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Relationship between age of cocoa (*Theobroma cacao* L.) trees and soil nutrient contents.

Resumen. La relación entre la edad de los árboles de cacao y las concentraciones de C orgánico, N, P disponible, K cambiable, Ca y Mg en el perfil y superficie de suelos fue estudiada en tres localidades en tres años.

La edad de los árboles de cacao varió de 4 a 37 años. Los valores del C orgánico del suelo, N, K cambiable, Ca y Mg fueron correlacionados positivamente con la edad de los árboles de cacao. El P disponible fue correlacionado negativamente con la edad de los árboles de cacao.

Hubo disminución en los contenidos nutritivos del suelo cuando la edad de los árboles de cacao aumentó a 37 años.

Cocoa, the mayor component of chocolate and many beverages consumed throughout the world, is an important cash crop in tropical countries. An investigation of the relationship between the age of cocoa trees and soil chemistry is expected to contribute to the understanding of the supplementary nutritional needs of the crop.

This relationship has not received sufficient attention, although it has generated controversy. In Ghana, Ahenkorah (1) observed that cocoa cropping deteriorates humus and the cation content of soil, but Wessel (10), in a discussion of cocoa soils of Nigeria, indicated that cocoa did not deteriorate soil chemical properties. Ahenkorah noted and absence of published information from other cocoa growing countries relating soil fertility with cocoa cropping. The present study, performed over three years at three locations in Nigeria, investigates changes in nutrient contents of surface and subsurface soil as a result of differing age of cocoa trees.

Materials and methods

In 1979 five Amelonado cocoa plots which were 34, 25, 22, 18, and 10 years old were selected at Apoje (6°57'N, 4°6'E). A profile pit was dug in each plot for the purpose of collecting soil samples from each specified horizon (Table 1). The soil at Apoje, classified as Psammentric Usthorthent (USDA), is derived from biotite, and the surface soil is composed of 75.0% sand, 8.6% silt and 16.4% clay (4).

In 1981 soil samples were collected at a 15 cm depth at Gambari (6°50'N, 4°33'E) over each of seven cocoa plots that were 4 to 37 years in age (Table 2). Soil samples from each plot were combined. The soil at Gambari has the same origin as the soil at Apoje, but the surface (0 to 15 cm) soil consists of 75.8% sand, 9.1% silt and 15.1% clay.

In 1982 three cocoa plots which were 10, 15 and 19 years old and 3.5, 4 and 5 ha in size respectively were located at Ilesa (6°32'N, 4°54'E). Specified numbers of surface soil samples were collected over each plot (Table 3) as dictated by soil colour variability. The soil at Ilesa, classified as Oxic Paleustalf, is derived from amphibolites and consists of 85.7% sand, 7.0% silt and 7.3% clay.

Each soil sample was air-dried and 2 mm sieved. Organic C was determined by the Walkey-Black method (9) and total N by the Kjeldahl method. Available P was determined by the molybdenum blue method after extraction with Bray and Kurtz solution No. 1.

Exchangeable bases were displaced by 1N ammonium acetate (pH 7.0), K was determined by flame photometry and Ca and Mg by atomic absorption spectrophotometry. The value of pH was determined using a glass electrode placed in 1:1 soil – 1N KCL medium

Results and discussion

Organic C in the 0 to 20 and 20 to 38 cm soil layers increased linearly with increase in age of cocoa trees (Table 1) But the relationship does not hold in the third (38 to 65 cm) horizon Mean organic C content in the soil profile also rose an linearly with the increase in the age of trees, the correlation coefficient being 0.97. At Gambari, organic C in surface soil tended to increase with the age of the tree (Table 2) up to 34 years, but fell to the minimum when the age of the tree increased to 37 years At Ilesa (Table 3), maximum and mean values of soil organic C also increased as the cocoa trees advanced in age from 10 to 19 years

Soil N contents in the first two horizons under 24, 25 and 22 year old cocoa trees (as compared with 18 and 10 year old trees) were greater The mean soil N content in the soil profile was positively correlated with the age of trees ($r = 0.92$) In surface soil at Gambari, mean soil N and the maximum value of soil N increased when the age of cocoa trees advanced from 10 to 19 years

Soil K contents in the first two horizons under 34 and 25 year old cocoa trees (as compared with 22, 20 and 18 year old trees) were greater The correlation between mean values of K in the soil profile and age of cocoa trees was 0.85

Soil Ca contents in the first two horizons under 34, 25 and 22 year old cocoa trees (as compared with 18 and 10 year old trees) were greater In the third horizon, greater amounts of Ca were observed under 34 and 25 year old trees compared with younger trees. The correlation coefficient between mean Ca content in the soil profile and age of cocoa trees was 0.97

At Gambari, exchangeable K and Ca in surface soil were positively correlated with the age of cocoa trees. It is shown that the values of soil K and Ca declined when cocoa trees reached the age of 33 years and rose at the age of 34 years before falling finally at the age of 37 years. The relatively low values observed for 33 year-old trees might be due to error. A similar observation was made at Ilesa, where the greatest

Table 1. Relationship between age of *Theobroma cacao* trees and chemical properties of soil horizons.

