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Comparative study of different organic manures and NPK fertilizer for improvement of soil chemical properties and dry matter yield of maize in two different soils

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A pot experiment was conducted to compare different organic manures with NPK fertilizer for improvement of chemical properties of acid soil from farmer's field in coastal area of Epe and nutrient depleted soil from research field of Institute of Agricultural Research and Training, Moor Plantation, Ibadan. Maize was planted for 12 weeks and dry matter yield was determined. Results showed that application of 5 ton/ha of each of the evaluated organic manures and 100 kg/ha NPK 15-15-15 fertilizer improved chemical properties of both acid and nutrient depleted soils compared with unfertilized soil. Application of different types of organic manures reduced the acidic levels of both the soils. Cow dung application resulted in the highest pH levels of 6.37 and 6.50 in acid soil and nutrient depleted soil respectively while NPK fertilizer gave lowest pH levels of 5.28 and 5.74 for both soils. Also, application of different types of organic manures enhanced soil organic C, total N, available P, exchangeable K and CEC better than NPK fertilizer in both soils. The study indicated that among the organic manures evaluated, cane rat droppings improved soil chemical properties best. Plant dry matter yield increased with application of NPK fertilizer compared with compost, poultry manure and cane rat droppings in both soils. In acid soil, application of NPK fertilizer gave the highest dry matter yield of 4.77 g/plant while in nutrient depleted soil; application of NPK fertilizer gave the highest dry matter yield of 5.58 g/plant.

Key words: Manure, fertilizer, dry matter, pH levels.

INTRODUCTION

Acid soils are highly weathered and contain large quantities of Al and Fe hydrous oxides that have the ability to adsorb major elements onto their surfaces such that much of added nutrients are fixed instead of being made available for crop use (Akinrinade et al., 2006; Enwezor et al., 1981). Vast areas of tropical lands that were once fertile have been rendered unproductive due to continuous cultivation and erosion which caused physical degradation, loss of soils organic matter and decreased cation exchange capacity (CEC) and as well as increased Al and Mn toxicity (Mba, 2006). As these soils suffered multi-nutrient deficiencies, application of mineral fertilizers has become mandatory to increase crop yields. However, mineral fertilizers are commonly scarce, costly, having imbalanced nutrition and their use could exacerbate the problem of soil acidity (Oguike et al., 2006; Nottidge et al., 2006). The problem is worsened by the continuous removal of government subsidies on fertilizers, and poor distribution systems. This is why Aduayi (1985), and Agbim and Adeoye (1994) recommended the use of crop residue and other organic wastes as supplements to inorganic fertilizers.

The expansions in animal enterprises and cassava processing industries have been followed by the

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production of a large amount of wastes in urban and peri-urban areas, which becomes potential environmental hazard. However, there is a renewed interest in proper and effective use of organic manures derivable from these wastes to get rid of such wastes and to improve agricultural soil fertility. These manures are known to decompose in soils to form humus and humid substances, which play a dominant role along with clay micelles in the complex soil reactions that, enhance the CEC of soils. The chemical transformations involving humus in soil colloidal ion exchange complexes are summarized by Brady (1990), and Agbim and Adeoye (1994) to increase the net positive or negative charge, depending on the pH prevailing. It has been stated by Akpegi et al. (2006) that this is a crucial factor to the soil buffer capacity. According to them, at low pH the hydrogen ions are said to dissociate from the carboxyl (-CoOH), hydroxyl, (-OH), and the phonetic (R-OH) sites, where R is a benzene ring, leaving an increased net negative surface charge on the colloid. An important factor in soil reclamation using organic matter derivable from organic residues is its role in improving the soil physical properties, by forming stable aggregates to improve soil structure, buffer the soil, improve aggregate stability, the population of soil microorganisms, and enhance water-retention capacity and the applied manures raise the soil pH in acid soils (Sanchez and Miller, 1986; Spaccini et al., 2002; Ogunlade et al., 2006; Olatunji et al., 2006). Repeated application of organic residues on soils has long-lasting positive effects on soils, (Adeniyan and Ojeniyi, 2003, 2005).

