

Chemical Properties and Nitrate Contents of Soils and Vegetables of Rugar Liman in Kware Local Government Area, Sokoto Metropolis, Nigeria

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Abstract – Nitrate is one of the common pollutants of both water and soil in the areas where intensive cultivation is carried out under vegetable production. High levels of nitrogenous fertilizers are commonly applied to vegetables to increase yield especially in the highly populated urban and periurban areas where demands for vegetables is also high. In view of this, a study was carried out in Kware Local Government Area of Sokoto State, to assess the nitrate content of soils and vegetables cultivated and supplied to markets in Sokoto town. To achieve this, soil samples were taken from three vegetable farms (onion (*Allium cepa*), spinach (*Spinaceaoleracea*) and lettuce (*Lactuca sativa*) and a control from a fallow land. From each farm, 3 composite samples at different depths (0–20, 20-40 and 40-60 cm) and nine plant samples each were collected. The samples were taken to laboratory and some chemical properties of the soils and crops were determined using standard methods. Soil pH, nitrate, organic carbon, phosphorous, cation exchange capacity, calcium, magnesium and potassium contents of the soils were significantly ($p \leq 0.05$) different based on location (farm-plots). Available phosphorous of soils was low and ranged from 2.60 to 4.36 mg/kg, cation exchange capacity (CEC) and calcium contents were also low. Magnesium value ranged from low ($0.27 \text{ cmol kg}^{-1}$) to moderate ($0.45 \text{ cmol kg}^{-1}$), while, potassium and sodium values were high. The organic carbon was also low with mean value range of 2.5 to 7.3 g/kg. The pH of the soil was strongly acid to neutral condition. Total nitrogen and nitrate in soils of the area were low and decreased with soil depth, indicating little or non-leaching of the applied fertilizers. The result obtained indicated low concentration of nitrate in the vegetable crops and there was no significant ($P > 0.05$) difference between the crops. Based on this result, no harmful health hazard is expected from consuming these vegetable crops in the studied area and there is no evidence of nitrate contamination of the soils.

Keywords – Chemical Properties, Fertilizer, Nitrate, Pollutant, Vegetable Consumption.

I. INTRODUCTION

Consumption of vegetables and fruits as food offers the most rapid means and lowest cost of providing adequate supplies of vitamins, minerals and fibers to the people who live in the Tropics. However, due to increased use of synthetic nitrogen fertilizers and livestock manure in intensive agriculture, vegetables and drinking water may contain higher concentrations of nitrate now than in the past [1]. Plants (vegetables) that do not have enough nitrogen will turn yellow and may not look healthy for

consumption. According to [2], nitrogen fertilizers stimulate growth of crops especially chloroplasts formation in plants, which are responsible for the process of photosynthesis, as a result, excessive amounts of inorganic fertilizers are applied to vegetables in order to achieve higher yield [3] and maximum value of growth [4], [5], [6]. Commercial synthetic fertilizer is considered a major source of plant nutrients [7],[8] but organic manure can serve as alternative practice to mineral fertilizers [8] for improving soil structure [6] and microbial biomass [9] and those sources of nitrogenous fertilizers can cause high nitrate accumulation in soils, water bodies and plants if applied at high rate and for prolonged period of time. Increased risk of nitrate-N leaching to ground water [10],[11] which may reach domestic wells, streams and lakes, contaminating drinking water and causing eutrophication and other associated problems [12], [13], [14],[11],[15]. Nitrate is a natural occurring form of nitrogen which is mainly sourced from fertilizers, decaying plants, manure and other organic residues. Nitrates are seen as a potential pollutants, therefore arousing serious environmental concern such that greater than $10 \mu \text{g L}^{-1}$ in drinking water has been reported to cause a potentially fatal disease (methemoglobinemia) in infants and had some carcinogenic threats, even in adults [16].

In addition, nitrate - N being negatively charged, do not bind to the soil exchange site and therefore held in soil solution, which is easily leached from the upper soil horizon by rainfall or irrigation water, and if sufficient water is added, the nitrate - N will even be leached below the rooting zone [17],[18]. This leaching of nitrate-N is facilitated by excessive precipitation or irrigation and high rates of N - fertilizer application, especially on excessively well drained soils with low water holding capacity [19] as obtain in Sokoto metropolis.

