EFFECTS OF RATES OF PHOSPHORUS FERTILIZER RATES ON SOIL PHYSICO-CHEMICAL PROPERTIES AND GROWTH PARAMETERS OF MAIZE IN SOIL FORMED FROM DIVERSE PARENT MATERIALS IN AKWA IBOM STATE.

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ABSTRACT
Increasing demand for food crop production for the ever-rising human population still remains a challenge of modern agriculture. However, application of phosphorous (P) fertilizer remains one of the soilmanagement practicesto increase soil available Phosphorousfor efficient crop growth and yield.The aim of this study was to assess the effects of rates of phosphorus fertilizer application on soil physico-chemical properties and growth of maize on soils formed from diverse parent materials in Akwa Ibom state. To achievethis, soils formed from Coastal plain sand (CPS) from Obio Akpa in Oruk Anam, LGA, Alluvium (ALL) from Uta Ewa in Ikot Abasi LGA and Beach ridge sand (BRS) from Ayadehe in Itu LGA were sampled at 0-20cm depth. The experiment was a 3x4 factorial fitted into a completely randomized design (CRD) with four treatments of P fertilizer (0, 0.14mg/kg, 0.28mg/kg and 0.42mg/kg) replicated three times. Data were collected on soil properties before and after experiment.Plant data were collected at 2, 4 and 6 weeks to assess the influence of P on the growth parameters (plant height, number of leaves, leaf area and stem girth). Results indicated that P fertilizer application at 0.42mg/kg improves soil pH, organic matter and available P when compared with the control. Results on the growth parameters shows that P fertilizer application at 0.42mg/kg significantly ($p < 0.05$) increased plant height, numbers of leaves, leaf area and stem growth when compared to control among the treatments and parent materials. It is therefore recommended that 0.42mg/kg of phosphorus fertilizer should be applied on soils of the study area for improve maize production.

Keywords: Phosphorus fertilizer, Maize, Physico-chemical properties and parent materials.

INTRODUCTION
In Nigeria, poor soil fertility and nutrients continue to represent huge obstacles to securing needed harvests (Sanginpa and Woomer, 2009; Ekong and Uduak, 2015: Ijah *et al.,* 2018). With the growth in human and animal populations, the demand for more food production is on the increase. However, the capacity of the soil to produce is limited and production limits are set by intrinsic, agro-ecological setting use and management (Edem *et al.,* 2012).The observations from researchers over the years on soil variation by location-specific field management based on crop performance and crop responses has shifted interest on flexible recommendations rather than on blanket recommendations. Flexible recommendation could be based on variations in soil characteristics that affect productivity and yield responses.Phosphorus is a major limiting factor for crop production on many tropical and sub-tropical soils (Norman *et al*., 1995; Ijah *et al* 2021a) as a result of high P fixation (Umoh *et al.,* 2021) and/or nutrient mining in traditional land-use systems, due to poor accessibility and high cost of soluble P fertilizers for a large population of disadvantaged farmers. Phosphorus deficiency is so acute that plant

growth ceases as soon as the phosphorus stored in the seed is exhausted in some soils of the humid tropics. Many Nigeria soils have available phosphorus (P) levels below critical level of < 8mg/kg and require P fertilizer application (Egwu *et al.,* 2010). Studies by Kolawole *et al.,* (2000) and Zhou *et al.,* (2023)among others, have shown that P fertilizers can significantly increase crop yields (Kolawole *et al.,* 2000). Response to P fertilizer and ultimately maize yield are dependent on factors that influence plant growth such as soil. Different soils based on the variation(Uduak *et al.,* 2017) in their physico-chemical properties (Federal Fertilizer Department Agriculture [FFDA], 2012) lead to different crop response potentials.

