

LONG -TERM EFFECTS OF NITROGENOUS BASED FERTILIZERS ON SOIL ACIDITY IN UMUNZE ANAMBRA STATE, SOUTH EASTERN NIGERIA

By

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ABSTRACT

Fertilizer application as a soil management practice improves crop quality and yield. Costs and environmental concerns often compel farmers to re-evaluate application rates so as to optimise the utilization of applied fertilizer and maximise crop production. Chemical perturbations as a result of human activity are particularly likely in agroecosystems because of the intensity of that activity, which include nutrient inputs intended to supplement native nutrient pools and to support greater biomass production and removal. An experiment was conducted to assess the long-term effect of nitrogenous based fertilizer on soil acidity. The trial consisted of three land used types, which are cultivated, fallow and forest respectively in the study area. Effects of ammoniacal N- fertilizer on cultivated land increase significantly ($P < 0.05$) exchangeable acidity EA (1.5 cmol kg^{-1}) with a decreases in cation exchange capacity (3.2 cmol kg^{-1}), (CEC). Percentage base saturation, decreases significantly (57%) in cultivated land with exchangeable Ca^{2+} and Mg^{2+} respectively as compared to fallow land and forest land, under the application of ammoniacal

Keywords: N N-fertilizer. (Nitrogen), C.E.C (Cation exchange capacity), EA (exchangeable acidity)

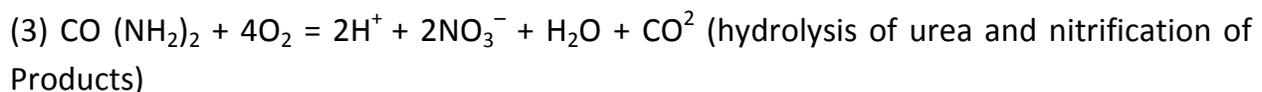
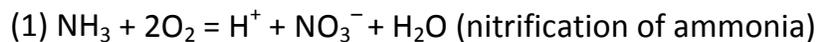
INTRODUCTION

Soil fertility maintenance is very essential in achieving and maintaining high crop yields over a period of time. There is need to apply fertilizers to maintain soil fertility because this is an important input that contributes to crop production. It increases the productivity of the soil for plant growth and improves the quantity and quality of produce. (Adeoye, 2013). An inorganic fertilizer when efficiently and effectively used ensures sustainable crop productivity by immobilizing nutrients that are susceptible to leaching (Ojeniyet al. 2009).

Nutrients contained in inorganic fertilizer are mobilized at a faster rate, and not usually stored for a longer time in the soil, thereby has no long term residual effect (Makinde and Ayoola, 2008).

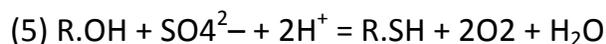
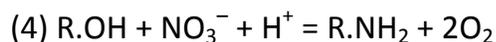
Agricultural activities have become the dominant ecological force over nearly one third of the land areas of the earth. Agroecosystems differ from natural systems in the auxiliary energy sources to enhance productivity, leading to high fluxes of inputs and outputs, and in the external, goal-oriented control rather than internal control via subsystem feedback. Key to the modern agroecosystem is nutrient inputs intended to supplement native nutrient pools and to support greater biomass production and removal. Almost none of the fertilizer materials in common usage are acidic, with the exception of sulfuric and phosphoric acids, which are very small parts of total fertilizer consumption in the study area, (Meister, 2013). Many nutrient inputs, however, are themselves Acid-forming.

The most important acid-forming reaction for fertilizers is microbial oxidation of ammoniacal fertilizers, which may themselves be strong bases, by the following reactions:



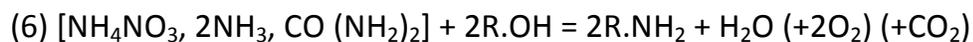
The materials above are the most common synthetic N inputs to agroecosystems, either as single or mixed NPK fertilizers, and will oxidize to the equivalent of nitric acid under the well-drained, aerobic conditions of most dry land agricultural soils (Adebayo 2010).

