Direct RESEARCH JOURNALS

Vol.5 (2), pp. 88-95, February 2017
ISSN 2354-4147
International Standard Journal Number (ISJN) e-ISJN: A4372-2604
Article Number: DRJA22560476

Direct Research Journal of Agriculture and Food Science
http://directresearchpublisher.org/aboutjournal/drjafs

ISJN

Research Paper

Effect of algae on phosphorus sorption characteristics of an ultisol of Southeastern Nigeria

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Received 2 December 2016; Accepted 30 December, 2016

A pot experiment was carried out in a Green House at Michael Okpara University of Agriculture, Umudike, to investigate the phosphorus sorption characteristic of soil treated with algae. The experiment was a 2×2 factorial in completely randomized design and soil samples were collected from 0-20 cm depth of a sandy-loam soil from the University Research farm. The treatment comprised of five rates (0, 1, 2, 3 and 4 t/ha) algae and each treatment replicated three times giving a total of fifteen observational units. The data generated from the sorption studies were fitted into Freundlich model and from P-sorption isotherms, the Standard Phosphorus Requirement (SPR) of these soils were calibrated. Results showed that application of algae to the soils increased the soils available phosphorus which in-turn influenced the SPR of these soils. The SPR values ranged from 90 mg/kg in the control to 10 mg/kg in the 4 t/ha algae treated soil which showed an inverse relationship between the SPR and the rate of application of algae. Results also showed that, the P-sorption capacity, the affinity coefficient (bonding energy) and the maximum buffering capacity (MBC) were lowest in the 4 t/ha algae treated soil. It is therefore recommended that to satisfy the phosphorus need of both soil components and plant nutrition, 4 t/ha algae should be applied in ultisols of southeastern Nigeria for sustainable crop production.

Key words: Phosphorus sorption isotherm, Algae, P-sorption energy, maximum buffering capacity.

INTRODUCTION

In tropical soils, phosphorus has been identified as one of the most limiting nutrient element in crop production due to its high demand to satisfy the need of both plants and soil components, such as the clay minerals and the sexquoxides (Osodeke, 2000). The reaction of PO_4 with soil components have been extensively studied from the point of view of soil fertility, soil chemistry and environmental concern (Sanyal and de Datta, 1999).

Phosphorus sorption in the highly weathered soils of most tropics has been attributed to different forms if Al and Fe oxides and other soil properties (Osodeke and Uba, 2005). The affinity with which the soil colloids attract P from the solution is stronger than the energy with which P is held in the solution and therefore P tends to be deficient in most tropical soils (Osodeke, 2000). Phosphorus sorption capacity describes the capacity of soils to adsorb and retain P within the soil colloids and the higher the capacity, the less the available P and hence, the higher the standard phosphorus requirement (SPR) for such soils to support optimum crop growth (Beauchemi and Simard, 1999). Research into management practices to reduce high P sorption, and thus, to increase P availability in the highly weathered ultisols of southeastern Nigeria remain highly imperative. The application of organic inputs has proved to be an effective and sound management practice to reduce PO_4 sorption and thereby increase P availability in these soils (Agbede, 2009).

Decomposition of organic matter liberates P which participates in the equilibrium reaction between free and adsorbed P ions. The presence of organic matter may also reduce P fixation by forming coatings around sexquoxides, thus, preventing them from complexing with phosphate ions (Agbede, 2009). Algae which are the major biological components of the soil have been found to enrich the soil with organic matter and other nutrients especially phosphorus (Eneje and Azu, 2009). Through decomposition, algae are able to produce organic acids and other decomposition products which may dissolve or displace fixed phosphate from rocks and soil minerals and thereafter release it to the soil pool of available phosphorus (Joseph, 2007).

Understanding phosphorus dynamics in soils and the relationship between the application of algae and phosphorus adsorption in soils will aid researchers and farmers in formulating viable P-management strategies that will ensure sustainability of crop production in southeastern Nigeria.

MATERIALS AND METHODS

This study was conducted in the green house of Michael Okpara University of Agriculture, Umudike located within latitude 5°29N and longitude 7°35 E in the southeast agro-ecological zone of Nigeria. The elevation is about 122 m above sea level. The climate and vegetation types are generally humid tropical rainforest with mean daily temperature range of 20 to 35°C The area is characterized with relative humidity of about 72% (Odurukwe *et al.,* 1995). Current mean temperature of the area is 32°C while the mean minimum is 21°C, and annual rainfall total exceeding 35000 mm (Njoku, 2006). The dominant soil type in Umudike has been classified as Haplic Acrisol (FAO/UNESCO, 1988) and the parent material is coastal plain sand (FPDD, 1990). These soils are usually acidic, have low CEC, low base saturation and of low fertility status (Onwuka *et al.,* 2007). Their prominent clay type is kaolinite (Okwunami, 1981). These soils are highly weathered with low available P and have high fixation capacity for P (Udo and Uzo, 1972).

