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Effectiveness of Cow Dung and Mineral Fertilizer on Soil Properties, Nutrient Uptake and Yield of Sweet Potato (*Ipomoea batatas*) in Southeastern Nigeria

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Abstract: As the price of chemical fertilizers in the Nigerian market continues to go high thereby making chemical fertilizers unreachable to peasant farmers and the urgent need to improve the fertility of the soils in which sweet potato (*Ipomoea batatas*) is grown, this investigation was carried out at Umudike, Southeastern Nigeria, to evaluate the comparative effect of Cow Dung (CD) and chemical fertilizer on soil properties, nutrient uptake and yield of sweet potato. The experiment was laid out in a randomized complete block design, with four replications. The treatments consisted of 4 t ha^{-1} CD, 400 t ha^{-1} NPK (15:15:15) fertilizer, 2 t ha^{-1} CD+200 kg ha^{-1} NPK fertilizer, 1 t ha^{-1} CD+300 kg ha^{-1} NPK fertilizer, 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer and control which did not receive any treatment. The result of the investigation showed that application of 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer improved Soil Organic Matter (SOM), available phosphorus, exchangeable cations, Effective Cation Exchange Capacity (ECEC) and base saturation more than other treatments. The treatments significantly ($p = 0.05$) improved nutrient uptake when compared to the control, but application of 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer recorded the highest values. The treatments improved the growth and yields of sweet potato more than the control with the highest tuber yield (8.9 t ha^{-1}) being produced with application of 3 t ha^{-1} CD + 100 kg ha^{-1} NPK fertilizer. Application of 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer is hereby recommended to farmers improvement of soil fertility and growth of sweet potato in this part of Nigeria.

Key words: Cow dung, sweet potato, nutrient uptake, tuber yield, soil fertility

INTRODUCTION

Sweet potato (*Ipomeoa batatas*) is one of the major food crop grown in the tropics. In monetary value and on the basis of total production, it ranks seventh in the world and on the basis of production value as an agricultural commodity, it ranks thirteenth (Woolfe, 1992). The leaves are source of proteins, vitamins A and E, while the tubers can be refined into fufu flour for baking and as raw materials in pharmaceutical, paper and textile industries (Truong, 1989).

In resent time, the production rate of sweet potato has been on the decrease despite its numerous economic and nutritional values. This decrease in production of sweet potato has been traced to the poor nutrient status of the soil where this crop is grown. High rainfall, crop removal, rapid mineralization of SOM and excessive cultivation of land due to increase in human population are responsible for this decrease (IITA, 1995).

In the past decades, intensive use of chemical fertilizers was advocated for crop production in the tropics in order to alleviate these nutrient deficiencies (Anonymous, 2000). Presently the use of chemical fertilizers as soil amendment has become cost intensive and beyond the reach of peasant farmers. Isola (1998) has reported that application of chemical fertilizer on highly weathered, low organic matter and nutrient poor soil without compensatory organic fertilizer under intensive farming system and shortened fallow periods could lead to nutrient imbalance and soil acidity with an attendant poor crop yield.

In view of these problems, the use of organic manure as a substitute for chemical fertilizers or in combination with chemical fertilizers at a reduced rate has become vital especially in this era of organic agriculture that reduces the negative effect of chemical fertilizers on climate change. Many studies have been carried out in Nigerian soil comparing the efficacy of organic and chemical fertilizers on tropical soils and crop yield, studies have not been carried out for most soils and crops in all the agro ecological zones. The objective of this study therefore was to evaluate the effect of cow dung and NPK fertilizer at different rates on soil properties, nutrient uptake and yield of sweet potato in Southeastern Nigeria.

MATERIALS AND METHODS

The experiment was carried out at during 2008 planting season at the Teaching and Research Farm of Michael Okpara University of Agriculture Umudike, Abia State Nigeria. Umudike is located on latitude 5° 29'N and longitude 7° 33'E with an elevation of 122 m above sea level. It has an annual rainfall of 1900 mm and a maximum temperature of 34°C. The area has two distinct seasons: the rainy season (April-October) and dry season (November-March). The rainy season has a bimodal distribution pattern with distinct peaks in July and September, typical of the Southeastern and Southwestern zones of Nigeria. There is usually dry spell in between the peaks mostly in the month of August (August break). Recently, there is a shift in the occurrence of this dry spell from the usual month of August, possibly due to current global warming with the attendant climate change. Soils of this area are predominantly Ultisol, derived from Coastal Plan Sands and are characterized by low pH, low cation exchange capacity, low SOM and poor water retention. The predominant occupation of people in this area is agriculture.

