Journal of Applied and Natural Science 4 (2): 172-177 (2012)
JANS

Agronomic efficacy of compost manure and NPK fertilizer on some soil chemical properties and maize production in an ultisol environment

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Received: May 21, 2012; Revised received: July 8, 2012; Accepted: August 2, 2012

Abstract: Studies were conducted as an on-farm trial at Evboneka in 2009 and 2010 cropping seasons to estimate the effect of soil amendments in enhancing soil fertility status and relative agronomic efficacy of maize yield in humid ultisol environment. Effects of compost was investigated at application rates of 20 and 40 t ha^{-1} while NPK and organo-mineral fertilizer effects were investigated at 200 kg/ha and a combination of 100 kg/ha NPK and 20 t/ha compost manure (organo-mineral fertilizer) with maize TZEE-W cultivar resulting in five treatments and replicated three times. The results obtained revealed that the tested soil was low in organic matter, total N, available P, moderately acidic and low cations (Ca, Mg and K). The compost manure was rich in N, P, Mg, K, organic carbon and Ca concentration. The application of compost manure and NPK to the soil improved the soil fertility status. The highest maize height (132.70 cm), greatest total dry weight (0.63 t ha^{-1}) and relative agronomic efficacy (%) were obtained from plots treated with 40 t/ha^{-1} compost manure while the plots treated with organo-mineral had the greatest LAI (2.75).

Keywords: Compost, Maize, NPK, Organo-mineral, Soil fertility

INTRODUCTION

The most prominent constraint to food production is low soil fertility. The rate of nutrient depletion of African soils has been reported to be on the increase (Julio and Carlos, 1999). These soils are poor in organic matter and available nutrients, hence its productivity decline over time under continuous cropping (Zingore *et al.,* 2003).

Maize is a heavy feeder of nutrient and its requirement can be fulfilled by supply nutrients through organic manures and inorganic fertilizers to maintain soil and crop productivity on a suitable basis. The need for proper soil fertility management led to an attempt to maintain soil productivity under continuous cropping through inorganic fertilizer application.

Inorganic fertilizer application to crop is a necessary condition for a good yield of crop in Nigeria due to inherent low fertility status of the soils. The use of inorganic fertilizers is reported to be responsible for over 50% yield increase in crops (Ayodele, 1983). Inorganic fertilizers exert strong influence on plant growth, development and yield (Stefano *et al.,* 2004). Ayoola and Adeniyan (2006) had reported that the use of inorganic fertilizer has not been helpful under intensive agriculture because it is often associated with unsustainable yield, nutrient imbalance, leaching and pollution of groundwater (Srinder and Adeoye, 2003). The use of inorganic fertilizer input is further constrained by unavailability of the right type of inorganic fertilizer at the right time, high cost, lack of technical know-how and lack of access to credit (Chude, 1999). This had diverted the attention of agronomists towards making use of organic nutrients (organic manures as well as organic wastes) for improving the soil fertility that allow for profitable crop production (Somani and Totawat, 1996).

The potential for improving soil organic matter level is through the application of organic manures. Composting of decomposable materials and returning them back to the soil is an historic method for maintaining soil fertility through natural nutrient cycling (Adediran and Banjoko, 2003). Various studies have shown the importance of organic nutrient improving crop yields and land productivity. Anikwe (2000) indicated positive responses of rice husk dust on soil productivity. Greater nutrient retention capacity in response to animal waste application has been reported by Mbah and Mbagwu (2006). Similarly, Law-Ogbomo and Remison (2009) reported an increment of 4 t/ha of maize grain yield on ultisol of Benin series due to the application of cured poultry manure.

The benefits derived from the use of organic manures have however not be fully utilized in humid tropics due to huge quantities required to satisfy the needs of crops as transportation and handling costs constitute major constrains. Supply of nutrients from the organic materials can be complemented by enriching them with inorganic nutrients that will be released fast and utilized by crop to compensate for their late start in nutrient release.

ISSN : 0974-9411 (Print), 2231-5209 (Online)

Complementary use of organic manure and inorganic fertilizer has been proven to be sound soil fertility management strategy in many countries of the world (Lombin *et al.,* 1991). High and sustained crop yield can be obtained with judicious and balanced NPK fertilizer application combined with organic manure amendment (Bayu *et al.,* 2006). Adeniyan and Ojeniyi (2005) have reported a higher yield of maize from a combined use of NPK fertilizer and poultry manure.

The present study was aimed at investigating the potential of separate and combined application of compost and NPK in improving soil nutrient status and their agronomic efficacies.

