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Effects of Organic Amendment on Potassium Quantity and Intensity Parameters of Some Soils in Ogun State, Nigeria

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ABSTRACT

The study was conducted to investigate the effects of three animal wastes namely: poultry, cattle and goat manure on the quantity and intensity of Potassium uptake as it relates to maize cultivation in some soils of Ogun State, Nigeria. The investigation was carried out at the screen house of Moshood Abiola Polytechnic's research and teaching farm. The treatments were arranged in a completely randomized design. The animal wastes were applied in the following rates; 50 and 100 g animal waste/5 kg soil equivalent to 0.94 and 1.88 t ha^{-1}. Results indicated that the studied soils were predominantly sandy and slightly acidic. A large portion of K in the studied soils was found in Non-exchangeable form. The quantity and intensity parameters in the studied soils were low before manure application but higher values were observed after manuring, reduction in energy of K-exchange (∆G) was observed in all treatments these increased the K supplying power of the studied soils. Leaf area, dry matter yield and K uptake by maize increased with an increase in rates of manure. Hence, a higher concentration of organic manure can be employed where considerable quantities of K are required and high crop yields are needed.

Keywords: Animal wastes, Quantity, Intensity, Potassium uptake and Maize.

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INTRODUCTION

Potassium (K) plays a significant role in several physiological processes in plants, this makes it a vital nutrient for crops. It has an effect on about 50 enzymes in plants which are responsible for energy transfer, sugars, starch and protein formations (Krauss, 1997). Potassium occurs in four forms in the soils: water soluble, exchangeable, fixed or non- exchangeable and structural or mineral K. The supply of this element from soil depends on the quantity, the form in which it is present and the rate at which the exchangeable K is replenished from non–exchangeable sites of the clay minerals (Riaz et al., 2014). The amount of water-soluble, exchangeable and non-exchangeable forms of K are used to determine the K supplying power of the soil (Adetunji and Adepetu, 1993; Taiwo et al., 2009). Quantity-intensity indicates the level of available K, the intensity (I) is referred to as the activity ratio (ARK) which shows the relationship of potassium ion activity with calcium and magnesium ions activities $(a_K/a_{Ca}+ a_{Mg})^{1/2}$. Sandy soils have low activity ratio but high in clayey soils, quantity (Q) is the amount of exchangeable K readily available to plants, it is high in clayey soils due to high CEC and high clay content (Deligianni et al., 1994). Potential buffering capacity is also a thermodynamic property that shows the possibility of the soil to release K from non-exchangeable form to exchangeable and soluble form when water-soluble K is depleted by crop uptake. In many developing countries like Nigeria, soils are deficient in potassium (K) this makes crops to become so expensive to grow and to have limited yields (Anikwe, 2000). Farmers have limited financial resources and can rarely purchase synthetic fertilizers due to the high cost and unavailability; it was also observed that synthetic fertilizers have a toxic effect on the soil organisms. On the contrary, there is a substantial amount of animal wastes which are regarded as agricultural wastes; that can be turned into fertilizers for crop production at low cost.

In South-Western Nigeria, large quantities of poultry, cattle, pig and goat manures are generated daily, these have given rise to disposal problems (Quansah, 2000). The use of organic manure as a fertilizer releases many important nutrients into the soil and also nourishes soils organisms, which slowly and steadily make minerals available to plants (Stone and Elioff, 1998). It serves not only as sources of plant nutrients but also as soil conditioners by improving soil physical properties such as water infiltration, water holding capacity, aeration, permeability, soil aggregation and root depth, decrease in soil crusting and bulk density (Allison, 1973; USDA, 1978). Par Clacicco (1987) observed that when organic manure of acceptable quality is returned to agricultural soils on regular basis, they contribute greatly to the overall maintenance of soil fertility and productivity, this lessens the need for mineral fertilizers. The Southwestern part of Nigeria is distinguished by intrinsically low soil fertility status and rapid nutrient depletion. However, this zone is distinct by abundant agricultural land with high potential for crop production. In view of this, the present study was conducted to observe the effect of integrated use of agricultural wastes on the quantity intensity parameters and potassium (K)-uptake by maize in some soils of Ogun State, Nigeria.

MATERIALS AND METHODS

Soil Samples Collection

The surface soil (0 to 20 cm) samples were collected from six (6) different locations which have slight differences in their latitudes and longitudes; (i) Funaab (7.22'N; 3.43'E), (ii) Osiele (7.21'N;3.37'), (iii) Alabata-estate (7.20'N; 3.47'E), iv) Gbokoniyi (7.32'N; 3.41'E), (v) Aiyedere (6.99'N; 3.27'E) and (vi) Aiyegbami (7.07'N; 3.28'E), they belong to three soil series Apomu, Iwo and Ibadan. The soil samples were air-dried, passed through 2 mm and 5 mm sieves, respectively, the former was used for laboratory analysis and latter for screen house experiment. The screen house experiment was carried out on teaching and research farm of Moshood Abiola Polytechnic, Ojere, Abeokuta. Moshood Abiola Polytechnic is located at Latitudes 7°06'N and Longitude 3°19'E. The average temperature and precipitation are 27.1°C, 197 mm, respectively. January, has the least amount of rainfall with an average of 13 mm, in June, the precipitate reaches its peak, with an average of 197 mm. The variation in the precipitation between the driest and wettest months is 184 mm. The variation in annual temperature is around 4°C (OGADEP, 2004).

