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Assessment of Soil Nutrient Status of an Oil Palm Plantation

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Abstract: Nutrient management is the key to success in oil palm plantation management, hence in this study soil and plant samples were analyzed to ascertain the nutrient status of some fields in an oil palm plantation in South-South Nigeria for fertilizer application. The results showed that pH values ranged from 4.58-5.85 indicating that the soil samples are slightly acidic, organic matter content ranged from 0.64-2.98%, nitrogen ranged from 0.008-0.143%, p ranged from 1.86-17.50 mg kg^{-1} while Mg content ranged from 0.08-1.28 cmol kg^{-1}. Statistical analysis showed significant difference in nutrient content of leaf samples analyzed from the critical levels. The results obtained revealed that the nutrient levels in the soil samples were low and application of inorganic fertilizer for faster and better availability of soil nutrients will be required.

Key words: Palm, nutrient, pH value, nutrient level, Nigeria

INTRODUCTION

Soil fertility in permanent agricultural systems is usually maintained through applications of organic materials, inorganic fertilizers, lime and the addition of legumes in the cropping systems or a combination of these. In general, the availability, use and profitability of inorganic fertilizers have been low whereas there has been intensification of land-use and expansion of crop cultivation to marginal soils. As a result, soil fertility has declined and it is perceived to be widespread (Henao and Baanante, 1999; Smaling, 1993; Shepherd and Soule, 1998). Similarly, low fertility is a constraint to increased food production and farm incomes (Shepherd and Soule, 1998; Belachew and Abera, 2010). It is difficult to assess soil fertility status of soils because most soil chemical properties either change very slowly or have large seasonal fluctuations but in both cases, it requires long term research commitment.

The oil palm is the most efficient oil bearing crop worldwide (Corley and Tinker, 2003). Typically, the considered economic life span of the oil palm is 25-30 years life span considering height cost of harvesting, etc. The nutrient requirements of the oil palm is large vary widely and depend on the target yield, the type of planting material used, palm spacing, palm age, soil type, ground cover conditions, climate and other environmental factors. The loss of nutrient through surface erosion and runoff has resulted in the use of fertilizer (organic and inorganic) in supplementing poor indigenous soil nutrient supply in oil palm cultivation (Uwumarongie-Ilori *et al*., 2012).

Mineral nutrients perform essential and specific functions in plant metabolism which results in normal plant growth and crop production (Mengel and Kirkby, 1987). Numerous studies have revealed the functions of mineral nutrients in metabolic processes as constituents of organic structures, activators of enzyme reactions, charge carriers and osmo-regulators (Goh and Hardter, 2003; Kogbe and Adediran, 2003). The various soils supporting the oil palm in Nigeria have been characterized for fertility management. Nutritional studies conducted at Nigerian Institute For Oil palm Research (NIFOR) on the oil palm have shown that potassium, nitrogen, phosphorus and magnesium are the key elements required by the oil palm for optimum vegetative growth and high bunch yield (Corley and Tinker, 2003; Tinker and Ziboh, 1959; Tinker, 1963; Tinker and Smilde, 1963).

In oil palm plantation management, nutrient management is the key to success. The right nutrient management is arrayed by information of soil fertility, leaf nutrient content, land nutrition poorness and plant nutrient needs. According to Witt *et al*. (2005), biophysic data such as yield potential, soil nutrient availability, soil limiting factors, leaf nutrient content status and the symptom of nutrient deficiency are needed to arrange the fertilizing recommendation. The sufficiency of soil and leaf nutrient can be achieved by comparing the soil and leaf analyses with nutrient threshold and critical content of nutrient on oil palm (Dierolf *et al*., 2000; Fairhurst *et al*., 2006).

Hence, the main objective of the study was to assess the fertility status of some fields in an oil palm plantation in Delta State, Nigeria using soil and plant laboratory analytical data.

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MATERIALS AND METHODS

Soil analysis: The oil palm plantation used for this study is located atthe South-South Zone of Nigeria. The plantation has ten fields planted at various times and the soil samples were collected from the 10 fields (A-J). Fields A-H were planted in the year 2000 while fields I and J were planted in the year 1975. The fields have not been fertilized, since establishment. The soil samples were randomly collected from 2 depths, viz., 0-15 and 15-30 cm. In each field, a composite soil sample of 10 sub-samples was taken from each soil depth and bulked into 6 samples (3 per depth). Analysis of variance was performed on data obtained.