Several households in Nigeria depend on cereals (most especially, maize) as one of the important sources of food and nutrition (Fadina and Barjolle, 2018).According to Dadarwal*et al., (*2009) and Edem *et al.,* (2015), maize (*Zea mays* L.) is one of the most important cereal crops in the world, serving as a staple food more than any cereal crop. Maize is a popularcereal in the tropics. In Nigeria, maize is a staple food and one of the most abundant crops (Ayinde *et al*., 2015). Maize has been rated the second grown food crop in Nigeria after cassava, followed by sorghum and rice (FAO, 2013). It is grown extensively in the temperate, subtropical and tropical regions of the world. World total maize production is 1.04 billion tonnes from which USA is the highest (50.4%) producer producing 361 million tonnes, followed by China and brazil (FAO, 2014). Maize crop production contributes to food security, which is mostly preferred to other crops such as sorghum and millet in Nigeria (Sertoglu*et al*., 2017). It is used in livestock feed and also serves as raw material for many agro-based industries (Iken and Anusa, 2004). Maize production plays a key role towards sustainable development of rural economy, food security and poverty reduction in Nigeria (Oyakhilomen, 2014). There is however very few information on the response of maize on different rates of phosphorus fertilizer. Therefore, this study was aimed to assess the effects of rates of phosphorus fertilizer on soil physico-chemical properties and growth parameters of maize in soil formed on diverse parent materials in Akwa Ibom State.

Materials and methods

The Study Area

The experiment was carried out at the screen house of the Department of Soil and Crop science Faculty of Agriculture, Akwa Ibom State University, Obio Akpa Campus, in Oruk Anam Local Government Area of Akwa Ibom State. Geographically, the state is located between Latitude $4^0 30^I$N and $5^0 33^I$N Longitude $7^0 25^I$E and $8^0 25^I$ E and experienced a humid tropical climate with an annual rainfall ranging from 2500 to 3000mm and annual mean temperature of about 26^0C-30^0C with relative humidity ranging between 75 to 79% (Petters*et al.,* 1998). The predominant parent materials in the state are: Shale or Sandstone mostly found in the northern part of the state, coastal plain sand found in the inland part and alluvium found in the coastal region of the state.

Experimental Materials used

The experimental materials used were Oba super 2 yellow maize grains and single superphosphate Fertilizer. Thirty-six polythene bags were purchase and perforated at the bottom to allow for easy drainage and facilitate aeration.

Preparation of Research Materials/ Treatments Allocation/Planting

Composite soil samples were collected at 0-20cm depth of soils formed from three parent materials. Coastal plain sand (CPS), Alluvium (ALL) and Beach ridge sand (BRS) using soil auger. The soil samples were air dried at room temperature grounded and sieve using 2mm sieve to remove debris and stones, 5kg of sieved soil was filled into the polythene bags.

Experimental Layout

The design was a 3 X 4 factorial experiment fitted into a Completely Randomized Design (CRD) with 3 replications giving a total of 36 experimental units.Three seeds of Oba super 2 yellow maize grains were sown per pot and later thinned to one stand per pot. Four levels of phosphate fertilizer 0, 0.14mg/kg, 0.28mg/kg, and 0.42mg/kg per 5kg of soil were applied to specific pots at 2 weeks after planting.

Laboratory Studies

The soil samples were analyzed usingstandard procedures as outlined by Udo *et al* (2009).Particle size distribution was determined by the Bouyoucous hydrometer method. Soil pH was determined in 1:2.5 soil: water ratio with a pH meter. Organic carbon was determined by Walkley Black Dichromate Oxidation Method. Organic matter was obtained by multiplying %OC values with a factor 1.72. Total nitrogen (N) was determined by the micro kjeldahl method. Available phosphorous (P) was extracted by the Bray 2 extraction method, and the content of P was measured using Spectrophotometer. Electrical conductivity was measured in 1:2.5 soil/water suspension using an electrical conductivity meter. Exchangeable bases (K, Na, Ca and Mg) were extracted with 0. I. N ammonium acetate; K and Na were read with a flame photometer while Ca and Mg were determined through the EDTA titration method. Exchangeable acidity was determined by leaching the soils with I N KCl and titrating the aliquots with 0.01 NaOH. Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases and exchangeable acidity. Base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying by 100. Plant data were collected at 2, 4 and 6 weeks to assess the effects of rates of P on the growth parameters (plant height, number of leaves, leaf area and stem girth).