The experimental site measuring 37×25 m dominated by guinea grass (*Panicum maximum*) which was under a year fallow was cleared with matchet and hoe. A composite soil sample was collected with soil auger at a depth of 0-30 cm. The sample was air dried, sieved to pass through 2 mm mesh sieve for physical and chemical analysis. A total of 24 experimental plots were mapped out each measuring 5× 5 m and each plot 1 m apart. The plots were tilled with hand hoe. The treatments consisted of 4 t ha^{-1} CD, 400 t ha^{-1} NPK (15:15:15) fertilizer, 2 t ha^{-1} CD+200 kg ha^{-1} NPK fertilizer, 1 t ha^{-1} CD+300 kg ha^{-1} NPK fertilizer, 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer and control which did not receive any treatment. The treatments were arranged in a randomized complete block design and were replicated four times. Appropriate quantities of dried CD was applied on the plots and then worked into the soil with hand hoe. The plots were properly labeled on the basis of the treatment assign to it for data collection. Sweet potato vine cutting of variety TIS 87/0087, 20 cm of length, were planted 60×90 cm at a dept of 15-25 cm and at an angle of 45°. Sprouting began 4-6 days after planting and supply of vacant stands was done 9 days after planting. Two Weeks After Planting (WAP) appropriate quantities of NPK fertilizers were applied on the plots. The site was fenced with wire gauze to prevent rodent infestation. Five plants were tagged on each plot for collection of data on weekly bases.

Three weeks after planting, the number of leaves of sweet potato on tagged plants was counted and the average calculated. The leave area was calculated using Asiegbu (1991) formula, which states that:

$$\text{Leave area} = 0.56\times P\times 6.20$$

where, P = length×breath of sweet potato leaves, 0.56 and 6.20 are constants which account for the irregularity of sweet potato leaves.

Vine length from soil surface was measured using metre rule while yield index was calculated as a ratio of economic yield and biological yield and multiplied by 100. Soil samples were analyzed as follows: Particle size analysis was by Bouyoucous (1951) Hydrometer method using sodium hexametaphosphate as dispersant. Soil pH in soil to water ratio of 1:2.5 was measured using electronic method of Mclean (1982). Total N was by Walkley and Black (1934) method. Available P was extracted using Bray and Kurtz (1945) method. Exchangeable bases were extracted using Thomas (1982) method. Exchangeable acidity was by Mclean (1965) method. Effective Cation Exchange Capacity (ECEC) was calculated as the sum of Total Exchangeable Bases (TEB) and exchangeable acidity. Base saturation was calculated by dividing TEB with ECEC and multiplied by 100.

Nine WAP, sweet potato plants were harvested according to plots, washed thoroughly with tap water and dried in an oven at 65°C to a constant weight for 72 h. They were ground with milling machine and subjected to ashing using porcelain crucible. The ashes were dissolved in 5 mL of 20% HCl. The solution obtained was used for determining the nutrient uptakes using the standard methods mentioned above. Data collected were subjected to Analysis of Variance (ANOVA) and significant means separated using standard error of differences between means and Duncan's New Range Multiple Test (DNRMT) (Duncan, 1955).

RESULTS AND DISCUSSION

The CD used in the study consisted of the following chemical composition: 1.6% N, 0.70% P, 0.53% K, 0.91% Mg, 2.71% Ca, 0.50% Na, 56.8% organic matter and C:N of 7.9. Low C: N of CD indicates low C mineralization and therefore CD and NPK fertilizer with high mineralization are expected to complement each other.

Results of the pre-cropping soil properties of the experimental site (Table 1) showed that the soil was texturally sandy loam, low in pH, organic carbon, total N, available P as well as exchangeable cations and ECEC. This was in conformity with Agboola *et al*. (1982) who had the same report for soils in Southeastern Nigeria. Also, Onweremadu *et al*. (2009) made the same observation on the poor fertility status of soils in Southeastern Nigeria.

Effect of CD and NPK fertilizer on soil properties (Table 2) showed no significant difference on the soil texture. This implies that under short term period, cattle manure does not affect soil physical properties spontaneously until it has stayed as least two years in the farm. Judith *et al*. (2009) observed that application of cattle manure and mineral fertilizer does not significantly increase the bulk density and total porosity under short term farming period. However, significant effect occurred on soil chemical properties. The highest rise in soil pH (H_2O = 5.3 and 1 NKCl = 4.8) was obtained with 3 t ha^{-1}+100 kg ha^{-1} NPK fertilizer. Application of 400 kg ha^{-1} NPK fertilizer did not significantly affect soil pH indicating that use of chemical fertilizers only on degraded soils increases soil acidity. Among the

