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EFFECTS OF DIFFERENT CASSAVA CROPPING PATTERNS ON SOIL FERTILITY, CROP YIELDS AND FARM INCOME

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SUMMARY

A cassava cropping systems trial was conducted in Caicedonia, Colombia, on a degraded Andosol with a history of five previous cassava crops. Starting 1980, cassava cv. Chiroza was grown either in monoculture or in rotation with *Crotalaria juncea* (as green manure), maize, dry, beans and grain sorghum. Cropping systems such as OM and CEC were improved by rotation. Most notably, legumes increased P availability but chemical fertilizer had little detectable influence. Cassava root yields, after declining to 15 t/ha during the five consecutive farmer-grown crops, were raised in the first experimental monoculture crop through improved agronomic practices to about 25 t/ha but declined to about 10 t/ha in the fourth experimental monoculture crop. By contrast, in the rotational system, yields were increased to over 35 and 25 t/ha in the second and fourth cycle, respectively. Besides root yield, root and shape were seriously affected under continued cassava cultivation. Results show that chemical fertilizer alone may not be sufficient to maintain high cassava root yield and quality and that rotation with green manure plants, cereals and legumes may be required to activate soil life and reduce phytosanitary problems.

RESUME

Un essai de systèmes de culture du manioc a été conduit à Caicedonia, Colombie, sur un andosol dégradé ayant déjà supporté cinq cultures de manioc. A partir de 1980, le manioc c.v. Chiroza a été conduit soit en monoculture, soit en rotation avec Crotalaria juncea (comme engrais vert), maïs, haricot à grains et sorgho à grains. Les systèmes de culture ont été subdivisés en traitements fertilisés ou non. Les paramètres du sol "matière organique" et "CEC" ont été améliorés par la rotation.

L'effet le plus notable est l'augmentation de la disponibilité du P par les légumineuses, alors que celui de la fertilisation minérale est à peine détectable. Descendus à 15 t/ha au long des cinq cultures consécutives en milieu paysan, les rendements en tubercules de manioc sont remontés en monoculture expérimentale à 25 t/ha en premier cycle (avec les itinéraires techniques utilisés) pour redescendre à 19 t/ha au quatrième. Au contraire les rotations ont permis d'obtenir 35 t/ha en deuxième cycle de manioc, et encore 25 t/ha au quatrième. Au delà des rendements, la taille et la forme des tubercules ont été sérieusement affectés en monoculture continue. Les résultats montrent que la fertilisation minérale ne suffit pas à maintenir un rendement et une qualité élevés des tubercules de manioc, et que la rotation avec des engrais verts, des céréales, ou des légumineuses est impérative pour activer la vie microbienne du sol et réduire les problêmes phytosanitaires.

INTRODUCTION

There are numerous examples of successful monoculture systems in temperate zones where powerful inputs in combination with mechanization can control the agricultural environment, which by nature is stable and well buffered (v. BOGUSLAWSKI et al 1976, DEBRUCK 1972, POMMER et al 1979). However, in the less stable ecosystems of the tropics, the switch from a traditional to an input-dependent production system with its impoverishment in crop diversity has often lead to soil degradation and accumulation of phytosanitary problems posing serious hazards to yield stability (LOMBIN 1981, McINTOSH and SURYATNA EFFENDI 1979, NICKEL 1973). If the question of how to hydroxide (Kocide 101) at a rate of 770 g a.i./ha. No insecticides and fungicides were applied to the sorghum. All crops were handharvested and maize and beans were handthreshed whereas sorghum was combine-threshed.

Soil samples were taken every time a new crop was planted and analyzed at CIAT. Methods of analysis were : the Walkley-Black method for organic matter : the glass electrode potentiometer method with a 1:1 soil:water mixture for soil pH; the Bray II method for P and K ; and KCl extraction for the cations Al, Ca, Mg, and Na. Zink and Cu were determined by the HCl-H2SO4 extractant of North Carolina and B by hot water extraction. Soil and root samples for mycorrhizal analysis were also taken at the age of 1, 5 and 11 months of cassava in 1983-84.

