EVALUATION OF NUTRIENT STATUS OF SOILS OF OIL PALM PLANTATIONS IN ONDO, SOUTHWEST NIGERIA

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ABSTRACT

In order to judiciously apply fertilizers for soil health management, there is a need to ensure that the adequate nutrient needs of the crop to be fertilized in order to avoid over- or under-application. Evaluation of the nutrient status of the soils of Adeyemi Federal University of Education Oil Palm Plantation, Ondo, Southwest Nigeria, was carried out in 2022. The whole farm was divided into sections A, B, C, D, E, and F. Thirty (30) soil samples were collected from the sites at 0-30 cm depth. The soil samples were bulked according to each section, air-dried, sieved through a 2 mm sieve, and analyzed for soil pH, OM, total N, available P, exchangeable K, Ca, and Mg. Others were Fe, Cu, Zn, and Mn, and soil textural classes. The pH of the soils ranged between 5.25 and 5.65. Organic carbon ranged between 0.25 and 1.48%, with a mean value of 0.93%. The sites were deficient in total N, with a mean value of 0.08%, ranging from 0.04% to 0.11%. The trends of N status in the oil palm plantation soils were 0.11, 0.10, 0.09, 0.08, 0.07, and 0.04% for sites E, A, C, F, B, and D, respectively. The order of available P ranged between 5.94 mg kg^{-1} and 11.46 mg kg^{-1} with a mean value of 8.52 mg kg^{-1}. Exchangeable K varied from 0.08 – 0.14 cmol kg^{-1} with a mean value of 0.12 cmol kg^{-1}. The Mg status of the oil palm plantation varied from 0.25 to 0.78 cmol kg^{-1} with a mean value of 0.47 cmol kg^{-1}. Available Ca concentration in the soil varied from 4.15 to 7.71 cmol kg^{-1}. The organic matter and ECEC were low, while the iron concentration ranged between 3.9 and 22.30 mg kg^{-1}. Sites A and E were too high in Cu and do not require any Cu fertilizer, likewise Fe and Zn.

Keywords: ***nutrients deficiency, Oilpalm Plantation, soil chemical properties, soil physical properties.***

INTRODUCTION

Fertilizer application without a soil test is commonly practiced among local farmers in Africa. Indiscriminate fertilizer application is a major problem leading to nutrient imbalance, the overall consequence of which is poor crop yield. Over-application of fertilizer may lead to wastage of fertilizer, with extra cost on farm inputs. For example, excess application of urea may lead to excessive plant growth and succulent stems and leaves, which attract insect pests, leading to plant diseases, while under-application of N fertilizer results in loss of chlorophyll and stunted growth of the plant. Also, excess application of calcium fertilizer results in the formation of a Ca-P complex, which renders phosphorus unavailable in the soil for plant uptake. The overall effect of nutrient imbalance or nutrient antagonism is soil infertility and poor crop performance. In order to guard against the negative effects of poor fertilizer application, there is a need to carry out periodic soil nutrient evaluations (every 5–10 years during active fruiting years) in tree crop plantations that spend longer periods on soil than arable crops to ensure sustainable soil fertility and optimum yield. Oil palm requires nutrients such as N, P, K, Ca, Mg, S, and micronutrients for growth (Goh and Po, 2005). Obeng *et al*. (2020) suggested that N, P, K, and Mg are the major soil nutrients required for optimum production of oil palm fruit bunches.

Nitrogen is known to enhance vegetative growth and chlorophyll formation (Almodares *et al*., 2008). Its deficiency in the oil palm plantation is likely to cause low fruit formation due to a reduction in the photosynthesis rate of oil palm. Phosphorus (P) helps in energy transfer (Foster, 2003) and ripening of fruits, which play a significant role in the early formation and ripening of oil palm fruits as well as root development. According to Ayeni (2011), a low level of potassium (K) in the soil might lead to wilting of oil palm due to inadequate water absorption. Calcium (Ca) is required in the division of plant cells at the root tips and the meristematic tissues. Like N, inadequate Mg in oil palm plantations might result in poor photosynthesis, while low sulphur (S) content might lead to low oil production in oil palm. Generally, an imbalance of micronutrients in the soil might induce a deficiency of other important major nutrient elements.

