International Journal of Soil Science and Agronomy Vol.2 (3), pp. 060-066, March, 2015. Available online at www.advancedscholarsjournals.org © Advanced Scholars Journals

Full Length Research Paper

Nutrient intake by Abelmuscus esculentus and its impacts on soil concoction properties as influenced by the use of manure

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Accepted 15 February, 2015

A field experiment was conducted as an on-farm trial at Uyinmwendin (Rhodic Paleudult), Edo State, Nigeria, in 2009 and 2010 to investigate the residue of compost manure, compost manure + NPK and NPK fertilizer treatments on nutrient concentration and uptake of *Abelmuscus esculentus* and soil chemical properties. Five treatments were selected viz: untreated (control), compost manure applied at the rate of 20 and 40 t ha^{-1}, NPK applied at the rate of 200 kg ha^{-1} and compost manure + NPK (that is, complementary use of compost manure applied at 20 t ha^{-1} and NPK applied at 100 kg ha $^{-1}$) using randomized complete block design and replicated three times. Analysis of the soil indicated that the soil is acidic, with low nutrient status. Application of fertilizer influenced the soil nutrient status positively. Optimum fruit yield was obtained at 40 t ha^{-1} compost (49.13 t ha $^{-i}$). Residually, the N, P and K concentration of okra were significantly higher in compost manure applied at both 20 (2.52% N, 0.43% P and 2.38% K) and 40 t ha^{-1} (2.09% N, 0.41% P and 2.18% K) and compost manure (2.13 % N, 0.43% P and 1.18% K) than NPK (1.22% N, 0.13% P and 0.62% K) and control (0.73% N, 0.11% P and 0.28% K). Compost manure used solely and in complementary quantity with NPK had higher nutrient uptakes than sole NPK use. The soil N, P and K concentrations were reduced by cropping. They were lowest in untreated control and increased with fertilizer application. The compost manure and compost manure + NPK showed a greater potential for increasing plant macronutrients (N, P, K, Ca and Mg) contents. The increases in the soil N, P and K contents after cropping associated with compost manure + NPK treated plots is an indication that compost manure + NPK treatment is a better alternative to inorganic fertilizers because it can sustain continuous cropping.

Key Words: Nutrient content and uptake, soil amendments, soil chemical properties.

INTRODUCTION

Okra production in Nigeria is predominantly carried out by the resource-poor farmers. The yield of okra in Nigeria is very low (about 2 t ha^{-1} (FAO, 2007)) owing to low native soil fertility status among other factors. Decline in native fertility status in most humid forest soil is due to intensive weathering and leaching, erosion, run-off, nutrient depletion, nutrient fixation, salinization and water logging (Vanlauwe, 2000). The stability of production depends on replenishing nutrients removed from the soil by crops, maintaining desirable physical condition of the soil, preventing an increase in soil acidity and toxic elements and minimizing or preventing erosion (Sanwal et al., 2007). This emphasizes the importance of fertility restoration in achieving and maintaining high crop productivity and it can be achieved through the use of external fertilizer input.

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Inorganic fertilizers have been used as a way of sustaining soil productivity. The addition of inorganic fertilizer is efficient, due to its nutrient concentration and relative ease of transportation. However, the extent to which farmers can depend on this input is constrained by unavailability of the right type of inorganic fertilizer at the right time, high cost, lack of technical know-how, weak extensive service and lack of access to credit (Chude, 1999). Other problems associated with the use of inorganic fertilizers include pollution of ground water after harvest, non-improvement of soil structure (Gordon et al., 1993); increased soil acidity, reduced crop yield, nutrient imbalance and depletion of organic matter. The problems associated with the use of inorganic fertilizers have diverted the attention of agronomists toward making use of organic materials (both organic manures and organic wastes) for improving the soil physical properties that allow profitable crop production (Somani and Totawat, 1996).

Organic manures are rich in nutrient composition and could be easily ploughed back into the field to enhance better performance and sustain agricultural production. They are cheap, easy to come by, always safe to use, non-poisonous to crops and environmentally friendly. In addition, organic manures build healthy soils. However, they have not been fully utilized in the humid tropics due to huge quantities required in order to satisfy the nutritional needs of crops owing to low nutritional concentration compared with inorganic fertilizers. This has resulted in high transportation and handling cost which constitute major constraints.