Screen House Experiment

Five kilograms (5 kg) of the sieved soils were weighed into 10 litres plastic pots whose base had been perforated. A large portion of the soil-potassium occurred in non-exchangeable form, so, to get a clear understanding of the fixing abilities of the soils and release of the element different rates of organic manures were used. The poultry, goat and cattle manures were dried at room temperature before incorporated separately into pots at 50 g and 100 g animal waste/pot equivalent to 0.94 and 1.88 tha^{-1}, no manure was added to the control pots. The treated soils were left to equilibrate for 2 weeks before planting as described by (Mbah, 2008). Maize seeds used for this research are locally known as "hybrid Oba super 2", they were purchased from the Ministry of Agriculture, Asero, Abeokuta, Ogun state, Nigeria. Three maize seeds were planted in each pot, watering was done once a day or as necessary when there is no rain fall. It was a factorial laid out in a completely randomized design with three replications. Maize crops were cultivated and harvested after six weeks; cultivation was repeated two more times to make three cycles. Two weeks after planting the maize plant were thinned to one plant per pot. At the end of each cycle, whole plant tops were harvested, oven dried at 60°C for 48 h. 5 gm of the plant tissue was milled digested with H_2SO_4-H_2O_2 mixture and K content was determined by flame photometry.

Soil Analysis

Particle size analysis of the soil samples was determined by Bouyoucous Hydrometer method as used by (Gee and Bauder, 1986). Soil pH was measured using a glass electrode in a 1:2.5 soil – H_2O ratio (Page, 1982). The titratable-acidity was extracted with 1M KCl solution and was titrated with 1M NaOH using Phenolphthalein as an indicator (Mclean and Watson, 1985). Soil organic carbon was determined by the modified Walker-Black method as described by Nelson and Sommer (1982). Exchangeable K, Ca, Mg and Na were extracted with 1M NH_4OAC. Extracted K and Na were determined by flame photometry while Ca and Mg were determined by atomic absorption spectrophotometry (Knudsen, 1982). Total K in the soil samples was digested with a mixture of HNO_3 and H_2SO_4 (1:1).

Available K was extracted with 1MNH_4OAC, water-soluble K was extracted from 1:5 soil: H_2O suspension after 1 h (Sharpley, 1987). Exchangeable K was obtained by deducting water-soluble K from available K. Non-exchangeable K was determined as the difference between total K and available K. The difference between the non- exchangeable K and the fixed K gave the mineral. Potassium (K) was measured in all extracts by using flame photometer (Sharpley, 1987).

Quantity Intensity

The method of Beckett as modified by (Yawson et al., 2011) was used to determine the quantity intensity relationships of K for the soil samples. Triplicate of soil samples, 2.5 gm each was treated with a series of KCl solutions of different K concentrations as follows 0, 0.2,

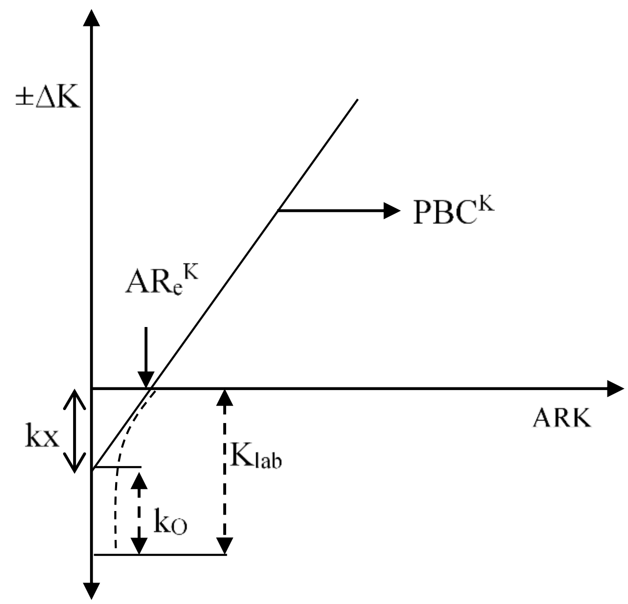

Figure 1. Schematic representation of a typical Q/I isotherm.