MATERIALS AND METHODS

On-farm trials were conducted at Evboneka in 2009 and 2010. The study area lies within rainforest which degraded to secondary forest as a result of trash and burn agricultural system. The soil used was ultisol of Benin formation (Smith and Montgomery, 1962). Soil analysis was carried out before and after cropping while the compost manure was analyzed before application and after application using Mylaravarapu and Kennelley (2002) procedure.

Compost manure made up of decomposed plant residues obtained from Lake Project Limited, Lagos, Nigeria while the maize cultivar TZEE-W and NPK were sourced from Agricultural Development Programme (ADP), Benin City, Nigeria.

The experiment was laid out in a randomized complete block design with three replicates. Five treatments were involved viz.: untreated (control), organic fertilizer at the rate of 20 and 40 t/ha NPK applied at 200 kg/ha (30 kg N + 13.58 kg P + 24.90 kg K) and organo-mineral fertilizer (i.e combined compost manure at 20 t/ha and NPK at 100 t/ha (15 kg N + 6.79 kg P + 12.45 kg K)). The compost manure applied was thoroughly mixed with the soil and then left for two weeks to allow for mineralization. NPK was applied one week after sowing (WAS).

Three grains of maize were sowed on the field at a spacing of 75 x 25 cm in March in both years. The seedlings were thinned to one per stand 2 WAS. Weeding was carried at 2 WAS and 6 WAS. At 50% tasseling day, data were collected on plant height, leaf area index (LAI) and total dry weight (TDW) from which relative agronomic efficacy (RAE) was computed as:

$$RAE = \frac{TDW(F) - TDW(C)}{TDW(C)}$$

Where F = treated plants, C = untreated control.

Data collected was combined for the two years and analysed using analysis of variance. The Least Significances Differences (LSD) at 5% level of probability was used to separate the means where significance exists.

RESULTS AND DISCUSSION

Some selected physical and chemical properties of the soil on which the trial was sited are presented in Table 1. The particle size analysis revealed that the soil is sandy loam. The soil is moderately acidic (6.00) with organic carbon content of 0.96% corresponding to organic matter content of 1.65. This is low when compared to its critical level (Oti, 2002). Deficiency in organic matter is an indication of poor water and nutrient retention. The soil also exhibited deficiencies in total N, available P and exchangeable bases (Ca, Mg and K) when compared to the critical level of N = 0.15 – 0.20% (Sobulo and Osiname, 1981), available P= 10-16 mg kg^{-1}, K= 0.16 - 0.20 cmol/kg^{-1} (Hunter, 1975), Ca=2.50 cmol/kg^{-1} (Akinrinde and Obigbesan, 2000) and Mg= 0.20 - 0.40 cmol/kg^{-1} (Adeoye and Agboola, 1985) considered as optimum for Southern Nigeria soils. The Ca:Mg ratio was far below threshold limit of 3.0 (Oti, 2002). This further indicated Ca and P deficiencies. This observation re-affirmed Akanbi and Togun (2002) who reported that most of our cultivated soils are impoverished due to intense weathering, leaching and intensive cultivation. This investigation showed that the soil in the trial site is largely deficit in major essential nutrients. Consequently, optimum growth and yield cannot be achieved without supplementary nutrients through organic manure and /or inorganic fertilizer.

The chemical composition of the compost manure used in the trial was characterized (Table 2) through laboratory analysis. The compost manure contained 1.5% total N, 92.3 mg kg^{-1} available P. The exchangeable Ca, Mg and K contents of the compost manure were 20.90, 14.10 and 5.7 cmol/kg^{-1} respectively. This implies that the compost manure is a source of most essential plant nutrients and thus a complete substitute to inorganic fertilizer (NPK)

Table 1. Some properties of the experimental soil prior to cropping.

Soil property	Value
Particle size (g kg^{-1})	
Clay	250
Silt	100
Sand	650
pH (H_2O)	6.00
Organic carbon (%)	0.96
Organic matter (%)	1.65
Total nitrogen (%)	0.12
Available phosphorus (mg kg^{-1})	9.56
Exchangeable cations (cmol kg^{-1})	
Ca	1.02
Mg	0.53
K	0.15

Table 2. Chemical composition of compost manure.

Soil property	Value
pH (H_2O)	7.20
Organic carbon (%)	2.10
Organic matter (%)	3.57
Total nitrogen (%)	1.50
Available phosphorus (mg kg^{-1})	92.30
Exchangeable cations (cmol kg^{-1})	
Ca	20.90
Mg	14.10
K	5.70

for sustaining crop production.