It is clear that the prospect of obtaining enough inorganic fertilizers to meet the requirement of the teaming population in the tropic is remote. The supply of organic manures and wastes on farms will likely be insufficient to overcome soil nutrient deficiency. Complementary use of organic manures with inorganic fertilizer is widely known to be reliable and sustainable soil fertility management strategy. It minimizes nutrient leaching, particularly in poor sandy soil and subsequent ground water contamination (Manna et al., 1999). This maximizes the use of available organic resources and minimizes the use of costly purchased inorganic fertilizers (Manral and Savena, 2003).

This trial was conducted to evaluate the residual effects of compost manure, compost manure + NPK and NPK fertilizer on nutrient concentration and uptake of *Abelmoschus esculentus* and soil chemical properties in degraded ultisol environment.

MATERIALS AND METHODS

The study was conducted in the forest ecological zone of Edo State, Nigeria in 2009 and 2010. Edo State is located between Latitudes 5° 4″ and 7° 38″ and Longitudes 5° 4″ and 7° 38″ of the equator. The soil used was ultisol of Benin formation (Smith and Montgomery, 1962). Composite soil samples collected from the experimental site before experiment were air-dried at room temperature, crushed and sieved with a 2 mm sieve to remove debris and other materials and prepared for laboratory studies according to Mylavarapus and Kennelley (2002) procedure. The compost manure made up of decomposed plant residues was obtained from Lake Projects Limited, Lagos, Nigeria; while the okra varietal "OCRA" was obtained from Premier Seed Limited, Benin City, Nigeria. The experiment was laid in a randomized complete block design with three replicates. Five treatments were involved viz: untreated (control), compost manure applied at 20 and 40 t ha^{-1}, NPK applied at the rate of 200 (30 kg N + 13.58 kg P + 24.90 kg K), kg NPK ha^{-1} and compost manure + NPK (that is combined compost manure at 20 t ha^{-1}) and NPK at 100 (15 kg + 6.79 kg P + 12.45 kg K) kg ha^{-1}. 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 transplanting. Each plot size was 3.60 x 3.00 m and consisted of beds.

Three seeds of okra cultivar "OCRA" were sown at 50 x 50 cm which was later thinned to one per stand. At harvest, number of fruits was counted per plant and fresh fruit weights obtained per plot was used to determine yield per hectare. After the field experiment, composite soil samples were taken from individual plots in the field that received different treatment combinations and prepared for laboratory analysis according to the methods described by Mylaravapus and Kennelley (2002). The experiment was repeated in January 2010. This time, no organic fertilizer or inorganic fertilizer was applied. However, at harvest, three fruits were randomly selected from each plot, weighed, sundried, and packed into brown envelopes and oven dried for 2-3 days at 60°C to a constant weight. The dried fruits were ground and passed through a 1mm sieve for N, P and K as per the methods described by Mylavarapus and Kennelley (2002). The nutrient uptakes were computed by multiplying the dried fruit weight with nutrient concentration. Data collected on yield, residual concentration, uptake and soil chemical properties were subjected to statistical analysis using analysis of variance (ANOVA). Mean separation was carried on using Least Significant Difference (LSD) test only where the F-values were significant.

RESULTS AND DISCUSSION

Soil fertility status

The chemical composition of the compost manure used in the trial is shown in Table 1. The compost manure was enriched with nutrients. This implies that compost manure is a source of most essential plant nutrient and thus a complete inorganic fertilizer (NPK) to be used for sustaining crop production. The physical and chemical properties of the soil on which the trial was conducted are presented in Table 2. The soil is slightly acidic (6.00) and the organic carbon is 0.96%. The nutrient contents were low when compared with their critical levels in Southern Nigerian soils (Adeoye and Agboola, 1985). This investigation has revealed that Benin soils are largely deficient in major essential nutrients. Therefore, it is expected that the application of organic and/or inorganic fertilizers such as NPK can increase yield of crops. The various fertilizer types used, raised the fertility status of the soil. NPK fertilizer increased soil acidity through its reduction in soil pH and organic carbon.

Improvement of the soil pH in organic and organomineral fertilizer treated plots might be due to the

Table 1. Chemical properties of compost manure.