The fertility assessment involved soil/plant sampling and analysis. From the composite soil samples, parameters analyzed included pH, organic carbon, total nitrogen, available phosphorus, potassium and magnesium. The pH of the composite soil samples was measured electrometrically in 1:2.5 soil water suspensions (McLean, 1982). Organic carbon content was determined by the wet digestion method of Walkley and Black and total nitrogen by the semi-micro kjeldahl method (Okalebo *et al*., 1993). The available phosphorus content was determined by the olsen's method. The exchange able bases (Mg and K) were determined in neutral ammonium acetate filtrates by atomic absorption spectrophotometer and flame photometer, respectively (Rhoades, 1982).

Plant analysis: In order to assess the extent of nutrient deficiency in the palms, leaf 9 (from fields A-H established in 2000) and 17 (fields I and J established in 1975) were sampled for N, P, K and Mg analysis using standard analytical methods (IITA, 1982).

RESULTS AND DISCUSSION

The leaf nutrient content: The leaf analysis results (Table 1) showed that the N, P, K and Mg nutrient content were low and that the sample leaves do not represent healthy plant. The N deficiency is usually associated with conditions of water-logging, heavy weed infestation (as seen in most locations) and topsoil erosion. Symptoms are a general paling and stiffening of the pinnae which lose their glossy lustre. Extended deficiency will reduce the number of effective fruit bunches produced, as well as the bunch size.

In oil palm, P deficient leaves do not show specific symptoms but reduction in frond length, bunch size and trunk diameter. Most soils on which oil palms are grown are very low in P but it appears to be very efficient in utilizing soil and fertilizer P.

Table 1: Mean leaf nutrient analysis result

Field	N (%)	P (%)	K (%)	Mg (%)
A	0.59	0.13	0.54	0.48
B	0.77	0.15	0.26	0.29
C	0.42	0.11	0.44	0.01
D	0.61	0.10	0.20	0.57
E	0.75	0.52	0.83	0.19
F	0.51	0.12	0.36	0.33
G	0.92	0.11	0.27	0.07
H	0.76	0.13	0.28	0.17
I	0.75	0.11	0.06	0.02
J	0.60	0.11	0.21	0.02
*Critical level	2.40-2.80	0.15-0.18	0.90-1.20	0.25-0.40

*Von Uexkull and Fairhurst (1991)

The K deficiency is very common and is the major yield constraint parameter. The most frequent symptom is confluent orange spotting, pale green spots which turn orange or reddish-orange on intensification of deficiency, orange blotch and mid-crown yellowing.

The Mg deficiency is often a problem in light textured and acid soils where the topsoil has been eroded. Symptoms of magnesium deficiency in older fronds are a yellowing of leaflets with leaflets exposed to sunlight showing more severe yellowing than do shaded leaflets (Von Uexkull and Fairhurst, 1991). Calcium deficiency is rare and the largest benefit from applied Ca (lime or dolomite) is improved P availability.

Soil pH is important chiefly because of the many effects it has on biological and chemical activity of the soil. The effect of pH on plant growth can be very large but is usually indirect through biological and chemical factors. The pH is important in the range that it influences availability of other nutrients. The soil nutrient analysis result given in Table 2 showed that pH varied considerably among the soil samples. The pH values of the subsurface layer samples were found to be less than that of the topsoil. The pH range was found to be 4.58-5.85 and median of 5.08 indicating that the soil is slightly acidic. Soil pH in this range is regarded as medium (4.5-5.5) to high (5.0-6.5). Considering the pH of the soil samples, there might be P fixation made by Al, Fe and Mn hydroxide and displacement of K nutrient by Al^{3+} and H^{+} from adsorption complex in mass manner. Hence, the secondary macro nutrient (Ca and Mg) might also be unavailable for plant growth.

