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Content and Distribution of Nitrogen Forms in Some Black Cotton Soils in Akko LGA, Gombe State, Nigeria

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ABSTRACT

A study was conducted to determine the content and distribution of nitrogen forms in some soils of Akko Local Government Area (LGA) of Gombe State, Nigeria. A total of 60 composite soil samples were collected from 0-15 and 15-30 cm depths from purposively selected representative locations in the study area and analyzed using standard procedures. Results obtained showed that the soils were generally low in nitrogen, with organic nitrogen accounting for about 72.8% of the total nitrogen in the soils. The nitrogen forms followed the trend: total nitrogen>total organic nitrogen >NH_4-N>NO_3^--N>NO_2^--N in content, while each of the nitrogen forms was more or less uniformly distributed in the study area. Owing to the low available nitrogen content in the soil (<12% of the total N), it is recommended that supplementary nitrogen application and improvement of the drainage conditions of all the soils be employed to improve the nitrogen status of the soils.

Key words: Content, distribution, nitrogen forms, black cotton soils, soil depth

INTRODUCTION

Nitrogen is one of the most widely distributed essential elements in nature. Of all essential nutrients, nitrogen appears to have the most pronounced effect on plant growth and development (Ayeni, 2011). It is an important component of many important structural, genetic and metabolic compounds in plant cells and is a major component of energy transfer compounds such as ATP (which allows cells to conserve and use energy released in metabolism) and nucleic acids such as DNA, the material that allows cells to grow and reproduce (Brady and Weil, 2005a; Wiseman and Halliwell, 1996). Nitrogen mainly enters the soils through the organic matter. Plants and animal wastes decompose, adding nitrogen to the soil through the action of bacteria that convert organic nitrogen into plant-usable nitrogen. Nitrogen can also be lost when bacteria change the nitrate into atmospheric nitrogen and fertilizers are turned into gasses which consequently return to the atmosphere (Lang, 2010). Nitrogen in soils exists in three general forms: organic nitrogen, ammonium ions and nitrate ions. About 95 to 99% of potential available nitrogen in the soil is in organic forms; either as plants and animals residue in the relatively stable soil organic matter, or in living soil organisms, mainly microbes. It was reported (Brady, 1996) that available nitrogen in soils is often supplemented by nitrogen released from soil organic matter or organic materials added to the soil.

In Nigeria today, there is a gradual drift from traditional to a more scientific agriculture. Consequent upon this, the increasing unit cost of nitrogen and the fragility of soils in Nigeria (Mustapha, 2007b), amongst others, the evaluation of the nitrogen forms in the soils becomes imperative. Such evaluations will ensure prudent and sustainable nitrogen application/utilization.

This approach is useful now as efficient fertilizer use, based on recommendations from soil testing that recognizes inherent variability in soil properties is the tool for achieving Nigeria's scientific agricultural rejuvenation (Mustapha, 2007a). The recommendations will differ from the blanket rates made over large geographical area which farmers are being encouraged to adopt (Ayodele and Omotoso, 2008). Recent studies have shown the inappropriateness of these blanket recommendations; being wasteful thus causing environmental pollution by, among others, irrational overuse of chemicals such as chemical fertilizers (Sokouti and Mahdian, 2011).

With the foregoing in view, this study was undertaken to determine the contents and distribution of nitrogen forms in the Black Cotton soils of Akko LGA, Gombe State, Nigeria.

MATERIALS AND METHODS

The study area: The study was conducted between May and August, 2010 in Akko LGA; located along Gombe-Adamawa road, about 30 km away from Gombe town. It is located at 12°30'N and 11°45'E, within the northern Guinea Savanna Zone of Nigeria. The geology of the area is said to be tertiary continental sandstone to the west of the Keri-Keri escarpment, clays and siltstones. The climate is characterized by two distinct wet and dry seasons. The wet season starts in May and ends in October while the dry season starts in November and ends in April. The annual rainfall is about 800 to 900 mm per annum with mean annual temperature ranging from 30 to 32°C (BSADP, 1982).

