NS
Error C	36	NS	NS	NS	NS
Total	71	NS	NS	NS	NS
CV% Rotation:		6.6	11.1	13.2	22.6

*, ** F test significant at 0.05 and 0.01 probability levels, respectively.

Table 4 Effects of rotation and N on cassava plant population/ha and root number/ha, 1985-1989

Rotation	0	45	90	Mean	0	45	90	Mean
	Nitrogen Level, kg/ha				Nitrogen Level, kg/ha			
	Plant Population X1000				Root Number X1000			
1985-1986								
Ca fb Ma fb Cp	6.1	5.8	6.2	6.0	49.4	45.8	52.4	49.2
Ca+Ma Fb Y+Cp	5.7	5.8	6.3	5.9	46.7	40.9	47.0	44.9
Ca+Ma+Me fb Ca+GMa+Ok	11.6	10.8	11.2	11.2	62.4	72.4	74.6	69.8
Mean	7.8	7.5	7.9	7.7	52.8	53.0	58.0	54.6
1986-1987								
Ma fbCp fb Ca	5.8	5.7	5.8	5.8	41.9	35.5	38.9	38.8
Y+Cp Fb Ca+Ma	5.1	5.8	5.5	5.5	24.4	27.7	24.9	25.7
Ca GMa+Ok Fb Ca+Ma+Me	8.0	8.6	8.8	8.6	29.4	30.4	39.2	33.0
Mean	6.3	6.7	6.7	6.6	31.9	31.2	34.3	32.5
1987-1988								
Ca fb Ma fb Cp	7.6	7.7	7.6	7.6	58.8	63.3	78.9	67.0
Ca+Ma fb Y+Cp	6.4	7.4	7.3	7.0	38.1	39.5	39.8	39.1
Ca+Ma+Me fb Ca+GMa+Ok	13.8	12.6	10.8	12.4	69.8	71.2	53.8	65.0
Mean	9.3	9.2	8.6	9.0	55.6	58.0	57.5	57.0
1988-1989								
Ma fb Cp fb Ca	8.4	8.6	8.5	8.5	83.3	80.3	81.3	81.6
Y+Cp fb Ca+Ma	8.6	8.0	8.2	8.3	73.9	77.3	83.7	78.3
Ca+GMa+Ok fb Ca+Ma+Me	15.0	14.8	14.8	15.0	91.4	93.0	107.6	96.4
Mean	10.7	10.5	10.5	10.6	82.9	83.5	90.9	85.4
Four Year Mean								
Ca fb Ma fb Cp	7.0	7.0	7.0	6.98	58.4	56.2	62.9	59.1
Ca+Ma fb Y+Cp	6.5	6.8	6.8	6.68	45.8	46.4	48.8	47.0
Ca+Ma+Me fb Ca+GMa+Ok	12.2	11.8	11.4	11.80	63.2	66.8	68.8	66.2
Mean	8.6	8.5	8.7	8.48	55.8	56.5	60.2	57.4

Table 5 Effects of rotation and N on cassava root and shoot yields in 1985-1989.

Rotation	Nitrogen level, kg/ha 0	45	90	Mean	Nitrogen level, kg/ha 0	45	90	Mean
	Root, t/ha				Shoot, t/ha			
				1985-1986				
Ca fb Ma fb Cp	13.2	12.8	18.9	15.0	21.6	26.2	24.7	24.1
Ca+Ma fb Y+Cp	10.8	12.1	13.4	12.1	10.2	12.0	11.8	11.3
Ca+Ma+Me fb Ca+GMa+Ok	17.0	22.4	23.0	20.8	15.8	19.6	19.8	18.4
Mean	13.7	15.8	18.4	16.0	15.9	19.3	18.8	17.9
				1986-1987				
Ma fb Cp fb Ca	15.7	12.2	13.1	13.7	15.6	13.5	13.4	14.1
Y+Cp fb Ca+Ma	6.2	9.1	6.5	7.3	6.7	9.2	6.2	7.4
Ca GMa+Ok fb Ca+Ma+Me	6.6	8.0	10.4	8.4	5.8	15.6	8.6	9.6
Mean	9.5	9.8	10.0	9.8	9.4	12.8	9.4	10.4
				1987-1988				
Ca fb Ma fb Cp	10.2	13.6	15.0	12.9	8.7	10.0	11.8	10.2
Ca+Ma fb Y+Cp	7.0	8.1	7.1	7.4	3.6	3.7	4.5	4.0
Ca+Ma+Me fb Ca+GMa+Ok	11.6	10.0	8.2	10.0	7.2	8.4	8.4	8.0
Mean	9.6	10.6	10.1	10.1	6.5	7.5	8.2	7.4
				1988-1989				
Ma fb Cp fb Ca	18.5	20.3	18.0	18.9	18.6	19.3	18.2	18.7
Y+Cp fb Ca+Ma	10.3	10.7	13.7	11.6	9.9	12.4	15.7	12.7
Ca+GMa+Ok fb Ca+Ma+Me	20.8	20.4	23.2	21.4	10.0	11.6	12.2	11.2
Mean	16.5	17.1	18.3	17.3	12.8	14.4	15.4	14.2
				Four Year Mean				
Ca fb M fb Cp	14.4	14.8	16.2	15.2	16.1	17.2	17.0	16.8
Ca+Ma fb Y+Cp	8.6	10.0	10.2	9.6	7.6	9.4	9.6	8.9
Ca+Ma+Me fb Ca+GMa+Ok	14.0	15.2	16.2	15.2	9.8	13.6	12.2	11.8
Mean	12.3	13.3	14.2	13.3	11.2	13.4	12.9	12.5

