A LONG TERM ROTATION TRIAL IN NEW BRITAIN, PAPUA NEW GUINEA

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SUMMARY

A twenty year rotation trial is described from the wet tropical lowland in New Britain.

Continuous cropping of sweet potato (*Ipomoea batatas*), taro (*Colocasia esculenta*), and peanuts (*Arachis hypogaea*) or cowpeas (*Vigna sinensis*) (narrow rotations) is compared with a one and a half year period of food crops rotated with a one and a half year period of food crops rotated with a one and a half year green manure crop (wide rotations). No cropping pattern has maintained yields of all crops at or near the original levels. The wide rotations are less bad than the narrow rotations. Fertility has dropped markedly, particularly in the narrow rotations.

RESUME

Un essai de rotation mené en vingt ans sur les basses terres de la Nouvelle-Bretagne a été exposé.

La culture ininterrompue d'*Ipomea batatas*, de *Colocasia esculenta* et d'*Arachis hypogaea* ou de *Vigna sinensis* (rotations étroites) a été comparée à la culture de plantes vivrières sur une période d'un an et demie en rotation avec celle d'une plante verte cultivée avec application d'engrais sur un an et demie (rotations larges). Aucun des systèmes essayés n'a maintenu ou approché le rendement initial de toutes ces plantes. Les rotations larges ne sont pas aussi mauvaises que les rotations étroites. Il y a eu baisse sensible de la fertilié, surtout en rotations étroites.

RESUMEN

Se describe un ensayo de rotación, por veinte años, de las tierras bajas tropicales en Nueva Bretaña.

El cultivo continuo de camote (*Ipomoea batatas*), malanga (*Colocasia esculenta*) y maní (*Arachis hypogaea*) o chícharo de vaca (*Vigna sinensis*) (rotaciones cortas) se compara con un período de año y medio de cultivos para production de alimentos ratados con año y medio de cultivos para forraje (rotaciones largas). Ninguno de los patrones de cultivo ha mantenido los rendimientos de todos los cultivos a los niveles originales o cerca de ellos. Las rotaciones largas son menos perjudiciales que las cortas. La fertilidad ha bajado mercadamente, particularmente en las rotaciones cortas.

INTRODUCTION

In Papua New Guinea sweet potato, taro, yams, bananas and the sago palm provide the bulk of the food for its two million inhabitants. A bush fallow farming system is employed in the lowlands and normally provides adequate crops. Under this system the cropping period is characteristically only about one year and the fallow period at least 10 years. However, as population increases, the fallow period is being reduced and the system becoming inadequate to provide sufficient food. So far this has occurred only in a few localities and has been alleviated by migration and some changes in farming systems.

In anticipation of such developments, a rotation trial in the lowlands was laid down in the early nineteen fifties and is reported here. The trial was near sea level at Keravat on the islands of New Britain at 4°21'S, 152°2'E. Annual rainfall is 2760 mm fairly evenly distributed throughout the year, although 1 or 2 dry months can be expected to occur in most years. The climax vegetation is lowland forest and the soil a young alluvial sandy loam derived from tuff.

METHODS

The trial has 7 rotational treatments (Table 1) each with a different sequence of 6 plantings. Each complete sequence of plantings is termed a cycle. Each cycle takes 3-3.5 years to complete. The first cycle of each treatment was planted in January 1954, and 19 years later in 1973 the trial is in its 6th cycle.

Each treatment is replicated 3 times in position. There are also 3 replicates in time, termed series. The 3 replicates within each series are associated in an incomplete block layout with 3 plots per sub-block. The 3 series were planted contiguously in the field.

Thus there are 63 plots in the trial (7 treatments x 3 replicates in space x 3 replicates in time (series). Each plot being 9 metres square.