Soil sample and sample preparation

The bulk soil sample was collected from Michael Okpara University of Agriculture, Umudike Research farm at a depth of 0-20 cm. This was air-dried and sieved using 2 mm sieve, after which sub-sample of 5 kg each were weighed into fifteen 12-litre capacity plastic buckets, perforated at the bottom.

Algae

The algae were collected from the irrigation path beside the University Research Farm and other fresh water habitats within Abia State. These were air-dried, crushed and passed through 2 mm sieve.

Pot experiment

The treatments comprised 5 rates (0,1,2,3 and 4 t/ha) of algae which is equivalent to (0, 142.9, 285.7, 4285.7 and 571.4 g/bucket). These were randomly assigned to each experimental bucket and each treatment was replicate three times given a total of fifteen observational units. The algae were applied by thoroughly mixing with the soils and watered appropriately for two months before sampling.

Sorption studies

The P-sorption characteristics of soils were determined after two months of algae application by equilibrating 3 g of each of the soils in 30ml of 0.01M $CaCl_2$ containing the following initial P concentrations as KH_2PO_4; 0, 5, 10, 20 ppm in 50 ml centrifuge tubes for five days at room temperature as described by Fox and Kamprath (1970). Three drops of toluene were added to each of the sample to suppress microbial growth. The samples were shaken twice daily for 30 minutes. At the end of five days, the suspension was centrifuged at 1600rpm for 15 minutes and P in the supernatant solution determined by the method of Murphy and Riley (1962). Sorbed P was calculated based on the difference between the initial solution concentration and the concentration in the filtrate. From the results, Standard P-Requirement, phosphate adsorption maximum and P-buffering capacity were determined using Freundlich model.

The Freunlich model: $x/m = aC^n$

Where x/m = amount of P sorbed x = mass of adsorbate m = mass of adsorbent

a = P sorption capacity

n = P sorption energy

c = P concentration in equilibrium solution

The Standard Phosphorus Requirement (SPR) of the soils were calculate from the P sorption isotherms as the amount of P sorbed at 0.2 mg/kg equilibrium P solution

Table 1. Physical and chemical properties of the soil for the study.

Properties	Values
Sand (%)	82.90
Silt (%)	8.80
Clay (%)	8.40
Textural class	Loamy sand
pH (H_2O)	5.01
pH ($Cacl_2$)	4.12
Organic carbon (%)	1.13
Organic matter (%)	1.95
Total Nitrogen (%)	0.103
Av. P (mg/kg)	15.12
Ca (cmol/kg)	2.00
Mg (cmol/kg)	1.10
K (cmol/kg)	0.11
Na (cmol/kg)	0.09
E.A (cmol/kg)	1.46
ECEC (cmol/kg)	4.76
B.S (%)	69.33

Table 2. Chemical properties of the algae used for the study.

Properties	Values
pH (H_2O)	8.86
pH ($Cacl_2$)	7.92
Available phosphorus	19.04
Nitrogen (%)	0.28
Calcium (%)	6.66
Magnesium (%)	2.81
Potassium (%)	0.53
Sodium (%)	0.09
Organic carbon (%)	2.03

concentration (Juo and Fox, 1977).