Table 1: Selected pre-cropping soil properties of the experimental site

Soil properties	Values
Sand (%)	82.0
Silt (%)	11.0
Clay (%)	7.0
Texture	Sandy loam
pH (H_2O)	4.82
pH (1 NKCl)	3.99
Organic carbon (%)	1.33
Total N (%)	0.11
Available P (mg kg^{-1})*	11.01
Exchangeable K (Cmol$^+$ kg^{-1})	0.13
Exchangeable Na (Cmol$^+$ kg^{-1})	0.30
Exchangeable Ca (Cmol^{++} kg^{-1})	3.11
Exchangeable Mg (Cmol^{++} kg^{-1})	1.20
Exchangeable acidity (Exch. Al and H)	1.82
Effective cation exchange capacity	6.21
Base saturation (%)	56.4

*Bray 2

Table 2: Effect of cow dung and NPK fertilizer on soil properties

Soil properties	T_1	T_2	T_3	T_4	T_5	T_6	±SE
Sand (%)	76.2	83.1	79.1	78.6	80.1	82.1	0.9
Silt (%)	5.5	4.8	6.9	7.4	9.9	7.9	1.7
Clay (%)	18.3	12.1	14.0	14.0	10.0	10.0	2.7
Texture	SL	SL	SL	SL	LS	LS	--
pH (H_2O)	5.1	4.8	4.9	5.2	5.3	4.8	0.1
pH (1 NKCl)	4.2	4.0	4.2	4.3	4.8	4.1	0.1
Organic carbon (%)	2.99	2.87	3.18	3.16	3.21	2.17	0.03
Total N (%)	0.14	0.10	0.20	0.18	0.24	0.09	0.02
Available P (mg kg^{-1})*	12.6	11.6	12.3	12.6	12.9	9.1	1.18
Exchangeable K (Cmol$^+$ kg^{-1})	0.13	0.13	0.13	0.16	0.18	0.09	0.01
Exchangeable Na (Cmol$^+$ kg^{-1})	0.29	0.32	0.29	0.3	0.3	0.3	0.06
Exchangeable Ca (Cmol^{++} kg^{-1})	4.46	3.20	4.39	3.75	3.85	2.61	0.34
Exchangeable Mg (Cmol^{++} kg^{-1})	3.12	2.60	3.0	2.8	3.01	2.04	0.38
Exchangeable acidity (Exch. Al and H)	1.32	1.0	1.27	1.09	1.17	1.31	0.15
Effective cation exchange capacity	7.19	6.96	7.84	7.9	8.25	6.39	0.46
Base saturation (%)	65.6	65.1	64.4	65.6	68.5	60.3	0.76

*Bray 2, SL = Sandy Loam, L S = Loamy Sand, T_1 = 4 t ha^{-1} CD, T_2 = 400 kg ha^{-1} NPK fertilizer, T_3 = 2 t ha^{-1} CD+200 kg ha^{-1} NPK fertilizer, T_4 = 1 t ha^{-1} CD+300 kg ha^{-1} NPK fertilizer, T_5 = 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer, T_6 = Control

treatments, application of 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer improved SOM, total N, available P, exchangeable cations and ECEC than others with control recording the lowest values. Application of 400 kg ha^{-1} NPK fertilizer recorded 4.87% soil organic carbon which is the lowest when compared to other treatments excluding the control. This was in concord with Layese *et al.* (2002) and Alvarez (2005) that mineral fertilizer alone is insufficient to maintain soil organic matter levels. High concentration of organic matter in the CD used in the study could be responsible for these improvements in soil chemical properties. Benckiser and Simarmata (1994) reported that 5 t of solid manure contains on the average 900 kg of organic matter. Sommerfelt and Chung (1985) observed that applying 1 t ha^{-1} CD increases SOM by 0.025% per annum. This result indicates that cattle manure can best be utilized in combination with mineral fertilizer for proper soil management. This was in agreement with Obour *et al.* (2009), who noted that applying organic manure in combination with an inorganic N source can increase forage yield of crops nutritive value while reducing the risk of soil P accumulation. The result also showed that low total N (0.10%) was recorded with application of 400 kg ha^{-1} NPK fertilizer when compared to total N in the control (0.09%). This could be attributed to high rate of mineralization of NPK fertilizer that makes N readily

Table 3: Effect of cow dung and NPK fertilizer on nutrient uptakes of sweet potato

	Nutrient uptakes (kg ha^{-1})					
Treatment	N	P	K	Ca	Mg	Na
T_1	8.2a	2.5ab	5.5a	8.6b	6.5a	0.34a
T_2	9.5a	2.8ab	6.0a	8.3b	5.9a	0.28a
T_3	9.8a	2.9ab	6.4a	8.6b	5.6a	o.44b
T_4	11.8b	3.2bb	8.8b	11.8c	7.6b	0.51b
T_5	12.3b	3.8bb	9.2b	12.0c	8.0b	0.52b
T_6	4.1c	1.6ac	2.7c	4.3d	2.3c	0.18c

