NIGER AGRIC. J. 34 (2003): 97-102

ASSESSMENT OF COPPER LEVELS IN THE SOIL AND VEGETATION FOLLOWING REPEATED APPLICATION OF BORDEAUX MIXTURE TO A COCOA PLANTATION IN SOUTH EASTERN NIGERIA.

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ABSTRACT

Copper concentration in an old cocoa plantation annually sprayed with bordeaux mixture to control a fungal disease was investigated. A nearby *Gmelina* plantation was used to obtain some background information. Samples of leaf, seed and bark of cocoa and *Gmelina* respectively as well as soil and some economic ground flora species from the two plantations were collected and analyzed for Cu and Fe. The concentration of Cu in the bark leaf, seed, ground flora and soil from Cocoa plantation were significantly higher by 95%, 87%, 72.2% and 53.6% respectively than those of *Gmelina* plantation. The highest concentration of Cu was in the cocoa bark (156.2mg kg-1). Cocoa seed contained 18.5mg kg-1 of Cu. Cocoa and *Gmelina* plantations had similar Fe concentrations only in their soil and ground flora samples. The leaf sample contained the highest concentration of Fe in both Cocoa and *Gmelina* plantations. The use of bordeaux mixture is gradually building up the Cu level in the Cocoa plantation, and urgent control need to be introduced on the use of the fungicide to reduce both the environmental degradation and the health risk posed to the local populace.

INTRODUCTION:

Copper (*Theobroma cocoa* Linn.) is a prominent cash crop of the humid lowland tropics grown predominantly by small-scale farmers in Nigeria. Production of cocoa had grown in recent decades because of farmer's enthusiasm and the anticipated economic returns that are promising. Between 1970 and 1995 the total world area under cocoa increased from 4.1 million ha to 6.57 million ha while the production of the crop doubled from 1.5 million tons to 3.0 million tons (FAO, 1995). The countries in West Africa that produce cocoa are Cameroon, Cote d'Ivoire, Ghana, Nigeria and Togo; and these countries accounted for 65% of the global cocoa output in 1996 (ICCO, 1997). In Nigeria, cocoa is grown on about 0.43 million ha of land (FAO, 1990). The major constraint to cocoa production encountered by farmers are persistent heavy yield loss and operational cost due to cocoa diseases particularly the blackpod disease caused by *Phytophthora palmvora* (Bakala, 1981). In the West African region, yield loss due to the disease could be as high as 80% in some years (Bakala and Kone, 1998). As a result of the scale of infestation farmers repeatedly spray a locally formulated fungicide, bordeaux mixture, on cocoa plantation to control the disease. An average spraying frequency of thrice per annum is common but this varies according to the financial capacity of the grower and the degree of infection of the cocoa plantation in Nigeria.

The proven efficacy of Bordeaux mixture and the frequent severe cases of blackpod infection drive the farmers to rely strongly on the fungicide. This dependency is arousing serious concern particularly on the distribution of its heavy metal component, copper, on the environment. Accumulation of heavy metals such as Cu, Hg, Fe, Zn, Cd etc. beyond the natural background levels result in deterioration of environmental quality (Chen et al, 1999). Higher concentration of Cu above the established tolerance limit elicit toxic effects on the biotic component of the environment. These include precipitation of protein in cells, reduced vitality and growth of plants, inhibition of their decomposition, poor nutrition and impaired reproductivity in mammals (Derome and Nieminen, 1998). Unlike the organic pollutants, Cu accumulation has a long-term toxicity threat due to its resistance to degradation (Purves, 1972). Unfortunately extensive research aimed at understanding the distribution of these heavy metals and possible effects on the environment of the region under study have not been done; also the important regulatory policies to minimize their environmental effects are not yet in place. This work was conducted to ascertain the level of Cu in some segments of the environment of a cocoa plantation following repeated application of bordeaux mixture.

MATERIALS AND METHODS:

Description of the study Area:

The study was conducted at Ibeku, Umuahia North LGA, Abia State Nigeria (5°35'N, 7°10'E) an area of lowland rainforest vegetation. The two major seasons that prevail in the area are dry season (October-February) and rainy season with bimodal pattern (March-September). Short dry and windy periods of harmattan usually occur within the dry season. The mean annual rainfall and mean maximum temperature are 1960mm and 30°C respectively. The site has slightly sloping gradient with clay loam soil that is fairly drained.

A 500 ha cocoa plantation of the "Amazon" variety was established in the area in the early part of 1960's through the assistance of Cocoa Research Institute of Nigeria (CRIN) which has a sub-station in the area (Meregini, 2000). Individuals according to the traditional system own plots in the plantation but all are collectively managed by few merchants who hold the plots on lease. The stand spacing of cocoa in the plantation is 3 m x 3m. As part of the management practice, the cocoa plantation is usually sprayed with bordeaux mixture at least thrice per annum to control blackpod disease mainly during the wet season when infection is high. The growers formulate the fungicide locally by adding a mixture of 150g of slack lime and 125g of copper oxide to 10 liters of water and boil the mixture afterwards.