0.4, 0.8, 2.0, 4.0, 8.0 mol L^{-1} with constant concentrations of mixture of 0.04M $CaCl_2$ + 0.04 M $MgCl_2$. The suspensions of the soil solution (1:10)were shaken for 3 h, and then allowed to stand for 24 h to equilibrate. The change in exchangeable K ($\pm$ ΔK) which is the quantity factor was determined from the differences of concentrations of K in the prepared solutions and equilibrated solutions. Activity ratio (ARK) which represents the intensity factors was calculated. The relationships between the quantity and intensity factors of the soils under study were drawn, by plotting $\pm$ ΔK on Y-axis and ARK ($\frac{ak}{\sqrt{aCa+aMg}}$) on the x-axis (Figure 1). Potential buffering capacity (PBC) and labile K was determined from the Q/I curve. Activity ratio (ARK) of potassium was calculated as stated above.

Data Analysis

Analysis of variance (ANOVA) was used to detect the significant difference of the treatment's effects and Duncan multiple range tests were used to separate the means using SAS, version 9.1.1 (2000). The effects of the manure on the quantity intensity parameters and properties were subjected to Pearson correlation.

RESULTS

Properties of the Studied Soils

It was observed that the soils had the highest proportion of sand which ranged from 77.20 % (Aiyegbami) to 86.20% (Funaab). Four of the soil samples were sandy loam, one was loamy sand and one was sandy clay loam in texture (Table 1). The pH values ranged between 5.57 (Funaab) and 6.51 (Aiyedere), soil had the highest electrical conductivity value (0.66 ds m^{-1}), the available phosphorus varied from 1.14 mg kg^{-1} in Aiyegbami to 2.58 mg kg^{-1} (Aiyedere) Least values were observed for Nitrogen in Gbokoniyi soil (0.06%) and Sodium (0.10 cmol kg^{-1}) in Aiyedere. Calcium content (5.14 cmol kg^{-1}) observed in Alabata soil was the highest while very low values were observed in the other five studied soils.

Potassium Status in Studied Soils

The forms of potassium in the studied soils are presented in Table 2, available- K, ranged from 0.06 cmol kg^{-1} in Aiyedere soil to 0.31 cmol kg^{-1} in Alabata soil. The concentration of water soluble-K in Aiyedere was 0.01 cmol kg^{-1} which was the least, the highest concentration (0.14 cmol kg^{-1}) was observed in Alabata soil. The total K in the soils varied from 70.74 cmol kg^{-1} in Alabata soil to 109.91 cmol kg^{-1} in Aiyegbami soil. The percent potassium saturation (%K saturation) in the studied soils was high in Gbokoniyi (15.24%) followed by 12.85% in Ayegbami soil and the least value was observed in Aiyedere soil (3.57%).

Potassium Quantity Intensity (Q/I) Parameters Before Manure Application

The equilibrium activity ratio (ARoK) which is the point, at which no K exchange takes place, was derived from the quantity intensity plots ranged from 0.02 mol L^{-1} in Gbokoniyi soil to 0.06 mol L^{-1} in Funaab and Aiyedere soils (Table 3). The specifically bonded K (K_x) which

Table 1. Physico chemical properties of soil samples used in screen house.

Sample Locations	pH	EC dsm^{-1}	Available Phosphorus	Total Nitrogen	Na	Ca	Mg cmol kg^{-1}	Exch. Acidity	ECE C	Organic Matter	Sand %	Silt	Clay	Textural Class
Funaab	5.57	0.37	1.36	0.18	0.30	0.81	1.01	0.02	2.31	1.38	86.20	0.80	13.20	LS
Osiele	6.05	0.23	1.90	0.08	0.15	0.56	0.60	0.06	6.51	1.21	84.20	1.80	13.20	SL
Alabata estate	5.99	0.66	1.22	0.22	0.53	5.14	0.50	0.03	6.28	1.80	81.40	3.60	15.00	SL
Gbokoniyi	6.34	0.49	2.48	0.06	0.13	0.72	0.57	0.02	1.52	0.60	82.20	3.00	15.00	SL
Aiyedere	6.51	0.30	2.58	0.12	0.10	0.10	0.34	0.05	0.65	1.23	82.20	3.80	14.00	SL
Aiyegbami	5.96	0.27	1.14	0.09	0.39	0.74	0.68	0.06	2.09	0.91	77.20	2.80	20.20	SCL
Mean	6.07±0.33	0.39±0.06	1.78±0.06	0.13±0.02	0.26±0.07	1.35±0.05	0.62±0.02	0.04±0.01	3.19±0.47	1.19±0.36	84.47±2.22	3.92±0.20	8.37±0.14	

SL = sandy loam, LS = Loamy sand, SCL = sandy clay loam.

Table 2. Potassium status in studied soils.