Parameter	Value
pH (H_2O 1:1)	7.20
Organic carbon (%)	2.10
Total nitrogen (%)	1.50
Available phosphorus (mg kg^{-1})	92.30
Exchangeable cations (cmol kg^{-1})	
Calcium	20.90
Magnesium	14.10
Potassium	5.70

Table 2. Soil fertility status after treatment with fertilizer before cropping with okra.

Parameter	Treatments				
	Control	20 t ha^{-1} CM	40 t ha^{-1} CM	NPK	CM + N
pH (H_2O) 1:1	6.00	6.10	6.20	5.50	6.10
Organic carbon (%)	0.90	1.10	1.30	0.74	1.30
Total nitrogen (%)	0.12	0.63	0.98	1.05	0.78
Available phosphorus (mg kg^{-1})	9.56	16.13	30.45	96.53	116.72
Exchangeable cations (cmol kg^{-1})					
calcium	1.02	5.15	6.00	9.18	16.10
Magnesium	0.53	1.10	5.50	8.35	16.51
Potassium	1.20	1.70	5,30	8.35	10.51
Particle size analysis (g kg^{-1})					
Clay	250.00	260.00	260.00	250.00	270.00
Silt	100.00	110.00	110.00	90.00	110.00
Sand	650.00	630.00	630.00	660.00	620.00

CM – Compost manure; CM + N – Compost manure + NPK.

possible enrichment of the soil with Ca from the compost manure. The incorporated compost manure into the soil influenced the soil nutrient status. However, the high organic carbon content, with increase in other soil chemical components, is an indication that compost manure has high potential of gradual release of nutrients to the soil that can help to improve the fertility of a degraded ultisol, thereby sustaining yield under intensive cropping system. The higher content of soil total N, available P and exchangeable cations in NPK treated plots compared with compost manure treated plots might be due to fast release of nutrients from it. This however, makes it prone to leaching and percolates deep into the soil, hence not utilized by the crops, it was intended for.

Fruit yield

The effect of fertilizer application on pod yield and its components is shown in Table 3. The yield obtained in the study is a reflection of the application of fertilizer to the soil nutrient. The fruit yield per hectare ranged from 7.92 to 9.13 t ha^{-1} for untreated control and compost at 40 t ha^{-1}, respectively. The observed differences among fertilizer types could be related to nutrient availability to okra plants and release patterns by the fertilizers. The reduced fruit yield produced from the untreated plants could be related to insufficient nutrient uptake as the plants have to rely on the native fertility of the soil. The yield analysis revealed that the fruit yield increase was due to fruit weight and number of fruits per plant. The highest fruit yield produced from 40 t ha^{-1} treated plots might be due to its cumulative effect of nutrients released by the compost manure in the soil.

The average yield of okra in Nigeria was estimated at 5.00 t ha^{-1} (FAO, 2007). But with improved management practice, yield up to 9.13 t ha^{-1} are possible. The observed yield differences among treatments could be related to nutrient availability to crops and release patterns by the organic fertilizer. The fruit yield obtained in the study is a reflection of improvement in nutrient status of the soil as a result of fertilizer application. The highest yield obtained at 40 t ha^{-1} of compost manure + NPK treated plots might be due to the cumulative effect

Table 3. fruit yield and its components.

Treatment	No. of fruits (plant^{-1})	Average fruit wt (g)	Average wt of fruit (g plant^{-1})	Fruit yield (t ha^{-1})
Control	8.33	15.25	126.67	7.92
20 t ha^{-1} Compost manure	10.33	13.57	139.67	8.73
40 t ha^{-1} Compost manure	11.67	12.56	146.00	9.13
NPK	10.67	13.30	141.33	8.84
Compost manure + NPK	11.00	12.73	140.00	8.75
Mean	10.40	13.48	138.73	8.64
LSD (0.05)	0.833	ns	10.113	0.240

ns – Not significant at 5% level of probability.

Table 4. Residual effects of soil amendments on nutrient concentration in okra.

Treatment	Nutrient concentration (%)		
	N	P	K
Control	0.73	0.11	0.28
20 t ha^{-1} Compost manure	2.52	0.43	2.38
40 t ha^{-1} Compost manure	2.09	0.41	2.18
NPK	1.22	0.13	0.62
Compost manure + NPK	2.13	0.43	1.81
Mean	1.74	0.30	1.45
LSD (0.05)	0.581	0.258	0.546

of nutrients released by the compost manure and NPK to the soil.

