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A preliminary survey of the fertility status of soils in Ondo State under traditional cultivation

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Abstract

Surface and subsoil samples, as well as maize leaf samples were collected from local fields at about ten kilometers intervals along the major and minor highways across Ondo state in 1977. The samples were subsequently processed and analysed for various components in the laboratory.

The surface 0-15cm soil samples showed a mean of 23;7ppm NO_3 -N, 13.6ppm avail. P, 119.4ppm exch. K, 1168 ppm exch. Ca, 98.2ppm exch. Mg, and Na-EDTA-extractable trace elements in the amount 131.9, 9.0, 319 and 1.3ppm of Fe, Zn, Mn, and Cu respectively. About 93% of the samples had a pH value between 5 and 7, while the soils had a mean O.M content of 1.9% and C.E.C. of 11.4 meq/ 100g soil. About 77% of samples had a base saturation exceeding 50%. The values of these parameters generally decline down the soil profile to the 90cm depth studied.

From the frequency distribution of various amounts of nutrients in the soil and plant tissue samples, it was concluded that N, P and Cu were generally deficient in the soils, while Ca, Mg, Fe, Mn, and Zn appeared adequate for optimum crop growth. However, it was difficult to make a definite statement, one way or the other, about K because of the seemingly contradictory conclusions that could be drawn from evaluating the soil and plant tissue data, which evaluations were based on what are generally believed to be the critical levels of K in soil and maize plant for optimum crop yield. Further studies to determine the internal and external critical nutrient requirements of crops in these soils is considered a priority.

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Further details regarding the fertility of any particular area in the State can be obtained from the Senior author.

Introduction

Like in other countries, the primary objectives of soil fertility research in Nigeria is to increase crop production and, in the process, enable farmers to maximize profits. The realisation of this goal would depend on how reliable fertilizer recommendations are in terms of the expected yield responses. Fertilizer application practice in Ondo State today, like in other states of the Federation, has limited success in yield response probably because the recommendations are based on over-generalized interpretations of a few, grossly inadequate field trials which were conducted mostly outside the state, and probably because a sound basic knowledge about the soils of the state is lacking.

In a paper presented at the agricultural seminar on tropical soil research, Corey and Schulte (1972) concluded that a much more reliable system of fertilizer recommendations could be achieved in Nigeria with a soil testing program than is attainable by the present system of generalized recommendations without soil tests. Experience in Brazil (Corey 1969), has shown that dramatic results were obtained in yield responses and in fermers acceptance of fertilizer use recommendations within a year after establishing a soil testing programme. A similar experience has been related for Kenya (Aduayi and Gatitu, 1973).

The most basic information necessary for the establishment of a soil testing program is : what tests should be included in the soil analysis program. The nutrient elements to be included in a soil testing program can be determined only through a survey of nutrient deficiencies across the area. Adegbola and Corey (1976) carried out a survey of nutrient deficiencies in Western Nigerian soils. Their results pointed to a general deficiency of N and Mg in the soils. The present study was aimed at providing an updated basic information about the fertility status of Ondo State soils.

Ondo State of Nigeria lies within a latitudes 6°N and 8°N. It has tropical humid, hot climate with two seasons: a relatively cool rainy season from end of April to late October, and a hot dry season between November and Mid-April. The rainy season is usually interrupted by a dry spell of about two weeks in August. The average annual rainfall is between 1650 and 1700mm, while the mean temperatures are about 27°C maximum and about 23°C minimum (Alofe 1978); there is no great daily variation in temperature throughout the year. Over ninety five percent (95.) of the state lies within the rain forest zone of Nigeria; a very small portion in the North-east of the state have a derived savannah vegetation.

A major part of the state has soil overlying metamorphic rocks of basement complex which show great variation in grain size and mineral composition, varying from coarse grained pegmatite to fine grained schist, and from acid quartzite to basic rocks consisting largely of amphiboles (Smith and Montgomerry, 1962). The coastal belt of the state consists of sedimentary formations, and the reverine areas in the extreme south.