Sample locations	Available K	Exchangeable K	Water soluble K cmole kg^{-1}	Non-exchangeable K	Mineral K	Total K	%K-Saturation
Funaab	0.17	0.09	0.08	91.08	90.80	91.25	10.44
Osiele	0.08	0.04	0.04	80.60	80.52	80.68	5.47
Alabata Estate	0.31	0.17	0.14	70.43	70.08	70.74	8.32
Gbokoniyi	0.08	0.05	0.03	80.90	80.76	80.98	15.24
Ayedere	0.06	0.05	0.01	81.73	81.62	81.73	3.57
Aiyegbami	0.22	0.14	0.08	109.69	109.42	109.91	12.85
Mean	0.15±0.10	0.09±0.03	0.06±0.01	85.74±13.43	85.53±13.42	85.80±13.27	9.32±4.42

Table 3. Potassium quantity intensity (Q/I) parameters before manure application.

Samples locations	AR_oK mole L^{-1}	K_x cmol kg^{-1}	Kpot cmol kg^{-1} mol$^{1/2}$ L$^{1/2}$	PBC^k cmol kg^{-1} mol$^{1/2}$ L$^{1/2}$	ΔG Cal mol^{-1}
Funaab	0.06	-0.01	-0.21	20.72	-3545
Osiele	0.03	-0.02	-0.52	25.74	-3772
Alabata estate	0.04	-0.20	-6.15	30.75	-4309
Gbokoniyi	0.02	-0.01	-0.23	22.99	-5230
Aiyedere	0.06	-0.02	-0.69	34.35	-3667
Aiyegbami	0.04	-0.03	-0.95	31.96	-3087
Mean	0.04±0.02	-0.05±0.01	-1.46±0.32	27.75±5.41	-3935±74.65

ARoK – Equilibrium activity ratio, Kx – Specifically – bonded K, Kpot – K potential, PBC^k – Potential buffering capacity, ΔG – Free energy of exchange.

gives an indication of the adsorbed K to non-specific (planar) sites varied from -0.01 cmol L^{-1} to - 0.20 cmol L^{-1}. Potential buffering capacity (PBC^k) is a measure of the ability of soil to maintain the intensity of a soil solution K and it is proportional to the cation exchange capacity (CEC), the PBC^k varied from

Table 4. Quantity intensity (Q/I) parameters after 50 g of organic manures application.

Sample locations	Goat					Poultry					Cattle				
	ARoK	Kx	Kpot	PBC^k	∆G	ARoK	Kx	Kpot	PBC^k	∆G	ARoK	K_x	Kpot	PBC^k	∆G
Funaab	2.41	-0.45	-16.26	36.14	-2721	4.08	-0.60	-29.34	48.90	-2713	2.10	-0.35	-17.12	27.86	-1709
Osiele	1.15	-0.36	-12.81	35.59	-2961	3.02	-0.72	-36.18	50.25	-2592	2.00	-0.36	-18.09	32.42	-1470
Alabata	2.10	-0.57	-26.23	46.02	-2139	2.50	-0.56	-32.74	58.46	-2011	2.04	-0.38	-22.22	37.93	-2164
Gbokoniyi	3.06	-0.56	-25.27	45.13	-1927	3.40	-0.78	-38.74	49.67	-1981	2.10	-0.28	-13.91	33.43	-1907
Aiyedere	3.10	-0.47	-21.28	45.27	-1731	4.20	-0.83	-49.54	59.69	-2107	2.45	-0.36	-21.49	37.48	-1820
Aiyegbami	2.10	-0.28	-13.14	46.93	-2010	5.40	-0.76	-45.98	60.50	-1333	2.26	-0.18	-10.89	37.29	-1907
Mean	2.32±0.	-	-19.17	42.51±5.1	-1605±	3.77±	-0.7	38.75±7.	54.58±5.5	-2122	2.16±0.1	-0.32	17.29±4	34.40±3	1829±3
	03	0.45±0.11	±3.14	9	17.90	0.38	1±0.11	75	0	±49.9	7	±0.08	.36	.95	1.41

ARoK – Equilibrium activity ratio, Kx – Specifically – bonded K, Kpot – K potential, PBC^k – Potential buffering capacity, ∆G – Free energy of exchange.

Funaab (20.72 cmol $kg^{-1}mol^{1/2} L^{1/2}$) to Aiyedere (34.35 cmol $kg^{-1} mol^{1/2} L^{1/2}$).

The K-potential is the product of Kx (K on specific planar site) and PBC^k, the highest K-potential value was observed in Gbokoniyi (-6.15 cmol $kg^{-1} mol^{1/2} L^{1/2}$) while Funaab soil had the least (-0.21 cmol $kg^{-1} mol^{1/2} L^{1/2}$).

