American-Eurasian Journal of Agronomy 2 (1): 07-12, 2009
ISSN 1995-896X

Effect of Organic and Mineral Fertilizer Inputs on Soil and Maize Grain Yield in an Acid Ultisol in Abakaliki-South Eastern Nigeria

[1]C.N. Mbah and [2]E.U. Onweremadu

[1]Department of Soil and Environmental Management,
Ebonyi State University, Abakaliki, Nigeria
[2]Department of Soil Science and Technology,
Federal University of Technology, Owerri, Nigeria

Abstract: In sustainable agricultural systems, recycling of nutrients is a major component of nutrient management. We conducted an experiment in Abakaliki South Eastern Nigeria in 2007 to investigate the effects of organic amendments (poultry droppings (PD), burnt rice husk dust, (BRHD), Unburnt rice husk dust (UBRHD) and inorganic fertilizer (NPK) on soil properties and their residual effect tested in 2008. Additions of amendments failed to significantly ($P< 0.05$) improve micro-aggregates (measured as dispersion ratio, DR) but significantly decreased bulk density, increased total porosity and macro-aggregate stability (measured as water stable aggregates WSA > 0.5mm). Similarly, significant improvements were observed in soil total N (%), OC (%), avail P and CEC (Cmol /kg). The highest relative yields of 2.10 and 1.23 $mgha^{-1}$ in the first and second seasons, were obtained in PD and UBRHD-amended plots, respectively. Results of the study also show significantly higher maize yield and improved soil properties in UBRHD and BRHD in the second season compared to PD and NPK indicating longer residual effect.Maize grain yield correlated positively with soil organic carbon, CEC, aggregate stability and bulk density indicating that these parameters contributed to final grain yield.Results of the study showed that organic and inorganic fertilizers are effective in restoring the productivity of degraded soils.

Key words: Fertility decline · Sustainable agriculture · Aggregation · Productivity · Nutrient depletion · Farming systems

INTRODUCTION

Many interrelated factors, both natural and managerial, cause soil fertility decline. This decline may occur through leaching, soil erosion and crop harvesting [1]. Unless the nutrients are replenished through the use of organic or mineral fertilizers, or partially returned through crop residues, or rebuilt more comprehensively through traditional fallow system that allows restoration of nutrients and reconstruction of soil organic matter, soil nutrient levels decline continuously.

In the Abakaliki Agro-ecological zone of south eastern Nigeria, large quantities of rice mill wastes accumulate from the numerous rice mills located in the area.Despite the magnitude of these wastes generated daily and the possible and adverse effects on the environment, no serious attempts have been made either for their effective utilization or safe deposal. Similarly, the farming system in this agro-ecological zone is primarily slash and burn method. Coupled with the intensive use of land and the absence of any definite management system, the productivity of the soil has been adversely affected. The rapid depletion of plant nutrients, low organic matter content {< 2.0 according to Enwezor, *et al.* [2]} and poor physical condition of the soil constitute strong limitations to crop production in an area regarded as the major food belt of the eastern region.

In sustainable agricultural systems, recycling of nutrients is a major component of nutrient management [3]. Several studies carried out indicated positive effect of organic wastes on soil productivity. For instance [4] reported that soil-incorporation of calliandra and leucaena green biomass with or without fertilizer increased total soil nitrogen by 1-8% over a period of four years.Similarly,

Corresponding Author: C.N. Mbah, Department of Soil and Environmental Management,
Ebonyi State University, Abakaliki, Nigeria

waste amended soils have been reported to have high organic matter content [5]. Soil organic matter influence the degree of aggregation and aggregate stability and can reduce bulk density, increase total porosity and hydrualic conductivity of heavy clay soils [5]. Variations in water retention and available water capacity for different soils amended with organic wastes have been reported by [6]. Combination of organic and mineral fertilizer nutrient sources have been shown to result in synergistic effects and improved synchronization of nutrient release and uptake by crop leading to higher yields. Leucaena biomass combined with mineral fertilizer gave higher crop yields as compared to sole use of mineral fertilizer or sole leucaena biomass [4].

A trial was set up 2007 and 2008 cropping seasons, using organic (poultry droppings and burnt/unburnt rice husk dust) and inorganic inputs (NPK) with the objective of addressing the decline in soil fertility in the study area. The study aimed at determining the effects of different organic wastes and mineral fertilizer inputs on maize yield in a degraded ultisol in Abakaliki South Eastern Nigeria.