Oil palm is one of the most economically valuable trees in West Africa. In fact, all parts of the oil palm are useful. Palm oil supplies vitamin E (Ofosu-Budu and Sarpong, 2013), and palm kernels are sources of income to both the farmer and the government. Palm wine that supplies vitamin B is a source of income (Wich, 2014). The fronds and trunks are used for building houses. Routine maintenance of oil palm plantations must involve periodic soil nutrient evaluation through routine soil chemical analysis. Adeyemi Federal University of Education's oil plantation was established in the year 1999 with no previous knowledge of soil nutrients evaluation since its establishment.

FAO (2020) asserted that the global oil palm production is approximately 272,055,131 tonnes from 18,917,400 hectares, with Africa having only 9%. There is a need for soil nutrient evaluation to be carried out on the plantation to enhance the judicious use of fertilizer to boost the university's oil palm plantation. Hence, the objective of this study was to determine the nutrient status of the Adeyemi Federal University of Education oil palm plantation for rational fertilizer use.

MATERIALS AND METHODS

Site Description

Adeyemi Federal University of Education oil palm plantation (Hybrid Block) is situated in Ondo, South-west Nigeria. Ondo town is located at Latitude: 7° 04' 60.00" N Longitude: 4° 49' 59.99" E with an elevation of 253.23meters (830.8 Feet).

The University's oil palm plantation, grown with the Tenera variety, is about 30 acres and is divided into six (6) blocks labeled A at (Lat: 7° 04' 18.0" N Long: 4° 49' 00" E), B(Lat: 7° 03' 20" N Long: 4° 48' 35" E), C(Lat: 7° 03' 16" N Long: 4° 48' 44" E), D(Lat: 7° 04' 15" N Long: 4° 48' 56" E), E(Lat: 7° 01' 23" N Long: 4° 46' 49" E) and F(Lat: 7° 01' 22" N Long: 4° 46' 48" E). The University oil palm plantation Block A was established in the year 1999, Block B was established in 2002, while Blocks C, D, E, and F were established in 2003. The oil palms in the plantation were fully mature. Farming activities were being carried out in all the experimental sites. Farm A is situated along Okegun Road. It has a gentle slope with scanty tall trees. The site is dominated by thick *Chromolaena odorata,* tall grasses, and other shrubs. Sites B and C are dominated by a bamboo colony, a gentle slope with parts having grown-up trees more than Site A. Site

C has a river that passes through the middle of the farm, with a rocky area at the end. Site D is dominated by grasses and scanty broad leaves. It is hydromorphic in nature and w*et all* the seasons of the year. The topography of site E is steep in slope with grown-up trees and *Chromolaena odorata* weeds (recently slashed) with minimal farming activities. It has a large number of pebbles. Sites A and B are demarcated by a farm road of about 2 km from each other, sites C and D are about 2 km from each other, while sites D and E are about 5 km from each other. Site F has the same characteristics as Site E because they are close to each other.

Soil Sample Collection

Soil surface (0–30 cm) samples were collected randomly from six (6) different blocks of the Adeyemi Federal University of Education oil palm plantation, Ondo. Thirty soil samples were collected from each of the blocks from the sites with a diagonal pattern using a soil auger. Thirty-centimeters (30 cm) depth was purposely selected because the primary and quaternary roots of the adventitious roots, known to absorb plant nutrients, are located within 30 cm depth (Ng *et al*., 1999; Obeng *et al*., 2020). All the soil samples were air-dried, sieved through a 2mm wire mesh, and kept in polythene bags for chemical analysis. The mean of the replicates of each soil profile was generated and used to compute the data. The soil chemical analysis carried out for the profiles included pH, organic carbon (OC), total N, available P, exchangeable K, Ca, Mg, Na, and S. Others were Fe, Cu, Zn, and Mn. Soil pH was measured using a glass electrode pH meter in a 1:2 soil-water ratio (Blakemore *et al*., 1987). Organic carbon was determined by the Walkley-Black wet oxidation method (Nelson and Sommer, 1982), total N was determined by the Microckjedahl distillation method (Bremer and Mulverey, 1982), available P by the Bray-1 method (Bray and Kurtz, 1945), and the exchangeable cations such as K, Ca, and Mg were extracted with 1.0N ammonium acetate and read with an atomic absorption spectrophotometer. Micronutrients were extracted with 1.0N HCl.