Secondly, leafy vegetables are group of foods which make the greatest contribution to nitrates consumption and are likely to contain high levels of nitrates [20], accounting for about 65-75% of the total intake in diets [21]. In view of the frequent application of fertilizers and excessive irrigation of vegetable farms grown in Sokoto metropolis, the study was carried out to determining the nitrate content of soils and some commonly cultivated vegetables crops and also the chemical properties of the soils of the vegetables farms.

II. MATERIALS AND METHODS

Study Area

The study was conducted in Rugar Liman village of Kware Local Government Area of Sokoto State. The area is located on Latitude $13^{\circ} 07'N$ and Longitude $5^{\circ} 28'E$. Sokoto State is in the dry sub-humid region surrounded by sandy savanna and isolated hills in the North-western part of Nigeria, between Latitudes $12^{\circ} 00'$ and $13^{\circ} 56'N$ and Longitudes $4^{\circ} 8'E$ and $6^{\circ} 54'E$ [20]. The total land area is about 32,000 square kilometres with a population of 3,696,999 million people [23].

There are two distinct seasons in the state; the rainy season which starts around May and lasts till September and the dry season from October to April. The annual rainfall is frequently erratic, poorly distributed and varies from 500 to 1300 mm [24]. There are two temperature extremes; the hot period (March to May) which is as high as $39^{\circ}C$ and the cold harmattan months of December to January; when cold, dust-laden winds blow from across Sahara bringing down the temperature to as low as $15^{\circ}C$, averaging about $27^{\circ}C$ [24].

Sample Collection and Preparation

Soil and plant samples were collected from some selected locations in RugarLiman village in Kware local government area, Sokoto metropolis. The location was chosen based on the prevalence of vegetable cultivation. A total of 36 soil samples including control and 9 plant samples were collected from three vegetable farmlands (onion, spinach and lettuce) designated as A, B and C. From each vegetable farm, three (3) samples of different depths (0–20, 20–40 and 40–60 cm) and a control were collected, three (3) plant samples of onion, spinach and lettuce were also collected from their respective plots and replicated three times. The soil samples were collected using auger and labeled A 1,2,3; B 1,2,3; C 1,2,3 (0-20 cm), A 4,5,6; B 4,5,6; C 4,5,6 (20-40 cm), and A 7,8,9; B 7,8,9; C 7,8,9 (40-60 cm). The plant samples were collected by randomly hand picking 5–10 leaves (economic part) at each of the plots and labeled A (1, 2, 3); B (1, 2, 3); C (1, 2, 3).

The samples were taken to laboratory and air dried, gently crushed using pestle and mortar. The crushed samples were sieved through 2 mm sieve and subjected to analysis, while plant samples were preserved in the refrigerator which was latter dried, grinded and subjected to laboratory analysis.

Soil and Plant Analysis

The soil samples were analyzed for soil pH, organic carbon, total nitrogen, available phosphorus, nitrate, exchangeable bases (calcium, magnesium, potassium, and sodium) and CEC. Soil pH was determined with a pH meter using 1:1 soil water ratio [25]. Organic carbon was determined by Walkley and Black oxidation method as described by [26] Nelson and Sommers. Total nitrogen was determined by Macro Kjeldahl digestion method [27].

Available phosphorus was determined using Bray No. 1 method [28]. Calcium and magnesium were determined using EDTA (Ethylene DiamineTetraacetic Acid) titration method. Sodium and potassium were determined using flame photometer. Cation exchange capacity (CEC) was determined using ammonium acetate saturation method [29]. Nitrate was determined using Macro Kjeldahl distillation and titration method [27]. While, determination of nitrate content in the plant samples was done using colorimetric method [30].

Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) using Randomized Complete Block Design (RCBD) to compare the different plots and depths for the chemical properties. All statistical analysis was performed using Statistical Analysis System [31].

III. RESULTS AND DISCUSSION

Chemical Properties of Soil

Soil pH

The result of the chemical properties of the soils is presented in table 1 and 2. Table 1 indicates how the chemical properties of the soils varied within the plots, which revealed that there was significant ($P<0.05$) difference in the values of all the chemical properties of the soils between the plots except total nitrogen and sodium.

