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NITRATE-NITROGEN AND RELATED NUTRIENT CONTENTS OF SOME ALLUVIAL VEGETABLE PRODUCTION SYSTEM IN DELTA STATE, NIGERIA

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ABSTRACT

A study was conducted in the alluvial soils located in Oko-anala in Delta State, Nigeria. These alluvial soils are primarily used for intensive vegetable production for commercial purposes. The total land area of about 3.34 Square kilometer was divided into three consociations and composite soil samples collected from pre-determined depths of 0-15 and 16-30cm. The samples were routinely prepared, analyzed for Nitrate-Nitrogen using spectronic 70 electrophotometer method. The other nutrient contents of the soils were also measured using appropriate laboratory methods. The results of the study showed that the Nitrate-Nitrogen (NO_3-N) contents of the soils were low and ranged from 0.12-0.16 gkg^{-1}. The soils pH were moderately acid to slightly alkaline 5.7-7.7, Organic carbon content were low to moderate 17.41-25.32 gkg^{-1}. Total nitrogen and available phosphorous were low being lower than 1.5 gkg^{-1} and 8.0 $mgkg^{-1}$. The exchangeable cations and CEC were within low to moderate ranges, while the percentage base saturation was above 80% in all the consociations. The particle size fractions varied from loamy fine sand, to sandy clay loam. The general results showed that nitrate-nitrogen was low at the surface horizons and tend to accumulate in the lower horizons due to leaching while the other nutrients evaluated were low to moderate in concentrations depicting low to moderate fertility of the soils.

KEYWORDS: Nitrate-Nitrogen, nutrient contents, alluvial soils, vegetable production system, Delta State.

INTRODUCTION

Nitrate and ammonium are the available forms of nitrogen in the soil, the nitrate form being more significant in terms of plant availability and abundance in the soil (Havlin *et al.*, 2005).The accumulation of nitrate is very common in vegetable crop production systems. This is because such system is usually fertilized with heavy doses of nitrogenous fertilizers without soil test either in the form of ammounium sulphate (NH_4SO_4), Ammonium nitrate (NH_4NO_3) or Urea ($Co(NH_2)_2$ in order to promote vegetative growth (Havlin *et al.,* 2005 and Brady and Weil, 1999). Majority of plant available nitrogen is in the inorganic forms of nitrate (NO_3) and ammonium (NH^+_4) and assimilated so fastly that its concentration within plant tissues never gets to critical level (Eckert, 1999). High nitrate-N accumulation in the soil which could arise as a result of over application of nitrogenous fertilizers could cause numerous problems such as low nitrogen use efficiency, environmental contamination, leaching of nitrate-N to ground water thereby causing eutrophication (Brady and Weil, 1999, Hong *et al.*, 2007 and Cui *et al.,* 2008). Eckert (2008) has also reported that nitrate content in the soil that is greater than 10mgl^{-1} in drinking water either in domestic wells, streams or lakes could cause a potential fatal disease such as methoemoglobinaemia in children and capable of promotingprostrate cancer in adults. Nitrate-nitrogen is negatively charged and as such, it does not bind to the soil exchange site very firmly but rather held in the soil solution which makes it being easily leached from the upper soil horizon by rainfall down to the rooting zone (Wild, 1988; Brady and Weil, 1999). In most alluvial soils of subtropical origin, nutrients deficiencies are major soil limiting problems resulting from excessive flooding, leaching, poor management of crop residues, wrong approach to fertilizer application, over cultivation of the land resources without appropriate replacement of used up nutrients and bush burning effects (Grubinger, 2007; Obiekwu *et al.*, 2009). These nutrient related problems notwithstanding, the alluvial soils remain the “Loci” of modern agriculture in the Sub-Saharan Africa and are extensively utilized. In recent years, the use of nitrogenous fertilizers and other fertilizer sources without adequate soil test is becoming worrisome to African soil scientists due to the lethal effects of high levels of nitrate in the total intake in diets (Roth and Fox, 1996, Onyesom and Okoh, 2006). Because of the increasing demand of vegetable crops as a cheap source of proteins, vitamins and essential amino acids and the increased involvement of youths in the production system as a potential mean of earning income in the face of increasing unemployment situation. It is therefore the objective of this study to examine the Nitrate – Nitrogen and other nutrient contents of the soil, if they are in excess concentration that could be lethal on consumption, sufficient or deficient.