Statistical Analysis

Analysis of variance (ANOVA) for soil and plant data were performed using Genstat 12th edition at 5% level of significance. Mean separation for treatment effects was done by Fisher's protected least significant difference (LSD) test. (Ibanda *et al.*, 2018).

Results and Discussion

Initial Physico-Chemical Properties of the Soil before treatment application

Table 1 shows the initial physico-chemical properties of the soil formed from diverse parent materials before treatment application. Alluvium soils had 72.80% sand content, 12.00 % silt content and 15.20% clay content. Beach ridge soils had 78.80% of sand content, 6.00% Silt content and 15.20% clay content. Coastal plain soils had 80.80% sand content, 6.00% silt content and 13.20% clay content. The textural class of the soils on the diverse parent material was sandy loam. The soil pH ranged from 5.10 (ALL), 5.30 (BRS) and 4.30 for (CPS). This pH level is considered to be moderately acidic. The high acidity could be attributed to high amount of rainfall which might have contributed to leaching (Ijah *et al* 2021b) of exchangeable bases from the top soils. The mean organic matter content of Alluvium soil 5.89%, 1.16% for beach ridge soil and 1.86% in coastal plain soils. The high organic matter content in alluvium soils could be attributed to the seasonal deposition of the organic material from plant debris. Generally, organic matter was high in alluvium soil and low in beach ridge sand and coastal plain soils. Total nitrogen was in the order of 0.280% > 0.056% > 0.098% for alluvium, beach ridge and coastal plain soils. The mean available P was 14.00 mg/kg in the alluvium soils, 6.30 mg/kg in beach ridge soil and 16.60 mg/kg in coastal plains soils. The low available Phosphorus (P) in tropical soils has been attributed to the nature of the chemical forms of P and the high content of the oxides of iron and aluminum associated with high P fixation. Exchangeable calcium was 6.40cmol/kg for alluvium soil, 3.60cmol/kg for beach ridge soil and coastal plain soils respectively. Exchangeable magnesium was 3.20 cmol/kg for alluvium soils and 2.00cmol/kg for beach ridge and coastal plain soil respectively. Exchangeable sodium was 0.154cmol/kg for alluvium soil, 0.074cmol/kg for beach ridge soil and 0.114cmol/kg for coastal plain soils. The mean value for potassium was 0.289cmol/kg for alluvium soil, 0.157 cmol/kg for beach ridge soil and 0.243 cmol/kg for coastal plain soils.The low level of potassium in the soil could be due to high exchange acidity leading to K fixation.The order of the abundance of the cations were Ca > Mg > K > Na. Exchangeable acidity was 2.00 for alluvium soil, 1.28 for beach ridge soil and 1.44 for coastal plain soils.Mean effective cation exchange capacity (ECEC) of coastal plain soils was 12.04cmol/kg, beach ridge was 7.11cmol/kg. Base saturation for Alluvium soils was 83.41%, beach ridge soil had 82.01% while coastal plain soil had 80.50%.

Table 1: Initial Soil Properties before treatment Application

Soil Properties	Alluvium	Beach Ridge sand	Coastal Plain sand
Sand (%)	72.80	78.80	80.80
Silt (%)	12.00	6.00	6.00
Clay (%)	15.20	15.20	13.20
Texture	SL	SL	SL
pH (H_2O)	5.10	5.30	4.30
OC (%)	3.42	0.67	1.08
OM (%)	5.89	1.16	1.86
TN (%)	0.280	0.056	0.098
Av. P (cmol/kg)	14.00	6.30	16.60
Ex. Ca (cmol/kg)	6.40	3.60	3.60
Mg (cmol/kg)	3.20	2.00	2.00
Na (cmol/kg)	0.154	0.074	0.114
K (cmol/kg)	0.289	0.157	0.243
TEB (cmol/kg)	10.043	5.831	5.957
EA (cmol/kg)	2.00	1.28	1.44
ECEC (cmol/kg)	12.04	7.11	7.40
BS (%)	83.41	82.01	80.50

OC=Organic carbon, OM= Organic matter, TN=Total Nitrogen, Av. P=Available phosphorus Ex. Ca=Exchangeable calcium, Mg=Magnesium, Na=Sodium, K=Potassium, TEB=Total Exchangeable Bases, EA=Exchangeable Acidity, ECEC=Effective cation exchangeable capacity, Bs=Base Saturation.