The method of Thomas (1982) was used for the determination of exchangeable acidity. The effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases and exchangeable acidity. The Bouyoucos method was used to determine the soil particle size (Bouyoucos, 1962; Gee and Or, 2002).

The index range of low (below 1.67), medium (between 1.67 and 2.33), and high (above 2.33) recommended by Ravikumar (2013) was used to assess the fertility status of the experimental sites. The rating chart for soil parameters and their nutrient indices was used. The formula for nutrient index (Ravikumar, 2013) is shown below:

$$NI = \frac{(L \times 1 + M \times 2 + H \times 3)}{TNS}$$

Where:
NI = nutrient index
L = number of samples in the low category
M = number of samples in the middle category
H = number of samples in the high category
TNS = total number of samples

Data Analysis

Data obtained from the laboratory analysis were analysed using descriptive analysis.

RESULTS AND DISCUSSION

Table 1 below shows the textural class of the Federal University oil palm plantation. All the sites A, B, C, D, E, and F were dominated by sand. According to Bah and Zaharah (2004), the texture of a soil usually determines the fertility status of the soil. The soil that is high in sand usually encourages high leaching, which might affect the plants or crops that have fibrous root systems without taproots, such as oil palm (Bah and Zaharah, 2004).

Table 1: Soil textural class of the experimental sites (%)

Location	Sand	Silt	Clay	Class
A	92.20	3.20	4.60	Sandy
B	89.20	5.40	5.40	Sandy
C	91.20	3.60	5.20	Sandy
D	83.20	11.40	5.40	Loamy sand
E	89.20	4.80	6.00	Sandy
F	85.60	9.00	5.40	Loamy sand
Mean	87.83	6.60	5.50	
SD±	1.20	1.21	0.12	
SE	2.94	2.98	0.28	

NB: The mean of the replicates of each soil profile was generated and used to compute the data. SD= standard mean SE= standard error

Table 2 below gives the soil chemical parameters of the experimental sites. For optimum yield production, Hartley (1988) suggested that there must be adequate availability of N, P and K and recommended the critical level of 0.2% for total N, 20 mg kg^{-1} for available P and 10 mg/kg for available K. Obeng *et al*. (2020) recommended 0.15% for total N as against 0.20% recommended by Hartley (1988). The Obeng *et al.* (2020) and Hartley (1988) might be a result of differences in the soil physical properties and the fertility status of the soils. Tiemen *et al*. (2020) recommended 0.2 cmol kg^{-1} as the critical threshold for exchangeable K for oil palm production. Also, Goh and Chew (1997) observed that there are other soil fertility parameters that enhance optimum crop yield apart from the nutrients available in the soil. For example, Goh and Chew (1997) and Mutert (1999) observed that oil palm required a CEC of 15-18 cmol kg^{-1}, a pH of 5.0-5.5, exchangeable K of 0.25-0.30 cmol kg^{-1}, and exchangeable Mg of 0.25-0.30 cmol kg^{-1}. The soils of the experimental sites were acidic. The pH level is adequate for oil palm production because oil palm is known to tolerate an acidic medium. According to Okon *et al*. (2016), the range of the acidity falls within 5.25-5.65. The order of increase in soil pH of the oil palm plantation was C>E>B>D>A=F. The level of acidity in the Federal University oil palm plantation was not expected to pose a threat to palm oil production since it was still within the critical range.