MATERIALS AND METHODS

Experimental Site: The experiment was located within the farm complex of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki. The area falls within longitude 8°3^{1}E and latitude 6°25^{1}N in the derived Savannah region of the south east agro ecological zone of Nigeria.. The rainfall in the area is very intensive with an annual range of 1200-2000 mm. The distribution is bimodal with peaks in July and September and a brief dry spell in August, popularly known as August break. The temperature is uniformly high with mean monthly average of 26°C. The soil belongs to the order ultisol [7] and is classified as Typic-Haplustult

Soil Amendments: The soil amendments comprised air dried poultry droppings (PD), burnt (BRHD) and unburnt Rice Husk Dust (UBRHD). The wastes were applied at the rate of 12 kg/plot (equivalent to 10 t ha^{-1}). Other treatments included NPK fertilizer (applied at 200 kg/ha) and control.

Land Preparation and Experimental Design: The area was mechanically ploughed in 2007 and followed by manual seed-bed preparation. The field layout was a randomized complete block design (RCBD) with five treatments replicated four times each. The wastes were ploughed into the plots and left for 10 days before maize (*zea mays* L) which was the test crop was planted while NPK was applied as base application. Two seeds per hill (of the test crop) were planted at a spacing of 0.75m and 0.25m and at a depth of 3cm. The seedlings were thinned to one stand per hill after two weeks of germination to give a total plant population of 53,333 per hectare. The area was reploughed in 2008 without further application of the amendments in order to determine the residual effects of the treatments.

Determination of Soil Physical Properties: Bulk density (bd) was determined using the core method described by [8]. Total porosity (TP) was obtained from bulk density value with assumed particle density (pd) value of 2.65 g cm^{-3} as follows:

$$Tp = 100\ (1\text{-}bd/pd)$$

Aggregate stability was determined at the macro level (WSA >0.5mm) and micro level (dispersion ratio, DR-ratio of % silt+clay dispersed in calgon) using the wet sieving techniques of Kemper and Rosenau, [9] and the Middleton, [10] DR, respectively. Particle size analysis was determined by the hydrometer method [11] using sodium hexametaphosphate (calgon) as the dispersant.

Determination of Soil Chemical Properties: Sample for soil chemical analysis were collected (at a depth of 0-20 cm) at the end of each crop harvest, air dried and passed through a 2-mm sieve. Soil P^H in water (1:2.5 soil to water ratio) was determined using the glass electrode P^H meter. Organic carbon (OC %) was determined by the [12] dichromate oxidation procedure and total Nitrogen by Kjeldahl method [13].

Maize Yield and Data Analysis: At maturity ten maize plants/plot were sampled for grain yield determination. They were sun-dried and the shelled grain yield was adjusted at 14% moisture content. Data collected were analysed using analysis of variance (ANOVA) for randomized complete block design (RCBD). Means significant were separated out using fisher's least significant difference (F-LSD) according to [14]. Simple regression analysis was employed to determine the relationship between yield and some measured parameters.

RESULTS AND DISCUSSION

The particle size analysis showed that the soil is sandy loam. Some of the chemical components of the soil

Table 1: Initial properties of the soil

Properties	Unit	Value
Clay	%	25
Silt	"	29
Sand	"	46
Texture		Sandy loam
P^H (H_2O)		6.4
OC	%	1.46
Avail. P	mg kg^{-1}	25.9
Total N	%	0.112
C/N ratio		1**3**
Exec. Bases	**Cmol/kg**	
Na	"	0.33
Ca	"	0.30
K	"	3.4
Mg	"	1.60
CEC	"	5.30
Exec. Acidity		
Al^{3+}	"	Trace
H^+	"	3.80

PD = Poultry Droppings, BRHD = Burnt Rice Husk Dust, URBHD = Unburnt Rice Husk Dust.

Table 2: Effect of amendments on some soil properties and maize yield

		Year 1								
Treatments	AS	DR	BD	TP	P^H	OC%	CEC	Total N%	Avail P	Yield
C	31.4	0.77	1.81	32.0	5.8	1.5	10.4	0.14	16	0.80
NPK	32.1	0.83	1.61	39.0	6.1	2.0	12.1	2.0	20.9	1.80
BRHD	35.2	0.79	1.77	33.0	6.0	2.0	13.6	0.16	19.6	1.50
UBRHD	34.8	0.79	1.62	39.0	6.1	1.8	15.0	0.17	16.8	1.60
PD	39.1	0.84	1.41	47.0	6.8	2.2	13.9	0.18	29.3	2.10
$LSD_{0.05}$	0.34	NS	0.3	1.84	0.12	0.23	0.18	0.01	0.42	0.17