Soil sampling and handling: A total of 60 composite soil samples were collected at 0-15 and 15-30 cm depths from 15 different, purposively selected representative locations in Akko LGA of Gombe State, Nigeria. Each composite soil sample was made of 5 sub samples.

The collected soil samples were properly labeled and stored in polythene bags and taken to the laboratory. In the laboratory, each sample was separately dried in air and then ground using porcelain pestle and mortar. The ground soil samples were sieved with 2 mm sieve and the fine earth fractions, collected in separate bags, were used for all the laboratory analyses.

Laboratory analyses: The processed soil samples were subjected to standard laboratory analyses as described by Page *et al.* (1982). Particle size distribution was determined using the hydrometer method (Bouyoucos, 1951) while soil pH was determined in water at a 1:1 soil to water ratio using glass electrode pH meter. Organic carbon was determined by the wet oxidation method (Walkley and Black, 1934). Total Nitrogen was determined by the micro-Kjeldhal method as described by Juo (1979), while the organic and inorganic forms of nitrogen were determined using the method described by Black (1965).

For the purpose of interpretation, critical limits provided by Esu (1991) were used for organic carbon and total nitrogen.

Data analysis: Data generated were subjected to simple descriptive statistics, including range and means (Harry and Steven, 1995). Analysis of variance was employed using the Minitab computer software to determine significant differences between means. Means that were statistically different were separated using the Least Significant Difference (LSD).

RESULTS AND DISCUSSION

Physico-chemical properties: The particle size distribution of the soils as shown in Table 1 indicates that the soils have relatively high sand (mean = 46.9%) and clay (mean = 30.1%) contents;

Table 1: Particle size distribution in the Black Cotton soils in Akko LGA, Gombe state, Nigeria

Variable	Sand%	Silt%	Clay %	pH (in H_2O)	Org. C. (g kg^{-1})
Location					
L. Mango	40.5	23.6	35.7	6.2	0.39
Zange	28.8	23.8	47.4	6.4	0.61
Lamba	25.5	24.6	49.9	6.3	0.87
Kumo	29.9	28.8	49.0	6.5	0.61
Tsamiya	35.1	19.1	45.4	6.2	0.87
M. Bakari	46.9	20.9	32.7	5.9	1.00
G. Wakili	45.0	30.8	24.0	6.0	0.76
A. Bose	50.9	20.3	27.4	6.1	0.62
W. Bappa	62.0	19.3	18.5	6.2	0.12
W. Yola	54.4	18.1	27.4	5.9	1.56
Kembu	60.4	22.4	21.5	5.8	1.22
S. Gari	54.4	19.8	25,5	6.1	0.94
Gamawa	47.7	29.3	23.0	5.9	0.83
Y. Shehu	55.2	26.3	18.5	6.1	1.09
W. Abba	66.9	15.1	17.9	5.7	0.90
Mean	46.9	22.8	30.1	6.1	0.83
Level of significance	***	***	***	* *	
LSD (p<0.05)/SE+	9.64	4.58	7.90	0.14	0.14
Depth (cm)					
0-15	48.3	23.5	28.7	5.8	0.99
15-30	44.4	22.0	33.1	6.4	0.75
Mean	46.4	22,8	30.7	6.1	0.87
Level of significance	NS	NS	*	***	*
LSD (p<0.05)/ SE±	7.21	3.42	12.14	0.72	0.40

NS = Not significant

giving the soils a generally sandy clay to clay texture. Clay content significantly ($p<0.05$) increased with soil depth. This is expected as some of the increase with depth in clay may be as a result of removal of the fraction by surface run-off and also by illuviation. This is a common phenomenon in soil in this agro-ecology as was also reported by Voncir *et al.* (2008). The results also indicate that all the fractions varied significantly ($p<0.05$) between the locations indicating wide variability in the fractions between soils from different parts of the LGA. Except for clay, however, all the other fractions did not vary significantly ($p>0.05$) with depth.