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Rotations 1,2,6 and 7 are termed wide rotations. In the wide rotations half of each cycle is cropped to a leguminous green manure crop and the other half to food crops. In rotations 1 and 2 half of each cycle is cropped to *Mimosa invisa* (see Table 1). In rotations 6 and 7 half of each cycle is cropped to *Pueraria phaseoloides*. These green manure crops are planted for about 1½ years. Sweet potato (*Ipomoea batatas*), taro (*Colocasia esculenta*) or sorghum (*Sorghum vulgare*) and peanuts (*Arachis hypogaea*) make up the rest of the cycle. Taro occurs in rotations 1 and 6 and sorghum in rotations 2 and 7.

Rotations 3, 4 and 5 are termed narrow rotations. These are cropped continuously with food crops. Rotations 4 and 5 are identical and consist of a continuous rotation of sweet potato, taro and peanuts. Initially, the 2 rotations differed slightly in the treatment of residues of the peanut crop. Peanut residues were removed in rotation 4 and returned to the plots in rotation 5. Rotation 3 is the same as the other narrow rotations except that a short term green manure crop *Vigna sinensis*, or another short term leguminous crop, replaces peanuts. At maturity of each food crop the following yields per plot were recorded — weight of main corms only in taro, weight of all sweet potato tubers, weight of dried, unshelled peanuts and weight of sorghum grain. From the 3rd planting, 4th cycle onwards quality of the root crops was also assessed. Sweet potato tubers longer than 10 cm and wider than 5 cm were classified as marketable and those with smaller dimensions as not marketable. Taro corms larger than 7 cm by 5.5 cm were classified as marketable. Top growth vigour, leaf colour, and flowering have been visually assessed from time to time by allocating a score to each plot after a visual assessment.

Residues from green manure crops were slashed, dried and incorporated in the soil upon maturity of the corresponding group of food crops.

Soil samples were collected before and during the trial using a 2 cm diameter soil auger. Ten samples were collected per plot for a depth of 0 — 30 cm, bulked and air dried before analysis.

YIELDS RESULTS

Results from the commencement of the trial until the completion of the 2nd planting, 6th cycle (March 1973) are presented. Yield levels of rotation 1 and 2 are generally similar, as are those of rotations 6 and 7, and the yields of the pairs have been plotted together. Rotation 1 differs from 2 and 6 differs from 7 only in that sorghum replaces taro in the cropping sequence.

Sweet potato yields

Yield trends for sweet potato are shown graphically in Figures 1 and 2. Statistical analysis has been performed on sweet potato only since this is the crop common to all rotations. Rotational effects are highly significant. The least significant differences between rotations were 5280 kg/ha (5% level) and 6979 kg/ha (1% level) for comparing means of one rotation only and 3734 kg/ha (5%) and 4935 (1%) for comparing means of two rotations.

Yield levels of all rotations were initially very similar, but differences between rotations became apparent by the middle of the second cycle (Fig. 1). Yields have declined from initial levels to a lower level, about which large fluctuations occur. The wide rotations (1,2,6 and 7) have yielded significantly more than rotations 4 and 5 in 10 out of 16 crops at the 5% level of significance, and better than rotation 3 in 6 crops. Rotation 3 has significantly outyielded rotations 4 and 5 in 3 crops.

Because narrow rotation plots are cropped twice as often with sweet potato as wide rotation plots, the cumulative yield per plot for that crop plant over the period of the trial is greater in the narrow than in the wide rotations, even though the yield per crop is lower. Similarly this occurs for taro and peanuts. The high yields obtained in the 3rd and 5th plantings in the fourth cycle cannot be readily explained from weather conditions at the time.

Large yield fluctuations can be attributed in some crops to particularly severe pest and disease attack and variations in cultural treatments, such as the cultivar used. These same factors are also responsible for some of the yield fluctuations in the other crops.

The two groups of wide rotations are compared in Fig. 2. Rotations 6 and 7 have significantly outyielded 1 and 2 in 5 crops. This may be because the *Pueraria* green manure crop (Rotation 6 and 7) breaks down faster than the *Mimosa* and provides more nutrients to the following sweet potato crop. Rotations 6 and 7 have yielded less than 10 t/ha of sweet potatoes in one crop only.

