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Assessing the Availability of Exchangeable Calcium (Ca), Magnesium (Mg), and Potassium (K) in Oil Palm (Elaeis Guineensis) Plantations Grown on Coastal Plain Sand Soil of Akwa Ibom State

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Abstract: A study was carried out to evaluate the content and quantitative ratios of exchangeable Calcium (Ca) Magnesium (Mg) and Potassium (k) in soils and plants in three oil palm plantation sites in Akwa Ibom State namely Ikot Obong Edong (IOE), Obioakpa (OBA) and Uta-ewa (UTE). Soil samples were taken from 0 – 20cm depth, from the three site, dried, sieved and analyzed in the laboratory. The data collected were subjected to statistical analysis and the following results were observed. The soils were sandy in texture, slightly acidic, values ranged from 4.5 (IOE) to 4.9 (UTE), exchangeable acidity were low, values ranged from 1.44 to 1.67cmol kg-1, organic matter (OM)were rated low to moderate, the trend were: 1.92% (10E) < 3.33% (OBA) < 3.36% (UTE), total N and available p were moderate and salt level were low. The exchangeable Ca, Mg and K (cmol kg-1) in soils and plants differ significantly within the locations, the exchangeable Ca, Mg and K (cmol kg-1) in soils contribute significantly to the uptake of Ca, Mg and K (mgkg-1) in plant. Values of Ca varies in the order; UTE (3.59mgkg-1)>IOE (3.29 mgkg1)>OBA (3.03 mgkg-1), the order of variation for Mg was UTE (2.79mgkg1)>IOE(2.72mgkg-1)>OBA (2.07mgkg-1) while K varies in the order; UTE (1.94mgkg1)>IOE(1.85mgkg-1)>OBA (1.51mgkg-1) With the low to moderate nutrient status of the soils, application of organic manure and inorganic fertilizer (NPK) as well as lime is recommended to enhance the nutrient content, increase the pH and promote higher crop yield.

Keywords: *Coastal Plain Sand, Soil Texture, Oil Palm Plantations, Exchangeable Cation and Nutrient Uptake and Growth yield*

1. Introduction

Soils are reservoirs of nutrients and water for plant growth and development. Nutrients available to plantsvary widely among soils and it depends on the concentration and activity of each nutrient in the soils (Umoh *et al.,* 2017). When a nutrient is applied in the form of fertilizers in soils, it can either be adsorbed on clay minerals, organic surfaces, used up by plants or through leaching. Umoh *et al.,* (2018) observed high leaching of potassium (K) and phosphorous (P) in soils formed from coastal plain sands. The rate of leaching increased with increasing amount of K and P applied and attributed this to the sandy nature of parent materials from which the soils were formed. This may lead to widespread nutrient deficiency and thus limit crop production. The soil properties influencing the availability of nutrients include texture, pH, organic matter, concentration of exchangeable Ca, Mg and K in soil, and amount and types of clay minerals (Schneider *et al.,* 2016)

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The mineralogy of these soils is predominantly Kaolinite which is a 1:1 type of clay, which contain Fe, and Al Oxide that lead to K, and Mg deficiency. The deficiency of Ca, Mg, and K in soils occur either because of nutrient fixation, lowconcentration, nutrient imbalances and activity of each nutrient element (Mei*et al.,* 2016). Soil availability of K and plant K concentration are influenced by Ca:K and Mg:K ratio in soil due to competitive effect (Schneider *et al.,* 2016) and increased levels of exchangeable Ca and Mg in soils decreased K concentration in sesame leaf tissue grown on paddy wetland soil.Moore *et al.,* (2008) reported that lime application in soil changes the levels of soil exchangeable cations (Ca^{2+}, Mg^{2+}, and K^{+}),improves soil fertility conditions and promotes soil productivity by alleviating Ca^{2+} deficiency, decreasing Al^{3+} toxicity and improving plant nutrient availability (Kunhikrishnan *et al.,* 2016). The Ca^{2+} cation which is the main component of lime, directly competes with K^{+} on the adsorption sites and displaced K^{+}which is consequently lost through leaching (Mei *et al.,* 2016; Umoh *et al.,* 2022). Potassium (K) uptake by crops is inhibited by high concentration of Ca^{2+} in the soil and liming increases availability of K^{+} by competitive adsorption of Ca^{2+}, and Mg^{2+} (Schneider *et al.,* 2016).