Interestingly, the assimilation of nitrate-N and sulfate-S to their organic forms (Organic N and S respectively), both consume protons (Pierre 2000), i.e., generate alkalinity, by the reactions:



Although uptake and assimilation of nitrate and sulfate cause release of alkalinity from the root, some of the alkalinity generated is retained in the shoot as organic anions

(Adebayo 2010). Uptake and assimilation of nitrate by biota, both plants and microorganisms, is, from a redox and proton production point of view, opposite in direction and is the reverse of the process of nitrification, although separated temporally and spatially (Adebayo *et al.*, 2013). The net reaction of ammoniacal-N addition, nitrification, and subsequent nitrate uptake and assimilation by biota is acid/base neutral:



From this perspective, soil acidification due to nitrification of N inputs is not directly caused by N inputs themselves but rather: (i) N inputs greater than those assimilated by biota and stored either in biota or soil organic matter, and (ii) incomplete return to soil of the alkalinity of organic anions (Adebayo 2010).

Other acid/base reactions involving the N cycle are denitrification, which consumes protons, and ammonia volatilization, which generates one proton for each cation reacting. It should be noted that reactions causing soil acidification and alkalization, other than nitrification and assimilation of N, are known (Van Breeman *et al.*, 2000). The most significant of these are redox changes, most notably with metals such as Fe and Mn. However, these processes will generally be of small magnitude in well-drained, well aerated soils compared to redox reactions of N added as fertilizers. In fact, the acid/base cycle of soils is intimately linked to the various components of the nitrogen cycle (Adebayo *et al.*, 2013).

MATERIALS AND METHODS

EXPERIMENTAL LOCATION

The experiments were carried out at the federal college of Education (Technical), Temporary and Permanent-site Umunze, Orumba south Local Government area of Anambra State. The area lies between latitude 50 581 911 N and longitude 70 1411711E. Umunze Aguata is located in the south east of Nigeria at Latitude 50 341 N and Longitude 70 541 E east of the Greenwich meridian.

The area falls within the semi-deciduous forest zone of Nigeria (Taylor, 1952). This zone is characterized by two rainy seasons and two dry seasons in a year (Walker, 1957). The major rainy season starts from March to July and the minor rainy season starts from September to November. There is a short dry period in August. The major dry season

occurs between the end of the minor wet season and the next major wet season (November to March). Rainfall distribution is bimodal with peaks in June and October. The mean annual precipitation exceeds 2000mm. Temperatures are generally low and uniform throughout the year. The mean monthly temperatures range from 21.3o – 30o C. Relative humidity is generally high in the mornings being about 90 % at 600 hours and falling to between 60 and 75 % in the afternoon (1500 hours). Generally, in the wet season relative humidity is high (about 95 %) while it is low (about 40 %) in the dry season (Federal Ministry of Agriculture 2010).

The vegetation in the study area is derived savannah, which is characterized by grasses such as elephant grass (*Pennisetumpurpureum*), guinea grass (*Panicum maximum*), spear grass (*Imperata cylindrical*), the pine grass and scattered short leguminous shrubs like *Leucenealeucocephala*, *Gliricidiasepium* *Ceasalphinaeapulcherima* etc. Tall green vegetation with spread palm tree plantation (*Ealaisguineensis*) are common features of this area. The soil of the area is an Alfisol, locally classified under Iwo soil series (Smyth and Montgomery, 1962). Alfisol are soil orders in the USDA (United States Department of Agriculture) soil taxonomy. In the FAO classification, most Alf refers to Aluminium (Al) and Iron (Fe). They are soils formed in semi-arid to humid areas, typically under a hardwood forest cover. They are mineral soils with surface horizon which is too thin or too light coloured (Ochricepipedon) to be classified as a Mollicepipedon (thick dark coloured not highly leached surface horizon).

FIELD STUDY

Three (3) land use types were identified, as cultivated, fallow and forest land. Soil sampling was done randomly with the aid of a soil urger on the three land use type. Samples obtain from each of the land use type were bulk together to form a composite sample. Soil samples were packed into polythene bags, neatly labeled and taken to the laboratory for chemical analysis.