Results

1. Cassava yields over a nine-year period

Cassava fresh root yield was only recorded with experimental precision during the four crop cycles starting in 1980. However, due to the farmer's record keeping on the number of truck loads of cassava obtained from his field during the five previous crop cycles and the known surface area of the field which was constant over the whole period, we were able to estimate the yields of these crops with a certain degree of accuracy and thus showthe yield trend over a nine year period (Fig. 1). Total fresh root yields started at the high level typical for the potential of the variety and the beneficial climatic and soil conditions of the region, but nine years of continuous cultivation without fertilization were enough to depress yield to about one third of what it had been when the first cassava crop was produced on this plot.

2. The effect of rotation and fertilization on cassava yields

Whilst the farmers cassava yields had dropped to about 65% of the initial level during five consecutive years of cultivation and this trend continued in the experimental monoculture crops to reach 31 per cent of the original yield in the ninth harvest (MO treatment), only one single rotational cycle with green manure in the first semester and a maize crop in the second semester was sufficient to bring cassava yields back to the original level (RO treatment). In the fourth experimental cycle (1984), the large superiority of the R treatments over the M treatments was maintained although the yield level was generally lower than in the second cycle (Fig. 2). There was no significant yield difference between the unfertilized and the fertilized cassava but productivity of the fertilized crop was always slightly lower than that of the unfertilized crop.

3. Effect of cropping patterns on soil parameters

Over time, the K, Zn and B levels were increased in the fertilized treatments whereas the other parameters remained unaffected by fertilization.
On the other hand, Fig 3 shows that there was a gradual built up of organic matter in the rotation plots which did not occur in monoculture. Under continuous cassava cultivation without fertilization, organic matter stayed at about 3.0 per cent throughout the sampling period whereas in the corresponding treatment under rotation this parameter was increased over time to reach almost 4.5 per cent. The application of fertilizer did increase organic matter in the monoculture whilst it did not in the rotation.

Mainly as a function of organic matter, the cationic exchange capacity (CEC) was also influenced by cropping pattern and fertilization. In the rotation without fertilization, the CEC reached and maintained the highest level of close to 14 meq/100g. The rotation with fertilization showed a somewhat lower level with declining tendency whereas CEC in the monoculture treatments increased slightly over time

