EXTRACTABLE COPPER CONTENT OF SOILS UNDER PEASANT COCOA FARMS IN IBADAN REGION, NIGERIA[1] /

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Resumen

Con el uso intensivo de fungicidas con base en cobre, desde 1960 el contenido de Cu extractable en los suelos dedicados a plantaciones de cacao, en la región de Ibadán, Nigeria, se ha incrementado y es significativamente mayor que en suelos de bosques secundarios en la misma región. El contenido de Cu en el extracto superior de los suelos de plantaciones de cacao se mostró entre 0.4 a 12.2, con un promedio general de 2.68 ppm en las 60 muestras analizadas. El promedio de Cu en el estrato superior del suelo del bosque secundario es de solamente 1.37 ppm. El aumento en los niveles de Cu en los cacaotales es más significativo en los primeros 15 cm del suelo que a mayores profundidades, en donde muchos suelos sólo presentan trazas de Cu.

El contenido de Cu en el suelo se correlaciona positivamente con el Ca^{++} intercambiable, con el CCI y con el contenido de cieno y arcilla, mientras que está negativamente correlacionado con el contenido de arena. El contenido actual de Cu en el suelo no parece ser tóxico para los cacaoteros, probablemente debido al moderado contenido de materia orgánica y estado nutricional del suelo y a su reacción neutra o ligeramente ácida.

Introduction

The accumulation of copper in soils has been investigated in the large coffee plantations of East Africa which are regularly sprayed with copper fungicides (1, 2).

But there are no comparable documented studies on the copper content of soils under peasant tree crop plantations, especially, cocoa. In Nigeria, for example, studies have focused rather on the effectiveness of various fungicidal copper compounds on the cocoa disease, *Phytophthora palmivora* (4) and on the fertilizer response (8, 9) and micronutrient nutrition of cocoa trees.

The widespread use of copper fungicides dates back to about 1960 when the government of Western Nigeria established a subsidy scheme to encourage farmers to apply the chemicals. Bordeaux mixture (copper sulphate) is the standard fungicide recommended to the farmers although Perenox (cuprous oxide) is used also and has been found to be equally effective (4).

This study examines the EDTA extractable-Cu content of soils under peasant cocoa farms in south-east Ibadan region, which used to be the core of the cocoa belt of central western Nigeria (3).

Study area

This study was conducted in Akanran area, south-east of Ibadan city. It lies within the oldest cocoa growing part of Ibadan region where most of the soils have been under cocoa for up to eighty years. The area, which lies between the river Osun and its tributary river Oni, is underlain mainly by schists and migmatised biotite and biotite-hornblende gneiss. The soils mainly Orthic and Chromic Luvisols belong to the Egbeda, Association, that is, "fine-textured brown-brownish red, fairly clayey to clayey soils, overlying red, brown, yellow and white mottled clay to depths in excess of 5 m" (7). However, there are steep valleysides and footslopes where coarse-textured soils (Chromic and Ferric Luvisols, and some Plinthic Luvisols) of the Iwo Association occur.

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The area receives over 1 270 m rainfall annually and has 240-250 rain days in the year. The mean annual temperature is about 27°C. The natural "dry" tropical forest has virtually disappeared and is now replaced by a mosaic of tree crop plantations and patches of forest fallows on the more sandy soils.

Materials and methods

Many cocoa farms in Akanran area now are largely dominated by kolanut trees. Such farms were excluded from this study. Fifteen suitable peasant farms which are still largely composed of cocoa trees were sampled; 60 sampling points were selected. The soils were sampled, with the aid of a core sampler, at two depths: 0-15 cm, and 15-30 cm. Besides, 10 sampling points were located in a secondary forest in the same vicinity for comparative purposes. Unfortunately, this forest patch is located on a valleyside where the soils are significantly more sandy than on the broad interfluves on which most of the cocoa farms are sited. The field evidence also suggests that the forestland had once been planted with cocoa and then converted to arable farmland before being left to revert to forest.

In addition to EDTA extractable-Cu (using dilute 0.1N HCl as extracting agent), the soil samples were analysed for particle-size distribution (by the hydrometer method), pH (soil: water ratio of 1:2), organic carbon (Walkley-Black method), total nitrogen (micro-Kjeldal method), exchangeable calcium and magnesium (by atomic absorption spectrophotometry using ammonium acetate leachate), potassium by flame photometry and cation-exchange capacity by the summation method.