Previous work of Harpstead (1972) suggested that the soils can be claffied as Oxisols and Alfisols as follows: OXIC TROPULDALF in the crystalline rock areas under rainforest vegetation; TYPIC HAPLORTHOX in the sedimentary areas under forest vegetation; and Haplustalf in the derived savannah area.

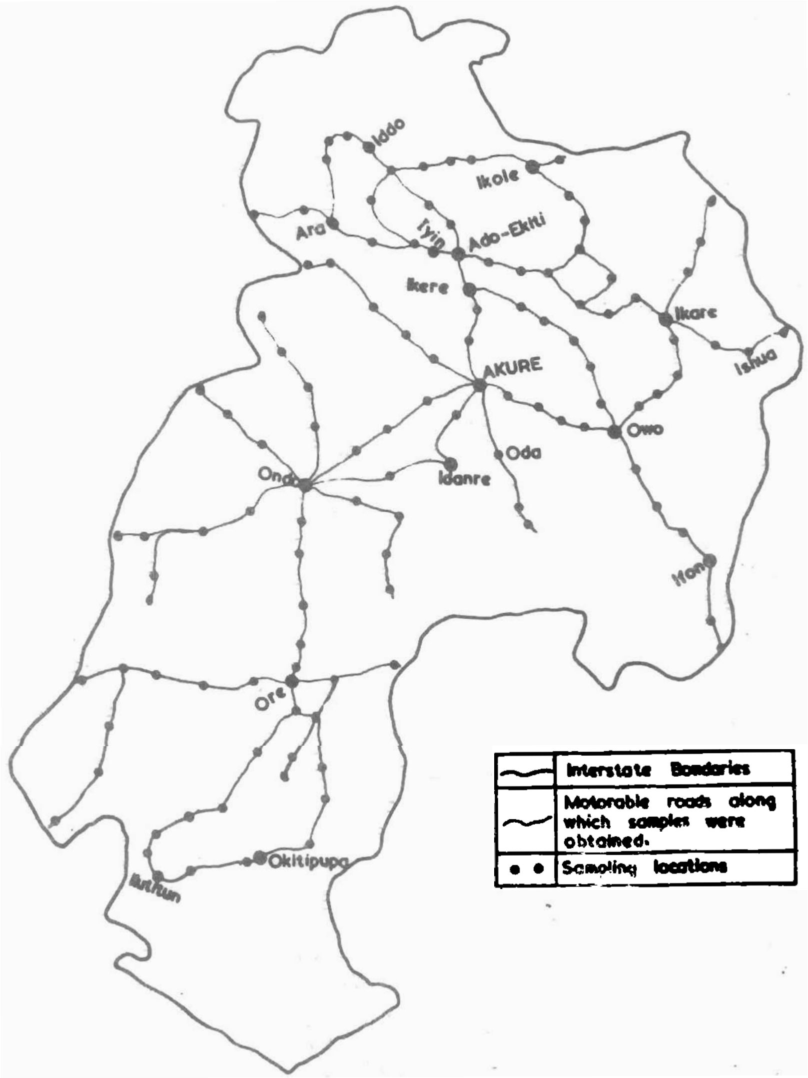
Materials and methods

Soil and maize leaf samples were taken from local fields of maize, at about ten kilometers along major and minor roads across Ondo State (Figure 1A), between June and August, 1977. Small-size maize field plots were selected as sampling sites based on the assumption that farmers in the state generally do not use fertilizers in such plots; discussion with farmers met in some of the sampled plots validated this assumption.

From each field, ten maize plants were randomly selected and two upper mature leaves were taken from each, giving a total of twenty leaves per sample. Soil samples were taken from each field at 0-15,15-30, 30-60 and 60-90cm levels; The soil samples were air-dried, ground and sieved through a 2mm sieve prior to grinding in Wiley mill.

