Journal of Agriculture and Environment Vol. 14 No. 1, 2018: 57-65
ISSN 1595-465X

AGRONOMIC EFFICACY OF FERTILIZER TYPES ON SOME SOIL CHEMICAL PROPERTIES AND SWEET POTATO PRODUCTION IN AN ULTISOL ENVIRONMENT

K. E. Law-Ogbomo, A. U. Osaigbovo and O. O. Ikpefan

Department of Crop Science, Faculty of Agriculture, University of Benin, PMB 1154, Benin City, Nigeria

ABSTRACT

Studies were conducted in 2014 and 2015 cropping seasons at the Experimental Farm of the Faculty of Agriculture, University of Benin, Benin City, Nigeria, to evaluate the effect of soil amendments on enhancing soil fertility status and relative agronomic efficiency of sweet potato yield in humid ultisol environment. The treatments were Cattle and Poultry manures at application rate of 15 t ha^{-1} each, NPK fertilizer at 400 kg ha^{-1} and control (no fertilizer) replicated three times. Data were collected on plant establishment, vine length, leaf area index (LAI), total dry matter and relative agronomic efficiency. The results obtained showed that the soil prior to the experiment was low in total N, available P and exchangeable cations, but moderately acidic and high in organic matter. The manures were rich in N, P, Mg, K, organic carbon and Ca concentration. The application of poultry manure, cattle manure and NPK to the soil improved the soil fertility status. The longest Sweet potato vines were observed in poultry manure (252.10 cm) and NPK (249.90 cm) treated plots. The highest LAI (5.15 cm) was observed from plots treated with poultry manure while the plots treated with cattle and poultry manures had the greatest total dry matter (TDM) and relative agronomic efficiency (RAE). TDM was positively correlated with vine length ($r = 0.360$) and RAE ($r = 0.569$). Vine length positively correlated with LAI and RAE with a coefficient of 0.416 and 0.360, respectively. Poultry and cattle manures at the application rate of 15 t ha^{-1} are therefore recommended for sweet potato growers in the humid ultisols environment for better performance.

Keywords: Cattle manure; growth; poultry manure; NPK; soil fertility

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) of the family Convulvulaceae originated in America (Mexico, Central America and Caribbean) and the North Western part of South America. Globally, it is among the important food crops in the world, after wheat, rice, maize, Irish potato, and barley (Ikeorgu, 2003). The crop is well adaptable to tropical and subtropical climates (Kareem, 2013).

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 their productivity decline over time under continuous cropping (Zingore *et al.,* 2003). Increase in productivity of land can be achieved through fertilizer application.

In order to obtain good yield, modern varieties of different crops require fertilizer application. Inorganic fertilizer application to crops is a necessary condition for a good yield of crops 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 (Priyadharshini *et al.*, 2016). 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. The use of inorganic fertilizer is further constrained by unavailability due to high cost and lack of technical know-how (Chude, 1999). The economic condition of resource-poor farmers often does not support them to use required quantity of inorganic fertilizers. The attention of agronomists towards making use of organic nutrients (organic manures as well as organic wastes) for improving the soil fertility and profitable crop production is more reliable (Somani and Totawat, 1996).

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

MATERIALS AND METHODS

Trials were conducted at the Experimental Farm of the Faculty of Agriculture, University of Benin, Benin City, Nigeria in 2014 and 2015. The study area lied within rainforest which has been degraded to secondary forest as a result of slash and burn agricultural system. The soil type was ultisols of Benin formation (Smith and Montgomery, 1962). Soil analysis was carried out before and after cropping while the organic manures were analyzed before application and after application using Mylavarapus and Kennelley (2002) procedure at the Central Laboratory of the Faculty of Agriculture, University of Benin, Benin City. Pre-planting soil samples were collected randomly on each plot with a soil auger. These were properly mixed together to form a composite sample and used for the analysis of physical and chemical properties using standard laboratory procedures.