Nutrient concentration

The residual effect of fertilizer application on nutrient concentration of okra is shown in Table 4. N, P, and K concentration of the plant were dependent on soil nutrient status. N and K were the main nutrients taken from the soil as against the small amount of P. The best residual effect was obtained from the compost manure at 20 t ha^{-1} (2.52%) treated plants. However, it was statistically similar to compost manure at 40 t ha^{-1} and compost manure + NPK treated plants with 2.09 and 2.13%, respectively. Lower N concentration of NPK treated plants compared with compost manure and compost manure + NPK treated plants conformed to the findings of Alabi and Odubena (2001).

Residually, compost manure alone and in complementary quantity with NPK had significant influence on P of the plant. The residual effect of compost manure and compost manure + NPK was not as pronounced on P as N. Compost manure at 40 t ha^{-1} and compost manure + NPK treated plants produced the highest P concentration of 0.43% which was at par with compost manure treated plants of 0.41%. NPK treated plants (0.13%) was not significantly difference from the untreated plants (0.11%). The pattern of distribution of P concentration was similar to K and there was no significant differences between NPK treated plants (0.62 %) and untreated control plants (0.28%). However, other treatments were superior to control. Compost manure at 20 t ha^{-1} produced the highest K concentration (2.38%) which was at par with compost manure applied at 40 t ha^{-1} (2.18%) and compost manure + NPK (1.81%).

Nutrient uptake

The residual effect of compost manure, compost manure + NPK and NPK fertilizer on nutrient uptake of okra is shown in Table 5. The residual effect of compost manure and NPK, used alone and combined had influence on N uptake of okra pod. The application of compost manure at 20 t ha^{-1} residually gave 73.58 kg N ha^{-1} uptake compared to 18.10 kg N ha^{-1} produced from the untreated plants. All treatments were at par but significantly different from untreated plants.

Generally, the nutrient uptakes of P and K under NPK and untreated plants were at par. The uptake of P and K were highest in plots from the residual effect of compost manure and its complementary use with NPK fertilizer. This observation is in agreement with Isitekhale and

Table 5. Residual effects of soil amendments on nutrient uptake of okra.

Treatment	Nutrient uptake (g kg^{-1})		
	N	P	K
Control	18.10	0.28	0.69
20 t ha^{-1} Compost manure	73.58	1.26	69.50
40 t ha^{-1} Compost manure	70.64	1.39	73.68
NPK	38.55	0.41	19.59
Compost manure + NPK	64.11	1.29	54.48
Mean	53.00	0.93	43.59
LSD (0.05)	26.873	0.181	19.519

Table 6. Residual effects of soil amendments application on soil chemical properties.

Parameter	Treatment						
	Control	20 t ha^{-1} CM	40 t ha^{-1} CM	NPK	CM + N	Mean	LSD (0.05)
pH (H_2O 1:1)	5.60	5.90	6.00	5.00	6.00	5.54	0.200
Organic C (%)	0.80	1.00	1.14	0.54	1.35	0.96	0.403
Total N (%)	0.03	0.76	0.99	0.95	1.01	0.71	0.320
Available P (mg kg^{-1})	6.73	18.56	46.17	22.54	101.19	45.19	28.765
Exchangeable cations (cmol kg^{-1})							
Calcium	0.52	5.96	7.40	6.90	13.35	6.63	3.633
Magnesium	0.35	0.95	4.35	6.10	16.00	4.34	3.683
Potassium	0.70	1.50	6.30	5.70	8.90	4.22	1.674

CM - compost manure, CM + N - compost manure + NPK.

Osemwota (2010). Isitekhale and Osemwota (2010) advocated the use of manure since it enhances the release, availability and absorption of nutrients when compared to NPK fertilizer even after the first year of application.