The variation of soil pH between the different plots was significant ($P<0.05$) with the highest value (7.08) recorded in plots C (lettuce) which was statistically similar to plots A (onion) and control. The least value of 4.90 was recorded in plots B (spinach) indicating strongly acidic condition (Brady and Weil, 2004). However, the result of the pH in table 2 shows there was no significant ($P>0.05$) difference in values between the soil depths but absolute values indicated a slight decrease in the pH at 0-20 to 20-40cm (6.28 - 6.05) (slightly acid condition). A decrease in soil pH over time is a function of crop nutrient uptake, nitrogen acidification, leaching and soil buffering capacity. The most serious problems are due to aluminum (Al) and manganese (Mn) toxicities which increase as the soil pH drops below 5.0 [32].

Organic carbon

The importance of organic carbon has increased interest and research on its build up in the soil-plant system with current emphasis on conservation tillage. The values of organic carbon of the soils was significantly ($P<0.05$) affected by plot. Table 1 shows that plots B had higher value of 7.3 g/kg than plots A and C with 6.3 and 6.4 g/kg, respectively, while control had the least value of 2.5 g/kg. This indicated that the lands where crops (vegetables) are being cultivated had encouraged organic matter build-up compared to the control soil. This may be due to agronomic practices used in growing different vegetable crops.

Table 1: Chemical Properties of the Soils

Location	pH	OC	N	NO ₃ ⁻	P	CEC	Exchangeable bases			
		g/kg	mg/kg				Ca	Mg	K	Na
							cmol (+) kg ⁻¹			
A	6.19 ^a	6.3 ^a	0.9	0.64 ^a	4.36 ^a	4.92 ^b	0.42 ^a	0.29 ^b	0.86 ^a	0.52
B	4.90 ^b	7.3 ^a	0.7	0.64 ^a	3.61 ^b	5.25 ^a	0.35 ^b	0.44 ^a	0.59 ^{bc}	0.46
C	7.08 ^a	6.4 ^a	1.2	0.62 ^a	4.03 ^{ab}	5.35 ^a	0.52 ^a	0.45 ^a	0.62 ^b	0.48
Control	6.61 ^a	2.5 ^b	1.8	0.50 ^b	2.60 ^c	5.16 ^{ab}	0.27 ^b	0.27 ^b	0.50 ^c	0.47
SE	0.28	0.11	0.03	0.05	0.18	0.10	0.03	0.05	0.03	0.03
Sig.	ns	ns	ns	*	*	*	*	*	*	Ns

Mean in the same column having different superscript differed significantly (P<0.05), ns = not significant; * significant at 5% level.

The content of the organic carbon of the soils was not significantly (P>0.05) affected by depths. The middle layer (20-40cm) had higher numerical value of 6.3 g/kg compared to upper (0-20cm) and lower (40-60cm) layers with 5.7 g/kg and 4.9 g/kg, respectively. Jones and Wild [33] reported organic carbon of 11.0 g/kg for soils of West

African savanna region. Based on the standard ratings of Esu[34], low organic carbon content was obtained in the soils of the area. Vanlauwe[35] advocated that optimum management of soil resources requires effective management of organic resources, mineral inputs and the soil organic carbon (SOC) pool.

Table 2. Chemical Properties of the Soils Based on Depth

Depth cm	pH	OC	N	NO ₃ ⁻	P	CEC	Exchangeable bases			
		g/kg	g/kg				Ca	Mg	K	Na
							cmol (+) kg ⁻¹			
0-20	6.28	5.7	1.6	0.68	3.98	5.38 ^a	0.46 ^a	0.48 ^a	0.71	0.54 ^a
20-40	6.05	6.3	0.9	0.18	3.61	5.18 ^b	0.38 ^b	0.35 ^b	0.62	0.46 ^b
40-60	6.24	4.9	1.1	0.09	3.35	4.96 ^b	0.34 ^b	0.26 ^b	0.60	0.45 ^b
SE	0.91	0.12	0.07	0.04	0.25	0.09	0.04	0.03	0.05	0.22
Sig.	ns	ns	ns	ns	ns	*	*	*	ns	*

Mean in the same column having different superscript differed significantly (P<0.05), ns = not significant; * significant at 5% level.