Soil organic matter consists of roots, plant residues and soil organisms whether living or dead and is usually referred to as the life blood of soils. It has a great influence on the chemical, physical and biological properties of the soil. The soil organic matter content ranged from 0.64-2.98% and has a median of 1.43%. The soil organic matter range indicates low to medium and as expected, the amount of total carbon decreased with increased depth. Equivalent to 11.1% of the samples had low level of organic matter for the

Table 2: Nutrient analysis result for soil

Location	Sample identity	pH	OM (%)	OC (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
A	A (0-15 cm)	5.24	1.740	1.010	0.093	6.630	0.0020	0.960	0.3200
	A (15-30 cm)	5.09	1.360	0.790	0.066	5.840	0.0011	0.770	0.2100
	B (0-15 cm)	5.42	1.880	1.090	0.108	5.850	0.0034	1.280	0.8000
	B (15-30 cm)	5.40	1.310	0.760	0.096	5.430	0.0017	1.030	0.8100
	C (0-15 cm)	5.21	1.990	1.150	0.086	7.650	0.0016	0.960	0.5600
	C (15-30 cm)	4.84	1.420	0.820	0.138	7.850	0.0014	0.560	0.4800
	Mean	5.20	1.617	0.937	0.098	6.542	0.0019	0.927	0.5300
	Standard error	0.09	0.120	0.070	0.010	0.410	0.0000	0.100	0.1000
B	A (0-15 cm)	5.13	2.310	1.340	0.057	13.110	0.0022	1.200	0.4000
	A (15-30 cm)	4.94	1.600	0.930	0.032	11.580	0.0012	1.120	0.0800
	B (0-15 cm)	4.76	1.340	0.780	0.020	10.510	0.0018	0.560	0.4000
	B (15-30 cm)	4.58	0.650	0.380	0.012	8.190	0.0010	0.320	0.2400
	C (0-15 cm)	4.85	1.750	1.020	0.057	11.980	0.0010	1.120	0.2400
	C (15-30 cm)	4.64	1.370	0.690	0.024	7.460	0.0004	0.880	0.1300
	Mean	4.82	1.500	0.860	0.034	10.470	0.0013	0.870	0.2500
	Standard error	0.08	0.220	0.130	0.010	0.910	0.0000	0.150	0.0500
C	A (0-15 cm)	5.29	2.240	1.300	0.079	7.650	0.0014	1.360	0.8000
	A (15-30 cm)	5.23	1.790	1.040	0.053	6.920	0.0010	1.060	0.5800
	B (0-15 cm)	5.16	2.180	1.260	0.103	7.250	0.0010	0.800	1.0400
	B (15-30 cm)	5.15	1.430	0.830	0.066	5.230	0.0012	0.490	0.8700
	C (0-15 cm)	5.12	1.400	0.810	0.123	6.450	0.0018	2.080	0.5600
	C (15-30 cm)	4.95	1.230	0.710	0.069	4.590	0.0010	1.040	0.2400
	Mean	5.15	1.710	0.990	0.082	6.348	0.0012	1.140	0.6800
	Standard error	0.05	0.170	0.100	0.010	0.490	0.0000	0.220	0.1200
D	A (0-15 cm)	5.23	1.910	1.110	0.118	7.520	0.0014	1.600	0.5600
	A (15-30 cm)	5.21	1.430	0.830	0.064	4.890	0.0010	1.240	0.5200
	B (0-15 cm)	4.82	1.350	0.780	0.123	6.920	0.0016	0.880	0.1600
	B (15-30 cm)	4.74	0.640	0.370	0.018	5.140	0.0009	0.520	0.1300
	C (0-15 cm)	4.86	1.660	0.960	0.027	11.040	0.0014	0.880	0.3200
	C (15-30 cm)	4.92	1.430	0.830	0.015	7.190	0.0014	0.880	0.3800
	Mean	4.96	1.400	0.810	0.076	7.120	0.0013	1.000	0.3450
	Standard error	0.08	0.170	0.100	0.020	0.900	0.0000	0.150	0.0700
E	A (0-15 cm)	5.18	1.380	0.800	0.036	7.720	0.0010	1.600	0.2400
	A (15-30 cm)	5.04	0.930	0.540	0.021	5.890	0.0006	1.380	0.2100
	B (0-15 cm)	5.15	1.820	1.060	0.039	9.710	0.0016	0.880	0.8800
	B (15-30 cm)	5.11	1.170	0.680	0.018	6.720	0.0010	0.510	0.7500
	C (0-15 cm)	5.49	1.540	0.890	0.019	12.790	0.0014	1.680	0.7200
	C (15-30 cm)	5.40	1.360	0.790	0.025	11.110	0.0018	0.600	0.1600
	Mean	5.23	1.370	0.790	0.026	8.990	0.0012	1.110	0.4900
	Standard error	0.07	0.120	0.070	0.000	1.090	0.0000	0.210	0.1300
F	A (0-15 cm)	4.98	1.730	1.000	0.083	9.250	0.0010	0.800	0.1600
	A (15-30 cm)	4.93	0.840	0.490	0.056	8.130	0.0013	0.590	0.1200
	B (0-15 cm)	5.09	1.550	0.900	0.106	8.050	0.0010	1.120	0.1600
	B (15-30 cm)	4.94	0.880	0.510	0.092	6.340	0.0011	1.010	0.1300
	C (0-15 cm)	5.12	1.630	0.950	0.089	7.980	0.0014	0.800	0.7200
	C (15-30 cm)	4.92	1.250	0.730	0.058	7.450	0.0018	0.800	1.2000
	Mean	5.00	1.310	0.760	0.081	7.867	0.0013	0.853	0.4150
	Standard error	0.04	0.160	0.090	0.010	0.390	0.0000	0.080	0.1800
G	A (0-15 cm)	5.16	1.910	1.110	0.072	5.520	0.0018	0.640	0.5600
	A (15-30 cm)	5.12	1.770	1.030	0.061	5.030	0.0011	0.450	0.2100
	B (0-15 cm)	4.90	1.510	0.880	0.036	5.390	0.0060	0.880	0.1600
	B (15-30 cm)	4.70	1.290	0.750	0.058	4.990	0.0060	0.640	0.9600
	C (0-15 cm)	4.87	1.350	0.780	0.075	5.990	0.0010	0.480	1.2800
	C (15-30 cm)	4.72	0.960	0.560	0.034	4.240	0.0013	0.320	1.0600
	Mean	4.91	1.470	0.850	0.056	5.190	0.0029	0.570	0.7050
	Standard error	0.08	0.140	0.080	0.010	0.240	0.0000	0.080	0.1900
H	A (0-15 cm)	4.86	1.240	0.720	0.010	4.520	0.0018	0.800	0.0800
	A (15-30 cm)	4.79	1.100	0.640	0.008	4.490	0.0009	0.580	0.1000
	B (0-15 cm)	5.23	1.320	0.770	0.017	2.000	0.0010	1.040	0.4800
	B (15-30 cm)	5.20	1.340	0.780	0.012	1.860	0.0008	0.970	0.4700
	C (0-15 cm)	5.08	1.720	1.000	0.044	5.190	0.0020	0.960	0.0800
	C (15-30 cm)	5.07	1.100	0.640	0.035	4.660	0.0006	0.720	0.1600
	Mean	5.03	1.300	0.760	0.021	3.790	0.0012	0.845	0.2283
	Standard error	0.07	0.090	0.050	0.010	0.600	0.0000	0.070	0.0800
I	A (0-15 cm)	5.02	2.660	1.540	0.098	17.500	0.0022	2.480	0.5600
	A (15-30 cm)	4.99	1.930	1.120	0.056	12.640	0.0013	1.790	0.2200
	B (0-15 cm)	4.68	2.420	1.400	0.093	6.990	0.0014	1.440	0.7200
	B (15-30 cm)	4.62	1.080	0.630	0.064	5.780	0.0005	0.810	0.5300
	C (0-15 cm)	5.07	2.980	1.730	0.060	6.990	0.0020	2.080	0.8800