The soil samples were analysed in the laboratory for pH in 0.01M $CaCl_2$ by a Pye Unicam pH-meter; available phosphorus by Bray number 1 extraction and Murphy and Riley colorimetric method (1962); Exchangeable potassium, calcium and magnessium by flame analysis after soil extraction with IN Ammonium acetate, Nitrate-Nitrogen by colorimetry, while available Cu, Mn, Fe and Zn were extracted from soil with EDTA and determined with Perkin Elmer 420 atomic absorption spectro-photometer; Soil organic matter (O.M) was determined by potassium dichromate-sulphuric acid digestion method, particle size by hydrometer and the

Fig 1A. Sampling sites across Ondo State



cation exchange capacity (C.E.C) according to Jackson (1958).

The leaf samples were ignited at 500°C in a muffle furnace for 2 hours, the ash dissolved in 4N HCI, filtered through Whatman No. 42 filter paper and analysed for P, K, Mg, Ca, Fe, Cu, Zn, and Mn.

Results AND Discussion

The proportions at which different soil pH values, Organic matter content and cation exchange capacity (C.E.C.) occur at various soil depths in the soils of Ondo state are presented in figure 1. Table 1 shows the ranges and means of soil analysis for the different depths of the soils.

Soil pH: The pH of the surface soil 0-15cm) varied from 4.4 to 6.8 with a mean of 6.0. About 93% of the top soil throughout the state has a pH value within the range 5 to 7; this probably represents an accumulation of bases in the surface soil (Bates, 1960). Although the pH decreased down the profile, it never got below a mean value of 5 even at 60-90cm depth. It appears therefore that, with proper soil management practices, the present soil reaction is quite ideal for the commonly grown crops of the state.

Soil Organic Matter and C.E.C.: The O.M. content of the surface soil varied from 0.5% at 7 km from Owena on Ilesha/Ondo road to 4.3% at 3 km from Ondo on Akure/Ondo road. About 44% of the samples contained over 2% O.M and about 13% contained less than 1%. The mean levels of O.M declined down the soil profile as 1.9, 1.15, 1.2 and 0.5% at 0-15, 15-30, 30-60 and 60-90cm respectively. The contents of O.M. observed in these soils are generally lower than values previously reported for South Western Nigerian soils by Agboola and Corey (1976); this could be attributed to the fact that the length of fallow period of Southern Nigeria today is generally much shorter than it was ten years ago (1968) when Agboola and Corey carried out their studies. Adepetu and Corey (1976) had reported a 37% drop in the O.M content of soils of Southern Nigeria within about 20 weeks of cropping in the greenhouse. Also, Adepetu *et al* (1978) reported a 58% drop over seven years of continuously cultivating an Iwo soil under field conditions.

The C.E.C of the surface soil had a mean of 11.4 meq:100g soil which, though low, is not usual for highly weathered tropical soil with relatively low content of O.M.

The frequencies in which different concentration

Fig. Frequency distribution of various ranges of pH, O.M; C.E.C, and Base-saturation at different depths of Ondo State soils.