The yields shown in Fig. 1 do not reflect the difference in root quality between rotations. As the data in Table 2 show, wide rotation crops often produce a greater proportion of saleable roots than the narrow rotations. No earlier records are available for root quality, but from experience with other sweet potato crops on newly opened land, it can be assumed that in the first few plantings of the trial most roots would have been classified as marketable.

Top growth vigour assessments for 2 crops are given in Table 3. High scores were allocated to more vigorous plots. Vigorous growth was characteristic of wide rotation plots, while the plants in narrow ro-

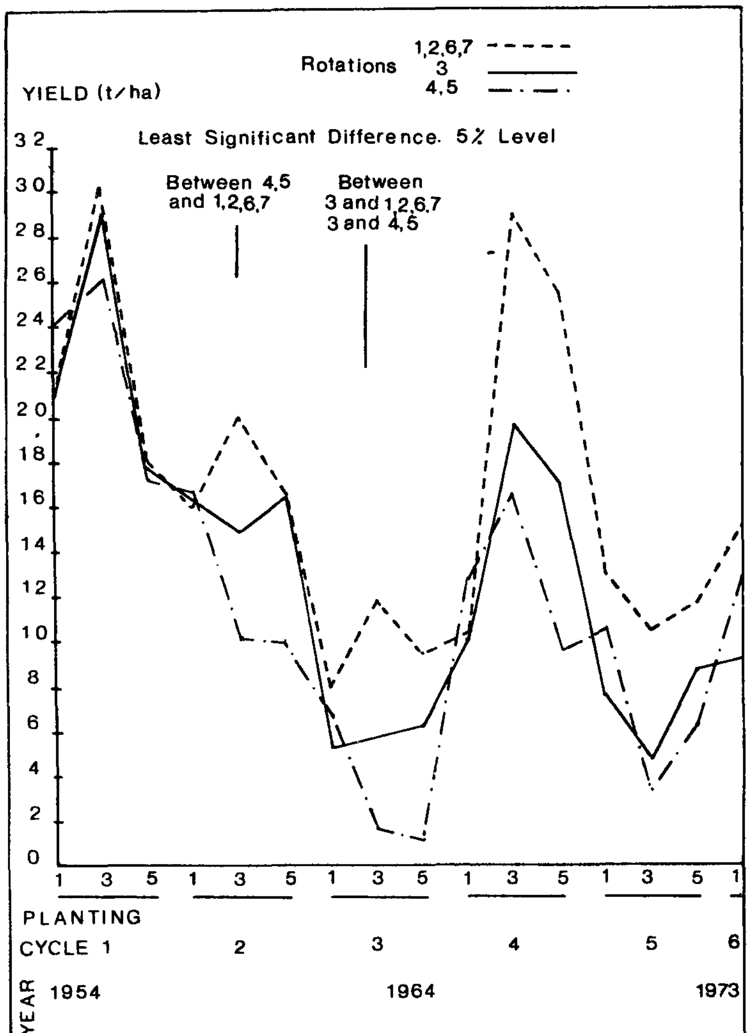

FIGURE 1. SWEET POTATO YIELDS. 1 ST CROP OF ROTATION

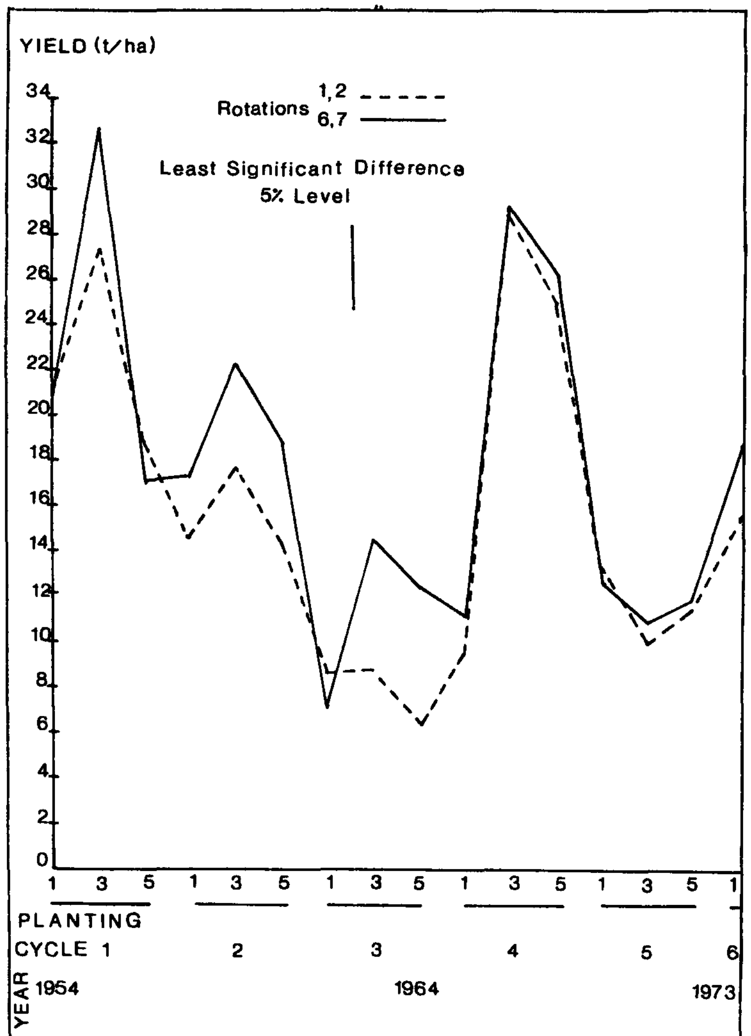

FIGURE 2. SWEET POTATO YIELDS. WIDE ROTATIONS.

tations showed poor, chlorotic growth. Rotation 3 is not very different from the other two narrow rotations in these 2 assessments. Top growth vigour scores reflect yield performance and have provided a quick qualitative way of estimating yield levels. Vigorous top growth and a high score are associated with high yields.

Taro yields

Yields are plotted in Figures 3 and 4. They were initially similar for all rotations, but differences between rotations became apparent by the 2nd cycle. Yields declined rapidly to very low levels but there was some yield recovery in the wide rotations. The wide rotations are clearly superior to the narrow rotations. Only in a few crops has rotation 3 yielded better than the other narrow rotations. In these rotations yields are very low.

There is little difference between yields of the two wide rotations (Fig. 4). There is some indication that rotation 1, with *Mimosa* as the green manure crop, is superior to rotation 6 with *Pueraria*, but the trend is not very strong. There is a greater proportion of larger corms in the wide rotations as can be seen from the two plantings given in Table 4. More suckers are also produced in the wide rotation plots.

Peanuts yields

Yields are given in Figure 5. Crop to crop fluctuations are large. Little or no long term yield trends are discernible, although there is a weak suggestion that there has been an overall downward trend. The wide rotations have yielded better than the narrow rotations fairly consistently from the end of the 3rd cycle, but the differences were small. There is little difference in peanut yield among the various wide rotations.