LABORATORY STUDIES

The Soil samples were air-dried, gently ground in a mortal and sieved with a 2mm sieve. Particle size distribution was determined by hydrometer method (Gee and Or 2002). Soil pH was determined using a glass electrode in a 1:1 soil-water ratio (H19017 Microprocessor) pH meter. Soil organic carbon (O.C) was determined using Walkley and Black method (Nelson and Sommers 1996) and Organic matter estimated by multiplying

with a factor of 1.724. Total Nitrogen was determined by The Micro-Kjehldal digestion method (Bremmer and Mulvancy1996). Available phosphorus was determined with spectrophotometer using Mehlich III as extractant (Mehlich, 1984), and exchangeable acidity by KCl extraction method (Mclean 1965). Exchangeable Bases (Ca, Mg, Na and K) were extracted by leaching with 1N NH₄OAC (pH 7.0). Ca and Mg were determined by atomic absorption spectrophotometer and Na and K by flame emission spectrophotometer. Cation exchange capacity (CEC) was determined by ammonium saturation method (Jackson 1968). Percent base saturation, effective cation exchange capacity (ECEC) and CEC/Unit clay were calculated.

RESULTS AND DISCUSSION

RESULTS:

Table 1: Soil sampling locations and their co-ordinates.

S/N	LOCATION	CO – ORDINATE	LAND USE TYPE
1	Temporary site	5 ⁰ 23 ¹ 4 ¹¹ N, 7 ⁰ 42 ¹ 27 ¹¹ E	Cultivated
2	Permanent site	5 ⁰ 58 ¹ 9 ¹¹ N, 7 ⁰ 14 ¹ 17 ¹¹ E	Fallow
3	Permanent site	5 ⁰ 43 ¹ 33 ¹¹ N, 7 ⁰ 44 ¹ 48 ¹¹ E	Forest

Table 2: Mean values and standard deviation of chemical properties and particle size of the studied soils studied.

Soil parameters	Cultivated	Fallow	Forest
Soil pH (H ₂ O)	5.0±0.04	6. 1±0.05	6.5±0.07
Organic carbon (g/kg)	21.05±0.47	25.97±0.66	28.59±1.62
Total Nitrogen (g/kg)	1.05±0.09	1.69±0.11	2.74±0.15
Available Phosphorous	5.87±0.40	8.57 ± 0.51	11.95±0.82

(mg/kg)

**Exchangeable bases
(cmol/kg)**

Ca	2.57±0.11	4.15±0.16	5.81±0.22
Mg	0.25±0.01	0.55±0.13	0.57±0.16
K	0.16±0.01	0.23±0.03	0.32±0.05
Na	0.22±0	0.22±0	0.32±0

**Exchangeable acidity
(cmol/kg)**

1.50±0	0.15±0	0.27±0
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**Percentage base saturation
(%)**

57±0	62±0	86±0
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Micronutrients (mg/kg)

Mn	105.05±12.24	121.32±7.02	80.28±0.23
Fe	75.04±5.15	83.67±6.23	170.18±12.31
Cu	0.98±0.29	1.09±0.03	0.49±0.01
Zn	2.68±0.52	5.67±0.96	4.69±0.29

Particle size (g/kg)

Sand	890.0±6.23	929.0±18.75	926.0±23.79
Silt	58.0±3.72	30.0±8.26	27.0±25.60
Clay	52.0±4.34	41.0±8.06	47.0±3.22

Textural class	Sandy clay loam	Sandy clay loam	Sandy clay loam
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EFFECT OF N FERTILIZER ON PH AND EXCHANGEABLE ACIDITY

The soil of the experimental site is an Alfisol, locally classified under two soil series (Smyth and Montgomery, 1962). Table 2 the result showed that application of ammonium nitrate and urea N fertilizers at the long-term fertility trial at Umunze south eastern Nigeria had caused soil acidification on the cultivated arable land. Mean treatment values of pH ranged from 6.5 to 5.0 when measured in water, respectively. The total nitrogen content of 1.05 g kg⁻¹ for cultivated arable land (temporary site) was lower the critical level of 1.5 g kg⁻¹ (Enwenzoret al., 2002). While the available P of 11.95mg kg⁻¹ for forest land (permanent site) was within the critical level of 10 - 16 mg kg⁻¹ (Adeoye and Agboola, 2000). While that of the cultivated arable land and fallow land (temporary and permanent site) was below the critical level for south eastern soils. 5.87g kg⁻¹ and 8.57 g kg⁻¹ respectively.