Oil Palm (Elaeis guineensis) is a tree crop that belongs to the Palmae family, it is monocotyledonous plant that grows to a height of 15-25m and can live for up to a century. Oil Palm is a tropical crop which thrives well on highly weathered soil. Oil Palm is a heavy feeder and requires quite large quantities of fertilizers to produce good yield. The Oil palm is the dominant source of vegetable oil consumed in the world. The best soil pH for profitable oil palm growth range from 5.0 - 6.0 while rainfall ranges from 2,000 - 2,500mm per annum (Peter *et al.,* 2019). Harvesting of oil palm implies that the soil nutrients are removed and may result in a decline in soil fertility if the soil not replenished (Hartemimik, 2015). This study was carried out to understand the relationship between some soil properties and exchangeable cations ($Ca2^{+}$, $Mg2^{+}$ and K^{+}) and its uptake by oil palm grown on different plantations in Akwa Ibom State.

2. Materials and Methods

2.1 Description of the study area

The soil samples used for this study were collected from three oil palm plantations: Ikot Obong Edong (IOE), Obioakpa (OBA) and Uta-Ewa (UTE)in Akwa Ibom State. The area is in rainforest zone, characterized by heavy rainfall ranging from 2500mm in land to over 3000mm along the coast, mean temperature range between 26^{0}c to 28^{0}c with relative humidity of 75 – 80% within a year. AKSU(Meteorological station, 2021). The soil is coastal plain parent material, the topography of Obioakpa and Utaewa is undulating and Ikot ObongEdong has a gentle slope to flat and other information is shown in Table 1.

Table 1:

Location	Coordinate	Vegetations
Ikot Obong Edong	5°10'N,7°43'E	Rainforest, dominant plant are *Tridax spp., Imperata cylindrica, Aspillia africana*
Obioakpa	4°45N 7°37' E	Rainforest, *manihot spp, zea mays aspillia Africana*
Uta-ewa	4°30'N7°43'E	Rainforest, dominant plant are andropogon gayanus, *Tridax spp., Imperata cylindrica, Aspillia africana*

2.2 Field studies and sample preparation

The soil and plant samples were collected from the three plantations, namely; Lutheran Palm Groves Limited in Ikot Obong Edong, Ikot Ekpene Local Government Area, Plantation at Akwa Ibom State University Research Farm, Obioakpa, Oruk Anam local Government Area, and Plantation at Uta-ewa in Ikot Abasi Local Government Area. Each location represents the Oil Palm ages above 15 years. The plot were divided into three replicates.Soil samples weretaken randomly within the marked locations at 0-20cm depth, using soil Aaugar. The samples were placed in polythene bags and labeled. The samples collected were air-dried under shade for 3 days crushed, sieved with a 2mm mesh and stored in polythene bags. They were subsequently subjected to a laboratory analysis using standard laboratory procedures as outlined by Udoh *et al.,* (2009).

Plant samples were also collected at random within the marked area at three replicates per plot. The frond (leaves) was taken from the three clustered frond to the meristem or Inflorescence using Machete and were washed with 2% Phosphate free detergent solution and quickly rinsed with distilled water before air drying to remove moisture and then oven dried for 24 hours at 80°C. The dried plant samples were milled using stainless steel mill and sieved to obtain particles less than 2mm. The samples were placed in labelled envelopes for laboratory analyses.

2.3 Laboratory Analyses

The following soil parameters as described by Udo *et al.*, (2009) were determined. Particle size distribution was determined by the Bouyoucos hydrometer method using sodium hexameta-phosphate as dispersing agent. The soil pH was measured in soil to water ratio of 1:2.5 using a glass electrode pH meter. The electrical conductivity was measured in the extract from 1:2.5 soils: water suspension using a conductivity bridge. Soil organic carbon was determined by wet oxidation method and the value was multiplied by a factor of 1.72 to obtain % organic matter. The nitrogen in the soil was determined by micro Kjeldahl distillation method. Available Phosphorous in the soil was determined by Murphy and Relay method after extraction by Bray p-1 extractant.The exchangeable cations in the soil were extracted using IN NH_4 OAC (pH 7.0). K and Na in the extracts were measured using flame photometry while Mg and Ca were determined by atomic absorption spectrophotometry.Effective Cation Exchange Capacity (ECEC) was obtained by the summation of the exchangeable cation and exchangeable acidity was extracted with IN KCL and determined by titration with 0.05N. NaoH using phenolphthalein indicator. Base Saturation (%) was calculated using the formula: $\frac{TEB}{ECEC} X \frac{100}{1}$ where TEB = total exchangeable bases and ECEC = effective cation exchange capacity

2.4 Statistical Analysis

All the data collected were subjected to analysis of variance (ANOVA). Means were compared using least significant difference (LSD) test and regression Analysis was done.