The experiment was laid out in a randomized complete block design with three replicates. Four treatments were involved viz.: untreated (control), cattle manure at the rate of 15 t ha^{-1}, poultry manure at the rate of 15 t ha^{-1} and NPK 15: 15: 15 applied at 400 kg ha^{-1}. The organic manures (cattle and poultry) were thoroughly mixed with the soil and then left for four weeks to allow for decomposition and equilibration. NPK was applied in two split at two and seventh weeks after planting (WAP).

Visibly healthy Sweet potato “var 0078-ppl” vine free from any form of infestation by pests and diseases were planted on the field at a spacing of 30 cm x 90 cm in August in both years. Weeding was carried at 4 WAP and subsequently as of when due. Data were collected on plant establishment (%), vine length, leaf area index (LAI) and total dry weight (TDW) from which relative agronomic efficacy (RAE) was computed as:

$$RAE = \frac{TDW(F) - TDW(C)}{TDW(C)} \; x \; 100$$

Where F = treated plants, C = untreated control.

Sweet potato tubers were harvested at 20 WAP after extensive drying up of most of the leaves and vines. After harvesting, soil samples were collected at four points from each plot with the aid of soil auger. These were mixed together on plot basis to form composite soil samples for plots and analyzed for their properties.

Data collected were combined for the two years and analyzed 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 of the selected physical and chemical properties of the soil on which the trial was sited are presented in Table 1.

Table 1:Some properties of the experimental soil before cropping

Soil Property	2014	2015
Particle size (g kg^{-1})		
Clay	83.60	60.00
Silt	36.40	30.00
Sand	880.00	910.00
pH (H_2O) 1:1	5.50	5.72
Organic carbon (g kg^{-1})	20.14	19.62
Organic matter (g kg^{-1})	34.72	33.82
Total nitrogen (g kg^{-1})	0.86	0.82
Available phosphorus (mg kg^{-1})	7.00	6.68
Exchangeable cations (cmol kg^{-1})		
Calcium	0.60	0.58
Magnesium	0.24	0.25
Potassium	0.34	0.25
Exchangeable acidity (cmol kg^{-1})	0.48	0.55

The particle size analysis showed that the soil was sandy loam. The soil was moderately acidic (5.72) with organic carbon content of 19.62g kg^{-1} corresponding to organic matter content of 33.82 g kg^{-1}. This was moderate when compared to the critical level (Berhanu, 1980). The soil was inadequate in total N, available phosphorus and exchangeable Ca; and moderate exchangeable 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) which were 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 deficiency. 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.

The chemical composition of the organic manure (Cattle and Poultry manure) used in the trial was characterized (Table 2) through laboratory analysis. The cattle manure contained 1.06 % total N, 5.22 % available P and poultry manure contained 1.25 % total N, 8.54 % available P. The exchangeable Ca, Mg and K contents of the cattle manure were 0.45, 0.58 and 0.40 cmol/kg^{-1} and poultry manure were 0.62, 0.59, 0.73 cmol/kg^{-1} respectively. This implies that organic manures contained plant essential nutrients and are viable substitutes for inorganic fertilizer (NPK) for sustaining crop production.

Table 2: Chemical composition of organic fertilizer

Property	Cattle manure		Poultry manure	
	2014	2015	2014	2015
pH (H_2O) 1:1	5.42	5.38	5.70	5.65
Organic carbon (g kg^{-1})	34.11	34.08	31.00	30.11
Organic matter (g kg-1)	58.67	58.75	53.32	51.91
Total nitrogen (g kg^{-1})	1.10	1.06	1.22	1.25
Avalable phosphorus (mg kg^{-1})	5.26	5.22	8.60	8.54
Exchangeable cations (cmol kg^{-1})				
Calcium	0.47	0.45	0.70	0.62
Magnesium	0.60	0.58	0.62	0.59
Potassium	0.42	0.40	0.80	0.73