Total Nitrogen

Nitrogen plays a prominent role in the cation-anion balance because it is the nutrient that is taken up at the highest proportion by most plant species [36], [37]. Nitrogen has been reported to be the most limiting plant nutrient in the tropical soils [11]. The variation in total nitrogen in the soils of the different plots was not significantly different (P>0.05). Plot C and control had higher values of 1.2 and 1.8 g/kg compared to plots A and B with 0.9 g/kg and 0.7 g/kg, respectively. This shows lower value of total nitrogen in the vegetable fields compared to the control soils where cultivation is not carried out. Comparing these values with the standard ratings of Esu[34], they were at high rate indicating that the soils were rich in total nitrogen. However, when comparing the values between the depths, there was no significant (P>0.05) difference. But absolute values showed that the upper layer had higher value of 1.6 g/kg and decreased to 0.9 g/kg at the subsurface (20-40cm). This may not be unconnected with the organic matter content of the surface layer and leaching of nitrates down the profile [11] as factor of richer total nitrogen content of the soils at the surface layer.

Table 3: Mean Values of Nitrate Concentration in Plants

Treatment	Nitrate concentration (mg/kg)
Onion	0.147
Spinach	0.220
Lettuce	0.223
SE	0.029
Sig.	Ns

ns = not significant; * significant at 5% level.

Nitrate

The nitrate content of the soils investigated was significantly affected by the plots as shown in table 1. However, based on the depths, there was no significant (P>0.05) difference between the values obtained (Table 2). Plots A, B and C were statistically at par while the control had the list value of 0.5mg/kg. The nitrate content of the profile showed that there was little or no migration/leaching of nitrate down the profile as the surface layer had the highest value of 0.68 mg/kg compared to the subsurface which had 0.18 mg/kg at 20-40 cm and 0.09 mg/kg at 40-60 cm depth translating to 73 and 86 % reduction down the profile, respectively. This may be due to richer organic matter content of the topsoil which directly determines the concentration of nitrate-N of the soil and persistent application of organic manures and

nitrogen fertilizers on the surface layer of the vegetable farms. Naeemet *al.*[38] stated that organic manure can serve as alternative practice to mineral fertilizers and those sources of nitrogenous fertilizers (mineral) can cause high nitrate accumulation in soils. When the input of nitrogen exceeds the demand, plants are no longer able to absorb it, and nitrogen then builds up in the soil, mostly as nitrates [39].

The nitrate concentration of plant sample is shown in Table 3. The result showed that there was no significant ($P>0.05$) difference in the values obtained between the three vegetables (onion, spinach and lettuce). Although there was no significant difference in the values obtained, mean values show that onion had the least concentration of nitrate (0.147 mg/kg), while spinach and lettuce had 0.220 and 0.223 mg/kg, respectively. The nitrate content of vegetables can be affected by several factors among which are the use of fertilizers and growing conditions, especially the soil temperature and light intensity [40], [41]. [42] also added that, the ability of a plant to capture nitrogen from the soil depends on soil type, environment and species and estimated that 50–70% of the nitrogen provided to the soil is lost.

Phosphorous

An adequate concentration of phosphorus in soil solution and its refilling from the solid phase of soil are necessary for the required production of agricultural crops [43], [44]. The variation of available phosphorous in the soils of the different farm plots was significant ($P<0.05$). However, in terms of absolute values, plots A and C had higher values of 4.36 and 4.03 mg/kg than B (3.61 mg/kg) while the control had the least value of 2.60 mg/kg, respectively. However, available P content of the soil profile was not significantly ($P>0.05$) affected by depth, although the mean values showed an inclination towards reduction down the profile. These values were generally less than 10 mg/kg of Esu[34] and so rated low in available phosphorous, which conforms the earlier findings of the International Center for Tropical Agriculture (ICTA). The soils of Nigerian savanna have been reported to be inherently poor in soil available phosphorous [45].