Quantity Intensity (Q/I) Parameters After 50 G Organic Manure Application

A slight increase was observed in all parameters as the manure rate increased, specifically bonded-K (Kx) values observed varied with manure type, it ranged from -0.18 cmol kg^{-1} in Aiyegbami soil to –0.83 cmol kg^{-1} in Aiyedere soil with poultry manure (Table 4). K potential (Kpot) values observed with poultry manure (29.34 to 49.54 cmol $kg^{-1} mol^{1/2} L^{1/2}$) were higher than values obtained with goat manure (13.14 to 26.23 cmol $kg^{-1} mol^{1/2} L^{1/2}$) and cattle manure (10.89 to 22.22 cmol $kg^{-1} mol^{1/2} L^{1/2}$). The most highly potential buffered soils were observed in soils with poultry manure and soils with cattle manure were least buffered (Table 4). Free energy of exchange (∆G) in the soils were lower than values observed in soils without the application of three types of organic manure, it varied from -1470 Cal mol^{-1} to -2164 Cal mol^{-1} with cattle manure. Free energy of exchange of K (∆G) ranged from -1133 Cal mol^{-1} in Aiyegbami with poultry manure to 2592 Cal mol^{-1} in Osiele soil with poultry manure.

Quantity- Intensity (Q/I) Parameters After 100g Organic Manure Application

The equilibrium activity ratio values (ARoK) observed in studied soils treated with the three types of manure were not significantly different (Table 5). Higher specifically bonded-K (Kx) values were obtained in some soils treated with poultry. K-potential values observed in soils with poultry manure were greater than values observed with goat and cattle manure. The potential buffering capacity (PBC^k) values observed, slightly increased at this rate with all the manure. The free energies of exchange of K (∆G) in the soils were reduced with a high rate of application of the three-organic manure.

Correlation Between Soil Properties and Quantity Intensity Parameters After Goat Manure Application

Specifically, bonded-K negatively correlated with Magnesium (- 0.756*), K potential correlated with calcium (0.653**), Magnesium (0.852*) at $p<0.05$, no correlation was observed with other soil properties of soil treated with 50 g manure. At 100g manure application, equilibrium activity ratio of K significantly correlated with exchangeable – K (0.583**), K potential had a significant relationship with organic matter (0.860*) and exchangeable – K (0.869*), potential buffering capacity was also observed to significantly correlated with organic matter (Table 6).

Correlation Between Soil Properties and Quantity Intensity Parameters After Poultry Manure Application

Equilibrium activity ratio of K (ARoK), correlated positively with organic matter (0.668**), silt (0.542**) and exchangeable K (0.993*). Specifically, bonded –K (Kx) was observed to have a positive relationship with organic matter (0.939*) and exchangeable K (0.993*). K potential (Kpot) had significant relationship with pH (0.573**) and exchangeable K (0.596**).

Specifically, bonded-K negatively correlated with Magnesium (- 0.756*), K potential correlated with

Table 6. Correlation between soil properties and quantity intensity parameters after goat manure application.

Soil Properties	AroK	50 g Kx	Kpot	PBC	∆G	ARoK	100 g Kx	Kpot	PBC	∆G
pH	0.372	0.080	-0.280	-0.410	0.252	-0.313	0.145	-0.057	-0.203	-0.404
Organic matter	0.233	0.797*	0.804*	0.186	0.430	0.322	0.652**	0.860*	0.526**	0.193
Clay	0.311	0.156	0.343	0.161	0.252	0.212	0.281	0.333	-0.123	0.121
Silt	0.190	0.031	0.139	-0.563**	-0.002	-0.008	0.210	-0.273	0. 175	-0.278
Sand	0.554**	0.925*	0.265	0.057	0.996*	-0.806*	0.513**	0.390	0.586**	0.382
Ca	0.134	0.162	0.753*	0.326	0.034	0. 362	0.341	-0.242	0.365	0.382
Mg	0.305	-0.765*	-0.852*	-0.510**	-0.075	-0.177	-0.219	0.053	0.313	0.107
Exch K	0.334	0.004	0.061	0.876*	0.817*	0.583**	0.493	0.869*	0.322	0.741*
Exch acidity	0.141	0.115	0.022	0.335	0.227	0.223	0.211	0.432	0.212	0.322
ECEC	-0.525**	-0.208	0.204	0.356	0.417	0.452	-0.229	0.151	-0.411	-0.635**

Table 7. Correlation between soil properties and quantity - intensity parameters after poultry manure application.

Soil Properties	AroK	50 g Kx	Kpot	PBC	∆G	ARoK	100 g Kx	Kpot	PBC	∆G
pH	0.138	-0.025	0.573**	0.177	0.053	-0.251	-0.251	-0.501**	-0.309	-0.466
Organic matter	0.668*	0.939*	0.052	0.581**	0.775*	0.432	0.431	0.097	0.329	0.127
Clay	12	0.12	12	12	12	12	12	12	12	12
Silt	-0.542**	0.041	0.060	0.548**	0.180	-0.154	0.297	-0.107	-0.051	-0.27
Sand	0.069	0.009	0.154	0.245	0.575**	0.633*	0.348	0.741*	0.874*	0.934*
Ca	12	12	12	12	12	12	12	12	12	12
Mg	0.308	0.003	0.171	0.256	0.318	-0.216	0.056	0.041	-0.176	-0.425
Exch K	0.310	0.993*	0.596**	0.421	0.313	0.501	0.863*	0.900*	0.585**	0.168
Exch acidity	12	12	12	12	12	12	12	12	12	12
ECEC	0.114	0.101	-0.197	-0.336	-0.092	-0.551**	0.122	0.104	-0.437	0.415

*= p< 0.05, ** = p < 0.01. ARoK – Equilibrium activity ratio, Kx – Specifically – bonded K, Kpot – K potential, PBC^k – Potential buffering capacity, ∆G – Free energy of exchange.

calcium (0.653**), Magnesium (0.852*) at $p<0.05$, no correlation was observed with other properties of soil treated with 50g manure (Table 5).