Physico-chemical properties of the soil after treatment application on soils formed from diverse parent materials

The effect of treatment application on soil physico-chemical properties is shown in Table 2. Application of phosphate fertilizer significantly ($p < 0.05$) increased sand content from 78.35-80.53%. Phosphate fertilizer application at (0.14 mg/kg) gave the highest sand content of 80.53% on coastal plain soils. Silt content ranged between 5.56-8.42%. Silt content was reduced with the application of phosphate fertilizer when compared to control. This indicates that responses to fertilizer P at a certain soil test level tend to be greater in sandy soils than on those containing more silt and clay. Clay content ranged from 13.10-13.91%. Silt content at (13.91%) was increased in alluvium soils when (0.14 mg/kg) phosphate fertilizer was applied. In all the study soils, the treatment did not affect the textural class. The pH of the soils was moderately acidic, with values ranging from 4.5 - 4.81 which is considered satisfactory for most crops (Aduayi*et al.,* 2002). Soil pH was increased at (4.81) when phosphate fertilizer (0.28mg/kg) was applied. These pH shows a slight increased with the application of phosphate fertilizer when compared with the control. Coastal plain sand gave the highest pH value of 4.89 among the parent materials. Organic matter was increased at (2.74%) with the application of phosphate fertilizer at 0.42 mg/kg in alluvium soils. Increased application of phosphate fertilizer and P availability increased the organic matter content of the soil. Application of phosphate fertilizer at 0.14 mg/kg increased soil nitrogen at (0.16g/kg) in alluvium soils. Generally, the treatment did not increase total nitrogen in the soil. Av. P at (14.26 mg/kg) was increased when 0.42 mg/kg of P fertilizer was applied in coastal plain sand. The available P in the soils were high, above the critical values of 12-15mg/kg proposed for most crops (Brady and Weil, 2002). Application of phosphate fertilizer at (0.28 mg/kg) increased Ex. Ca (4.8cmol/kg) in alluvium soils. Ex. Mg was increased (2.36cmol/kg)when phosphate fertilizer at 0.28mg/kg was applied in alluvium soils. Applicationof phosphate fertilizer at 0.28mg/kg and 0.42 mg/kg increased Ex. Na and K at (0.10 and 0.21cmol/kg) among the treatments respectively when compared to thecontrol. Among the parent materials alluvium soil gave the highest effect of P fertilizer application. Soil exchangeable acidity was increased to (1.70cmol/kg) on alluvium soils among the parent materials. 0.42cmol/kg of phosphate fertilizer application gave the highest ECEC (8.99cmol/kg) on alluvium soils. Generally, irrespective of the rate, the treatment increased the ECEC in all the soils studied.Base saturation was increased to 87.10cmol/kg at 0.28mg/kg phosphate fertilizer application on beach ridge soils.

Table 2:Physico-chemical properties of the soil after treatment application and on diverse parent materials OM=Organic

Treatment	Sand (%)	Silt (%)	Clay (%)	pH	OM (g/kg)	TN (g/kg)	Av. P (mg/kg)	Ex. Ca (cmol/kg)	Ex. Mg (cmol/kg)	Ex. Na (cmol/kg)	K (cmol/kg)
T1	78.35	8.42	13.10	4.51	2.32	0.12	9.97	3.87	1.74	0.07	0.19
T2	80.53	5.56	13.91	4.63	2.46	0.16	11.61	4.41	2.13	0.08	0.19
T3	80.19	6.65	13.11	4.81	2.60	0.14	12.29	4.83	2.36	0.10	0.21
T4	80.24	6.63	13.13	4.77	2.74	0.14	14.26	4.81	2.26	0.10	0.21
P(<0.05)	0.383	0.792	0.782	0.029	0.030	0.035	0.026	0.062	0.162	0.001	0.004
BRS	83.59	3.01	13.36	4.73	1.19	0.06	6.60	4.012	1.97	0.091	0.17
ALL	71.65	13.94	14.31	4.42	4.30	0.24	10.61	5.335	2.40	0.097	0.26
CPS	84.23	3.51	12.26	4.89	2.10	0.12	18.87	4.107	2.007	0.087	0.18
P(<0.05)	0.332	0.686	0.678	0.025	0.026	0.031	0.023	0.054	0.140	0.001	0.003