		Year 2								
Treatments	AS	DR	BD	TP	P^H	OC%	Total N %	CEC	Avail P	Yield
C	26.2	0.83	1.78	33	5.8	0.78	0.07	0.3	10	0.48
NPK	31.3	0.80	1.64	38	6.2	0.98	0.10	10.2	15	1.98
BRHD	30.9	0.81	1.51	43	6.3	1.08	0.13	12.1	18	1.19
UBRHD	32.1	0.78	1.53	42	6.2	1.06	0.14	12.8	19	1.23
PD	30.8	0.82	1.60	40	6.4	1.00	0.11	11.1	16	1.07
$LSD_{0.05}$	0.32	NS	0.04	2.95	0.19	0.02	0.08	0.92	0.06	0.03^{xx}

C = Control, UBRHD = Un-burnt Rice Husk dust, PD = Poultry Droppings, BRHD = Burnt Rice Husk Dust

before use showed that N, P, K, Ca, Mg, Na the and OC % were of low values which revealed that the soil is low in fertility (Table 1). The soil P^H is slightly acidic with a value of 6.4. Similarly, analysis of the organic amendments used revealed higher levels of organic carbon (OC %) and available P $mgkg^{-1}$in UBRHD and BRHD compared to PD. However, PD on the average had highest level of other nutrients compared to UBRHD and BRHD. Analysis of the wastes showed OC% of 18.6(PD), 18.2(BRHD), 27.3(UBRHD), Total N% of 2.3(PD), 0.73(BRHD) and 0.8(UBRHD).Comparatively, the organic amendments contained higher levels of exchangeable bases than the soil.

The results of the study showed encouraging improvements in the properties of the degraded ultisol with application of organic and inorganic amendments. It demonstrated the relative abilities of the amendments to improve the bulk density and total porosity of the soil (Table 2).

A trend of lower bulk densities (bd) was observed with the addition of the amendments. In the first and second seasons, the lowest bulk density values of 1.41gcm^{-3} and 1.51gcm^{-3} were observed in PD and BRHD-amended plots, respectively.Observed bd value(1.51$gcm^{-3)}$ in BRHD in the second season was 18, 7,6 and 1% lower than bd values in C,NPK,PD and

UBRHD,respectively. Total porosity values ranging from 32-47% and 33-43% were obtained in the first and second seasons respectively with the control plots having the least values. The increase in total porosity could be attributed to increase in percentage of macro-pores. Macro-pores are transmission pores and if stable ensure more water intake and less run-off and erosion from lands. In both seasons the amendments with the highest bulk density had lowest total porosity values confirming the inverse relationship between bulk density and total porosity. Mbagwu [15] showed that the decrease in bulk density obtained with rice-shaving and poultry manure treated soil were directly related to increased organic matter which played a significant role in reducing compaction of soil. As source of organic matter the organic amendments promotes soil faunal activity and plays a major role in the build up and stabilization of soil structure. The significant decrease in soil bulk density could be attributed to the direct and indirect effect of soil organic matter (SOM) levels. Directly, OM due to its low bd and ability to increase soil aggregate stability results in lower soil bd and soil compactibility. Indirectly, the decrease is as a result of bulk density decrease and improved structure as is partly substantiated by increased porosity. The importance of this parameter lies in the fact that it may be particularly critical for crop growth and development. Small changes in bulk density can cause major changes in root growth.Chareau and Nicou, [16] reported that bulk density decrease of 0.1mgm^{-3} in an Alfisol in Senegal had beneficial effect on root development and yield of sorghum and groundnut.

The macro-aggregate stability measured as percent water stable aggregates (WSA) > 0.5mm is shown in Table 2. The incorporation of the amendments showed significant effect on the stability of the aggregates. Poultry droppings (PD) gave the highest percent water stable aggregate of 39.1% in the first season. The value 39.1% was 10, 20, 18 and 11% higher than the values in NPK, C, BRHD and UBRHD, respectively. Percent water stable aggregate values of 32.1% (UBRHD), 30.1% (NPK), 30.9% (BRHD), 30% (PD) and 26.2% (C) were observed in the second season. At micro-aggregate level, the amendment showed no significant effect on the dispersion ration (DR) used as index of stability. The amendments, however, showed lower values of DR relative to the control in the second season. The observed non-significant effect on soil DR is in line with the observations of [6] who reported that it will take massive application of wastes to make significant improvement in the stability of micro-aggregates.

Because of the increase in porosity and aggregate stability induced by application of the amendments, other soil physical properties as infiltration capacity [17] decreased runoff volumes and a decrease in the amount of soil particles detached by rain drop impact [18] may have occurred. Earlier studies by [19] showed improvements in soil properties as a result of addition of organic and inorganic amendments.