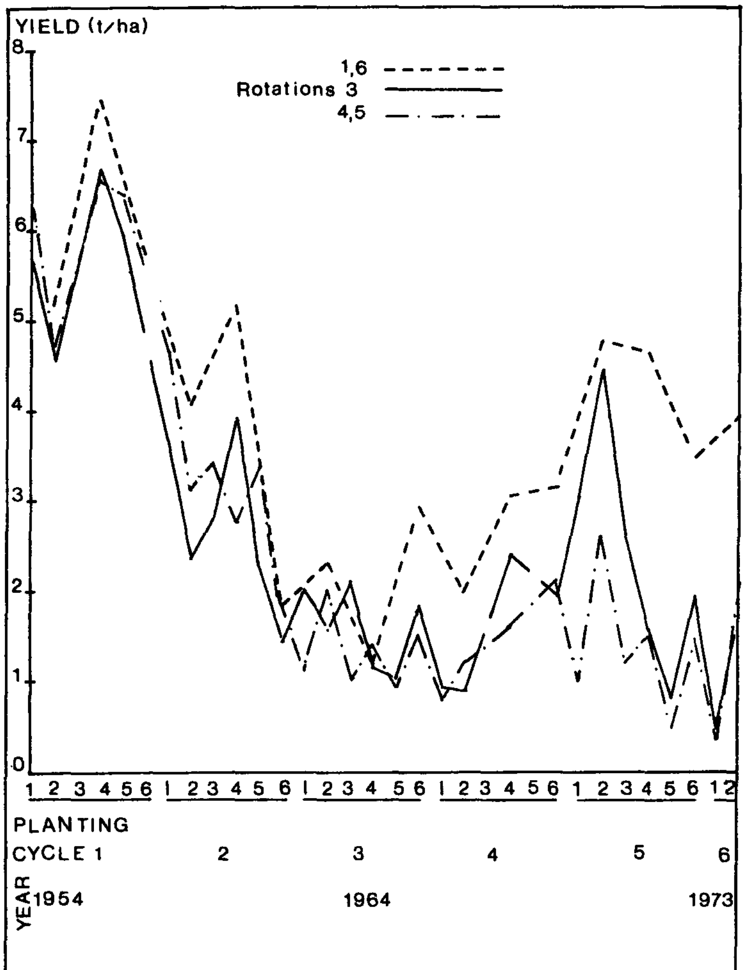

FIGURE 3. TARO YIELDS. 2ND AND 5TH CROP OF ROTATION.

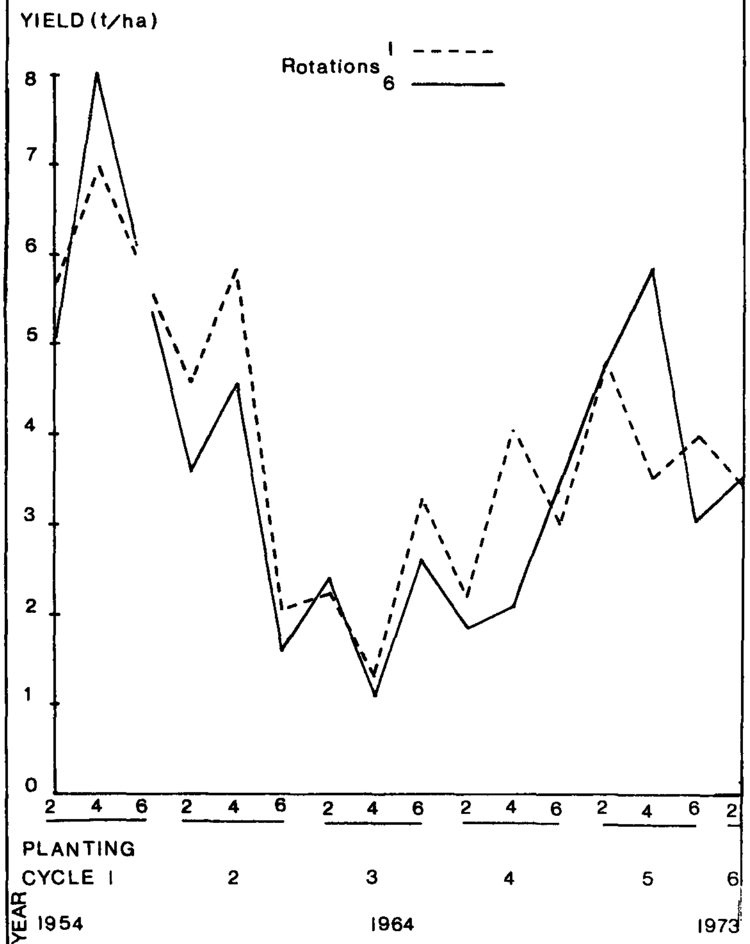

FIGURE 4. TARO YIELDS. WIDE ROTATIONS.