The mean and coefficient of variation of the data on each soil parameter have been calculated as well as the correlation between copper content and the other soil properties. The Student's t-test has been used to compare the mean copper contents of the soils under cocoa and under forest regrowth vegetation.

Results

Table 1 summarises the laboratory data on the soils giving the range of values, the group mean and the coefficient of variation for each soil parameter. The extractable-Cu contents of the cocoa topsoils range from 0.4 to 12.2 ppm; but most are in the range 1.0 to 5.4 ppm and the group mean is only 2.68 ppm which, nevertheless, is significantly higher than the mean of 1.37 ppm for the top layer of the forest soils (t-test at 5% confidence limit). The concentration of copper in the subsoils (15-30 cm) under cocoa are significantly less than in the topsoils; 25 per cent of the samples only show traces of copper while about half have copper levels below 1.5 ppm. The subsoil mean is 1.01 ppm which is not significantly higher than the mean value of 0.90 ppm for the forest subsoils.

Table 2 shows the results of the simple Pearson product moment correlation analysis, between copper content and every one of the other soil properties analysed. For the cocoa topsoils, copper content has significant positive correlations with exchangeable calcium, cation-exchange capacity and the silt and clay contents. By contrast, it is significantly negatively correlated with sand content. In the subsoil, copper has significant positive correlations only with silt and clay contents; it is also negatively correlated with sand content.

As for the forest soils, the only noteworthy relationship is the negative correlation between copper content and base saturation in the topsoil.

Discussion

The copper contents of the cocoa soils under study are fairly low compared with those of soils under coffee in East Africa which are regularly sprayed with copper fungicides. For instance, Aduayi (1) obtained topsoil copper levels ranging from 3 to 11 ppm with a mean of 7 ppm. Similarly, in the subsoil he obtained copper levels ranging from 1 to 9 pmm with a mean of 4 ppm. The irregular and variable use of fungicides by peasant cocoa farmers may account for the comparatively low levels and wide variations (as judged by the CV values) in the extractable-Cu content of the cocoa soils. A questionnaire interview of the cocoa farmers revealed that the rate of application of fungicides annually by individual farmers varied from about 3 litres/ha to 67 litres/ha, although most farmers fell in the range of 3-22 litres /ha. Most farmers apply the fungicides three times in a year; but a few can only afford a single application while some claim to apply the chemicals four to six times in a year.

There is no evidence that the copper levels such as have been analysed for these soils are toxic to the cocoa trees. Similarly, Aduayi (1) did not find any symptoms of copper toxicity on the coffee plantations despite the high copper levels of the soils. He suggested that it was probable that the normal growth of the trees and the absence of copper toxicity could be due to the large amounts of fertilizers regularly applied on the plantations. The same factor cannot be used to explain the situation in Akanran area; only a few farmers claimed to have applied chemical

Table 1. Summary of comparative laboratory data on the soils under cocoa and under secondary forest.

Property	Soil Depth	COCOA			SECONDARY FOREST		
		Range	$\overline{X}$	CV	Range	$\overline{X}$	CV
Extractable	T	0.4 – 12.2	2.68	75.4	0.3 – 4.6	1.37	89.8
Cu (ppm)	S	Tr – 4.1	1.01	109.1	Tr – 1.7	0.90	241.2
pH (in H_2O)	T	5.8 – 6.8	6.42	3.1	6.0 – 6.6	6.37	2.5
	S	6.1 – 7.5	6.66	6.1	5.8 – 7.1	6.37	5.7
Organic C (%)	T	0.69 – 4.03	2.49	26.5	1.04 – 2.79	2.27	25.1
	S	0.23 – 1.90	1.24	29.9	0.78 – 1.75	1.10	22.8
Total N (%)	T	0.03 – 0.36	0.18	44.4	0.03 – 0.4	0.21	61.9
	S	0.06 – 0.23	0.13	23.0	0.09 – 0.19	0.11	27.5
Exchangeable Ca^{++}	T	2.5 – 19.0	7.71	42.9	2.0 – 9.5	4.80	56.5
(me/100 g)	S	1.2 – 13.0	4.37	59.8	0.8 – 10.0	3.42	89.0
Exchangeable Mg^{++}	T	1.15 – 5.63	2.79	34.4	1.25 – 3.04	1.97	27.9
(me/100 g)	S	0.22 – 4.26	1.71	48.0	0.17 – 1.78	0.84	52.7
Exchangeable K^+	T	0.15 – 1.36	0.40	65.0	0.15 – 0.84	0.35	57.1
(me/100 g)	S	0.09 – 0.82	0.26	74.5	0.08 – 0.21	0.14	28.5
CEC (me/100 g)	T	4.35 – 24.11	11.52	35.2	4.07 – 13.22	8.06	39.8
	S	2.62 – 17.08	6.94	46.8	2.00 – 11.79	4.94	67.8
Sand (%)	T	47.2 – 89.2	73.0	11.24	77.8 – 89.2	82.5	4.8
	S	43.2 – 85.2	65.3	14.4	64.2 – 81.2	72.6	7.5
Silt (%)	T	5.4 – 35.4	71.1	31.9	5.4 – 18.0	11.1	34.1
	S	6.8 – 30.0	13.3	32.0	6.0 – 17.6	10.7	33.7
Clay (%)	T	4.4 – 25.4	9.9	48.0	4.2 – 10.0	6.4	32.0
	S	6.8 – 38.8	21.2	35.2	12.8 – 20.8	16.7	17.9