The soil reaction ranged from pH 5.7-6.5 (mean = 6.1) indicating slightly acidic reaction. Though generally acidic, the pH values varied significantly ($p<0.05$) between the locations and depths considered. The upper 0-15 cm was more acidic (pH = 5.8) than the lower 15-30 cm (pH = 6.4). This could be attributed to the removal of basic cations from the surface of the soils to the lower depths as was also observed by Voncir *et al.* (2008) and Kolo *et al.* (2009) and probably the use of acid-forming fertilizers such as urea for agricultural purposes.

Organic carbon: Results in Table 1 show that organic carbon content was generally low (Esu, 1991) through the locations; with values ranging from 0.39 to 1.56 (mean = 0.83) g kg^{-1}. Even though the surface 0-15 cm soils contained more organic carbon (0.99 g kg^{-1}) than the lower 15- 30 cm (0.75 kg^{-1}), the differences were not statistically significant ($p>0.05$). Similar low organic carbon values have been reported by Lombin (1983) for the Nigeria Savannah soils and Mustapha and Nnalee (2007) for soils in the northern guinea Savanna zone of Nigeria.

Table 2: Distribution of nitrogen forms in the Black Cotton soils of Akko LGA, Gombe state, Nigeria

Variable	Total N.	Total organic N.	Total inorganic N.	NH_4-N	NO_3-N.	NO_2-**N**
Location						
L. Mango	760.0	560.0	85.3	68.8	14.3	2.8
Zango	1915.0	935.3	136.0	116.8	15.8	3.5
Lamba	1005.0	827.3	133.8	115.0	12.5	6.3
Kumo	790.0	646.5	98.8	78.3	16.0	3.5
Tsamiya	1020.0	818.0	139.0	114.5	21.0	3.5
M. Bakari	950.0	763.8	215.0	119.8	17.0	3.3
G. Wakili	560.0	451.5	74.8	56.3	13.0	4.8
A. Bose	720.0	575.0	97.5	79.3	14.5	3.8
W. Bappa	1065.0	851.8	92.8	69.8	18.3	5.0
W. Yola	1200.0	969.5	114.4	91.3	19.3	3.8
Kembu	1140.0	903.3	124.8	98.8	20.5	5.5
S. Gari	880.0	664.3	91.8	67.3	19.8	4.8
Gamawa	920.0	739.5	87.0	66.3	17.5	3.3
Y. Shehu	1090.0	946.8	106.8	81.3	20.3	6.3
W. Abba	785.0	669.0	56.5	35.0	16.0	5.5
Mean	986.7	754.8	110.3	83.9	18.5	4.1
Depth (cm)						
0-15	1040	884.9	126.3	102.1	19.8	4.5
15-30	773	630.7	94.4	65.8	14.4	4.2
Significance	***	***	NS	*	***	NS
LSD ($p<0.05$)/SE±	898.3	741.5	57.4	74.5	15.1	1.7

It is noteworthy, however, that locations M. Bakari, W. Yola, Kembu and Y. Shehu contained 'medium' levels of organic carbon ranging from 1.00 to 1.56 g kg^{-1}. It is probable that farmers in these locations apply quite appreciable quantities of organic residues to their farmlands as a means of improving the fertility owing in part to the high cost of inorganic fertilizers.

Total nitrogen: The total nitrogen content of the soils (Table 2) followed a similar trend as the organic carbon content. The values were generally low ranging from 560.0 to 1915 mg kg^{-1} and were not statistically different between the locations (Table 2). The distribution of the total nitrogen, however, varied significantly ($p<0.05$) with soil depth. This variability could be attributed to the organic matter content on surface soil resulting from liter fall and other means of organic matter deposition on the soil surface. The values obtained are typical of the Nigeria savanna soils as reported by Lombin and Esu (1987).

Organic nitrogen: Table 2 shows that the organic nitrogen content ranged from 451.5-969.5 (mean = 754.8) mg kg^{-1}. Even though there appeared to be a wide variability in total organic nitrogen content in the soils studied between locations, the differences were not statistically significant ($p>0.05$). Importantly, however, is that the organic-N fraction forms the bulk of the total nitrogen in the soils; accounting for about 72.8% of the total. Brady and Weil (2005b) had earlier reported that about 95-99% of the soil nitrogen is in organic compounds that protect it from loss; thus leaving it largely unavailable to plants. The results obtained from this study tend, to a large extent, agree with this assertion.