Residual soil chemical properties

The residual effect of fertilizer application on soil chemical properties is shown in Table 6. Residually, compost manure and NPK applied alone and their combinations had significant influence on the soil chemical properties. After cropping with okra, the soil pH was reduced to 5.60 in control, 5.90 in compost manure applied at 20 t ha^{-1}, 6.00 in compost manure applied at 40 t ha^{-1}, 5.00 in NPK and 6.00 in compost manure + NPK. The lowest pH of 5.00 associated with NPK treated plots is in agreement with Ibeawuchi et al. (2006), who observed that continuous use of inorganic fertilizer can lower the soil pH which will result in reduction in crop yield. The least pH recorded in NPK treated plots compared with compost manure treated plots is consistent with acid forming nature of inorganic fertilizer due to its N and P content. Organic carbon also varied significantly among the fertilizer types. Organic carbon was reduced in all the treatments including control except compost manure + NPK treated plots, where it increased from 1.20 to 1.35%. The reduction in organic carbon is owing to complete removal of the biomass from the field (Yihenew, 2002). The low soil organic content has consequently resulted in soil acidity, nutrient imbalance and low crop yield. This observation is in agreement with Agboola and Omueti (1982) who reported that the response of crop to fertilizer application depends on soil organic matter.

Organic carbon contents play a crucial role in sustaining soil fertility, crop production and environmental quality due to their effect on soil physical, chemical and biological properties, such as soil water retention, nutrient cycling, gas flax and plant root growth (Bauer and Black, 1994;Saiju and Kalisz, 1990). The continuous use of NPK alone drastically reduced organic carbon and consequently lowers soil fertility. The total N content increased in the entire treated plots except control and NPK treated plots. In NPK treated plots, the total N content decreased from 1.05% before cropping to 0.95% after cropping. This might be due to leaching and volatilization. This observation is in agreement with Padwick (1983) who reported that many African soils show nutrient deficiency problems after a short period of cultivation, with N being most depleted. Application of compost manure and compost manure + NPK compensated for the low level of total N which is a major defect and characteristic of most tropical soils (Ipinomoroti et al., 2006).

Available P after cropping decreased in control and NPK treated plots and increase in compost manure and compost manure + NPK treated plots. It was highest (101.19 mg kg^{-1}) in compost manure + NPK treated plots. Higher residual available P in plots treated with compost manure than pre-cropping is due to decrease in P sorption.

Exchangeable Ca increased in compost manure and compost manure + NPK treated plots, but decreased in control and NPK treated plots. Exchangeable K varied from 0.52 cmol kg^{-1} in control to 12.35 cmol kg^{-1} in compost manure + NPK treated plots. However, exchangeable Mg was reduced after cropping. It varied from 0.35 cmol kg^{-1} in control to 10.00 cmol kg^{-1} in compost manure + NPK treated plots. The reduction in exchangeable Mg was highest in control plots with the value of 34% followed by NPK (27%) and the least was compost manure + NPK treated plots (5%). Exchangeable K followed the same trend as exchangeable Mg. It ranged from 0.70 cmol kg^{-1}in control to 8.90 cmol kg^{-1} in compost manure + NPK treated soils. The highest reduction was observed in NPK treated plots (46%) and the least was obtained from compost manure applied at 20 t ha^{-1} with a value of 6.30%. The higher mean values in exchangeable cations observed in compost manure and compost manure + NPK were highly influenced by high organic carbon (organic matter) accrued to them.

This study revealed that total N, available P and exchangeable cations were significantly reduced by okra cropping in untreated plots. Higher content of total N, available P, exchangeable Ca and Mg observed in compost manure and compost manure + NPK treated plots can be attributed to the improved organic carbon status of the soil leading to higher organic matter. Organic matter is a natural source of nutrient and exchangeable cations.

This revealed the higher potentials of compost manure and compost manure + NPK for sustained long-term cultivation. However, compost manure + NPK showed a greater potential for increasing soil nutrient contents. This is attributed to the quick release and utilization of inorganic fertilizer by crops to compensate for late release of nutrients from the compost manure which in turn minimizes leaching out of nutrient from inorganic fertilizer. The highest soil nutrient content attributed to compost manure + NPK after cropping is an indication that the NPK requirements of okra can be met by the complimentary use of compost manure and compost manure + NPK as a viable alternative to inorganic fertilizers.

Conclusion

This study has demonstrated the effectiveness of the various fertilizer types in improving the fertility status of degraded ultisol for sustainable okra production. Compost manure when used alone or in combination with NPK residually increased N, P and K concentrations and uptake. The use of the compost manure in combination with NPK best enhanced residual soil fertility and therefore recommended for farmers.

Compost manure + NPK may be a useful management practice to minimize leaching losses, improve soil structure, and reduce production cost by reducing the use of expensive inorganic fertilizer with the additional advantage of a clean environment through the use of compost manure. It also helps to overcome insufficient nutrients in the compost manure.

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