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EFFECT OF LAND-USE PATTERN ON PHOSPHORUS AND POTASSIUM FIXATION AND MAIZE PERFORMANCE

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ABSTRACT

The effect of three different lands-use types for ten years on Phosphorus and Potassium Fixation and maize performance were studied at University Teaching and Research Farm. Soil samples were collected from the different land-use systems; continuous cultivation of arable crops without fertilizer (CC-F), continuous cultivation of arable crops with fertilizer (CC+F), and Fallow.
The samples were subjected to routine analysis and fixation studies in the laboratory. Greenhouse investigation was also carried out for six weeks to evaluate maize performance in the three different land use systems. Data were subjected to analysis of variance. CC+F released the highest amount of Phosphorus (P) while the fallow released more Potassium (K). The K released was a reflection of its high organic matter (4.5%). The continuously cultivated soil without fertilizer (CC-F) had the highest P and K fixation capacity and therefore would require the largest amount of P and K fertilizer for optimum yield than CC+F and Fallow. Dry matter yield of maize correlated with soil organic matter; root weight; Nitrogen (N). P and K uptake; and P and K in solution at zero addition. Significant correlation was only found between yield and organic matter and N uptake for all the soils indicating the importance of these two related parameters for good crop performance. Also significant correlation between yield and root weight was only found in Fallow and not in the cultivated soils since root impedance caused by high bulk density and gravel content probably occurred in the cultivated soils. A continuously cultivated soil thus have high nutrient fixing capacity since continuous cropping rapidly depletes the nutrients on the exchange sites or nutrient reserves of soils and when fertilizer is added to the soil it first replenishes it exchange sites before meeting the needs of crops. Cropping practices therefore play a vital role in determining yield and nutrient release capacity of soil in conjunction with the soil characteristics.

Key words: Land-pattern, Phosphorus, Potassium, Fixation Maize

INTRODUCTION

In Nigeria and Sub-Sahara Africa it has been observed that crop yield declines to less than 25% of the annual yield after about 3 to 4 years of continuous cultivation (Agboola, 1970; Adesina, 2010 and NEPAD, 2010). This has been attributed to changes in physical, chemical, biological soil properties and recent changes in climatic conditions. The nutrient release pattern of the soil could also be a possible reason for a decrease in crop yield. Crop yield is not only affected by the amount of nutrient present in the soil but also by their availability to plants. Soils of Western Nigeria have been known to fix applied or native immobile nutrients like phosphorus, thus making them less soluble and less available to plants (Ayodele and Agboola, 1981; Adeoye, 1986). Phosphorus fixation refers to any change in P while in contact with the soil in terms of solubility, concentration and availability to plants. This factor results in P deficiency in the tropics and a marked reduction in crop yields (Sobulo *et al.,* 1975). Potassium fixation can also be defined as the change of water-soluble K into forms that are neither water soluble or instantly replaceable. The definition of available K is dependent on vegetation and time factors. It is therefore more precise to define fixed K as applied K, which is not immediately replaceable by the usual cation exchange reagents as ammonium acetate. Since this phenomenon of element immobilization or fixation affect the availability of elements to plants (Adeoye, 1986), it is therefore desirable to assess the fixation capacity of soils for essential plant nutrient element. With the introduction of high yielding and fertilizer responsive crop varieties in multiple cropping system, notable changes in the soil available nutrients are likely in a much shorter span of time because of higher levels of fertilization and heavy removal of nutrients by the crops. The availability of nutrients from the soil to plants is therefore known to be affected not only by the inherent soil characteristics but also by the fertilizer use and cropping practices. This paper therefore reports the effects of three different land-use systems on phosphorus and potassium fixation and maize performance in the green house.

MATERIALS AND METHODS

Soils from Barth road, Agronomy Department Experimental Site, University of Ibadan, which had been subjected to the following were studied

CC-F Continuous cultivation with out fertilizer for ten years –

CC+F. Continuous cultivation with N-P-K fertilizer with an annual application of 100N, 30 P and 60 K for ten years.

Fallow. Fallow for ten years.

The soil of the experimental site is an Alfisol (Soil Survey Staff, 1975). Two experiments were carried out namely: Greenhouse experiment to determine the effect of different land-use on dry matter yield, root weight, and nutrient uptake of maize at 6 weeks. Laboratory experiment to determine some physical and chemical properties and P and K fixing capacity of these studied soils.