3. Results and Discussion

3.1 The Physicochemical Properties of the Soils Studied

Results of selected physical and chemical properties of the soils used in this study are presented in table 2. A significant differences were observed in sand, silt and clay contents but the texture of the soil were sand. The highest sand content of 94.47% recorded in IOE and the lowest (85.13%) in (UTE) Utaewa location but UTE recorded the highest silt content of 4.00% and 10.87% clay, while Ikot ObongErong (IOE) had the lowest silt (2.20%) and clay 3.33%. The relatively higher sand content and lower silt and clay contents in each of the locations may indicate dominance of erosion over soil formation and accumulation and may also attributed to the undulating terrain of the area. This observation agree with the findings of

Ellerbrock and Gerke (2013) who revealed that during erosion, clay size particles can be transported along hill slopes to foot slope areas forming the colluvic soil at topographic depression. There were no significant differences in soil pH. The reactions were slightly acid which is considered satisfactory for most crops production in these zones. (Aduayi *et al.,*2002). The electrical conductivity (EC) of the soil were low, organic matter (OM) content shows a significant difference, the trend were: 3.36 (UTE) > 3.33 (OBA) > 1.92% (IOE), these values were rated low to moderate for the soils and the moderate OM of UTE and OBA could be attributed the accumulation of liters over the years. The observation agrees with the findings of Umoh *et al.,* (2021) who evaluated nutrient statues on different land use system. The exchangeable acidity values were less than 4(cmolkg-1) in the soil. The value reflects the slightly acid pH of the soils (Udo *et al.,* 2019). The concentrations of Total Nitrogen ranged from 0.57% in IOE to 0.42% in UTE and available P values ranged from 6.5% in IOE to 7.31 in UTE and were moderate based on the ratings of Udo *et al.,* (2009). This suggests that the soils were fragile and of inherently low fertility. Umoh *et al.,* (2018)observed high leaching loss of exchangeable K in coastal plain sand soils and attributed this to the sandy texture of the soils.The effective cation exchange capacity ranged from 4.52cmolkg^{-1} (UTE) < 4.57 cmolkg^{-1} (OBA) < 4.89 cmolkg^{-1} (IOE) respectively. The exchangeable bases were below the critical requirement for oil palm production base on the rating of Udo *et al.,* (2009). Base saturation ranged from 73.0% (UTE) to 77.3% (IOE). The variation in the percentage observed could be due to excessive leaching of the bases element in soils. (Umoh *et al.,* 2018; Sunday *et al.,* 2020).

3.2 Levels of exchangeable Ca, Mg and K in the Soil

Table 3 shows the values of exchangeable Calcium (Ca),Magnesium (Mg) and Potassium (K) in the soils. Calcium was the dominant cation with values ranging from 2.01cmol kg^{-1}(IOE) to 1.85 cmol kg^{-1} (OBA). There was a significant difference in the concentration of Mg, Ikot Obong Erong (IOE) having the highest exchangeable Mg of (1.50 cmolkg^{-1}) while Utaewa (UTE) had the lowest concentration of 1.31 cmolkg^{-1} respectively. There were also significant differences in Potassium (K) concentration among the soils. The concentration of K were IOE (1.32)> OBA (1.24)> UTE (1.05) cmol kg^{-1}the value were moderate according to the rating of Udo *et al.,* (2009). The moderate concentration of Ca, Mg and K may have been due to the accumulation of liter over the years on the surface layer which corroborates with similar work done by Umoh *et al.,* (2021). The higher concentration of K (IOE) could be due to high concentration of Ca and Mg which may competes with K^+ on adsorption sites and displaced K to release in soils (Schneider *et al.,* 2016). The low concentration of K observed in UTE could be linked to the displacement of this mobile K^+ to leaching. This observation is in agreement with the findings of Umoh *et al.,* (2018) and Umoh *et al.,* (2022) who revealed high release and leaching of K in soils of Obioakpa due to high concentration of Ca and the sandy nature of the soil.