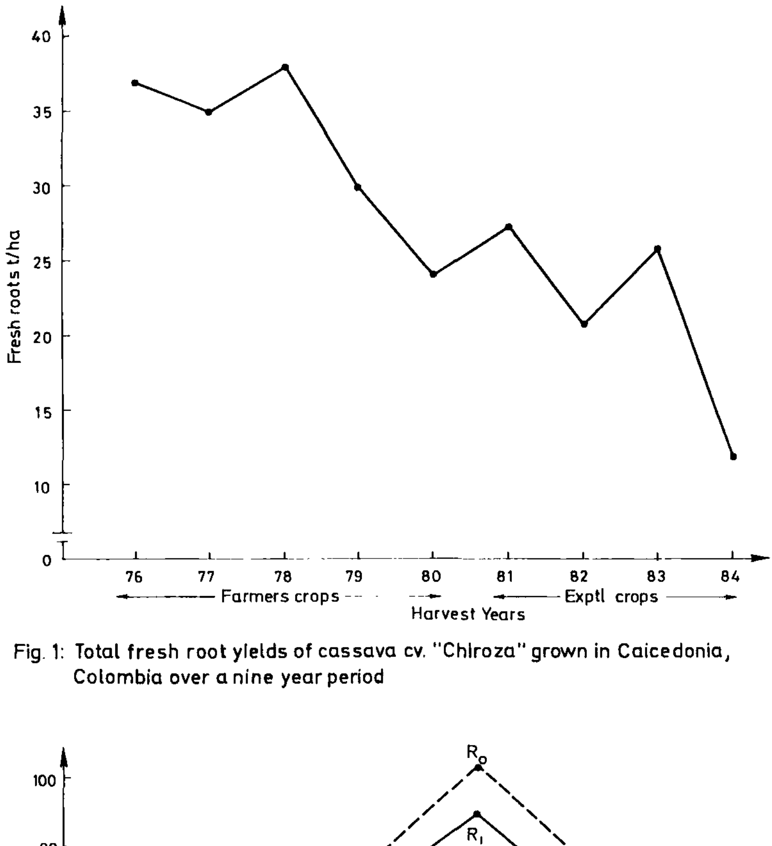

Fig. 1: Total fresh root yields of cassava cv. "Chiroza" grown in Caicedonia, Colombia over a nine year period

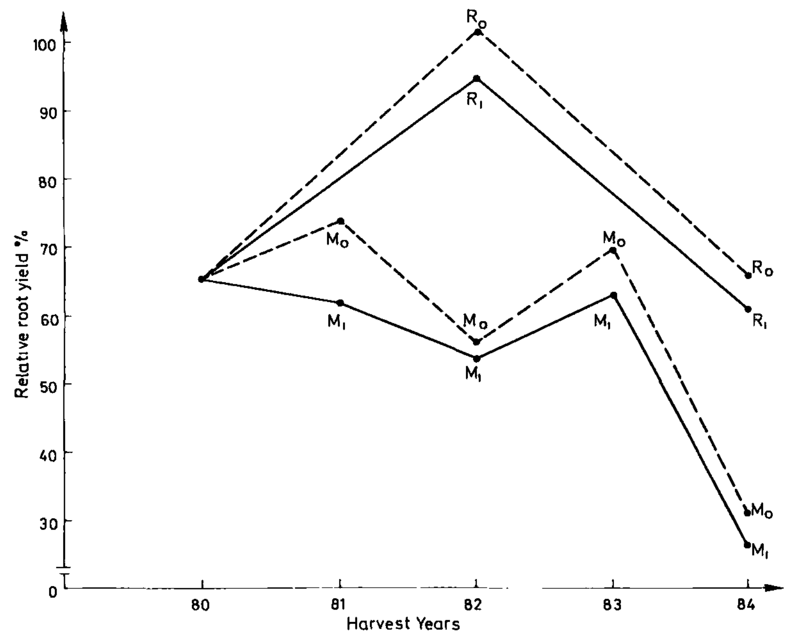

Fig. 2: Cassava total fresh root yield in one farmers and four experimental crops with the yield of the first farmers crop (1976) equal to 100 per cent.