The OC status of the oil palm plantation is shown in Table 2. The organic C ranged between 0.25 and 1.48%, with a mean value of 0.93%. Site C had the highest OC (1.22%), while site D recorded the lowest OC (0.25%). Sites E and C were fairly adequate in OC (Bah and Zaharah, 2004). The order of increase of OC was E>C>F>A>B>D. The sites required the addition of OC for optimum production of palm oil and kernels. Organic matter is known to be the source of plant nutrients, and the higher the organic matter, the higher the nutrient status of the soil (Ayeni, 2011). All the experimental sites required the addition of organic matter, which might be in the form of organic residues.

Site E of the oil palm plantation recorded the highest total N (0.11%), while site D recorded the lowest total N (0.04). The trend of N status in the oil palm plantation was in the order of 0.11, 0.10, 0.09, 0.08, 0.07, and 0.04% for E, A, C, F, B, and D sites, respectively. Based on the critical level for optimum oil palm production recommended by Wich *et al*. (2014) and Tiemen *et al.* (2020), all the sites were deficient in total N and required N fertilization, but the amount of N required by the individual site would be different from one another. The low OM and N status of the soil was expected due to the sandy nature of the soil.

The phosphorus status of the oil palm plantation ranged between 5.94 and 11.46 mg kg^{-1} with a mean value of 8.52 mg kg^{-1}. Site D recorded the highest phosphorus value, while site A recorded the lowest phosphorus value. The order of increase in the value of phosphorus is D>E>F>C>B>A. The critical level of phosphorus requirement for oil palm in Southwestern Nigeria is between 8 and 10 mg kg^{-1} Obeng *et al*., 2020). Going by Obeng *et al.* (2020) assertion, only sites D and E, though low, were fairly adequate in available phosphorus, with values of 9.46 mg/kg for D and E, respectively. According to the Federal Fertilizer Department (2012), soils with a pH range between 5.5 and 6.5 are known to be good for the solubility of P. Going by Hartley (1988), who suggested 20 mg/kg of phosphorus for optimum oil production, the whole farm was grossly deficient in phosphorus. Therefore, the soils required phosphate fertilizer application at different rates. Available K varied from 0.08 to 0.14 cmol kg^{-1}. Site F recorded the highest available K, while site A recorded the lowest available K. Sites B, C, D and E were adequate in available K, while sites A and D were deficient in K. The order of availability of available K was F>C>E>B>D>A.

According to the Federal Fertilizer Department (2012) ranking, the critical limit for K in oil palm production is 0.5 mg kg^{-1}. This shows that each site needs specific K, and the K deficiency would determine the amount of potash fertilizer expected to be applied.

The calcium content ranged between 4.15 and 7.71 cmol kg^{-1}. Site A recorded the lowest Ca content, while site E recorded the highest Ca content. The values of Ca content in the site were 4.15, 5.57, 6.53, 6.83, 7.71, and 5.44 cmol kg^{-1} for sites A, B, C, D, E, and F, respectively.

Researchers have categorized Ca content in the soils of the Southwest below 1.5 cmol kg^{-1} as low, 1.5-4.5 cmol kg^{-1} as medium, and Ca values above 4.5 cmol kg^{-1} as high. The Ca content in site A was at a medium level, which could sustain palm oil production. The Ca content in sites B, C, D, E, and F was high. High Ca content might reduce the availability of phosphorus. The Ca content in all sites was above 2.4 cmol kg^{-1}, recommended as the critical level for optimum performance of crops in Southern Nigeria. Magnesium content recorded the highest value in site B and the lowest Mg value in site F, with the mean value of 0.50 cmol kg^{-1}. The magnesium status of the sites was 0.31, 0.78, 0.51, 0.52, 0.43 and 0.25 cmol kg^{-1} for A, B, C, D, E and F, respectively. The critical Mg required for oil palm production is 0.30 mg kg^{-1}. The amount of Mg that would be needed as Mg fertilizer in site F would be higher than any other site, while site B would require less Mg fertilizer. Magnesium is known to play a prominent role in chlorophyll formation as well as oil formation. This means inadequate Mg might lead to a reduction in palm oil produced by the Adeyemi Federal University oil palm plantations. Inorganic sulphur (S) varied from 0.12 mg kg^{-1} to 1.42 mg kg^{-1}. Site A recorded the highest inorganic S, while site D recorded the lowest inorganic sulphur. Availability of inorganic sulphur in Adeyemi oil palm plantation varied as follows: 1.42, 1.02, 0.92, 0.61, 0.72, and 0.69mg/kg for sites A, B, C, D, E, and F, respectively.