Property		Age of cocoa (year)				
	cm	34	25	22	18	10
C (percent)	0–20	4 1	3 2	2 8	2 7	1.2
	20–38	3.2	3 0	1 8	1 4	0.9
	38–65	2 8	1.2	0 9	1 3	0.7
N (percent)	0–20	0 19	0 19	0 14	0.10	0.10
	20–30	0 17	0.11	0 18	0 09	0.10
	38–65	0 08	0.11	0 16	0 08	0.06
P (ppm)	0–20	8.7	9.3	8.3	11 2	10.9
	20–30	2 1	0 6	3.7	3.9	3.6
	38–65	0 6	0 6	0.6	1 8	1.6
K (meq/100 g)	0–20	1 41	0 38	0 04	0 05	0 04
	20–38	0 49	0 19	0.11	0 04	0 04
	38–65	0.10	0 08	0 21	0.18	0.20
Ca (meq/100 g)	0–20	11 1	2 5	8 6	0 8	2 2
	20–38	10.0	1 5	5.4	0 5	1.2
	38–65	6 4	2 3	0.8	0 5	2 2
Mg (meq/100 g)	0–20	0 86	0 68	0 85	0 44	0 36
	20–38	0.59	0 45	0 84	0 44	0 23
	38–65	0 70	0.62	0.21	0 32	0 47

Table 2. Relationship between age of *Theobroma cocoa* trees and soil chemical properties at Gambari.

Age of tree (year)	C (percent)	P (ppm)	K (meq/100 g)	Ca (meq/100 g)	pH
4	1 7	25 7	0.02	1 2	6 1
18	2 0	8 5	0 07	3.2	6 8
22	2 5	11 2	0 11	3.6	7.1
30	3 0	9 3	0 09	7.9	6 9
33	3.0	8 3	0.14	2.8	7 0
34	3.3	4 0	0.21	16 2	7.2
37	1 2	2 4	0 12	2.0	6 8
Correlation with tree age	0 34	−0 91	0 59	0 40	0.77

mean values of soil K and Ca were observed under 15 year old trees compared with 10 and 19 year old trees

Soil Mg contents in the first two horizons under 34, 25 and 22 year old trees (as compared with 18 and 10 year old trees) were greater In the third horizon, soil Mg content was greater under 34 and 25 year old trees. The correlation coefficient between age of trees and mean Mg content in the soil profile was 0 93. At Ilesa, mean Mg content in surface soil increased with the age of trees between 10 and 19 years

The value of soil pH in surface soil rose non-linearly with the age of cocoa trees (Tables 2 and 3) This is consistent with positive correlations observed between age of cocoa trees and concentrations of soil K, Ca and Mg

Available soil P content was smaller under old cocoa trees in all horizons In the first and third horizons, the soil under 18 and 10 year old trees had greater P content than the soil under 34, 25 and 22 year old trees. The second horizon under 34 and 25 year old cocoa trees (as compared with younger trees) had a smaller P content. The correlation coefficient between mean soil P in the profile and age of cocoa trees was − 0.78. In surface soil at Gambari, soil P content was smaller under older cocoa trees

Increases in concentrations of soil organic C, N, exchangeable K, Ca and Mg with the age of cocoa trees from 4 to 34 years are consistent with the fact that the cocoa canopy closes about the fourth year (3) The canopy cover and litter fall increase until cocoa trees reach 30 to 40 years in age (10). The drastic reduction in concentrations of soil organic C, K and Ca when cocoa trees reach the age of 37 years may be due to insufficient canopy shading. Trunk die-back and consequent reduction in shading is a common feature of old cocoa farms of about 40 years in age (2). Increased shading and litter turn-over with advanced age of cocoa trees up to 34 years might increase soil organic C and N contents and reduce base leaching. The fact that K content increased deeper into the soil profile in 10, 18 and 22 year old cocoa plots suggests that K leaching from surface soil occurred in the sandy soil at Apoje (4)

Table 3. Range in values of chemical properties of surface soil in *Theobroma cocoa* plots of different ages at Ilesa.

Age of tree (year)	No. of Samples	C	N	K	Ca	Mg	pH
		percent		meq/100 g		meq/100 g	
19	19	1 4–3.2 (2 4)	0 11–0.32 (0 20)	0 05–0 36 (0.10)	0.08–10 0 (3.2)	0.24–1 42 (0 85)	5 4–8.8 (8 3)
15	19	1 5–3 0 (2 2)	0 12–0 29 (0 19)	0 06–0.95 (0.25)	0 9–10.2 (3.9)	0 17–1 30 (0 69)	5 3–8.4 (6 8)
10	21	0 8–2.5 (1 5)	0 12–0.22 (0.18)	0 05–0.38 (0 10)	0 3–4 0 (0 5)	0 22–1.44 (0 67)	5.2–8.0 (6.6)

Values in parentheses are means

An observed increase in concentrations of soil N, K, Ca and Mg and reduction in soil P with older cocoa trees are consistent with the results of nutritional studies on cocoa. Whereas N fertilizer decreased cocoa yield in Nigeria (5, 6, 7, 8), application of urea to cocoa seedling produced a beneficial effect (11). Responses of mature cocoa to K, Ca and Mg fertilizer were rare (6). Experiments in Ghana (1) and Nigeria (7) showed that P was the macronutrient delimiting the yield of cocoa, although there was only response to P when N was applied.

It is suggested that more emphasis be placed on supplementary nutritional needs of young cocoa plants compared with old plants. This is because soil organic C, N, K, Ca and Mg contents increased with the age of cocoa trees. However efforts should be made to prevent likely deficiencies of P in soil under mature cocoa trees since available soil P decreased as cocoa trees got older.

Summary

The relationships between age of cocoa trees and concentrations of organic C, N, available P, exchangeable K, Ca and Mg in the soil profile and surface soil were studied at three locations during three years. The age of the cocoa trees varied between 4 and 37 years. Values of soil organic C, N, exchangeable K, Ca and Mg were positively correlated with the age of cocoa trees, while available soil P was negatively correlated. There was a decrease in values of soil nutrient contents when the age of cocoa trees increased to 37 years.

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