K potential, specifically bonded – K (K_x) and potential buffering capacity (PBC) had a significant relationship with exchangeable – K when 100 g manure was applied (Table 7).

Correlation Between Soil Properties and Quantity Intensity Parameters After Cattle Manure Application

Specifically bonded-K (Kx), potential buffering capacity (PBC^k) and equilibrium activity ratio of K (ARoK) correlated with exchangeable K, (0.646**, 0.846*, and 0.833*), K potential, equilibrium activity ratio of K (ARoK) and potential buffering capacity (PBC^k) correlated significantly with organic matter (0.937*, 0.524**and -0.597**), free energy of exchange (∆G) negatively correlated with pH, no correlation was observed with other soil properties at 50g manure application. Equilibrium activity ratio, K potential and specifically bonded-K correlated positively with exchangeable K (0.614**, 0.751* and 0.763*), other parameters did not correlate with quantity intensity parameters at this rate with 100g manure application (Table 8).

Effects of Organic Manure on Leaf Area, Plant Height, K- Uptake and Dry Matter Yield of Maize in The Screen House

Analysis of variance showed that different locations, manure types and manure rates had significant effects on leaf areas, plant heights at two, four and six weeks of planting. It was also observed that these sources of variation had significant effects on K- uptake by maize and dry matter yield of maize (Table 9). Interactions of locations x manure,

Table 8. Correlation between soil properties and quantity intensity parameters after cattle manure application.

Soil properties	AroK	50 g Kx	Kpot	PBC	∆G	ARoK	100 g Kx	Kpot	PBC	∆G
pH	-0.204	-0.308	0.026	-0.170	-0.591**	-0.487	-0.158	-0.268	-0.463	-0.498
Organic matter	0.524**	0.216	0.937*	0.597**	0.043	0.108	0.624	0.399	0.130	0.100
Clay	0.225	0223	0.452	0.327	0.087	0.342	0.225	0.389	0.121	0.361
Silt	-0.105	-0.151	-0.477	0.164	0.341	-0.130	-0.347	-0.332	0.003	-0.565*
Sand	0.145	0.140	0.117	0.110	0.278	0.268	0.269	0.291	0.119	0.2 22
Ca	0.289	0.242	0.443	0.422	0.431	0.227	0.216	0.323	0.298	0.433
Mg	-0.063	-0.149	0.241	0.280	0.230	-0.162	0.098	0.103	0.478	0.079
Exch K	0.846*	0.644*	0.451	0.833*	0.144	0.614*	0.763*	0.751*	0.116	0.206
Exch acidity	0.212	0.334	0.336	0.056	0.362	0.332	0.431	0.331	0.343	0.376
ECEC	-0.199	0.154	0.491	-0.231	-0.151	-0.165	0.298	0.231	-0.013	-0.220

*= p< 0.05, ** = p < 0.01. ARoK – Equilibrium activity ratio, Kx – Specifically – bonded K, Kpot – K potential, PBC^k – Potential buffering capacity, ∆G – Free energy of exchange.

Table 9. Effects of organic manure on leaf area, plant height, K- uptake and dry matter yield of maize in the screen house.

Source of Variation	Df	Leaf area 2wap	Leaf area 4wap	Leaf area 6wap	Plant height 2wap	Plant height 4wap	Plant height 6wap	K-uptake	Drymatter yield
Block	2	743.99**	2086.11**	16097.02**	3318.15**	14857.82**	26742.54**	8.05**	226.02**
Location	5	1437.85**	13917.17**	61892.63**	220.36**	5507.89**	1614.02**	7.41**	67.88**
Manure	2	45776.69**	429404.70**	568447.68**	1243.02**	12593.89**	21274.43**	115.48**	230.53**
Rate	4	21180.25**	140168.20**	738578.40**	5472.42**	35556.93**	42961.89**	290.38**	632.29**
Location x Manure	11	867.61**	2727.71**	16708.02**	63.00**	4430.35**	265.47*	3.08**	19.50**
Location x Rate	22	203.03**	580.64**	5157.12**	29.15**	4225.57**	5176.01**	1.21**	17.24**
Manure x Rate	4	3353.17**	17251.76**	140054.02**	90.74**	5061.81**	963.46**	13.11**	36.63**
Location x Manure x Rate	43	357.20**	920.30**	2872.60**	24.15**	4335.63**	4127.55**	0.84**	12.10**
Error	176	7.74	18.13	640.73	7.43	96.19	77.55	0.08	3.85