T = 0-15 cm depth

S = 15:30 cm depth

Tr = trace

$\overline{X}$ = mean

CV = coefficient of variation

Table 2. Correlation between Cu and other soil properties.

Type and depth		Investigated parameters										
		pH	Org. C	N	Ca^{++}	Mg^{++}	K^+	CEC	BS	Sand	Silt	Clay
Cocoa	T	−0.20	0.14	−0.22	0.46*	0.23	0.02	0.45*	0.25	−0.64*	0.50*	0.54*
	S	−0.09	0.10	0.18	0.06	−0.09	0.06	0.03	−0.01	−0.37*	0.25*	0.28*
Forest	T	0.33	−0.48	−0.13	−0.08	−0.09	−0.40	−0.01	−0.63*	−0.01	−0.39	−0.01
	S	0.16	−0.08	−0.25	−0.25	0.01	−0.18	−0.21	−0.38	0.14	−0.19	−0.04

T = 0-15 cm depth

S = 15-30 cm depth

* Indicate statistically significant correlations at 95%confidence limit.

fertilizers at one time or the other in the past and only four of them currently apply them fairly regularly. However, it is perhaps reasonable to assume that the low acidity of the soils and their moderate organic matter and exchangeable base contents are acting as buffer against increased levels of copper concentration in the soils. For example, it has been pointed out above that the copper content of the soils is significantly correlated with exchangeable calcium, cation-exchange capacity and the silt and clay contents. The negative though weak, correlation between pH and copper content is worth noting also. Aduayi (2) has shown that copper toxicity is dependent on soil pH. He observed that acid soils (pH 4.5-5.0) receiving Cu concentrations greater than 5 ppm resulted in stunted growth of coffee trees while neutral-to-alkaline soils greatly reduced the stunting effects of high concentrations of Cu added to the soils. Copper is among the micronutrients that become very soluble at low pH so much so that they may become toxic to certain plants.

Jacintho *et al.* (5) observed that organic matter constitutents (e.g. P) tend to absorb and form very stable complexes or chelates with copper added to the soil. This phenomenon is thought to help in reducing copper toxicity in soils having high organic matter levels. Furthermore, it is important to note that soil organic matter contributes substantially to the nutrient capital of tropical soils. The significance of soil organic matter in these cocoa soils is attested to by the correlation analysis (results not shown in Table 2) which indicates significant positive correlations between organic carbon and exchangeable calcium and magnesium and base saturation.

Summary

With the widespread use of copper fungicides since about 1960, the extractable-Cu contents of cocoa soils in Ibadan region, Nigeria, have increased and are significantly higher than those of soils under secondary forest in the same region. The cocoa topsoil copper levels range from 0.4 to 12.2 ppm with an overall mean of 2.68 ppm for all the 60 samples analysed. The mean copper level in the forest topsoils is only 1.37 ppm. The increase in copper levels in the cocoa soils is more significant in the top 15 cm than below where many soils show only traces of copper. The soil copper levels are significantly correlated with exchangeable Ca^{++}, CEC and silt and clay contents whereas they are negatively correlated with sand content. The present soil copper levels do not appear to be toxic to the cocoa trees perhaps because of the moderate organic matter and nutrient status of the soils and their neutral-to-slightly acidic reaction.

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