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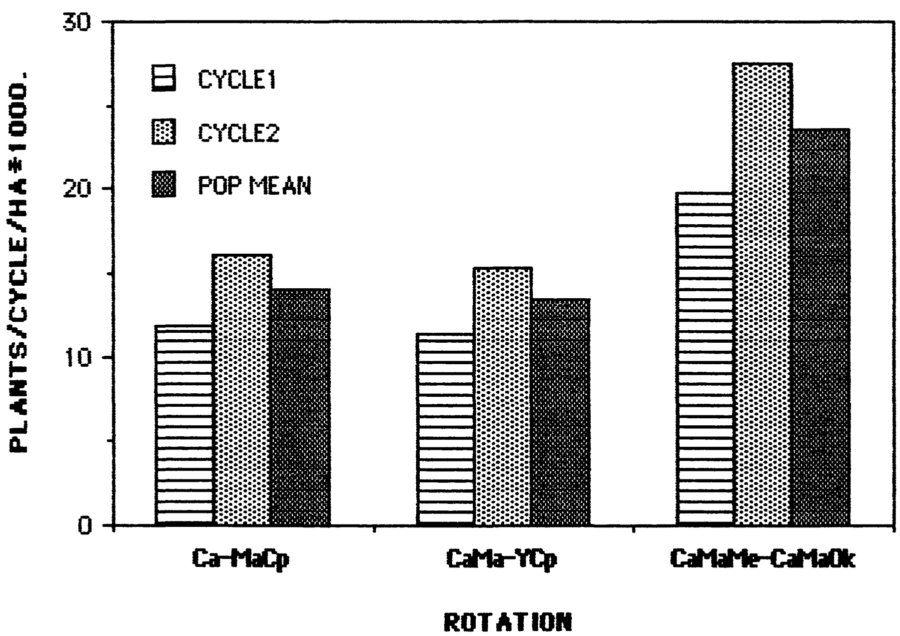
FIG. 3a. ROTATION EFFECTS ON NO. OF CASSAVA PLANTS.