At the opposite side of the descent of the cocoa plantation is also located a 40 ha *Gmelina aborea* plantation of about 28 years old. The cocoa and *Gmelina arborea* plantations share the same soil and climatic characteristics because of their proximity. However the *G. arborea* was uncontaminated by the fungicidal spray and was used in this study to obtain the natural background values of the study area (Tarras-Wahlberg et al, 2000).

METHOD OF EVALUATION:

The study was conducted as a 2-factor split plot design with 4 replications using the plantations as main plot and the sample materials (bark, leaves, seed, ground flora and soil) as sub-plots. Sample plots of 100m x 50m were demarcated in the cocoa and *Gmelina* plantations with each having 4 plots at a separating distance of 200m between plots. Each plot was further divided into 4 subplots from where sample materials were randomly collected for chemical analysis. The sample materials collected were bark, leaves, seeds, soil and ground flora from the *Gmelina* and Cocoa plantations respectively. Collections for each type of sample from the same plot were bulked together separately. The soil samples were collected from 0 – 15cm soil depth, where copper from anthropogenic sources was mostly concentrated (Ano, 1994). Plant species collected as ground flora samples were species of economic importance often used as livestock forages or for various domestic purpose (Table 1). Composited plant samples were oven-dried at 40°C to constant weight, milled, sieved and later digested.

A wet digestion method was carried out by weighing 1g of the sample into a digestion flask to which 2ml of nitric perchloric acid mixture of ratio 2:1 was added. After 24 hours, digestion was then done at 150°C for one and half hours before adding 1ml HCL acid solution of ratio 1:1 allowing to heat for 30 minutes. Distill water (30ml) was later added to the digest and allowed to cool before sieving with a Whatman No. 42 filter paper. The extracts were analysed for Cu and Fe using the Atomic Absorption Spectrophotometer (Unicam 919 Solar 1995) at the Central Laboratory, University of Uyo, Nigeria. Analysis of Fe in the samples was done to support any inference that could be drawn on Cu since there was no anthropogenic introduction of Fe in either of the plantations through spraying or other means. Data gathered were analyzed using the ANOVA technique and Duncan's multiple range test was used to separate means along columns while least significant difference (LSD) was used to compare those along rows.

Table 1: List of species collected as ground flora samples from cocoa and *Gmelina* plantations.

Ground flora Samples	Uses
Thaumacoccus danielli	Wrapping material, therapeutic uses
Glypheae brevis	Forages
Albizia zygia	Forages
Palisota hirsuta	Wrapping material browse
Mallotus oppositifolus	Wrapping therapeutic

RESULTS:

There were differences in the concentration of the considered elements between and within the plantations. In table 2, the mean total concentration of copper in the cocoa plantation was 79.1% significantly higher than that of *Gmelina* plantation. In all the materials sampled, i.e. bark, leaves, seed, ground flora and soil, the concentration of copper were significantly higher by 95%, 87%, 81%, 72% and 53.6% respectively in cocoa plantation than those of *Gmelina* plantation (Table 2).

The concentration of Fe in the samples varied between the plantations but the differences were significant only for bark, leaf and seed samples. The concentration of Cu in the cocoa plantation was not similar in all the sample materials. The highest concentration of Cu was in the cocoa bark (156.2mg kg^{-1}) followed by that contained in the soil (93mg kg^{-1}). The minimum level of Cu in the cocoa plantation was obtained in the seed sample. The concentration of Cu in the cocoa seeds was 78.8%, 56.7% and 66.4% lower than that contained in the bark, leaves and soil respectively (Table 2). In the *Gmelina* plantation, the concentration of Cu in all the samples were similar ranging from 1:91mg kg-1 in seed to 4.64 mg kg-1 in leaves with the exception of the soil which had 27.8 mg kg-1. The Fe concentration in the *Gmelina* plantation was also highest in the leaves (168mg kg-1) followed by that in the ground flora; and they were significantly higher than Fe concentration in the *Gmelina* seeds and soil (Table 3).

The highest concentration of Fe in the cocoa plantation was from the cocoa leaves (217mg kg-1). Only the seed and bark had similar concentrations that were significantly different from the other.

DISCUSSION:

The concentration of Cu in the cocoa plantation which was remarkably higher than that of nearby *Gmelina* plantation is evidence of on-going accumulation of Cu as a result of the treatment of cocoa plantation with bordeaux mixture. Although the current results recorded were higher, the pattern was similar to the report from virgin forest and an adjacent cocoa plantation treated with Cu-based fungicide in Gambari and Obudu in Nigeria (Ayanlaja, 1983), which considered only soil samples. The aging plantation and the worsening yield losses have made farmers to increase the concentration and the spraying frequency, which could lead to greater accumulation of Cu ion. Cocoa bark contained the highest concentration of Cu than all other sample materials namely: seed, leaves, soil and the ground flora of cocoa. In fact the Cu level in bark was 78.9% higher than that contained in the seed. This situation could be related to the foliar method of application of the fungicide adopted by the farmers, which leaves a substantial quality of CuO on the leaves and bark long after spraying that could easily be absorbed by plant tissues. In a related investigation, Lombi, *et al* (1998) reported that Cu levels were highest in the leaves of sunflower and this was attributed to its fairly high mobility within plants. Following the cocoa bark, in terms of magnitude of Cu concentration, was the soil (92mg kg-1).