RESULTS AND DISCUSSION

Physical and chemical properties of the soil for the study

The physical and chemical properties of the soil used for the study is presented in (Table 1). The textural class was loamy sand with silt content below 10% and sand above 80% indicating that the soil is porous and thus could encourage nutrient loss through leaching (Brady and Weil, 2006). According to Lekwa and Whiteside, (1986), soils with high content of sand (80% and above) are generally porous, with high infiltration rate, fragile and therefore prone to erosive forces. The soil was acidic with values of 5.01 and 4.12 in water and $Cacl_2$ respectively. These value are below the pH range of 5.5-5.7 proposed by Raemaekeu (2001) for crop production in the tropics. Organic carbon was low with value of 1.30%, indicating low fertility since organic carbon content reflects the fertility status (Woomer and Ingram, 1990). The total nitrogen had a value of 0.10% which is less than the critical value of 0.15% reported by Adeoya and Agbola, (1984) for soils of humid tropical regions. The soil showed a medium level of phosphorus which is slightly higher than the critical level of 15 mg/kg for most crops (Osodeke and Ubah, 2005). Generally, the soil indicated low content of basic cations, while the total exchangeable acidity was relatively high. The effective cation exchange capacity was low and the percent base saturation was 69.33%. Several researchers (Osodeke and Ubah, 2005; Eneje and Azu, 2009; Onwuka et al., 2007) have also reported similar characteristics for soils of Umudike. Table 2 shows the chemical properties of the algae used for the study. Results showed that the algae contained high amount of nitrogen, phosphorus, calcium and magnesium, but moderately low in potassium and sodium. The pH was high indicating the ability of algae to reduce acidity in soils. This corroborates with the findings of Eneje and Azu, (2009) who reported high phosphorus, nitrogen and pH of some algae investigated in southeastern Nigeria. This high nutrient content in algae will have the potential of establishing greater improvement on soil fertility especially phosphorus fertilization.

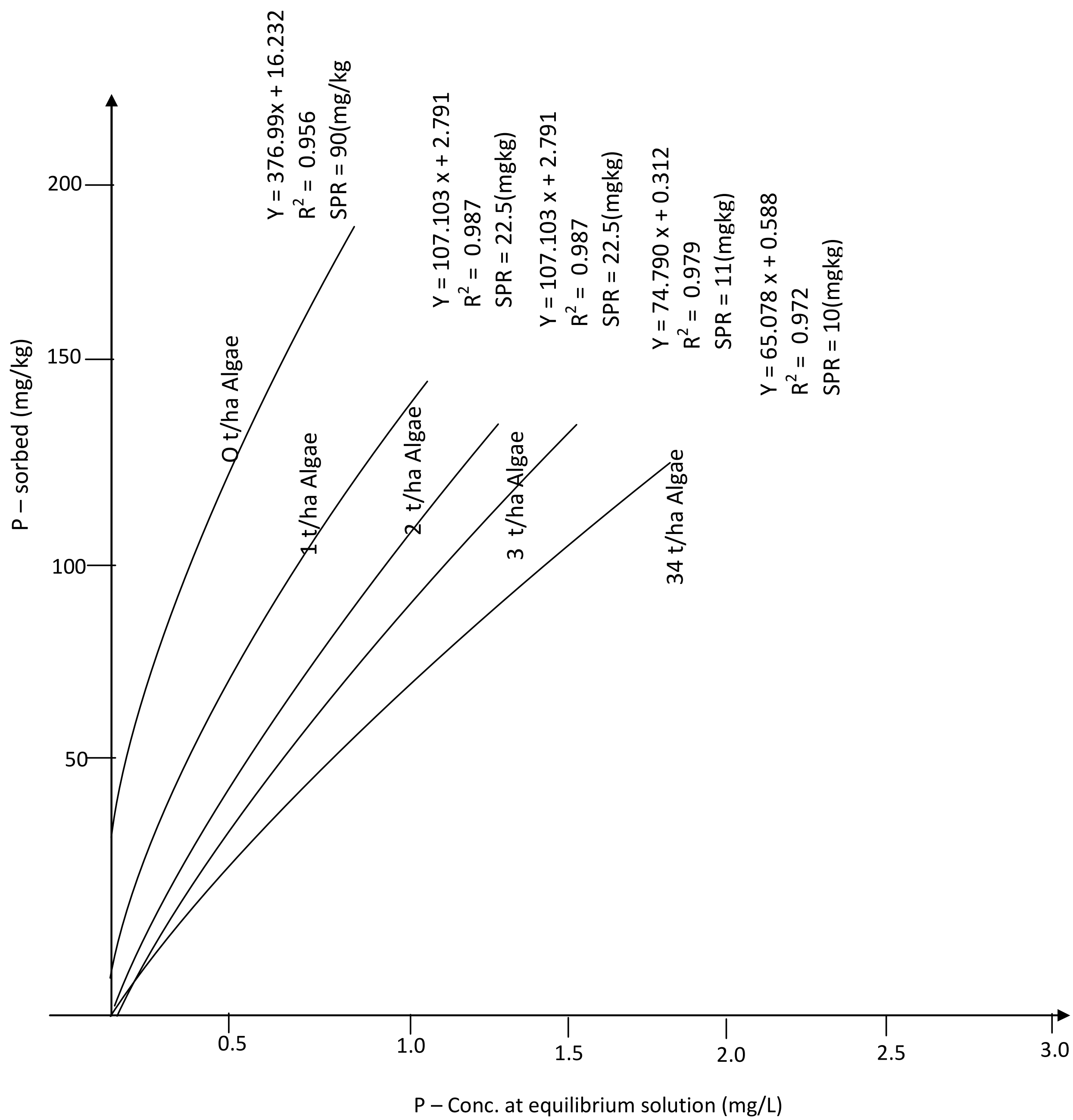

Figure 1. Phosphate sorption isotherm of the soils treated with different rates of Algae.