Cation Exchange Capacity

Cation exchange occurs due to the negative charges carried by soil particles, in particular clay minerals, sesquioxides and organic matter [46]. The CEC in the soils of the different plots was significantly ($P<0.05$) affected. Plots B and C were statistically similar which was little above mean value (5.16 cmol/kg) obtained in control. CEC content among different depths was also significant ($P<0.05$). Upper layer (0-20cm) had higher value (5.38 cmol/kg) compared to middle (20-40cm) and lower (40-60cm) with 5.18 cmol/kg and 4.96 cmol/kg, respectively. FAO [47] reported CEC of 8-10 cmol/kg for West Africa soils as indicative of minimum values in the top 30cm for satisfactory crop production. Based on this rating, the CEC level of the study area could be rated low which is an indication of low fertility of the soil since CEC of soils controls the nutrient and water holding capacity of the soils [48].

Exchangeable Bases (Ca, Mg, K and Na)

Calcium is one of the dominant cation of most soils of West Africa [11]. The calcium value in the soils of the different plots was statistically significant ($P<0.05$). Plot C had higher value (0.52 cmol/kg) than A, B and Control (0.42, 0.35 and 0.27 cmol/kg).

There was also significant ($P<0.05$) difference in the values of calcium distribution within the profile. The upper (0-20cm) layer had higher value of 0.46 cmol/kg compared to middle (20-40cm) and lower (40-60cm) layers with 0.38 and 0.26 cmol/kg, respectively. Low Ca value (2.0 cmol/kg) was observed in Fadama soils of Kebbi State [48]. Based on the rating standard of Esu[34], the soils of the study area were generally low in calcium content. Michael and Donald [49] stated that parent materials from which soils are formed may be contributory factor to the content of exchangeable cations in soils.

The magnesium and potassium contents of the soils of the different plots differed significantly ($P<0.05$), while sodium was not. Magnesium content of farm plot A, B and C were statistically at par while plot A recorded the highest value of potassium (0.86 cmol/kg). Based on the standard ratings [34], magnesium was rated medium while potassium and sodium were rated high. These values of exchangeable cations obtained was within the normal range of calcareous soils that are relatively rich in exchangeable bases. However, because of low replenishment, widespread deficiency of potassium has been reported in many of the intensively cultivated soils [50].

IV. CONCLUSION

The result of the investigation indicates that the soils of the vegetable crops of the studied area were moderately fertile. The concentration of nitrate-N both in vegetable crops and soil were relatively low and decreased down the soil profile. Therefore, currently, there is no threat of nitrate contamination of the soils of the area and consumption of onion, spinach and lettuce from these farms may not cause any health hazard.

REFERENCES

- [1] Santamaria, P. 2006. Nitrate in Vegetables: Toxicity Content, Intake and European Commission Regulation. *Journal of Science and Food Agronomy*, 86: 10 – 17.
- [2] Gromove, A.A., Abaimer, V.F., Kanhove, N.D. and Schukin, V.B. 1994. The effect of increasing calculated dose of fertilizers in cereal fallow-row rotation on southern Chernozem in the Orenburg region. *Agro-Khimiya*, (6): 59-66.
- [3] Stewart, M.W., Dibb, W.D., Johnston, E.A. and Smyth, J.T. 2005. The contribution of commercial fertilizer nutrients to food production. *Agronomic Journal*, 97: 1–6.
- [4] Badr, L.A.A. and Fekry, W.A. 1998. Effect of inter-cropping and doses of fertilization on growth and productivity of taro and cucumber plants. I-vegetative growth and chemical constituents of foliage. *Zagazig Journal for Agricultural Resources*, 25: 1087–1101.
- [5] Arisha, H.M. and Bardisi, A. 1999. Effect of mineral fertilizers and organic fertilizers on growth, yield and quality of potato under sandy soil conditions. *Zagazig Journal for Agricultural Resources*, 26: 391–405.