The OC%, CEC Cmol(+)kg^{-1}, Total N% and Avail. P mg/kg levels on the soils which received the amendments were significantly higher than in the control (Table 2).

The OC% increased from 1.5% in the control to 2.2% in PD-amended plots in the first season. Similarly, observed total N% values rose from 0.07% in the control to 0.14% in UBRHD-amended plots in the second season. Poultry droppings (PD) gave the highest CEC values of 13.9 Cmol(+)kg^{-1} in the first season. In comparism with the control, CEC was increased by 34,46, 22%and 54% respectively in PD, BRHD, NPK and UBRHD-amended plots in the second season. Table 2 also showed that the amendments increased the soil P^{H} compared to the control in both seasons. Observed P^{H} values ranged between 5.8-6.8 and 5,8-6.4 in the first and second seasons,respectively.In the first season,the amendments PD,BRHD,UBRHD and NPK showed 17,3,5,and 5% increase in P^{H} relative to the control. The organic materials had a positive contribution to soil carbon compared to mineral fertilizer and control. The higher OC% levels observed in organic materials-amended plots could be attributed to the fact that organic materials had a major impact on mineralization rates and increasing soil C directly, where as the effect of the mineral fertilizer was less pronounced since it increased C inputs only indirectly by improving plant growth [20]. Manures had the advantage of supplying essential plant nutrients either directly and indirectly by alleviating AL toxicity or producing organic acids which complex with AL thereby increasing nutrient availability [21]. The P^{H} increase with amendments corresponds with the finding of [10] and could be attributed to reduction on AL in the soil. The maize grain yields were significantly different ($P < 0.05$) between treatments in both seasons (Table 2).

The control gave consistently the lowest grain yield in both seasons. Compared with the control maize grain yield rose by 126, 100, 88 and 163% respectiveiy, in NPK, BRHD, UBRHD and PD-amended plots in the first season. With respect to the amendment the residual effect on maize yield was in the order UBRHD > BRHD > NP > PD > C while percent (%) yield reduction was in the order PD > NPK >UBRHD > BRHD. The higher grain yield obtained

Table 3: Relationship between maize yield and some soil properties

Parameter	Regression model	r^2
Yield vs OC	Y = 0.948+1.32x	0.831
Yield vs BD	Y = 2.042-0.294x	0.786
Yield vs AS	Y =-49.29+0.295x	0.733
Yield vs CEC	Y = 6.38-0.372x	0.699

in the amended plots relative to the control could be attributed to improved soil physicochemical conditions in the amended plots. Table 3 confirms the relationship between increased grain yield and soil properties.

The relatively higher yields obtained in PD and NPK-amended plots in the first season could not be sustained in the second season. Percentage yield reduction (YR%) calculated as

$$YP = 1\text{-}Y2/Y1 \times 100\ /1$$

(where Y1= yield in year 1 and Y2 = yield in year 2) showed 49,46,40,23 and 21 % in PD,NPK,C,UBRHD and BRHD respectively in the second season. The observed higher yield reduction in PD and NPK amended plots could be due to higher decomposition rates [19] and rapid loss of the nutrients through erosion and leaching. The higher C/N ratio of BRHD and UBRHD and the possible slow rate of decomposition may have contributed to their lasting residual effects on soil properties and maize yield. The result of this study is line with those of [10, 22].

CONCLUSION

Results from the study have shown that organic and inorganic amendments improved the physicochemical properties of the studied soil. The higher values in physicochemical properties observed in amended plots relative to the control could be due to higher levels of OM which increased aggregate stability and hence other properties. The improvement in these properties led to increased grain yield of maize in the amended plots.On the average PD gave the highest grain yield in the first season and the highest yield reduction in the second season. Similarly, NPK showed higher yield reduction compared to BRHD and UBRHD in the second season. Since PD may not be available in large amounts required for application and NPK is scarce and/or costly, farmers are encouraged to use BRHD and UBRHD that accumulated in large quantities in the study area as manure to enhance production.The use of this cheap and available wastes by the poor resource farmers in the area will not only improve the soil properties but enhance crop production on long term basis in the area regarded as food belt of the eastern region.

ACKNOWLEDGEMENTS

The authors are grateful to the laboratory staff of Department of Soil Science, University of Nigeria Nsukka and Ebonyi state University, Abakaliki.