According to Olatunji et al. (2006), the application of organic manure haD been found to have higher comparative economic advantage over the use of inorganic fertilizer. A study conducted by Nwajiuba and Akinsanmi (2002) in Southeastern Nigeria, showed that returns per ha were higher in organic farms though outputs were slightly less in inorganic farms. Therefore, replenishment of nutrients and improvement in quality of nutrient depleted and acid soils could be achieved through the application of inorganic fertilizers, organic manures or a combination of both organic and inorganic fertilizers (Adeniyan and Ojeniyi, 2005). The aim of this work therefore was to investigate the effects of different organic manures and NPK 15-15-15 fertilizer on soil chemical properties and maize dry matter yield in acid soil and nutrient depleted soil.

MATERIALS AND METHODS

Collection and preparation of soil samples

The soils used for the pot experiment were collected from one of the experimental sites of Institute of Agricultural Research and Training, Moor Plantation Ibadan (Latitude 7° 22/ N, 3° 50/ E) and a farmer's field at Epe (Latitude 6° 27/ N, 3° 57/ E). Ibadan soil was classified as nutrient depleted soil after it has been cropped for many years (over 35 years) and therefore was unable to support plant growth without heavy fertilization or a long time fallowing. The soil at Epe was coastal acidic. The dominant soils in Ibadan and Epe are Alfisol and Entisol respectively. According to the USDA (1975) classification, both soils are oxic paleustalf. This contains predominantly kaolinite minerals and is abundant in iron oxides. The soils were air-dried and sieved through 2 mm sieve and thereafter 10 kg soil sample was weighed into a perforated polythene pot.

Treatments

Five different organic manures (cow dung, cassava peelings compost, poultry manure, rabbit droppings and cane rat droppings) and NPK 15: 15: 15 inorganic fertilizer were applied to the potted soils at the rate equivalent to 5 ton/ha of the organic manure and 60 kg/ha of NPK fertilizer for the pots to be planted with maize. The rates amounted to 5 kg and 3.59 g per pot of organic manure and NPK fertilizer respectively. The pots were arranged in a completely randomized design with three replicates. The manures were incurporated into the soils two weeks before planting while the NPK fertilizer was applied at split-dose first at three weeks after planting and second at maize tasselling. The control pots were planted without any treatment application. Two seeds of maize (variety DMR-ESR Yellow) were planted and were later thinned to one healthy seedling at germination. The soil was watered daily to field capacity throughout the growing period. The pot experiment was terminated at maize maturity (12 weeks after planting).

Soil and plant samples analyses

Pre-planting soil samples from acid soil and nutrient depleted soil were collected from ten points at Epe and Ibadan sites respectively and then bulked separately, while post-planting soil samples were collected from the three replicates according to the treatments applied and bulked accordingly. Analyses of acid and nutrient depleted soil samples were then carried out. The air-dried soil samples were allowed to pass through 2 mm sieve. Soil pH was determined in 1:2 soil:water ratio. Soil organic matter was determined by Walkey-Black dichromate method. Total N was determined by steam distillation technique (Bremner and Keeney, 1966), soil available P was determined by Bray and Kurtz (1945) extraction method. Exchangeable bases were determined by the ammonium acetate method, while Ca and Mg were determined using EDTA titration. Organic manures were also analyzed for total N, P and exchangeable bases.

At 12 weeks after planting, the shoot was harvested and washed with mild concentration (2%) of detergent, rinsed with deionized water, put in an envelope and oven dried at 65°C for 48 h. The plant samples were ground with Willey mill to pass through 0.5 mm sieve. The ground samples were digested with nitric-perchloric-sulphuric acid mixture (AOAC, 1970). Total N was determined by the micro-Kjeldahl procedure (Jackson, 1967). Phosphorus was determined colorimetrically by the vanado-molybdate method, K and Ca were determined on flame photometer, while Mg was determined using atomic absorption spectrophotometer. Concentration of nutrients was expressed as the percentage of dry plant material. Dry matter yield amount was determined. Nutrient uptake was calculated using the formula: Dry matter × nutrient content of plant (%) (Ombo, 1994).

Statistical analysis

The data collected were statistically analyzed using analysis of variance procedure. Means were compared using Duncan multiple range test at 5% level of probability.

Table 1. Chemical and physical analysis of soils used for the pot experiment.