Exchangeable acidity was strongly dependent upon the rate of N fertilization applied. As much as 50% of the potential acidity added as ammoniacal N fertilizers remained in the top 20-cm as exchangeable acidity (Adeoye 2013). Consequently a long term soil acidification equally limits the availability of soil phosphorous. Phosphorous combine easily with iron (Fe) and aluminum (Al) under acidic soil condition, this available soil phosphorous are usually fixed as Fe₂pO₄⁻ and AlpO₄⁻ exist (Akande, M. O., Adediran, J. A. and Oluwatoyinbo, F. I. 2012).

CHANGES IN CEC

The increase in exchangeable acidity associated with N fertilization was accompanied by a decline in exchangeable base cations. The decline was most significant in exchangeable Ca²⁺, Mg⁺ and K⁺ respectively. The K status for soil of the cultivated arable (temporary site) was 0.16 cmol kg⁻¹ also less than the critical level of 0.2 c mol kg⁻¹ (Adeoye, 2012). Although exchangeable acidity increased most in those treatments in which exchangeable base cations were most depleted, the losses of exchangeable bases were not entirely offset by the addition of exchangeable acidity. The cation exchange capacity (CEC) of the long-term fertility plots, determined here as the sum of exchangeable base cations and exchangeable acidity and sometimes termed effective cation exchange capacity (ECEC), showed a strong negative correlation to the rate of N fertilizer. Therefore the fate of the cation exchange capacity in these studies is not known based on any direct evidence for these soils. Many soils have mixed constant and variable charge components and CEC is pH-dependent, either due to a high content of

free oxides of Fe, Al (sesquioxides), and Si (typical of more weathered soils) or humic substances in the soil organic matter, which contain weakly acidic and very weakly acidic groups South eastern soils by Enwendo et al. (1979).

Other possible explanations for CEC reductions due to prolonged soil acidification include both mineral weathering, including weathering of the clay minerals themselves, and formation of non exchangeable hydroxy-Al complexes in the interlayer region of the clays. Acid dissolution studies conducted under laboratory conditions have shown that the rate of dissolution of montmorillonite clay minerals is correlated to the degree of substitution in the clay lattice (Omuetti, 2003).

This suggests that the soil clays of the study sites and the loess-derived soils of the southeastern Nigeria may be particularly prone to dissolution upon soil acidification. On the other hand, although all permanent negative charge in the phyllosilicate clays must be balanced with cations, not all of the cationic charge is necessarily exchangeable (Suleiman et al., 2015).

Formation of polynuclearhydroxy-Al interlayer in the 2:1 expansible clay minerals, either smectite or vermiculite, is associated with reduction in cation exchange capacity because the polynuclearhydroxy-Al material forms non exchangeable "atolls" or "pillars" in the interlayer (Omuetti, 1995). The process of formation of hydroxy-Al interlayers is a recognized form of soil weathering, often termed "chloritization" because of its tendency to form aluminous chlorite as an end product.

The extent of reversibility of the charge reduction associated with soil acidity at this site is known. Of the three explanations for CEC reduction, clay mineral dissolution and chloritization are almost certainly not reversible processes within a soil environment, and certainly not reversible with soil lime amendment (FAO 2014). If the cation exchange capacity reduction is due to variable charge considerations, then the reduction may be reversible by pH amelioration and base supply with soil liming, although hysteresis cannot be ruled out. Without studying the mechanism of charge reduction in this soil and the extent of the reversibility of the phenomenon, the extent to which soils have been permanently altered by common agronomic fertilization practices will be unresolved.

CONCLUSION

Not only CEC may be altered due to acidification caused by nitrogenous based fertilizers. Both nitrification of ammonium and mineralization of organic matter may be affected, as well as generation of phytotoxic levels of Mn. Changes in CEC may affect the nutrient retention properties of soils, increasing the level of fertility management required for productivity. Even though changes in CEC have been detected, weathering of other soil components less easily quantified, such as minerals in the silt fraction, may be occurring at an accelerated rate due to acidity.

RECOMMENDATIONS

- ❖ Evidence of CEC reduction due to N inputs, and its potential for reversibility, might be more widespread if repeated measurements of CEC of agricultural fields were made routinely or well-documented soil samples were more commonly archived.
- ❖ Agricultural limestone (CaCO_3) equivalent required to neutralize soil acidity should be applied routinely.

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