- [6] Dauda, S.N., Ajayi, F.A. and Ndor, E. 2008. Growth and yield of water melon (*Citrulluslanatus*) as affected by poultry manure application. *Journal of Agricultural Science Society*, 4: 121–124.
- [7] Adediran, A.J., Taiwo, B.L., Akande, O.M., Sobulo, A.R. and Idowu, J.O. 2004. Application of organic and inorganic fertilizer for sustainable maize and cowpea yields in Nigeria. *Journal of Plant Nutrition*, 27: 1163–1181.
- [8] Naeem, M., Iqbal, J. and Bakhsh, M.A.A. 2006. Comparative study of inorganic fertilizers and organic manures on yield and yield components of Mungbean (*Vignaradiat L.*). *Journal of Agricultural Science Society*, 2: 227-229.
- [9] Suresh, K.D., Sneh, G., Krishn, K.K. and Mool, C.M. 2004. Microbial biomass carbon and microbial activities of soils receiving chemical fertilizers and organic amendments. *Archives Agronomic Soil Science*, 50: 641–647.
- [10] Don, Z. X., Fox, R. H. and Toth, J. D. 1995. Seasonal soil nitrate dynamics in corn as affected by tillage and N source. *Soil Sci. Soc. Am. J.* 59:858-864
- [11] Brady, N.C and Weil, R.R 2004. *Nature and Properties of Soil*, 12th edition. Upper saddle, N.J Prentice hall.
- [12] Battaglin, W. A. and Goolsby, D. A. 1994. Spatial Data in Geographic Information System Format on Agricultural Chemical Use, Land Use, and Cropping Practices in the United States. Reston, U.S. Geological Survey.
- [13] Dubrovsky, N. M. and Kratzer C. R., 1995. Water Quality in the San Joaquin-Tulare Basins, California, 1992-95, U.S. Geological Survey.
- [14] Nolan, B. T. and Ruddy, B. C. 1996. Nitrate in the Ground Waters of the United States Assessing the Risk, U.S. Geological Survey.
- [15] Smith, R. A. and Alexander, R. B. 2000. Sources of Nutrients in the Nation's Watersheds. Managing Nutrients and Pathogens from Animal Agriculture, Camp Hill, Pennsylvania, U.S. Geological Survey.
- [16] Eckert, D. 2008. Efficient fertilizer use manual; Nitrogen. <http://www.mossaico.com/fertilizer/nitrogen> (Retrieved May 26, 2008).
- [17] Tisdale, S. L. and Nelson, W. L. 1975. *Soil fertility and fertilizers* 3rd ed. Macmillan publishing company, Inc. New York and Collier macmillan publishers, London. pp128-140.
- [18] Wild, A. 1988. Plant nutrients in soil: Nitrogen. In *Soil conditions and plant growth*. A. Wild (ed), 11th edition. Longman Group UK. Limited pp 652-694.
- [19] McNeal, B. L., Stanley, C. D., Graham, W. D, Culreath, P. R., Downey D. and Greigton, J. F. 1995. Nutrient loss trends for vegetable and citrus fields in west Florida: I. Nitrate. *Journal of Environmental Quality*, 25:95-100.
- [20] Bryne, C., Maher, M.J., Hennerly, M.J., Mahon, M.J. and Walshe P.A. 2004. Reducing Nitrate Content of Protected Lettuce Teagasc Research Centre, Dublin
- [21] Onyeson, I. and Okoh, P.N. 2006. Quality analysis of nitrate and nitrate contents in vegetables commonly consumed in Delta state, Nigeria. *British Journal of Nutrition*, 96, 902-905
- [22] Mamman, A. B., Oyeabanji, J. O. and Peters, S. W. 2000. In Nigeria. A people united, a future assured (survey of states) Calabar, Gabumo Publishing Company, pp 6-7.
- [23] NPC (National Population Commission). 2006. Population of Nigeria by sex, report.
- [24] SMANRD, 1998. Sustainable Agricultural, Environmental and Rural Development. A survey of report prepared by Sokoto State Ministry of Agri. and Natural Resources, March, 14th, p. 149.
- [25] Bates, R.C. 1954. Elimination pH determination. John Wiley and Sons Inc, New York, Pp. 22-23.
- [26] Nelson, D.W. and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. In: *Methods of Soil Analysis, Part 2*, 2nd ed., A.L. Page et al., Ed. Agronomy. 9:961-1010. Am. Soc. of Agron., Inc. Madison, WI.
- [27] Jackson, M.L. (1962). *Soil Chemical Analysis*. IITA. Manual Series No.1 70pp
- [28] Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic and available form of phosphorus in soil. *Soil Science*, 59:39-45.