matter, TN=Total nitrogen, Av. P=Available phosphorus, Ex. Ca=Exchangeable calcium, Mg=Magnesium, Na=Sodium, K=Potassium, TEB=Total Exchangeable bases, EA=Exchangeable acidity, ECEC=Effective cation exchangeable capacity, Bs=Base saturation. T1= Control, T2=0.14mg/kg, T3=0.28mg/kg, T4=0.42mg/kg. BRS= Beach Ridge Soil, ALL= Alluvium Soil, CPS= Coastal Plain Soil.

Effect of treatment on plant height on soils formed from diverse parent materials

Table 3 shows the effect of treatment application on plant height on soils formed from diverse parent materials at different weeks. Phosphate fertilizer application at 0.42mg/kg significantly ($p < 0.05$) increased plant height and gave the highest result in week 2, 4 and 6 when compared to the control. The result obtained shows the following values 17.72 > 17.56 > 17.22 > 13.28 for week 2, 30.89 > 28.33 > 30.67 > 20.22 for week 4, and 47.30 > 43.40 > 43.30 > 29.00 for week 6. For the parent material the result gave the following values 20.29 > 14.83 > 14.21 for week 2, 30.00 > 26.60 > 26.00 for week 4 and 47.33 > 37.25 > 35.79 for week 6 on coastal plain soil, alluvium and beach ridge soils respectively. Plant height shows a continuous increase in weeks, this is because high P supply is particularly important for stimulating early root formation and growth. This result agrees with that of Ademba*et al* (2015).

Table 3: Effect of treatment on plant height on soils formed from diverse parent materials

Treatment	Week 2	Week 4	Week 6
T1	13.28	20.22	29.00
T2	17.22	30.67	43.30
T3	17.56	28.33	43.40
T4	17.72	30.89	47.30
p(< 0.05)	2.28	6.13	8.12
BRS	14.21	26.0	35.79
ALL	14.83	26.6	37.25
CPS	20.29	30.0	47.33
p (< 0.05)	1.97	5.31	7.04

T1= Control, T2=0.14mg/kg, T3=0.28mg/kg, T4=0.42mg/kg. BRS= Beach Ridge Soil, ALL= Alluvium Soil, CPS= Coastal Plain Soil.

Effect of treatment on number of leaves on soils formed from diverse parent materials

Table 4 shows the effect of treatment application on number of leaves on soils formed from diverse parent materials at different weeks. Phosphate fertilizer application (0.42mg/kg) shows significant ($p < 0.05$) increased on number of leaves at week 2, 4 and 6 and on the diverse parent materials. The result obtained gave the following values of 5.44 > 5.11 > 4.89 > 4.44 for week 2, 7.22 > 6.56 > 6.89 > 5.67 for week 4, and 8.00 > 8.22 > 7.33 > 6.33 for week 6. For the parent material the result was in the order of 5.58 > 4.25 > 5.08 for week 2, 7.08 > 6.58 > 6.08 for week 4 and 8.41 > 7.41 > 6.58 for week 6 in coastal plain soil, alluvium and beach ridge sand respectively. The increased in the number of leaves was as a result of adequate P available for plant uptake. The increase in number of leaves also stemmed from the same reason advanced for plant height of maize. Naomi *et a*l.,(2021) also reported increase in number of leaves in maize from application of phosphorous.

Table 4: Effect of treatment on number of leaves on soils formed from diverse parent materials

Treatment	Week 2	Week 4	Week 6
T1	4.44	5.67	6.33
T2	4.89	6.89	7.33
T3	5.11	6.56	8.22
T4	5.44	7.22	8.00
P(< 0.05)	0.85	1.41	1.34
BRS	5.08	6.08	6.58
ALL	4.25	6.58	7.41
CPS	5.58	7.08	8.41
P(< 0.05)	0.74	1.22	1.16

T1= Control, T2=0.14mg/kg, T3=0.28mg/kg, T4=0.42mg/kg. BRS= Beach Ridge Soil, ALL= Alluvium Soil, CPS= Coastal Plain Soil.