Table 2: Continue

Location	Sample identity	pH	OM (%)	OC (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
	C (15-30 cm)	5.01	1.770	1.030	0.078	6.440	0.0014	1.360	0.1600
	Mean	4.90	2.140	1.240	0.075	9.390	0.0015	1.660	0.5120
	Standard error	0.08	0.280	0.160	0.010	1.910	0.0000	0.240	0.1100
J	A (0-15 cm)	4.90	2.640	1.530	0.143	8.580	0.0022	2.000	0.8000
	A (15-30 cm)	4.77	0.890	0.520	0.047	6.310	0.0010	1.020	0.4800
	B (0-15 cm)	5.16	2.130	1.240	0.125	10.310	0.0030	1.920	1.0400
	B (15-30 cm)	5.12	1.340	0.780	0.090	7.780	0.0016	1.040	0.5800
	C (0-15 cm)	5.48	2.760	1.600	0.125	9.380	0.0030	3.040	1.2000
	C (15-30 cm)	5.37	1.270	0.740	0.098	8.650	0.0010	1.440	0.4000
	Mean	5.13	1.840	1.070	0.100	8.500	0.0020	1.740	0.7500
	Standard error	0.11	0.320	0.180	0.010	0.560	0.0000	0.310	0.1300
All	Mean	5.05	1.580	0.910	0.065	7.350	0.0016	1.080	0.5000
	Standard error	0.23	0.050	0.030	0.010	0.330	0.0000	0.120	0.2500

subsurface whereas 88.8% of the subsurface samples were within the medium range (1-3%). The soil organic carbon ranged from 0.37-1.73% with a median of 0.83% rating the soil samples as very low (<2).