Parameter	Acid soil	Nutrient depleted soil
pH	5.10	6.20
Organic carbon (%)	0.80	0.67
Total nitrogen (%)	0.08	0.06
Available phosphorus ($mgkg^{-1}$)	2.74	4.14
Exchangeable K (cmol kg^{-1})	0.19	0.25
Exchangeable Ca (cmol kg^{-1})	2.38	1.12
Exchangeable Mg (cmol kg^{-1})	0.78	1.42
Exchangeable Na (cmol kg^{-1})	0.56	0.36
CEC (cmol kg^{-1})	3.91	3.15
Sand (%)	86.00	87.00
Silt (%)	10.00	8.00
Clay (%)	4.00	5.00
Soil textural class	Sandy loam	Sandy loam

Table 2. Chemical analysis of poultry manure used for the pot experiment.

Organic manure	Organic C (%)	N (%)	P (%)	Parameter K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)
Cow dung	13.5	1.30	0.58	2.15	0.99	0.52	129	128
Poultry manure	15.1	2.21	2.98	2.05	3.28	1.06	700	180
Cassava peelings compost	12.3	1.70	0.86	1.50	1.06	0.63	208	140
Rabbit droppings	16.7	1.04	0.99	2.05	1.13	0.54	493	168
Cane rat droppings	20.9	1.95	2.06	3.30	2.82	1.99	838	196

RESULTS AND DISCUSSION

Table 1 shows the initial chemical properties of the Epe soil (coastal acid soil) and Ibadan soil (nutrient depleted soil) used for the experiment. The chemical properties of both soils indicated that they have low nutrients (organic C, total N and CEC). The pH of the soil sample from Epe was slightly more acidic with the recorded pH value of 5.10 compared to the soil sample from Ibadan with the recorded pH value of 6.20. Also, the Epe soil was higher in organic C, total N and CEC with the recorded values of 0.80%, 0.08% and 3.91 $cmolkg^{-1}$, respectively, compared to the soil sample from Ibadan with the recorded values of 0.67%, 0.06% and 3.15 $cmolkg^{-1}$. Table 2 shows the chemical contents of the organic manures applied. Nitrogen, phosphorus and calcium contents of the poultry manure were the highest compared to other organic manures used for the experiment.

It was observed from Tables 3 and 4 that application of organic manures to both the acid soil and nutrient depleted soil increased considerably the soil organic C, total N, available P, exchangeable K and CEC compared to using NPK fertilizer. The increase in the levels of soil organic C and organic matter was expected, since, organic manures have the ability of increasing soil organic matter content (Ojeniyi, 2000). It has also been reported that the contents of some major nutrients in the soil were slightly dependable on the level of organic matter (Adeniyan and Ojeniyi, 2005). Organic matter shows a greater capacity to retain nutrients in forms that can easily be taken up by plants over a longer period of time. The nutrients in the (N-P-K) fertilizer (inorganic fertilizer) were already in the mineralized form and it provides a ready source of nutrients to the soils. By implication, the nutrients released from NPK fertilizer were for a short period of time because leaching of nutrients may be higher in the soil treated with NPK fertilizer than the soil treated with organic manures. Several workers have reported longer residual effect of organic manures when applied to the soil (Adeniyan and Ojeniyi, 2003' Adetunji, 1997).

The acid soil and nutrient depleted soil treated with organic manures had significant pH values ranging from 6.20 to 6.35 and 6.21 to 6.38, respectively compared to soil treated with NPK fertilizer with pH values ranging from 5.28 to 5.75, respectively. Under both situations, the values in NPK fertilizer treated plots (5.28, 5.75) were not significantly different from their respective control values (5.08 and 5.53). These results indicated that organic manures have greater potential of raising soil pH

Table 3. Effects of applied treatments on acid soil chemical properties.

Treatment	pH H_2O	Organic C (%)	Total N (%)	Avail. P ($mgkg^{-1}$)	Exch. K ($cmolkg^{-1}$)	CEC ($cmolkg^{-1}$)
Poultry manure	6.30^{a}	1.83^{ab}	0.38^{ab}	4.80^{a}	0.83^{a}	2.91^{a}
Rabbit droppings	6.28^{ab}	1.55^{c}	0.20^{c}	3.90^{c}	0.71^{c}	2.59^{b}
Cane rat droppings	6.20^{b}	1.96^{a}	0.47^{a}	4.27^{abc}	0.91^{a}	3.10^{a}
Cow dung	6.37^{a}	1.70^{b}	0.28^{b}	4.13^{abc}	0.78^{b}	2.64^{ab}
Cassava peelings compost	6.25^{ab}	1.89^{ab}	0.40^{ab}	4.30^{abc}	0.89^{a}	2.94^{a}
NPK	5.28^{cd}	0.44^{d}	0.26^{bc}	4.03^{bc}	0.66^{d}	2.39^{c}
Control	5.08^{b}	0.06^{e}	0.09^{d}	2.20^{d}	0.11^{e}	0.90^{d}

Means with different letter(s) are statistically different by DMRT.