3.3 Concentration of Ca, Mg and K in Plant

Table 4 shows the concentration of Ca Mg and K in the leaves of the oil palm. The exchangeable Ca concentration were significantly different within the soils. The trend were 3.59 (UTE) > 3.29 (IOE) > 3.03mgkg-1) (OBA). Magnesium (Mg) concentration in UTE and IOE were statistically similar. Values ranging from 2.07 OBA to 2.79 mgkg^{-1} in UTE while potassium concentration were similar ranging from 1.51mgkg^{-1} (OBA) to 1.94 mgkg^{-1} (UTE). This observation indicated that the soils cations contributed positively to uptake of Ca Mg and K in plant, as the ratio of Ca:Mg 3:1 to 5:1 and K:Mg 1:1 is the normal range for this soils rated by Udo *et al.,* (2009) and also indicated that above the ranged will cause inhibition of Mg and P and below the ranged deficiency of Ca occurs. This result conform with the report Umoh *et al.,*(2015) and Umoh *et al.,* (2016) for sandy soils

3.4 Correlation of soil properties and nutrient accumulation in plant

The link between the soil properties and nutrient accumulation in plant is presented in Table 5. Silt, Clay, pH, EC, OM, EA and Exchangeable Ca, Mg and K correlated negatively with sand this contributing to the acidic nature of the soil. Organic matter (OM) correlated positively with silt and clay showing that, organic matter contributed positively to the increase content of silt and clay – Calcium (Ca), Magnesium (Mg) and Potassium (K) in soil correlated positively with Ca (plant), Mg (plant) and K (plant) showing that, the exchangeable Ca^{2+}, Mg^{2+} and K^+ in soils contributed to the uptake of Ca, Mg and K. Similar finding was observed by Peter *et al.,(* 2019).

3.5 Regression of nutrients in plant with the soil properties

Table 6 shows the regression of nutrients in plants with the soil properties. Calcium (Ca^+) in plant increased as EC increases by a factor of 11.6 and the intercept (2.735) which is the amount of Ca that would have been obtained if the values of EC was 0., Mg in plant increased as EC increases by a 1.670 with the highest R^2 values of 86.79., Mg in plant increased as exchangeable magnesium increases by a factor of 4.83, Mg in plant also increased with increasing exchangeable K by a factor 2.070, Potassium (K^+) in plant increased with increasing Electrical conductivity (EC) by a factor of 1.165 with the lowest R^2 values of 48.49 which shows a weak relationship with K uptake in the plantation site. Similar finding was observed by Peter *et al.,* (2019).

Table 2: Some physicochemical properties of soils at the studied locations

Location	Sand	Silt	Clay	Texture	pH H_20 (1:2.5)	EC	OM	TN	AV.P	EA	ECEC	BS
	%	%	%			dSm^{-1}	%	%	%	$Cmolkg^{-1}$	$Cmolkg^{-1}$	%
IOE	94.47a	2.20b	3.33c	Sand	4.57b	0.057b	1.92b	0.57b	6.5b	1.44b	4.89a	77.3a
OBA	88.47b	3.07ab	8.47b	Sand	4.97a	0.052c	3.33a	0.62a	6.8b	1.48b	4.57b	75.5b
UTE	85.13c	4.00a	10.87a	Sand	4.89b	0.063a	3.36a	0.60a	7.3a	1.67a	4.52b	73.0c

Means that do not share a letter are significantly different

EC – Electrical Conductivity, OM – Organic Matter, EA – Exchangeable Acidity, IOE – Ikot Obong Edong , OBA – Obio Akpa, UTE – Uta-ewa

Table 3: Concentration of Ca, Mg and K in the soils studied

Location	Ca	Mg	K
	←	$cmolkg^{-1}$	→
IOE	2.01b	1.50a	1.32a
OBA	1.85c	1.43b	1.24b
UTE	2.13a	1.31c	1.05c

Means that do not share a letter are significantly different

Ca – Calcium, Mg – Magnesium, K – Potassium IOE – Ikot Obong Edong , OBA – Obio Akpa, UTE – Uta-ewa

Table 4: Concentrations of Ca, Mg and K in the leaves of the oil palm

Location	Ca	Mg	K
	←	mg kg^{-1}	→
IOE	3.29b	2.72a	1.85a
OBA	3.03c	2.07b	1.51a
UTE	3.59a	2.79a	1.94a