Phosphorus sorption characteristics of the soil

Sorption isotherm which related the amount of P sorbed to the concentration of P in equilibrium solution is presented in (Figure 1). It is applied in the study of soil phosphorus (Henry and Smith, 2002) and in the determination of standard phosphorus requirement of soils and therefore in recommending P fertilizer rates of soils (Osodeke, 2000). The curves showed that P additions were proportional to the amount of P sorbed until when the sorption sites are saturated. This was shown when each curve tends to flatten and approach maximum indicating that the soils are saturated. The SPR was least at the treatment application of 4t/ha indicating little or no P fertilizer requirement. These observation can be attributed to the fact that algae contains high amount of phosphorus (Eneje and Azu, 2009) which saturated the adsorption sites and thereby reducing P adsorption resulting in the lowering of SPR. The SPR values when compared with the range of values proposed by Jue and

Table 3. Freundlich P sorption parameters.

Treatment (t/ha)	pH (water)	P sorption Capacity (a) mg/kg	P sorption Energy(n) mg/kg	Maximum Buffering Capacity mg/kg	Correlation coefficient (R^2)
0	4.95	263	0.35	91.26	0.524
1	5.24	130	0.21	27.82	0.566
2	5.59	100	0.17	16.60	0.745
3	5.90	98	0.17	16.62	0.76
4	6.03	75	0.19	13.92	0.831

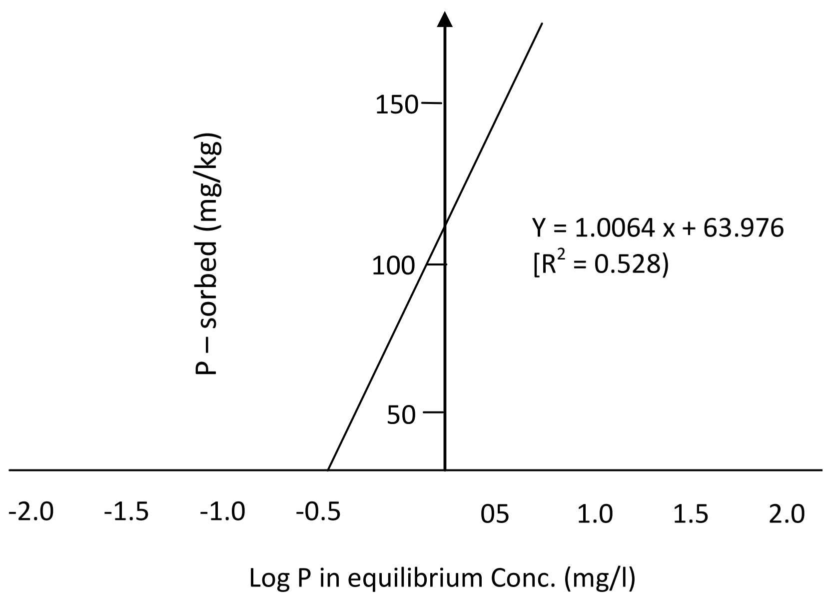

Figure 2. Freundlich Phosphate Isotherm for 0 (ton/ha) Algae.