The post-harvest chemical properties of the soil are presented in Table 3. The pH was reduced to 4.36 from 5.72 in the untreated plots (control) and highest pH was observed in poultry manure (5.71). The reduction in pH is attributed to crop removal inducing the replacement of cations with oxide and hydroxide of Fe and Al. There was decreased in organic C in control and NPK treated plots and increase in cattle and poultry manures treated plots. Organic carbon was lowest in control and highest in poultry manure treated plots. This observation is in agreement with Ojeniyi (2000), who reported that the use of inorganic fertilizer has not been 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 including control. The highest value of N (2.37 %) was observed from NPK treated plots. Similar observation had earlier been reported by Law-Ogbomo *et al*. (2012). The increment could probably be due to nutrient released by some dead decomposed sweetpotato crop. There was decrease in available P in control treated plots. This was in agreement with Law-Ogbomo *et al*.(2012) who observed similar trend in maize. The reduction in available P could be due to phosphate sorption arising from decrease in pH and leaching. The highest available P was observed in NPK treated plots. The highest total N and available P observed in NPK treated plots could be attributed to high concentration of readily available nutrients in the inorganic fertilizer. Exchangeable Ca was lower in control plots compared to pre-planting value. The reduction of exchangeable Ca in the control plots could be due to decrease in soil pH (Nathan *et al*., 1999). Lower pH induced Ca and Mg deficiencies and increase Mn and Al toxicity; in addition to P sorption. Highest concentration of exchangeable Ca was observed in cattle manure (0.60 cmol kg^{-1}) and poultry manure (0.64 cmol kg^{-1}) treated plots after harvesting; this could be due to the liming potential of the organic manures used; increase in soil pH due to poultry and cattle manure application which increased exchangeable Ca content in soils (Samsunnahar *et al*., 2006; Gichangi and Mnkeni, 2009). Exchangeable Mg values remain statistically comparable among treatments. Exchangeable K decreased in control compared to the initial value in pre-planting analysis. Exchangeable K (1.86 cmol kg^{-1}) was observed in NPK treated plots.

The increase in soil N, P, K and Ca contents after cropping associated with poultry and cattle manure treated plots is an indication that, organic fertilizer can sustain continuous cropping and adequate nutrients, required to support crop production can be attained from poultry and cattle manure application (Farhad *et al*., 2009).

The effect of manures and NPK fertilizer application on sweetpotato growth performance is presented in Table 4. Plant establishment varied from 78.60 % to 86.20 % and there were no significant differences among treatments. The vine length was significantly influenced by fertilizer application. All fertilized plots produced vines that were significantly longer than the untreated control. Poultry manure treated plots produced the longest vine length (252.10 cm) which was statistically comparable to NPK treated plants (249.90 cm). LAI was lowest in the untreated plants (4.46) and NPK treated plants (4.26) and the highest LAI was observed in poultry manure treated plants (5.15). Higher LAI observed on poultry manure treated plants signified greater leaf production rates, leaf area expansion and leaf area duration than other treatments.

The TDM among different treatments were significantly influenced by soil amendments. The lowest TDM was observed in the control and NPK plants while the highest TDM was observed in cattle (0.51 t ha^{-1}) and poultry (0.52 t ha^{-1}) manures. The observed TDM differences among treatments could be related to nutrient availability to crops and release patterns by the soil. This is in agreement with the findings of Meenatchi *et al*. (2010) who reported that the higher TDM observed on fertilized plants were due to increased supply and uptake of plant nutrients. Higher TDM content of organic fertilizer treated plants was an indication of less fibre and more accumulation of nutrients in comparison with NPK and control (Sanwal *et al.*, 2007).