Sorghum yields

Sorghum yields are given in Figure 6. Sorghum only occurred in the wide rotations. As with peanuts, long term trends are not clear and crop to crop fluctuations are large. There is little difference between the rotations, except that, as with taro, there is a suggestion that the wide rotation, including *Mimosa* (rotation 2) may give superior yields to that including *Pueraria* (rotation 7).

Soil analysis results

A summary of the chemical analysis for 10 soil factors from four samplings over a period of 17 years is presented in Table 5. Other samples were not analysed. Rotation 3 has been grouped with the other narrow rotations as the values differ little between these 3 rotations. The first sampling was done before the first planting, first cycle in January 1954. The 8th sampling was done after harvesting the first planting, 3rd cycle in October 1961. The 9th sampling was done after harvesting the 6th planting, 3rd cycle in December 1964, and the 10th sampling was collected during the 3rd planting, 5th cycle in August 1970. The 1st and 8th samplings were analysed on an oven dry basis, and the 9th and 10th samplings on an air dry basis.

Soil analysis has shown declines in N%, C%, pH, specific conductivity, exchangeable Ca, Mg, K and Na as well as the total exchange capacity and the K/N ratio (Table 5). For most factors the decline was greater in the narrow than in the wider rotations and especially for exchangeable K and Mg.

The differences in N% between wide and narrow rotations is not very large, suggesting that the leguminous green manure crops in the wide rotations have not prevented long term soil N decline. Because the soil is low in clay content, maintenance of fertility and exchange capacity is expected to depend upon maintenance of soil humus. This had dropped to about half of the original levels.

Olsen-P level had apparently increased with time. However both the 1st and 8th samplings were analysed in 1963, 9 and 2 years after collection respectively. The apparent rise between these 2 samplings might be due to P fixation during storage of soil from the first sampling. Other P analyses from the area suggest that the first sampling figure is incorrect, and P levels have changed little over the period of the trial.

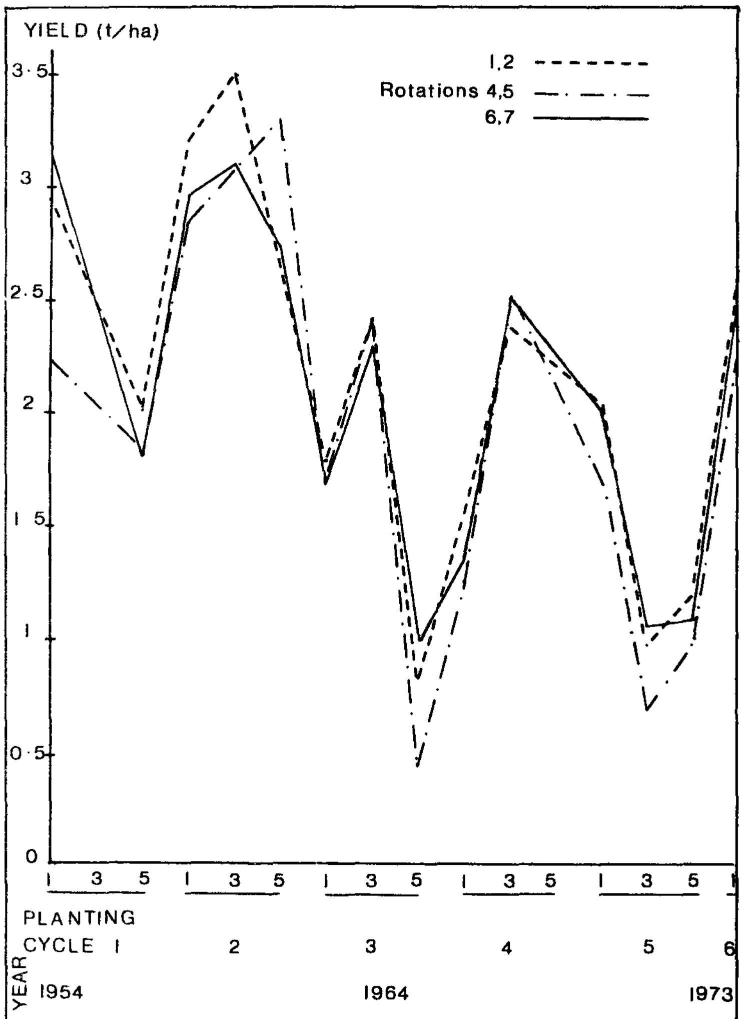

FIGURE 5. PEANUT YIELDS.

