EFFICIENCY AND SUSTAINABILITY OF SELECTED ORGANIC MANURES ON A DEGRADED ULTISOL IN OWERRI, SOUTHEASTERN NIGERIA

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Abstract

Treatments consisting of 6t ha^{-1} each of cow, goat, poultry and swine manures were incorporated in a randomized complete block design with 3 replications into plots measuring 4 x 4 m^2 and maize (*Zea_mays*) planted at a distance of 25 x 75 cm^2. Maize heights at 4, 8and 12 weeks after planting (WAP), root, shoot, total biomas and grain yields and soil properties after crop harvest were evaluated. Sustainability and efficiences of the manures were estimated using sustainability yield index, nutrient uptake, nutrient use, nutient utilization and agronomic efficiencies. Plant heights at the various growth stages, root, shoot, total biomas and grain yields and post treatment soil properties enhanced significantly ($LSD_{0.05}$) with manures relative to the control. Best heights at 4 WAP were 2.03 cm with swine manure, 8 and 12 WAP (95.70 and 485.00cm respectively) with poultry manure. Best root and grain yields (100.75 and 1.96 kg ha^{-1} respectively) were with poultry manure while shoot and total biomass yields (1827.50 and 1884.26 kg ha^{-1}respectively) were with swine manure. Poultry and swine manures gave best agronomic efficiency (0.27) and sustainabilityyield index (0.999982). Nutrient uptake, utilization and use efficiencies varied with manures with poultry and swine being more efficient for most nutrients. Generally, the organic manures sustained the efficiences of maize production and could be suitable inputs for restoring the fertility of degraded Ultisol of Owerri, southeastern, Nigeria.

Key Words: Efficiency, Sustainability and degraded Ultisol

Introduction

Ultisol constitutes about 72% of soils of southeastern Nigeria and is characterized by high acidity, multiple nutrient deficiencies, low organic matter content and poor fertility status (FMANR, 1990). Its use for sustained crop production is only possible using external nutrient inputs especially organic and inorganic manures. Due to high costs, scarcity and environmental problems associated with inorganic manures however, its application is often constrained, resulting to the extensive utilization of organic manures by resource poor farmers.

Organic manures vary, with the common types including farmyard manure, goat, sheep, cow and poultry manures. Land application of organic manure improves soil pH, OM, CEC, nutrient concentration, water holding capacity, aggregate stability and soil structure (Hargreaves and Warman 2009). Its demerits however, include its bulkiness, content of pathogenic organisms, high cost of handling and application and slow nutrient release (Babalola et al., 2005).

In soils amended with organic manures, crop performances and soil properties vary depending on manure types. For instance, it has been noted that soil pH, OM, CEC, P, total N, and bulk density varied widely with the addition of poultry manure, burnt and unburnt rice husks and NPK fertilizers in a degraded Ultisol in Abakiliki, Southeastern Nigeria (Mbah and Onweremadu 2009). Also better maize height, dry matter yield, tissue N, P, K and Na with poultry waste and better tissue Ca and Mg with oil palm sludge relative to other manures have been reported in field trials with poultry manure,cow dung, oil palm sludge, calcium ammonium nitrate and urea fertilizers (Opara-Nadi et al.,2000). Furthermore, in a degraded Ultisol in Nsukka, southeastern Nigeria, Nnaji et al. (2005) obtained improved cassava yield, soil pH, P and exchangeable cations with poultry manure and OM with rice mill waste in trials with poultry manure, rice mill waste and mineral fertilizer.

Variation in crop and soil responses with manure types indicates that their efficiences will differ. Manure efficiency has been expressed in terms of the agronomic and nutrient use efficiences (Uzoho et al., 2012). Agronomic efficiency refers to crop yield per unit quantity of applied manure while nutrient use efficiency is the per unit crop yield per unit nutrient content of the applied manure (Ma et al., 1999). Nutrient use efficiency has been extensively reported for nitrogen and phosphorus (Ma et al., 1999; Kogbe and Adediran 2003) and is partitioned into nutrient uptake and nutrient utilization efficiencies (Moll et al., 1982). Nutrient uptake efficiency reflects the efficiency of crops to obtain nutrients from the soil while nutrient utilization efficiency is the ability of plants to transplant nutrient uptake into yields (Rahimizadez et al., 2010).