The ECEC of the plantation ranged between 4.79 and 8.52 cmol kg^{-1}. Site E had the highest ECEC of 8.52, while site A recorded the lowest ECEC. According to Osinuga (2012), the ECEC of a typical soil for oil palm production below 6 cmol kg^{-1} is considered low, 12-15 cmol kg^{-1} is considered medium, while 18 cmol kg^{-1} and above is ranked high. Based on this, the university oil palm plantation had low ECEC, indicating that some of the exchange bases, especially K and Mg, might be required. The C/N ratio of the soil shows that 8.8, 11.71, 13.56, 6.25, 13.45, and 11.25 were recorded for sites A, B, C, D, E, and F, respectively. According to Ayeni *et al*. (2011), the decomposition of organic matter by microorganisms would be very easy and fast because the C/N ratio was low.

Table 2: Nutrient status of the experimental sites

Location	pH	Ca	Mg	K	Na	Al+H	CEC	Sat	N	O C	P	S
		---------------------cmol kg^{-1}-------						--------%-----------------			mg kg^{-1}	
A	6.25	4.15	0.31	0.08	0.16	0.19	4.79	98.12	0.10	0.88	5.94	1.42
B	6.50	5.57	0.78	0.11	0.17	0.10	6.73	98.51	0.07	0.82	7.26	1.02
C	6.65	6.53	0.51	0.13	0.19	0.08	7.47	98.53	0.09	1.22	7.96	0.92
D	6.50	6.83	0.52	0.09	0.20	0.12	7.72	98.96	0.04	0.25	11.46	0.61
E	6.60	7.71	0.43	0.12	0.16	0.10	8.52	98.83	0.11	1.48	10.37	0.72
F	6.25	5.44	0.25	0.14	0.23	0.12	6.18	98.06	0.08	0.90	8.13	0.69
Mean	6.46	6.04	0.47	0.12	0.19	0.10	6.90	98.55	0.08	0.93	8.52	0.80
SD±	0.07	0.51	0.08	0.01	0.01	0.01	0.53	0.15	0.01	0.17	0.83	0.12
SE	0.17	1.25	0.19	0.02	0.03	0.01	1.31	0.37	0.03	0.41	2.04	0.30

SD= standard mean SE= standard error

The nutrient availability index of the experimental site is shown in Table 3 below. All six sites recorded high pH and Ca index, showing that the soil pH and Ca present in the soil were adequate for oil palm production. Magnesium, Na, K, ECEC, OC and N were low in all the sites. Sites D and E had medium P, which could reasonably sustain oil palm, while available P was low in sites A, B, C and F. Oil palm at the experimental sites was grossly inadequate in all the nutrients except Ca. Generally, site C seems to have a good standing relative to fertility status among all the experimental sites. This might be a result of good management practices and a reduction in other farming activities. Mixed cropping and weed competition normally reduce crop yield due to competition for nutrients, water, air, and space. The slashed weeds might serve as mulching materials that cover the ground.

The pH was ranked high because oil palm performs well in an acidic medium (Obeng *et al*., 2020; Mutert, 1999; and Goh and Chew, 1997). All the sites had favorable soil pH. Calcium and potassium contents of the soil were rated high and medium, respectively, and the sites need no calcium or potassium fertilizer application. This might be as a result of oil palm fronds lying fallow and decaying on the soil. Oil palm residues are known to be rich in Ca and K. The soils need moderate Mg fertilizers. The low ECEC coupled with low organic matter showed that the soils need the addition of organic manure, which is the storehouse of plant nutrients. The addition of organic manure, nitrogenous fertilizers, and phosphate fertilizers would alleviate N and P deficiencies in the experimental sites. Ring weeding is expected to reduce leaching of plant nutrients, as the weeds would serve as cover while their dead leaves would serve as manure.