- [29] Chapman, H.D. 1965. Cation exchange capacity in methods of soil analysis, *Part II, Agronomy* No. 9, Black, C.A. (ed.) American Soc. of Agronomy, Madison, Wisconsin, Pp. 891-901
- [30] IITA (International Institute of Tropical Agriculture) 1989. Selected methods of soil and plant analysis. *Manual Series No. 1*. IITA, Ibadan, Nigeria, 70p
- [31] SAS 2002. Statview Statistical Package. SAS. Inc. New York.
- [32] Black, A.C. 1993. Soil fertility evaluation and control. Lewis Publishers, Boca Raton, FL.
- [33] Jone, M.J. and Wild, A. 1975. Soil of the West Africa savanna, technical communication 55 of the Common wealth Bureau of soils, Horpenden, England, Pp. 2-84.
- [34] Esu, I.E. 1991. Detail soil survey of Nigeria Institute for Horticultural Research (NIHORT) Farm at Bunkare, Kano State.
- [35] Vanlauwe, B. 2004. Integrated soil fertility management research at TSBF: the framework, the principles, and their application. In: Bationo, A. (Ed.), *Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa*. Academy Science Publishers, Nairobi, Kenya.
- [36] Marschner, H. 1995. Mineral Nutrition of Higher Plants. 2nd edn. Academic Press, London, UK. 889pp.
- [37] Mengel, K. and Kirkby, E.A. 2001. Principles of plant Nutrition. 5th edn. Kluwer Academic Publishers. Dordrecht, Boston, London.
- [38] Naeem, M., Iqbal, J. and Bakhsh, M.A.A. 2006. Comparative study of inorganic fertilizers and organic manures on yield and yield components of Mungbean (*Vignaradiat L.*). *Journal of Agricultural Science Society*, 2: 227-229.
- [39] Nosengo, N. 2003. Fertilized to death. *Nature*, 425: 894 – 895.
- [40] Gangolli, S. D., Van Den Brandt, P. A., Feron, V., Janzowsky, J. C. Koeman, J. H., Speijers, G. J. A., Spiegelhalter, B., Walker, R., and Wishnok, J. S. 1994. Assessment: nitrate, nitrite and N-nitroso compounds. *European Journal of Pharmacology Environmental Toxicology and Pharmacology*, 4 (1): 1–38.
- [41] FAO/WHO, 1995. Evaluation of certain food Additives and Contaminants. Geneva, World Health Organization, Joint FAO/WHO Expert Committee on Food Additives, World Health Organization Technical Report Series, 859: 29–35.
- [42] Hodge, A., Robinson, D. and Fitter, A. 2000. Are microorganisms more effective than plants at competing for nitrogen. *Trends in Plant Science*, 5: 304–308.
- [43] Denison, R.F. and Kiers, E.T. 2005. Sustainable crop nutrition: constraints and opportunities. In: Broadley M.R., White P.J. (eds.): *Plant Nutritional Genomics*, Blackwell, Oxford, 242–286.
- [44] Reid, W.V., Scholas R. 2005. Millennium Ecosystems and Human Well-being: Synthesis. Island Press, Washington DC.
- [45] Idoga, S. 2006. Characteristic, classification and uses of fadama soils in Makurdi metropolis, Benue State, Nigeria. In: V.O Chude, O. O. Agbede, A. E. Isenmila and A. Raji (eds) *Management of Fadama Soils for Environmental Quality, Food Security and Poverty Eliviation In Nigeria: Proceedings of the 30th Annual conference of Soil Science Society Of Nigeria; University of Agriculture, Makurdi, Nigeria. 5th-9th December, 2005*. Pp. 32-37.
- [46] Reeuwijk, L.P. 2002. Procedures for Soil Analysis. 6th edition. – Technical Paper/International Soil Reference and Information Centre, Wageningen, The Netherlands.
- [47] FAO, 1996. Soil and water resources survey of the Sokoto valley, Nigeria. Arid Report 5 FAO, Rome, Italy, Pp. 66-119.
- [48] Singh, B.R. 1999. Fertility, salinity and sodicity status of fadama soils in North Western Nigeria 1. Kebbi State. *Nigerian Journal of Basic and applied Science*, (3): 1-14.
- [49] Michael, J.S. and Donald, N.M. 1999. Soils, An Introduction. 4th edn. Prentice Hall, Upper Saddle River, NJ. P 527
- [50] Karki, K.B. 2004. Status of potassium in intensively cultivated soils from Kathmandu Valley. *Nepalese Journal of Science and Technology*, 5: 83-89.

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