The incorporation of fertilizer types into the soil raised the fertility status of the soil (Table 3). Fertilizer types improved all the chemical properties of the soil investigated. However, percentage increase in soil property value differed among the fertilizer types and rate of application. The pH rose from 6.00 to 6.20 for compost manure and organo-mineral fertilizer except the NPK amended soil where it reduced to 5.50. The pH increase as compost manure increased. The increase in soil pH could be attributed to ion exchange reactions which occur when terminal OH^- of Fe or Al are replaced by organic anions such as tartrate, malate and citrate (Besho and Bell, 1992). The organic matter content rose from 0.96% to 1.30% for compost manure and organo-mineral fertilizer treated plots and decreased to 0.74% for NPK treated plots. This observation is in agreement with Odedina *et al.* (2003) who showed that organic fertilizer increased soil organic matter. Earlier, Agboola and Omueti (1982) had reported that the low inherently fertility characteristics of tropical soils have made nutrient availability in them to be largely controlled by organic matter. Organic matter plays a crucial role in sustaining soil quality, crop production and environmental quality due to its effects on soil physical, chemical and biological properties (Bauer and Black, 1994).

The total N increased progressively as compost manure increased also with organo-mineral and NPK fertilizers. The highest value of N (1.05%) was obtained from NPK treated plots. The available P increased with compost manure, NPK and organo-mineral fertilizers application. The increase in P availability in compost manure treated plots could probably be due to increase in soil pH (Giesler *et al.,* 2005) and anions such as tartrate, malate and citrate competition with soil phosphorus (Liu and Huang, 2000). The exchangeable Ca rose from 1.02 to 5.10 cmol/kg^{-1} for control and organo-mineral fertilizer treated plots, respectively. Exchangeable Mg follows a similar trend with Ca. the highest value of Mg (2.52 cmol/kg^{-1}) was obtained from the organo-mineral fertilizer treated plots, followed by NPK (2.35 cmol/kg^{-1}) treated plots. Exchangeable K in all the treatments was higher than the untreated plots. The exchangeable K rose from 0.15 cmol/kg^{-1} to 1.55 cmol/kg^{-1} in NPK treated plots.

This investigation revealed that the compost manure,

Table 3. Soil chemical properties after compost manure and NPK fertilizer application**.**

Treatment	Soil property						
	pH (H_2O)	Organic C (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable cation (cmol kg^{-1}) Ca	Mg	K
Control	6.00	0.96	0.12	9.56	1.02	0.55	0.15
20 t ha^{-1} CM	6.10	1.10	0.65	16.13	3.15	1.10	1.20
40 t ha^{-1} CM	6.20	1.30	0.96	30.45	3.60	1.15	1.30
NPK	5.50	0.74	1.05	96.53	4.18	1.35	1.55
OF	6.00	1.20	0.78	116.72	5.10	1.52	1.10
Mean	5.96	1.06	0.71	53.88	3.41	1.13	1.06

CM - Compost manure, OF – Organo-mineral fertilizer

Table 4. Soil chemical properties after compost manure and NPK fertilizer application and cropping with maize.

Treatment	Soil property						
	pH (H_2O)	Organic C (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable cation (cmol kg^{-1}) Ca	Mg	K
Control	5.70	0.5	0.07	9.52	0.65	0.34	0.10
20 t ha^{-1} CM	6.00	1.00	0.70	18.00	2.56	1.50	1.34
40 t ha^{-1} CM	6.10	1.20	0.98	25.12	3.35	2.05	1.38
NPK	5.30	0.55	0.90	63.10	3.56	2.00	1.20
OF	5.90	1.10	0.80	110.00	4.00	2.46	1.43
Mean	5.80	0.87	0.66	45.15	2.82	0.87	1.43

CM - Compost manure, OF – Organo-mineral fertilizer

Table 5. Maize performance at 50% tasselling as influenced by compost manure and NPK fertilizer application.

Treatment	Days to 50% tasselling	Plant height (cm)	LAI	TDW ($t\ ha^{-1}$)	RAE (%)
Control	59.67	86.00	1.52	0.20	0.00
20 $t\ ha^{-1}$ CM	57.00	120.00	2.09	0.49	138.70
40 $t\ ha^{-1}$ CM	58.33	132.70	2.48	0.63	211.00
NPK	53.33	117.70	1.95	0.54	165.00
OF	57.67	127.00	2.75	0.54	157.00
Mean	58.00	116.70	2.16	0.48	134.30
LSD (0.05)	ns	25.800	0.095	0.061	23.560

CM-Compost manure, OF-Organo-mineral fertilizer

NPK and organo-mineral fertilizer raised the fertility status of the soil. However, the high organic carbon content coupled with increased in other soil chemical components associated with compost manure and organo-mineral fertilizer, is an indication that they are potential sources of soil amendment to sustain yield under intensive cropping system.