REFERENCES

1. Donova, G. and C. Casey, 1998. Soil fertility management in Sub-Sahara Africa. 2002. Phosphorus and nitrogen based manure and compost application. Agron. J., 94: 128-135.
2. Enwezor, W.C., A.C. Ohiri, F.E. Opuwaribo and J.E. Udu, 1990. Literature review on soil fertility investigations in Nigeria. Fertilizer Procurement and Distribution Division (FPDD). Federal Ministry of Agriculture and Natural Resource, Lagos.
3. King, L.D., 1990. Soil nutrient management in the united states. In sustainable Agricultural system, Ed. C.A. Edwards *et al*., St Lucie Press, FL., pp: 89-106,
4. Mugendi, D.N., P.K.R. Nair, J.N. Mugwe, M.K. O'Neill and P.L. Woomer, 1999. Calliandra and Leucaena alley cropped with maize. Part 1 Soil fertility changes and maize production in the sub-humid highlands of Kenya. Agrof. Systems, 46: 39-50.
5. Anikwe, M.A.N., 2000. Amelioration of a heavy clay loam with rice husk dust and its effect on soil physical properties and maize yield. Biores Technol., 74: 169-177.
6. Mbagwu, J.S.C. and G.C. Ekwealor, 1990. Agronomic potentials of brewer's spent grains. Biologic. Wastes, 163: 94-102.
7. FDALR., 1985. Reconnaissance Soil Survey of Anambra State of Nigeria; Soil Reports 1985. Federal Department of Agriculture and Land resources (FDLAR), Lagos, Nigeria.
8. Stolt, J., 1997. Manual of soil physical measurements. Version 3 Wageningen, D.L.O. Staring Centre Teach Doc., pp: 37.

9. Kemper, A. and K. Rosenau, 1986. Size distribution of aggregates. In: Methods of Soil Analysis. Klute, A. (Ed.). Part 1 ASA, Madison, W1., pp: 425-442.
10. Munecheru-muna, M., D. Mugendi, J. Kung`u, J. Mugwu and A. Bationo, 2007. Effects of Organic and Mineral fertilizer inputs on maize yield and soil chemical properties in a maize cropping system in meru south district, Kenya. Agro-forest system , 69: 189-197.
11. Bouyoucous, G.H., 1951. A recalibration of hydrometer for mechanical analysis of soil. Agron. J., 43: 434-438.
12. Walkley, J.T. and A. Black, 1934. An examination of the Degte Jaref method of determining soil organic matter and a proposed modification of the chronic titration method. Soil Sci., 37: 29-38.
13. Bremnen, J.M. and C.S. Mulvaney, 1982. Nitrogen Total. In page et al (eds). Methods of Soil Analysis. Part 2. ASA, No 9. Madison, Wisconsin, pp: 595-624.
14. Steel, G.D. and J.I. Torrie, 1980. Procedure of statistics. A biometrical approach 2nd Ed. McGraw Hill Book Company, Inc. New York, pp: 633.
15. Mbagwu, J.S.C., 1992. Improving the productivity of a degraded ultisol in Nigeria using organic and inorganic amendments. Part 2 changes in physical properties. Biores Technol., 42: 169-175.
16. Charreau, A. and R. Nicou, 1971. L Amelioration du profil culturel dans les sols sableaux el sabco-agrileux du la zone tropicale sectie. Quest-Africane et ses incidence agronomiques. Agron trop., (France), 26: 565-631.
17. Ekwue, E.L., 1992. Effect of organic and fertilizer treatments on soil physical properties and erodibility. Soil Till. Res., 22:199-209.
18. Mazurak, A.P., L. Chesnin and A.E. Tiark, 1975. Detachment of soil aggregates by simulated rainfall from heavily manured soil in eastern Nebraska. Soil Sci. SOC. Am. Proc., 39: 732-736.
19. Haynes, R.J. and R. Naidu, 1998. Influence of line, fertilizer and manure application on soil organic matter content and soil physical conditions, a review. Nutrient cycling in Agro-ecosystems, 51: 123-137.
20. Antill, R.S., R.D. Lovel, D.J. Hateh and S.C. Jarvis, 2001. Mineralization of nitrogen in permanent pastures amended with fertilizer or dung. Biol. fertile, Soils, 33: 132-138.
21. Nziguheba, G., C.A. Palm, R.J. Buresh and P.C. Smithson, 1998. Soil phosphorus fractions and adsorption as affected by organic and inorganic sources in: the biology and fertility of tropical soils. TSBF report, pp: 22.
22. Nnabude, P.C. and J.S.C. Mbagwu, 2001. Physicochemical properties and productivity of a Nigerian typic-Haplustult amended with fresh and burnt rice-mill wastes. Biore. Technol., 76: 265-272.