Greenhouse experiment

Soil samples from 0-15cm were dug up randomly to fit into a two (2) Stripe bucket of 16 cm surface diameter with minimal disturbance to the soil. Ten of such samples were dug up from each land use. The soil samples were then watered and allowed to equilibrate for 24 hours. Four maize seeds were planted per pot and later thinned to 2 seedlings. The plants were harvested at 6 weeks, dried at 70^{o}C in an oven, weighed, ground and analysed for N, P and K. Nitrogen in the plant tissue was determined by the macro Kjeldahl method while P and K were determined by digesting 0.5g of each sample with nitric, perchloric and sulphuric acid mixture. Phosphorus was analysed colorimetrically by the vanado molybdate method and K by flame photometry. Nitrogen, Phosphorus and Potassium uptake were determined by multiplying the concentration of the nutrient in plant tissue by the dry matter yield. The roots were also dried and weighed.

Laboratory experiment

Soils samples from each land-use were analysed for some physical and chemical properties.

(a) Mechanical analysis was carried out using the hydrometer method (Bouyoucous, 1951). The percent gravel was determined by weighing 2 kg of the dried and crushed soil, sieving the soil with a 2 mm sieve and finding the percentage weight of the gravel retrieved after sieving. Bulk density was determined using the core sampler method (Blake, 1965). pH meter in 1:1 soil water ratio determined soil pH. Organic matter was determined by the wet dichromate oxidation (Walkey and Black, 1934). Total nitrogen was determined by the Kjeldahl method of Jackson (1962) and available phosphorus by the Bray P-1 method (Bray and Kurtz, 1945). Exchangeable K was extracted using neutral ammonium acetate and analysed using the flame photometer.

(b) Fixation studies: Solutions containing 0, 35, 70, 140, 280, and 560mg/kg of Phosphorus and 0, 0.11, 0.22, 0.45, 0.90 and 1.80 meq/100ml of potassium were prepared from KH_2PO_4. 2.5g of soil samples was scoped into bottles in racks used for routine soil analysis and 2.5ml of the treatment solution was added. The racks were shaken for thorough mixing of the soil with the treatment solutions. The bottles were then covered with paper and the soils incubated for 1, 7 and 42 days. The samples were kept moist by adding distilled water. P and K were extracted each time from duplicate samples using modified $NaHCO_3$ and the elements determined by routine procedures.
Dry matter yield was later correlated with root weight, organic matter; N, P and K uptake and P and K in solution.

(c) Fractional Recovery: The term Fractional Recovery (FR) was used to mean the proportion of the added P removed by the extraction procedure. The FR also corresponds to the slope of the regression equation between P added and P recovered by the extractant. The linear regression expressing the relationship between FR and rates of P addition was calculated at different incubation period as used by Adeoye (1986).

$Y = a + bx$

where Y= P extracted (mg/kg)
x = rate of P addition in (mg/kg)
a = P extracted at zero addition, and
b = fractional recovery

RESULTS AND DISCUSSION

Table 1 shows the result of some physical and chemical properties of the studied soils. The cultivated soils were light textures with lower silt and clay than the fallow soil. They also have high bulk density of 1.61 g/cm^3 and 1.58 g/cm^3. The soils had pH ranging from 6.7 – 7.2. The fallow soil had higher organic matter (4.5%) than the cultivated 'soils'. Since organic matter is a composite indicator of soil physical, chemical and biological status of soil in the tropics, its decline under continuous cultivation leads to a rapid decrease in soil fertility. The cultivated soils were also found to be low in total N (0.09 and 0.12%). CC+F were high in P (136.64 mg/kg). This could be attributed to P accumulation from previous P fertilizations since during the ten (10) years of cropping 300 kg/ha of P was applied at an annual rate of 30kg/ha. CC-F had higher P (8.36 mg/kg) than fallow soil (5.98 mg/kg). This type of behaviors had earlier been reported by Oko and Agboola (1974) that as soil organic matter declines, most of the organic P is presumably converted to mineral form. Therefore, the extractable inorganic P in most cases would be more than what would be present in such soils under the normal bush fallow system. The fallow soil had the highest K value of 0.82 meq/100g soil

Table 1: Some Physical and Chemical Properties of the Studied Soil

Parameters	CC-F	CC+F	Fallow
Sand %	89.2	85.2	63.2
Silt %	4.8	6.8	18.8
Clay %	6.0	8.0	18.0
Gravel %	33.74	29.09	8.70
Bulk Density (g/cm^3)	1.61	1.58	1.02
pH (H_2O)	6.7	7.2	7.1
Organic matter %	1.78	2.44	4.5
Total N %	0.09	0.12	0.23
Available P (mg/kg)	8.36	136.64	5.98
Exch. K (meq/100g)	0.51	0.24	0.82

CC-F -- Continuously cultivated soil without fertilizer
CC+F -- Continuously cultivated soil with fertilizer
Fallow-- Fallow soil

Fixation studies

The relationship between extractable P and the different rates of P addition at different periods of incubation is presented in Table 2. There was an increasing recovery of P with increasing P addition. The significant 'r' values observed suggest a direct relationship between P added and P recovered. As the incubation time increased the amount of P recovered decreased for cultivated soils CC-F and CC+F and there was a slight desorption at the 42nd day of incubation for the fallow soil.