MATERIALS AND METHOD

Description of the study area

The study was conducted in the alluvial soils located in Oko-anak in Delta State, Nigeria. The study site is an extensive land mass of about 3.34 square kilometers. located at latitude 06°14'N and longitude 6°42`E of the equator, and in the tropical rainforest zone that is characterized by seven months of rainfall starting from the months of April and extends up to October. The annual rainfall is between 1,525mm-1.875mm with a mean temperature of 35.4°C and a relative humidity of 75.3% (NIMET, 2010). The overall topography is typically of unconsolidated marine and fluvial deposits formation due to its proximity to the River Niger which tends to overflow its bank annually and flood the entire area for at least three months before the flood recedes. The vegetation is of rainforest types made up of grasses, weeds and sedges. Land use is typically based on rain-fed agriculture and extensively cultivated during the dry seasons due to its high water table because of the flood cycle as it receded. Vegetables that are of dietary and economic importance extensively cultivated at commercial level include fluted pumpkin (*Telfaria occidentalis*), water leaf (*Talinium triangulare*), tomato (*Lycopersicum esculentum*), Okra (*Abelmoschus esculentus*), Groundnut (*Arachia hypogea*), Scent leaf (*Ocimum gratissmum*), Hot pepper (*Capsicum frutescens*) and a host of others.

Soil sampling/experimental design

For effective coverage, the study area was divided into three mapping units designated as 'Consociations'. Thus, there were three consociations namely Consociation 1 (C_1), Consociation 2 (C_2) and Consociation 3 (C_3). From each of the consociations measuring about 0.47 square kilometers, surface (0-15cm) and sub surface (16-30cm) soil samples were collected at $0.5m^2$ intervals (i.e. grid nodes) with the aid of Dutch auger. Composite samples were taken in all possible combinations making six combinations in this way: C_1D_1, C_1D_2; C_2D_1, C_2D_2; and C_3D_1, C_3D_2 and the experiment laid in a Randomized Complete block design (RCBD) replicated 3 times.

Sample Preparation/Analysis

The collected composite samples were air-dried, crushed and sieved through a 2 mm sieve mesh and properly packaged for the analysis of some physico-chemical properties of the soil. Particle size fractions were determined by the Bouyoucos (1951) hydrometer method. Soil pH was determined using Pye unican model 290 MK2 pH meter in a 1:2.5 soil/water suspension. Organic matter was determined by Walkley-Black dichromate wet oxidation method (Nelson and Sommers, 1982). Total nitrogen was determined by Micro-Kjeldahl technique as described by Bremner and Mulvaney, (1982). Available phosphorus was extracted by the Bray No. 1 method (Bray and Kurtz, 1945) and phosphorus in the solution determined calorimetrically by the ascorbic method. Exchangeable bases (Ca, Mg, K and Na) were brought into solution by repeated extraction procedure with neutral I N ammonium acetate (pH_7) Solution (IITA, 1982). Ca^{++} and Mg^{++} in solution were read in an atomic absorption spectrophotometer, while K^+ and Na^+ were read on a flame emission photometer. Cation exchange Capacity (CEC) was determined by the Ammonium acetate (NH_4OAC) saturation method (Rhoades, 1982). The electrical conductivity (EC) was measured in 1:2.5 saturation extract using digital electric conductivity meter. The nitrate-N content was analyzed by B and L spectronic 70 electrophotometer method (Greweling and Peech, 1965).

Data Analysis

Measured variables in the data set were analysed using classical statistical methods. A one-way analysis of variance (ANOVA) was used to compare the consociations and soil depths. Where F-values were significant, treatment means were separated using LSD (Least Square Difference). The statistical analysis was performed using SAS (1998).

RESULTS AND DISCUSSION

Particle size fractions

The results of the particle size fractions of the soil are shown in (Table 1).