The RAE of the fertilized plants was significantly higher than unfertilized plants. However, the organically fertilized plants were statistically comparable but higher than NPK fertilized plants. The higher RAE exhibited by cattle and poultry manure treated plants was mainly attributed to increase availability of nutrients in soil and sweetpotato uptake of the applied fertilizers. This observation is in agreement with the report of Adenawoola and Adejoro (2005) that the cumulative agronomic value of some organic manure applied to agriculture soils could be five times greater and more beneficial than in the application of inorganic fertilizers.

Table 3: Postharvest chemical property of the soil

Treatmen	pH (H_2O) 1:1			Organic carbon (g kg^{-1})			Total nitrogen (g kg^{-1})			Avalaible P (mg kg^{-1})			Exch Ca (cmol kg^{-1})			Exch Mg (cmol kg^{-1})			Exch K (cmol kg^{-1})		
	2014	2015	combined	2014	2015	combined	2014	2015	combined	2014	2015	combined	2014	2015	combined	2014	2015	combined	2014	2015	combined
Control	4.34	4.37	4.36	14.02	14.06	14.04	1.07	0.75	0.91	4.13	4.23	4.18	0.39	0.35	0.37	0.29	0.16	0.23	0.21	0.22	0.22
Cattle manure	5.54	5.53	5.54	19.51	18.96	19.24	1.03	1.08	1.06	7.35	7.53	7.44	0.59	0.60	0.60	0.24	0.21	0.23	0.45	0.65	0.55
Poultry manure	5.76	4.67	5.71	20.38	20.05	20.21	1.55	1.11	1.33	8.38	8.62	8.50	0.57	0.71	0.64	0.25	0.25	0.25	0.53	0.68	0.61
NPK	4.72	4.39	4.55	15.62	16.05	15.82	2.40	2.34	2.37	19.89	20.03	19.96	0.43	0.39	0.41	0.34	0.17	0.26	1.85	1.88	1.86
$LSD_{(0.05)}$	ns	0.130	0.138	0.630	1.150	0.625	0.660	0.130	0.0332	1.210	1.220	0.774	0.150	0.060	0.081	ns	0.040	ns	0.300	0.230	0.177

Ns= not significant; Exch = Exchangeable

Table 4: Sweet potato growth performance as influenced by manures and NPK fertilizer application

Treatment	Plant establishment (%)			Vine length (cm)			Leaf area index			Total dry weight (t ha^{-1})			Relative agronomic efficiency (%)		
	2014	2015	Combined	2014	2015	Combined	2014	2015	Combined	2014	2015	Combined	2014	2015	Combined
Control	60.20	97.00	60.20	180.40	152.50	166.50	4.60	4.30	4.46	0.27	0.20	0.26	0.00	0.00	0.00
Cattle manure	74.40	91.33	82.90	248.20	182.90	215.60	5.43	4.03	4.73	0.64	0.37	0.51	137.00	85.00	111.00
Poultry manure	75.90	96.50	86.20	291.60	212.70	252.10	6.10	4.20	5.15	0.68	0.29	0.49	152.00	45.00	99.00
NPK	70.90	95.50	83.20	287.30	212.20	249.90	3.98	4.54	4.26	0.45	0.30	0.38	67.00	50.00	59.00
$LSD_{(0.05)}$	ns	ns	ns	47.260	40.710	29.880	0.620	ns	0.790	0.190	0.140	0.118	20.157	40.33	30.360

ns - Not significant at 0.05 level of probability

The correlation of vine length with LAI (r = 0.416), TDM (r = 0.360) and RAE (r = 0.569) were significantly positive (Table 5). The positive correlation of vine length and LAI implied that vine length is a growth character directly linked with the productive potential of sweet potato in terms of tuber yield. Increase in vine length will lead to increase in LAI. Increasing LAI led to higher TDM due to better utilization of solar radiation which favoured photosynthetic capacity (Law-Ogbomo and Egharevba, 2008).