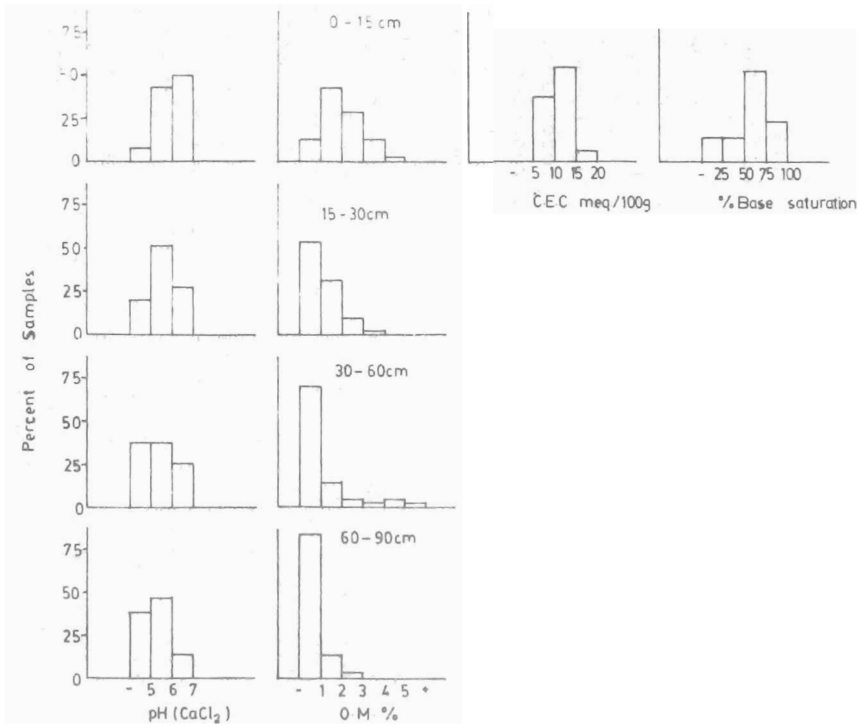


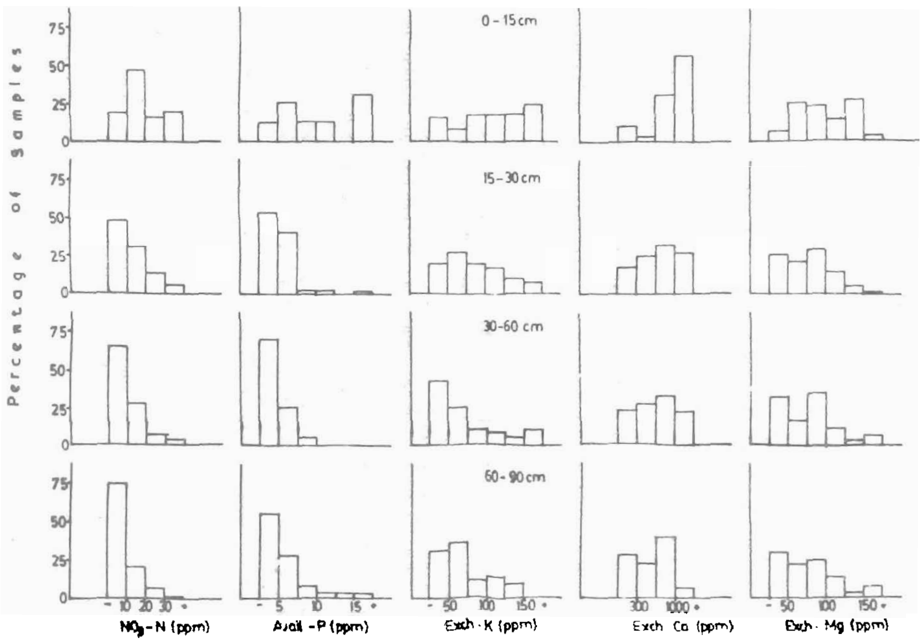
Table 1. Means and ranges of soils analysis values at various depths of Ondo State soils.

Sample Depth		NO_3-N	P	K	Ca	Mg	Fe	Zn	Mn	Cu	O.M	pH ($CaCl_2$)	C.E.C.	Base - Sat.
		ppm									%		Meq./100g	%
0-15cm:	mean	23.7	13.6	119.4	1168	98.2	131.9	9.0	319.9	1.3	1.9	6.0	11.4	59
	range	3.2-96	2-32.5	33-233	147-1867	19-169	30-240	1.3-63	10-1000	0.6-9.0	0.45-4.30	4.35-6.80	5.5-18.8	19.2-96.5
15-30:	mean	16.8	4.96	85.17	726.2	7412	105.53	5.84	259.2	1.20	1.15	5.53		
	range	0.2-96	1.22.5	27-200	160-1867	26-177	7-190	1.3-19.9	0-800	0.4-6.0	0.2-3.60	4.00-6.80		
30-60:	mean	10.9	4.05	73.6	611.7	74.0	93.3	4.3	221.4	1.02	1.2	5.3		
	range	0.2-67	1-8	25-200	133-1773	27-108	4-230	1.0-13.5	0.0-760	0.0-7.0	0.15-6.5	3.95-6.70		
60-90cm:	mean	8.94	6.30	66.27	522.8	69.2	76.28	7.31	275.7	1.13	0.52	5.0		
	range	0.2-30	1-62.5	20-150	120-1240	16-209	4-200	1.4-79.0	0-3000	0.5-9.0	0.15-1.45	3.85-6.50		