The Cu concentration in the soil of cocoa plantation was 53.6% higher than that of *Gmelina* plantation. The level of Cu in the cocoa soil could be attributed to the phenomenal washing down of the Cu-based fungicide soon after spraying by rainwater into the soil where it would be held in complex forms (Ayanlaja, 1983). The Cu complexes formed are retained in the soil through strong sorption processes promoted by some minerals. In addition, heavy litter from the cocoa canopy was observed at the plantation floor and this ~~would have~~ contributed greatly to higher levels of Cu in the soil recorded in this study. The level of Cu in the cocoa plantation was greatly higher than the acceptable limit of copper concentration in farmland soils, which is an indication of serious toxicity (Table 4).

Table 2: The Concentration of copper in the different samples collected from cocoa and *Gmelina* plantations

	Cu levels (mg-kg-1)	
Sample	Cocoa	*Gmelina*
Bark	156.2d	3.88a
Leaves	67.1d	4.64a
Seed	18.5a	1.91a
Soil	92c	27.8b
Ground flora	20.2a	3.36a

Means values in the same column followed by different lettered are significantly different at $P<0.05$.

Table 3 The Concentration of Fe in the different samples collected from cocoa and *Gmelina* plantations

	Fe levels (mg-kg-1)	
Sample	Cocoa	*Gmelina*
Bark	168c	125.1b
Leaves	217d	168d
Seed	182c	102a
Soil	79.5a	82.1a
Ground flora	129b	142b

Means values in the same column followed by different letters are significantly different at $P<0.05$

Table 4: The standard level of Fe and Cu in the soil and food materials for environmental control

Element	Soil	Food materials
Cu [2,3]	35mg kg $^{-1}$ (farmland)	8.7mg kg $^{-1}$
Fe [1]	5.81%	NA

[1]. Ano (1994) [2]. Chen et al, 1999; [3], Ayanlaja, 1992, NA = not available

The concentration of Cu in the soil has implications on the environment by inhibiting the establishment of new cocoa seedlings and other phytotoxic effects (Ayalanja, 1983); depletion of soil microbial biomass with serious influence on the soil fertility through reduced mineralization of plant debris (Alloway and Ayres, 1997; Derome and Nieminen, 1998); and the possibility of it being drained into the neighbouring water bodies where it might produce serious impact on aquatic ecosystem (Terra-Wahlberg, 2000).

Cocoa seeds had lower concentration of Cu than either the leaves or bark of cocoa plant. However the level of Cu in the seed was about twice the accepted standard of Cu level in food items (Table 4). The plant physiological process of partitioning nutrients may have moderated the Cu level in the seed. Although the species are not related, the seeds of *Gmelina* had also the lowest level of Cu when compared to either its leaves or bark. The ground flora samples in the cocoa plantation had 20.2mg kg-1 as Cu concentration while these same species in the *Gmelina* plantation had 3.26mg kg-1. These species had low concentration of Cu regardless of the prevailing high level of Cu in the soil of cocoa plantation as well as possible spray droplets that might reach these species as unintended targets. These species may have avoided Cu related toxicity through inherent physiological processes. Nevertheless there was significantly higher level of Cu in the ground flora collected in the cocoa plantation than those of *Gmelina* plantation. Similarly, a higher level of heavy metals including Cu were reported near a copper ore and copper smelting plant in China (Dai et al, 1993). In fact the authors reported that in some situations in China the level of the metals contained in some sampled vegetables were 3-7 times higher than the Food Health Standard. In the current study the situation poses a threat because these species are used domestically for livestock feeds, for wrapping food items and traditional herbal practices as there are possibilities of Cu building up in the food chain and affecting human health. The degree to which the Cu is available for biological uptake raises strong suspicion as to the safety of the Cu-based fungal spray. Even if the Cu ion may be bound in the soil or sediment, which makes it immediately unavailable for biological uptake, the Cu ions are later gradually released into their absorbable form through biological activities or changes in pH (Tarras-Wahlberg, 2000). Copper is normally only sparingly soluble when pH is high but dissolved ionic concentration of Cu may increase with lowering of soil pH.

Although cocoa production suffers greatly as a result of blackpod disease in south eastern Nigeria, the use of bordeaux mixture to control the disease should be minimized because of the rate of accumulation of Cu in the environment. Rural growers in the area are very reluctant to adopt the option of calling off and replanting aged plantations, which usually borne heavy disease load, with disease-free seedlings because of the maturing period they have to wait for economic returns. However, assistance in terms of compensation need to be provided to these growers for them to adopt this option in order to check the alarming rate of accumulation of this contaminant in the environment.

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