manure x rates and locations x manure x rates were significant on the plant growth parameters, K-uptake and dry matter yield at p < 0.05 and p < 0.01. There were significant effects of different locations, manure and rates on leaf areas at two, four and six weeks after planting and plant heights at two weeks after planting, no significant effect was observed in plant heights at four and six weeks after planting. The rates had a significant effect (233.17**) on K - uptake at p< 0.001 while locations, manure and rates significantly related with the dry matter (40.02**, 238.15**, 243.26**) at p < 0.01. The locations x manure; manure x rates and locations x manure x rates had no effect on plant heights at four and six weeks after planting and K- uptake.

In third planting, the interactions of locations x manure; manure x rates had no effect on leaf areas at two weeks and four weeks after planting. Locations x manure and location x rates had no significant relationship with plant heights at two, four, and six weeks after planting. There were significant effects on interactions of locations x manure x rates on leaf area at six weeks after planting and dry matter yield.

DISCUSSION

The physicochemical analyses of the studied soils showed that they all had a high concentration of sand (77.20 to 86.20%), soils with this characteristic cannot hold a significant amount of water or nutrients for plants and they will require additional fertilization to support healthy plant growth. The high sand content of the soil could be attributed to the high content of quartz in the parent material (Brady and Weils, 1999). All the soil samples were acidic in nature; this may be due to their coarse nature, pH value within the expected range (5.5 to 7.5) for soils (Agbogidi, 2005). The acidic nature of the soils of the studied area may be traced to the leaching of the exchangeable bases and dissociation of strong and functional groups in the organic matter, this is similar to the report of (Esu, 2001). The soils samples were low in nutrients this may be as a result of the low pH which affects nutrients by converting them into forms not readily available to crops, it will also increase the solubility of plant toxic metals such as Aluminium. This is in accordance with the reports of Ojeniyi and Akanni (2008); they reported that soil in the Southwestern part of Nigeria is mostly weathered alfisols and deficient in nutrient. Low organic matter which may result from its rapid decomposition by high solar radiation and high moisture, this favours optimum microbial activities in the soils. Annual seasonal bush burning which depletes organic matter accumulation in soil may also be responsible (Landor, 1991). Total nitrogen observed in all the studied soils may be attributed to the low-level organic matter which contributes 90 to 95% of soil nitrogen, acidic nature of the soils might have enhanced high fixation of phosphorus resulting in low content of the nutrient in the studied soils (Nnaji et al., 2002). Low contents of cation exchange capacity and exchangeable acidity could be as a result of leaching of exchangeable bases, parent material from which the soils were formed and low organic matter (Olatunji et al., 2007). The low concentrations of Ca^{2+}, Mg^{2+} and Na^{+} observed in the samples attributed to the low level of electrical conductivity of all the soil samples (Warman and Termeer, 2005; Egbuchua, 2012).

The quantities of water-soluble K observed in soil samples collected from Aiyedere was lower than the critical value of 0.05 cmol kg^{-1}which was proposed by international potash institute (IPI, 2000), while the remaining soil samples were higher than the critical value. The low values of the water-soluble K do not retard the release of exchangeable K but are not enough to support plant growth and were much lower than the requirement for most crops (Datta and Sastry, 1988). The values obtained for Alabata, and Aiyegbami soils were similar to the observation of (Ogundare et al., 2012), they reported 0.22 cmol kg^{-1} for Ejiba soil (Kogi state) while the values of available K observed do not agree with the report of (Darwish et al., 2003), who reported that available K values for some Lebanese soils ranged between 0.4 to 2.0 cmol kg^{-1}. Al-Zubaidi et al. (2008) reported the critical value for available K in soils as 0.41cmol kg^{-1}, this shows that all the soils studied were low in available K, so they are expected to positively respond to potassium fertilization. The study showed that available K constituted a considerable part of supplying power of K in the soil samples because available K consisted 28.57 to 88.57% of fixed K. A large portion of the K in the studied soils occurred as non - exchangeable K (fixed K), this indicates that the studied soils are expected to have high supplying power for long term cropping (Havlin and Westfall, 1985). Potassium present in the soil samples occupied a small portion of cation exchange capacity (CEC) of the soils, this was revealed by the average % K saturation (8.78%) of the soil samples (Al-Zubaidi et al., 2008). The values of free energy of replacement (ΔG) observed in the soils before the application of organic manure indicates that studied soil from Aiyegbami had medium supplying power of K (3087 to 3317 Cal mol^{-1}) while other soils were poor in supplying potassium. (Al- Zubaidi, 2003) observed that soils with high supplying power of potassium have ΔG less than -2000 $Calmol^{-1}$, soils that have ΔG ranging from -2000 to -3500 $Calmol^{-1}$ have medium supplying power of potassium while soils that have ΔG values greater than -3500 Cal mol^{-1} are poor in supplying potassium.