ranges of NO_3-N, available P, and exch. K, Ca and Mg occur in soils of Ondo state are presented in figure 2 for soil depths 0-15, 15-30, 30-60, and 60-90cm. Table 1 shows the ranges and means of these parameters in the soils.

Nitrate-Nitrogen: About 80% of the surface samples contained NO_3-N that is less than 30 ppm, a level considered the critical minimum for good crop growth (Edward and Barber, 1977), assuming reasonable rate of N supply from O.M mineralization and minimum loss through leaching; The levels ranged from a low of 3.2

Fig. 2 Frequency distribution of various ranges of NO_3-N, Available-P, Exch K, Exch Ca, and Exch Mg at different depths of Ondo State Soils.



ppm at Okitipupa to 96 ppm about half-a-kilometer outside Ore on Ore/Agbobu road, with a mean of 23.7 ppm. It appears therefore that, generally, supplementay supply of fertilizer-N is imperative for optimum crop performance in the soils. An earlier study by Adepetu and Corey (1977) on a Western Nigerian forest soil showed marked maize yield response to N fertilizer application.

As expected, NO_3-N content of the soils declined with soil depth, to a mean value of 8.9 ppm at 60-90cm depth. The subsoil generally had highest proportion of samples showing less than 10 ppm NO_3-N. Even then the substantial amounts of NO_3-N in the subsoil, even at 60-90cm depth, will serve in supplementing the top soil Nitrogen content especially for deep rooted arables and tree crops.

Phosphorus: Available soil phosphorus, as determined by Bray 1 extractant, was generally low in soils of the state (Table 1) having a range, in the top 0-15cm soil, of 2 ppm at Ogbagi near Ikare to 32.5 ppm at Odeaye in Ikale local government area, with a mean of 13.6 ppm. In this top 0-15 cm layer of soil, 30.8 of samples had available P content within the range of 15.0 to 32.5 ppm while 25.7% had values in the range 4.0 to 7.5 ppm; the highest proportion of samples fell within these two ranges of available P content. The critical available P level has not been established for Nigerian soils, and available literature on tropical soil research provides no values on the critical Bray-1-extractable P level in soils of the humid tropics. However, Navas *et al* (1966) working with volcanic ash soils of tropical Columbia, concluded that the critical Bray-11-extractable P level in tropical Latin America is 20 ppm. Since Bray number 11 is a more acidic extractant than Bray number 1, it probably extracts more P from soil than Bray 1 by physical corrosion of some of the Fe and Al minerals. Hence the critical Bray-1-extractable P (available -P) should be a bit lower in magnitude than the value for Bray 11. Assuming therefore a critical available P level of 15 ppm for Ondo state soils, the result presented in figure 2 suggests that about 70% of this area are P-deficient. Kamprath (1973) observed that the highly weathered ultisols and exisols of the tropics are generally quite deficient in P. Also, Agboola and Corey (1976) conducted a nutrient deficiency survey of maize across Western Nigeria in 1968 and concluded that a very high proportion of samples from the rainforest south contained low P levels.

It had earlier been observed that about 50% of total P in the rain forest soils of Nigeria occur in the organic form (Adepetu and Corey, 1976; Uzu *et al* 1975; Enwezor and Moore, 1966). Also Adepetu and Corey (1977) observed that about 25% of soil organic P in a surface soil of South Western Nigeria was mineralized within a year, resulting in the release of approximately three times as much inorganic P as was taken up by two crops of maize within that year. Hence, when soils of the South Western forest zones of Nigeria contain reasonable levels of O.M, the rate of organic P mineralization may be rapid enough for a few years following land clearing to maintain adequate P activity for plant growth.