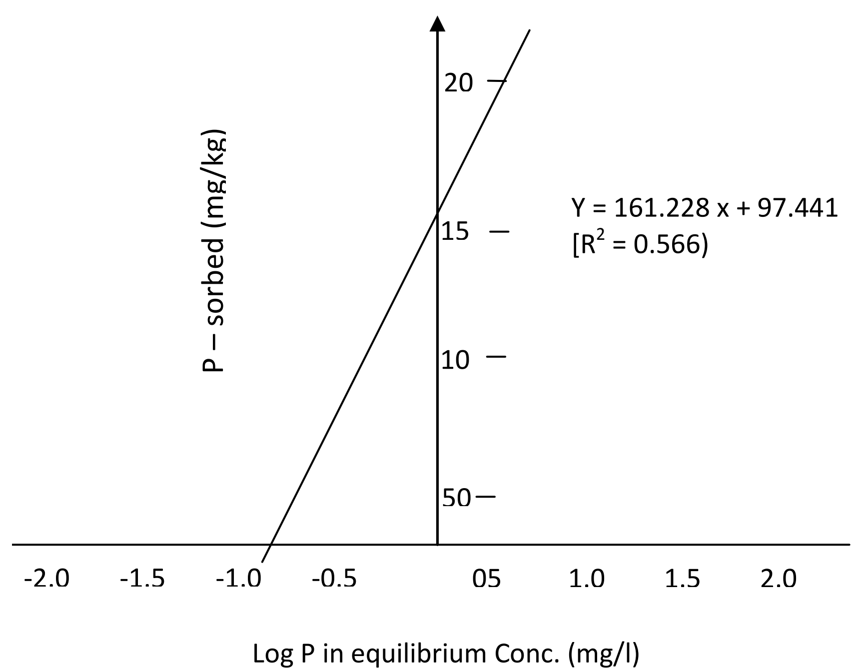

Figure 3. Freundlich Phosphate Isotherm for 1(ton/ha) Algae.

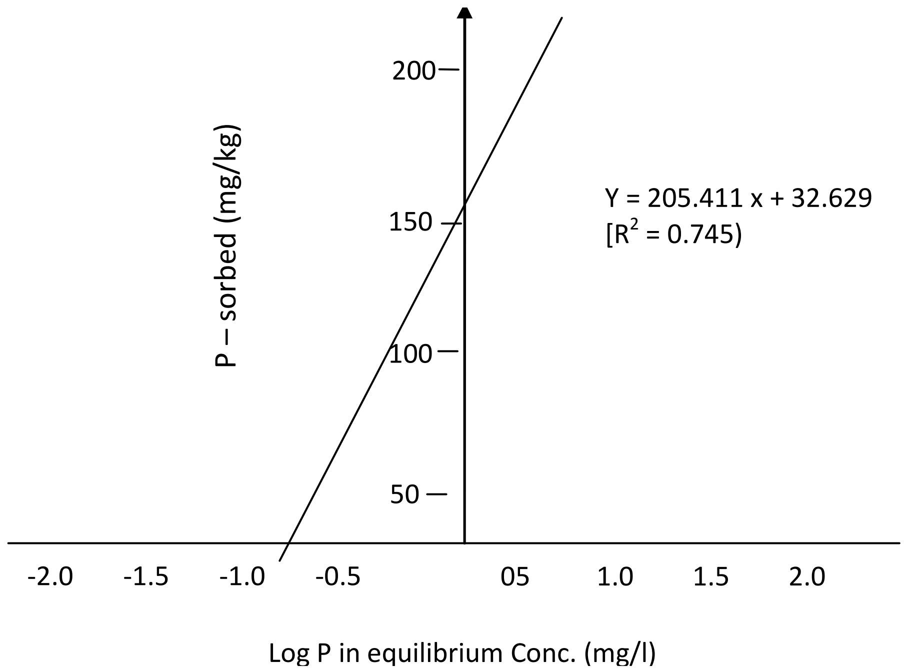

Figure 4. Freundlich Phosphate Isotherm for 2 (ton/ha) Algae.

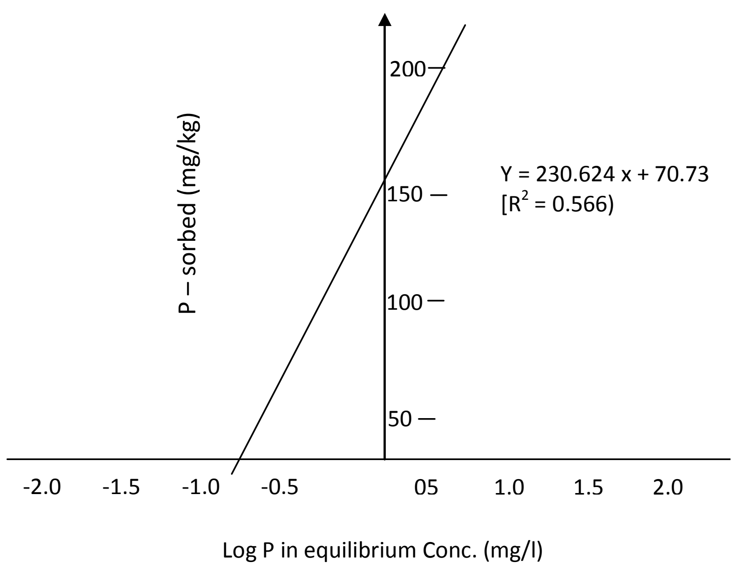

Figure 5. Freundlich Phosphate Isotherm for 3 (ton/ha) Algae.