Efficiency of manures influences their sustainability. Singh et al. (1990) noted that sustainability of agricultural practices and manure types can be estimated using sustainability index. Efthimiadou et al. (2010) obtained sustained maize agronomic efficiency with double cow manure application on a clay loam soil in Southern Greece, attibutable to the high sustainability index.

Even though organic manures are commonly used for crop production in Southeastern Nigeria, information concerninig their efficicency and sustainability is scanty. The main objective of this study was to evaluate the efficiency and sustainability of selected manures on a degraded Ultisol in Owerri, Southeastern, Nigeria.

Materials and Methods

Study Location

The study site was the Teaching and Research farm of the Federal University of Technology, Owerri located between Latitudes 5^0 21^1 and 5^0 27^1N and Longitudes 7^0 02^1 and 7^0 15^1E. Its mean annual rainfall is 2500 mm, mean relative humidity of 85% and mean daily temperature of 32^0C. Soil type is Arenic Hapludult (Lekwa and Whiteside, 1986). Climax vegetation was spear grass (Imperata cylindrica) and the main economic activity of the area is farming.

Field Experiment

Treatments consisting of 6 t ha^{-1} each of cow, swine, poultry and goat manures plus a control were applied and properly incorporated into the soil on plots measuring 4 x 4 m^2. Experimental design was a randomized complete block with 3 replications. Four weeks after treatment application, 3 healthy maize (variety: Oba super) seeds which were later thinned to one plant per stand were planted at adistance of 25 x 75 cm^2. Weeding was at three weeks after planting (WAP) and crops were allowed to grow to maturity. During the growth period, plant heights at 4, 8 and 12 WAP were determined using steel tape from the base to the collar of the last leaf. Root, shoot, total biomass and grain yields were determined at harvest after oven drying at 105^0C for 48 hrs. The oven dried biomass yield was then milled using a Wiley mill and stored ready for tissue analysis. Surface soil samples of treatment plots were also collected after crop harvest. Both post and pretreatment (randomly collected soil from the field prior to treatment application) soils in addition to manure samples were air dried, sieved through 2 mm diameter mesh and stored in clean polyethylene bags.

Laboratory Analysis

Samples (soil, manure and plant tissue) were analyzed for the following properties. Soil particle size distribution (Gee and Or 2002), pH in 1:2.5 solute/solvent ratio (Hendershort et al., 1993), organic carbon (Nelson and Sommers, 1982), total nitrogen (Bremner and Mulveney, 1982), available P (Olsen and Sommers, 1982), exchangeable cations (Ca, Mg, K, Na) (Thomas et al., 1982). Manure OC, TN, P, Ca, Mg, K and Na were analyzed as for the soil samples above while moisture conent was obtained as the difference in weight between wet and air dried samples. Plant tissue N, P, K and Ca were analyzed using standard methods.

Calculations

Parameters such as Agronomic efficiency, sustainability index, nutrient uptake and nutrient use, utilization and uptake efficiencies were calculated using the following relations:

Nutrient Uptake (kg ha^{-1}) = Dry matter yield x plant nutrient content (1)

Agronomic Efficiency (kg ha^{-1}) = Dry matter yield of Amended plots – Yield of control / Amount of Applied treatments (2)

Nutrient Use Efficiency (NUE) (kg kg^{-1}) = Crop dry matter yield / Nutrient supply (sum of soil nutrient at sowing + mineralized nutrient + nutrient in manure (3)

Nutrient Uptake Efficiency (NupE) (kg kg^{-1}) = Nutrient Concentration in plants / Nutrient supply (4)

Nutrient Utilization Efficiency (NUtE) (kg kg^{-1}) = Dry matter yield / Nutrient Uptake (5)

Sustainability Yield Index = Mean yield – Standard deviation / Maximum yield from ammendment plots. (6)

Statistical Analysis

Analysis of variance (ANOVA) and mean separation using LSD at 5% probability were conducted on the samples using Genstat statistical package (Buysse et al., 2004).