The term "fractional recovery" is used to indicate the proportion of added P that is extractable at any particular time of incubation and is the slope b, from the linear regression equation relating P recovered to P added (Table 2). The fractional recovery (FR) increased at the 7th day and later decreased at the 42nd day of incubation for unfertilized cultivated soil (CC-F). It decreased sharply till the 7th day and later increased slightly at the 42nd day of incubation for fertilized cultivated soil (CC+F). The FR was almost stable at all times for the fallow soil. The P extracted at zero addition was the highest.

In the fertilized cultivated soil CC+F and the soil also released more P than soils CC-F and Fallow, due to its inherent high P value. The fallow soil had the highest FR with an average of about 0.25, which is about 25% of the added P was extracted. Thus, the fallow soil releases more P per unit P added than the cultivated soils. However, all the soils generally have high P fixing capacities since they have low FR values.

The amount of P required to raise the soil test value by 1 mg/kg was calculated from the relationship Adeoye (1986):

$$\text{P required} = \frac{\text{P added at rate R}}{\text{P recovered at rate R} - \text{P in untreated sample}}$$

These were calculated at all rates of P addition at 42nd day of incubation (Table 3).

The mean value was 3.49 mg/kg with soil CC-F having the highest value of 3.81 mg/kg. This indicates that soil CC-F fixes more P than CC+F and Fallow and therefore needs more fertilizer P to satisfy its exchange sites.

Table 2: The relationship between modified N_aHCO_3 extractable P and Different rate of P addition at different times

	Days								
Soils	1			7			42		
	a	b	r^2	a	b	r^2	a	b	r^2
CC-F	33.21	0.234	0.91**	19.31	0.245	0.97**	13.39	0.227	0.94**
CC+F	56.47	0.200	0.80*	61.54	0.174	0.78*	45.04	0.185	0.85*
Fallow	19.54	0.247	0.90**	6.66	0.248	0.95**	17.91	0.251	0.93**

*Significant at 0.05 level
**Significant at 0.01 level
Extractable P (mg/kg) = a + b (a= amount added); b = fractional recovery

Table 3: Amount of P required for increasing extractable P by 1 mg/kg using fixation study

Soils	42-day incubation Rate of P application in mg/kg					
	35	70	140	280	560	mean
CC-F	4.19	3.89	3.50	2.72	4.73	3.81
CC+F	2.58	3.54	1.70	3.05	5.41	3.26
Fallow	3.62	3.82	2.86	2.37	4.31	3.41
Overall mean						3.49

Potassium

The relationship between extractable K and the different rates of K addition at different periods of incubation is presented in Table 4. There was a general increase in K fixation as the incubation period increased for all the soils. The FR in soil A was low at the 1 day incubation as indicated by the high FR of 0.72 which later increased at the 42nd day of incubation. The fallow soil released more K than the cultivated soils. This could be due to its high organic matter which lower K fixation (Adeoye, 1986).

The amount of K needed to raise the soil test value by 1 ug/ml is shown in Table 5. The values decreased from CC-F to Fallow with mean value of 2.29 ug/ml. The continuously cultivated CC-F was generally found to have the highest P and K fixation and therefore require the highest amount of fertilizer P and K for optimum yield. This could be due to the fact that the exchange sites have been exhausted due to continuous cropping without replenishment of nutrients.

Table 4: The relationship between modified $NaHCO_3$ extractable K (meq/100g soil) and Different rates of K addition at different times

Soils	Days: 1			7			42		
	a	b	r^2	a	b	r^2	a	b	r^2
CC-F	0.58	0.72	0.94**	0.65	0.61	0.99**	0.42	0.47	0.99**
CC+F	0.69	0.57	0.91**	0.53	0.50	0.98**	0.41	0.32	0.99**
Fallow	1.00	0.58	0.97**	1.02	0.46	0.88**	0.68	0.44	0.97**

*Significant at 0.05 level
**Significant at 0.01 level

Table 5: Amount of K required for increasing extractable K by 1 ug/ml using fixation study.