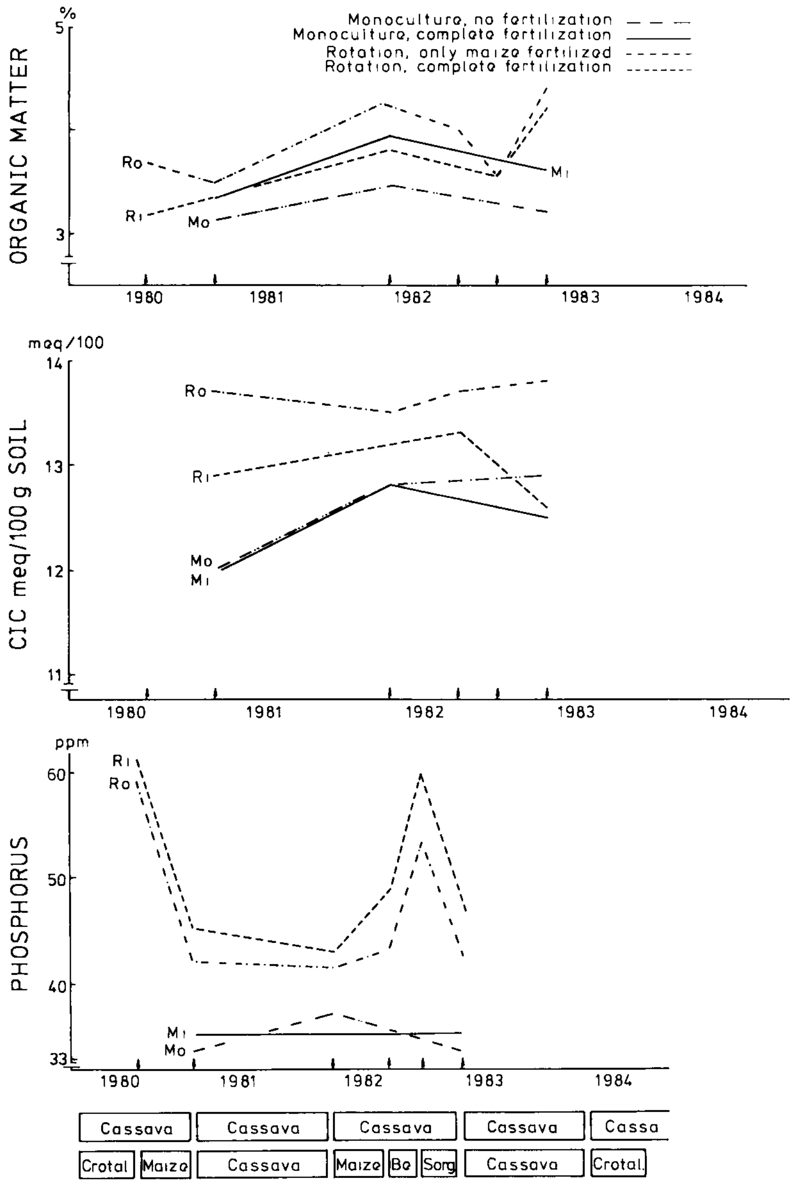

Fig. 3: Trends in soil organic matter; cationic exchange capacity and phosphorus in a monoculture and rotation cropping system with and without fertilization. Caicedonia, Colombia, 1984.

from 12 to about 12.5 meq/100g with little difference between the fertilized and unfertilized treatments.

The most marked changes were recorded with regard to P in this trial. In the rotational pattern the P level was always clearly superior to that obtained under monoculture. P levels in the fertilized rotation were permanently above those of the unfertilized rotation. Whenever a legume was grown in the rotational cycle (Crotalaria in 1980 and field beans in 1982), this boosted P availability substantially, something not observed in the monoculture system (Figure 3).

4. Additional effects of cropping patterns

a) Root quality

When the second cassava cycle was harvested, cassava grown in rotation showed a small advantage over that grown in monoculture in terms of root size and shape, with 93 per cent of roots being classified as "commercial" in rotation compared to 90 per cent in monoculture (weight basis, average of fertilized and unfertilized treatments). This difference was more accentuated in the fourth crop with 82 per cent of roots being classified as commercial in rotation against only 66 per cent in monoculture. In addition, roots from the fourth cycle showed a noticeable difference in starch concentration, reaching 35 per cent in rotation as opposed to 31 per cent in monoculture. On the other hand, there was never a severe root rot problem with a maximum rot percentage of 2.9 in the second and 1.2 in the fourth cycle.

b) Insect dammage and weeds

There were several light and one heavy attack of the cassava hornworm during the four experimental crop cycles, the latter ocurring when the fourth cycle was about half completed (age of cassava six months). On that occasion, the hornworm selectively caused in almost 100 per cent defoliation in the monoculture plots whereas plants in the rotation plots were not seriously damaged with an estimated 10-20 per cent defoliation by the time the insecticide application was made.