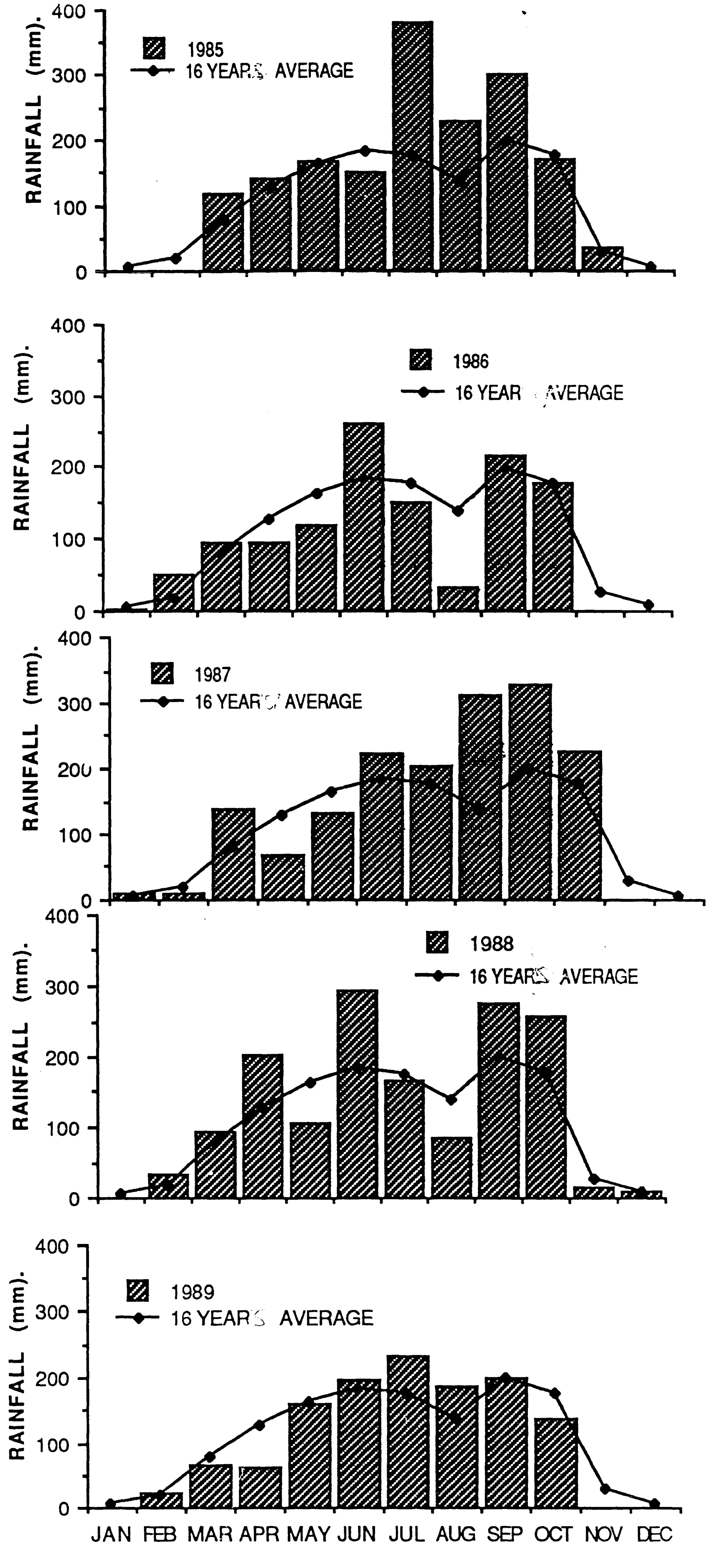


Figure 1: Monthly rainfall at IITA, Ibadan, Nigeria.

FIG.3b. ROTATION EFFECT ON ROOT NO. PER HA. PER CYCLE.

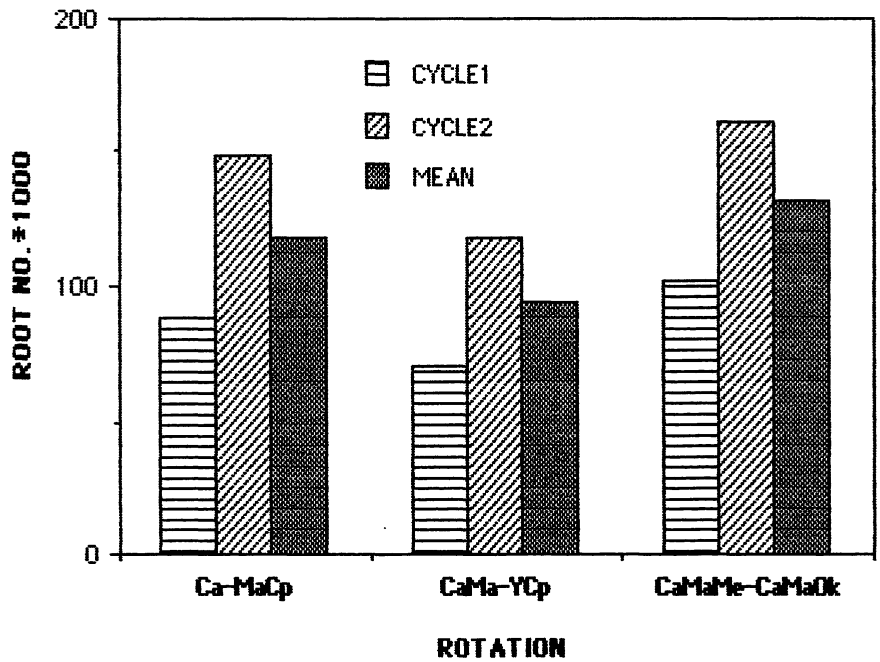


FIG.4 ROTATION EFFECT ON TOTAL CASSAVA ROOT YIELD.