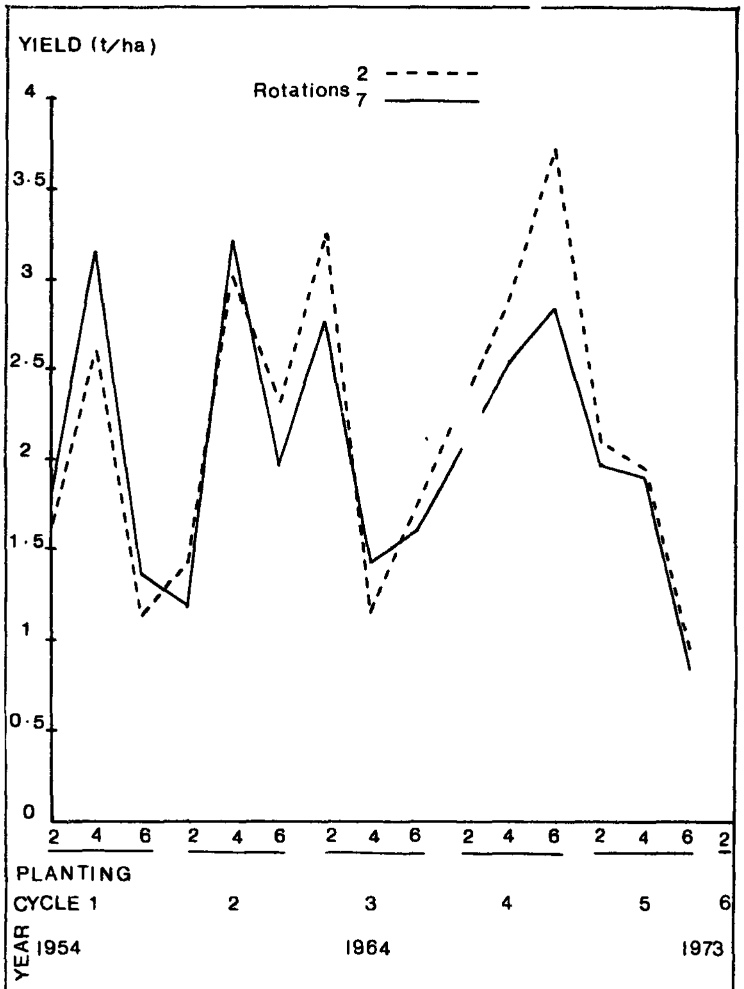

FIGURE 6. SORGHUM YIELDS.

Pests and diseases

Few quantitative assessments of damage have been made, but in some crops very high pest and disease incidence is likely to be the cause of low yields or crop failures. Chemical control has been used to reduce the incidence of the most severe pathogens and insect pests. Hand weeding has been used to control weeds.

DISCUSSIONS AND CONCLUSIONS

Sweet potato and taro yields have declined markedly over 19 years of cropping. The wide rotations were less deleterious than the narrow rotations but total production from the narrow rotations over the trial period has been greater than from the wide rotations because there are twice as many crops in the narrow rotations. The narrow rotation that included a short term green manure crop (rotation 3) was the least bad.

More severe pest and disease problems have been experienced in the trial than are usually encountered with traditional, less intensive farming systems. It can be anticipated that pest and disease problems will be more severe in any intensive farming system than under the traditional bush fallow system.

None of the rotations tried (which have not included fertilizer dressings) has provided a satisfactory alternative to the bush fallow farming system. The use of inorganic fertilizers has now been introduced.