There was also a more serious weed problem in the cassava monoculture plots as compared to the rotation plots. This was particularly noticeable towards the end of the cassava growth cycles when solid weed covers had formed under monoculture cassava whereas little weeds were found under the intense shade of cassava grown in rotation. In the monoculture plots, the weed population shifted from a mixed broad leaf-grass composition to a population consisting mainly of grasses, and from annual to perennial species, the predominant weed being Bermuda grass (Cynodon dactylon).

c) Mycorrhizae

There seemed to be a positive influence of crop rotation on mycorrhizal sporulation as spore counts during the fourth crop cycle would indicate. There were 20, 31 and 36 per cent more spores in soil samples taken at 1, 5 and 11 months after cassava planting from the rotation plots than from the monoculture plots. On the other hand, samples from fertilized treatments had lower spore counts than those from unfertilized plots during the greater part of the growth cycle (SIEVERDING, personal communication).

5. Economic appraisal

The complete set of data to analyze these two types of systems were not available, since the rotational trial was carried out for only one four-year cycle and no data existed on the average length and effectiveness of the pasture fallow. The economic analysis will thus shift focus somewhat and evaluate the economic costs or incentives for utilizing rotational systems to recuperate the productivity of a degrading cassava monocropping system. In this respect the different systems can be compared over the four year period of the trial. To make the systems comparable principally on the basis of yield differences no price changes are introduced. Both output and input prices are held constant at their 1981 levels, when the farmer would make decision on which system to choose. Prices, production costs, and net income for the four different systems are presented in Table 1.

The income streams between the rotation and monoculture systems are very different, with the advantage of the rotation being realized by the significantly higher cassava yields every other year. To make these different income streams comparable, the annual net incomes are discounted through time under the assumption that the farmer has a four-year planning horizon. The net present value of the income stream in 1981 is then calculated (Table 1). Two discount rates are utilized. The 7 per cent rate is the real rate of interest that farmers in the region must pay for capital from credit institutions. The 11 per cent rate reflects the real cost of capital without subsidies.

Table 1 CUMULATIVE ECONOMIC APPRAISAL AND NET PRESENT VALUE OF FOUR YEAR INCOME STREAMS FOR DIFFERENT CROPPING SYSTEMS

YEAR	COMMODITY	YIELD TOTAL	KG/HA COMMERCIAL	NET INCOME US$/HA	NET PRESENT VALUE FOR DISCOUNTRATE AT 7%	AT 11%
			CASSAVA MONOCULTURE, NO FERTILISATION			
1980-81)	Cassava	27 500	25 900	2 675)		
1981-82)		20 900	19 340	1 691)	4 073	3 811
1982-83)		25 950	23 190	2 268)		
1983-84)		11 580	7 490	- 87)		
			ROTATION, FERTILISATION MAIZE ONLY			
1980	Crotalaria	-	-	- 100)		
1980-81	Maize	2 865	2 865	148)		
1981-82	Cassava	37 800	35 315	4 087)	4 692	4 265
1982	Maize	3 670	3 670	389)		
1982	Beans	1 395	1 395	149)		
1982-1983	Sorghum	3 591	3 591	240)		
1983-84	Cassava	24 270	20 120	1 808)		
			Cassava MONOCULTURE, COMPLETE FERTILISATION			
1980-81)	Cassava	22 910	20 950	1 813)		
1981-82)		20 100	17 750	1 334)	5 762	5 383
1982-83)		23 300	20 590	1 759)		
1983-84)		9 790	6 670	- 330)		
			ROTATION, COMPLETE FERTILISATION			
1980	Crotalaria	-	-	- 100)		
1980-81	Maize	2 673	2 673	- 29)	5 629	5 120
1981-82	Cassava	35 100	32 800	3 590)		
1982	Maize	3 442	3 442	202)		
1982	Beans	1 745	1 745	380		
1982-83	Sorghum	3 402	3 402	154)		
1983-84	Cassava	22 480	18 270	1 411)		

Discussion

An interpretation of the above results will first of all have to aim at answering the following two questions :