TABLE 1: Particle size distribution and texture of the soils

Dept (cm)	Sand (%)	Silt (%)	Clay (%)	Texture
		Consociations 1		
0-15	80	8	12	LFS
15-30	74	6	20	SCL
mean	77.0	7.0	16.0	
		Consociations 2		
0-15	82	4	16	LFS
15-30	76	4	20	SCL
mean	79.0	4.0	18.0	
		Consociations 3		
0-15	70	18	12	FSL
15-30	68	16	16	FSL
mean	69.0	17.0	14.0	

Abbreviations: LFS = Loamy fine sand, SCL = Sandy Clay loam, FSL = Fine sand loam

The texture of the soils ranged from loamy fine sand for consociations 1 and 2 at the top horizons, to sandy clay loam at the sub soil horizons. Consociation 3 had fine sand loam at both the surface and sub surface horizons. In all the pedons, sand fractions appeared to be the dominant particles with mean values of 77, 79 and 69 percent respectively. There was no significant difference ($P < 0.05$) in the particle size fractions. Clay fractions on the other hand, were found to increase with depth with mean values of 16, 18 and 14%'s respectively in all the consociations. The physical attributes explained the high rate of nitrate-N leaching down the profiles due to the coarse-textured nature of the soil (Lincoln *et al.,* 2007). It also showed that alluvial soils have god physical attributes to support a wide variety of crops. Except for the period of flooding, the soils do not experience any aeration problems (Egbuchua, 2012).

Chemical properties

The pH values in all the soil units ranged from 5.7-7.7 (Table 2) indicating moderately acid to alkaline reaction and that most nutrients could be available for plant uptake. This also falls within the range of 5.5-10.0 Havlin *et al.*, (2005) in which nitrification can take place and nitrate content of the soils could increase rapidly (Onyesom and Okoh, 2006). The organic matter content across the consociations were in the range of very low to moderate (17.41-25.32 gkg^{-1}) with mean values of 21.89 gkg^{-1}, 20.44 gkg^{-1}, and 20.91 gkg^{-1} for consociations 1, 2 and 3 respectively. There was no significant difference ($P<0.05$) in the organic matter content of the soils. The low organic matter content could be attributed to the intensive cultivation of the soils, the cultural practices of burning the land prior to cultivation and complete removal of harvested crop residues instead of returning them back to the farm land. The moderate level on the other hand, could be as a result of all sorts of fluvial materials that are deposited on the soils during flood regime.

Total nitrogen and available phosphorous were low being generally less than 1.5 gkg^{-1} for nitrogen and 8 $mgkg^{-1}$ for phosphorous as recommended bench marks for the ecological zone (FDANR, 1996).

The low content of total nitrogen could be accounted for by the low organic matter content of soil which supplies about 75-85% of soil organic nitrogen (Grubinger, 2007). Low available phosphorus on the other hand, could be due to low phosphate potentials of the parent material and high fixation rate of phosphate ion in the soil. Akamigbo *et al.* (2001) and Udo, 2011 respectively have also reported low to very low P-contents of some alluvial soils in Nigeria. The exchangeable bases of calcium (Ca) and Magnesium (Mg) which were the most dominant cations in the soils ranged from 5.21 – 5.74 $cmolkg^{-1}$ and 1.53 – 1.74 $cmolkg^{-1}$ respectively (Table 2). Sodium (Na) and Potassium (K) were within the normal range. The electrical conductivity (EC) ranged from 1.36 – 1.61 dsm^{-1} in all the soil units (Table 2). This is an indication that salinization is not a significant pedogenetic process within the study area. Udo (2001), Ayolagha (2001) and Egbuchua (2012) have reported low values of electrical conductivity in some alluvial soils of the Niger-Delta regions, Nigeria. The cation exchange capacity (CEC) were low to moderate in all the soil units (Table 2). Low to moderate values of CEC have been reported to be an indication of the dominance of kaolinitic clays in the fine earth fractions (Ojanuga *et al.*, 1981). The percent base saturation of the soils were generally high. This could be as a result of the nature of the parent material being from alluvium. Udo (2001) has also reported high base saturation of some alluvial soils in Nigeria.