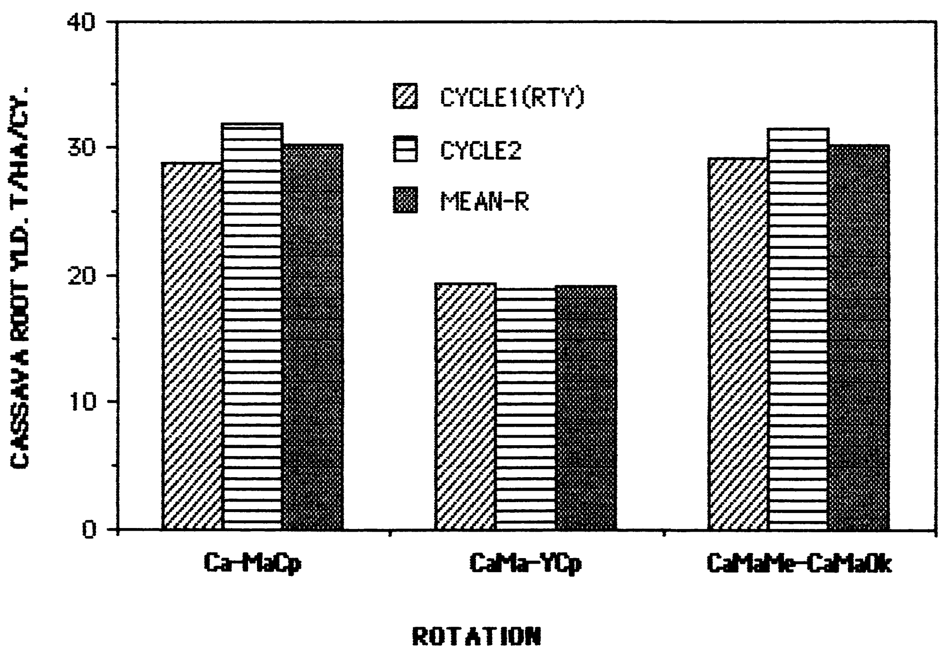
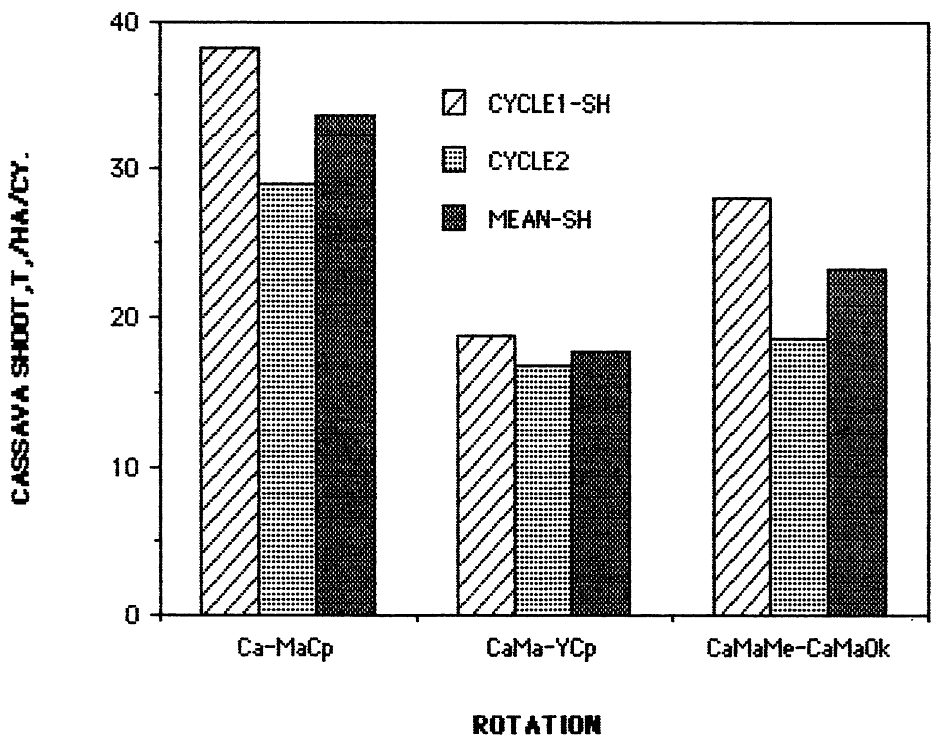
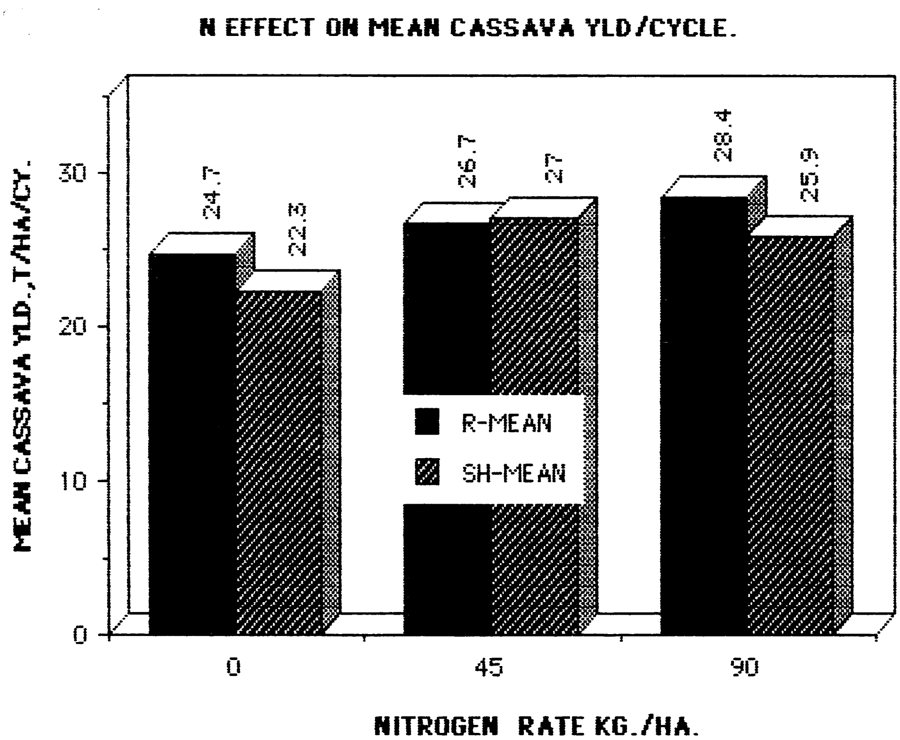