(1) What caused the yield decline in the cassava monoculture treatments and (2) what prevented this decline in the rotation ? A likely answer to (1) would be that after nine years of continuous cassava cultivation without fertilization, soil nutrients should be depleted to a degree that the observed yield decline would be a consequence of deficient plant nutrition. McINTOSH and SURYATNA EFFENDI (1979) have given examples for general nutrient exhaustion after continuous cassava growing in Indonesia and CHAN (1980) associated yield decline after continuous cassava cultivation in Malaysia with K exhaustion of the soil since this element was removed with the roots in the largest quantities. However, had this been the case, in the present trials, the complete fertilization provided to cassava in the fertilized monoculture treatment should have corrected the deficiences resulting in a positive yield response to fertilization which was actually not observed.

The originally very fertile soil and the fact that even after nine cassava crops without fertilization, important soil parameters shown in Table 1 and Figure 3 were not below the critical level for cassava may be a possible explanation for the lack of fertilizer response. However, if soil nutrients per se were not deficient, plants may not have been able to make use of them due to an overall reduced biological activity of the soil. First indications for a less active soil life under monoculture cassava are derived from the fact that organic matter in the soil remained stagnant, with declining tendency, in the continuous cassava system whereas it increased by an average of 1.5% after four years of rotation cropping. More organic matter may also have meant a greater cationic exchange capacity which was actually found under rotation. Legumes in the rotation formed an effective symbioses with soil microorganismes judging both from their profuse nodulation (no qualitative data recorded) and from their pronounced positive influence on P availability which was not observed in the monoculture plots. Finally, direct observations of mycorrhiza which may reflect soil life in general, showed greater sporulation in the rotation system, suggesting that the soil in that treatment was biologically more active than under continuous cassava cultivation. Thus, the multiple, more active components of soil life may in fact be responsable for preventing a cassava yield decline in the rotation, leading us to a partial answer to question (2). Based on the limited data available we are inclined to believe that the soil under monoculture was not chemically but biologically exhausted and that rather than fertilization, practices such as the incorporation of green manure and the use of legumes and graminaceous crops following the root crop cassava were able to counteract this trend.

A second answer to question (1), frequently applicable to tropical production systems, is that an either gradual or spectacular build-up of phytosanitary problems caused yields to decline (LOZANO et al, 1980, OLIVEROS et al 1974, PIMENTEL 1961). Whilst there was no single spectacular disease, insect or weed problem responsable for the declining of cassava yields in monoculture, it is almost certain that several small, individually unquantified and partly interrelated factors added up to a substantial effect. The somewhat weaker monoculture cassava appeared to have suffered more from hornworm attacks than the vigorous rotation crops. More defoliation was connected with a more serious weed problem in monoculture which allowed a particularly hard to control weed population to build up whereas the frequent tillage in rotation combined with a more varied chemical weed control kept weeds well below yield reducing levels. A second answer to question (2) is thus a very simple and universally known one : greater diversity in the rotation system prevented individually small but in their combined action important phytosanitary problems from developping, the rotation system was better buffered against these influences than the monoculture.

Several conclusions follow from the economic results. First, on the fertile soils in this region there is a net loss of income if fertilizer is applied. Second, evaluated in the limited context of this four year framework, there is still a slight economic advantage to planting the monoculture system, with the difference narrowing with lower interest rates. However, the income difference of 2 to 5 per cent is minimal, indicating that there is little economic loss in planting the rotation and significant longer-term benefits that are not captured in this analysis. Third, the relative price of cassava to the cereal grains (0,5 to 0,6) is very high in this zone and dominates the profitability of the system. Where cassava and grains compete in the same markets, a more normal range is on the order of 0,25 to 0,33. At such relative prices the rotational system would dominate. In general, a rotational system appears to be an economically viable method for recuperating a degrading cassava monoculture or fallow system.

Aknowledgement

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