Means that do not share a letter are significantly different

Ca – Calcium, Mg – Magnesium, K – Potassium IOE – Ikot Obong Edong , OBA – Obio Akpa, UTE – Uta-ewa

Table 5: Correlation of soil properties and nutrient accumulation in plant

	Sand	Silt	Clay	pH	EC	OM	EA	Ex. Ca	Ex. Mg	Ex. K	Ca(plant)	Mg(plant)
Silt	-0.931**											
Clay	-0.995**	0.890**										
Ph	-0.771*	0.616*	0.795*									
EC	-0.04	0.216	-0.009	-0.547								
OM	-0.890**	0.832**	0.885**	0.816**	-0.247							
EA	-0.931**	0.752*	0.957**	0.880**	-0.269	0.888**						
Ex. Ca	0.197	0.053	-0.26	-0.115	0.079	-0.177	-0.377					
Ex. Mg	-0.264	0.167	0.285	0.569	-0.727*	0.572	0.450	-0.213				
Ex. K	-0.053	0.168	0.02	-0.326	0.697*	-0.198	-0.179	0.130	-0.636			
Ca(plant)	-0.373	0.495	0.332	-0.149	0.848**	0.118	0.077	0.046	-0.581	0.837**		
Mg(plant)	0.072	0.089	-0.114	-0.548	0.932**	-0.366	-0.366	0.230	-0.813**	0.848**	0.866**	
K(plant)	-0.156	0.45	0.072	-0.31	0.696*	-0.025	-0.156	0.427	-0.525	0.446	0.554	0.579

** significant at 1% level of probability , * significant at 5% level of probability

EC – Electrical Conductivity, OM – Organic Matter, EA – Exchangeable Acidity, Ex. Ca – Exchangeable Calcium, Ex. Mg – Exchangeable Magnesium, Ex. K – Exchangeable Potassium, Ca – Calcium, Mg – Magnesium, K – Potassium

Table 6: Regression of nutrients in plants with the soil properties

Dependent variable	Independent Variable	Regression equation	R^2 (%)
Ca(plant)	EC	Ca(plant)=2.735 + 11.61 EC	71.88
Mg(plant)	EC	Mg(plant)=1.670 + 17.50 EC	86.79
Mg(plant)	Ex.Mg	Mg(plant)=4.827 - 1.011 Ex. Mg	66.12

Mg(plant)	Ex. K	Mg(plant)=2.070 + 0.517 Ex. K	71.92
Mg(plant)	Ca(plant)	Mg(plant)=-1.398 + 1.188 Ca(plant)	75.05
K(plant)	EC	K(plant)=1.164 + 12.33 EC	48.49

Ca – Calcium, Mg – Magnesium, K – Potassium

EC – Electrical Conductivity, Ex. Mg – Exchangeable Magnesium, Ex. K – Exchangeable Potassium, Ca – Calcium, Mg – Magnesium, K – Potassium

4. Conclusion and Recommendation

The result of the study shows that, the pH of the three plantation were low, values range from 4.57 (IOE) <, 4.97 (OBA) < 4.89 (UTE) indicating a slightly acidic condition. EC, OM were low; the values increase from UTE > OBA > IOE the texture of the soils were sand. The concentration of Ca, Mg and K in soils varies in locations, UTE plantation, had the highest Ca concentration (2.13 $cmolkg^{-1}$)while OBA had the lowest (1.85$cmolkg^{-1}$) and were significantly different. IOE had the highest Mg concentration of (1.50) while UTE had the lowest concentration of (1.31 $cmolkg^{-1}$). The potassium (K) concentration were lower in UTE than OBA and IOE. When linking the concentration of Ca, Mg, and K in soil and plant, the concentration were significantly different and values ranged from Ca: (UTE) 3.59 > 3.29 (IOE) and 3.03 $mgkg^{-1}$in OBA: Mg: UTE (2.79 $mgkg^{-1}$) > IOE (2.72$mgkg^{-1}$) > OBA (2.07$mgkg^{-1}$). K: UTE (1.94$mgkg^{-1}$) > IOE (1.85$mgkg^{-1}$) > OBA (1.51 $mgkg^{-1}$). The result also shows that Mg Ca, K ($cmolkg^{-1}$) in soils contributed significantly to uptake of Mg Ca, and K ($Mgkg^{-1}$) in the three plantations. With the low nutrient status of soils and the acidic nature, little lime is recommended to be applied to raise the pH of soil to a levels that will gives optimum yield.

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