Table 3: Nutrient availability index of the experimental sites

Parameters	index	R	index	R	index	R	index	R	Index	R	Index	R
	A		B		C		D		E		F	
pH	3	Ad	2.9	Ad	3	Ad	3	Ad	3	Ad	3	Ad
Ca	3	High	3	high	3	high	3	High	2.9	High	2.7	High
Mg	1	Low	1.2	low	1	low	1	Low	1.1	Low	1	Low
Na	1.67	Low	1.67	low	1.67	low	1.67	Low	1.67	Low	1.67	Low
K	2	Med	2.22	med	2.24	med	2	med	2.23	Med	2.32	Med
ECEC	1.5	Low	1.69	low	1.7	low	1.72	low	1.71	Low	1.68	Low
N	1	Low	1	low	1	low	1	low	1.67	Low	1	Low
P	1.67	Low	1.69	low	1.69	low	2		2		1.68	Low
OM	1.66	Low	1.66	low	2.1	med	1.69	low	2.3	Med	1.68	Low
S												

NB: R = Remark, med = medium, Ad = Adequate

Table 4 below shows the micronutrient status of the oil palm plantation. The range of Cu falls within 0.74-1.17 mg kg^{-1}. Site A had the least Cu, while site E had the highest Cu. The mean range of available Cu in the oil palm plantation was 0.92 mg kg^{-1}. The order of increase in available Cu was E>F>C>D>B>A. The available Cu in all the sites was low at 6-7 mg kg^{-1}, recommended as the critical level for agricultural land in southwestern Nigeria (Olowolafe *et al*., 2012). Iron (Fe) concentration in the land ranged between 3.90 and 22.30 mg kg^{-1}, with a mean value of 12.25 mg kg^{-1}. Site A recorded the highest Fe, followed by site D, while site B recorded the lowest Fe.

Manganese concentration ranged between 8.75 and 23.70 mg kg^{-1}. Site C recorded the highest concentration of Mn, while site A recorded the lowest Mn concentration. The order of increase in available Mn is C>E>D>B>F>A. Manganese is high in all the sites. The Mn present in all the sites was higher (above 1 mg kg^{-1}) than required for oil palm production (Federal Fertilizer Department, 2012). This might negatively affect other nutrients' availability, as excess Mn is known to cause soil acidity.

The level of Zn ranged between 2.44 and 6.29 mg kg^{-1}. The zinc level was fairly adequate and might not need any fertilizer. The order of increase in Zn is B>E>D>E>F>A.

Table 4: Micronutrient content of the Oil Palm Plantation (mg kg^{-1})

Site	Cu	Fe	Mn	Zn
A	0.74	22.30	8.75	2.44
B	0.76	3.90	13.10	6.29
C	1.12	5.95	23.70	3.70
D	1.09	16.60	17.40	3.61
E	1.17	9.05	19.20	5.29
F	1.11	15.80	9.40	2.46
Mean	0.99	12.25	14.73	3.97
SD±	0.07	2.90	2.68	0.63
SE	0.19	7.09	6.60	1.55

SD= standard mean SE= standard error

CONCLUSION AND RECOMMENDATION

The soil at the Oil Palm Plantation of Adeyemi Federal University of Education was found to be deficient in all the major nutrient elements, which require urgent attention, and adequate in minor nutrients. The low ECEC coupled with the low organic matter showed that the soils need the addition of organic manure, which is the storehouse of plant nutrients. Periodic evaluation of the nutrient status of the plantation should be carried out to ensure that the soil nutrients are at a sustainable level. The addition of organic manure, nitrogenous fertilizers, and single superphosphate fertilizers will alleviate N and P deficiencies in the experimental sites. Fertilizer usage on the plantation should be based on soil nutrient test values. Periodic addition of organic manures in subsequent years to maintain soil fertility is also needed. Ring weeding should be practiced in order to save costs and keep the soil mulched with periodic clearing of the bush to reduce competition with the oil palms. The residues of the cleared bush should be left on the farm to serve as manure. Other farming activities on oil palm plantations that deplete soil nutrients should be minimized.

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