A sharp decline in available P was observed from 13.6 ppm at surface 0-15cm to 5.0 ppm just below the surface at 15-30cm depth; from there down the P level seemed to change very little. Similar observations have previously been made for Nigerian soils by Bates and Baker (1960), and by Enwezor and Moore (1966) who suggested the decline to be a reflection of large decrease in the amount of organic P in soils below 5cm depth. In the present study, the greatest proportion of subsoil samples contained less than 5 ppm available P (Figure 2). Hence, significant contribution of the subsoil to available P supply of crop would not be expected in these soils.

Potassium: The exchangeable K level in the top soil varied between 33 ppm at Odeaye in Ikale and 233 ppm near Ondo town, with a mean of 119 ppm. The mean value obtained for top soils of this state is similar to the mean values observed earlier for combined zones of Western Nigeria - 110 ppm - and the rainforest South Western Nigeria - 114 ppm (Agboola and Corey, 1976); and are not much different from the values observed for soils of other tropical regions (Palencia and Martini, 1970; Boock and Freire, 1960; and Silva and Freire, 1968). Although the critical exchangeable K level has not been established for Nigerian soils, it was assumed to fall somewhere between 75 ppm and 100 ppm, based on an evaluation of available literature on crop yield responses to K application at varying soil test values. Figure 2 shows that about 60% of top soil samples from Ondo state contained more than 100 ppm exchangeable K; and just about 23% of the samples contained less than 75 ppm. This result seems to suggest that soil K supply is not a limiting factor to crop production in Ondo state soils at present. It must be noted that even though exch. K level in the soils declined down the soil profile, the decrease from surface down was not very sharp; and that about 54% of the samples collected at 15-30cm soil depth contained greater than 75 ppm exch. K. Hence, the subsoil should be a significant supplementary source of K supply in these soils.

Calcium and magnesium: Exchangeable Ca concentration of the soils was quite high, and showed first a sharp decline and then very gradual decline from top down the profile. While a mean of 1168 ppm exch. Ca was indicated for the top soil of Ondo state in this study, Agboola and Corey (1976) reported a mean value of 772 ppm for the top soils of South Western Nigeria. However, Agboola and Corey sampled the top soil at 0-30cm level, whereas the present study involved 0-15cm as the top soil. The much higher concentration of exchangeable Ca in the top soil than subsoils is probably a reflection of the relatively high O.M content of the topsoil which provide most of the cation exchange sites in these soils. Over 87% of the surface soil samples contained more than 500 ppm exch. Ca. Therefore, Ca should not constitute a yield limiting factor in the soils of Ondo state for some time in the future.

The exchangeable Mg in the soils averaged 98 ppm for the top soil, declined to about 74 ppm at 15-30cm and remained at approximately this level for the rest of the soil depths sampled. Earlier, Agboola and Corey (1976), and Lombin and Fayemi (1976) had reported mean values of 249 ppm and 162 ppm respectively for Western Nigerian soils. In the present study, about 70% of Ondo state soils were found to contain more than 75 ppm exch. Mg in the top 0-15cm layer, a soil Mg concentration that we considered adequate for optimum crop performance.

The Ca: Mg ratio, calculated from the milliequivalent levels of exch. Ca and exch. Mg in the soils, showed a mean value of 7.12 for soils of the state. This falls within the acceptable range of Ca: Mg ratio 1 to ratio 30, which soil condition is usually not expected to produce induced Mg deficiency in plants (Barber 1974).