The equilibrium activity ratios (ARoK) derived from the quantity intensity plots before manure application were low, this was as a result of low organic matter and low Ca^{2+} and Mg^{2+} observed in the studied soils. An increase was observed in the equilibrium activity ratios of the soil samples after treating with three organic manures at different rates this may be due to increase in Ca^{2+}, $Mg^{2+}$and organic matter levels in the soils by the applied organic manure (De et al., 1993). The observed values for specific K (Kx) were low compared to the values (-0.08 to -0.76 cmol kg^{-1}) reported by (Yawson et al., 2011) for some Ghanian soils, the low values observed in all the soil samples before manure application could be due to the acidic nature of these soils. This indicates that more K was adsorped to non-specific sites of the clay minerals in the soil samples. After the introduction of the manure, the values of specific K increased, this showed the contribution of organic matter to the labile K (Abaslou and Abtahi, 2008). Initially, potassium (K) intensity of the soils were generally low because the soils had higher sand fractions and lower clay fractions, this can be attributed to low competitive ability of K for adsorption sites in the acidic environments (Olasantan et al., 1997). The potential buffering capacity (PBC^{k}) values observed after manure application were higher than values observed before manuring, the observed values were higher than those reported by Subba Rao (1990) and (Yawson et al., 2011) (0.03 -0.10 cmol $kg^{-1}mol^{-1/2}$). The high PBC^{K} resulted from increase in concentration of Ca and Mg in soil solution, this may be as a result of the positive effect the applied manure had on the soil nutrients. This is an indicative that the treated soils have greater capacity to maintain K concentration for a long period (Tembakazi et al., 2007). Abaslou and Abtahi (2008) reported that K potential buffering capacities (PBC^{k}) can also determine the tendency of the soil to adsorb or release K and it is also an essential indicator of K availability. The poultry manure had more positive effect on the quantity – intensity parameters, compared to goat and cattle manures. Potential buffering capacity (PBC^{k}) showed positive correlations with Ca, Mg, Organic matter, effective cation exchange capacity (ECEC) and pH, this may be due to the competitive relationship existing between the activity of K and the activity ratio of Ca and Mg. This relationship is in agreement with the report of Absalou and Abtahi (2008), they observed a significant relationship between PBC^k and ECEC, Ca and Clay content of the soils. K-potential showed strong relationships with clay, Ca, K, ECEC and sand, Olk and Cassman (1993), observed that this relationships are transitive from the relationship existing between these parameters and the components of K-potential, they also observed that whether the relationship is positive or negative is likely to depend more on specifically bonded K (K_x).

The standard free energy of exchange (∆G) showed a positive relationship with organic matter, this is contrary to the report of Askegaard et al. (2003), they pointed out that free energy depends extensively on soil properties such as clay content and effective cation exchange capacity (ECEC). Significant correlations were found between the quantity- intensity parameters and some soil properties after the treatment with the different organic manure. The highest K-potential and specifically bonded K (Kx) were observed in soils treated with poultry manure, this indicated that, on equilibration, more K was released from non-specific planar sites leading to a higher PBC^K (Abaslou and Abtahi, 2008), this eventually led to low free energy of exchange or replenishment (∆G) which is an index of the amount of work that must be done to remove one mole of K^+ from the exchange complex or from the soil solution or to fix it (Pal et al., 1999). The soils had high specifically bonded K (Kx) values; this indicated that more potassium (K) was released from the adsorption sites. (Abaslou and Abtahi, 2008). The response of the maize plants in terms of plant height, leaf area showed that the poultry manure performed best in all parameters measured. This supports the findings of Olatunji et al. (2006) and Okonmah (2012), the former observed that poultry manure had the greatest increase in growth and yield of okro and tomatoes while the latter observed significant growth of maize plants in manure-treated soil. Mohammad and Enayatollah (2012) also observed that the increase in plant height was attributed to the cementing action of polysaccharides and other nutrients released during the decomposition of the organic manure, thus leading to taller plants. K-uptake observed in maize leaf and dry matter yield were significantly affected by organic manure ($p< 0.05$) this may be due to the fact that Potassium could increase the rate of Co_2 stabilizing with interference in osmosis regulation, improving stoma closure thereby increasing (Okonmah, 2012).

CONCLUSION

Initially, the soil analysis showed that the soil samples had low equilibrium activity ratio of K (ARoK), specifically bonded K (Kx), K potential, Potential buffering capacity and high free energy of exchange (∆G) thereby, indicating that the soils had low supplying power of K. These parameters increased after the application of the different manure which made more K available to the plant. The high free energy of exchange (∆G) which was reduced after manuring making the studied soils to have high supplying power of K. hence, organic manures are recommended as bio-fertilizers for soils with high K fixing capacities. Further study can be done on the clay mineralogy of the studied soils.

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