Nitrogen (N) is essential for plant growth. Most of the nitrogen in the soil is in the organic form. The inorganic form which are mainly ammonium and nitrate (available forms), constitute <2% of total soil N. In this study, the total N content of the soils ranged from very low (<0.1) to low (0.1-0.2) but mostly very low. The high total N content occurred where C-organic content was high, indicating that increasing C-organic content will increase the total-N content in soil as they tend to have close relationship. In tropical soils, nitrogen can be regarded as the most limiting nutrient followed by phosphorus (Dibabe, 2000).

The phosphorus content of the soil samples ranged from 1.86-17.50 mg kg^{-1} with a median of 6.92 mg kg^{-1}. These values are rated as very low (<3) to moderate (7- 20 mg kg^{-1}). Considering the pH values obtained in this study, phosphorus might be unavailable to the palms as phosphorus in soils is commonly considered to be most available at pH values near 6.5 with the availability decreasing at both lower and higher pH values. Also, the significantly low soil pH in the lower layer as compared to the topsoil might have exhibited its effect on phosphorus availability because of P sorption capacity of the soil in the subsoil layer.

Potassium is important in the growth and development of the oil palm and is required in the plant's general metabolism in the movement of the stomata thereby activating cell division (Manciot *et al*., 1981). Potassium plays essential roles in palm flowering (inflorescence production) and fruit formation. According to Amapu (1990), insufficient potassium in the soil gives rise to poor growth of palms with thin trunks, sparse canopy, few and smaller fronds and leaflets. Potassium levels in the soil samples analyzed ranged from 0.0004-0.006 cmol kg^{-1} with median of 0.0014 cmol kg^{-1}. These values were rated as low (<0.15 cmol kg^{-1}). Omoti (1989) reported that over 50% of the total potassium in the soil is removed by palm fruits which are permanently lost from the plantation. The least amount of K in the leaf samples were found in samples I and J established in 1975.

Extractable Mg in the soil samples ranged from 0.08-1.28 cmol kg^{-1} rating the soil samples as low to medium with a median of 0.48 cmol kg^{-1}. Acid sandy soils are low in magnesium and frequently in calcium. Considering the soil exchangeable Mg/K ratio obtained for the soil samples analyzed, magnesium uptake by the palm may not be affected as Mg/K ratio were >2 (Tinker and Ziboh, 1959; Tinker and Smilde, 1963). Corley and Tinker (2003) reported that soil exchangeable Mg/K ratio <2 leads to magnesium deficiency. Calcium is the most important neutralizing element. The depletion of calcium and magnesium by leaching and plant uptake leads to the prevalence of hydrogen and aluminum ions in soil which lowers soil pH as seen in most of the soil samples.

CONCLUSION

The relationship between leaf analysis and plant productivity is generally evident for most crops and an assessment of fertilizer needs can be based on such an analysis. However for a cost-effective approach, leaf analysis has to be integrated with soil analysis. This is because there may be instances where plant uptake of nutrients present in adequate amounts in the soil may be inhibited by the lack of another limiting element, e.g., uptake of K can be reduced by the lack of N. In a case of this kind, leaf analysis will reflect the need for N and K fertilizer. Reference to soil analysis will indicate that the K reserves in the soil are adequate and thus, K fertilizers need not be used. This allows a savings in the cost of inputs. Also, balance fertilization can increase oil palm yield. Fertilization efficiency is influenced by the amount of nutrient to be added and the methodof fertilizing. Spreading the fertilizer over the ring weeded ground/soil surface is recommended for oil palm field fertilization. The study results revealed that nutrient status of the soil to which the oil palm have been cultivated for over 10 years without fertilization were low hence, the need to apply inorganic fertilizer for faster and better availability of soil nutrients.

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