FIG.4b. ROTATION EFFECT ON CASSAVA SHOOT YIELD.





N EFFECT ON MEAN CASSAVA YLD/CYCLE.
MEAN CASSAVA YLD.,T/HA/CY.
30
20
10
0
24.7
22.3
26.7
27
28.4
25.9
R-MEAN
SH-MEAN
0
45
90
NITROGEN RATE KG./HA.

FIG. 6A.N & ROTATION EFFECTS ON CASSAVA ROOT TLD.

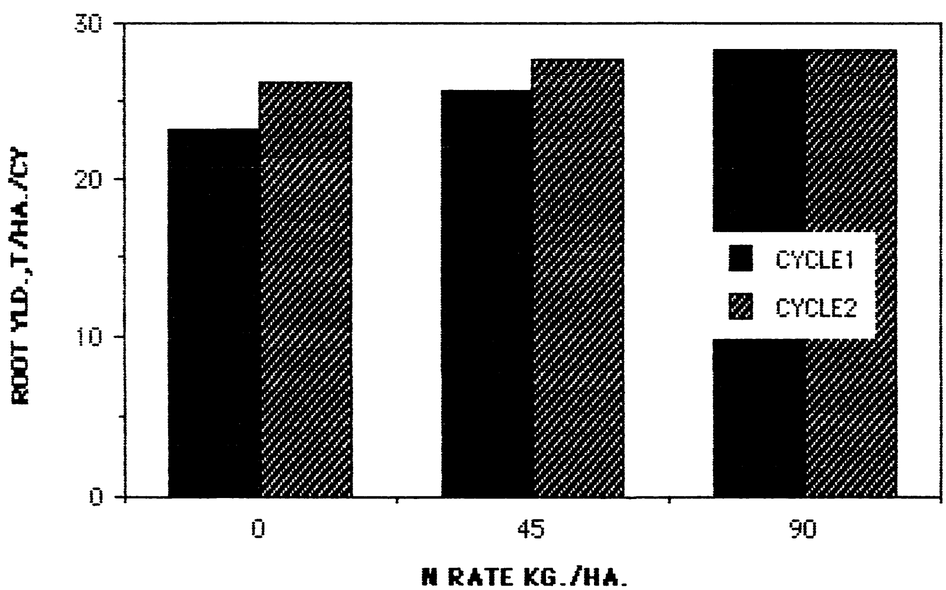


FIG. 6~~a~~ b NITROGEN & ROTATION EFFECTS ON CASSAVA ~~ROOT~~ SHOOT YLD.