Results and Discussion

Soil and Manure Characterization

Texture of the soil was sandy (Table 1), a reflection of the parent material which is coastal plain sands (FMANR 1990). Its pH was acidic with values less than 4.20, indicative of severe aluminium toxicity. Concentrations of soil OM, TN, available P, Mg, K and Ca were low and below critical limits for Southeastern Nigeria soils (FMANR 1990). In general, the soil could be described as coarse textured, acidic, low in organic matter and soil nutrients as characteristic of most Ultisols of Southeastern Nigeria (FMANR 1990). Coarseness and poor organic matter content of the soil suggests poor aggregation and with the intense rainfall prevalent in the area, it is highly degraded via erosion and leaching.

Composition of the manures varied with manure types (Table 2) with percent organic matter and nutrient concentrations about five times higher than the soil. The pH was alkaline with values between 6.5-8.40. Based on their excellent characteristics (high pH, OM and nutrient stock), the manures could be useful for restoration of fertility of degraded soils.

Maize Performance

Performance of maize differed with manure types (Table 3). Maize heights and yields (shoot, root, total biomass and grain) increased significantly ($LSD_{0.05}$) with manures compared

Table 1. Selected Properties of Pretreatment Soil used for the Study

Depth	Sand	Silt	Clay	TC	pH	OM	TN	Avail P	Ca	Mg	K	Na
cm		%			H_2O		%	mg kg^{-1}		Cmol kg^{-1}		
0-15	90.68	1.12	8.20	S	4.15	0.86	0.04	3.61	0.70	0.42	0.01	0.01
15-30	92.68	1.12	6.20	S	4.12	0.67	0.04	3.30	0.63	0.41	0.01	0.01
30-45	91.68	1.12	7.20	S	4.08	0.48	0.03	2.98	0.55	0.40	0.01	0.01

TC = Textural class, OM = Organic matter, TN = Total nitrogen, Avail = Available, S = Sandy

Table 2. Selected Properties of Manures Used

Manures	pH	MC	DM	OM	TN	P	Ca	Mg	K	Na
	H_2O		%			g kg^{-1}			Cmol kg^{-1}	
Cow	8.0	39.30	60.69	51.60	1.30	3.30	5.00	5.83	6.65	0.43
Goat	8.0	31.67	68.31	78.11	1.96	12.00	4.00	5.00	21.99	0.43
Poultry	8.4	86.48	13.52	63.95	1.61	12.80	6.00	6.67	30.69	0.87
Swine	6.5	55.27	44.72	52.15	1.31	10.90	4.00	5.00	27.62	0.43

Table 3. Effect of Manures on Maize Height, Root, Shoot, Total Biomass, Shoot/Root ratio, Grain Yields, Agronomic Efficiency (AE) and Sustainable Yield Index (SYI)

	Maize Height (cm)			Total Biomass	Root	Shoot	Grain	Shoot/Root	AE	SYI
Treatments	4 WAP	8 WAP	12 WAP		Yields (kg ha^{-1})					
Control	0.73	13.50	115.00	278.67	11.99	266.10	0.27	22.20	0.00	0.99987
Cow	1.00	35.30	271.00	986.57	41.24	944.80	0.98	22.90	0.12	0.999981
Goat	1.70	49.70	339.00	982.12	65.21	913.70	1.78	14.01	0.12	0.999981
Poultry	1.90	95.70	485.00	1879.81	100.70	1774.20	1.96	17.62	0.27	0.999982
Swine	2.03	77.00	434.00	1884.26	54.15	1827.50	1.69	33.76	0.27	0.999982
LSD $_{0.05}$	19.90	20.60	18.10	2.79	0.79	70.90	0.01	0.72	0.18	0.000083
% CV	0.55	21.00	112.10	0.50	0.80	3.30	0.40	1.70	2.40	0.0000