Effect of treatment on stem girth on soils formed from diverse parent materials

Table 5 shows the effect of treatment application on stem girth on soils formed from diverse parent materials at different weeks. P application at 0.42mg/kg gave the highest result in week 2, 4 and 6 and on the diverse parent material when compared with the control. The result obtained was 1.75 > 1.74 > 1.58 > 1.47 for week 2, 2.32 > 2.22 > 2.27 > 1.75 for week 4, and 2.70 > .63 > 2.47 > 2.16 for week 6. For the parent materials the result obtained was 2.07 > 1.55 > 1.30 for week 2, 2.45 > 2.10 > 1.87 for week 4 and 2.87 > 2.47 > 2.13 for week 6 in coastal plain sand, alluvium and beach ridge sand respectively. The increase in stem girth could be attributed to high P supply. The result obtained is in consonant with that reported by Noami *et al.,* (2021)

Table 5: Effect of treatment on stem girth on soils formed from diverse parent materials

Treatment	Week 2	Week 4	Week 6
T1	1.47	1.75	2.16
T2	1.58	2.27	2.47
T3	1.74	2.22	2.63
T4	1.75	2.32	2.70
p(<0.05)	0.20 NS	0.26	0.39
BRS	1.30	1.87	2.13
ALL	1.55	2.10	2.47
CPS	2.07	2.45	2.87
p(<0.05)	0.17	0.23	0.34

T1= Control, T2=0.14mg/kg, T3=0.28mg/kg, T4=0.42mg/kg. BRS= Beach Ridge Soil, ALL= Alluvium Soil, CPS= Coastal Plain Soil.

Effect of treatment on leaf area on soils formed from diverse parent materials

Table 6 shows the influence of treatment application on leaf area and on diverse parent material at different weeks. Phosphate fertilizer application at (0.14mg/kg) gave the highest leaf area at week 2 in the order of 68.6 > 67.0 > 61.5 > 44.00 when compared to the control soil. Application of phosphate fertilizer at (0.42mg/kg) gave a significant ($p < 0.05$) increased at week 4 and 6 and on the diverse parent materials when compared to the control. The result was in the order of 151.0 > 132.7 > 130.3>60.30 for week 4, and 168.20 > 135.10 > 141.10 > 51.20 for week 6. For the parent material the result gave the following 70.40 > 65.20 > 45.20 for week 2, 166.8 > 111.9 > 77.0 for week 4 and 173.40 > 127.90 > 0.30 for week 6 in coastal plain sand, alluvium and beach ridge sand respectively. The result obtain from this study is in line with the report of Arubalueze (2016) that application of phosphorus significantly increased leaf area per plant.

Table 6: Effect of treatment on leaf area on soils formed from diverse parent materials

Treatment	Week 2	Week 4	Week 6
T1	44.0	60.3	51.20
T2	68.6	132.7	141.10
T3	67.0	130.3	135.10
T4	61.5	151.0	168.20
P(< 0.05)	28.25 NS	34.19	36.51
BRS	45.2	77.0	70.30
ALL	65.2	111.9	127.90
CPS	70.4	166.8	173.40
P(< 0.05)	24.46 NS	29.61	42.16

T1= Control, T2=0.14mg/kg, T3=0.28mg/kg, T4=0.42mg/kg. BRS= Beach Ridge Soil, ALL= Alluvium Soil, CPS= Coastal Plain Soil.

Conclusion

Results obtained from this study indicated that application of P fertilizer at 0.42mg/kg increased soil pH, organic matter, available P,plant height, number of leaves, leaf area and stem girth. Among the parent material studied coastal plain sand gave the best response to P fertilizer application. It is therefore recommended that farmers in the study area should apply P rates (0.42mg/kg) for sustainable maize production.

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