Table 4. Effects of applied treatments on nutrient depleted soil chemical properties.

	pH H_2O	Organic C (%)	Total N (%)	Avail. P ($mgkg^{-1}$)	Exch. K ($cmolkg^{-1}$)	CEC ($cmolkg^{-1}$)
Poultry manure	6.38^{a}	2.94^{a}	0.68^{ab}	6.37^{ab}	1.02^{ab}	2.97^{ab}
Rabbit droppings	6.21^{b}	2.57^{de}	0.57^{c}	6.33^{ab}	0.92^{b}	3.12^{a}
Cane rat droppings	6.32^{a}	2.98^{a}	0.71^{a}	5.93^{ab}	1.12^{a}	3.39^{a}
Cow dung	6.50^{a}	2.49^{e}	0.59^{b}	6.13^{ab}	0.80^{d}	2.84^{b}
Cassava peelings compost	6.38^{a}	2.92^{ab}	0.69^{a}	6.60^{a}	1.07^{a}	3.20^{a}
NPK	5.74^{cd}	2.85^{b}	0.56^{c}	5.73^{ab}	0.85^{c}	2.89^{b}
Control	5.53^{d}	0.49^{e}	0.04^{d}	3.25^{c}	0.20^{e}	1.13^{c}

Means with different letter(s) are statistically different by DMRT.

compared to NPK fertilizer. This implies that organic manures could serve as good amendment materials in ameliorating acid soils. Soil acidity has been reported as one of the major constraints to crop growth in tropical region (Busari et al., 2005). This is due to the usual accompanying effect of Al and Mn toxicity, nutrients imbalance and deficiencies and their consequential detrimental effects on crop growth and yield (Oguntoyinbo et al., 1991). While comparing the nutrients enhancement between the acid soil and nutrient depleted soil with the application of poultry manures, it was observed to be higher in nutrient depleted soil.

Specifically, the increase in soil nutrients with the application of organic manures to the acid soil and nutrient depleted soil was more obvious with the application of cane rat droppings with respect to organic C, total N, exchangeable K and CEC compared to other organic manures. This might be due to the fact that the nitrogen, K, Ca and Mg contents of the cane rat manure applied were relatively high compared with values in other organic manures. However, these values were not significantly different from that of poultry manure and cassava peelings for soil N, P, K, Ca and Mg.

The dry matter yields of the maize plant shoot from acid soil and nutrient depleted soil that were treated with organic manures and NPK fertilizer are shown in Table 5. The organic manures and NPK fertilizer significantly increased dry matter yield over control (unfertilized pot). The application of NPK fertilizer gave the highest dry matter yield under acid soil and nutrient depleted soil. However, this was not significantly different from that of compost, poultry manure and cane rat droppings.

Conclusion

Application of different types of organic manures and NPK fertilizer enhanced availability of soil nutrients and cation exchange capacity considerably in both acid soil and nutrient depleted soil. The applications of organic manures performed favorably the same or better than NPK fertilizer, and cane rat manure seemed to be the best among the organic manures applied. To derive maximum benefits, large quantity of organic manure will be required for large scale farming which the cane rat droppings may not provide. The poultry manure and cassava peelings performed favorably almost well like cane rat droppings and NPK fertilizer when applied to the acid soil and nutrient depleted soil. Therefore, the present study clearly indicates that the marginal and unproductive soils can be reclaimed by the application of cassava peelings and poultry manure for the optimization of crop production.

Table 5. Effects of applied treatments on dry matter yield of maize plant.

	Dry matter	Yield (g/plant)
Treatment	Acid soil	Nutrient depleted soil
Compost	3.17[ab]	2.49[c]
Poultry manure	2.88[ab]	2.90[b]
Rabbit droppings	2.60[b]	3.80[ab]
Cane rat droppings	3.38[ab]	3.74[ab]
Cow dung	2.27[b]	1.81[cd]
Cassava peelings	2.59[b]	2.60[bc]
NPK	4.77[a]	5.58[a]
Control	1.90[c]	1.12[d]

Means with different letter(s) are statistically different by DMRT.

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