Table 5: Correlation coefficient among different variables of sweet potato

	TDM	Vine length	LAI	RAE	Plant establishment
TDM	1.000	0.360*	0.282*	0.569*	-0.099
Vine length	0.360*	1.000	0.416*	0.360*	-0.091
LAI	0.282*	0.416*	1.000	0.282*	-0.099
RAE	0.569*	0.360*	0.282*	1.000	-0.099
Plant establishment	-0.099	-0.091	-0.252	-0.099	1.000
	TDM	Vine length	LAI	RAE	Plant establishment

CONCLUSION

Poultry manure, cattle manure and NPK fertilizers are effective sources of nutrients for increasing soil fertility and performance of sweet potato. The organic manures (Poultry manure and cattle manure) and NPK fertilizer used separately sustained soil productivity, crop performance and relative agronomic efficacy. Application of poultry and cattle manures at 15 t ha^{-1} had the best vine length, LAI, TDM and relative agronomic efficiency (RAE). Poultry and cattle manures are thereby recommended for the sweet potato growers in humid ultisols.

REFERENCES

Adenawoola, A. R. and Adejoro, S. A. (2005). Residual effects of poultry manure and NPK fertilizer residues on soil nutrients and performances of jute (*Corchorus olitorius*). *Nigerian Journal of Soil Science*, 15: 133 – 135.

Adeoye, G.O. and Agboola, A.A. (1985). Critical levels for soil pH available P, K, Zn and Mn and maize ear leaf content of P, Cu and Mn in sedimentary soil of Southwest Nigeria. *Fertilizer Research*, 6:65-71.

Akanbi, W.B. and Togun, A.O. (2002).The influence of maize stover compost and nitrogen fertilizer on growth, yield and nutrient uptake of Amaranth. *Scientia Horticulturae,* 93: 1-9.

Akinrinde, E.A. and Obigbesan, G.O. (2000). Evaluation of fertility status of selected soil for crop production in five ecological zones of Nigeria. *Proceedings of 26th Annual Conference of Soil Society of Nigeria* held at Conference Centre University of Ibadan, Nigeria. October 30-November 3, pp 279-288.

Ayoola, O. T. and Adeniyan, O.N. (2006). Influence of poultry on yield and yield components of crops under different cropping systems in South West Nigeria. *African Journal of Biotechnology*, 5:1386-1392.

Berhanu D. (1980). The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land use planning and regulatory department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Chude, V.O. (1999). Perspectives on fertilizer use in the 21st century.Book of abstracts, Soil Science Society of Nigeria, Benin, 1999. 25th Annual Conference Held at Precious Palm Royal Hotel from 21st-25th November, 1999.

Farhad, W., Saleem, M.F., Cheema, M.A., Hammad, H.M. (2009). Effect of poultry manure levels on the productivity of spring maize (Zea mays L.). *Animal and Plant Science Journal*, 19 (3): 122–125.

Gichangi, E. M. andMnkeni, P. N. S. (2009). Effects of goat manures and lime addition on phosphate sorption by two soils from Transkei region, *South Africa. Communications in Soil Science Plant Analysis*, 40:3335-3347.

Ikeorgu, J. E. G. (2003). Creating employment opportunities in the Agro-Allied Sub-Sector: the case of yam production. *Bullion Magazine*, pp. 15 - 22.

Julio, H. and Carlos, B. (1999).Nutrient depletion in the agricultural soils of Africa.A 2020 Vision Brief 62 pp 1 -2 International Food Policy Research Institute, Washington, D.C. USA.

Kareem, I. (2013). Fertilizer treatment effects on yield and quality parameters of sweetpotato (*Ipomoea batatas*). *Research Journal of Chemical and Environmental Science*, 1(3): 40 - 49

Law-Ogbomo, K. E. and Remison, S.U. (2009).Growth and Yield of Maize as Influenced by Sowing Date and Poultry Manure Application. *Not. Bot. Hort. Agrobot. Cluj.*, 37 (1): 199-203.