	42 days incubation					
Soils	Rate of k application in meq/100ml					
	0.11	0.22	0.45	0.90	1.80	mean
CC-F	2.75	1.47	3.75	2.37	2.12	2.49
CC+F	2.20	1.75	3.46	4.50	1.80	2.39
Fallow	2.20	2.20	1.25	1.96	2.28	1.91
Overall mean						**2.29**

Table 6 shows the effect of different land use pattern on dry matter yield (DMY), root weight (DRY), nutrient uptake of maize and Phosphorus (P) and Potassium (K) in solution, at zero fertilizer level. The DMY from fallow soil was about 300% higher than that of CC-F, while that of CC+F doubled that of CC-F. This indicates that when a land is just out of a long fallow, the yields are high but it rapidly declines under continuous cultivation. (Agboola and Corey, 1973; Adesina, 2010). The low root weight of maize in the cultivated soils compared to that of fallow could be due to root impedance caused by their high bulk density and gravel content. The cultivated soils especially CC-F had low nutrient uptake. This could be due to their low soil nutrient content and nutrient releasing capacity; reduced nutrient absorption by roots due to root impedance and low soil organic matter. Since organic matter serves as a storehouse of nutrients, therefore the consequent low yield and nutrient release rate of soils CC-F and CC+F is related to low soil organic matter. CC+F had the highest amount of P in solution due to its high P value. CC-F fixed more of it's at the 42nd day while Fallow fixed or converted a great proportion of its P to organic constituents by the 7th day. Fallow had the highest amount of K in solution, which is also due to its high K value and organic matter.

Table 7 shows the coefficient r of correlation between DMY of maize at 6 weeks and root weight, soil organic matter, N, P and K uptake and P and K in solution at zero addition.

There was a significant correlation between yield and root weight only in fallow soil. The lack of significant correlation between yield and root weight in the cultivated soils could be a result of impeded root development brought about by the high bulk density and gravel content of the soils. The relationship between DMY and organic matter was significant in CC-F and highly significant in CC+F and Fallow. This indicates that soil organic matter is a very important yield determinant in the tropics since it is determinant of soil fertility (Agboola and Corey, 1973). There was also a significant correlation between yield and N uptake in all the soils especially fallow soil. This is because N is a very essential element to plants particularly maize and it brings about increase in vegetative growth. Phosphorus and Potassium uptake had positive effect but not significantly correlated with DMY probably because plants do not only make use of available nutrients for growth but also organic nutrients in reserve.

Table 6: Effect of different land use on dry matter yield (DMY) of maize at 6 weeks; root weight (DRW); nitrogen (N); phosphorus (P) and potassium (K) uptake and P and K in solution at zero addition

Soil	DMY (gm)	DRW (gm/pot)	Nutrient uptake by maize (mg/g)			Phosphorus in solution per days (mg/kg)			Potassium in solution (meq/100ml)		
			N	P	K	1	7	42	1	7	42
CC_F	3.10	2.50	3.66	0.77	8.68	20.51	17.23	7.07	0.51	0.64	0.43
CC+F	6.37	3.00	6.05	1.27	21.66	33.63	41.79	25.7	0.58	0.56	0.46
Fallow	9.00	5.30	12.06	1.80	21.60	21.41	9.97	9.00	1.02	1.02	0.64

Table 7: Correlation coefficient (R) between DMY of maize at 6 weeks and root dry weight, organic matter nutrient uptake and P and K in solution at zero addition

	Soils		
Parameters	CC-F	CC+F	Fallow
Root Weight	0.41	0.42	0.63*
Organic Matter	0.70*	0.83**	0.88**
N uptake	0.63*	0.67*	0.82**
P uptake	0.49	0.60	0.53
K uptake	0.37	0.34	0.38
P in Solution			
1day	0.12	0.15	0.04
7days	0.25	0.23	0.33
42days	0.15	0.30	0.15
K in Solution			
1 day	0.13	0.19	0.09
7 days	0.08	0.04	0.09
14days	0.41	0.44	0.30

*, ** - Significant at 5% and 1% level respectively

CONCLUSION

The results of this study indicate that the release of a particular element like P to plants depends on factors such as the soil characteristics, content of the element in the soil, the fixation capacity of the soil for the element and land use system or cropping practices. A soil whose fertility has been lowered due to continuous cropping, if fertilized, will fix a lot of nutrients to satisfy its exchange sites before releasing nutrients to crops. If the fertilizer is not enough, the crops suffer at the end. The fixation capacity of a soil for an element in relations to the type of land use must be considered when applying fertilizer for optimum yield.

However, to maintain good crop performance under continuous cropping, appropriate soil management practices involving organic fertilizer inputs which adequately rejuvenates the soil is essential in the tropics.

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