to the control probably due to improvement in soil properties with manures. It has been noted that manures enhance soil properties through improvement in soil nutrient concentrations, nutrient retention, pH, CEC, organic matter, soil structure, aggregate stability and biological activities (Hargreaves and Warman, 2009). In manure and none manure amended plots, maize height increased with time probably due to enhanced root development and better nutrient uptake (Uzoho and Oti 2005) and with poultry manure better relative to others. Also root and grain yields were better with Poultry manure while shoot and total biomass yields performed better with swine manure. Swine manure also gave better Shoot/root ratio thus indicating that the manue promoted better shoot weight per unit increase in maize root weight. Variation in agronomic efficiency (AE) amongst manure types was low (CV = 2.4%), with poultry and swine manures better than cow and goat manures (Table 3). Sustainability of the various manures as indicated by the sustainabilityyield index (SYI) was high thus confirming the observation that organic manure constitutes a low input technology for sustained crop production in the tropics (Akinrinde et al., 2000). Poultry and swine manures however, sustained agronomic efficiency slightly better than cow and goat manures. The high sustainability of the manures signifies the suitability of each of the manures in restoring the fertility status of the degraded Ultisol of Owerri, southeastern Nigeria.

Nutrient Uptake, Nutrient Utilization, Use and Uptake Efficiencies of the Manures

Nutrient (N, P, K and Ca) uptake significantly (LSD $_{0.05}$) increased with manure amendments relative to the control (Table 4). Uptake of the various nutrients was distinctly greater with poultry manure relative to the other manures propably due to better crop yield with poultry manure. It has been indicated that nutrient uptake increases with crop yield (Efthimiadou et al., 2010; Uzoho et al., 2012). Values of nutrient uptake for poultry manure were 276.30, 67.50, 9.02 and 63.91 kg ha^{-1} for N, P, Ca and K respectively. Soil properties also affected maize nutrient uptake (Table 5). For instance K uptake was significantly correlated with soil BS, ECEC, P, Ca, OM and K, N uptake with soil P, BS, ECEC and Ca and P uptake with soil P. Averaged over manures, mean nutrient uptake were 148.80, 45.96, 32.85 and 4.50 kg ha^{-1} for N, P, K and Ca with the order being an increased sequence of Ca < K < P < N indicating that N uptake was higher than other nutrients probably due to its great importance in maize nutrition (Babalola et al., 2005).

Nutrient use, nutrient uptake and nutrient utilization efficiencies of the various nutrients varied with manure types. For instance efficiency in N and K use was better with poultry manure while that for P and Ca were better with cow and swine manures respectively. Also P, Ca and K uptake efficiences were better with Cow while N was with swine manure. Finally, N and K utilization effiiency was better with poultry while those for P and Ca were better for swine and goat manures respectively. Variation in efficiences of the various nutrients could be due to differences in manure composition and the rate of mineralization (Ma et al., 1999).

Table 4. Effect of Treatments on Nutrient uptake (kg ha^{-1}) and Nutrient Uptake, Utilization and Use Efficiencies (kg kg^{-1})

	N				P				Ca				K			
Treatments	Uptake	NUE	NUptE	NUtE	Uptake	NUE	NUptE	NUtE	Uptake	NUE	NUptE	NUtE	Uptake	NUE	NUptE	NUtE
Control	16.70	0.00	0.00	0.00	7.90	0.00	0.00	0.00	0.67	0.00	0.00	0.00	2.23	0.00	0.00	0.00
Cow	117.40	0.04	0.89	0.05	59.60	0.15	0.55	0.27	3.60	0.51	0.40	0.79	27.62	0.20	0.93	0.21
Goat	96.20	0.03	0.49	0.06	30.80	0.04	0.26	0.16	3.93	0.62	0.50	0.81	42.23	0.06	0.50	0.12
Poultry	276.30	0.06	0.89	0.07	67.50	0.08	0.28	0.29	9.02	0.80	0.40	0.50	63.91	0.68	0.51	1.33
Swine	237.40	0.05	0.93	0.05	64.00	0.09	0.31	0.30	5.28	0.83	0.35	0.42	28.26	0.09	0.90	0.05
LSD $_{0.05}$	0.10	0.02	0.04	0.02	0.21	0.02	0.09	0.11	0.16	0.04	0.05	0.09	0.02	0.03	0.02	0.05
% CV	0.00	23.20	3.10	21.30	0.20	15.80	17.10	27.90	1.90	3.60	8.40	9.30	0.00	6.90	1.60	7.90