ACKNOWLEDGEMENTS

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TABLE 1

Plan of rotations in one cycle. Series A.

Planting No. (6 plantings = 1 cycle)	Rotation 1*	2*	3†	4†	5†	6*	7*
1	SP	SP	SP	SP	SP	SP	SP
2	To	So	To	To	To	To	So
3	P	P	CP	P	P	P	P
4	M	M	SP	SP	SP	Pu	Pu
5	M	M	To	To	To	Pu	Pu
6	M	M	CP	P	P	Pu	Pu

SP Sweet potato (*Ipomoea batatas*)
To Taro (*Colocasia esculenta*)
P Peanuts (*Arachis hypogaea*)
CP Cowpeas (*Vigna sinensis*) or *Vigna calcarata* or *Indigofera calcaratus*
M *Mimosa invisa* (as green
So *Sorghum vulgare* manure)
Pu *Pueraria phaseoloides* (as green manure)
* Wide rotation
† Narrow rotation

TABLE 2

Percentage of sweet potato tubers which were marketable (larger than 10 cm x 5 cm)

Rotation	3rd planting 5th cycle		5th planting 5th cycle		1st planting 6th cycle	
	Marketable	Non Marketable	Marketable	Non Marketable	Marketable	Non Marketable
1,2	66	34	39	61	30	70
3	48	52	49	51	12	88
4,5	50	50	41	59	18	82
6,7	72	28	43	57	28	72

TABLE 3

Sweet potato. Top growth vigour assessment. Maximum score 30.

Rotations	1st planting, 3rd cycle 20 weeks after planting	3rd planting, 5th cycle 8 weeks after planting
1,2	18.5	23.5
3	3.5	15.0
4,5	5.0	13.0
6,7	16.5	23.0

TABLE 4

Percentage of taro corms which were marketable

Rotations	4th planting, 5th cycle		2nd planting, 6th cycle	
	Marketable	Non Marketable	Marketable	Non Marketable
1	59	41	81	19
3	40	60	70	30
4,5	45	55	61	39
6	71	29	76	24
Critical limit	8.5 x 6 cm.		7 x 5.5 cm.	

TABLE 5

Summary of chemical analysis of soil

Rotations	Sampling	pH	Spec. Cond. mhos x108	Olsen P ppm.	Exchangeable cations m.e.% Ca	Mg	K	Na	Total exch. cap. m.e.%	Carbon %	N %	K/N ratio
1,2 (Wide)	1st(Jan.54)	6.6	.122	4	18.3	2.4	1.24	-	2.5	6.0	.653	1.90
	8th(Oct.61)	6.2	.135	8	16.1	1.9	0.75	-	23.4	6.0	.551	1.36
	9th(Dec.64)	6.1	-	-	12.0	1.5	0.85	0.6	16.7	-	-	-
	10th(Aug.70)	5.5	.045	7.6	9.0	0.6	0.4	0.1	14.0	3.3	.33	1.21
3,4,5 (Narrow)	1st(Jan.54)	6.3	.109	3	15.4	2.5	1.2	-	24.3	6.2	.579	2.06
	8th(Oct.61)	6.2	.123	7	15.3	1.9	0.6	-	21.5	5.3	.486	1.26
	9th(Dec.64)	6.1	-	-	10.0	1.2	0.7	0.5	14.7	-	-	-
	10th(Aug.70)	5.6	.028	7.8	8.1	0.5	0.2	0.2	11.4	2.5	.280	0.75
6,7 (Wide)	1st(Jan.54)	6.6	.128	5	21.3	2.8	1.41	-	27.0	5.9	.591	2.39
	8th(Oct.61)	6.2	.133	7	15.4	2.0	0.75	-	24.3	5.6	.519	1.45
	9th(Dec.64)	6.1	-	-	10.0	1.4	0.81	0.5	15.9	-	-	-
	10th(Aug.70)	5.5	.037	7.7	9.3	0.7	0.41	0.2	12.8	3.0	.340	1.21