TABLE 2: Some chemical properties of the soils

Soil depth (Cm)	pH (H_2O)	pH ($CaCl_2$)	O.M. (gkg^{-1})	Total N (gkg^{-1})	Avail P. ($mgkg^{-1}$)	Ca →	Mg →	K $Cmolkg^{-1}$	← Na	← CEC	← EA	EC dsm^{-1}	BS %
Consociation 1													
0-15	5.8	6.8	25.32	1.25	5.76	5.74	1.64	0.28	0.37	13.46	2.54	1.36	78.5
15-30	7.5	4.7	18.46	0.92	3.86	5.61	1.53	0.21	0.37	11.76	3.15	1.55	42.4
Mean	6.65	5.75	21.89	1.09	4.81	5.68	1.59	0.25	0.37	12.61	1.46	1.46	85.5
Consociation 2													
0-15	5.7	6.5	23.46	1.18	6.34	5.87	1.75	0.31	0.32	13.76	2.35	1.47	77.3
15-30	7.3	4.6	17.41	0.87	5.10	5.27	1.58	0.27	0.33	10.78	3.11	1.50	97.9
Mean	6.50	5.55	20.44	1.03	5.72	5.57	1.67	0.29	0.33	12.27	2.73	1.49	87.60
Consociation 3													
0-15	5.8	6.2	22.48	1.34	5.84	5.35	1.63	0.27	0.27	12.87	2.47	1.53	77.6
15-30	7.7	4.7	19.34	0.97	3.96	5.21	1.53	0.24	0.27	11.71	3.35	1.61	90.5
Mean	6.55	5.45	20.91	1.16	4.90	5.28	1.58	0.26	0.27	12.29	2.91	1.57	84.05

Nitrate-N content

The nitrate-N (NO_3-N) content of the soils were low and ranged from 0.12 – 0.16 gkg^{-1} (Table 3). Generally, the inorganic forms of soil nitrogen either as ammonium nitrogen (NH_4-N) or nitrate nitrogen (NO_3-N) which were utilized by plants occur in relatively low amount in cultivated soils (Roth and Fox, 1990, Havlin *et al.*, 2005). Low values of nitrate-nitrogen (NO_3-N) across the soil units could be due to the leaching of nitrate-N in the soils (Mcneul *et al.*, 1995, Cui *et al.*, 2008). High mobility of nitrate in the soil due to their negative charge makes it not easily absorbed by most soil colloids and thus, more vulnerable to leaching. The same findings have been reported by Abdullahi *et al.,* (2010) in some vegetable farms in Nigeria.

TABLE 3: Nitrate-N contents of the soils

Soil Code	Depth (cm)	Values (gkg^{-1})
Consociation 1	0-15	0.12
	15-30	0.25
	Mean	0.19[a]
Consociation 2	0-15	0.16
	15-30	0.31
	Mean	0.24[a]
Consociation 3	0-15	0.16
	15-30	0.35
	Mean	0.26[a]

Means with the same alphabets are not significantly different at 5% level of probability

TABLE 4: Location mean values of some physico-chemical properties of the soil

Soil Units	Sand →	Silt %	Clay ←	pH (H_2O)	No_3-N gkg^{-1}	O M gkg^{-1}	N gkg^{-1}	P $Mgkg^{-1}$	Ca →	Mg	K $Cmolkg^{-1}$	Na ←	CEC	BS %
Consociation 1	77.0[a]	7.0[a]	16.0[a]	6.65a	0.19[a]	21.89[a]	1.09[a]	4.81[a]	5.63[a]	1.59[a]	0.25[a]	0.37[a]	12.61[a]	85.40[a]
Consociation 2	79.0[a]	4.0[a]	18.0[a]	6.60a	0.24[a]	20.74[a]	1.03[a]	5.72[ab]	5.57[a]	1.67[ab]	0.29[a]	0.33[a]	12.27[ab]	87.60[a]
Consociation 3	69.0[a]	7.0_a	14.0[a]	6.55a	0.26[a]	20.91[a]	1.16[a]	4.90[a]	5.28[a]	1.58[a]	0.26[a]	0.27[a]	12.29[ab]	84.05[a]

Means with the same alphabets are not significantly difference at 0.05% probability level

CONCLUSION

The inorganic forms of soil nitrogen especially the nitrate-N (NO_3-N) and other related soil nutrients are very fundamental in crop production and essentially useful in promoting vegetative growth in plants. The study showed that nitrate-N content in all the soil units were low and could be attributed to excessive leaching of this highly mobile and negatively charged ion. Other nutrient elements investigated in the study were found to occur in low to moderate status or levels. Alluvial soils in the Sub-Saharan Africa are exhaustively utilized because of their high agricultural potential and water being an essential factor in crop production.

To fully harness the potentials of these soils, copious use of both organic and inorganic fertilizers are indispensable.

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