Fox, (1977), falls within the low and very low category of soil, indicating that the algae were able to add large organic phosphorus to the soils.

Phosphorus sorption parameters using Freundlich model

The linear sorption isotherms were obtained by plotting the amount of P sorbed (x/m) against the logarithm of phosphate concentration at equilibrium solution (log C) as shown in (Figures 2-6). From the Freundlich model, the maximum adsorption capacity, affinity coefficient and maximum buffering capacity of the soils were determined (Table 3). Relative to control, soils modified with algae had the lower values of these parameters and these were inversely proportional to the rate of application. P sorption capacity ranged from 263 mg/kg in control (0 t/ha) to 75 mg/kg in 4 t/ha algae treatment. Similarly, the P sorption energy and the maximum buffering capacity range from

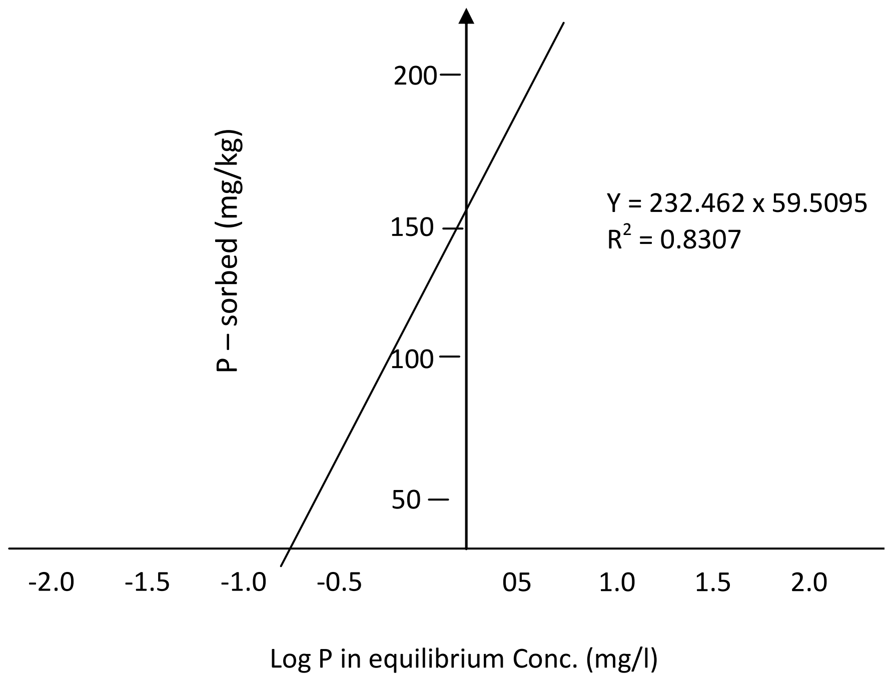

Figure 6. Freundlich Phosphate Isotherm for 4(ton/ha) Algae.

0.35 to 0.19 mg/kg and 91.26 to 13.92 mg/kg respectively. The lowest values of these parameters were obtained in the pot that contained 4t/ha algae while the least values were obtained in the control. Since P availability increases as these parameters decreases, the treatment that had the lowest values of these parameters (4t/ha) is expected to have more available P with little or no P fertilizer requirement for optimum crop production. The low P sorption capacity observed in the soils treated with algae may be attributed to high organic P present in algae (Eneje and Azu, 2009) which helps in saturating the adsorption sites and hence reduction in P sorption. P sorption capacity correlated negatively with soil pH (r = 0.879) indicating that the more the acidity, the more the P sorption and thus the more unavailable P becomes.

Conclusion and recommendation

The results showed that algae treated soils had low P adsorption relative to control indicating low standard P requirement. This is as a result of the high organic P present in algae which saturates the adsorbing sites indicating little or no P fertilizer requirement for these soils. The low P adsorption capacity, low energy of adsorption and low maximum buffering capacity observed in the algae treated soils showed high P availability and it is therefore recommended to apply algae to tropical soils to reduce P adsorption and thus improves P availability in order to achieve optimum and sustainable crop production in southeastern Nigeria.

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