Law-Ogbomo, K.E. and Egharevba, R.K.A. (2008). Effects of planting density and NPK fertilizer on growth and fruit yield of tomato (*Lycospersicon esculentus* Mill). *Research Journal of Agriculture and Biological Sciences*, 4(3): 265-272.

Law-Ogbomo, K. E., Osaigbovo, A. U. and Ekwueme, I. (2012). Agronomic efficacy of compost manure and NPK fertilizer on some soil chemical properties and maize production in an ultisol environment. *Journal of Applied and Natural Science,* 4 (2): 172 – 177.

Mba, C.N. and Mbagwu, J.S.C. (2006).Effects of animal wastes on physic-chemical properties of a dystricleotosol and maize yield in Southeast Nigeria. *Nig. J. Soil Sci.,* 16: 96 - 103.

Meenatchi, R. Giraddi, R.S. Biradar, D.P. and Vastrad, A.S., (2010). Studies on effect of vermitechnologies on insect pest activity and yield of soybean. *Karnataka Journal of Agricultural Science,* 32(2):249-252.

Mylavarapus, R. S. and Kennelley, D.E (2002). *UF/IFAS extension soil testing laboratory (ESTL): Analytical procedures and training manual.* Institute of food and Agricultural Sciences.University of Florida. Gainesville. U.S.A. pp. 28.

Nathan, M., Stecker, J., Erwin, E., Dunn, J., Warmund, M., Trinklein, D., Rothenberger, R., Schraf, P., Lee, T., (1999). Soil Test Interpretations and Recommendation Guide Commercial Fruits, Vegetables and Turf.College of Agriculture, Food, and Natural Resources, University of Missouri Extension, Columbia, Missouri, United States of America. Pp. 17 – 18.

Ojeniyi, S. O. (2000). Effect of goat manure on soil nutrients and okra yield in a rain forest area of Nigeria. *Applied Tropical Agriculture,* 5: 20-23.

Oti, N.N. (2002). Discriminate functions for classifying erosion degraded lands at Otamin, South Eastern Nigeria. *AgroScience,* 3(1): 34-40.

Priyadharshini, C., Amikapathy, V. and Panneerselvam, A (2016).Effect of biofertilizer on andrographispaniculata. P.G Research Department of Botany and Microbiology, AVVM Sri Pushpam College (Autonomous), *Poondi, Thanjavur*, 2(2): 168-173

Samsunnahar, Nahar, S. and Baten, M. A. (2006). Effect of organic farming on soil properties and growth and yield of red amaranth. *Bangladesh Journal of Environmental Sciences,* 12 (2): 323 - 325.

Sanwal, S.K., Lakminarayana, K.,Yadav, R. K. Rai, N., Yadav, D. S. and Mousumi, B. (2007). Effect of organic manures on soil fertility, growth, physiology, yield and quality of turmeric. *Indian Journal of Horticulture,* 64: 444-449.

Smith, A.J. and Montgomery, R.F. (1962).*Soil and land use in Central Western Nigeria.* Ministry of Agriculture and Natural Resources, Western Nigeria. 265pp.

Sobulo, R.A. and Osiname, O.A. (1981). Soils and fertilizer use in Western Nigeria.*Research Bulletin,* No 11, I.A.R.T. University of Ife.

Somani, L.L and Totawat, K. L. (1996). *Soil conditioners and amendments*. AgrotechPublication.Academy, Udaipur. 1stedition.pp. 28 - 160.

Stefano, P., Dris, R and Rapparini, F. (2004). Influence of growing conditions and yield and quality of cherry. II. Fruit. *Journal of Agriculture and Environment*, 2:307-309.

Zingore, S.B., Mafongoya, P., Myamagafota, P. and Giller, K.F. (2003). Nitrogen mineralization and maize yield following application of tree pruning to a sandy soil in Zimbabwe. *Agroforestry System*, 57: 199-211.