After cropping with maize as presented in Table 4, the pH was reduced to 5.70 in control, 6.00 in compost manure (20 t/ha), 6.10 in compost manure (40 t/ha), 5.30 in NPK and 5.90 in organo-mineral fertilizer. The reduction in pH is attributed to crop removal inducing the replacement of cations with oxide and hydroxide of Fe and Al. Organic carbon was reduced in all the treated plots and control, but was more drastic in the control and NPK treated plots. This observation is in agreement with Ojeniyi (2000), who reported the use of inorganic fertilizer has not be helpful under intensive agriculture because it is often associated with soil degradation brought about by loss of nutrient due to its unsustainable utilization by crops and leaching. The total N increased in all the treated plots except NPK treated plots. The reduction could probably be due to crop removal and leaching. The increase in compost manure and organo-mineral fertilizer could be attributed to gradual mineralization of organic matter thereby releasing moderately nitrate into the soil. Available P decreased in control and NPK treated plots owing to phosphate sorption arising from decrease in pH.

Exchangeable Ca increased in compost manure and organo-mineral fertilizer treated plots but decreased in control and NPK treated plots. Exchangeable Mg was reduced after cropping and varied from 0.34 $cmol/kg^{-1}$ in control to 2.46 $cmol/kg^{-1}$ in organo-mineral fertilizer treated plots. The reduction was highest in control plots to the value of 38%, followed by NPK (29.5%) and the least was organo-mineral fertilizer (3.9%). Exchangeable K ranged from 0.10 $cmolkg^{-1}$ in control to 1.43 $cmol\ kg^{-1}$ in organo-mineral fertilizer treated plots. There was drastic reduction of exchangeable K in control plots and NPK treated plots to the tune of 33.30% and 16.10%, respectively.

The increase in soil N, P, K and Ca contents after cropping associated with compost manure and organo-mineral fertilizer treated plots is an indication that, it is a better alternative to inorganic fertilizer because it can sustain continuous cropping. This is an indication that adequate nutrients, required to support crop production can be attained from compost manure application by enrichment with inorganic nutrients (Ayoola and Makinde, 2007).

The effect of compost manure, NPK and organo-mineral fertilizer on maize production at 50% tasselling day is presented in Table 5. Days to 50% tasselling varied from 57 to 59.67 days and there were no significance differences among treatments. The plant height was influenced positively and comparable among treated plots. All treated plots produced plants that were significantly taller than from the untreated control. Organo-mineral fertilizer treated plots produced the highest LAI (2.75) and were significantly different from all treatment and control. LAI increased with increase in compost manure application level. The higher plant heights and LAI of compost manure and organo-mineral fertilizer treated plots over NPK treated plants is in agreement with Ipinmoroti *et al.* (2002) who reported that the slow nutrient release of the organic constituents must have sustained the continuous better performance of *Amaranthus cruentus* and grain yield of maize over control. The TDW among different treatments were significantly influenced by soil amendments alone or in combination during both years of trials. The observed TDW differences among treatments could be related to nutrient availability to crops and release patterns by the soil amendments. The application of compost manure at 40 t/ha resulted in significantly highest TDW (0.63 t/ha. This observation is in conformity with the findings of Bano *et al.* (1987). This was mainly attributed to increased supply and uptake of plant nutrients. The highest TDW associated with composted manure treated plant at 40 t/ha indicated less fiber and more accumulation of nutrients in comparison with NPK and control (Sanwal *et al.,* 2007). The RAE among different treatments was significantly influenced by fertilizer application. The 40 t/ha compost manure treatment was the more superior in terms of RAE, followed by NPK and organo-mineral fertilizer which were at par and the least was compost manure at 20 t/ha. The higher RAE exhibited by treated plots was mainly attributed to increase availability of nutrients in soil and maize uptake of the applied fertilizers.

Conclusion

Compost manure, NPK, and organo-mineral fertilizers are effective sources of nutrients for increasing soil fertility and performance of maize. The compost manure use alone or combine with NPK at reduced level sustained soil productivity, crop performance and relative agronomic efficacy. Application of compost manure at 40 t/ha had the best performance since plant height, total dry weight and relative agronomic efficacy were maximized at that level due to its cumulative and complementary effect on nutrient availability.

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