NUE = Nutrient use efficiency, NUptE = Nutrient uptake efficiency and NUtE = Nutrient utilization efficiency

Table 5. Simple Correlation between Soil Properties and Maize Nutrient Uptake

Soil Properties	Maize Nutrient Uptake			
	N	P	Ca	K
P	0.81**	0.51*	0.41ns	0.83**
BS	0.69*	0.39ns	0.36ns	0.86**
Ca	0.81**	0.34ns	0.48ns	0.92**
ECEC	0.83**	0.32ns	0.47ns	0.92**
K	0.46ns	0.11ns	-0.06ns	0.64*
OM	0.47ns	-0.29ns	0.31ns	0.75**
pH	0.18ns	-0.02ns	-0.27ns	0.45ns
N	0.12ns	-0.20ns	-0.12ns	-0.12ns

Table 6. Effect of Manures on Soil Properties

Treatments	pH	OM	TN	P	Ca	Mg	K	Na	ECEC
		%		mg kg^{-1}	cmol kg^{-1}				
Control	4.16	1.81	0.05	3.60	0.40	0.03	0.01	0.01	1.25
Cow	4.50	3.38	0.08	12.01	2.30	2.50	0.06	0.03	5.63
Goat	4.46	4.31	1.00	8.40	2.10	1.90	0.04	0.02	4.66
Poultry	4.23	3.38	0.08	11.76	2.50	2.40	0.03	0.02	5.63
Swine	4.28	2.34	0.06	11.20	2.09	1.92	0.03	0.02	4.70
LSD 0.05	0.04	0.03	0.08	0.94	0.31	0.28	0.02	0.02	0.52
%CV	0.4	0.60	17.50	5.30	8.90	8.50	29.40	41.80	6.30

Manure Effects on Soil Properties

Addition of manures significantly (LSD $_{0.05}$) enhanced soil properties compared to the control (Table 6). It has been noted that organic manure improves soil properties through increase in soil pH, OM, ECEC, nutrient status, aggregation and nutrient holding capacity (Hargreaves and Warman 2009). Soil properties were enhanced by about 0.07-0.12 units (soil pH), 0.53-2.50% (OM), 0.01-0.95% (N), 4.80-8.41 mg kg^{-1} (P), 1.69-2.10 cmol kg^{-1} (Ca), 1.87- 2.47 cmol kg^{-1} (Mg), 0.02-

0.05 cmol kg^{-1} (K) and 3.45-4.38 cmol kg^{-1} (ECEC). Magnitude of soil soil property improvements varied with manure types as noted by others (Opara-Nadi et al., 2000; Nnaji et al., 2005; Mbah and Onweremadu, 2009). Cow manure promoted soil pH, P, Mg, K and ECEC, goat manure (soil N and OM) and poultry manure (soil exchangeable Ca) better than other manures. This showed that cow manure was superior in most soil properties, contrary to poultry manure as reported by other workers (Opara-Nadi et al., 2000; Nnaji et al., 2005).

Conclusions

In conclusion maize performance and soil properties improved with manure amendments relative to the control. Rate of crop and soil performances varied with manure types, with poultry and swine manures superior to others. Efficiency of maize production on degraded Ultisol in Owerri was better sustained with poultry and swine manures than others, with the former slightly superior to later.

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