Base saturation of the cation exchange complex of the soils was calculated according to Tisdale and Nelson (1971), with the assumption that the dominant cations, apart from H+, on the exchange sites are Ca, Mg, Na and K. Table 1 shows the percent base saturation in the soils, indicating a mean of 59% base saturation for soils across the state. According to Sanchez and Buol (1975), agriculture in the tropics first developed in areas of high base status soils, and the impact of the "green revolution" programs is, to date, very much limited to areas of high base status soils, particularly those that are irrigated. Hence, high base status is almost synonymous with high native soil fertility and relatively low cost of supplying additional nutrients. Figure 2 indicates that about 77% of the soils across Ondo state had greater than 50 percent base saturation; and about 23% of the soil samples had values exceeding 75. Sanchez and Buol (1975) have suggested that tropical soils of this nature should be managed with the aim of maximizing the potential of high yielding crop varieties, and improving the cropping system with intensive fertilizer input.

Trace elements: The levels of Na-EDTA-extractable Iron, Manganese, Zinc and Copper at various depths of soils across the state are presented in table 1. Figure 3 indicates the frequency of occurrence of these micronutrients at the indicated ranges of magnitude at difference soil depths. Deficiency of Fe or Mn should probably not occur in these soils at the present levels of fertility. On the other hand Mn toxicity could become problematic under poor soil management conditions. With intensive cultivation, it would become imperative to adjust the type of fertilizers to use in these soils such that the pH remains near neutral condition,as well as evaluating crops, especially legumes, for Mn tolerance.

Extractable Zn seems to be low in the soils. Over 88% of the area appear to contain less than 10 ppm EDTA-extractable Zn in the top soil (Fig.3), and in fact about 54% of the area contained less than 5 ppm Zn. Osiname (1972) had reported a mean of 4.6 ppm for 28 soils across South Western Nigeria. Cox (1973) however, summarized the reports of several workers in tropical Latin America and concluded that the critical level of EDTA-extractable soil Zn ranged from 0.8 to 1.4 ppm. If this range holds for soils of Ondo state of Nigeria, then Zn deficiency should not be common in the soils. Orode (1973) had similar conclusion from a general survey for Zn deficiency in Western Nigeria soils.

Extractable soil Cu was found to be very low in the soils, with a mean of 1.3 ppm in the top soil and a range from less than 1 ppm in over 30% of the locations sampled to 9 ppm at Ilara in Akure Local Council Area. Osiname (1972) had earlier reported a mean value of 2.46 ppm for some soils of Western Nigeria.Also, Pinta and Ollat (1961) observed a tendency of rainforest tropical soils of Dahomey to be Cu-deficient. Accordsoils declined down the soil profile, the decrease from surface down was not very sharp; and that about 54% of the samples collected at 15-30cm soil depth contained greater than 75 ppm exch. K. Hence, the subsoil should be a significant supplementary source of K supply in these soils.

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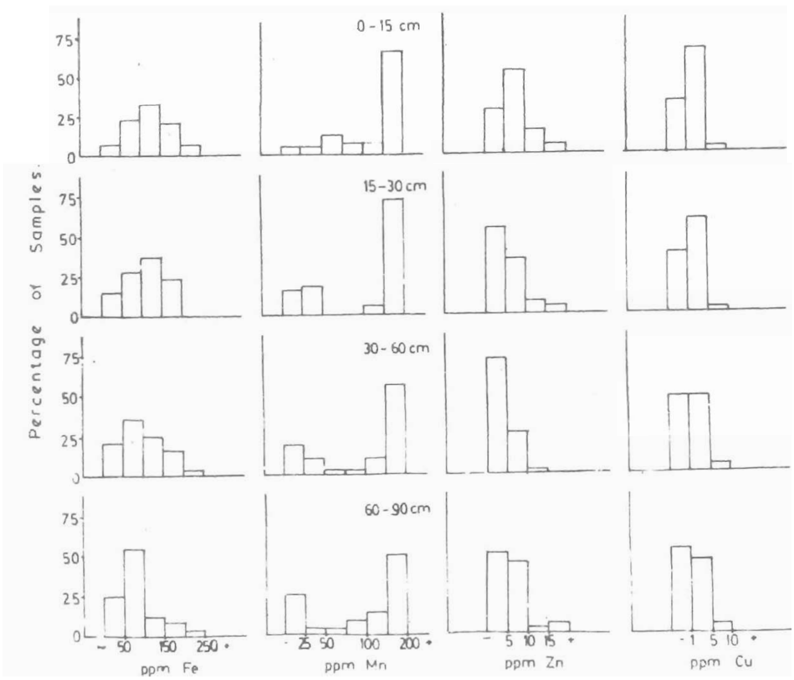
Fig. 3 Frequency distribution of various ranges of EDTA Extractable Fe, Mn, Zn and Cu at different depths of Ondo State Soils