Mean following the same letter(s) within a column are not significantly different (p = 0.05). T_1 = 4 t ha^{-1} CD, T_2 = 400 kg ha^{-1} NPK fertilizer, T_3 = 2 t ha^{-1} CD+200 kg ha^{-1} NPK fertilizer, T_4 = 1 t ha^{-1} CD+300 kg ha^{-1} NPK fertilizer, T_5 = 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer, T_6 = Control

Table 4: Effect of cow dung and NPK fertilizer on sweet potato growth and yield

Treatment	No. of leaves	Vine length (cm)	Leaf area (cm^2)	No. of branches	Yield index	Tuber yield (t ha^{-1})
T_1	23a	80a	346a	4ab	13.0aa	6.0a
T_2	25a	76a	349a	5ab	12.4aa	5.3a
T_3	26a	79a	351a	6b	13.7bb	7.1ab
T_4	35ab	81a	372ab	7b	14.8bb	7.4ab
T_5	41b	93b	406b	7b	16.3ab	9.6b
T_6	18c	45ab	250c	3ac	4.2cc	1.8c

Mean following the same letter(s) within a column are not significantly different (p = 0.05). T_1 = 4 t ha^{-1} CD, T_2 = 400 kg ha^{-1} NPK fertilizer, T_3 = 2 t ha^{-1} CD+200 kg ha^{-1} NPK fertilizer, T_4 = 1 t ha^{-1} CD+300 kg ha^{-1} NPK fertilizer, T_5 = 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer, T_6 = Control

available and can easily be leached out. The treatments increased available P more than the control with the highest available P (12.86 ppm) recorded with application of 3 t ha^{-1} CD+ 100 kg ha^{-1} NPK fertilizer. The same trend was also observed exchangeable cations. The highest ECEC (8.25) as recorded with application of 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer could be attributed to the better buffer capacity associated with CD.

Effect of CD and NPK fertilizer on N, P, K, Ca, Mg and Na uptakes (Table 3) showed that the treatments significantly (p = 0.05) increased the nutrient uptakes with the highest uptakes recorded with application of 3 t ha^{-1} CD +100 kg ha^{-1} NPK fertilizer. There was no significant difference between 4 t ha^{-1} CD and 400 kg ha^{-1} NPK fertilizer showing that 4 t ha^{-1} CD has higher comparative advantage over 400 kg ha^{-1} NPK fertilizer both in cost and its effect on the environment.

Application of 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer produced the highest values in all the growth parameters measured (Table 4). A maximum sweet potato tuber yield of 9.6 t ha^{-1} and yield index of 16.3 was produced by the same rate. This was as a result of the effect of CD and its combination with little NPK fertilizer on soil properties and nutrient uptakes. The reason for the superiority of application of 3 t ha^{-1} CD+100 kg ha^{-1} NPK over other rates could be that, little amount of chemical fertilizer (1 kg ha^{-1}) was applied. This mineralized rapidly and provided nutrient elements for sweet potato growth at early stage of development before CD with low rate of mineralization released its nutrient that sustained and enhance sweet potato growth and yield. Application of 400 kg ha^{-1} NPK fertilizer or other rates with high chemical fertilizer had shown to cause soil acidity. Acidity in this type of soil could results to P deficiency and Al toxicity.

CONCLUSIONS

Efforts are made towards minimizing the negative impacts of nutrients on the environment through implementation of Best Management Practices (BMPs) that can simultaneously increase crop productivity, economic profitability and environmental sustainability, this study was carried out in line with the above target. Results of this investigation showed that the fertility of a degraded or highly leached soil can be improved by addition of CD or its combination with reduced quantity of NPK fertilizer. Combination of these amendments improved soil properties, nutrient uptake, growth and yield of sweet potato better than when only chemical fertilizers are applied. They improved the fertility of the soil by making nutrients available for sweet potato uptake which enhanced better growth and yield of the crop. Application of 3 t ha^{-1} CD+100 kg ha^{-1} NPK fertilizer proved superior over other rates in improving soil properties, nutrient uptake, growth and yield of sweet potato and therefore is recommended to farmers for sweet potato production in southeastern Nigeria. Application of this rate is more beneficial on degraded and highly leached soils (ultisols, luvisols, acrisols and feralsols) that are low in exchangeable cations, organic matter, available P, total N and pH. There is need to investigate this in other agro ecological zones with other crops.

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