The top 0.15 cm is in the soils, contained significantly ($p>0.05$) higher (888.9 mg kg^{-1}) amount of organic nitrogen than the soils in the 15-30 cm stratum (630.7 mg kg^{-1}). This may not be unconnected to the higher organic matter content in the top 0-15 cm soil as was observed in the soils studied (Table 1).

Total inorganic nitrogen: Total inorganic nitrogen in the soils studied (Table 2) varied widely ranging from 56.5-215.0 (mean = 110.3) mg kg^{-1} and contributed about 11.6% to the total nitrogen present in the soils. The wide variability may not be unconnected to the variability in organic carbon contents earlier observed in the soils studied and probably the variable use of agricultural inputs, especially nitrogen fertilizers, in the area studied.

Depth wise, inorganic nitrogen content appeared to decrease from 126.2 to 94.4 mg kg^{-1} with increasing depth. This decrease was, however, not statistically significant ($p>0.05$).

Ammonium-bound nitrogen: Of the three main forms of inorganic nitrogen forms (NH_4-N, NO_3-N and NO_2-N), ammonium nitrogen formed the bulk (range = 35-119.8; mean = 83.9 mg kg^{-1}), accounting for about 76.1% of the total inorganic nitrogen and 8.7% of the total nitrogen contents of the soils (Table 2). The results corroborate the reports of O'Leary *et al.* (2002) that NH_4-N, the most common form of N taken up by plants through the roots, is the most abundant form of inorganic nitrogen soils. USEPA (1994) attributed the high contents of NH_4-N in soils to the amount of organic matter, microbial activities and the soil pH. Even though NH_4-N was fairly similar in distribution between the locations considered in the LGA, it significantly ($p<0.05$) varied with depth; following similar trend as organic and inorganic nitrogen.

Nitrate-nitrogen: Nitrate-bound nitrogen (range = 12.5-21.0; mean = 18.5 mg kg^{-1}) did not vary significantly ($p<0.05$) between the locations in the study area, though it did with depth (Table 2). It was next to NH_4-N; accounting for about 16.8% of the total inorganic nitrogen and 1.8% of the total nitrogen content of the soil. The preponderance of NH_4-N over NO_3^- N in the present study may not be unconnected to the pH of the soils in the study area. Chude *et al.* (2004) reported that while NO_3-N predominates in higher pH levels, NH_4^+-N are more common in low (acid) pH levels. It is noteworthy that plants take up nitrogen from the soil solution mainly as NH_4 and NO_3- ions. However, owing to its ease of mobility in water, nitrate (NO_3-) could be of concern in underground water contamination which affects human and ruminant health (Bahmani *et al.*, 2009); hence the need to constantly monitor its accumulation (Scott and Daryl, 1993).

Nitrite-nitrogen: The results of the present study (Table 2) indicate that NO_2-N is the lowest in content of all the inorganic nitrogen forms studied. It did not significantly ($p<0.05$) vary both with location and with depth in the soils. Ranging from 2.8 to 6.3 (mean = 4.13) mg kg^{-1}, NO_2-N accounted for only 3.7% of the total inorganic nitrogen and about 0.5% of the total nitrogen of the soil.

CONCLUSION

Results of the present study indicate that the soils studied were low in nitrogen available for plant uptake, with organic nitrogen form accounting for the bulk (about 72.8%) of the total nitrogen in the soil. The content of the nitrogen found in the soils followed the trend: total nitrogen >total organic nitrogen>total inorganic nitrogen N>NH_4^+- N>NO_3-N>$N0_2^-$ N. Owing to the very low nitrogen levels in the soil and low percentage (<12%) of this as available for plant uptake, supplementary application of nitrogen is recommended for successful crop production. The need for proper monitoring of the accumulation of NO_3- is further emphasized as it can contaminate underground waters and be toxic to, especially newborns, causing anoxia or internal suffocation. Results of the study further indicate that the pH and drainage conditions of the soils be improved to stimulate microbial degradation of organic matter and consequently release the organic nitrogen for plant use.

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