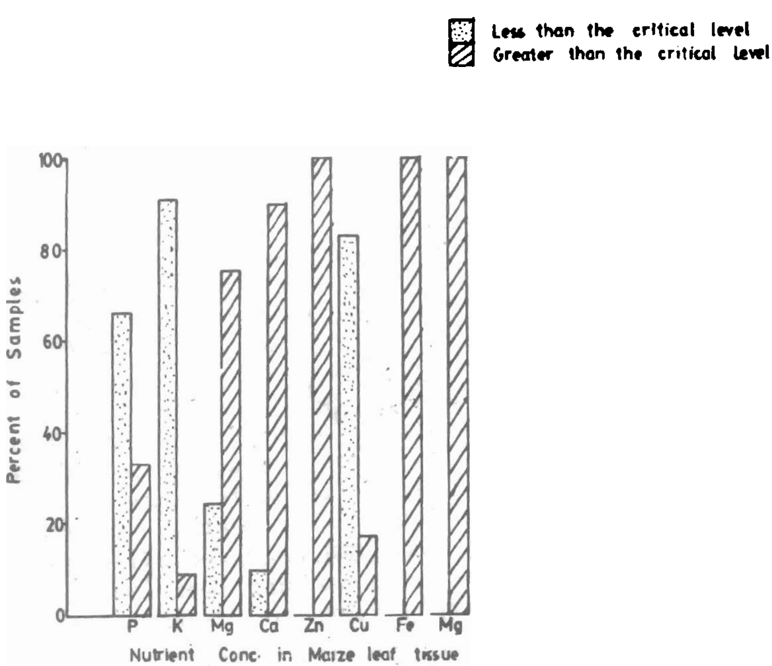


ing to Smyth and Montgomery (1962), most of the soils of Western Nigeria are derived from acidic parent materials and are therefore likely to be inherently low in Cu. On the basis of this information, the low Cu levels observed in this study for Ondo stat" soil is not surprising. However, Ondo state is the major area for cultivation of cocoa on which Cu-fungicides have been continuously applied for several years, hence it was expected that soils in this state would contain high levels of Cu. Observations made in Central America showed that Cu toxicity problems occurred after extended fungicide applications on bananas (Cox 1973). The result of the present study seems to suggest that the Cu sprays used in cocoa plantations did not affect adjacent arable or fallow lands.

Maize leaf Analysis:

Analysis of the maize leaf samples showed the following mean concentrations of P, K, Ca, Mg, Fe, Zn, Mu and Cu respectively: 0.17%, 0.26., 0.39., 0.22%, 434 ppm, 152 ppm, 108 ppm and 315 ppm. Because the internal critical nutrient requirements of maize have not been established for Nigerian conditions, the following critical levels of elements currently being used for the state of Wisconsin, U.S.A have been used in this study, as a first approximation, in constructing figure 4/0.2% P, 1.8% K, 0.2% Ca, 0.2% Mg, 11 ppm Fe, 20 ppm Zn, 20 ppm Mn and 6 ppm Cu. If these critical values obtained for maize grown in Ondo state soils, the results presented in figure 4 would suggest that P, K and Cu are generally deficient in soils of the state, the others should be adequate for optimum maize yields.

Fig. 4. Proportions of Maize leaf samples, from across Ondo State, showing nutrient compositions below or above the critical internal requirements of various nutrients.



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